PROCEEDINGS OF FIFTH ASIAN-PACIFIC WEED SCIENCE SOCIETY CONFERENCE

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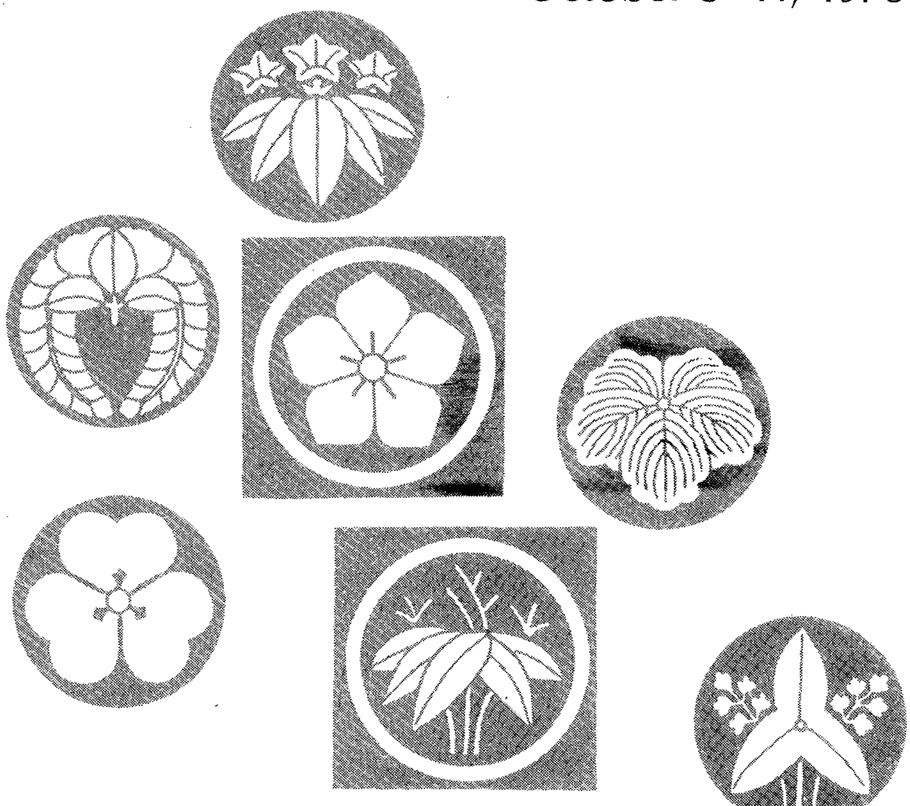

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Presidental Address

Kenji NODA

Ladies and Gentlemen, Fellow Delegates:

It is indeed a great honor for me to be given the opportunity to express an opening address to you.

On behalf of the Executive Members and all members of the Asian-Pacific Weed Science Society, I would like to give all of you a word of welcome and extend my sincere appreciation to your deep concern and efforts to participate in this conference. In particular, it is the greatest pleasure for me that more than 100 oral papers, covering all aspects of weed science and weed control, have been submitted, and approximately 300 excellent persons can be with us in Tokyo from all over the world. This situation has never been experienced in the past conference of this society.

First of all, please allow me to briefly introduce the history of the Asian-Pacific Weed Science Society and its present status for new members. In 1967, the First Asian-Pacific Weed Control Interchange was called to order in Hawaii, U.S.A., under the chairmanship of Dr. Y. B. Goto, and the co-chairmanship of Dr. H. F. Clay, Dr. R. R. Romanowski, and Dr. D. L. Plucknett. At the final meeting of this interchange, it was decided that the Asian-Pacific Weed Science Society begins with all delegates present and the interchange be designated the First Asian-Pacific Weed Science Conference.

In 1969, the second conference was held in International Rice Research Institute, the Philippines, under the presidency of Dr. M. Vega. The third one was in Kuala Lumpur, Malaysia, in 1971 under the presidency and chairmanship of Dr. C. Van der Schans and Dr. D. E. Barnes, respectively.

The fourth conference was convened by Mr. L. J. Matthews in 1973, Rotorua, New Zealand. During the time from 1971 to 1973, constant efforts were made by the past president, Mr. L. J. Matthews to establish the Asian-Pacific Weed Science Society as a scientific society. At that time, rules were established for the society, the publication policy for conference proceedings was set in the right direction, the allocation and responsibility of the Executive Members and Area Convenors were agreed upon and so on.

Some 20 countries and about 200 members attended the past conference each, representing not only the Asian-Pacific areas but also others such as Europe and Africa. Today, the Asian-Pacific Weed Science Society Conference ranks as the broadest international weed science conference in the world, at least until a global interantional weed science society that is now being organized by the Steering Committee is established. Of course, I trust, the APWSS will become the most helpful and assisting society with

EWSS, WSSA, and ALAM when International Weed Science Society is established.

The objectives of the society were directed in the first interchange in Hawaii, and I believe that remains alive today. They are the establishment of the importance of weed control in Asian-Pacific Areas, the interchange of current weed control information, and the enlightenment of training and research needs of the future in weed control and weed science. In general, the less dramatic crop damage from weeds than those from plant diseases and pest insects has not provoked the recognition of the importance of weed control in agriculture, especially in emerging countries and areas with plentiful labor sources. In any event, the importance of weed control in crop production as well as on the environment must be evaluated based on its economic input and output with reference to long term effects on the environment.

As you know, modern weed control developed very rapidly after World War II and inclined to put special emphasis on herbicide utilization in developed countries like England, USA, and Japan. On the other hand, in developing countries, traditional and laborious means remains as important as ever. The interchange of current weed control information between developing and developed countries, between governmental and industrial scientists, or intensive affiliation between basic knowledge and practical technology in weed control is very significant, and originally one of the major goals of this society.

The inclination towards over utilization of herbicides to achieve weed control in some developed countries has brought with it, a number of problems as well. Among these are a decline in the proper development of scientific weed control, and diminished training and research in official institutions. In Japan, for instance, herbicide usage per unit area ranks first in the world, but training and research in weed science are behind those in both plant pathology and entomology. I can estimate one weed scientist for seven plant pathologists and entomologists each in governmental institutions. Further, the educational system is even further behind. In the United States, I have heard that they were faced with less weed scientists and budget than those of diseases and pest insects, especially until around 1960, regardless of the importance of weed technology.

On the other hand, however, it is very delightful for us that recently organized international institutions such as IRRI, CITA, IITA, and CIMMYT have developed along the lines of one entomologist, one weed scientist, and one plant pathologist. Emerging countries also are beginning to equal the same pattern, as Mr. L. J. Mattews showed as already.

When we employ weed control as a problem of not only agriculture but also the environment, the research and education needs of scientific weed control must be promoted more and made tangible hereafter. Dr. A. S. Crafts said in the FAO Interchange in 1970. "Basic research is essential to the long range control of weeds. It might well point the way to chemical modification for increasing its effectiveness, and further in the case of non-chemical methods such as cultural and biological methods, basic studies on the biology of weeds should increase the effectiveness, particularly against perennial weeds." This is in the direction of integrated weed control, a hightlight of this conference.

In conclusion, I am very happy if this conference can provide an useful stage for further development of weed science and weed control, and directly or indirectly contributes to the solution of food problem and the improvement of environment in the world. I would offer my best wishes for a success in the above line, looking forward for your kind and deep cooperation.

Meanwhile, we Japanese shall endeavour to process the programme somewhat focussing on the situation in Japan and to make you feel at home in Japan during the conference. We are also very happy if you have good times and be able to make this conference a worthwhile experience for all concerned.

Finally, I would like to deeply thank the Weed Science Society of Japan and the Japan Association for the Advancement of Pyto-Regulators for kindly co-hosting this conference as well as the Ministry of Agriculture and Forestry for sponsoring the symposium on Integrated Weed Control, and further the Science Council of Japan and other organizations concerned for supporting everything.

Thank you very much for your kind attention.

Welcome Address

Yoshiji TOGARI*

Dear friends!

I wish to extend my hearty welcome to you who have come from so many parts of the world to attend this conference.

As a matter of fact, I was deeply impressed with the very finely organized conference held in 1973 in New Zealand. Since Japan has been selected as the location for the 5th APWSS Conference, the Japan Association for Advancement of Phyto-Regulators (JAPR), led by me, has willingly provided for this meeting together with the Weed Science Society of Japan and the Ministry of Agriculture and Forestry. Anyway, we have endeavoured to make the 5th Conference an even better one than that held in New Zealand.

Incidentally, taking this opportunity, I wish to briefly introduce JAPR to you. JAPR was inaugurated in 1964 as a juridical foundation. Its main purpose is to act as a proxy agency for the Ministry of Agriculture and Forestry in the field of plant regulators.

The main activities of the association are as follows:

1) To assist governmental and commercial organizations in the development and utilization of herbicides and plant-growth regulators.
2) To submit data for registration of chemicals.
3) To exchange information and materials with foreign countries. And if requested, to undertake experimentation and field trials on such chemicals.

The management of JAPR is composed of representatives from the Ministry of Agriculture and Forestry, prefectural officers, and chemical manufacturers. To assist this board and to manage various affairs smoothly, the following special committees consisting of qualified research personnel of national research institutes and experiment stations have been organized.

Lowland rice field, upland field, vegetables, orchard, forage crops, winter crops, tea plant field, mulberry field, forest, lawn, plant-growth regulators, mulching culture, assay of chemical residue of plant and soil.

The achievement of JAPR will be explained later by Dr. Nakayama.

I believe that in the future, weed control will become more and more important in order to achieve better crop production as well as preservation of the environment

* Chairman, Organizing Committee of the Fifth APWSS Conference, and President, the Japan Association for Advancement of Phyto-Regulators.

throughout the globe. Therefore, international weed conferences like APWSS must play a great role in interchanging useful information and advanced technologies.

I hope your studies here will be fruitful and contribute to the mutual benefit of all countries.

For our part, we shall do our best to make you feel at home in our country, welcome again, dear friends!

Thank you.

Agriculture in Japan

Tomoji EGAWA

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Japan is an archipelago situated to the east of the Asian continent yet separated from it by the Japan Sea. The archipelago stretches for 1,900 kilometers between 35 degrees and 45 degrees north latitude, and has a total area of nearly 370,000 square kilometers.

The topography of Japan is characterized with numerous mountains, 580 of which are 2,000 meters or higher. The topography is complex because of small areas of basins and plains and abundant rainfall. The archipelago is a part of the Pacific volcanic ridge, so that a considerable numbers of volcanoes as well as soils derived from volcanic ash are widely distributed throughout the country. As a high mountain range runs through the central part of the archipelago, the weather conditions differ by region.

As Japan is situated within the monsoon belt, rainfall is relatively abundant, averaging between 1,000 mm and 2,500 mm yearly.

Japan's total land area is 370,000 square kilometers, of which 69% is forest land,

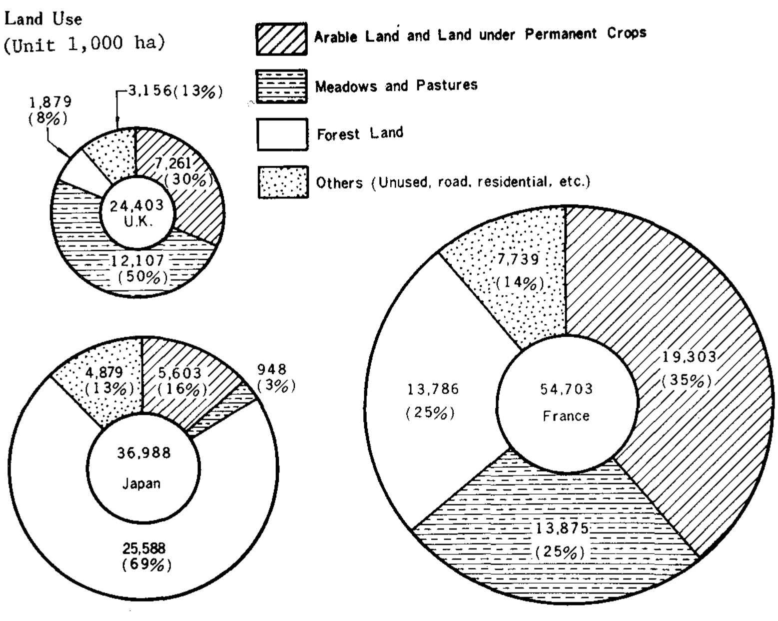

Fig. 1. Total land area and land use in the U.K., Japan and France.

and only 16% is arable land and land under permanent crops. The total agricultural area including meadows and pastures is only 19%. As shown in Fig. 1, these figures are obviously smaller than those of the United Kingdom or France. Consequently, intensive land use is absolutely imperative.

The population engaged in agriculture per square kilometer of arable land in 1970 is shown in Fig. 2. Comparing with India, West Germany, Italy, U.S.S.R. and U.S.A., we can find the highest value of Japan, which suggests the shrinkage of farming units.

Socio-economically, Japan's agriculture had been carrying the burden of a severe tenant system prior to World War II, that was closely connected with the shrinkage of farming units. The transition of number of farms by tenure is shown in Fig. 3.

As seen in the figure, tenant farms almost completely disappeared by the agrarian reform after World War II.

In the rapid economic growth centered on manufacturing industries, the relative

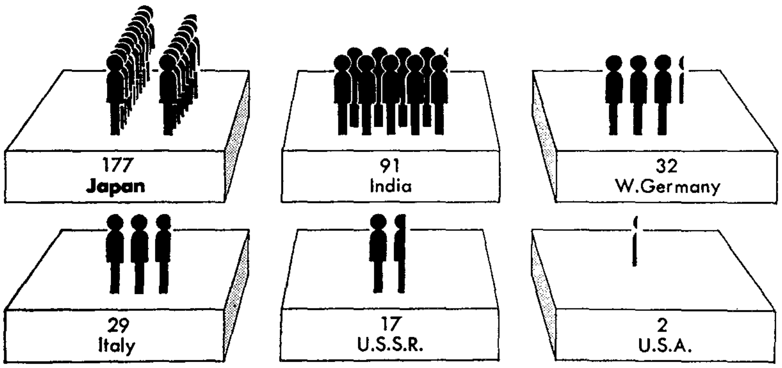

Fig. 2. Population engaged in agricultural occupations per sq. km of arable land (1970).

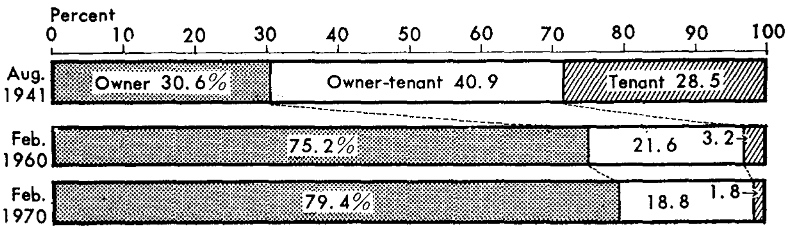

Fig. 3. Number of farms by tenure in percentage.

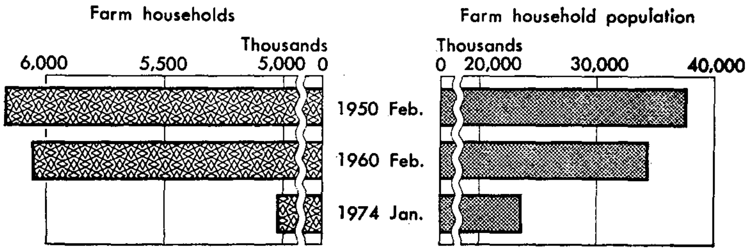

Fig. 4. Number of farm households and farm household population.

importance of agriculture in the national economy has been registering a consistent decline with an increasing imbalance between industry and agriculture. Both number of farm households and household population have shown a marked decline during the last 15 years as shown in Fig. 4.

The transfer of labor from agriculture to other industries in the recent years of rapid economic growth is more clearly shown in Table 1.

The percentage of full-time farm households has markedly dropped, making a striking contrast with the increase of part-time farmers, particularly those who are mainly engaged in jobs other than farming. The decrease is especially noticeable in the younger age brackets in either male or female as shown in Fig. 5. This means an increasing share of aged farmers in the rural population.

Table 1. Number of farm households classified by full-time and part-time farming.

(In thousands)

	Full-time	Part-time			Grand total
		Mainly farming	Mainly other jobs	Total	
1941 Aug.	2,245	2,019	1,148	3,167	5,412
1950 Feb.	3,086	1,753	1,337	3,090	6,176
1960 Feb.	2,078	2,036	1,942	3,979	6,057
1965 Feb.	1,219	2,081	2,365	4,446	5,665
1970 Feb.	832	1,802	2,709	4,510	5,342
1974 Jan.	630	1,222	3,176	4,398	5,027

Source: Ministry of Agriculture and Forestry.
Notes: Figures for 1941–1970 are based on the agricultural census; for 1974 the agricultural survey.

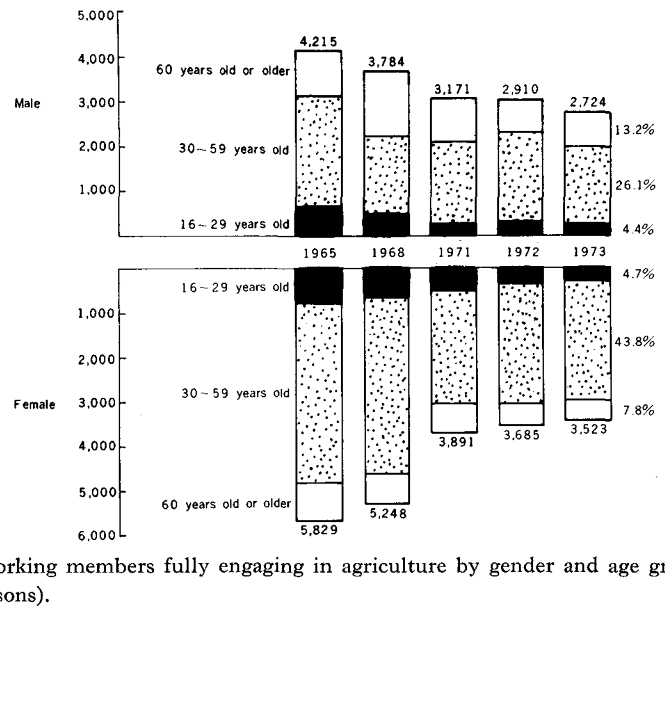

Fig. 5. Working members fully engaging in agriculture by gender and age group (Unit: 1,000 persons).

The adverse effects of the decrease in the farm labor force and its resultant structural changes of Japan's agriculture in the recent years of rapid economic growth should not be overlooked. One of undesirable effects is the possible decrease of soil fertility owing to the decrease of return of raw organic materials such as compost or farmyard manure to the soil. The apparent high crop yields have been maintained by increasing inputs of materials for agricultural production such as machines, fertilizers and pesticides. As for machines, only threshing machines and motors were used in agriculture before 1955. Since 1960, however, small power tillers in place of domesticated animals have rapidly become more widespread. Cultivation has been almost entirely mechanized with the introduction of such small power tillers.

The application of chemical fertilizers in volume has become popular to help to raise the productivity of scarce land holdings, particularly under tight supply of labor force in recent years. High agricultural productivity has been undoubtedly maintained with large inputs such as machines, chemical fertilizers and pesticides. Worrying about possible adverse effects of heavy application of such materials on the natural ecosystem or human environment, Japanese scientists have started recently integrated studies on environmental conservation problems.

Rice is the traditional staple food of the Japanese people, and Japanese agriculture has long concentrated on rice production. Rice production continued to increase after World War II until it reached its peak with a 14, 453,000 ton crop in 1967. This increase was attained through improved plant breeding, land enrichment, rational use of chemical fertilizers, insect extermination, and labor-saving devices, as well as the incentive of higher Government purchasing prices for rice. The planted area and yield per 10 ares of paddy rice are shown in Fig. 6. The consumption of rice has been considerably decreased, while the rice yield per unit area has consistently maintained a high level

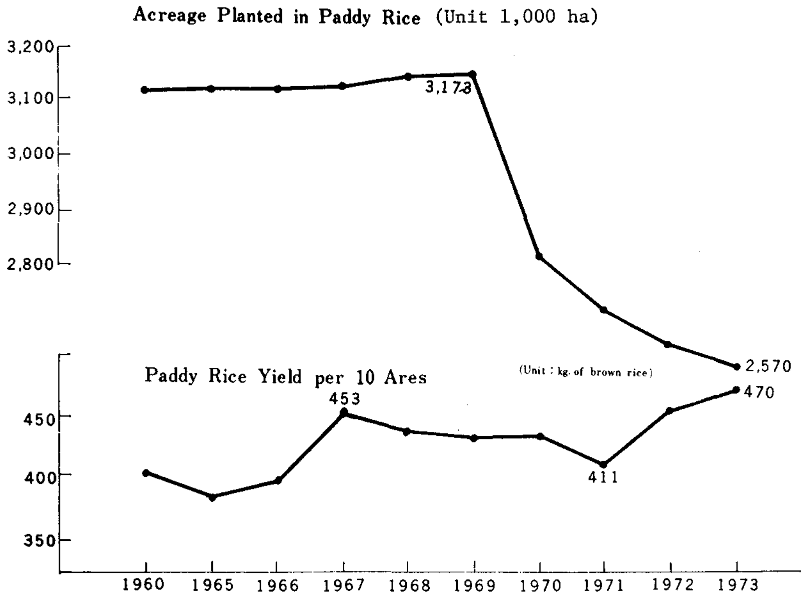

Fig. 6. Acreage of paddy-rice-planted field and yield per 10 ares.

during the last decade, thanks to integrated technological progress in rice production. The overproduction of rice resulting in a troublesome surplus problem has come out under the circumstances. In 1971, the Government established a five-year program for production adjustment to balance the supply and demand of rice. The rapid decrease of planted area from 3,173 ha in 1969 to 2,570 ha in 1973 represents the influence of this policy.

Nevertheless, rice is the mainstay of Japan's agriculture, and its production will no doubt continue to hold an important place in Japan's agriculture.

Relating further to the food problems, Table 2 showing per capita food-consumption by product clearly demonstrates the recent westernization of the dietary habits of the Japanese.

Total calory intake per capita per day has gradually increased with the decrease of the share of starch, and protein intake has increased with the increase of the share of animal and fish meats. In contrast to the decrease of the consumption of cereals, particularly of rice, increase in meats, vegetables, fruits, eggs and sugar is remarkable in the last decade.

Although production of vegetables has increased by 4.5% on an average annually since 1965, the supply has been unable to keep pace with the demand.

Vegetable cultivation methods may be divided into two types: covered and open-air cultivation. Of the covered cultivation, vegetables are grown mostly in hothouses

Table 2. Net food supply per capita.

(Grams per day)

	1934–38 av.	1960	1965	1970	1971	1972	1973
Cereals	431.8	409.9	397.3	352.0	347.0	342.6	341.3
Rice	369.8	314.9	306.2	260.5	254.6	251.3	249.6
Wheat	23.4	70.6	79.4	84.3	84.6	84.6	84.8
Barley	11.5	10.6	5.4	2.0	2.3	2.2	3.0
Others	27.1	13.8	6.3	5.2	5.5	4.5	3.9
Potatoes and strach	110.2	106.4	85.0	66.3	66.4	67.1	66.1
Pulses	23.3	27.7	26.8	27.1	27.4	26.8	26.9
Vegetables	191.9	272.3	300.5	316.8	327.5	321.1	307.8
Fruits	41.9	61.0	78.0	104.7	104.3	121.5	119.8
Meat *	6.1	14.2	24.3	34.6	39.6	42.3	44.2
Eggs	6.3	17.2	31.7	40.7	40.7	39.9	39.6
Milk and products	9.0	61.0	102.8	137.2	138.2	142.0	144.9
Fish	26.4	75.9	80.3	87.0	90.3	91.5	94.0
Seaweed	1.7	1.8	2.0	2.5	2.9	2.6	3.2
Sugar	39.1	41.2	51.4	73.3	73.3	76.9	77.7
Fats and oils	2.6	11.9	18.3	25.8	26.9	29.0	30.5
Miso	29.1	23.8	21.0	20.1	19.8	19.4	19.5
Shoyu	38.0	37.2	31.4	32.4	32.3	32.9	35.8

Source: " Food balance sheet," Ministry of Agriculture and Forestry.
Note: *Includes poultry and whale meat.

built with vinyl or other sheeting. Vinyl hothouses occupy about 9,000 ha in whole Japan in 1970, and about 10% of all the vegetable farmers are applying such hothouse cultivation method.

As previously mentioned, the demand for meat and milk products has increased very rapidly. To meet the needs of the consumers, animal industry has emerged as a very important and growing sector of agriculture in Japan. Table 3 shows the increasing tendency of the number of livestock. Heads of dairy cattle, swine and chickens have been constantly increasing, while number of horses and sheep has been decreasing.

The increasing shares of livestock production in the total agricultural productoin from 1960 to 1972 is shown in Fig. 7.

At this point, I should refer to the remarkable decline of self-sufficiency rate of food and feed grains. For instance, in case of soybean, about 3 million, 6 hundred

Table 3. Number of livestock in Japan.

(In thousands)

		1935	1965	1969	1970	1973	1974
Cattle	Dairy ...	—	1,289	1,663	1,804	1,777	1,752
	Beef	—	1,886	1,795	1,789	1,792	1,898
	Total...	1,654	3,175	3,458	3,593	3,569	3,650
Horses		1,404	322	190	137	73	66
Swine		934	3,976	5,429	6,335	7,313	8,018
Sheep		47	207	64	21	17	16
Goats		123	325	198	161	105	124
Chickens		51,322	138.476	198,379	223,531	242,155	249,497

Source: Ministry of Agriculture and Forestry.
Notes: Figures for 1935 are as of end of year, for 1965–74 as of Feb. 1. Figures for 1973 (except chickens) and 1974 include Okinawa.

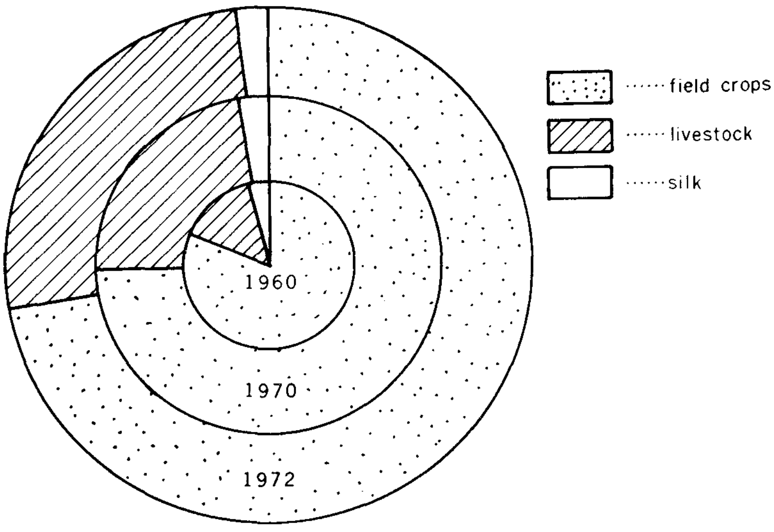

Fig. 7. Shares of livestock production in total agricultural production.

thousand tons are imported mainly from U.S.A. The share in the total domestic supply is 96%, which means self-sufficiency rate is only 4%. As for other food and feed grains, the situation is not so much different.

In conclusion, what I have roughly explained in relation to Japanese agriculture in the above may be briefly summarized and supplemented as follows.

Japan's agriculture today is confronted with three major problems as shown in Fig. 8: the first is the food problem, or decline of self-sufficiency rate of food and feed grains. The second is the energy and resource problem, to be more specific, the unstable supply of oil, and the third is the environmental problem or pollution of air, land and water.

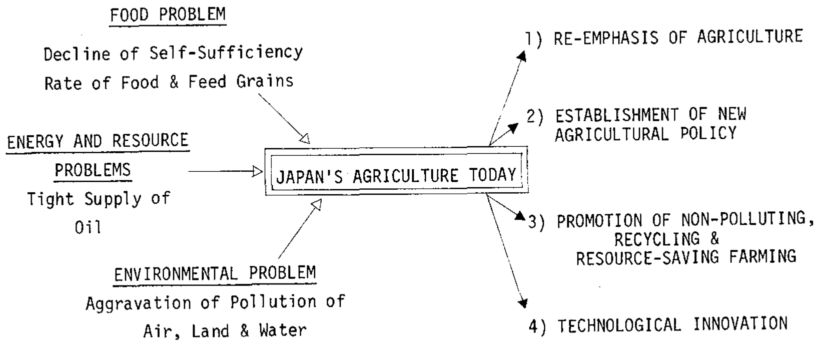

Fig. 8. Schematic representation of today's agriculture in Japan.

Because of limited space, I cannot furnish any data concerning the environmental pollution, but the problem is quite serious nowadays in agricultural production.

In order to overcome those problems, I believe that re-emphasis of agriculture is absolutely necessary as the most fundamental idea. We must give new life to agriculture. Agriculture must recover its lost prestige. Establishment of new agricultural policies are needed for this purpose. Technological innovation is of course necessary to improve agricultural production, but the new technology should always be closely combined with socio-ecological concern, and non-polluting, recycling and resource-saving farming should be promoted in future agricultural production.

Remarks

Tables 1, 2, 3 and Figures 2, 3, 4 were quoted from: Nippon—A charted survey of Japan 1975/76, the Tsuneta Yano Memorial Society.

Figures 1, 5, 6, 7 were quoted from: Agriculture and Food in Japan, Ministry of Agriculture and Forestry, 1974.

Figure 8 was made by the author.

Present Situation of the Herbicides in Japan

Haruhiko NAKAYAMA

Director, Research Institute of the Japan Association for Advancement of Phyto-Regurators, Ushiku, Ibaraki, 330–12, Japan.

A summary of the present situation of herbicides in Japan can easily be obtained from a glance at the total expenditure for herbicides and from the area of treated land. In 1974, the total amount of money for treatment had reached up to about 35.6 billion yen. This amount corresponded one-third of that for all pesticides. The rate of increase has been about 20% per year throughout the past several years, and if such an increase rate is continued herbicide usage will stand first passing insecticides in less than 2 or 3 years. On the other hand, the herbicide usage on arable lands in Japan is 6.4 million hectare on paddy fields, and 3.2 million hectare on uplands. Therefore a diffusion rate to all the lands in the former becomes about two hundred per cent owing to the double applications on the same field, and in the latter about 95 per cent though there are maldistribution conditions.

Also, the number of herbicides registered affords a key for the solution of the present situation. In Japan, 146 herbicides had been registered until last year. This is the chemical number, and if the different formulations of a chemical are counted, this is increased to 233. According to a classification by chemical groups on all herbicides shipped in 1973, ureas, diazins, amides, nitriles, accounted for less than one %, respectively, ammonium salts 2%, organic acids 3%, phenols 4%, triazines 5%, phenoxies 7%, inorganic acids 8%, carbamates 33%, and diphenyl ethers 35%. The last two groups were an overwhelming majority. However, even for such leading chemicals, there is a representive herbicide each, for instance, 81% in diphenyl ethers group is covered by CNP, and 64% in carbamates by benthiocarb. It can be concluded then that few herbicides are being distributed these days. Although many herbicides had their ups and downs during a regular herbicides history for the past 25 years in Japan. It seems that the untiring efforts regarding herbicides problem stimulated an increase of their number, and produced the leading herbicides at the present.

We have some remarkable topics in our herbicidal history. For instance, in 1953, water soluble salt formulations of 2,4-D and MCPA had been developed, soon after these chemicals were introduced in Japan. In those days, these herbicides made an opportunity for the adaptation and distribution of a new weeding method by chemical control. In this history, also we had some typical ages, such as PCP since 1960, diphenyl ether since 1964, and benthiocarb since 1971 and so on, but an incident in 1962 brought a change in the current herbicide science. It so happened that a toxicity problem of PCP against fishes and shellfishes had occurred in western Japan owing to the outflow of PCP from the paddy fields caused by concentrated rainfall.

At that time, the persons concerned had quickly established a counterplan to search for low toxicity herbicides in place of PCP. After one and half year, MCPCA, nitrofen, dichlobenil, and propanil had been recommended for the damaged districts. It is not too much to say that the diphenyl ether herbicides had been a development on the paddy fields taking advantage of that time. Regarding the herbicide situation in Japan, paddy field herbicides had sufficient development being supported by a large area of over 46% of the total arable land, and by the paying business of herbicide suppliers. According to an economic study on the effect of herbicides utilization in paddy rice cultivation, the labor-man numbers for weeding per hectare have clearly been reduced, for instance, this required 63-men in 1950, 34-men 1960, 16-men in 1970, now 12-men or less.

Some explanations of the paddy herbicide practices here, seems appropriate to introduce the characteristics of the delicate applications under the intensive agriculture conditions in Japan. In eastern Japan, the number of times necessary for herbicides application is twice or more to control weeds occuring in the paddy fields because of the long periods of low temperature throughout the early cultivation stage. One is done over about a one week period from before to after the rice transplanting. The other is applied about ten days or more after that, or at the 2 or 3 leaf stage of barnyardgrass on the fields. As occasion demands, another is treated between both applications. We have a custom that the registration of herbicides for paddy fields is permitted conditionally, such as day numbers from the rice transplanting or the leaf stage or rice and weeds. If a herbicide were misapplied, it may damage the rice and result in an ineffectural result against weeds.

For instance, oxadiazone emulsion should be applied just after the last puddling on paddy fields, that is, 2 days before the transplanting. In the case of this oxadiazone, it is called an incorporation treatment in paddy fields, and has a characteristic that this herbicide in irrigated water susides with the fine soil particles when the muddy water is settling, and a herbicidal thin layer is formed on the soil surface. Usage of this oxadiazone is increassing since before last year, and reached up to 2 hundred thousand hectare last year. In the cases of the three leading diphenyl ether herbicides, that is, CNP, nitrofen, and chlomethoxynil, these should be applied in 10 or 12 days periods, from 3 days before the transplanting to 7 or 9 days after that.

Another leading herbicide, that is butachlor, should be applied in a 6 day period, from 4 to 10 days after the transplanting. These herbicideds except CNP also distributed over one hundred fifty thousand hectare or more last year, respectively. By such applications, these herbicides are very effective against annual weeds in paddy rice, but ineffective against barnyardgrass above the two leaf stage. With butachlor, it is possible to control by such application even perennials such as laterflowering flatsedge and dwarf arrowhead. The herbicides which are applied 15 to 20 days period after the transplanting, are almost all granule herbicides combined with 2 or 3 other chemicals.

In general, these have the distinct characteristics that one ingredient effects the mesophyll tissue, and the other side, the growth points in growing weeds, caused by the different activities of each chemical. In the cases of three combination herbicides, these are very effective to the spread of certain kinds of target weeds and have increased efficacy against older weeds. For instance, with molinate-simetryne-MCPB, it is possible to kill even little bigger barnyardgrass at 3.5 leaf stage.

As mentioned before, the labor-man number for weeding in paddy rice cultivation has been clearly reduced by herbicide applications. However these applications are almost all hand application. On the contrary, a knapsack type power applicator having a long tube of 20 or 30 meter has been developed in Japan. Such a long tube is used across a paddy field. With this applicator, the granule herbicides can be spread in a half-hour or less per hectare. On account of the granule formulation, use of such a power applicator is safer to the operator and neighborhood than other dust or mist application methods, and allows for even spreading on the fields. Herbicides used for this applicator are of a fine granule type with diameter of 0.6 to 0.8 mm. Benthiocarb-CNP (Saturn M), nitrofen, molinate-simetryne-MCPB, molinate-simetryne (Mametto), CNP, benthiocarb-simetryne (Saturn S), swep-MCPB and chlomethoxynil are adequate enough, even the common sizes on the market. It is possible with this application method to decrease the dosages of the herbicides per unit area. For instance, a 20 kg granule application shows almost equal efficacy to a 30 kg hand application. It is said that this reduction results from the uniformity of granule being spreaded by a power applicator.

Even with such herbicide practice developed in paddy fields, we have a problem with the increase of perennial weeds. The reasons are the change of rice cultivation techniques for the sake of saving labor, and the continual use of low activity herbicides against perennials for many years. The main troublesome perennials are Japanese bulrush, dwarf arrowhead, globular arrowhead, and laterflowering flatsedge. A round-leaf pondweed in perennials is now a thing of the past because of the effect of prometryne. According to an investigation last year, the occurence area of these perennials reached about 10 to 20% of the total paddy fields, particularly in eastern Japan where their incidence reached 30% or more in some places.

In order to control such troublesome perennials, now bentazone is being tested, applied both alone or in combination with the other leading herbicides. Its herbicidal activity is highly selective in rice and is very effective Cyperaceare and monocotyledonous weeds occuring in paddy fields. But the dosage in Japan is higher (twice or more) that than used in other countries, for instance, America, Africa, and southern Europe. This varied from herbicide to herbicide, and we know of an opposite example in a molinate application where the rate in Japan is less than that in many other countries which use the same granule.

Subsequently, we mentioned something about the present situations on the upland fields and forest land in Japan. In the case of upland fields, many kinds of herbicides have been registered, although their use is less than one-third compared with paddy fields. Now the rate of herbicides registered has increased more than three times during the past five years. The main herbicides currently used are paraquat (it accounted for 35% of the total upland herbicides), simazine (30%), diuron, linuron (10%, respectively), trifluralin, propanil, mecoprop, sodium chlorate (5% or less, respectively).

Other developed herbicides are dinoseb and its acetate for pre-emergence treatment, a mixture of lenacil and pyrazon for post-planting of sugar beets, and atrazine for maize. As is well known, the continuous use of the same herbicide for many growing seasons will almost inevitably result in problems. Therefore the utilization of two herbicides, for instance, benthiocarb and prometryne, is common against gramineous and broad leaf weeds. As imcorpration treatment, simazine, trifulralin, and vernolate are being satisfactorily used. Perennial weed problems are also serious in upland fields. Main perennials are pink woodsourrel and purple nutsedge in western Japan, and perennial sowthistle and quackgrass in eastern Japan. As a whole, in upland fields, the mechanization for herbicide application currently is becoming a pressing need.

For vegetables, the area rates of herbicidal usage are as follows: 80% in onions; persely, carrots, 50% respectively; garlic, mitsuba, strawberries, 40%, respectively Chinese yam, lettuce, 30%, respectively; celery, cabbage, tomatoes, 20%, respectively. It seems that utilization of herbicides in these vegetable crops is a developing condition. As for ornamental plants, traditional methods of weeding by hand are still prevalent. Compared to the suggestions for chemical weed control in horticultural crops, some dosages in Japan are less than America; for instance, diuron in asparagus is used from 0.8 to 1.2 kg/ha in Japan, but from 2.3 to 3.4 kg/ha in America for same weed problem; diphenamid in strawberries, 1.6–4.0 kg/ha in Japan, 4.5–6.7 kg/ha in America. We know other examples, such as nitrofen in cabbage and cauliflower, propham in lettuce, and so on. Such differences of the dosages among countries seem to be an important problem in the development of herbicidal science.

In deciduous orchards, simazine, diuron, dichlobenil, paraquart, asulam, and combinations of amitrol and diuron, and of diuron and terbacil are being used. The herbicidal usage in deciduous orchards is less than 10% in total. Now the development of application equipment for herbicides is needed.

In forest lands, weed control is also of importance. In Japan the main trees are Japanese ceder (it covered 32% of total forest lands), Japanese cypress (15%), larch (14%), pine (8%), and others. About one-third of the country forest land, that is, five hundred fifty thousand hectare of forest is afforested every year. After afforestration, weeding and tending are necessary for several years. Therefore the total area for weeding reaches two million hectare each year. Supposing 10-men per hectare are needed for weeding, twenty million men are necessary every year throughout growing season. In forest lands, sodium chlorate was very effective against bamboo grass. Instead of 2,4,5-T, MCPA, a combination with dalapon, tetrapion, and ammonium sulfamate are highly effective against forest weeds. For the weeds of tree seedling beds, simazine, nitrofen, and trifulralin are very effective. For perennial weeds, for instance, purpul nutsedge and field horsetail, tetrapion is very effective.

Lastly, I should add some commently regarding toxicity problems. The regulation for the control of pesticides in Japan was partially amended in 1971. Beginning then, the regulations for the control of pesticides had became more and more severe. Owing to the registration of herbicides, the residue in crops, soils, and waters are tested, and the contents in those materials are checked according to the rules. In toxicity tests, acute toxicity is required using mice and rats, along with other tests, for instance, L.D. 50%, the succeeding generation tests throughout three month feeding experiments, and also, the chronic toxicity tests using small higher animals throughout two years. The expenses for those tests will amount from 50 million to 100 million yen per one herbicide.

When we consider the other large expenses for the required experiments against weeds and crops, the value of newly developed herbicide may be entitled to be called amonument of modern science. Now, pollution problems are also becoming severe.

Although there are waste matters accompany the development of mankind, almost all problems can be managed in a way so as avoid disasters. In spite of the many unfavorable situations which surround herbicides, the agricultural chemical industries are fully prepared to do all the required efforts and more for the development and supply of better herbicides at the lowest possible costs to the farmers.

We must minimize the losses of crop production due to weed damage in order to cope with the food situation in the near future which is being brought about by the increasing population of the world.

Weed Problems and Prospects for Chemical Control in Indonesia

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Abstract. Weeds in various habitats, their present control measures and prospect for future chemical control were discussed.

In rubber and oilpalm plantations the main weed problems are *Imperata cylindrica*, *Paspalum conjugatum*, *Mikania micrantha* (in West Java), *M. cordata* (in other areas) and *Chromolaena odorata*. In tea: *I. cylindrica*, *Panicum repens* and *Ageratina riparia* are dominant in some areas. In coconut plantations, *Paspalum conjugatum* and *M. micrantha* are the most serious weeds. In sugarcane: *Cynodon dactylon*, *Cyperus rotundus* and *Brachiaria mutica* are important weed species difficult to control. In ricefields dominant weed species are: *Monochoria vaginalis*, *Leptochloa chinensis*, *Marsilea crenata*, *Salvinia molesta*, *Scirpus lateriflorus* and *Fimbristylis littoralis*. It is predicted that in the future, wild rice (*Oryza sativa* var. *fatua*) and (*O. perrenis*) will bceome a serious problem in rice estates outside Java. Important weed species in open waters and irrigation canals are: *Eichhornia crassipes*, *Salvinia molesta*, *S. cucullata*, *Hydrilla verticillata* and *Scirpus grossus*.

In North Sumatra, herbicides are widely used in plantation crops, especially in rubber, oilpalm, tea and cocoa, mainly to control *I. cylindrica*, *M. cordata* and other broadleaf weeds. Important herbicides are dalapon, MSMA coctail (MSMA+2,4-D+sodium chlorate), paraquat, paracol, diuron and Ustinex.

In Java, dalapon and paraquat are used to control weeds in rubber, tea and coffee, while diuron and cyanazin are used for pre-emergence applications. Picloram is used to control *Chromolaena odorata*, a noxious weed in rubber and coconut plantations, while in lowland ricefields MCPA and 2,4-D (amine salt) are used. In aquatic ecosystems where *Eichhornia crassipes* is a dominant weed species, a mixture of paraquat+2,4-D is used to control them.

Introduction

Some inorganic herbicides such as arsenics and chlorates were used non-selectively during the pre Second World War period in plantations (Anon., 1935) and during the post period of the war from 1950 to 1960 (Soerjani, 1970). The use of the more selective herbicides in plantation, food crop and aquatic ecosystem has been studied and thought of since the 1950th (Adiwinoto, 1950, Anon., 1950; van de Goor, 1950; Vaas, 1951; Gonggrijp, 1950; 1951). However, only in plantation crops and aquatic system that this has been subsequently materialized. This has received an increasing attention close to 1970, concurrent with the increase of the intensive use of herbicides (Soedarsan and Hendarin, 1967, Soerjani *et al.* 1971, Soerjani and Tirtarahardja, 1971; Soerjani and Azis, 1973; Widyanto and Soerjani, 1975). The present use of herbicides in particular and pesticides in general, is regulated by the Minister of Agriculture with a letter of decision no. 125/Kpts/Um/4/1975 on April 2, 1975. The present weed problem in Indonesian plantation crops and open waters and prospects for chemical weed control is discussed in this paper.

Weed Problems and Control in Plantation Crops

Plantation crops that are facing serious problems of weeds are rubber, tea, oilpalm, cocoa, coffee, cinchona, coconut, fiber crops, sugarcane and tobacco. The important weed species causing the most serious problem in each crops is given in Table 1.

Weed control in rubber. The use of herbicide has increased due to the fact that mechanical control may damage the roots and labour cost is increasing. From the total 2.3 million ha of rubber plants, 475,000 ha are owned by estates of which 60% of the area is sprayed with herbicides. The most widely used herbicides are dalapon, paraquat, paracol, diuron, 2,4-D and cyanazine. The use of picloram (in a mixture with 2,4-D or 2,4,5-T) gives a promising solution to overcome problems in controling *Chromolaena odorata* and other shrubs in rubber plantations. The use of cocktail (MSMA+2,4-D+sodium chlorate), Ustinex (amitrol+MCPA+diuron) and PCP was discontinued since 1975 due to the restriction of the use of MSMA, amitrol and PCP. In North Sumatra, the use of herbicides to control weeds in rubber smallholder plantation has been introduced by a development project financed by the World Bank which in the first instance covers 8,200 ha rubber plantation. The planters will receive a packet of dalapon 30 kg/ha for *Imperata cylindrica* control, while the use of other herbicides to control other weeds such as *Mikania cordata* is still under study (Mangoensoekarjo, 1975).

Weed control in tea and cinchona. There is a substantial acreage of young plantation in tea areas in North Sumatra and West Java. So far weeding in the newly planted area is done manually because of the fear of spray drift that may cause injury to the young plants. However, chemical weeding is practiced in most of the old plantations. In the past cocktail mixture was widely used, while at present the old plantations are sprayed with dalapon, paraquat, paracol, diuron and 2,4-D. Cinchona plantations has only an area of 2,000 ha, however, Indonesia is the producer of almost all quinine products of the world. The plantation is located nearby the tea plantations in West Java. Herbicides used in cinchona plantations are dalapon for grasses and paraquat for the broad leaves.

Weed control in oilpalm. Only circle weeding is commonly practiced in oilpalm plantations. In nurseries weeding is still done manually. In areas where *Mikania* is dominant paraquat is used for weed control, while delapon is sprayed where *I. cylindrica* is common. However, precaution has to be taken to avoid possible injurious effect of dalapon to young oilpalm trees. There is also a development project in North Sumatra to introduce the use of herbicides in oilpalm smallholder plantations in North Sumatra. The pilot project has ±1,000 ha oilpalm plantation, and a packet of dalapon of 30 kg/ha is given to control *I. cylindrica.*

Weed control in sugarcane. Sugarcane plantations in Java (approx. 110,000 ha) are located in rotation with rice and soybean, etc. The cane culture needs an intensive use

Table 1. List of important weed species in some plantation crops (5 species selected from each crop).

Weed species	Rubber	Tea	Oilpalm	Cocoa	Coffee	Cinchona	Coconut	Fiber crop	Sugarcane	Tobacco	Remarks
1. *Imperata cylindrica*	×××		××		×××	×××	××	×××			
2. *Mikania cordata*	××		×××	×							Mostly outside Java.
3. *M. micrantha*	(××)		(××)				×××				In West Java.
4. *Paspalum conjugatum*	×		×	××		××					
5. *Cyperus rotundus*					××			××	××	××	
6. *Mimosa invisa*							×			×××	
7. *Borreria alata*		×××		×××	×						
8. *Euphorbia prunifolia*		××		×						×	
9. *Ottochloa nodosa*	×		×			×					
10. *Croton hirtus*		×									
11. *Drymaria cordata*						×					
12. *Chromolaena odorata*				×		×	×				
13. *Ageratum conyzoides*				×	×				×	×	
14. *Amaranthus spinosus*									×	×	
15. *Polygala paniculata*	×							×			
16. *Momordica charantia*			×								
17. *Polygonum barbatum*								×			
18. *Panicum repens*		×					×				
19. *Cynodon dactylon*								×	×××		
20. *Brachiaria mutica*									×		
21. *Ageratina riparia*		×									
Total area (×1,000 ha)	2,300	30	120	2	400	2	1,800	200	110	10	
Cost of weeding/ha/year (×Rp. 1,000)*											
a. Manual	7–10*	—	8–10	10–15	—	—	—	—	—	42	
b. Chemical	4–8*	8–12	6	8–12	—	—	—	—	10–15**	—	

* 1 US $ eq. Rp. 415,—. The lower figures refer to old planting areas, while the higher figures are prices in young planting areas.

** Integrated control: manual and chemical methods

××× very abundant, ×× abundant, × less abundant of labour, particularly during the planting period in May and June. In certain areas the activity corresponds to rice harvesting that will be followed by corn and soybean planting, so that there is a temporary shortage of labour. This stimulates the use of an integrated weed control method, i.e. handweeding before planting and the application of ametryne+2,4-D amine at the rate of 1.3–1.6 kg/ha and 1 kg/ha respectively, just after planting and several handweedings later (Kuntohartono and Ariadi, 1975). It is estimated that approx. 55,000 ha of cane area (approx. 50% of the total area) in Java will use herbicides. Approximately 30,000 ha of cane plantation will be established in 1980 and this will be intensively subjected to herbicide application program.

Weed control in cocoa, coffee and tobacco. The cost of manual weeding in these 3 comodities is becoming increasingly expensive, especially in young planted area of perennial crops. In tobacco, intensive soil cultivation requires a very high price of weeding, i.e. Rp. 42,000.— (approx. US $100)/ha. Therefore, the use of herbicides as an alternative of manual weeding is now under intensive studies.

Weed Problems and Control in Food Crops

The most important food crop in Indonesia is rice, in particular lowland rice (approx. 6 million ha). Second to rice is maize, sago, cassava, etc. The most dominant weeds present in lowland rice fields are *Monochoria vaginalis*, *Scirpus lateriflorus* and *Fimbristylis littoralis* (Sundaru, 1973). The use of herbicide for rice is still in a very limited scale. This is because weeding is mostly done manually. Only in thinly populated areas such as Pamanukan (West Java) the farmers start to use MCPA (Sundaru, 1975) while in North Sumatra in an area of ±2,000 ha the farmers already use MCPA and 2,4-D amine since 1970. The seed farm Sang Hyang Seri at Sukamandi (West Java) has applied propanil and phenoxy compounds for its 500 ha rice plantation. Prospect of future intensive use of herbicides lies in the newly opened rice estates outside Java such as in Palembang, Jambi in Sumatra, etc. As expected (Soerjani, 1970) the current development of industry in Java has absorbed to a certain extent the availability of manpower for intensive rice cultivation. This facilitates further trend of the use of herbicides in rice fields nearby industrial developments such as in Krawang area (near Jakarta). Other herbicides for rice under considerations are piperophos, butachlor, TCE-styrene, trifluralin and 2,4-D IPE. The use of herbicides for other food crops is still in a limited scale such as the use of simazine in maize estates in lampung.

Weed Problems and Control in Aquatic Ecosystem

There is an increase awareness of the serious need of proper management of water resources in Indonesia. This has been indicated by the recent efforts in overcoming weed problems in open waters, including natural lakes (Rawa Pening, Central Java; Kerinci, West Sumatra; Tempe lake, Sulawesi; etc.) built dams that create new man-made lakes (Jatiluhur, West Java; Karangkates, and Selorejo, East Java; etc.). There is also a serious problem of weeds in irrigation canals. The five most important weed species in a quatic areas in Indonesis are: *Eichhornia crassipes*, *Salvinia molesta*, *S. cucullata*, *Hydrilla verticillata* and *Scirpus grossus*. Efforts in controlling these weeds (especially that of *E. crassipes*) are done manually. There is a trend, however, to use more herbicides in the future. The most commonly practised chemical weeding of *E. crassipes* is a mixture of paraquat+2,4-D (at the rate of 0.5+2 kg/ha). From experimental results there are promising uses of other: the mixture of diquat+2,4-D, and single application of ametryne (Guritno and Pheang, 1975; Widyanto, 1976). The use of rubber based formulations of paraquat, 2,4-D and ametryne for slow release of herbicides to prevent drift and pollution is another prospect for future uses of herbicides for aquatic ecosystem (Widyanto, 1976).

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A Program in Broad Based Weed Science Education

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Abstract. Worldwide emphasis on increased food production has resulted in expanded interest in weed science and created an international need for additional formal education and practical experience opportunities. The International Plant Protection Center at Oregon State University (USA) conducts a program aimed at helping meet some of these needs through disseminating publications, a free newsletter, and reprints, as well as participation in short courses and direct response to technical inquiries. IPPC also coordinates an AID-sponsored weed research program in several developing countries.

Unrelenting pressures on the world's food production capacity have had one positive aspect. The international community, realizing the necessity of controlling weeds to boost crop yields, has moved to accord weed science the importance and status it deserves.

Ten years ago there was but a handful of pioneering weed science professional groups, societies, and conferences. Today there are four multi-national organizations, including the Asian-Pacific, 24 national groups and an uncounted multitude of regional and local associations. A further sign of worldwide concern is evidenced by the International Weed Science Society, now in the process of formation to serve as an overall link between groups and to foster the interchange of weed science information.

Surging interest has prompted many more individuals to take up research and practical application within the weed science discipline. For some, formal education related to weed science may have been cursory and actual experience brief or even nil. Additional education, training, and experience in weed science stands an excellent chance of proving beneficial to this group.

Several institutions support efforts to bridge the education-experience gap by offering exposure to weed science at a practical, usable level. One, the International Plant Protection Center (IPPC) at Oregon State University, USA, conducts a three-pronged effort including coordination of an Agency for International Development weed research program in developing countries. In the nations where the program has had on-site personnel, host country counterparts, usually from a governmental organization, work in close cooperation with program research scientists, thereby gaining practical experience in the entire gamut of field research program activities from planning to reporting of results.

Frequently counterparts have not had an opportunity to study for an advanced degree. While IPPC does not have facilities nor funds for formal training, it gladly assists in identifying and recommending outstanding prospects for graduate training and then helping with actual arrangements.

Short courses and workshops. On-site weed science short courses offer another rational alternative for increasing ability, refreshing memories, and instilling confidence. The Regional Center for Tropical Biology at Bogor, Indonesia, has carried out a series of annual in-country weed science short courses utilizing weed scientists from a variety of organizations (including IPPC) around the world.

In June 1975, IPPC joined with Centro Internacional de Agricultura Tropical (CIAT), an international agricultural research center in Colombia, to organize and present a month-long intensive weed science workshop at CIAT's Cali facility. Thirty-one persons representing 12 Latin American nations were invited to attend the workshop based on recommendations and potential for future contributions to their nations' weed science program.

Information covering basic definitions to sophisticated research technology was presented—all in Spanish for this particular workshop—by a team of instructors from CIAT and IPPC. A varied program offered classroom lectures and discussion, field trips, and "hands-on" laboratory/plot work.

Participants formed 5-man teams and each team selected an actual short term weed control research project to carry out during the course using laboratory and screenhouse facilities. Each team also had to solve a given weed problem. Findings were reported back to the entire workshop utilizing scientific format.

A 2-hour written examination was given the first day and repeated at the end of the course. The latter contained material 75 percent identical to the first exam plus additional new questions. The group raised their test scores 25 percent the second time. One individual increased his score from 2 points to 70. A before-and-after laboratory practical exam was also given, resulting in a 37 percent average overall improvement.

Information resources. Many weed scientists, while working in areas that may not be blessed with extensive information sources, experience the off-the-main-line-and-out-of-touch syndrome. IPPC has attempted to attack this condition by publishing a free periodic newsletter and sending it to weed scientists (and others) in well over 100 countries. The newsletter is intended as a link and an information resource leading to useful materials.

A second arm of IPPC's publications program includes several bilingual weed identification guides containing color plates and detailed taxonomic descriptions of economically important weed species. A manuscript currently under review is expected to result in a practical field manual for weed research methodology replacing an earlier title, "Weed Research Methods Manual", which was first published in English and later in a Spanish version. IPPC sends its publications without cost to non-commercial researchers, educators, and officials in developing countries and charges a low recovery cost to others. Over 2,000 copies (in total) were distributed during calendar 1974.

Several other manuscripts generated by IPPC programs and personnel are expected to be printed in the near future, such as a Spanish and English review of certain herbicide families, and a summary of factors affecting herbicides in soil.

Reprints of useful papers, that may not be widely circulated, are now offered free by IPPC as part of its information clearing house role. There are currently 15 titles in the reprint series known as IPPC papers.

In addition to servicing requests for publications, IPPC also carries out a limited direct response activity for specific inquiries related to weed research and control. The Center's staff either supplies the requested information (drawing upon data maintained on file) or, through extensive connections with numerous other individuals and institutions and knowledge of their programs, refers the inquiry to another source.

Together with other institutions, IPPC is attempting to provide usuable information and assistance and thus help to enhance viable and effective weed science linkages worldwide.

Economics of Herbicide Use

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Abstract. Economic evaluation of herbicides is not simple, especially when concern is with the community as a whole. Social effects are both monetary and non-monetary and may be negative or positive. The market at times fails to give true indications of social benefits and costs. Pollution, reduced environmental quality, and unemployment caused by technologic shifts are examples of externalities (market failures). Measures to correct externalities generally focus on modifying the incentive structure or governmental control. Multi-disciplinary research is necessary to provide policy makers with source scientific estimates of herbicide effects.

The economic evaluation of increased agricultural productvity due to herblicide use appears to involve basicaly three fundamental steps: first, obtain a physical measure of the increase in productivity as a result of the herbicide use; second, multiply the increased yield by its monetary value; and three subtract the increased cost from the monetary benefits to obtain a net figure. This methodology is perfectly valid for the individual profit maximizing farmer. Furthermore, it is often argued that the summation of the producer net benefits yields an estimate of the benefits accruing to the community as a whole. This simple aggregation procedure involves several potential fallacies with which weed scientists should be familiar. They will be discussed in this paper.

Let me hasten to state that there is ample evidence to support the position that herbicide use, at least in developed countries, is a profitable capital expenditure. Herbicide use has increased more rapidly during the last decade than most other agricultural inputs including all other types of pesticides. Herbicides have replaced or supplanted more expensive mechanical and manual means of weed control on almost every major crop. From 1966 to 1971 in the United States the use of herbicides doubled to reach 288 million pounds of active material. Corn was the major recipient of herbicides, accounting for about 44 percent of all herbicides used on crops. This apparent increasing willingness of farmers to pay is strong evidence of the profitability and benefits arising from herbicide use.

Generally the fallacies that occur in the economic analyses arise in the assumptions that are utilized. One assumption often implied if not specifically stated is that the production function for herbicides is linear. (A production function specifies the physical relation between the quantity of output and the quantities of an input or inputs used, herbicides in this case.) By a linear function it is meant that the increased product is constant regardless of the quantity of herbicide used. This in general is false. Nevertheless, decisions are often based on this fallacy.

A second fallacy occurs when market prices are influenced by government intervention or other market imperfections. The price therefore may not reflect true economic value of the product. While to the individual producer the controlled price is the price he receives, the true value to society of the commodity may be higher or lower depending upon whether the controlled price is lower or higher than that which would prevail under market conditions.

A third potential fallacy occurs when experimental results, or for that matter individual producer results, are aggregated to the community as a whole. Increased aggregate output may result in reduced product prices. Individual producers usually face demand curves which are invariant with respect to the quantity sold, i.e. are perfectly elastic. However, agricultural producers in total face a demand curve where the price changes inversely with the quantity of product offered for sale. Thus there is a built in tendency to over-value the product.

Another problem in economic evaluation is when non-market effects or externalities exist as agricultural inputs are used. These costs or benefits are not priced and compensated in the market system. An externality is said to exist whenever the utility of one of more individuals is dependent upon among other things, one or more activities which are under the control of someone else.

Examples of exterinalities are:

Case A. One farmer uses a chemical herbicide to kill a noxious weed in his crop that drifts over his boundaries and destroys valuable plants of an adjacent neighbor. One farmer's beneficial actions are detrimental to another. The benefit could be positive if unproductive weeds were curtailed in the adjacent field through the drift. When damages are easily identified, compensation or court action may result, or if the problem is severe enough, governmental action or control may be taken.

Case B. The reduction in environmental quality, the destruction and change of vegetation, the contamination of water and herbicide toxicity to fish, and the detriment to wildlife are also costs not ordinarily reflected in our market system. What few studies there have been made indicate that these costs may be low. However, J. M. Way (1974) in the XII British Weed Control Conference warns that herbicides may be prefectly safe when used in small areas, but have damaging consequences when applied to large ones. To be perfectly frank, inadequate information exists to assess these cases in general.

Case C. The use of chemical herbicides may cause increased levels of unemployment which in turn cause decreased levels of social welfare. The income distribution from an equalitarian standpoint may be worsened by increasing the efficiency of those who have capital in comparison to those who do not, or by reducing employment of part of the labor force. Some would argue that this is not an externality in the classical sense. But since the welfare of the rural worker is worsened as a result of technology shifts, it is viewed consistent with the definition.

Economic effects of incorporating ext. costs. External benefits and costs such as those discussed in all three of the above cases are uncompensated and not reflected in the market system. Where external costs occur and if they were actually incorporated into the cost structure, the firm cost curves would shift upward. This in turn would mean that a reduced amount of output would be forthcoming at any given cost.

Consider the Fig. 1. If the firm cost curves increase (A movement to the left MC_1 to MC_2), at a constant output price (assumed in pure competition) the quantity of output will decrease from Q_1 to Q_2. Only a price increase to P^2 would maintain the same output.

A reduction in the quantity produced without a corresponding price increase means that farm income decreases (Fig. 2). Note that area AEFD is less than area ABCD. The farmer has therefore assumed all of the increased costs. None were passed on to the consumer.

In reality in a large area, since regional production is the aggregation of individual farm units, the assumption of constant prices is difficult to maintain. The amount produced does affect the product price, as previously stated (Fig. 3). The demand schedule is less than perfectly elastic and the costs of production will be distributed according to the relative supply and demand elasticities. The supply curve being the marginal cost curves for the individual farm producer above average variable costs.

Generally if the quantity of food produced was lowered because of the increased costs, consumers would have to pay more than the increased costs to the farmers. This is because the demand for food, other than meat and oils, is inelastic. (There are no good substitutes for food.) Many foods have elasticities less than —0.5. This means that should production be decreased by 20 percent, farmers would gain should their cost increase be less than 40 percent.

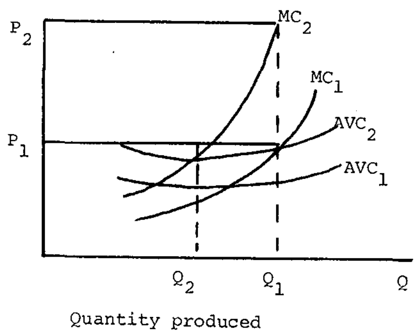

Fig. 1. Upward shift in marginal cost curves.

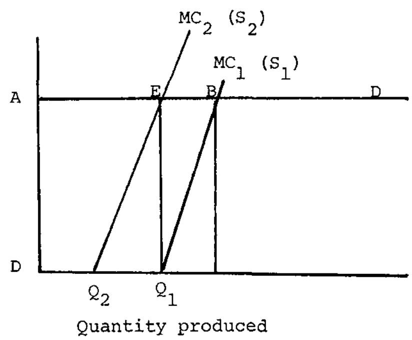

Fig. 2. Decreased farm income as a result of increased supply.

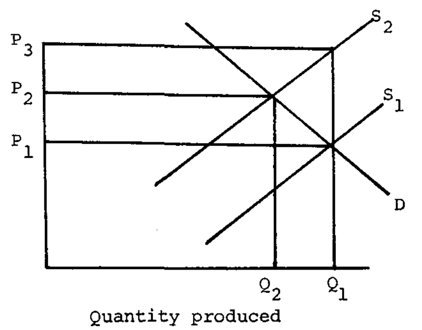

Fig. 3. Price changes as a result of supply shifts.

Possible solutions to external cost problems. The existence of externalities, a form of "market failure," is often used as justification for government intervention. The decision to intervene will be based upon whether the intervention will lead to a better state of affairs. Carlson and Castle (1971) give three general means for correcting market failure.

1. Modifying the incentive framework
2. Administrative regulation
3. Government ownership

When a problem exists which is inconsistent with community desires, most economists believe that the appropriate economic institution is not functioning, i.e., that the incentive framework has failed. Economists will strive to modify the incentive framework to correct the problem. This they will do through modification of the incentive structure to reflect the ratio of benefits to costs. They may use taxes on externalities, subsidies, redefinement of property rights, and market manipulation. The transaction costs of engaging in this correcting method are generally high and have precluded their use.

Administrative regulation standards may be imposed upon the economic system or individuals within the system to which they are expected to conform. The regulations are generally rather crude. They treat symptoms, not causes. Examples may be forced hiring, import embargos, complete prohibitions of various practices, or air quality standards. These administrative rules are generally enforceable at low cost and are favored by policy makers.

Government ownership or socialization may correct a problem. If government owns all resources then all costs are considered, in theory; no externalities exist since all costs are internalized. That is, control of all resources passes to the government which is trustee of all people's welfare. The fact that socialist nations have complete control of resources suggests that unsatisfactorily high levels of pollution and deteriorating environmental quality should not exist. However, this is not the case and casts doubt upon this as a means of correcting the market failure.

Whichever of the first two methods are employed, estimates of the true social cost of herbicide use must be known to develop sound policy. The social cost must include estimates of the non-market as well as market costs. Scientists engaged in technological changes must be prepared to estimate both. Failure to do so will not forestall policy, as evidenced by the creation of pollution standards by the Environmental Protection Agency in the U.S.A. It is recognized that all agronomists are not trained to research areas of externalities and economic and social costs. This suggests the need for multidisciplinary teams of agronomists and economists working together in the analysis of herbicide use. It is my hope that this will be the wave of the future.

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Herbicides on Peasant Farms

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Abstract. Herbicides have proven to be very useful tools in the more developed agricultural areas of the world. The peasant farmers have not benefited from this technology because they do not understand the value of herbicides, because they do not have the money to buy herbicides and because herbicides are not reliable under the extreme environmental conditions common in the peasant farm regions. There are, however, situations in which the peasant farmer could use herbicides without fear of losing his crop : (1) as an aid in vegetation removal prior to seedbed preparation (2) vegetation control after seedbed preparation but before planting, (3) vegetation control during the fallow period. Herbicides also offer a means of controlling certain weed species which cannot be controlled manually and otherwise will seriously reduce production. The cost of herbicides and application equipment and general knowledge level of peasant farmers will continue to keep herbicide use at a low level.

DISCUSSION

The peasant farmers of the world, regardless of where they live, have benefited little from the tremendous advances in agricultural technology made in the past fifty years. In fact, as the progressive farmers of the world adopt new ways, life on the peasant farm becomes even more difficult because the technical, economical and social systems leave them even farther behind. The industrial sector is generally unable to provide alternative or supplemental income so there is little choice but to continue to struggle with the land for subsistence. The struggle is made more difficult by the steadily increasing number of people dependent upon a given piece of land.

A common factor limiting crop production in one way or another on the peasant farm is undesirable vegetation. The area planted may be limited to that which can be cleared of brush. Or a family may plant only as much as can be hand weeded during the season. Weeds reduce production by direct competition with the crop and all too often the damage is already done by the time the weeds are removed. Weeds at harvest time also reduce production by making it difficult to see and separate the crop. With so much effort and loss attributable to weeds and their control, it is natural for concerned people to look to herbicides.

Herbicides have been widely accepted in much of the world for some very good reasons:

1) They can often be more effective than mechanical means because they can work during wet weather periods, and weeds are controlled before or soon after emer-

gence.

2) Herbicides replace scarce or expensive labor and also reduce problems associated with labor such as housing, feeding and transpotation.

3) Soil erosion is reduced when tillage is reduced.

4) Damage to roots and other below ground parts is reduced when manual or mechanical methods are replaced by herbicides.

Peasant Farms. A discussion of the future of herbicides on peasant farms should be preceded by a general description of the farms, the people and the environment in which they exist.

1) Farms—The land being farmed may not even legally belong to the farmer. It is invariably a small piece of land and usually the terrain is hilly. The different crops are grown in very close association and often some sort of mixed cropping is practiced.

2) People—The people are uneducated and generally cannot read. They are reluctant to accept change and are suspicious of government people and programs. They have no understanding of herbicides and usually rely on family labor to do all weeding. Understanding and experience with equipment is very limited.

3) Economy—Little or no money is available to these people. If any is available, it is spent for seed, insecticides and fungicides first. Credit systems are nonexistent or expensive. There is usually very little room for additional risk with the family food supply.

4) Weather—Most of the peasant farmers of the world live in tropical, subtropical, or arid regions. The weather in these areas is either predictably unfavorable for crop production or very unpredictable. Extremes in temperature and moisture conditions are common.

Herbicides. Herbicides also have general characteristics which should be considered in relation to their interaction with the above items:

1) Reliability—Most of the herbicides available today work best within a range of environmental conditions. It has just been pointed out that weather conditions in much of the area involved are not only unpredictable but are subject to extremes. This means that herbicides are subject to partial or complete failure. This failure may be in the form of poor weed control or crop injury.

2) Safety—We are fortunate that most herbicides are not highly toxic to people and other animals. However, nearly all herbicides can be harmful if handled improperly.

3) Hazard to other crops—All herbicides are a potential threat to other crops in the area, either through drift, volatility, surface movement or soil residue. Hilly land, heavy rains, mixed cropping and the farmers' lack of understanding of the problems make the threat even greater.

4) Container size—Most herbicides are available from the manufacturer only in containers which are too large for the needs of the farmer who wants to spray less than one hectare. This has resulted in repackaging by local distributors. Of course, this presents an ideal opportunity to dilute the herbicides with nonactive materials. Unfortunately, beverage bottles are commonly used to repackage liquid herbicides. This presents an obvious health hazard. The labels, use instructions and cautions are seldom transferred to the new containers. However, these items are of limited value since most

of the farmers concerned cannot read.

5) Species shifts—All herbicides, when used at normal rates for more than 2 or 3 years, will change the predominant species in an area. More advanced farmers are able to cope with this problem by using herbicide combinations, by changing herbicides periodically, or by supplementing the herbicide with tillage and crop rotation. The peasant farmer, in failing to recognize the problem, could be faced with an even more serious weed complex.

6) Cost—Herbicides are expensive. In a system where family labor is considered to have no cost, herbicides may be considered an unjustifiable luxury.

Potential Uses. With this rather pessimistic background, it would be understandable if one were to conclude that peasant farmers were to be denied the use of herbicides in the foreseeable future. This probably is true from an economical standpoint. Some very major changes must be made before the peasant farmer is able to afford herbicides. This is not necessarily true from a technical standpoint. There are some situations where herbicides can be useful in spite of the problems discussed.

1) Land clearing—In some regions land is allowed to go uncropped for 1 to 3 years. The growth of weeds and brush must be removed before a seedbed can be prepared. This is difficult, time consuming labor. A foliage applied brush herbicide followed by fire can reduce the labor requirement considerably.

2) Preplant treatment—A nonselective, nonresidual herbicide can be used to control existing weeds on a previously prepared seedbed. The crop is then seeded with no further soil disturbance. If climatic and soil conditions will allow seeding to be delayed for 2 weeks after the seedbed is prepared, this can be a very effective method.

3) Off-season weed control—Some regions have distinct dry or wet seasons in which crops are not planted. Yet weeds continue to grow and greatly increase the hand labor needed to prepare a seedbed in the next season. A short term residual herbicide or a contact, non-residual herbicide could be used to keep the weed population under control. In such a program, attention should be given to erosion problems and soil reaction to increased sun-light.

In all of the above potential uses for herbicides, the problems associated with misapplications are much reduced because there are no crops present when the herbicide is applied.

4) Special weed problems—There are weeds which are nearly impossible to control by manual methods. Large areas of land are abandoned and production is greatly reduced in other areas because of weeds such as *Imperata cylindrica, Cynodon dactylon, Sorghum halepense, Cyperus rotundus, Striga* spp., and others. Herbicides seem to offer the only practical method of controlling such weeds in crop lands. *Cyperus rotundus* and the parasitic weeds still are not controlled satisfactorily with herbicides.

Annual crops. Because of the risk involved most herbicides now available are not suitable for the annual food crops grown on the peasant farms. The safety margin and level of weed control are not adequately reliable under the conditions prevalent on the peasant farm. Even atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] with its great safety to corn (*Zea mays*) is a hazard to nearby or following crops. The farmer simply is in no position to accept additional risk to his food crops. Nor should we as agronomists be willing to recommend herbicides under these conditions.

Conclusion

At today's costs, herbicides will not be widely used on peasant farms. If the cost picture changes, there are some technical changes needed to help reduce the risk involved. We need to search for better application methods and formulations to reduce the possibility of misapplication. Herbicides should be made available in small containers and labels should be designed with the non-readers in mind. Education efforts need to be directed toward the peasant farmer.

Taxonomy and Distribution of Weed Oats in Japan and Korea

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Abstract. The detailed collections of weed oats in Japan and Korea were carried out, and the collected materials were raised in the experimental field. Slender oat, wild common oat (*Avena fatua* L. sens. strict.), common oat and wild red oat were found to be weeds in the broad sense. The harmful to crop production in Japan and Korea is only wild common oat. The wild common oat in Japan and Korea includes many taxonomic varieties and some ecotypes adapted to fields of Asian barley or wheat. The geobotanic examinations of weed oats were made in detail in this study.

INTRODUCTION

Weed oats are not so much harmful to crop production in Japan (Kasahara, 1968) and Korea, because in the Far East the winter cereals, i.e. wheat, barley or oats, are planted as a second crop of the paddy rice. As oat seeds are killed under the submarged conditions of the paddy fields in summer (Yamaguchi, 1975), weed oats did not come into the subject of agronomy in Japan and Korea. While wild common oat and wild red oat are the unwelcome and obstructive weeds in cereal fields in the western world; Australia (Whalley and Burfitt, 1972), Canada (Sexsmith, 1958), England (Thurston, 1957), France (Barralis, 1961), Germany (Bachthaler, 1966) and USA (Toole and Coffman, 1940).

It is well known that wild common oat (*Avena fatua* L. sens. strict.) is a widespread and polymorphic species in the temperate. The geobotanic study of wild and cultivated oats in the world was carried out by Malzew (1930), but the oats of the Far East were not studied in detail. Nakao (1950) made the ethnobotanic examination of weed and cultivated oats in Mongolia. Yamaguchi and Nakao (1975) studied the weed oats in Japan and reported some peculiar varieties and forms. The additional works to the report of Yamaguchi and Nakao (1975) in Japan and the geobotanic works of weed oats in Korea are reported in this paper.

MATERIALS AND METHODS

Collections were carried out in 1972 and 1973 in Japan and in 1974 in Korea, respectively. Collected materials were raised in the experimental field of University of Osaka Prefecture. Herbarium specimens of Tokyo University (TI), Kyoto University

(KYO), the National Science Museum (TSM) of Japan, Seoul University (HAS), Songuinggung University (SKK) of Korea and the raised specimens were examined for taxonomic work. The classification of weed oats was made according to Malzewian system (1930).

RESULTS AND DISCUSSION

Verietal components (phenotype) and distribution of weed oats in Japan and Korea are as follows:—

A) *Avena fatua* L. sens. ampl.

(1) subsp. *septentrionalis* Malz.

Phenotype: var. *valdepilosa* Malz., var. *glabripaleata* Malz., var. *sparsepilosa* Malz., var. *glabella* Malz., var. *kiharae* Nakao, var. *pilosiformis* Yamaguchi, subvar. *pumila* Yamaguchi, subvar. *zine* Yamaguchi, subvar. *naniformis* Yamaguchi, subvar. *pseudo-nana* Yamaguchi, subvar. *spissa* Yamaguchi (new subvariety: Plant erect ca. 30–50 cm in height, panicle very short ca. 10 cm long, branch of panicle shortened, lemma densely hairy, hair of lemma base short ca. 1–2 mm long, caryopsis brown at mature, sometimes awnless. Type specimen; Abe, K. 11 et 15 in TI, Murata, G. anno 1952 in KYO), subvar. *compacta* Yamaguchi (new subvariety: Plant erect ca. 60 cm in height, panicle very short ca. 5–8 cm long, branch of panicle very shortened, upper glume of spikelet sometimes reduced, lemma glabrous, hair of lemma base ca. 1–2 mm long, caryopsis grey to black at mature, most of lemma awnless, awned lemma distribute in upper part of branch of panicle. Type specimen; Yamaguchi 1179, Morikawa, H. 128 in TI, Fujisawa, T. anno 1949 in KYO, Yamaguchi cult. st. 342). Distribution: Normal form; Eastern coast of Tohoku, Kanto, Tokai, Hokuriku, Kinki, Chugoku, Shikoku, Kyushu districts of Japan and Kyoungsong, Chonla, Kyoengi, Cheju districts of Korea. Dwarf races (short culm ecotypes; subvars. *pumila*, *zine*, *naniformis*, *pseudo-nana*); Kanto, Kinki, Chugoku, Shikoku, Kyushu, Cheju. Compact panicle races (subvars. *spissa*, *compacta*); Chugoku, Shikoku, coast of Kyoungsong.

(2) subsp. *nodipilosa* Malz.

Phenotype: var. *piligera* Malz., var. *glabriuscula* Malz., var. *chaharensis* Nakao, var. *subglabra* Malz., var. *glabra* Malz., var. *imanishiae* Nakao, var. *hyugaensis* Yamaguchi, var. *nipponica* Yamaguchi. Distribution: Chugoku, Shikoku, Kyushu of Japan and Kyoungsong, Kyoengi, Kwangwoen of Korea.

(3) subsp. *fatua* Thell.

Phenotype: var. *pilosissima* S. F. Grey, var. *glabrata* Peterm., var. *intermedia* Lej. et Court., var. *vilis* Hausskn., var. *cinerea* Pran., var. *pilosa* Syme, subvar. *scabrida* Malz. Distribution: Hokkaido, Kanto, Kinki, Hokuriku, Chugoku, Shikoku, Kyushu dists. of Japan and Kyoungsong, Chonla, Cheju, Kyoengi dists. of Korea.

(4) subsp. *sativa* Thell.

Phenotype: var. *brachytricha* Malz., var. *glaberrima* Malz., forma *subcontracta* Yamaguchi. Distribution: Hokkaido, Tohoku, Hokuriku, Shikoku, Kyushu.

(5) subsp. *macrantha* Malz.

Phenotype: var. *longipila* Malz., var. *asiatica* Malz., var. *calva* Malz. Distribution:

Tokai of Japan.

(6) subsp. *cultiformis* Malz.

Phenotype: var. *pseudo-culta* Malz. subvar. *pachycarpa* Malz. Distribution: Hokkaido of Japan.

(7) subsp. *praegravis* Malz.

Phenotype: var. *leiantha* Malz. Distribution: Hokkaido, Tohoku, Tozan, Kanto, Chugoku, Shikoku, Kyushu of Japan.

B) *Avena sterilis* L. sens. ampl.

(8) subsp. *trichophylla* Malz.

Phenotype: var. *subcarvescense* Malz. Distribution: Kanto.

(9) subsp. *ludoviciana* Gillet et Magne

Phenotype; var. *glabrescens* Dur. Distribution: Kinki.

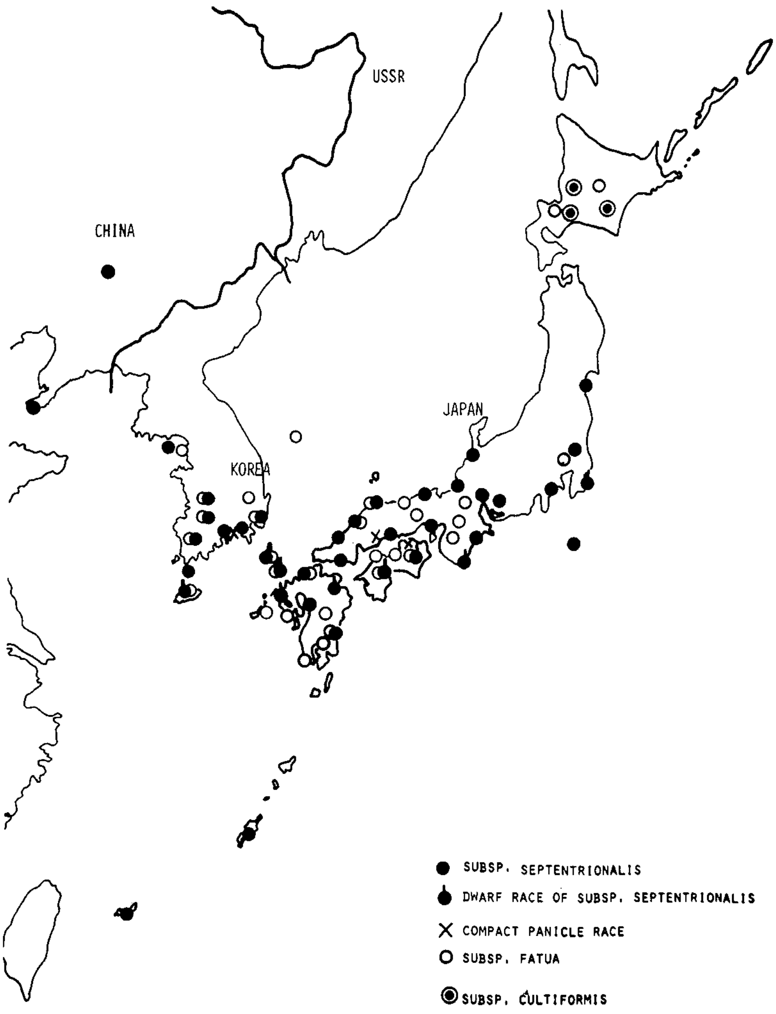

Fig. 1. Distribution map of wild common oat in Japan and Korea.

(10) subsp. *macrocarpa* Briq.

Phenotype: var. *setosissima* Malz. subvar. *maxima* Malz. Distribution: Kanto.

C) *Avena strigosa* Schreb. sens. ampl.

(11) subsp. *barbata* Thell.

Phenotype: var. *typica* Malz. Distribution: Tokai and Kinki.

As mentioned above, weed oats in Japan and Korea are 3 species and 11 subspecies, however the harmful are only wild common oat: ssp. *septentrionalis*, ssp. *fatua* and ssp. *cultiformis*. Distribution of wild common oat is shown in Fig. 1. Normal forms of ssp. *septentrionalis* and the ssp. *fatua* except for from Hokkaido are found both in arable and urban areas of Japan and Korea. If they infest in the fields of cereals, they could be found out easily because their panicles are over from the ear level of the cereals. While the dwarf races with shorter culms could not be found out easily. Therefore, it can be said that they are well adapted to the Asian local cereals. The new races; subvars. *spissa* and *compacta*, are more adaptive ones to Asian barley. Their plant habit resemble to that of the local barley. On the other hand, ssp. *fatua* and ssp. *cultiformis* in Hokkaido are found in the fields of cultivated oats. The geobotanic results described in this paper will be useful for control of weed oats and oat improvement in the world.

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Requirement of Temperature Conditions in Germination of Annual Weed Seeds and its Relation to Seasonal Distribution of Emergence in the Field

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Abstract. Seeds of common lambsquarters (*Chenopodium album* L.), Himeinubie, a variety of barnyardgrass (*Echinochloa crus-galli* Beauv. var. *praticola* Ohwi), and pale smartweed (*Polygonum lapathifolium* L.) were examined in germination behaviour to temperature conditions. It was demonstrated that periodicity of emergence from spring to summer in common lambsquarters and Himeinubie was controlled by diurnal soil temperature variation in surface layer. It was probable, however, that secondary dormancy was involved in emergence of pale smartweed from summer to autumn and in common lambsquarters in autumn.

INTRODUCTION

Periodicity of emergence of annual weeds has been studied by many workers. As Koller (1964) and King (1966) review and comment on the field emergence, there are many factors involved, and those affecting the periodicity of weed emergence are not completely clarified. The purpose of this paper was to make clear the germination behaviour of seeds to temperature conditions and determine how soil temperature affected the periodicity of emergence.

MATERIALS AND METHODS

The seeds used were collected in 1973: common lambsquarters (*Chenopodium album* L.), Himeinubie, a variety of barnyardgrass (*Echinochloa crus-galli* Beauv. var. *praticola* Ohwi), and pale smartweed (*Polygonum lapathifolium* L.). The experiments were run twice in a period from January to July in 1974. One hundred seeds were dispersed in the soil of about 15 cc sieved with 35 mesh and enclosed in a nylon-net and buried in wagner pots that were held at 10°C in common lambsquarters and Himeinubie, and at 5°C in pale smartweed. After 70–80 days, the seeds were recovered in the dark, and placed on moist filter paper in petri dishes. Each treatment was replicated twice. Seeds were kept in darkness by wrapping the dishes by aluminium foil. Prior to incubation, seeds were preirradiated with sunlight for 5 minutes. Seeds were tested for germination in 21 treatments; being subjected to a variety of combinations of two alternate temperatures within a day, 8 hours to higher temperature and 16 hours to lower temperature.

RESULTS AND DISCUSSION

The mean figures for the experiments are shown in Table 1. The high rate of germination of the seeds preirradiated was obtained, especially when temperature conditions were unfavorable. The seeds of Himeinubie and pale smartweed completely germinated at 20°, 25°, and 30°C during the preceding temperature treatment of the two alternate temperatures and the differences among temperature treatments as a whole became very small. When the higher counterpart of two alternate temperatures was lower than 10°C, the seeds of pale smartweed happened to germinate markedly at a 10°–5°C temperature combination, while those of Himeinubie germinated only 2 percent. The common lambsquarters seeds showed relatively a wide range of difference in germination rates among the treatments.

In the dark, the seeds of 3 species germinated well at alternating temperatures. Lang (1965) reviewed that alternating temperatures were effective in germination of many species. The seeds of common lambsquarters showed high percentage of germina-

Table 1. Rate of germination under a variety of two alternate temperatures.

Combination of temperatures	Common lambsquarters		Himeinubie		Pale smartweed	
′ ″	*Light (%)	Dark (%)	*Light (%)	Dark (%)	*Light (%)	Dark (%)
30/30	39.8	3.5	100	82.5	92.1	66.8
30/25	50.1	3.8	95.7	70.6	99.0	56.2
30/20	56.7	5.2	98.9	79.6	99.0	61.1
30/15	65.4	6.5	100	86.9	97.9	68.9
30/10	97.3	10.0	100	97.9	100	95.5
30/5	95.4	45.4	100	98.0	99.0	98.5
25/25	50.9	2.3	97.2	31.8	98.2	45.0
25/20	65.0	0.8	95.9	11.8	87.4	21.6
25/15	77.1	6.4	100	16.6	97.2	33.2
25/10	89.3	6.0	99.7	44.3	99.3	98.0
25/5	97.5	40.4	99.5	86.3	98.4	99.5
20/20	47.1	0.4	94.6	4.5	90.5	17.6
20/15	65.2	2.4	95.5	3.8	83.3	20.7
20/10	74.7	3.1	98.1	7.8	97.8	30.6
20/5	93.8	33.0	97.9	7.3	98.7	98.2
15/15	53.4	1.8	85.6	3.6	66.8	3.2
15/10	60.9	1.8	72.5	1.8	68.0	12.3
15/5	83.8	15.3	81.8	1.8	93.4	67.6
10/10	33.7	1.0	15.3	1.1	10.3	2.0
10/5	50.5	7.0	2.1	0	90.6	54.3
5/5	8.7	0	1.7	0	8.1	0

′ 8 hours exposure.
″ 16 hours exposure.
* Preirradiated with sunlight for 5 minutes.

tion when the lower temperature was 5°C and the other counterpart temperature was higher. It was considered that the seeds of this weed needed the most strict requirement of temperature conditions in germination. Himeinubie seeds germinated very few when high temperature treatments were kept lower than 20°C, and at 25° they did fairly well when the following alternate temperature was 5°C. At 30°C they germinated well regardless of the degree of the following alternate temperatures ranging from 30°C to the lower. The pale smartweed seeds were similar to common lambsquarters in response to the preceding higher temperatures at 15° and 20°C, and to Himeinubie at 25° and 30°C.

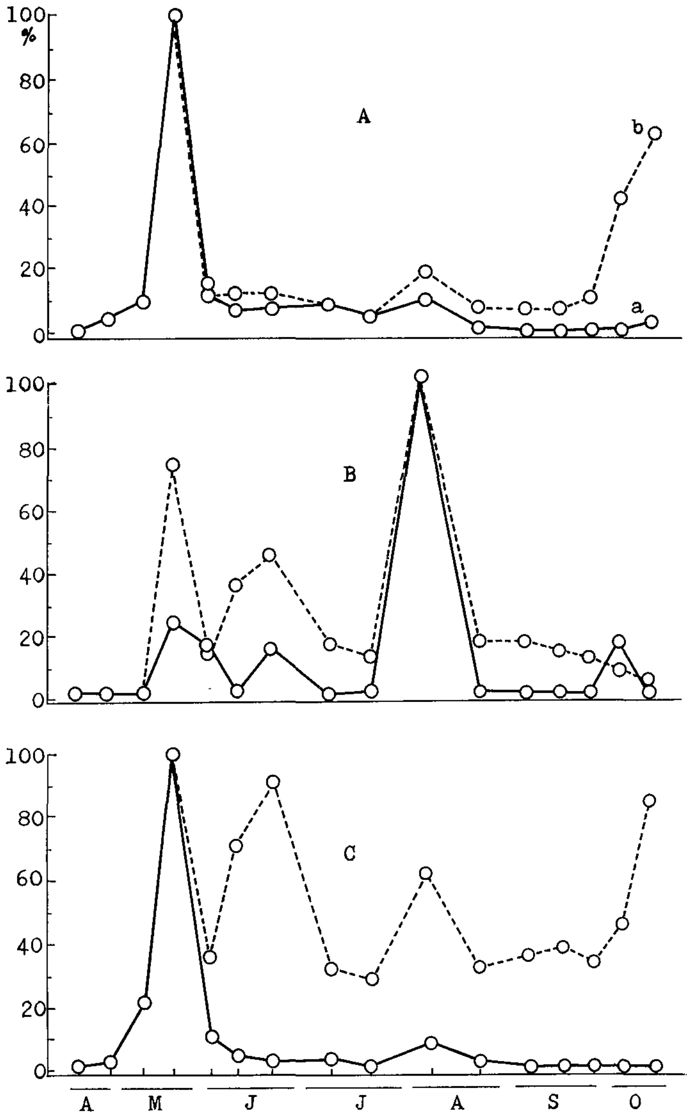

Fig. 1. Seasonal distribution of emergence (a), and theoretical germination curves (b) obtained by plotting figures of darkness in Table 1, and (A) represents common lambsquarters, (B) Himeinubie, and (C) pale smartweed.

Fig. 1 shows a comparison of the results of seasonal distribution of emergence in 1971 reported by Watanabe and Hirokawa (1975a) with the theoretical results of periodicity in germination. The theoretical germination curves were obtained by plotting germination percentages in the dark of Table 1 and checking the germination percentages expected from the combination of the mean maximum and minimum soil temperatures in the surface layers during the given period in 1971. It was found that in common lambsquarters and Himeinubie, the theoretical curves of seasonal distribution of germination almost coincided with the observed patterns of emergence in a period from May to September. It was evident that the seasonal emergence pattern of these weeds during the time from spring to summer was controlled mainly by diurnal soil temperature variation in the soil surface layer. However, the emergence of pale smartweed during the time from June to October and common lambsquarters in October decreased considerably against the emergency rate expected from the soil temperatures. It was also shown by Watanabe and Hirokawa (1975b) that viable seeds of these weeds developed an induced dormancy during the time from June to August. Therefore, the emergence patterns of these weeds in such induced dormancy are not able to explain by their response to soil temperature distribution. Accordingly, it can be concluded that the emergence patterns of these weeds are governed by the interaction of soil surface temperature and physiological state of seeds in soil.

Acknowledgment

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Dissemination of Weed Seeds in Forage Lands

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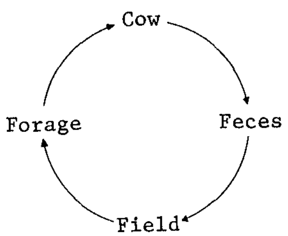
Abstract. Fields were much infested with weeds by spreading of liquid manure. The infestation was serious when cows were fed with green foder or hay containing large quantities of livid amaranth (*Amaranthus lividus* L.) seeds. On the other hand, the infestation was negligible when they were fed on the silage.

INTRODUCTION

Use of animal waste for fields is very important to maintain soil fertility. Much weed, however, emerged in the fields where animal waste was spread (Kagami, 1972; Nakamura *et al.*, 1972), and the method to get rid of viable weed seeds is required to be established. So, the viability of weed seeds was examined in each step of the seed cycle illustrated below.



MATERIALS AND METHODS

Number of weed emergence, green yield (grass and weed) and number of mowed weed seeds were examined both in the liquid manure plots and in the compound fertilizer plots of forage lands where Italian ryegrass and rhodes grass had been cultivated continuously for 8–9 years.

A Holstein cow was fed 50,000 seeds of livid amaranth (*Amaranthus lividus* L.), large crab-grass (*Digitaria adscendens* Henr.) and Italian ryegrass respectively, mixed with 1 kg of concentrated feed. During the experimental period, the cow was bound in a barn and fed concentrated feed and hay free of weed seeds. Feces defecated by the cow were collected for 5 days after the feeding. Seeds were recovered from 10 percent of the feces by washing and decanting through a series of sieves and were tested for germination. The germination test was conducted for 30 days in a green house on the soil treated by an autoclave.

In one trial, original seeds kept in nylon-meshe bags were stored in manure tank from October to November or to January, in the other, in stack silo from August to October under three water-content conditions of silage. Temperature of liquid manure was similar to the open air, and pH of the manure ranged within 7.0–7.3. Maximum temperature of stack silage was 48°C under high and moderate water-content conditions and was 42°C under low water-content condition. Water-content conditions of silage were 72–75% (high), 56–63% (moderate) and 32–35% (low). At the end of these storages, seeds were recovered and tested for germination. The germination tests were carried out on Petri-dishes in a growth chamber.

The examinations were conducted both in 1973 and in 1974.

Results

Weed yields were more than grass yields at the first mowing of rhodes grass both in liquid manure plots and in compound fertilizer plots. Livid amaranth formed 86% of green yield in the liquid manure plots and large crab-grass formed 66% in the compound fertilizer plots (Table 1). There were many livid amaranth seeds (65,000 seeds/m^2, at the first mowing) in mowed rhodes grass of liquid manure plots (Table 2) and many large crab-grass seeds (at the second mowing) in mowed rhodes grass of compound fertilizer plots.

Number of weed germination from an aliquot of feces sample was maximum at the second day and minimum at the fifth day after feeding. Livid amaranth seeds with an original germination of 83% showed 53% germination and large crab-grass seeds with an original germination of 82% showed 26% germination after the passage through the digestive tract of the cow (Table 3).

Table 1. Green yield of forage land (31th July, 1973).

Plots of forage land	Grass (g/m^2)	Large crab-grass (g/m^2)	Livid amaranth (g/m^2)	The other weeds (g/m^2)	Total (g/m^2)
Liquid manure	138	59	3,385	374	3,956
Compound fertilizer	491	1,206	100	29	1,826

Table 2. Seed production of liquid manure plots (31th July, 1973).

Species	Seed weight (g/m^2)	Thousand-kernel-weight (mg)	Number of seeds (seeds/m^2)
Italian ryegrass	0.24	1,020	235
Large crab-grass	0.03	510	59
Livid amaranth	39.77	610	65,196
Common purslane	0.75	91	8,242

Table 3. Number of seeds germinated after the passage through the digestive tract of the cow.

Species	Days after feeding						*Germination (%)
	1	2	3	4	5	total	
Livid amaranth	81	976	883	603	92	2,635	53
Large crab-grass	118	884	251	37	0	1,290	26
Italian ryegrass	132	1,248	139	3	1	1,523	31

* Germination: ratio to 5,000 seeds
Original germination: livid amaranth 83%
large crab-grass 82%
Italian ryegrass 96%

Table 4. Germination in percentage of seeds stored in manure tank.

Species	Storage duration month		Original (%)
	1 (%)	3 (%)	
Livid amaranth	95	91	94
Large crab-grass	80	22	91
Italian ryegrass	2	0	89

Table 5. Germination of seeds stored in stack silo (percentage to original germination).

Species	Water-content condition		
	High (%)	Moderate (%)	Low (%)
Livid amaranth	0	0	5
Large crab-grass	0	0	0

Viability of livid amaranth seeds was little affected by the storage in manure tank for 1 or 3 months, but that of large crab-grass seeds was reduced. Italian ryegrass seeds lost viability mostly by the storage for 1 month and lost it completely for 3 months (Table 4).

By the storage in silo for 2 months, livid amaranth seeds were devitalized under both high and moderate water-content conditions, but were viable a little (5% germination) under low water-content condition. Large crab-grass seeds were completely devitalized under all water-content conditions (Table 5).

Discussion

It has been known that some kinds of weed seeds or forage seeds remain viable after the passage through digestive tract of domestic animals (Atkeson, Hulbert & Warren, 1934; Yamada & Kawaguchi, 1972). But the knowledge on the ecological dynamics of seeds is so far missing. We investigated the ecological dynamics of some kinds of weed seeds and clarified that spreading of liquid manure over fields caused weed infestation, especially when cows were fed with green foder or hay containing large quantities of livid amaranth.

From the viewpoint of weed control, we clarified that most seeds of weed were devitalized after the storage in silo. Tildesley (1937) showed that the reduced viability of the different seed species treated by him was probably chiefly due to the concentration of lactic and acetic acids produced in the silo. Viability of weed seeds may possibly depends on some conditions of ensilage (Barnett, 1954). We found that the viability was largely affected by the temperature and water-content condition in silo.

Furthermore, raw feces are not used willingly by vegitable farmers, not only for its bad smell and its characters but also for its weed seeds mixed in them. But the feces were found to lose its viable seeds to some degree by being dried and completely by being fermented after drying (Table 6).

Table 6. Number of seeds germinated from raw and treated feces.

Species	Raw	Dried*	Dried and** fermented
Livid amaranth	2,635	817	0
Large crab-grass	1,290	186	0
Italian ryegrass	1,523	131	0

* Dried in a vinyl house for 1 month.

** Dried in a vinyl house for 1 month and fermented in a piled feces for 2 weeks.

ACKNOWLEDGMENTS

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Ethylene and Carbon Dioxide as Factors Regulating Initial Growth and Development in Several Perennial Aquatic Weeds

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Abstract. The initial growth of three perennial aquatic weeds, two species of arrowhead (*Sagittaria pygmaea* and *S. trifolia*) and pondweed (*Potamogeton distinctus*), is greatly promoted by C_2H_4 and CO_2 in the dark. Not only addition of C_2H_4 stimulated the growth but also the removal of endogenously evolved C_2H_4 or CO_2 greatly reduced the growth, indicating that C_2H_4 and CO_2 acted as natural factors for regulating the early development and elongation.

Introduction

Two species of arrowhead (*Sagittaria pygmaea* and *S. trifolia*) are reported to occur in 555,299 ha in paddy fields of Japan. This is almost 20% of all rice cultivation acreage, 2,628,330 ha. Thus, arrowhead species, with other two weed species, *Cyperus serotinus* and *Scirpus hotarui*, are considered as four main perennial weeds in paddy fields of Japan. Another perennial aquatic plant, pondweed is also known as a serious weed in paddy fields all over Japan.

I report here evidence for the hypothesis that C_2H_4 and CO_2 are natural factors regulating initial development and elongation of arrowhead species and pondweed.

Materials and Methods

Ten corms of arrowhead species or ten winter buds of pondweed were selected for uniformity in size and transferred into 50 ml Erlenmyer flasks containing 3 ml of water. In some experiments center well contained either 1 ml of 20% KOH to remove endogenous CO_2 or 1 ml of mercuric perchlorate to remove endogenous C_2H_4. The flask were fitted with vaccine caps, and C_2H_4 was introduced or sampled through the caps with gas-tight syringes. The flasks were kept in the dark at 30°C. C_2H_4 in the 2 ml gas sample was measured with a flame ionization gas chromatograph (Shimazu GC 4BPTF model) equipped with Porapak-Q column at 50°C.

To test the effect of container size on initial elongation, 10 corms or winter buds were enclosed in flasks ranging from 50 to 2000 ml. Effect of water depth on the initial elongation was also tested using 30 ×125 mm glass cylinders in which 10 corms were submerged at different depths. These flasks and cylinders were incubated in the dark at 30°C. In the CO_2 studies the gas released from a CO_2 cylinder was mixed with air supplied from an air pump. To obtain fixed ratios of CO_2 and air, the flow rates of the gases were adjusted with flow meters. The flasks containing corms were flushed with the CO_2-air mixture to replace the air and then a vaccine cap was fitted on the flask.

Results and Discussion

Submergence is effective in promoting shoot elongation of *S. pygmaea* and pondweed. Elongation of the 1st leaf as well as successive leaves was also promoted by submergence. To test the possibility that volatiles might affect initial development and elongation, 10 corms or winter buds of the species were incubated in containers of different volumes. The results for arrowhead species and pondweed show elongation decreased in relation to increasing container volume. The stimulation of elongation could be due to the production of gases by the corms or winter buds and C_2H_4 and CO_2 would be obvious suspects. The height of plants increased as a function of increasing C_2H_4 concentrations. Low concentrations of C_2H_4 produced maximum elongation and a concentration as high as 10,000 ppm did not inhibit elongation in 3 species in the dark. C_2H_4 evolution and growth were followed over 8 day periods in *S. pygmaea* and pondweed.

In *S. pygmaea*, increase in plant height and leaf expansion accompanied by C_2H_4 production, but elongation of the 1st internode was not observed until the 4th day of incubation. In pondweed, stem elongation was comparatively slow until 6th day of in-

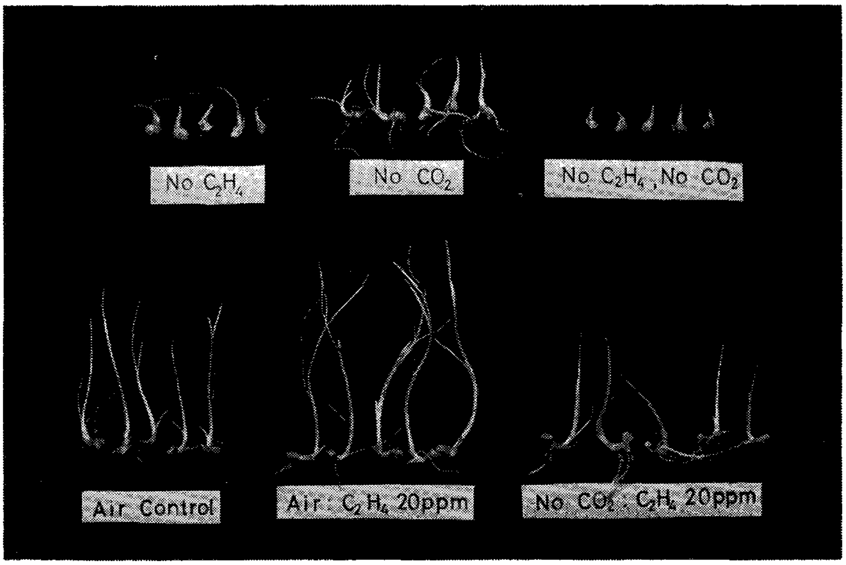

Fig. 1. Influence of C_2H_4 and CO_2 on leaf expansion and development and root elongation of *Sagittaria pygmaea*. Ten corms were enclosed with 3 ml of water in each 50 ml flask. To remove endogenously evolved C_2H_4 or CO_2, 1 ml of mercuric perchlorate or 20% KOH was placed in the center well, respectively. The flasks were fitted with vaccine caps, and C_2H_4 was introduced through the cap with a gas-tight syringe. Photograph was taken after 9 days incubation at 30°C in darkness.

cubation, then increased rapidly attended by a rise of C_2H_4 evolution.

If C_2H_4 is indeed a growth regulator controlling the growth of arrowhead and pondweed plants, one might expect that elongation would be mimimized when they are grown C_2H_4 free atmospheres. A variety of atmospheres, with and without endogenously produced or added C_2H_4 and CO_2, were therefore tested, C_2H_4 had a dramatic effect on the growth of arrowhead plants in the dark (Fig. 1). CO_2 also promotes elongation, however, CO_2 alone (C_2H_4 removed) had a lesser effect. Gas-chromatographic detection revealed that 0.29 and 0.23 ppm C_2H_4 were found in the sealed control and CO_2-free air, respectively. Not only did removal of evolved C_2H_4 reduced elongation but also addition of C_2H_4 stimulated growth. Similar results were obtained with *S. trifolia* and with pondweed (Fig. 2). Both C_2H_4 and CO_2 dramatically influenced growth of pondweed buds in darkness. Removal of CO_2 markedly reduced elongation. Gas-chromatography revealed that 0.14 ppm C_2H_4 was present in the sealed control after 8 days as well as in CO_2-free air. Elongation of *S. pygmaea* was maximal over the range from 0.1 to 10% CO_2 when 20 ppm C_2H_4 was added, whereas 5% CO_2 caused maximum elongation when endogenously evolved C_2H_4 was removed.

The results of these experiments indicate that C_2H_4 and CO_2 are involved in regulating development and elongation in 3 aquatic perennial plants, in the dark. The synergism is remarkable since C_2H_4 usually acts as an inhibitor of elongation and CO_2 is antagonistic to the action of C_2H_4 (Burg and Burg, 1967). Suge (1972) speculated that CO_2 acts as a synergist of C_2H_4 action in systems in which C_2H_4 acts as a promoter, whereas CO_2 acts as antagonist of C_2H_4 action in systems in which C_2H_4 acts as an inhibitor. The present results agree with this assumption.

Although, morphologically different, 5 types of organs are known to elongate in

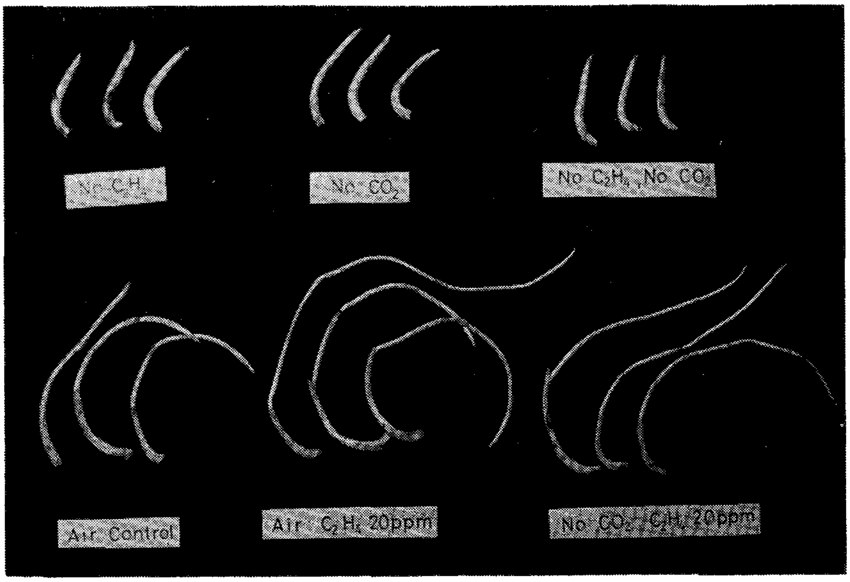

Fig. 2. Influence of C_2H_4 and CO_2 on shoot elongation of *Potamogeton distinctus*. Ten winter buds were enclosed with 3 ml of water in each 50 ml flask. Other explanations are same as that in Fig. 1.

response to C_2H_4; rice coleoptile (Ku *et al.*, 1970) and mesocotyl (Suge, 1971), *Callitriche* water stem (Musgrave *et al*, 1972), *Ranunculus* leaf petiole (Musgrave and Walters, 1973) and *Regnillidium* rachis (Musgrave and Walters, 1974). All these are known as fresh water plants.

Goeschl *et al.* (1966) showed that physical stress applied to pea epicotyls induced C_2H_4 production with consequent growth modification. Submergence of rice seedlings in water also provide a stress, possibly with a similar consequence since elongation of rice coleoptile is proportional to the depth of water in which the seeds are submerged (Ku *et al.*, 1970). This response to submergence suggests that release of C_2H_4 may be a general mechanism whereby aquatic plants adjust to water depth.

Composition of soil atmosphere is richer in CO_2 and poorer in O_2 than the free atmosphere. CO_2 in soil is known to vary in range from 0.1 to 10%, whereas it is almost constant at 0.03% in the free atmosphere. Smith and Russell (1969) reported that the C_2H_4 content of aerobic soil was 0.07 ppm in the upper 15 cm, but could increase to 10 ppm when soil was soaked with water. Kuwazuka *et al.* (1973) and Yoshida and Suzuki (1975) also reported that submerged or water logged soil produces much C_2H_4 than that of aerobic soil. Furthermore, Yoshida and Suzuki (1975) showed that addition of crushed rice straw or other organic substances to the soil increase C_2H_4 evolution markedly.

In Japan, rice paddies are drained in the fall for harvest, and they are not flooded again until next spring. Usually, the soil of paddy fields contains many rice roots and much stubbles. Thus, an increase in C_2H_4 evolution by flooding soil containing abundant organic matter which accumulates comparatively high level of CO_2, favors the emergence and initial development in such aquatic weeds as arrowhead and pondweed.

Endogenously evolved C_2H_4 from those plants also play an important role as well as C_2H_4 evolved from the soil surrounding the corms and winter buds of those species. Although much experimental work is needed before a complete understanding of the problem is achieved, the present evidence adds weight to the contention that C_2H_4 and CO_2 are important factors in regulating initial development and elongation in the majority, if not all, of aquatic plants.

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Growth Behavior of *Scirpus maritimus* L.

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Abstract. The pattern of growth of *Scirpus maritimus* was studied with emphasis on tuber development and shoot formation. A non-dormant tuber germinated in 3 to 5 days and new tubers which gave rise to shoots were formed in 3 weeks. At 6 weeks after germination, a system of numerous stolons and tubers was developed. Dormant tubers were formed at 10 weeks reaching a maximum of about 73 at 23 weeks. At the same time, the mother shoot started to die and at 27 weeks all the shoots of the first generation were dead. Second generation shoots were formed at the 25th week. Flowering was observed in the second generation shoots that grew from the non-dormant tubers.

INTRODUCTION

Scirpus maritimus L. is a perennial sedge which propagates mainly by means of underground tubers. It is a serious weed in Isabela and Nueva Viscaya in the Cagayan Valley, Albay in Bicol and some areas of Laguna near San Pablo City (De Datta and Lacsina, 1972). Very competitive, the presence of 20 shoots per sq m at transplanting reduced rice grain yield by 79% (Lubigan and Mercado, 1974).

Ghosh *et al.*, (1971) made a preliminary study on germination, growth rate and control of perennial sedge and showed that the tubers desiccate easily through soil drying. Water management and tuber depth in the soil appeared to affect tuber germination. The present study was conducted to determine more closely the growth behavior of *Scirpus maritimus* with emphasis on tuber development.

MATERIALS AND METHODS

Uniform tubers were obtained from the ricefields, and allowed to germinate on moist filter paper inside the laboratory locker. After 1 week when the shoots were 5 cm long, uniform seedings were planted in earthen pots filled with soil taken from the lowland ricefields and with 2 to 3 cm standing water. Plants in 3 pots sampled at random were dug up every 2 weeks until the end of their growth cycle. Observations were made on the pattern of development of mother shoot, formation of stolon, tubers and shoots, flowering and seed formation, and production of second germination shoots.

Results and Discussion

Pattern of development of the mother shoot. Germination took place in 3 to 5 days and some tubers had only 1 shoot each, others had 2 or 3.

The mother shoot was about 34 cm high at 3 weeks after germination. Its maximum height of about 65 to 70 cm under the experimental conditions was attained at 7 week after germination although under field conditions, it can reach as high as 100 to 125 cm. That height was then maintained for a period of 1 or 2 weeks and decreased as a consequence of the drying of some leaves.

The number of leaves present on the mother shoot increased from the germination stage up to 7 or 8 weeks later. The number of living leaves was then maintained for a short period. Some leaves soon became yellow, leading to the death of the mother shoot at about 11 weeks after germination. The maximum number of leaves of the mother shoot varied from 10 to 13.

When the mother shoot was about 6 to 8 cm high, fibrous roots developed at the point where the shoot sprouted. The newly developed roots were white and changed to yellow, brown, dark brown and finally black as they aged. New stolons began to appear from the base of mother shoot at about 3 weeks after germination. The mother shoot, although dead at 11 weeks was still attached to its tuber. The upper part of the shoot was rotten and broken but the lower part was still attached to the mother tuber under the soil. A longer time might be required to rot all of such shoot, leaving the mother tuber alone as found in the ricefields. Such tuber may germinate again under favorable conditions. It can be carried by the irrigation water to other places where its infestation may occur. Thus, the tubers found in the field pass at least one cycle of growth.

Formation of stolons, tubers and shoots. At about 3 weeks after germination two stolons were formed at the point of attachment of the shoot to the tuber. Each stolon ended up with a young small tuber bearing a shoot. New fibrous root system formed at these young tubers. The tuber bearing the new shoot gave rise to another tuber at about 4 weeks after germination. At 6 weeks a system of numerous stolons and tubers was developed.

The newly developed stolon was white and changed to yellow, light brown, brown, dark brown and finally black as it aged. The length of the stolon between one plant and another varied from at least 2 cm to 35 cm. The internodes of a stolon varied from 2 to 6.

Until the 9th week whenever a new tuber was formed, a new shoot would sprout from it. The young tuber was at first white then turned to creamish white, yellow, light red, red, red brown, brown and finally to black. Tubers were generally round or global in shape.

At about 10 weeks after germination, dormant tubers were formed. The number of dormant tubers increased to its maximum of 73 at about 23 weeks after germination (Table 1).

The formation of dormant tubers began at the time when the mother shoot started to die. Death of the mother shoot was almost complete at 11 weeks and all the other shoots died at 27 weeks. This marked the end of the first generation of *Scirpus maritimus* shoots derived from a single mother tuber.

Table 1. Changes in number of living shoots, dormant tubers, dead shoots and newly formed shoots observed from the germination of a single mother tuber until 31 weeks.

Weeks after germination	No. of green shoots	No. of dead shoots	No. of newly formed shoots	No. of dormant tumbers
3	1.0			
5	10.7			
7	22.0			
9	35.0			
11	39.7			1.7
13	54.3			13.3
15	67.7			23.7
17	58.0	3.7		39.7
19	11.3	13.0		44.0
21	4.7	19.3		60.7
23	4.0	52.7		73.2
25	3.0	65.3	3.3	73.0
27	2.0	67.0	4.3	73.0
29			4.7	7.30
31			7.0	71.0

A maximum number of 70 shoots was attained at about 15 weeks after germination. Most of the tubers of *Scirpus maritimus* had only 1 shoot and only a few had 2 shoots. The second in most cases would sprout much later than the first. Removal of the shoot apex also induced the growth of the second shoot indicating the dominance exercised by the main apex on the other shoots. Kim and De Datta (1974) have shown that benzyladenine can break the dormancy of the tuber and at the same time overcome apical dominance.

Flowering and seed production of Scirpus maritimus. Not one of the shoots formed during the first generation flowered. Flowering was instead observed at 25 weeks after germination in 1 to 2% of the second crop of shoots that grew from the non-dormant tubers. At the same period (March, April, May) flowering shoots of *Scirpus maritimus* were also observed in the ricefields. The mechanism involved in the flowering of *Scirpus maritimus* is still unknown. Recent studies on the photoperiodism of *Scirpus maritimus* carried out at IRRI disclosed that different photoperiods do not induce flowering (Visperas, personal communication).

Production of second generation shoots. Second generation shoots started growing on non-dormant tubers when almost all of the shoots in the first generation were dead. As shown in Table 1 these new shoots grew 25 weeks after germination. During the succeeding 6 weeks only 4 additional shoots were produced, a much slower rate than that observed in the first generation shoots.

Acknowledgment

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Ecology of a Paddy Perennial Weed, *Eleocharis kuroguwai* Ohwi

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Abstract. Ecological studies of the emergence mechanism over soil surface were conducted in *Eleocharis kuroguwai* Ohwi (Cyperaceae). Upright elongation of the negative-geotropic rhizome was promoted by low oxygen concentration in water and dark condition, while the stems and roots which became visible at the tip of negative-geotropic rhizome required high oxygen concentration for the growth.

In field, it was found that almost all plants sprouted from the tubers formed in previous year which were dispersed evenly in depths of soil by the manipulation for the paddy rice cultivation. There was a positive linear correlation between the lengths of negative-geotropic rhizomes and the soil depths the tubers located at. The plants developed within 6 cm below soil surface from the stem and root primordia at the tip of negative-geotropic rhizomes.

INTRODUCTION

Eleocharis kuroguwai Ohwi, a perennial Cyperaceae which has "Kuroguwai" as a Japanese name, is reportedly confined to Japan and Korea (Ohwi, 1972). Kuroguwai is an annoying weed in a rice paddy of Japan. By use of herbicides, most of annual and some perennial weeds have become satisfactorily controlled in the paddy fields while some perennials become rampant, and also so in Ōhara district of Kyoto under our field study.

The fasciculate plant of kuroguwai propagates by means of the rhizome elongating horizontally from June until autumn and then formes the various tubers in size at the tips of rhizomes elongating plageotropically. These tubers spend the winter in dormant state. A tuber has four to six buds at the top covered with prepuces. The sprouting activity of each bud can be increased by removing the prepuces (Ueki *et al.*, 1969; Ueki and Sakaguchi, 1969). Kuroguwai emerges over a period through June to September from the underground tubers prolifically formed in the previous year. "The negative-geotropic rhizome" which was named temporarily by Ueki *et al.* (1969) elongates upward from the tuber locating below soil surface. The primordia of stems and roots locating at the upper apex of the rhizome differentiate into the fasciculate plant. Both the emergence over soil surface and the tuber formation are critical determinants for propagation of kuroguwai. In the control of this weed, therefore, it is important to know the emergence mechanism.

Ecological studies of kuroguwai tubers were undertaken to determine the mechanism of emergence over soil surface and the elongation of negative-geotropic rhizome in a greenhouse. Field studies were also conducted by using a few rice paddy fields of Ōhara district, Kyoto, in 1975.

Materials and Methods

Greenhouse experiments. In a greenhouse, we studied on the depths of planting and oxygen concentrations which affected the growth of negative-geotropic rhizome in length, using the undormant tubers of kuroguwai which were collected from fields in spring.

For the depth of planting, the tubers were incubated in three kind of soils (sandy loam, sand and gravel) at the depth of 2, 8 or 17 cm. We also incubated other group of tubers in water at 17 cm below the surface under a light or dark condition at 30°C. On a month after the incubation in soil or water, the length of negative-geotropic rhizomes and the number of stems and roots were determined.

For the oxygen concentration, four conditions (high, moderate, low and lowest) of oxygen concentrations were prepared in water of 300-ml wide-mouth glass bottles. The high O_2 condition of the water was obtained by bubling it with air, the moderate O_2 condition by use of a tap water as it was, the low O_2 condition by using a boiled water exchanged every day, and the lowest O_2 condition by use of a boiled water as it was. Their actual O_2 concentrations were measured by Miller method (D.A.C.K.U., 1957). The tubers were placed in the water for ten days at 30°C and determined on the length of the negative-geotropic rhizomes, the number of stems and rooting rate.

Field experiments. In Ōhara district of Kyoto a few studies were carried out on the vertical distribution of kuroguwai tubers and the lengths of negative-geotropic rhizomes in actual field soils. A vertical distribution of tubers in field was determined in February by digging up the 50×50 or 100×100 cm^2 quadrate-sized soil with three replications and measuring the depths tuber locating at. In June to July, the length of negative-geotropic rhizomes were examined by sampling the fasciculate plants which grew between rice plants.

Results and Discussion

Greenhouse experiments. When kuroguwai tubers were planted at 17 cm depth in sandy loam, sand and gravel, the growth of negative-geotropic rhizome in the upright elongation was 9.6, 6.6 and 1.7 cm in length, respectively. In all the soils used, the growth of the rhizome in length decreased and the number of both roots and stems which became visible at the apex of the rhizome increased inversely as the planting depth was decreased (Table 1). The length of the rhizome was considerably short in the gravels having much interstitial space with air. In water, the growth of the rhizome in length was 5.5 cm in dark condition, while 0 cm in light condition. It was also observed that the rhizome growth in length ceased when the dark was switched to light condition on a way of the incubation in water.

Oxygen concentration around tubers also affected the growth of negative-geotropic rhizome in length (Table 2). The upright elongation was promoted by low O_2 condition,

Table 1. Effect of planting depth on the growth of kuroguwai tuber for one month.

Soil type	Depth (cm)	Length of negative-geotropic rhizome (cm)	Number of roots	Number of stems
Sandy loam	2	0.6	6.2	4.3
	8	4.6	2.9	2.7
	17	9.6	0	1.0
Sand	2	0.7	11.2	3.5
	8	5.1	6.6	3.1
	17	6.6	0	1.7
Gravel	2	0.4	7.7	4.8
	8	2.6	0	1.4
	17	1.7	0	1.1
Water	17(Light)	0	13.2	5.2
	17(Dark)*	5.5	0	1.8

* In water, it was also observed that the rhizome growth in length ceased when the dark was switched to light condition on a way of the incubation in water.

Table 2. Effect of the oxygen concentration on the growth of kuroguwai tuber for ten days at 30°C.

Oxygen condition*	Change of oxygen concentration in water**			Length of negative-geotropic rhizome (cm)	Number of stems	Rooting rate (%)
	Mean (ppm)	Start (ppm)	End (ppm)			
High	6.62	7.13 ……	6.11	0.0	4.2	7.3
Moderate	3.87	7.23 ……	0.61	0.2	1.1	0.0
Low	2.35	3.20 ……	1.50	0.1	1.0	0.0
Lowest	1.98	3.20 ……	0.75	0.5	1.0	0.0

* High oxygen condition was prepared by bubling water with air, moderate by leaving as it was, low by changing a boiling water every day, lowest by leaving a boiled water as it was.

** Oxygen concentration was measured by Miller method.

but the stems and roots required a high O_2 condition for the growth. Thus, it appeared that the negative-geotropic rhizome needed both a dark and low oxygen conditions for the growth in upright elongation. In the deep zone of soil, there seems to be dark and low O_2 conditions. Light and high O_2 conditions which seem to be around soil surface were promotive to the differentiation of stems and roots from the primordia at the apices of rhizomes.

Field experiments. In determination of the vertical distribution of tubers, we dug up quadrate-sized soil in rice paddies and found that there were the new tubers formed in the previous autumn and the old tubers formed in the autumn before the previous year. The new tubers could be distinguished from the old by tuber color. The former were those had red or reddish-black color and the latter, black or aborted. Depths of the new and old tubers in soil were 12.3 ± 5.7 (0–28, n=105) and 15.7 ± 7.1 (1–30, n=289) cm, respectively, and their difference was significant at 1% level. This may indicate that the distribution of old tubers was disturbed by rice cultivation (Ueki and Kobayashi, 1975), especially by the tillages both before irrigation and for transplanting rice seedlings in the late spring of the previous year. The new tubers must have located in the soil zone where they formed, because they were formed after the rice cultivation, the soil disturbances.

When we examined 84 plants of kuroguwai by sampling them in the fields in June to July, the number of plants which originated in the new tubers were 83 and only one from the old tuber. The soil depth of tubers positively correlated to the lengths of negative-geotropic rhizomes ($r=0.95$). Most of the plants were given rise from the tubers which located at shallower depths than 12 cm, though the tubers must have dispersed evenly up to 28 cm in depth. The stem and root primordia located from the soil surface up to 6 cm in depth. In its vertical distribution, there may be two groups statistically, namely one group for 76 plants at 0 to 40 mm and the other for 5 plants at 45 to 60 mm in depth.

Results in our experiments indicate that plants of kuroguwai developed within 6 cm in depth from the stem and root primordia at the apices of negative-geotropic rhizomes. In the soil zone, there seems to be a high oxygen condition which promotes the growth of the stems and roots. The rhizome, therefore, may drive the primordium into the favourable condition near the soil surface to grow. In the depth further below, there must exist both dark and low oxygen conditions which promote the growth of the rhizome in length. The rhizomes originated principally in the new tubers formed in the previous autumn which were dispersed evenly in the soil up to 30 cm in depth. This even distribution was obtained by rice cultivation, espeially by the tillage for transplanting the rice seedlings, from the shallower-sided distribution.

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Problems and Control of "Alang-alang" [*Imperata cylindrica* (L.) Beauv.] in Indonesia

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Asbtract. *Imperata cylindrica* (L.) Beauv. is widely distributed throughout the tropical countries and also in certain parts of South America, Africa, southern Europe, India, Pakistan, southern China, Japan and Australia. It consists of five varieties. *I. cylindrica* var. *major* occurs in Southeast Asia. It is in this area that the grass causes the worst effects. In Indonesia this grass is a troublesome weed especially in perennial crops. Because of its high competition value (partly through an allelopathic effect), its fire hazard and its possible mechanical damage to the crop it may cause a tremendous loss in crop yield. The reproduction capacity is high, once established it propagates vigorously through rhizomes, causes it extremely difficult to control. Alang-alang also occupies vast acreage of land in shifting cultivation areas. The characteristics by which it decrease crop yield are responsible for the elimination of many other plant species in those areas. It also tends to deteriorate soil quality. These alang-alang areas are a big problem in Indonesia and methods are searched to rehabilitate these areas to be used for agricultural purposes. Natural succession may lead to reafforestation and is therefore one way to rehabilitate these areas.

Methods known to control this weed are mechanically, ecologically, chemically or combination of these. In general, a careful management of an alang-alang infested area is of primary importance.

INTRODUCTION

Imperata cylindrica (L.) Beauv. is found in the warm regions of the world, and forms a dreaded weed in parts of the tropical region. This perennial grass is of particular importance in Southeast Asia, although it is also of importance in West Africa and elsewhere (Hubbard *et al.*, 1944). Holm and Herberger (1970) have described *I. cylindrica* as one of the "top ten" worst weeds of the world.

In Southeast Asia it is known as lalang in Malaysia, cogon in the Philippines, illuk in Ceylon, cotranh in Vietnam, sbauv in Kmer, yak-ka in Laos and Tailand and alang-alang in Indonesia. In Indonesia local names are for instance: eurih (Sunda), weri (Ambon), ilalang (Minangkabau), lalang (Madura, Bali), halalang (Dayak), dewai (Irian), reya (Makassar) and rih (Batak).

Alang-alang is of importance as a weed in cultivated land throughout Indonesia, especially in upland areas. It has been regarded as a serious noxious weed since 1930. During the last few years an increasing attention is being paid in Indonesia to the alang-alang problem, because of the serious and increasing economic problem it presents in cultivated and shifting cultivation areas in this country.

Biology and Egology

The species *Imperata cylindrica* (L.) Beauv. is classified into five groups, each with the status of variety, i.e.: vars. *major*, *africana*, *europea*, *condensata* and *latifolia*. Var. *major*, occuring in Indonesia, differs from var. *africana* and var. *europea* by its slightly smaller spikelets and anthers and usually hairy nodes. It differs from var. *europea* by its thinner and wider leaf-blades and by its softer and less dense inflorescence, due to the fewer hairs and lesser number of spikelets for a given length of inflorescence. It may be distinguished from var. *latifolia* by the smaller size of the culms, leaves and inflorescence, and from var. *condensata* by its shorter spikeletes. *Imperata exaltata*, the other representative of the genus in Indonesia is distinguished by having one stamen, while *I. cylindrica* has tow. Local varieties or forms of *I. cylindrica* var. *major* probably exist in Indonesia.

The above ground part of alang-alang is formed by 10–200 cm long culms, 1–4 noded and up to 8 mm in diameter. The leaves consists of smooth overlapping leafsheats, a short ligule and blades from short up to 150 cm long, 4–18 mm wide, stiff and rigid. The upper blades are shorter than the lower ones. The leaf margin is scabrid.

The culms arise from tough, branched extensively creeping scaly rhizomes, 2.0–4.5 mm in diameter, which may reach 15–40 cm (Coster, 1932) or even 1 m depth (Soerjani, 1970). However, 50% of the rhizome mass occurs in the first 20 cm (Soerjani, 1970). The internodes are 1.5–3.0 cm long, become shorter at the apical ends or where the rhizome reaches the soil surface and forms an aerial shoot. Every 25–50 cm the rhizome bends upward to form a shoot (Coster, 1932; Soerjani and Soemarwoto, 1969). The nodes contain dormant buds. Usually at places were shoot formation occurs, side rhizomes may develop from these buds. These rhizomes may stay short and form shoots, constituting a tuft of shoots around the main shoot, or may extend to 25–50 cm where they bend upward to form a new main shoot. The cause of this upward bending is not known. The rhizome appears neither morphologically nor physiologically uniform throughout its full length.

Visible and viable buds are only found at nodes of the apical part of the rhizomes (Soerjani and Soemarwoto, 1969). Sprouting of the buds is prevented by apical dominance. Sprouting ability of one-node rhizome sections is stimulated by light, and shows a temperature optimum of 30°C. The color of the buds gives an indication of its sprouting capacity, dark brown buds sprouted less than brown-white buds (Soerjani and Soemarwoto, 1969). Bud sprouting capacity is not affected by bud size, bud position, node length and node diameter. Growth of shoots from these buds, however, is positively correlated with bud size and node length. It also shows a temperature optimum of 30°C. Growth of shoots developed from these buds stops after about 110 days (Soerjani & Soemarwoto, 1969). Flower formation, however, only occurs after a hot period (Hubbard *et al.*, 1944). Besides by rhizomes, alang-alang also propagates by seeds. Freshly harvested seeds are only slightly dormant and seed germination is stimulated by light (Soemarwoto, 1959). Burning and slashing stimulates flower formation especially in the dry season. Flowers produced in this way, however, seldom contain seeds.

It is said that alang-alang mainly occurs on poor soils (Backer, 1928–34; Garot and Subadi, 1960). This appears to be due to a better control of this grass in areas with good soils and also to its ability to invade areas that will not support other plants. Alang-alang decreases soil quality. Organic matter, nitrogen and phosphate content of soil under an alang-alang vegetation is lower than under other types of vegetation (Satari, 1968), and soil erosion is less prevented by alang-alang than by other plant species. Leaching in an alang-alang vegetation is greater than where other species are dominant (Coster, 1938). According to Hubbard *et al.* (1944) and Soerjani (1970) better growth of alang-alang occurs on acid soils.

Soerjani (1970) observed in field studies in Java that alang-alang may produce 3–6 million shoots per ha, 7–18 tons of leaves and 3–11 tons of rhizomes. The rhizome/shoot ratio (weight/number) ranged from 0.9 to 3.2 and the leaf/shoot ratio (weight/number) from 2.2 to 3.5. Eussen & Wirjahardja (1973) found in southern Sumatra a value of the rhizome/shoot ratio of 1.3. Shading, flooding and drought have marked influences on the growth of alang-alang (Soerjani, 1970). Production of shoots, rhizome and leaf mass is drastically reduced, while no influence could be observed on the leaf/shoot ratio (weight/number), indicating that the influence of these treatments on the above ground part is only a decrease in shoot number. Rhizome/shoot ratio (weight/number) is, however, strongly reduced. Flooding causes stronger effects than drought. Also slashing reduced rhizome mass drastically (Soerjani, 1970).

Although alang-alang frequently spreads over large areas to the virtual exclusion of other plants, it may be associated with other types of vegetation. It occurs in association with *Andropogon* spp., *Saccharum spontaneum* and *Themeda arundinacea* in the Lesser Sunda Islands (Malm, 1934). It may grow along with *Panicum repens* and *Saccharum spontaneum* in Java (Hubbard *et al.*, 1944), or *Chromolaena odorata, Eupatorium inulifolium, Melastoma affine, Mimosa invisa, Mikania cordata, Digitaria adscendens* and *Paspalum conjugatum* (Soerjani, 1970). Usually moist places show a more mixed vegetation. Also protection from fire leads to an alang-alang vegetation in which more different plant species occur (Danhof, 1940; Hubbard *et al.*, 1944).

Possible Uses

In certain cases alang-alang can be useful as ground cover, preventing soil erosion and consolidating dikes and dams (Hubbard *et al.*, 1944; Soerjani, 1970). In Sumatra regular burning of alang-alang appears to clean the tabacco plots of weeds which may be susceptible to slime disease, alang-alang itself is immune from it (Hubbard *et al.*, 1944). In several parts of Indonesia, especially Bali, alang-alang leaves are used for roof thatching and the grass is sometimes cultivated for this purpose (Soerjani, 1970). Other uses include shade material in nurseries, medical purposes, packing material, etc. (Hubbard *et al.*, 1944; Heyne, 1950; Soerjani, 1970). However, none of these uses seems to have any significant economic value. Many investigations on the fodder value of alang-alang leaves have been carried out. It is generally agreed upon that only the young succulent leaves of alang-alang, appearing after burning or slashing this plant, make good feeding (Hubbard *et al.*, 1944). However, recently some interesting results are obtained by using alang-alang leaves as roughage in cattle feed (Soewardi *et al.*, 1974). The nutritive value of alang-alang appears not to be inferior to that of napier grass (*Pennisetum purpureum*) (Soewardi *et al.*, 1974). Besides it may be processed in pellet form (Soewardi, 1975). Rhizomes of alang-alang have also a fodder value especially for pigs (Hubbard *et al.*, 1944) although with a lower nutrient value than the leaves (Heyne, 1950).

Characteristics as a Weed

Because of its high growth rate alang-alang forms a strong competitor with other plants for the common resources as water and nutrients. It decreases soil nutrient status (Backer, 1928–34; Satari, 1968). Nitrogen accumulation in the soil is inhibited by alang-alang (Hubbard *et al.*, 1944), and an allelopathic mechanism in its harmful effect upon other plants is evident (Eussen and Wirjahardja, 1973; Eussen *et al.*, 1976). By these characteristics alang-alang tends to suppress the growth of associated plant species. Besides it may cause mechanical damage to associated plants. The leaves can easily catch fire in the dry season and due to the great quantity of organic matter a severe fire may follow, damaging associated plants or killing them. Alang-alang escapes serious damage because the underground rhizomes remain unharmed (Soerjani, 1970). The rhizomes of alang-alang can also cause mechanical damage to the roots of associated plants. The sharp apical ends of the rhizomes may grow through roots. Besides it may be a breeding place of locusts and may indirectly cause damage to associated plants (Hubbard *et al.*, 1944).

All these characteristics together make alang-alang a serious noxious weed whenever it occurs in cultivated areas in annual, however, especially in perennial crops as rubber, tea, teak, coconut, oilpalm, cinchona, etc. (Backer, 1928–34; Coster, 1932; Danhof, 1940; Hubbard *et al.*, 1944; Gonggrijp, 1952; Garot and Soebadi, 1960; Dilmy, 1960; Soemarwoto, 1961). Besides its significance as a weed in agricultural sites it is also regarded as such in shifting cultivation areas. In areas where the original forest vegetation has been removed large fields of so called sheet-alang may develop. Due to its characteristics mentioned above, and mainly because of the repeated burning of the alang-alang vegetation either by accident or on purpose, the forest vegetation is unable to re-establish itself. In 1970 it was estimated that in Indonesia 16 million ha were covered with this grass, while the annual increase was thought to be 150,000 ha (Soerjani, 1970). These areas constitute an economical problem in Intonesia as they have to be used for agricultural purposes, especially in transmigration projects. Methods are sought to convert these alang-alang fields into agricultural land.

Control

Considering the great regeneration capacity of alang-alang by way of rhizomes it is essential in the control of this grass to eradicate all viable buds or at least prevent them from forming new aerial shoots. Hand-weeding in which all plant parts are removed from the field may therefore be an effective control method, however, is costly. In this method (hand-) tractors may be used (Wijk, 1951; Sihombing, 1970). Type of soil and time of weeding with regard to the season are important factors in this type of weeding. Soil tillage and removing the rhizomes seems not effective as a control method on heavy soils when done in the rainy season, because of the impossibility to draw all the rhizomes out of the clods of earth (Coster, 1932). Tillage has to be carried out during the dry season, clods can dry up and rhizomes can be easily removed in this way. According to van der Goot (1932) ,however, tillage can be carried out in the wet season or when the soil is still moist. The alteration of the wet and dry periods then causes the rhizome to rot. Van der Goot (1932, 1935) pointed out that not all rhizomes have to be removed as only the apical ends contain viable buds and shoots developing from deep rhizomes are not able to reach the soil surface. This has been confirmed by studies of Soerjani & Soemarwoto (1969) and Soerjani (1970). Repeated slashing of alang-alang is sometimes practiced as a control method (Rudin, 1935). Preventing regrowth of alang-alang by exhausting the food reserves in the rhizomes forms the theoretical background of this method. However, this method alone seldom leads to a complete control (Soerjani, 1970) Besides leaves left behind on the soil in this way may influence crop growth adversely because of their high C/N ratio ($\pm$40) and probably by growth inhibiting substances present in the leaves. Simandjuntak (1963) also disagreed with this method because it requires a lot of labour, and besides broad leaves species with their beneficial effects are also destroyed.

The first herbicides used in the control of alang-alang were nonselective contact herbicides as sodium arsenite and sodium chlorate (Adiwinoto, 1950). Sodium-arsenite at rates of 15 kg/ha at intervals of 4 weeks during 2–3 months gave good results (Riepma, 1968). However, the poisonous nature of this chemical made it rather dangerous to use. Sodium chlorate at 2–4%, alone or mixed with amitrol was used (Simandjuntak, 1963; Gonggrijp, 1950), however, the chemical when sprayed on the plants makes them highly inflamable (Gonggrijp, 1950). These disadvantages together with the necessity of repeated applications, since they never achieved a complete control, made these chemicals unattractive to use. Also with mineral oils, sometimes in combination with PCP or DNOC (Gonggrijp, 1932), rhizomes are not sufficiently killed and dormant buds sprouted as soon as shoots above ground had been killed, resulting in a new stand of the weed. Repeated applications were again needed. TCA has been used, but the necessary doses (100–200 kg/ha) were uneconomical. Under tropical conditions dalapon gives more reliable results at more lower rates, and up to now is still used to a large extend (Samsoe, 1966; Riepma, 1968; Staalduine, 1974). Typical recommended rates are 10–15 kg/ha with lower (5–10 kg/ha) doses for subsequent spraying (Samsoe and Santosa, 1963; Simandjuntak, 1963; Soedarsan and Hendarin, 1967). However, regular control rounds are necessary as not all rhizomes are killed, and shoots emerging from escaped rhizome have to be destroyed before new rhizomes are formed. Paraquat is used in quantities of 0.2–1.7 kg/ha in about 100 *l* of water with 0.1% Teepol or Agral (Simandjuntak, 1965). The effect is very rapid, however, also rapid regrowth occurs so that again repeated spraying is necessary. At the moment most often dalapon, paraquat and MSMA are used in the chemical control of alang-alang (Staalduine, 1974). Various spraying programmes with these products and mixtures of products are used mainly in areas where manual labour is limited. None of these chemicals is, however, completely effective and the organisation of spraying programmes is an essential factor for its success.

Other herbicides as amitrol, uracils, ureas and triazines have been tested in experiments in various crops, however, with less satisfactory results. Recently good results have been obtained with the herbicide glyphosate. Mangoensoekarjo and Kadnan (1976) reported that it is equal effective as dalapon.

From all experiments and field practices it is clear that alang-alang can be killed without damage to the crop with various methods, chemically as well as mechanically However, to prevent regrowth from underground plant parts by the known methods is still very difficult at the moment. In trying to prevent this growth and also to prevent new infestations with alang-alang the use of cover crops is often recommended and may be effective. The cover crop has to grow fast so that it can cover the ground completely in a relatively short period, and should not compete with the crop. The shading capacity of these plant species is the main important characteristic by which they prevent regrowth of alang-alang. Besides they protect the soil against erosion, insolation and lost of organic matter. These plants may be found among annual catch crop such as groundnut, cassava and corn, or creepers like *Mimosa invisa*, *Calopogonium muconoides*, *Pueraria phaseoloides*, *Vigna hosei*, *Psophocarpus palustris*, *Centrosema pubescens*, *Canavalia maritima*, and *Mikania cordata*, or shrubs like *Crotalaria* spp., *Indigofera* spp., *Stylosanthes* spp., *Desmodium heterocarpum*, *Tephrosia candida*, *Moghania macrophylla*, *Chromolaena odorata*, *Eupatorium inulifolium* and *Lantana camara* (Backer and van Sloten, 1924; Coster, 1939; Anon., 1935; Hubbard *et al.*, 1944; Heyne, 1950; Soerjani and Soemarwoto, 1969).

As mentioned above, large areas in Indonesia are covered with dense mats of alang-alang. The kind of shifting cultivation practiced in those areas seems to be the main reason for the origin of those fields, while repeated burning of these vegetation causes maintenance of alang-alang fields (Danhof, 1940; Soemarwoto, 1961; Warsopranoto, 1968; Schwaar, 1972). Natural succession of an alang-alang vegetation to a secondary forest may occur (Danhof, 1940; Hubbard *et al.*, 1944; Warspranoto, 1968; Eussen and Wirjahardja, 1973). The succession seems mainly governed by light competition between species of the different succession stages (Eussen and Wirjahardja, 1973). Frequently observed in an alang-alang vegetation are: *Chromolaena odorata*, *Melastoma affine*, *Mimosa invisa*, *Saccharum spontaneum* and *Lantana camara* on relatively dry places and additionally *Mikania cordata*, *Centrosena pubescens*, *Scleria purpurascens*, etc. on wetter places (Eussen and Wirjahardja, 1973). It appeared that on drier places fire resistance in combination with a deep root system are the main characteristics by which plants can exist in the alang-alang vegetation. Protection from fire of such a vegetation leads to the expansion of these species and the introduction of species with a higher canopy e.g.: *Piper aduncum*, *Bridelia glauca*, *Vitex pubescens*, *Ficus glomerata*, *Trema orientalis* etc. (Eussen and Wirjahardja, 1973). Clearing those succession stages leads soon to an alang-alang vegetation again as still some alang-alang plants are present in these stages. It is therefore advisable to wait till the succession had proceeded so far that no alang-alang occurs any more, before such an area is cleared for agricultural purposes (Eussen and Wirjahardja 1973).

To speed up the improvement of the alang-alang fields a kind of "artificial" succession is sometimes applied. Trees or shrubs are planted in the alang-alang vegetation and care is taken that these plants establish themselves, *Gliricidia maculata* seems effective in these methods (Sukartaatmadja and Siregar, 1970). However, the use of these kind of control method for large areas is still to be determined.

CONCLUSIONS

Control of alang-alang in Indonesia is important in the production of crops and the rehabilitation of alang-alang fields. Existing methods are in general insufficient to kill the plant completely. Regular control operations are required for eradication of the plant from agricultural sites and from large waste fields. Combination of mechanical, chemical and ecological methods appeares to give the best results. A good management is a must for the success of these types of control methods.

Artificial rehabilitations of large alang-alang areas with shade trees is a costly affair. If natural succession is used for improving these areas, rehabilitation will be cheaper. It seems therefore important to gain information on how these succession proceeds under different environmental conditions. Once alang-alang has been replaced by other types of vegetation the value of these areas increase tremendously.

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Ecological Studies and Control of Mugwort

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Abstract. Shoots of mugwort (*Artemisia princeps* Pamp.) began to develop early in April and to flower early in October. The number of seeds per plant was about 5,000–40,000. New rhizome formation was observed from April to May, and the total length and fresh weight of rhizomes of one mugwort plant was 5.35 m and 63.0 g respectively in the growing season. Mugwort control by mechanical means was impossible and resulted in scattered infestation. Asulam (*N*′-methoxycarbonylsulfanylamide) and amitrole (3-amino-*s*-triazole) were effective on the growth of mugwort shoots and rhizomes, but regrowth of rhizome was inhibited completely by asulam but insufficiently by amitrole.

Introduction

Mugwort is a perennial weed which causes much trouble in orchards and fields in Japan. Propagation is conducted primarily by rhizomes, and few seedlings are found in the field. This report will present observations on the rhizome development of mugwort and effects induced by asulam when applied as a foliar treatment.

Methods

Vertical distribution of the rhizome in soil. Rhizome samples were taken from mugwort growing in a field which was lying fallow in the current year. Distribution of the rhizomes in the soil was examined.

Bud activity of rhizomes cut into sections. New rhizomes of 30 cm in length which had developed since April were used. The rhizome material was cut into one node segments and each segment was planted in a plastic container (30×20×5 cm) to examine but activity. Germination percentage of the segments was compared with that of intact rhizome.

Resprouting activity of rhizome segments according to the depth of soil. The rhizome samples were cut into sections of 1, 3 and 5 cm in length. Ten rhizome sections each were planted in a pot (20×50 cm) at depths of 1, 4, 7, 10, 13, 16, 20, 30 and 40 cm. The pots were placed in a greenhouse at 25°C. Resprouting activity of the rhizomes was then observed.

Life cycle of mugwort. Mugwort plants were established in the field from 3-node rhizome segments. Plant materials were sampled monthly during the growing season

in the following year, and plant height and fresh weight of rhizomes were recorded.
Effect of asulam and other herbicides on mugwort. Rhizome segments of mugwort were laid in a plastic pot in the greenhouse on March 1973. Effects of the following herbicides were tested: amitrole, asulam, 2,3,6-TBA (2,3,6-trichlorobenzoic acid), 2,4,5-T[(2,4,5-trichlorophenoxy)acetic acid] and bromacil (5-bromo-3-sec-butyl-6-methyluracil).

The herbicides were applied with hand. The height of mugwort at the time of treatment ranged from 20 to 30 cm. The effects of asulam against mugwort were determined at the doses of 10, 20, 40, 60, 120 and 200 g/a of the chemical. Rates of injury to shoots and rhizomes were recorded.

RESULTS

Vartical distribution of rhizome in soil. A rhizome varied according to the soil depth from 1 to 13 cm, and about 80% of the rhizomes distributed within 6 cm in depth (Table 1).
Bud activity of rhizomes cut into sections. Emergence percentage of rhizome buds was 80% for each section, and 20% for the intact rhizomes. These data indicate that control by mechanical means is impossible and results in scattered infestation (Table 2).
Resprouting activity of rhizome segments according to the soil depth. The relative resprouting activity corresponded closely to the length of rhizome sections. The Rhizome sections resprouted from the depth of 30 cm, but did not from the depth of 40 cm (Table 3).
Life cycle of mugwort. Shoots of mugwort began to develop early in April in the southern part of Japan. The maximum plant height was 120–140 cm at the time of flowering and the number of seeds per plant was about 5,000–40,000 (Fig. 1).

New rhizome formation was observed in April to May when the shoot reached at about the 10 leaf stage and its fresh weight was 2–3 g. The rhizomes emerged late in October. The total length of rhizomes, fresh weight and the number of rhizomes of a mugwort plant in the growing season were 5.35 m, 6.30 g and 5.5 respectively.

Table 1. Vertical distribution of rhizome in the soil.

Percentage distribution (%)													
Depth (cm)													
0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14
7.8	9.4	15.6	12.5	18.8	17.2	4.7	1.6	3.1	4.7	3.1	0	1.6	0

Table 2. Bud activity of rhizomes cut into sections.

	Total length of rhizome (cm)	Total no. of bud on the rhizome	No. of buds emerged	Bud activity (%)
One bud rhizome section	41	22	15	68.2
Intact rhizome	41	22	5	22.7

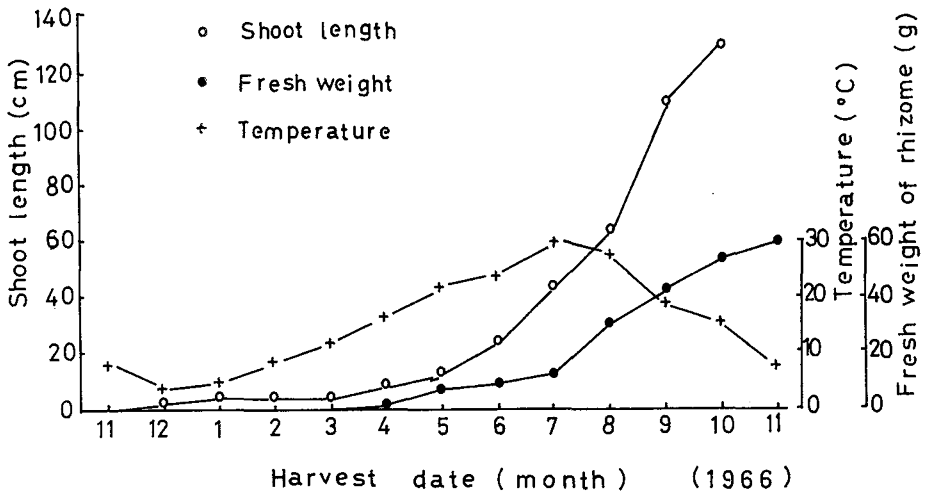

Fig. 1. Life cycle of mugwort in the southern part of Japan.

Table 3. Resprouting activity of rhizome segments according to the soil depth.

Length of rhizome segment (cm)	Emergence percentage (%)								
	Soil depth (cm)								
	1	4	7	10	13	16	20	30	40
5	100.0	100.0	85.0	85.0	70.0	73.0	55.0	35.0	0
3	100.0	100.0	85.0	95.0	75.0	45.0	30.0	30.0	0
1	100.0	100.0	86.0	65.0	75.0	0	0	0	0

Table 4. Effect of asulam and other herbicides on mugwort.

Herbicide	Dose (g/a)	Injury rating* on shoots					Resprouting activity after treatment (%)
		Days after treatment					
		10	20	30	45	60	60
Amitrole	45.0	1	2	3	5	5	20.0
Asulam	120.0	1	2	3	5	5	0.0
2, 3, 6-TBA	84.0	3	5	5	5	5	100.0
2, 4, 5-T	87.0	1	1	1	1	1	100.0
Bromacil	32.0	2	3	5	5	5	100.0

* Scale 0: no injury, 5: all leaves dead. Defoliation, necrosis and chlorosis were considered in rating.

Effect of asulam and other herbicides on mugwort. Amitrole and asulam were effective on shoots and rhizomes of mugwort. Bromacil and 2,3,6-TBA were effective on shoots but not on rhizomes, and 2,4,5-T gave poor control (Table 4). Regrowth of rhizome was inhibited completely by asulam but insufficiently by amitrole. Shoots of mugwort were killed within two months after treatment with 20 g/a of asulam, but regrowth from the rhizomes was observed. Growth of shoots and rhizomes was inhibited completely by the treatment with 120 g/a of the chemical.

Rhizome apices and buds showed symptoms of necrosis 4 weeks after foliar treatment with asulam, and resprouting activity appeared to be lost.

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Autecological Study of *Mikania* spp.

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Abstract. *Mikania* spp., vigorous creeping and climbing weeds of the family Asteraceae (Compositae) are widely spread through Indonesia. Species corresponding to *M. cordata*, which has the large florets (over 5 mm), has been found since 1886, while *M. micrantha* was discovered recently in 1951. An intermediate form of flower morphology between the species has also been found. The National Biological Institute at Bogor received a plant material from Paraguay in 1949 registered as *M. cordifolia* subsequently planted in the Botanical Gardens, is apparently *M. micrantha*. In 1956 this species was introduced as a non-legume ground cover. The altitudinal distribution of *M. micrantha* is from 0–700 m, while *M. cordata* is found from 5–2,000 m. The greater part of rubber plantations and abandoned agricultural areas in West and East Java and South Sumatra is occupied by *M. micrantha* and the intermediate form, but in Central Java these species are not found. A small population of *M. cordata* was found in Central and East Java at altitudes of ±530 and 700 m respectively. Regarding the results of the study in pollen viability, fruit-set, seed viability, bud and stump regeneration ability and SGR, gave an indication that *M. micrantha* and the intermediate form are more competitive than *M. cordata*.

Introduction

The genus *Mikania* has about 250 species, mostly found in the warmer parts of America, Africa and Asia (Robinson, 1934). *Mikania cordata* (Burm. f.) B. L. Rob., *M. micrantha* H. B. K. and an intermediate form in flower morphology between these species are found in Indonesia. Method to distinguish between *M. cordata* and *M. micrantha* are as follows: 1) length of the phyllaries (the bracts enclosing the individual flower heads) which is generally 5–6 mm in *M. cordata* is only 3–4 mm in *M. micrantha*, 2) "nodal appendage" between the leafstalks is useful to distinguish the vegetative stage of the species, viz. the nodal appendage of *M. cordata* is hairy, while that of *M. micrantha* and the intermediate form are hairless (Parker, 1972 and 1975). There are evidences, that *M. cordata* was found since 1886 in Indonesia, and plant material of *M. micrantha* was received from Paraguay by the Botanical Garden Bogor in 1949 and subsequently introduced as non-legume ground cover for rubber plantation in 1956. However, *M. cordata* is now not as widely distributed as *M. micrantha* in Indonesia. *M. cordata* is found only in small population in several places with an altitudinal distribution of 0–2,000 m, and *M. micrantha* is widely spread through abandoned agricultural areas from 0–700 m above sea level, and causing serious problems, especially in coconut and rubber plantations.

The study was aimed to clarify which is or are the species causing the problem in terms of the competitive ability of the species, and be devided into a reproductive and vegetative component. The reproductive component is the study of pollen viability, fruit-set and seed viability, while the vegetative component consists of the study in bud regeneration ability and the vigour in terms of summed growth ratio (SGR), a modification of Numata's method (1971), i.e. $1/3\times$ (length of stem+number$\times$length of leaves+dry weight).

MATERIALS AND METHODS

The reproductive component: study on pollen viability, fruit-set and seed viability. Pollen grains were collected in the field and stained with acetocarmine for examination. Pollen that failed to stain (examined under $450\times$ of magnification) are considered as unviable. These pollen were shrunken and non turgid in appearance (Henderson, 1964).

Flowers of *Mikania* are born in dense clusters, and these clusters are composed of many small heads, each containing 4 flowers, surrounded by an involucre of 4 bracts. One thousand of dry heads were randomly sampled from the flowering plant of every species, and the number of the mature fruits (achenes, commonly named as seed too) were counted to determine the percentage fruit-set. It was evident, that the achenes were often empty, and mostly only one of the 4 achenes in each head was mature.

The seeds (achenes) used for viability study were prepared without distinction of size, form and weight. One hundred mature seeds of each species were put in a filter paper in petri dish of 7 cm diameter. The filter paper was moistened with 10 ml distilled water, and the 9 petri dishes of 3 replicates for each species were kept under room condition. The seedlings were counted at regular intervals after seeding until the time when any seedling does not appear.

To determine the fruit weight, fruits were taken from planted clones at experimental site at BIOTROP. The fruits were dried at 100°C in the oven in 24 hours and then weighed.

The vegetative component study. Clones of *M. micrantha* from the Botanical Garden (Paraguay clone), the intermediate form and of *M. cordata* were propagated in experimental site at BIOTROP and used as experimental materials.

The regeneration ability study. Stem of each species were cut into one node cuttings of 2 cm length and planted in rectangular plastic pots of $20\times14\times8$ cm with washed sand as medium for germination. Fifteen cuttings of each species were planted in each pot with 6 replicates. Every week ,the length of shoot developed from the node, and the number and length of leaves were measured. After 20 days, the number of propagules were recorded and the number of rotted cuttings were counted.

The study of summed growth ratio (SGR). Healthy propagules from the former experiment with a uniform height of 7 ± 0.3 cm were selected. They were transplanted into cement pots of $(35\ cm)^3$ capacity in a mixture of soil, manure and sand (1: 1: 1) as medium of germination. Each pot was planted with 1, 2 or 3 propagules in 6 replicates. The length of stem, number and length of leaves were measured at weekly intervals commencing the first week. After 2 months the stems were cut about 2 cm above the ground surface, dried in an oven at 100°C in 3 days, and then weighed. After being cut, the stems of *M. micrantha* regenerated, but none from the stems of *M. cordata.*

Results and Discussion

Results of the experiments on percentage pollen viability, fruit-set and seed viability are summarized in Table 1. The intermediate form had the lowest pollen viability percentage, fruit-set and seed viability, while the weight of the seed is almost the same as *M. micrantha*. *M. cordata* had the highest value in the reproductive component, but it was possible that the seed dispersal was the shortest between them, because of the heavy seed and assuming that the dispersal agents are similar.

The result of the experiment of the average of bud regeneration ability and the SGR between the species and the intermediate form is given in Table 2. In Table 3 the quantities in Tables 1 and 2 are converted into relative values based on the highest value of each quantity. From the average of the quantities it might be concluded that *M. micrantha* had the highest competitive ability, followed by the intermediate form and *M. cordata*, with the relative value of competitive ability: 92.31, 74.64 and 70.04 respectively. Another facts that might be added regarding the competitive ability were:

—after slashing, the stumps of *M. micrantha* regenerated, while that of *M. cordata* could not regrenerate again,

—the dry weight curve of *M. micrantha* from the intraspecific competition shown in

Table 1. Percentage reproductive components of *M. cordata*, *M. micrantha* and the intermediate form.

	(1) Pollen viability	(2) Fruit-set	(3) Seed viability	(4) Seeds/gram
M. cordata	70.24	28.26	85.60	3,255
M. micrantha	68.35	32.31	63.44	7,342
Intermediate form	34.40	17.50	45.37	7,025

Table 2. Percentage vegetative components of *M. cordata*, *M. micrantha* and the intermediate form.

	(5) Bud regeneration ability	(6) SGR
M. cordata	39.22	18.12
M. micrantha	98.95	49.88
Intermediate form	91.74	47.69

Table 3. Converted values of quantities in Tables 1 and 2 into relative values.

	(1)	(2)	(3)	(4)	(5)	(6)	Average
M. cordata	100	100	100	44.33	39.63	63.32	70.04
M. micrantha	97.30	82.48	74.11	100	100	100	92.31
Intermediate form	48.97	61.92	53.00	95.68	92.71	95.60	74.64

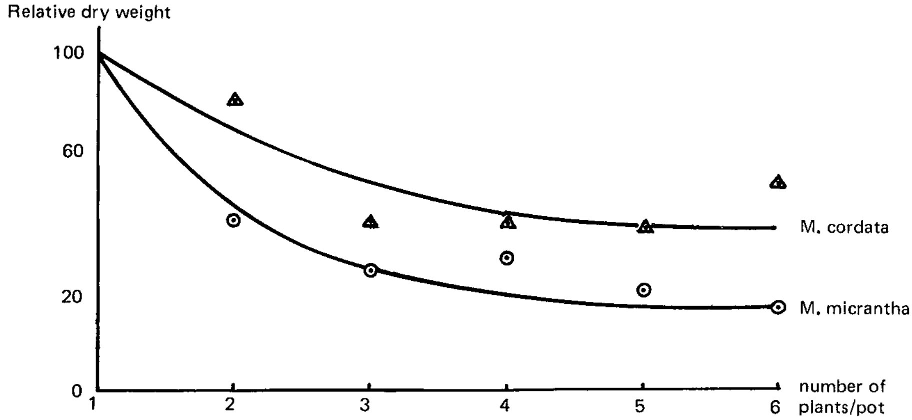

Fig. 1. Curves of relative dry weight of *M. cordata* and *M. micrantha* in an intraspecific competition.

fiigure 1 decreased sharper than that of *M. cordata* beginning with 2 plants/pot,
—the area of distribution of *M. micrantha* is very wide.

However, further experiment and information regarding the agressiveness of this weed are necessary. Competitive ability was not always associated with morphological traits, i.e. SGR, the vigour etc., which might be supposed to favour competition. Also an investigation of root characters has not yet been undertaken in our experiments. In spite of this, it is quite certain that the competitive ability in plants is a genetic characters and is subjected to the influence of the environmental factors. More data are needed for discussing this problem.

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Polyphenolic Substances in *Cyperus rotundus* L. and *Cyperus serotinus* Rottb.

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Abstract. Polyphenolic substances identified in nutsedge (*Cyperus rotundus* L.) and serotinus (*Cyperus serotinus* Rottb.) were primarily catechol tannin of leucocyanidin. Contents of the substances were high in rhizomes, seedheads, basal bulbs, and mature tubers. But the contents were very low in leaves and roots. In nutsedge tubers, leucocyanidin content increased as sprouting and growth stages proceeded. There was much higher content of the leucocyanidin in immature tubers than in mature ones. Leucocyanidin content was, however, lower in leaves and roots. The content gradually decreased in primary new tubers, rhizomes, roots and shoot as maturation proceeded.

Introduction

Nutsedge is troublesome perennial weed infesting upland fields, and serotinus is one of the most problematic weeds in the irrigated paddy fields in Japan. These weeds are difficult to control by either hand-weeding or herbicides because of their underground tubers and rhizomes. Nutsedge tubers have a vigorous propagation ability as well as a stage of dormancy. It was reported that the dormancy was due to the presence of phenolic substances in the tubers (1971). Berger and Day (1967) attempted to identify inhibitory substances, and reported that salicylic acid was the major component among many inhibitors found in the foliage of nutsedge, but it was not found in the tubers. Chris, Nishimoto and Tang (1974) reported that extracts from the tubers contained inhibitors against sprouting of the tubers and they suggested the presence of various phenolic substances as main components and the possible existence of abscicic acid as a minor component. However, there is no sufficient information on physiological ecological and biochemical significances of polyphenolic substances in plants. This report presents some results of our experiments conducted to elucidate the physiological function and chemical constituents of polyphenols which are contained in nutsedge and serotinus plants.

Materials and Methods

Experiment 1. Chemical constituents of the polyphenols were determined by using nutsedge and serotinus tubers from fields, Osaka, Japan. Polyphenolic substances were extracted from one kg of diced tubers by homogenizing them in a blender with three liters of 80% ethanol. The homogenate was heated in a boiling water bath under reflux for 24 hr. The extract was filtered, and the filtrate was evaporated to remove ethanol in CO_2 gas stream under reduced pressure at 35°C. Sodium chloride (200 g) was added into the extract, and the solution was kept for 24 hr at 5°C. The precipitate was collected by centrifugation and was dialyzed for 24 hr. After dialysis, the suspended solution in the dialyzer was again centrifuged, and the precipitate was dissolved in 50 ml methanol, and concentrated under vacuum. The concentrate was mixed with four volumes of ethyl ether and was incubated for three days at 0°C. Polyphenolic substances, which precipitated during the incubation period, were collected by centrifugation, and were identified by spectrophotometry, paper chromatography and other qualitative analytical procedures.

Experiment 2. Studies were also conducted on the distribution of the polyphenols in the two cyperacea plants and on the change of the contents during the course of sprouting and growth. Mature plants of nutsedge and serotinus were collected from upland and paddy fields, respectively. For the distribution study, they were divided into subterranean and terrestrial portions. The subterranean portion was separated into original tubers, roots, basal bulbs, rhizomes and immature tubers. The terrestrial portion consisted of leaves, fascicles and rachises with seedheads. For the study of change of polyphenolic content in sprouting and growth, ten nutsedge tubers were planted in a 30-cm pot at a depth of one cm in sand loam, and contents of polyphenols in various parts of the plant were examined every ten days for two months after planting.

Plants were ground and then polyphenolic substances were extracted with 80% methanol in a boiling water bath for 2 hr. Leucocyanidin was quantitatively determined by a colorimetric method with HCI-isoamylalcohol, which was specific for leucoanthocyanin analysis. Leucocyanidin content was determined from the standard curve which was prepared by using authentic cyanidin chloride.

RESULTS AND DISCUSSION

Results of qualitative analyses of polyphenols extracted from tubers of nutsedge and serotinus are shown in Table 1. The polyphenols extracted from the two Cyperacea weeds were identified as catechol tannins mainly consisting of leucoanthocyanin. In the extract, there were other polyphenols in a small amount. Further identification of the leucoanthocyanin by visible absorption spectrophotometry and chromatography, indicated that the leucoanthocyanin primarily existed as a form of leucocyanidin.

Leucoanthocyanin is a general term for compounds having flavan-3,4-diol or its glucoside structures. It is commonly found in flowers, leaves, fruits and heartwood of various plants (1966). Exogenous leucoanthocyanin were reported to be a precursor of anthocyan, flavonol and lignin (1967). However physiological and biochemical functions of leucoanthocyanin and other polyphenols have been little known.

Leucocyanidin contents in different parts of the two weeds at the stage of maturity are given in Table 2. Leucocyanidin contents were found to decrease in the following order; basal bulb > mature tuber > fascicle > seedhead > rachis > leave > root. It was found that leucocyanidin content of serotinus was higher than that of nutsedge. Leuco-

Table 1. Qualitative analysis of polyphenolic substances extracted from nutsedge and serotinus tubers.

Test		Nutsedge	Serotinus
UV-spectrum with ethanol (nm)	λ max.	281	281, 330
	λ min.	264	267
Visible absorption spectrum of anthocyanidin yielded by HCl-isoamylalcohol reaction (λ max nm).		553	551
*Paper chromatogram of anthocyanidins yielded by HCl-isoamylalcohol reaction (Rf value)		0.65	0.63

* Solvent system: 2N-HCl, n-butanol (1: 1)
Paper: TOYO filter paper No. 51
Rf value of authentic cyanidin: 0.67

Table 2. Leucocyanidin contents in different parts of nutsedge and serotinus plants at the stage of maturity.

Organ tissue	Leucocyanidin content (mg/g dry wt.)*	
	Nutsedge	Serotinus
Seedhead	0.48	1.20
Rachis	0.25	1.00
Fascicle	0.52	0.80
Leave	0.07	0.25
Basal bulb	2.48	4.05
Root	0.08	0.08
Mature rhizome	0.60	1.10
Dormant mature tuber	0.83	1.53
Sprouting mature tuber	1.30	2.12

* Leucocyanidin content is expressed as mg of cyanidine chloride per g of dry weight of plant tissue.

Table 3. Changes of leucocyanidin contents during the course of development from a single nutsedge tuber.

Organ tissue		Days after planting								
		0	10	20	30	40	50	60	90	120
Original tuber	A	0.81	1.02	1.65	1.55	1.60	1.65	2.00	2.14	1.90
	C	41.5	37.0	36.6	33.6	30.8	30.1	28.5	28.0	26.4
Fascicle and Leave	A	—	1.21	1.19	0.95	0.98	0.95	0.90	0.95	0.96
	B	—	0.06	0.56	0.77	1.26	2.26	3.66	5.02	5.94
Root	A	—	—	0.17	0.10	0.08	0.08	0.09	0.09	0.08
	B	—	—	0.14	0.50	1.10	1.67	2.14	2.99	3.67
Basal bulb	A	—	—	10.74	5.18	3.50	1.93	1.42	0.91	0.95
	B	—	—	0.12	0.30	0.66	0.83	1.95	2.46	2.82
Rhizome	A	—	—	—	0.79	0.72	0.70	0.65	0.59	0.54
	B	—	—	—	0.10	0.17	0.31	0.54	0.69	0.80
Primary new tuber	A	—	—	—	—	5.65	3.60	2.00	1.54	1.05
	B	—	—	—	—	0.20	1.96	5.50	13.46	21.78

A: Leucocyanidin contents (as cyanidin chloride mg/g dry wt.)
B: Dry weight (g) of plant tissues developed from 10 tubers
C: Dry weight percentage/10 tubers

cyanidin contents of nutsedge and serotinus were 0.83 mg and 1.53 mg per g of dry weight of mature tubers respectively. As the stages of sprouting and growth proceed from a single tuber to mature plants, leucocyanidin contents change as shown in Table 3. Leucocyanidin contents in original tubers increased as the stages of sprouting and growth proceeded. The content of leucocyanidin in young tissues was higher than that in old ones. But the contents decreased in the primary new tubers, rhizomes, roots and shoots as the growth stage proceeded. This change in leucocyanidin content during the course of growth suggests that the compound may participate in the lignification and maturation of tissues in the weeds. Possibly the polyphenols have a regulatory role for phenolic components and are important throughout the life cycle of nutsedge and serotinus.

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Vegetable Crop Losses Caused by Purple Nutsedge Competition

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In the tropics and subtropics, purple nutsedge (*Cyperus rotundus* L.) is recognized as one of the most serious weeds (Holm, 1969), especially where crops such as vegetables are intensively and continuously grown. Because purple nutsedge spreads rapidly (Hauser, 1962) and predominates when competition from other weed species is removed by intensive cultivation or application of herbicides (Harwood and Bantilan, 1974; Romanowski and Nakagawa, 1967), the weed may compete with the crop, thereby reducing the potential yield and occasionally rendering the land completely unproductive.

Crop Losses

Most weed control experiments that report crop losses are designed to measure the loss in yield due to full-season competition from a native population of weeds that germinate and grow during that particular season. However, information regarding the competition from a single widely adapted weed species, such as purple nutsedge, has only recently become available.

Ranade and Burns (1925) recognized that purple nutsedge was a serious pest in India as early as 1925. They estimated that general crop yields were reduced by 25 to 30% due to nutsedge competition. Since then, Colombian researchers (Cruz *et al.*, 1971) reported that corn yields were reduced by 40% when each corn plant competed with 220 nutsedge plants for the entire season. In Brazil, a mixed population of purple nutsedge and *C. rotundus* ssp. *tuberosus* (600 plants/m^2) reduced dry bean (*Phaseolus vulgaris* L. 'Rico 23') yields by 57 and 81% when grown during the wet and dry seasons, respectively (William, 1973). Purple nutsedge (439 plants/m^2) also reduced the grain yield of upland rice ('IR 5') by 41% in the Philippines (Okafor and De Datta, 1974).

Vegetable crop losses caused by full-season competition with purple nutsedge were recently reported by William and Warren (1975). In these experiments conducted in Brazil, selective preemergence herbicides were applied to control annual weeds leaving only purple nutsedge to compete with the crop. Purple nutsedge caused moderate to severe yield losses in all vegetables tested (Table 1). Purple nutsedge competed by developing a competitive leaf canopy and leaf area index (LAI$=$1.0 during the warm, wet season) at a rate similar or faster than the vegetable crops, even though purple nutsedge grew only 40 cm tall (William and Warren, 1975).

Crop losses were generally caused by competition for light in the slow-growing,

Table 1. Vegetable crop losses due to full-season competition of purple nutsedge in Brazil (William and Warren, 1975).

Crop, variety and planting method	Weed treatments*		Crop loss
	Weedy**	Hand-weeded	
	(kg crop product/5 m²)		(%)
Direct seeded			
Garlic (bulbs) ' Mineiro '	0.06	0.53	89
Okra ' UFV 1152 '	4.9	12.9	62
Carrot ' Nantes '	10.3	20.7	50
Carrot ' Kuroda '	4.4	7.2	39
Green bean (*Phaseolus vulgaris* L.) ' Topcrop '	1.9	3.2	41
Cucumber ' Aldai '	11.2	19.6	43
Transplanted			
Cabbage ' Louco '	4.2	6.5	35
Tomato ' Santa Rita '	8.1	17.2	53

* Selective herbicides were applied to the crop and purple nutsedge to reduce competition from other weed species.

** Purple nutsedge shoots were counted in 16 competition experiments with the above mentioned crops during the cool-dry and warm-wet seasons. Average infestations of nutsedge for both seasons were 1600 plants/m² when counted 5 to 7 weeks after field preparation.

non-competitive crops and for nutrients in all crops. Competition for water was negligible because the vegetables were irrigated regularly. Garlic yield was also reduced by hand weeding because many germinating bulblets were accidently mistaken for nutsedge shoots. In addition, the leaf canopy of purple nutsedge provided a favorable environment for certain insects and diseases and reduced the efficiency of control measures. The black cutworm (*Agrotis ypsilon* Hufnagel) reduced the plant populations of carrot, okra and cucumber in the nutsedge plots that were not weeded. Fruit quality of green bean and cucumber was reduced by small slugs and snails. Symptoms of curly top virus infected only the tomato plants where nutsedge was not controlled during the first 5 weeks because the insecticide did not fully penetrate the canopy and control the vector.

Successful Crop Culture by Managing Purple Nutsedge Growth

Culture of many crops should not depend upon complete eradication or control of purple nutsedge after it is established, but should be based on successful suppression and management of weed growth. For example, most competition studies that are designed to measure the required period of weed-free maintenance show that weed competition must be reduced to a minimum during the first third of the crop-life cycle (Kasasian and Seeyave, 1969), or until an effective crop canopy is formed that will compete against the later growing weeds. William and Warren (1975) showed similar data for purple nutsedge competition with several vegetable crops. Table 2 presents information to help the vegetable grower identify a stage of growth when continued removal of

Table 2. Vegetable crop stage of growth after which continued hand removal of nutsedge is no longer beneficial to crop yield.

Crop and planting method	Description of vegetative stage
Direct seeded	
Garlic	Initiation of bulbing
Okra	Crop ht: 10 to 15 cm
Carrot	Leaf ht: 7 to 10 cm
Green and dry bean	Formation of leaf canopy (≃4 weeks)
Cucumber	Initiation of runners
Transplanted	
Cabbage	Head initiation (≃4 weeks)
Tomato	Crop ht: 20 to 30 cm

Adapted from William and Warren, 1975.

nutsedge foliage by hand weeding is generally more damaging to crop yield due to root pruning and leaf breakage than additional nutsedge competition.

Competitive crops and cultivars can also be planted during the appropriate season to reduce the crop losses caused by purple nutsedge competition. William and Warren (1975) reported that crops which form competitive canopies or grow above the nutsedge can be selected so that crop losses and weedings are maintained at a minimum level. Examples of such crops are transplanted cabbage, tomato, and sweet potato, and direct seeded cucumber, green bean, soybean and several cover corps (William, 1976). In addition, a taller cultivar of okra ('Chifre de veado') and a more robust carrot ('Kuroda') required fewer nutsedge weedings during the life-cycle of the crop than other shorter cultivars (William and Warren, 1975). Garlic also required fewer weedings and produced marketable bulbs in a shorter period when planted later in the growing season because nutsedge growth and competition was reduced due to the cooler temperatures during the fall period in Brazil.

Harwood and Bantilan (1974) also showed that the density of various competitive crops grown in sequence was important in reducing the infestation of purple nutsedge when a low level of herbicide was applied, followed by one or two hand weedings. When higher levels of herbicides were applied alone to control weed growth, purple nutsedge became a serious problem because competition from other weed species was eliminated. Romanowski and Nakagawa (1967) showed similar increases in the number of nutsedge shoots that appeared 50 days after a single application of several herbicides to a mixed population of weeds in Hawaii. Consequently, many vegetable growers and research workers in tropical regions hesitate to use herbicides because the weed populations shift rapidly to species that tolerate the herbicide. We, therefore, must learn to manage the growth of the entire weed population by adapting and integrating all methods of weed control and weed suppression into a system rather than expect that a single method such as chemical weed control will solve our weed problems.

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Effect of *Emilia* Density on Some Vegetable Crops

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Abstract. A wide degree of competition to *Emilia javanica* was noted with the four vegetable crops studied. The order of susceptibility was as follows : lettuce>mustard cabbage>tomato >corn. Corn yield was not reduced by 45 *Emilia* per 0.09 sq. m, the highest density of *Emilia* imposed. At the same density, lettuce yield was reduced by 92%, mustard cabbage by 60%, and tomato by 30%.

Introduction

Emilia javanica (Burm.) Rob. is the most widespread among the four species of Emilia reported by Fosberg (1948) present in Hawaii. *E. javanica* first came into prominence in Hawaii in 1932 when it was found to be the favored host of the pineapple yellow spot virus (Now known as tomato spotted wilt virus) and *Thrips tabaci*, the insect vector of the virus (Linford, 1932). In Hawaii, *E. javanica* is commonly present in vegetables, fruit and nut crops, sugarcane (*Saccharum officinarum*), and is also a common weed along roadsides, ornamentals, and home gardens.

Emilia has not been considered as a serious crop competitor. However, it is relatively tolerant to most herbicides used in vegetable crops. Thus, it is possible that *Emilia* may become one of the predominant weed species in vegetables. This study will attempt to evaluate the effects of specific densities of *Emilia* on growth and yield of lettuce (*Lactuca sativa* var. *Anuenue*), mustard cabbage (*Brassica juncea* Waianae strain), sweet corn (*Zea mays* H-68), and transplanted tomato (*Lycopersicon esculentum* N-52).

Materials and Methods

The field was fumigated with 4.88 kg of methyl bromide per 100 sq. m to control all weed species. Mustard cabbage, lettuce, and corn were direct-seeded at 31 cm between hills and 92 cm between rows. The 5-week old tomato seedlings were transplanted at 92×92 cm. *E. javanica* seeds were sown the same day as planting, and thinned to specific densities at 3 weeks after planting. Densities ranged from one to as high as 50 weeds per 0.09 sq. m at crop harvest.

Lettuce, mustard cabbage, and tomato received 73 kg per ha of N, P_2O_5 and K_2O preplant and incorporated, and 55 kg N per ha at 5 to 6 weeks. Corn received 146 kg per ha of N, P_2O_5, and K_2O at planting, and 55 kg N per ha at 5 to 6 weeks. The soil type was Waialua silty clay loam. Overhead irrigation was applied to non-limiting levels.

Each crop was treated as a separate experiment using a randomized complete block design with, four replications. Yield was measured as dry weight at maturity for lettuce, and mustard cabbage. Corn yield was measured as dry weight of stover and fresh weight of husked ears at maturity. Tomato fruit fresh weight over five harvest periods represented tomato yield. Dry weight of *Emilia* was also taken at crop maturity.

Mineral composition was also determined. N was determined by Kjeldahl, while other elements were determined by the X-ray fluorescence quantometer.

Results and Discussion

The degree of *Emilia* competition with the different crops varied tremendously (Fig. 1). Lettuce was most severely affected by *Emilia* competition, whereas corn was virtually insensitive to competition. Mustard cabbage was moderately affected by competition, and tomato was only slightly affected. For example, at 30 *Emilia* per 0.09 sq. m, yields of lettuce, mustard cabbage, tomato, and corn were reduced by about 90%, 50%, 20%, and 0% respectively.

The relationship of *Emilia* dry weight at crop harvest and *Emilia* density is shown in Fig. 2. It is interesting to note that *Emilia* dry weight is greatest with lettuce, the least competitive crop.

Growth curves of *Emilia* with corn, a tolerant crop, and *Emilia* with lettuce, a susceptible crop, are provided in Figures 3 and 4. It is clear that corn grows more rapidly than *Emilia*, and probably retards *Emilia* growth by shading. However, *Emilia* and lettuce seem to have similar growth rates up to 27 days after planting, at which time *Emilia* grows taller than lettuce, and would provide considerable shade to lettuce. At harvest, it was estimated that densities of 5, 11, 27, and 48 *Emilia* per 0.09 sq. m provided 35, 90, 98, and 92% shade respectively. The reduction in shading at harvest at the highest density occurred because some *Emilia* plants lodged.

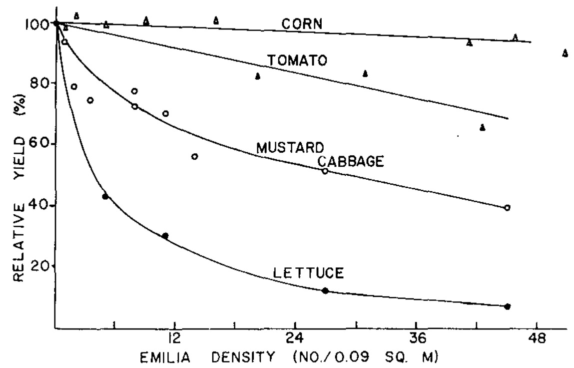

Fig. 1. Yield of various vegetable crops in relation to increasing densities of *Emilia javanica*. Data for mustard cabbage and corn are taken from two experiments.

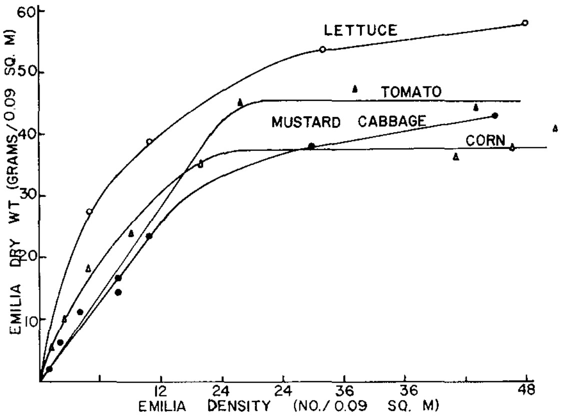

Fig. 2. Yield of *Emilia* at various densities when grown in association with several vegetable crops. *Emilia* was harvested at the time when the crop grown in association with was harvested (lettuce=54 days, mustard cabbage=50 days, tomato=91 days, corn=73 days).

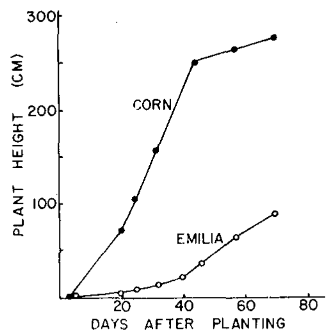

Fig. 3. Growth curve of *Emilia* and corn at a density of 16 *Emilia*/0.09 sq m.

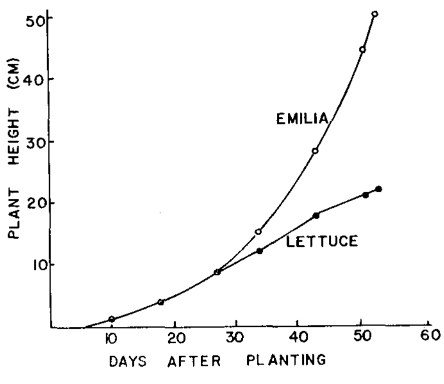

Fig. 4. Growth curve of *Emilia* and lettuce at a density of 5 *Emilia*/0.09 sq m.

Mineral composition of lettuce and *Emilia* was also determined since competition for nutrients may be important in the severe yield reduction of lettuce. However, only a slight decrease in N content of lettuce was observed with increasing densities of *Emilia* (Table 1). N composition of *Emilia* was also reduced with increasing densities. However, there was a tendency for concentrations of P, K, Ca, and Mg to increase in lettuce with an increase in *Emilia* density. This is probably attributed to the poor growth of lettuce at increasing densities of *Emilia* (Fig. 1), and thus concentrate the limited amount of elements absorbed in low tissue weight.

Correlation and regression analyses were used to compare the relative effects of the specific densities of *Emilia* on the different vegetable crops (Table 2). To determine the best correlation between crop and weed relationship, linear, quadratic, and square root functions of the data were compared. The function that gave the highest correlation coefficient was used to show the specific crop-weed relationship. The correlation co-

Table 1. Mineral composition of lettuce (L) and *Emilia* (E) when lettuce is grown with specific densities of *Emilia javanica**.

Emilia per 0.09 sq. m	%N		%P		%K		%Ca		%Mg	
	L	E	L	E	L	E	L	E	L	E
0	4.76a		0.61b		6.47d		1.72b		0.58a	
5	4.37b	3.93a	0.63b	0.45a	7.00cd	6.02a	1.76ab	1.19b	0.53b	0.40c
11	4.63ab	3.64a	0.73a	0.42a	7.68ab	5.61a	1.97ab	1.18b	0.52b	0.45b
27	3.98c	3.41b	0.71a	0.42a	8.12a	5.64a	2.10a	1.34a	0.50b	0.50a
47	4.00c	3.44b	0.72a	0.45a	7.37b	5.88a	1.95ab	1.38a	0.51b	0.48a

* Treatment differences are based on the Duncan's Bayes lsd. Any two means followed by the same letter in the same column are not significantly different at the 5% level.

Table 2. Summary of the correlation coefficients and regression equations between crop yields, weed dry weights, and stand counts.

Variables* (Crop versus Weed)	Correlation coefficient (r)	Regression equation ($Y=a+b\,X_1$)
1. Lettuce dry weight (Y) vs		
a. *Emilia* dry weight ($X^{1/2}$)	−0.938	$\hat{Y}_{1a}=18.2-2.1\,(X^{1/2})$
b. *Emilia* stand count ($X^{1/2}$)	−0.864	$\hat{Y}_{1b}=14.9-2.3\,(X^{1/2})$
2. Mustard cabbage dry weight (Y) vs		
a. *Emilia* dry weight ($X^{1/2}$) (1st Crop)	−0.822	$\hat{Y}_{2a}=39.2-3.0\,(X^{1/2})$
b. *Emilia* stand count ($X^{1/2}$) (1st Crop)	−0.820	$\hat{Y}_{2b}=39.5-4.6\,(X^{1/2})$
c. *Emilia* dry weight (X) (2nd Crop)	−0.732	$\hat{Y}_{2c}=30.2-0.4\,(X)$
d. *Emilia* stand count ($X^{1/2}$) (2nd Crop)	−0.745	$\hat{Y}_{2d}=30.6-2.8\,(X^{1/2})$
3. Tomato fruit weight (Y) vs		
a. *Emilia* dry weight ($X^{1/2}$)	−0.713	$\hat{Y}_{3a}=12661-220\,(X^{1/2})$
b. *Emilia* stand count (X)	−0.812	$\hat{Y}_{3b}=12562-22\,(X)$

* Lettuce and mustard cabbage, as well as corresponding weeds are in g per 0.09 sq m. Transplanted tomato and corresponding weeds are in g per 0.36 sq m.

eficients indicated that the weed dry weights and stand counts were negatively correlated with crop yields. With the exceptions of the *Emilia* dry weight and the Emilia stand count in the second crops of mustard cabbage and transplanted tomato, respectively, the square root functions gave the best correlation coefficients. The square root function indicate a curilinear relationship between crop yield and the weed parameters, which is clearly illustrated in Fig. 1.

Acknowledgments

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Effects of Some Weed Species on the Growth of Young Tea

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Abstract. The effects of seven weed species on the growth of two year old tea of the Kiara 8 clone were studied. There were 8 treatments including one control, each in 4 replicates. Each experimental plot contained 49 tea plants. The weeds were planted 4 months after transplanting the tea plants in the field. Observations were made on the growth of the tea plants in a sampling unit (1×1 m) in the centre of each experimental plot. Adverse effects of *Paspalum conjugatum*, *Eupatorium riparium* and *Ageratum houstonianum* on the height of the stem, the length and total numbers of primary branches were recognized after two months. Retarding effects of *Imperata cylindrica*, *Artemisia vulgaris* and *Panicum repens*, only appeared over a longer period. However, *Borreria alata* did not effect the growth of the tea plant. The dense root system and the high rate of regrowth of *P. conjugatum*, *E. riparium* and *A. houstonianum* appeared to be decisive in suppressing the growth of the tea. Yellowing and reduction of the tea leaf size were also observed in plots with *P. conjugatum* and *A. houstonianum.*

INTRODUCTION

Competition by weeds are most hazardous during the early growth stage of the tea plant (Digitarius, 1963; Sharma, 1967). Therefore weed control is particularly desirable in young tea since competition for nutrient and water can prolong the non-productive period appreciably (T. R. I., 1969).

According to Venkataramani (1962) grasses might affect the growth of young tea plants adversely by releasing toxic substances besides competing for water and nutrients.

This paper deals with the effect of seven weed species on the growth of young tea plants.

MATERIALS AND METHODS

The trial has been conducted at the Tea Experimental Garden of Pasir Sarongge, West Java, Indonesia, at an elevation of 1,230 m above sea level on an andosolic soil type. The total rainfall during the experimental period of 11 months being 3,332 mm. The pH value of the soil was 5.5. The experimental area was unshaded.

The trial has been laid out in a randomized block design with 8 treatments in four replications (Table 1).

Two year old cuttings of the tea clone Kiara-8 serving as plant material were

Table 1. Treatments.

Weeds		Planted as
Family	Species	
Poaceae	*Imperata cylindrica*	shoots with rhizomes
Poaceae	*Panicum repens*	shoots with rhizomes
Poaceae	*Paspalum conjugatum*	stolons
Asteraceae	*Ageratum houstonianum*	seedlings
Asteraceae	*Artemisia vulgaris*	shoots with rhizomes
Asteraceae	*Eupatorium riparium*	seedlings
Rubiaceae	*Borreria alata*	seedlings
—	—	(reference plot, clean weeding).

arranged at a planting distance of 50 cm × 50 cm.

The weed species were planted 4 months after transplanting the tea cuttings from the nursery. They were planted as seedings, stolon or shoots with rhizomes.

Each experimental plot of 5 m × 3 m contained 49 tea plants. Within each plot a sampling unit of 1 m × 1 m with 9 tea plants has been laid out. From this sampling unit data on heights of the tea plants, lengths and numbers of the primary branches were collected every 2 months.

The heights of the tea plants were measured from the base of the stem to the top of the shoot.

From each of 5 tea plants in the sampling unit the lengths of 5 primary branches were measured.

Six months after the weeds had been planted they were slashed and thereafter slashing was carried out, once in two months at 10 cm above the soil surface. Weed on the reference plot were pulled off regularly once in a forthnight. The dry weights of weeds from the sampling units were also determined.

RESULTS

Heights of the plants. The heights of the tea plant are summerized in Table 2. Within four months after the weeds have been planted the mean heights of the tea plants on plots with *Paspalum conjugatum*, *Ageratum houstonianum* and *Eupatorium riparium* were markedly less compared to that of the reference plot. Such an adverse effect was induced by *Artemisia vulgaris* after six months, and by *Imperata cylindrica* and *Panicum repens* only after eight and ten months respectively. It was obvious that *Borreria alata* did not reduce the growth rate of the tea plants.

From Fig. 1, it can be seen that tea plants in both *B. alata* and reference plot have more or less the same growth rate.

Lengths of the primary branches. From Table 3 it is seen that *P. conjugatum*, *A. houstonianum* and *E. riparium* reduced the growth rate of the primary branches in te early growth stage of the tea plants.

Numbers of the primary branches. With the exception of *P. repens* plot, all the other

Table 2. Mean heights of the tea plant+ and total dry weights of the weed

Weed species	Mean heights					Total dry weight weed (g/m^2)
	1st (cm)	2nd (cm)	3rd (cm)	4th (cm)	5th (cm)	
I. cylindrica	291.21	240.62	298.84	257.02*	240.01*	1065.75
P. repens	221.70	242.61	298.02	258.69	287.43*	973.08
P. conjugatum	220.10	237.59*	283.14**	259.19**	263.77**	1255.98
A. houstonianum	216.89	231.16*	282.09**	237.90**	272.66**	700.35
A. vulgaris	216.91	238.32	289.71*	244.00**	271.07**	187.82
E. riparium	218.10	237.14*	283.34**	231.85**	260.04**	1622.69
B. alata	218.09	243.79	304.10	262.27	291.51	41.23
—(Ref. plot)	222.32	246.12	303.48	272.33	302.74	—

+ Data adjusted
* Significant at 5% level
** Significant at 1% level

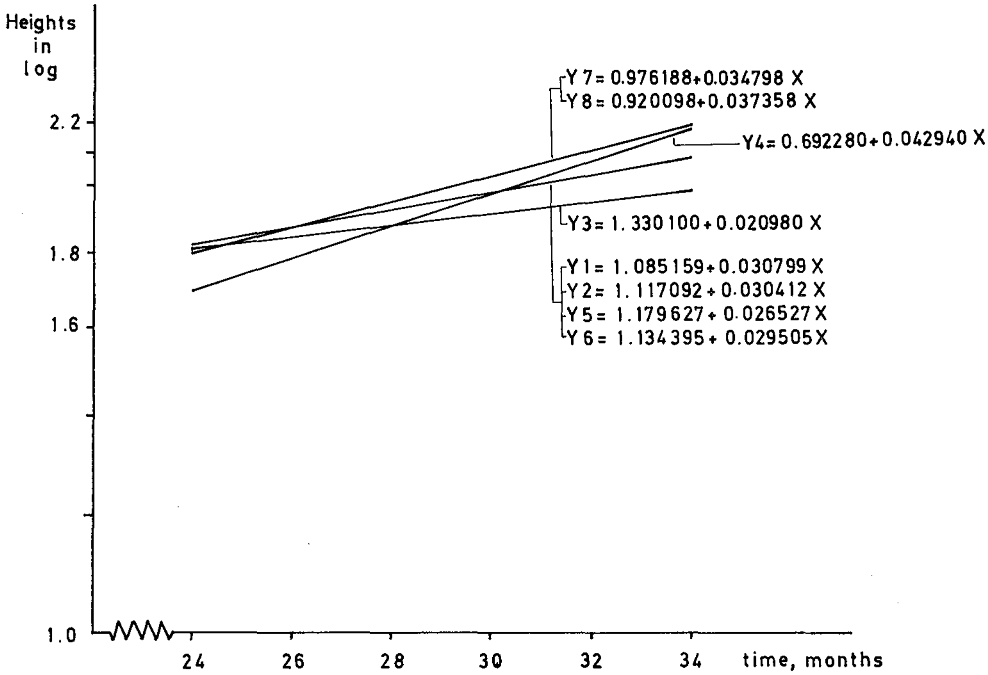

Fig. 1. The height of the tea plant (in log cm) in relation to its age (in months).

plots, show significantly smaller numbers of primary branches as compared with those of the reference plot (Table 3) within four months. However, the adverse effect of *P. repens* could be seen in later period.

Dry weights of the weeds. From Table 2 it is seen that *E. riparium*, *P. conjugatum* and *I. cylindrica* belong to weed species with a high production of organic matter. Compared with the other weed species *B. alata* shows the lowest weight of dry matter.

Table 3. Mean lengths (in cm) and numbers+ of the primary branch of the tea plant.

Weed species	Observation				
	1st	2nd	3rd	4th	5th
I. cylindrica	24.26	28.52	32.81	34.81	35.50*
	(3.36)	(3.70)**	(4.09)	(4.45)**	(4.67)**
P. repens	22.56	28.41	31.62	36.61	38.52
	(3.43)	(4.02)	(4.26)	(4.48)**	(4.78)**
P. conjugatum	20.82	22.54**	24.56**	26.40**	28.51**
	(3.27)	(3.65)**	(4.03)**	(4.24)**	(4.69)**
A. houstonianum	20.00	22.42**	24.68**	26.90**	29.27**
	(3.35)	(3.68)**	(4.07)**	(4.33)**	(4.48)**
A. vulgaris	23.87	28.05	33.54	36.28	37.64
	(3.22)	(3.77)**	(4.11)**	(4.31)**	(4.48)**
E. riparium	21.90	24.83*	27.34**	28.48**	29.74**
	(3.46)	(3.78)**	(4.12)**	(4.31)**	(4.39)**
B. alata	22.93	29.16	34.71	39.37	40.28
	(3.32)	(3.80)**	(4.25)	(4.57)**	(4.93)**
—(Ref, plot)	23.48	30.58	36.85	41.30	43.21
	(3.38)	(4.14)	(4.31)	(4.77)	(5.12)

+ Transform data with $\sqrt{x}$
* Significant at 5% level
** Significant at 1% level
Figures within brackets indicate numbers of the primary branch.

Visual symptoms. Yellowing of young tea leaves was observed in several plots. In plots of *P. conjugatum* and *A. houstonianum* yellowing was more pronounced than in plots with *I. cylindrica* and *E. riparium.*

It was also recognized that the leaf size of the tea in plots with *P. conjugatum* and *A. houstonianum* were smaller than that in the reference plot.

Discussion and Conclusions

It appears from the experiment that the total dry weights of *E. riparium, P. conjugatum* and *I. cylindrica* were higher than those of the other weed species. It also observed that those species retarded the growth of the tea plant to a higher extent.

On the other hand no adverse effect of *B. alata* on tea plant was observed. This was due to the fact that bimonthly slashing of this species hampered its regrowth.

The production of organic matter by weed should be in some way related to the extent of nutrient uptake. The amount of nutrients taken from the soil differs from species to species. It is probable that growth retardation of the tea plant was caused by insufficient nutrient.

There are indication that the growth retardation of the tea plant was related to nutrient uptake of the weed. However, the possibility that toxic exudates of weeds could play an important role in retarding the growth of the tea plant should not be excluded

(Venkataramani, 1962).

ACKNOWLEDGMENTS

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3-Phenoxypyridazine Herbicide

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Abstract. Among phenoxypyridazine compounds, 3-(2-methylphenoxy)pyridazine (credazine) gave good control of many broad-leaf weeds and annual grass with much less injury to solanaceous and rosaceous crops. In the resistant species, there was a chemical mechanism for breaking down the phytotoxic molecule to non-toxic derivatives.

When used through the soil by pre-emergence application, credazine acted by inhibiting the germination seeds and seedling stages of weeds. The herbicide inhibited plant cell devision and its elongation in the meristematic regions. The site of action of its chemical was associated with interference with auxin.

Credazine plus oxazolidone compounds showed the synergistic effects with a minimum injury to solanaceous and rosaceous crops. Credazine plus some foliar-applied herbicides inhibited effectively the growth of weeds in rosaceous fruit orchards.

INTRODUCTION

In our systematic search for new excellent herbicides we found that 3-phenoxypyridazine compounds provided excellent control of common weeds with much less injury to solanaceous and rosaceous crops.

In this abstract we report extensive experimental results in the processes of our discovery of 3-phenoxypyridazine compounds as a herbicide and the development of the chemicals for use in agriculture.

RELATIONSHIPS BETWEEN CHEMICAL STRUCTURE AND HERBICIDAL ACTIVITY

Maleic hydrazide, a plant growth regulator, can be considered as one of pyridazine derivatives. From this point of view, in our search for new potent herbicides, we proceeded systematically from pyridazine compounds.

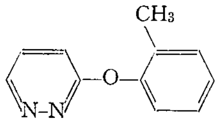
We studied the herbicidal activity of the compounds in submerged and non-submerged pot tests, and found that 6-unsubstituted-3-phenoxypyridazine compounds had remarkable herbicidal activity.

Then in such experiments, we screened out the active compounds such as 3-phenoxypyridazine and ortho-methyl-3-phenoxypyridazine. And this ortho-methyl-derivative on benzene ring showed the strongest herbicidal activity. When applied to the soil the 3-phenoxypyridazine compounds act on the weeds in their seedling stages; in fact, it is best used as a pre-emergence treatment. These 3-phenoxypyridazine compounds have little contact action on growing plants.

Generally, susceptibility of plants to 3-phenoxypyridazines decreases in the following order; Gramineae, Cyperaceae, Liliaceae, Cucurbitaceae, Umbelliferae, Chenopodiaceae, Compositae, Cruciferae, Malvaceae, Leguminosae, Rosaceae, Solanaceae.

Solanaceous crops tolerate 3-phenoxypyridazines about ten times as strong as gramineous crops. For example, ortho-methyl-3-phenoxypyridazine at 2–3 kg/ha controls effectively the common weeds in the upland fields, but at the higher rates of 12 kg/ha it has no adverse effect on solanaceous and rosaceous crops. This high tolerance indicates that ortho-methyl-derivative on benzene ring (credazine) is most devoid of phytotoxicity to solanaceous crops (i.e.; tomato, eggplant, pepper, potato, tobacco) and rosaceous crops (i.e.; strawberry).

Physico-chemical properties of credazine



3-(2-methylphenoxy)pyridazine

Molecular weight: 186.22

Solubility (water 25°C)	2,000 ppm
Melting point	78°C
pH (2,000 ppm)	8.5
Formulation	50% wettable powder

Therefore credazine is effective as a pre-emergence herbicide which selectively controls many kinds of grass and broad-leaf weeds in solanaceous and rosaceous crops.

This herbicide persists for 2 months within the soil and is of low mammalian toxicity.

In paddy fields, credazine attains satisfactory control of all common weeds, especially slender spikerush.

When the rice seedlings at 4–5 leaf stage are transplanted deeper than 3 cm, the rice seedlings tolerate a recommendable dosage.

The Mechanism of Selectivity of 3-Phenoxypyridazine Compounds

When plants are grown in 3-phenoxypyridazine solution, the selectivity between plant species also shows as well as in the solanaceous and rosaceous fields. This fact indicates that credazine attains excellent selective performance without so-called "depth protection" of the crop in the soil.

The young plants of tomato, strawberry and rice were grown in credazine solution for a certain period, and then plants were transfered in Knop's solution without credazine. After one or two weeks, the injury of tomato and strawberry plants were gradually recovered, but rice injury was not easily recovered.

Next, credazine was added to freshly pressed juice of tomato plants and after 24–48 hours only a few percent of added amounts was found by chemical assay. Fresh rice juice in similar tests produced a recovery of over 90%. From these results we considered that selectivity between species is principally the results of differential breakdown of credazine. Later, Nakagawa et al. investigated the metabolism of credazine in plants, and showed that the detoxication of credazine in the resistant plants was mainly due to the cleavage of the aromatic ether linkage of credazine and that the metabolites had scarcelly herbicidal activity.

Soil Factors affecting the Herbicidal Activity of Credazine

In crop fields, credazine is distributed in the about 0–3 cm in depth layer of the soil by rainfall or irrigation water and credazine moves upward within the credazine treated layer, which contains the zone of germinating weeds, with water movements.

In soils differences in response to crediazne can be related to the differences in leaching. Experiments of movement in soil showed that credazine moved slightly in high organic soil, while it moved quite freely in sandy loam soil. The rate of movement in organic soil was not influenced by dosage of the chemical and artificial rain intensity, but slightly influenced by the quantity of water supply. These three factors affected the credazine movement in sandy loam soil. The soil moisture content had almost no effect on herbicidal activity or crop injury by credazine in high organic matter soil, while in sandy loam soil its effectiveness was unstable and crop injury was easily observed depending upon dosages. Soil, high in clay and organic matter, binds credazine more extensively than light textured soil. And credazine is adsorbed in the largest amount by the soil colloids, organic matter, especially by humic acid.

Soil pH may directly or indirectly influence the detoxication of herbicides affecting many conditions. In the case of credazine, as it is a weak basic compound, its detoxication in the soil at low pH level is also observed. Because the adsorption of credazine by soil at pH 4 is much greater than at pH 6–7. But in common soils, the influence of soil pH on the herbicidal activity is negligible.

Site of uptake in barnyardgrass, wild oat and crabgrass is primaly through the coleoptile, whereas in rice and wheat through the root. In cotyledonous species, some plants which contact their cotyledons or primary leaves with treated layer in soil at their emergence are easily injured.

Mode of Action of Credazine

Credazine has little effect on germination of plants, but after germination the growth is greatly inhibited. Credazine at the sublethal concentrations has no adverse effect on the utilization of storage products.

Credazine at so-called "physiological dosage" causes abnormalities in the habits of plants. In gramineous plants treated by credazine, dwarfing and excessive tillering are observed. In broad-leaf plants, abnormal large and thick cotyledons and increase in number of true leaves which are normal in length but much reduced in width are observed. Namely, as credazine may reduce the amount of mesophyll without influencing the development of veins, strap-like leaves are formed.

Tests on the effects of credazine on enzyme production in plants proved that protease biosynthesis is inhibited a little and that α-amylase biosynthesis is not affected.

Respiratory effects are small and the inhibition rate of dehydrogenation of succinic dehydrogenase in roots is a little.

The results of the detailed study of effects of credazine on photosynthesis indicated that the chlorophyll content, Hill reaction and CO_2 fixation were not interfered. And its high concentration produced a small decrease in the carbohydrate.

Credazine inhibits plant cell division and its elongation in the meristematic regions. And the chemical inhibits severely the auxin-induced growth. The radish growth inhibitory effects of excess auxin can be recovered by additional low concentration of 3-phenoxypyridazine compounds. Conversly, the gowth inhibition of 3-phenoxypyridazine derivatives can be overcome by the presence of additional low auxin concentration. Moreover, as the loss of apical dominance by these compounds is also observed, the site of action of these chemicals is found to be associated with interference with auxin. The auxin induced growth is antagonistically inhibited by credazine, but a little inhibition of IAA transport is observed and the native auxin level is not influenced. From this point of view, we consider that the mode of action of credazine is the inhibitory effects on auxin behaviours.

Research for Synergistic Substances

Urea, triazine and oxazolidone compounds plus credazine showed the synergistic effects. Urea and triazine compounds affects the selectivity of credazine. But, N-(2-phenoxyphenyl)-oxazolidone does not affect solanaceous and rosaceous crops and shows remarkable synergistic herbicidal effects with credazine.

Credazine plus some foliar-applied herbicides inhibits effectively the growth of weeds in rosaceous fruit orchards.

MT-101: A Selective Herbicide for Rice

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Abstract. MT-101 [α-(β-naphthoxy)propionanilide] is a broadleaf herbicide for paddy rice. It has high herbicidal selectivity between rice and weeds and a broad spectrum of activity, too. The rate of 2 to 4 kg/ha can control most annual and perennial weeds except barnyardgrass (*Echinochloa crus-galli* L.), when applied pre- and post-emergence. Herbicidal activity and phytotoxicity of MT-101 are not affected by environmental factors such as temperature, soil type and movement of irrigated water in paddy fields. MT-101 is ideally suited for use in combination treatments with most grass killers for paddy rice.

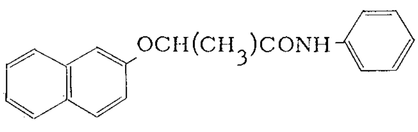
INTRODUCTION

In Japan, molinate, benthiocarb and swep have been widely used as excellent grass killers for paddy rice. However, there is very little broadleaf herbicide which is suited for use in combination treatments with these grass killers. At present triazine and phenoxy herbicides combined with grass killers are commonly used as broadleaf herbicides. But these herbicides have some defects. Their herbicidal activity and phytotoxicity to rice plant are often affected by environmental factors. They do not give satisfactory control of perennial weeds, either, some of which have become dominant weeds all over Japan and pose serious weed problems in paddy rice cultivation. So that, we commenced a research of this subject and succeeded in developing naphthoxy herbicide "MT-101", which was found to have excellent herbicidal properties as broadleaf herbicide in comparison with other conventional herbicides.

MT-101 is of low mammalian and fish toxicity. It also does not pose any soil and rice residue problems.

PHYSICO-CHEMICAL PROPERTIES AND TOXICITY

The chemical structure of MT-101 is shown by the following formula:



It is odorless white crystals with a melting point of 127–128°C. Solubility in water is 0.7 ppm at 27°C. It is soluble in organic solvents. Its acute oral LD_{50} is greater than 1231 mg/kg to mice and 10000 mg/kg to rabbits. Fish toxicity for carp (TLm 48 hr) is 95 ppm. Study of chronic toxicity is in progress.

Herbicidal Properties

Weed spectrum. Experiments were carried out in greenhouse to study the sensitivity of various weeds in paddy fields against MT-101. The herbicide was applied pre- and post-emergence under flooded condition. As shown in Table 1, MT-101 has broad effectiveness against various broadleaf weeds and several cyperaceous weeds. But barnyardgrass is very tolerant to this chemical both at pre- and post-emergence application.
Selectivity. The most important property of MT-101 is that it has high selectivity between rice and broadleaf weeds. Experiments were conducted in greenhouse on the selectivity of MT-101 between transplanted rice and broadleaf weeds. 1 to 32 kg/ha of MT-101 in granular formulation was applied 3 days after transplanting prior to the emergence of weeds. As a result, effective dosage of MT-101 against broadleaf weeds was 1 to 2 kg/ha, approximately ten times as much as that of comparative herbicide, MCPA-EE (ethyl 2-methyl-4-chlorophenoxyacetate). But MT-101 was very safe to rice, which was slightly affected even at high rate of 32 kg per hectare. It showed excellent selectivity for rice. On the contrary, MCPA-EE was very toxic to rice, which was completely killed at rate of 1.6 kg per hectare. At low rate MCPA-EE caused many tubuler leaves, which were the typical symptoms of auxin herbicide damage in leaves of rice.

MT-101 was also safe to direct-seeded flooded rice, which was susceptible to it at germination stage, but was not affected after one leaf stage.
The effect of temperature and soil type on herbicidal activity and phytotoxicity. The ex-

Table 1. Sensitivity of weeds to MT-101 at rates of 2 to 4 kg/ha.

Weeds	Pre-emergence	Post-emergence
Echinochloa crus-galli L.	R	R
Monochoria vaginalis Presl.	S	S
Rotala indica Koehne	S	S
Lindernia procumbens Philcox.	S	S
Ludwigia prostrata Roxb.	S	S
Dopatrium junceum Hamilt.	S	S
Gratiola japonica Miq.	S	S
Elatine triandra Schk.	S	S
Sagittaria pygmaea Miq.	S	S
S. trifolia L.	S	R
Alisma canaliculatum A. Br. et Bouche	S	S
Cyperus difformis L.	S	S
C. serotinus Rottb.	S	R
Eleocharis acicularis Roem. et Schult.	S	R
E. kuroguwai Ohwi	S	R
Scirpus hotarui Ohwi	S	S

S = Sensitive, R = Resistant.

periments were conducted in outdoor growth cabinets using two different types of soil, sandy soil and clay loam soil at two different temperatures, low (day temp. 22°C, night temp. 15°C); high (day temp. 35°C, night temp. 28°C). 1 to 6 kg/ha of MT-101 was applied 3 days after transplanting prior to the emergence of weeds. As a result, herbicidal activity and phytotoxicity of MT-101 to rice plant were not affected by any temperature or soil types.

Behaviour in the soil and irrigation water. From the viewpoint of practical use, it is very important to clear the behaviour of a herbicide in the soil and in the irrigated water. Outdoor pot experiment was carried out to investigate soil persistence of this chemical. Seeds of *Alisma canaliculatum* A. Br. et Bouché were sown at weekly intervals after the application of 3 kg/ha of MT-101 under flooded condition. Herbicidal effect of MT-101 persisted more than 3 weeks in the soil, which indicates that it was more persistent than that of comparative herbicide MCPA-EE.

Movement of MT-101 in soil was studied using a leaching column filled with clay loam soil. The result was that MT-101 hardly moved through the soil column, while comparative herbicide, both bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-(4)3H-one 2,2-dioxide] and MCPA-EE easily moved through the soil column.

Herbicidal activity is affected by vertical movement of irrigation water in paddy fields. To prove this point, another experiment was conducted to study the effect of water Leakage on potency of MT-101. Herbicidal activity of MT-101 was not affected by water leakage of 1 to 3 cm/day, while potency of bentazon and MCPA-EE was reduced.

Herbicidal activity is also reduced by horizontal movement of irrigation water in paddy fields. Horizontal movement means drainage or overflow of irrigated water from paddy field by heavy rain. Factors affecting horizontal movement of herbicide are solubility, diffusion, and soil adsorption. 3 kg/ha of MT-101 in granular formulation was applied in Wagner pot (0.05 m^2) flooded at the depth of 4 cm. Water samples were collected at the depth of 1 cm below the water surface. The active ingredient in the water samples, which diffused from granule into water, was analized. The diffusion appeared slowly and the maximum concentration of the chemical in water occurred 3 hours after treatment and it was approximately 0.7 ppm, which gradually decreased thereafter, while bentazon applied as comparative herbicide diffused much rapidly than MT-101 due to the high water solubility. This fact shows that the potency of MT-101 was hardly affected by horizontal movement of irrigated water in paddy fields.

Combination. As stated in the introduction, MT-101 is primarily a broadleaf herbicide, so that it must be combined with grass killers in order to obtain complete control of all major weeds in paddy fields. Combinations of MT-101 with many grass killers have been evaluated in green house and paddy fields. Especially, combination of 10% of MT-101 with 7% of benthiocarb in granular formulation was tested under the experimental name MT-B-3015 GRANULAR at many agricultural experiment stations in Japan, and was evaluated as a herbicide for transplanted rice, having stable and excellent effectiveness against annual and perennial weeds without any injury to rice plant. The result of field trials in direct-seeded flooded rice also proved that the combination could be used for practical weed control. Consequently, MT-101 having excellent herbicidal properties, will be widely used as a broadleaf herbicide for paddy rice near future.

A Review of the Herbicidal Activity of a New Diphenyl Ether Herbicide in Field Crops

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Abstract. RH-2915 [2-chloro-1-(3′-ethoxy-4′-nitrophenoxy)-4-trifluoromethyl benzene] is a new selective diphenyl ether herbicide being developed by Rohm and Haas Company, Philadelphia for weed control in a wide variety of agronomic, tree fruit and tropical plantation crops. RH-2915 controls a wide spectrum of annual broadleaf weeds and grasses when used either pre-emergence or post-emergence. In addition, RH-2915 exhibits a high degree of herbicidal activity at low rates. RH-2915 is especially effective pre- or post-emergence against many broadleaf weeds and is ideally suited for use in combination treatments with many other herbicides.

Physical and Chemical Properties

Structural formula. 2-chloro-1-(3-ethoxy-4′-nitrophenoxy-4-trifluoromethyl benzene

Emperical formula. $C_{15}H_{11}Cl\ F_3NO_4$

Molecular weight	—361.72
Physical state and color	—Orange crystalline solid at room temperature
Melting point	—84–85°C
Solubility	—<0.1 ppm in water at 25°C Soluble in most organic solvents
Vapor pressure	—2×10^{-6} mm Hg at 25°C

Formulation. The emulsifiable concentrate contains 240 gm of active ingredient per litre.

Toxicology. RH-2915 is a pesticide of low toxicity as indicated hereunder:

	Technical product	*EC formulation*
Acute oral LD_{50} (male rat)	>5,000 mg/kg	5,080±110 mg/kg
Acute dermal LD_{50} (rabbit)	>10,000 mg/kg	>3,000 mg/kg
Primary skin irritation (rabbit)	non-irritating	non-irritating
Eye irritation (rabbit)	non-irritating	non-irritating
Acute inhalation (rat)	—	negative at 327 mg/lt.

Fish and wildlife studies.

Incipient LC_{50} for bluegills—0.200 ppm

Incipient LC_{50} for rainbow trout—0.260 ppm

LC_{50} mallard duck—<4,000 ppm

LC_{50} bobwhite quail—390 ppm

PHYSIOLOGICAL PROPERTIES

Metabolism in soil and influence of environmental factors. RH-2915 is absorbed onto soil clay and organic matter. The activity of the compound is directly related to the organic matter content of the soil. The greatest herbicidal activity is on heavy textured soils low in organic matter. The product does not readily move across the soil surface as run-off. The product undergoes slow microbial breakdown in the soil. In laboratory studies, RH-2915 undergoes rapid photochemical degradation. It has been established that other DPE herbicides (e.g. nitrofen) and orthosubstituted diphenyl ether herbicides requires light and that activity tends to be higher in the field than in the greenhouse, possibly because of greater light activity.

As with other DPE herbicides, adequate soil moisture following treatment is necessary to insure satisfactory pre-emergence weed control.

Mode of action. The mode of action of RH-2915 has not been clearly defined. At this time the product can be described as a non-systemic, contact-action herbicide.

BIOLOGICAL PROPERTIES

Weed control.

1) *Pre-emergence.* A number of agronomically important weed families are sensitive to RH-2915 in the dosage range of 0.25 to 2.0 kg ai/ha.

2) *Post-emergence.* RH-2915 provides effective post-emergence weed control at dosages as low as 0.125–0.25 kg ai/ha. These low dosage rates will control a wide range of annual grasses and particularly dicot weeds when in a seeding growth stage. Higher dose rates (0.5–2.0 kg ai/ha) are required for the control of annual weeds that have matured or hardened off due to adverse weather conditions.

Post-emergence sprays of RH-2915 will also provide residual pre-emergence control of new germinating weeds following the initial kill of weeds present at the time of treatment. The length of the residual pre-emergence activity is dependent on both dosage rate and environmental conditions.

Crop tolerance spectrum. The pre-emergence and post-emergence crop tolerance spectrum of RH-2915 is shown hereunder.

Pre-emergence crop tolerance to RH-2915 at rates which will provide good weed control.

Tolerant	*Moderately Tolerant*
Sugarcane	Soybeans
	Wheat
	Potato

Post-emergence crop tolerance to RH-2915 at rates which will provide good weed control.

Tolerant	*Moderately Tolerant*
Transplanted onions	Wheat
Perennial crops	Transplanted rice
such as:	
Tree fruit (PDS)*	

Grape vines (PDS)*
Plantation crops (PDS)*
Cotton (PDS)*
Corn (PDS)*
* PDS—Post directed spray application

Suggested Crop Uses

RH-2915 is recommended for experimental trial use as a pre-emergence, post-emergence and directed post-emergence treatment in the following crops. Combination treatments of RH-2915 with other herbicides are recommended for improved broad spectrum weed control. These suggestion given below are based on results obtained from replicated field experiments conducted in many parts of the world.

Corn. In areas infested with *Striga asiatica* (witchweed), RH-2915 at rates of 0.5–2.0 kg ai/ha is effective in pre- and post-emergence applications to the weed. The treatment should be directed to the base of the crop plants when the crop is 0.45–1.0 meters in height.

Cotton. In situations where commonly used cotton herbicides e.g. trifluralin do not provide adequate broadleaf weed control, RH-2915 (at 0.25–0.5 kg ai/ha) applied as a post directed spray (PDS) treatment has yielded promising results. Application was made when the crop was 0.3 meters high.

Onions. In onion transplants, RH-2915 at dosage rates ranging from 0.25–1.0 kg ai/ha, applied early post-emergence to the weeds, has provided excellent residual broad spectrum weed control.

Potato. Pre-emergence applications of RH-2915 at dosage rates ranging from 0.25–1.0 kg ai/ha warrant further evaluation.

Soybean. Surface pre-emergence applications of RH-2915 at 0.125 and 0.25 kg ai/ha provided equivalent weed control to commercial standards. Crop injury has been reported where higher dosage rates were evaluated. Combination treatment of RH-2915 at 0.125 to 0.25 kg ai/ha with other herbicides e.g. alachlor and chloramben should improve the spectrum of weed control—in particular the control of grass species. In areas where pre-plant incorporated treatments are commonly employed, consideration should be given to evaluate RH-2915 at 0.37–0.75 kg ai/ha in combination with reduced rates of such herbicides e.g. trifluralin.

Sugarcane. Treatments with RH-2915 applied pre-emergence to the cane and early post-emergence to the weeds are suggested at rates of 0.75 and 1.5 kg ai/ha. Combination treatments with other commonly used sugarcane herbicides will also be investigated.

Tree fruit, Grape vine and Plantation crops. Results to date indicate that RH-2915 does not leach in soils or cause injury to newly transplanted tree and vine crops. RH-2915 is inactive against many established perennial weeds e.g. *Cynodon dactylon; Imperata cylindrica; Paspalum conjugatum; P. distichum; Sorghum halepense* and *Convolvulus arvensis*. Therefore, in situations where these weeds predominate, only combination treatments with recommended perennial grass herbicides e.g. dalapon should be considered. The following dosage rates of RH-2915 are recommended: 0.5, 1.0 and 1.5 kg ai/ha for the control of pre- and early post-emergence weeds.

In the absence of perennial weeds, or in situations where these weeds are not economically important, RH-2915 alone for pre- or early post-emergence weeds, at the above dosage rates, is suggested. Where weeds are in an advanced stage of development, combination treatments with e.g. paraquat and napropamide have resulted in broad spectrum residual weed control.

Research of a New Diphenyl Ether
A) A Review of the Herbicidal Activity of a New Diphenyl Ether Herbicide in Japan

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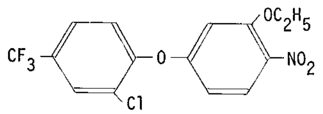
Abstract. A newly synthesized, diphenyl ether herbicide, RH-2915 (2-chloro-4-trifluoromethylphenyl-3′-ethoxy-4′-nitrophenyl ether), has shown excellent herbicidal activity in paddy rice fields. RH-2915 exhibits strong herbicidal activity in transplanted paddy rice fields at lower dosage levels, and with little or no phytotoxicity to rice plants. Field experiments throughout Japan in 1974 have shown that RH-2915 has practical efficacy for weed control in transplanted rice fields when applied before rice seedling transplanting.

INTRODUCTION

In Japan, herbicides are applied extensively for control of weeds in paddy rice fields with about 99% of the total hectarage treated. In more than half of the paddy fields, weeds are systematically controlled by two or more applications of herbicides during the rice growing season.

The desirable herbicides for paddy fields in Japan are those that can be applied about the time of transplanting. Experience to date indicates that the diphenyl ether type herbicides can best satisfy this requirement.

RH-2915 is a new diphenyl ether herbicide recently synthesized by Rohm and Haas Company, U.S.A. The efficacy of RH-2915 as an herbicide for possible use in Japanese paddy rice fields is under intensive investigation.



RH-2915

MATERIALS AND METHODS

Experiment I used various species of weed seeds in pots (1/5,000 are) under paddy field conditions to evaluate efficacy of RH-2915 to prevent the development of weeds. The young rice seedlings were transplanted, then FH-2915 was applied in July 31.

Experiment II used paddy fields which had been developed various species of annual weeds extensively (black volcanic humus soil) where young rice seedlings were transplanted in June II. RH-2915 was incorporated into soil in 15 cm depth at the first puddling stage or RH-2915 was applied on the surface of paddy fields one day before or 9 days after rice seedling transplanting.

Experiment III used barnyard grass seeds incorporated in paddy soil in pots (1/5,000 are) to eliminate any possible phytotoxicity of RH-2915 by its soil incorporation. The transplanted rice seedlings were relatively weak adult one. RH-2915 EC was applied to the surface of the paddy water.

RH-2915 formulations used in these experiments were 2% granular for soil incorporation experiments, 0.17% granular for soil surface application experiment, 24% emulsifiable concentrate and RH-2915 fertilizer with 0.16% RH-2915 a.i. Generally, RH-2915 was incorporated into soil with 2 to 4 cm depth of water except by the application at the first plowing stage. The experiments were carried out in 3 replications in pot experiments and 2 replications in 3.2 m^2 plots in the field experiments.

Results and Discussion

The mode of action of RH-2915 is essentially the same as that of nitrofen when applied before weed germination. RH-2915 attacks the foliar parts including young buds of weeds, and requires light to activate its herbicidal efficacy. According to Matsunaka (1967) diphenyl ether herbicides are classified into two groups.

RH-2915 attacks only above ground parts of plants including leaves and buds and is therefore demanding light. RH-2915 may be classified in the same group as nitrofen, CNP, chlomethoxynil, however it is different from the group which includes TOPE. RH-2915 was found to develop quite a high efficacy against barnyard grass, and other annual weeds even at a small dosage level. Expressed another way, it appears that RH-2915 is stronger by 25 times than nitrofen and CNP, or stronger by 10 times than chlomethoxynil, and stronger by 5 times than oxadiazon. RH-2915 is believed to have quite a promising furtue for soil surface application before transplanting of rice seedlings and for soil incorporation which can save labor requirement in Japan. These advantages were proved as shown in Table 1.

Recommended dosage of RH-2915 may be summarized in Table 2. But the dosage of 0.17% a.i. RH-2915 granular was 0.05 to 0.1 kg a.i./ha by its soil surface application before rice transplant.

The advantages of RH-2915 will promise a wider application as one of the soil incorporation herbicides such as lower dosage, broader spectrum to wild weeds, labor saving. While RH-2915 developed phytotoxicity to some paddy rice plants by the soil surface application, it caused little to substantially no phytotoxicity to rice plants by the soil incorporation method even at the same or higher dosage levels. Any phytotoxicity (browning of leaf sheaths) was observed temporary and did not decrease the final yield of rice grain. Crop injury appears to be related to soil incorporation depth and the deeper the RH-2915 incorporation depth, the less injury developed to rice plants. The herbicidal efficacy of RH-2915 for barnyard grass was decreased with an increase of

Table 1. Evaluation of RH-2915 as a herbicide for rice fields. (Sanyo Trading Co. Totsuka Ex. St. 1973)

Chemicals	Dosage (kg/ha)	Application method	*Herbicidal activity				Rice plant	
			Barn-yard grass	*Mono-choria*	*Cy-perus*	Oth-ers	**Phy-totoxic-ity at the early stage	Growth condition at the harvest time
Check	0	—	0	0	0	0	−	Bad
RH-2915 (EC)	0.1	Soil incorp. at first pudd. stage (Two days before transplant)	7.2	9.6	10	9.4	−	Good
	0.25	,,	9.2	9.8	8	10	−	Very good
	0.5	,,	10	10	10	10	±	Very good
RH-2915 (G)	0.1	,,	7.2	9.3	6	10	−	Good
	0.25	,,	9.4	10	10	10	±	Very good
	0.5	,,	10	10	10	10	±	Very good
Oxadiazon (EC)	0.75	Soil incorp. at final Pudd. stage (one day before transplant)	10	10	10	10	+	Very good
RH-2915 (G)	0.025	On the soil surface after final pudd. stage (one day before transplant)	8.3	9.5	8.6	9.3	−	Good
	0.05	,,	9.9	9.8	8.6	9.6	−	Good
	0.1	,,	9.9	9.9	9.6	10	−	Very good
	0.25	,,	10	9.9	10	10	+++	Moderate
Nitrofen (G)	2.1	,,	7.8	9.8	10	10	−	Good
RH-2915 (G)	0.05	On the soil surface 9 days after trans-plant	9	5	7.6	8.4	−	Moderate
	0.1	,,	9.9	6.5	9	9.1	++++	Moderate
	0.25	,,	9.7	6	8.6	9.1	+++	Moderate
Nitrofen (G)	2.8	,,	9.7	7.8	9	6.7	++	Good—Moderate

* 53 days after transplanting
None—0, 1, . . . , 9, 10—100% Control
** Degree of phytotoxicity: None— −, ±, +, ++, +++, ++++, +++++—Very severe

Table 2. Suitable dosage of RH-2915 on soil incorporation method.

Application time	Formulations	Suitable dosages (kg a.i./ha)
Plowing stage (before irrigation)	Granular	0.8 to 1.0
	Mixed fertilizer	0.5 to 1.0
First puddling stage	Granular	Ca. 0.75
	Emulsion conc.	Ca. 0.5
	Mixed fretilizer	Ca. 0.5
Final puddling stages	Granular	Ca. 0.5
	Emulsion conc.	0.25 to 0.5
	Mixed fretilizer	0.25 to 0.5

incorporation depth, however, RH-2915 decreased its herbicidal efficacy less than oxadiazon with respect to incorporation depth. This suggests that RH-2915 has greater use lattitude with soil incorporation. In some post transplanting experiments, RH-2915 has developed slight temporary injury (i.g. browning of leaf sheaths, wilting of leaves), from application just after transplanting of rice. However in no case was rice yield affected. We entered the Japan official experiment station trials in 1974 to further determine the properties of RH-2915. It was found that herbicidal efficacy was greatly affected by application conditions. RH-2915 developed good efficacy from application at the final puddling stage and the first puddling stage. Herbicidal efficacy was not as good from soil incorporation before irrigation. While slight temporary leaf browning occurred when RH-2915 was applied just after irrigation in the paddy field in about half of the experiment station trials, the degree of injury was no greater than normally occures from other dipheny ether herbicide products. Even though RH-2915 caused some temporary injury, no significant decrease in final yield was observed. The efficacy and residual activity of RH-2915 was good when it was incorporated into soil before irrigation or just after transplanting of rice. No leaf browning occurred from RH-2915 soil incorporation before irrigation. Further experiments to determine optimum dosage, soil incorporation depth, optimum application timing etc. are in progress. RH-2915 appears to be a promising addition to the rice herbicide market in Japan. Table 3 summarizes the herbicidal spectrum of RH-2915 for weeds in the paddy fields obtained from the official experiments. The activity spectrum of RH-2915 was slightly broader than that of nitrofen and CNP and other diphenyl ether herbicides and rice plant injury was minimal.

Table 3. RH-2915 herbicidal spectrum.

Common name	Scientific name	Control
Barnyardgrasss	*Echinochloa crus-galli* Beauv.	Excellent
Chufa	*Cyperus microiria* Steud.	,,
Monochoria	*Monochoria vaginalis* Presl.	,,
Waterwort	*Elatine triandra* Schk.	,,
Toothcups	*Rotala indica* Koehne var. *uliginosa* Mig.	,,
Abunome	*Dopatrium junceum* Hamilt.	,,
False pimernel	*Lindernia pyxidaria* All.	,,
Slender spikerush	*Eleocharis acicularis* Rome. et Schult.	Good
Waterchestnuts	*Eleocharis kuroguawai* Ohwi	Poor
Arrowheads	*Sagittaria pygmaea* Mig.	Poor
Flatstage	*Cyperus serotinus* Rottb.	Fair-good
Hotarui	*Scirpus hotarui* Ohwi	Fair-Good

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The Development of Pronamide as a Herbicide on Lettuce Field and Turf in Japan

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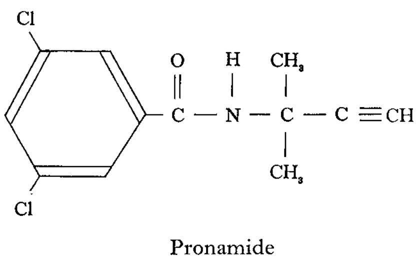
Abstract. Pronamide WP, *N*-(1,1-dimethyl-2-propynyl)-3,5-dichlorobenzamide (formerly coded as RH-315), is an acid amide type herbicide developed by Rohm and Haas Company. When pronamide is applied, it keeps its very long herbicidal activity in the soil at low temperature conditions. Pronamide is applicable to lettuce, Zoysia and bermuda turf. Moreover we have studied the safety period for the rotation crops to prevent the possible occurence of damage. Soybean, rice and cabbage may be planted shortly after the application of pronamide, but cucumber and tomato need about two months safety period, while two-row barley needs six months or more safety period.

INTRODUCTION

Pronamide WP is a widely used herbicide for upland fields. Pronamide attacks the growing points of roots and shoots of young plants to inhibit the differentiation and growth when it is applied before the germination of plants. But pronamide has a definite selectivity of weed and crop on the level of family. Pronamide showed favorable results on lettuce, Zoysia and bermuda grass turf in the Japanese official experiments from 1970 to 1973. Pronamide has been used practically on turf in Japan and other crops in other countries.



Pronamide

When pronamide is applied on the surface of soil, it maintains its herbicidal activity for a long time. As was reported by Roy. Y. Yih *et al.* (1970), the effective period of pronamide depends on the temperature. When pronamide is applied under low temperature conditions (15°C or less), pronamide loses its herbicidal activity quite slowly and keeps its practical herbicidal activity for a very long period. This property is one of the great advantages of pronamide in turf due to its longer effective period. The longer effective period of pronamide is also one of the favorable properties when pronamide is applied in the upland fields. However, crop land is very highly utilized in Japan, and the crop rotation is very rapid, and pronamide application might affect certain of the rotation crops. We have therefore studied the effects of pronamide on the crops to be planted after pronamide application with the typical upland crops in Japan.

Materials and Methods

Experiment I (Table 1) Pack a fixed amount of upland soil in petri dishes 9 cm diameter, plant seeds of various crops, apply 20 ml of pronamide preparation at the various concentration per petri dish, and manage the systems under the upland conditions.

Experiment II (Table 2) After various crops seeds were sowed, pronamide was applied at 25 g-ai/are with water at 10 liter/are, then the systems were kept under the upland conditions.

Experiment III (Table 3) Various kinds of turf planted on March 20, 1972 for which pronamide was applied with water at 20 liter/are on July 20.

Experiment IV (Fig. 1) Various compositions were applied on April 3, 1970 on the 3-year-old Zoysia turf. The weed status was determined at 30, 60, 90 and 120 days after pronamide application. (one of the main species of weeds was *Poa annua*).

Experiment V (Fig. 2) Pronamide was applied with water at 10 liter/are from January 12, 1973 for seven times. A day after final pronamide application, May 15, soybean, rice, wheat, tomato, cucumber and cabbage were seeded on the same date after leveling the entire soil layer. The growth of plants was determined on May 26 and June 22.

Experiment VI (Fig. 3) Pronamide was applied to soil every 2 months from May 20 under the upland field conditions. From one month after every application, wheat was seeded every ten days. The activity of pronamide in the soil was evaluated the germination and growth of wheat.

Results and Discussion

Table 1 presents the sensitivity of plants for pronamide when it is applied after seeding. Generally, pronamide has a definite selectivity in each family except for the Gramineae family plants. Based on these results, we studied the sensitivity of the crops for pronamide in the fields. As is obvious from the results in Table 2, the sensitivity of various crops for pronamide is different. Great difference is presented in sensitivity between the dosage levels from 15 to 40 g ai/are, which is the normal dosage level of pronamide for weed control. Lettuce is one of the plants of Chrysanthemum. Pronamide exhibited favorable results on lettuce also in official experiments. Table 3 presents the safety of pronamide to Zoysia and bermuda turf.

As was reported by Roy Y. Yih *et al.* (1970), pronamide maintains herbicidal activity for a very long period in the soil. This is particularly true when pronamide is applied under low temperature conditions (15°C or less). This is a definite advantage

Table 1. Pronamide conc. which inhibits plant growth 25% or more.

Plant	Concentration (ppm)	Plant	Concentration (ppm)
Rice	50	" Azuki " red bean	30
Wheat	10	Welsh onion	40
Barnyardgrass	10	Eggplant	5
Manna-grass	1	Tomato	5
Spinach	10	Red pepper	20
Beet root	1	Carrot	30
Cucumber	5	Celery	40
Melon	20	Parsley	30
Edible burdock	100	Japanese radish	50
Garland chrysanthemum	100	Chinese cabbage	50
Lettuce	100	Cabbage	60
Garden pea	30		

Table 2. Crop safety for pronamide in fields.

Family	Field crops	Growth inhibit rate	
		Test I (%)	Test II (%)
Leguminosae	Peanut	5	10
	Soy bean	15	0
	" Azuki " red bean	15	5
	Garden pea	5	10
	Broad bean	—	0
Compositae	Lettuce	0	0
	Edible burdock	0	0
	Garland chrysanthemum	0	0
Cruciferae	Japanese radish	20	35
	Chinese cabbage	—	50
	Cabbage	—	80
Chenopodiaceae	Spinach	50	65
	Beet root	50	60
Gramineae	Rice	5	55
	Wheat	—	100
Liliaceae	Welsh onion	10	40
	Onion	—	45
Umbelliferae	Carrot	5	10
Solanaceae	Tomato	75	50
Cucurbitaceae	Cucumber	—	45

when pronamide is treated on such no rotation crop as turf as shown in Fig. 1. However, the sensitive crops can not be planted to soon after the application of pronamide. Lettuce normally has a short growing term and this short field cultivation period is further reduced in case of transplanting cultivation in Japan. Fig. 2 presents the planted period

Table 3. Activity of various herbicides for turfs.

Composition		Zoysia grass			Bentgrass			Tifdwarf (bermudagrass)		
Chemicals	g a.i./a	6 days	17 days	31 days	6	17	31	6	17	31
Pronamide	20	–	–	–	–	++	+++	–	–	–
Nitrofen e.c.	35	–	–	–	±	±	–∼±	–	–	–
Propanil	24.5	±	–	–	+	++	++	–	–	–
Untreated	–	–	–	–	–	–	–	–	–	–

– None, ± very slightly, + slightly, ++ moderate, +++ severe, ++++ very severe

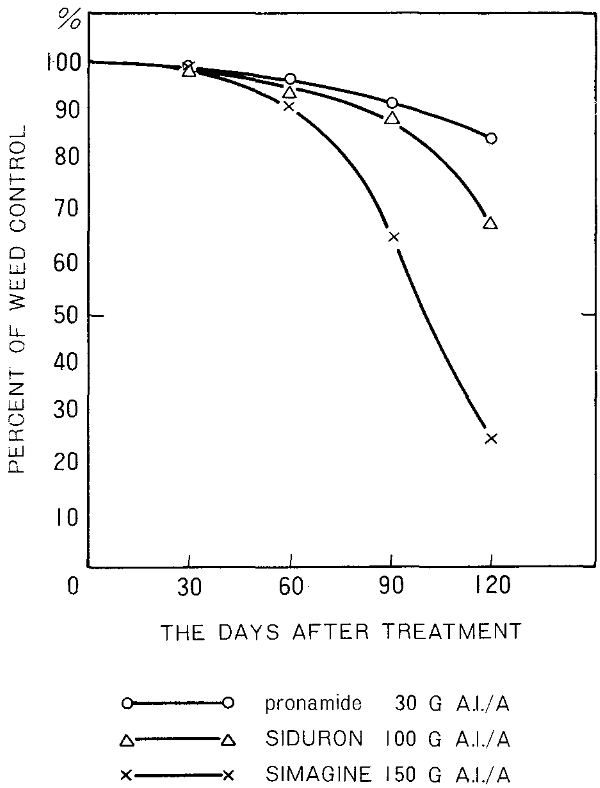


Fig. 1. Residual activity of various herbicides on Zoysia turf.

and sensitivity of representative rotation crops for pronamide after its application to lettuce. It is essential to make about 6-month safety period in case of two-row barley, and 2-month safety period in cases of direct sowing cultivation of cucumber. No unfavorable effects resulted in the cases of soy bean, cabbage, and rice. It takes about 40 to 50 days from transplanting to harvest in case of lettuce. Therefore, it can be assumed that lettuce fields treated with pronamide can rotate with soy bean, rice, cucumber, cabbage and tomato, if pronamide is applied just before or immediately after transplanting of lettuce. Table 4 . . . summarizes the data from Experiment I, II and V. It represents

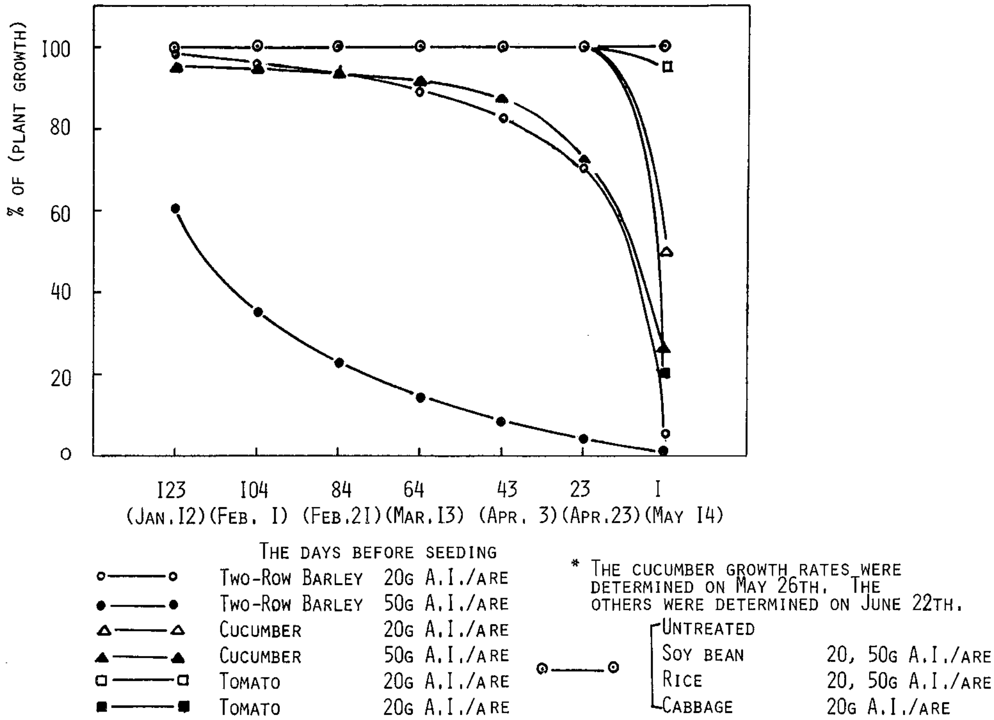


Fig. 2. Pronamide active period on various crops.

Table 4. Pronamide safety for rotation crops about 40 days after its application.

Upland field crops	Utility
Rice Cabbage, Japanese radish, Chinese cabbage Lettuce, Edible burdock, Garland chrysanthemum Soy bean, Garden pea, Azuki bean, Broad bean, Peanut Carrot, Celery, Parsley	Safe
Cucumber, Melon, Water melon Eggplant, Tomato, Red pepper Beet root, Spinach	Apply with reasonable attention depending on soil and weather conditions
Wheat, Barley	Should not be seeded 6 months or more after pronamide application

the safe crops following pronamide application. Fig. 3 presents the test results when pronamide is applied on wheat under the various temperature conditions. Wheat is one of the most sensitive crops to pronamide. As is clear from this results, the length of residual activity depends on the application period. In any case, wheat is very sensitive to pronamide. Therefore, planting wheat in short period after pronamide treatment will be dangerous. Some crops may be safe as rotation crops when the crop cultivation methods are changed. We are planning to study this matter.

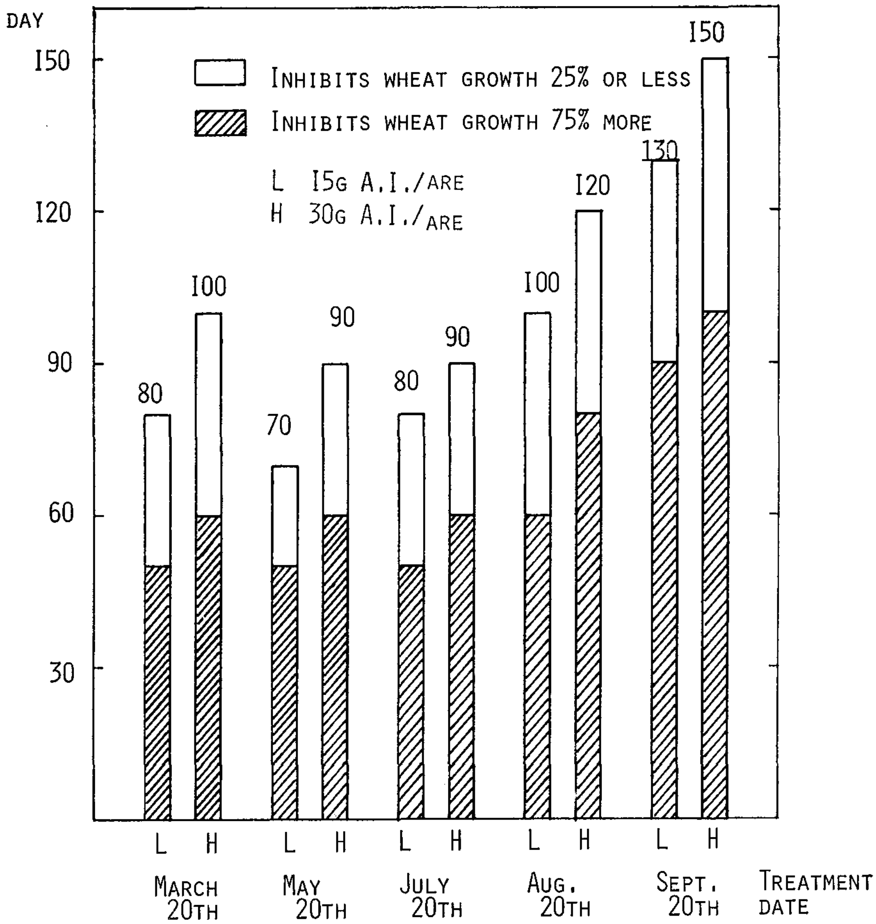


Fig. 3. Pronamide active length in soil.

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N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine —A New Preemergence Herbicide for Upland Crops and Transplanted Rice

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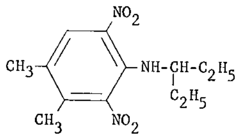
Abstract. STOMP (trademark), N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine, is a new herbicide discovered by American Cyanamid Company. It is selective as a preemergence or preplant incorporated treatment on cotton, maize, soybeans, peanuts, peas, beans, sugar cane, wheat, barley, upland rice and certain other crops. STOMP is effective against most grasses and many annual broadleaved weeds infesting these crops. It is also selective in transplanted paddy rice.

Physical and Chemical Properties

STOMP is a substituted dinitroaniline herbicide. Its chemical name and structure are as follows:

Chemical Name: N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine.

Structure:



Technical STOMP is a yellow solid with a melting point of 56°–57°C and a very low water solubility (0.3 ppm at 20°C). It is readily soluble in a number of organic solvents. It is relatively nonvolatile (vapor pressure approximately 3×10^{-5} mm Hg at 25°C).

The standard formulations of STOMP in international development are STOMP 330E, an emulsifiable concentrate containing 330 gms per litre, and STOMP 3% and 5% granules. Wettable powders and a number of combination formulations have also been prepared for experimental use.

STOMP has been widely tested under the code numbers AC 92,553, ANK 553, and the trademarks STOMP, PROWL and HERBADOX.

Toxicity, Metabolism and Residues

The acute toxicity of STOMP to mammals is low. The acute oral LD_{50} of the technical product for male rats has been determined at 1,250 mg/kg. The acute oral LD_{50} for the dog is in excess of 5,000 mg/kg. The acute dermal LD_{50} for the rabbit is also over 5,000 mg/kg.

In subacute and chronic toxicity studies, the following dietary levels and periods of feeding have been shown to produce no major adverse toxicological effects: 500 ppm in rats for 24 months, 5,000 ppm in mice for 18 months, 1,000 mg/kg bodyweight/day in dogs for 90 days. Other tests have demonstrated that STOMP does not have mutagenic or teratogenic properties.

Fish toxicity tests carried out in Taiwan and Japan indicate that STOMP should be classified as rank B in the Japanese classification system, bases on the toxicity of technical and formulated material to carp (*Ciprinus carpio*). However, determinations of the TLm_{50} of STOMP to carp have varied widely, possibly due to the very low solubility of the compound in water. Further fish toxicity tests are planned.

Plant and animal metabolism studies have been undertaken with STOMP. Soil breakdown studies have also been completed. In general, the principal routes of biological degradation in animals, plants and soil are by oxidation of the 4-methyl group on the benzene ring, and oxidation of the *N*-1-ethylprophyl group on the amine moiety.

None of the identified metabolites has a higher acute mammalian toxicity than the parent compound.

Numerous studies have shown that residues of STOMP in crops at harvest, following preemergence or preplant incorporated treatments, are very low or undetectable. In nearly all cases, residues of STOMP and metabolites have been below 0.05 ppm.

Residues of STOMP in soil persist for several months, but the disappearance is sufficiently rapid to prevent build-up in soil and harm to sensitive follow crops. STOMP is not readily leached. Residues in soil are decomposed by light, but photodecomposition is considerably less rapid than is the case with trifluralin.

In the U.S.A., the EPA has established tolerances for combined negligible residues of STOMP and its alcohol metabolite in or on corn grain, fodder and forage, and cottonseed at 0.1 ppm. Comparable temporary tolerances have been granted by the EPA for soybean forage, hay, and soybeans. Full U.S. registration on corn and cotton was obtained during 1975. In Australia, a maximum residue level of 0.05 ppm STOMP has been established for cottonseed and wheat. Elsewhere, STOMP is registered in France, West Germany, Brazil and Argentina.

Performance

Upland Crops. STOMP, applied preemergence (PRE) or preplant (PPI) at doses of 0.5 to 2.0 kg a.i./ha, has been found to give excellent control of annual grasses and small-seeded broadleaved weeds in a number of crops. It can be used successfully under most conditions in cotton, corn, winter wheat and barley, upland rice, soybeans, peanuts, other legume crops, sugar cane and carrots. It is also selective in a number of transplanted vegetable crops, including onions, cabbage and lettuce.

PRE applications of STOMP have wider crop selectivity than PPI applications. PRE application is normally required for selective weed control in monocot crops such as maize, wheat and barley, and upland rice and for transplanted vegetables. Under some conditions, PRE application gives control of a wider range of broadleaved weeds; however, PPI application may be more effective for grass control.

PPI application is generally superior to PRE where soil moisture is low.

In Japan, PRE application has given better results than PPI application on soybeans and peanuts; however, in the U.S.A., PPI application is generally preferred on these crops.

Trials in the Philippines, Colombia and Venezuela have shown that STOMP is particularly effective against the troublesome grass weed, *Rottboellia exaltata.* STOMP at 1.5 to 2.0 kg a.i./ha applied PRE has given excellent control of this weed.

As with other soil acting herbicides, STOMP is effective at relatively low doses in light sandy soils, but higher doses are required on heavy soils or soils with a high organic content.

Some work has been carried out to evaluate aerial application of STOMP in the USA. On cotton, where PPI application is generally preferred, it has been found that delays of up to ten days between application and incorporation have not adversely affected performance.

Mixtures of STOMP with other herbicides may be necessary in some situations to give an adequate spectrum of weed control. On corn, in the USA., tank mixture of STOMP with atrazine or cyanazine have given good results. In Australia and in the USA., PPI application of STOMP followed by an overlay of fluometuron has given good performance on cotton.

Paddy Rice. Trials in Japan, Korea, Taiwan, the Philippines and India have shown that STOMP, applied shortly after transplanting, is selective in temperate and tropical paddy rice. Under temperate conditions, young seedlings, as used for machine plantig, may suffer transient damage, but this has not been shown to affect yield.

STOMP, applied to the paddy water between 1 and 5 days after transplanting, controls many paddy weeds, including barnyardgrass (*Echinochloa crus-galli*), *Monochoria vaginalis, Cyperus difformis, Lindernia pyxidaria* and *Rotala indica.* The dosage required for effective control varies in different circumstances; under good water management conditions in the Philippines, heavy weed populations have been completely controlled by 0.5 kg a.i./ha, whereas in Taiwan doses as high as 2.0 kg a.i./ha have been required for full weed control. Emulsifiable and granular formulations have been equally effective.

Under tropical and sub-tropical conditions, STOMP provides control of all major annual weeds of transplanted rice. However, under Japanese conditions, certain sedges (Cyperaceae) are not well controlled. These species include *Scirpus juncoides* and *Eleocharis acicularis.* Combinations of STOMP with compounds effective against Cyperaceae are currently being evaluated.

A New Versatile Herbicide: 3-Cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione

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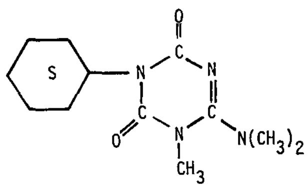
Abstract. 3-Cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione (DPX 3674) is a new triazine dione which has exceptional herbicide activity on a wide range of perennial grasses and broad leaved weeds including a number of shrubs and tree species. It is a water soluble compound which is effective when applied on plant foliage or to the soil. Optimum levels of weed control are achieved when application is made during the period of maximum vegetative growth. Microbial decomposition appears to be the major factor in its disappearance from the soil.

Experimental work conducted in Australia, New Zealand and South East Asia from 1973 to 1974 has shown DPX 3674 to be a very effective chemical for the control of weeds at industrial sites. It showed also that DPX 3674 used alone and in combination with diuron could effectively and selectively kill weeds in crops such as sugar cane, rubber and asparagus with adequate crop safety. Its performance on the control of aquatic weeds, both emergent and submerged species, has been most encouraging. Evidence obtained on the exceptional tolerance of *Pinus radiata* to the herbicidal activity of DPX 3674 was probably the most stimulating aspect of its selective toxicity.

This paper deals with the characteristic features of DPX 3674 and present status in regard to its versatile herbicide activity.

INTRODUCTION

DPX 3674 (trade name: VELPAR) is available as a 90 percent soluble powder and has a solubility of 32,000 ppm in water at 25°C. It is non-flammable, non-volatile, and non-corrosive and has the following molecular structure:



The compound has moderate acute oral toxicity and low chronic oral toxicity. It produced reversible ocular effects and is neither a skin irritant nor a skin sensitizer. Acute dermal and inhalation toxicity is low. DPX 3674 has an oral LD_{50} for male rats of 1690 mg/kg and for male guinea pigs of 860 mg/kg. When administered orally to male rats at a repeated dose of 300 mg/kg/day for a total of ten doses over a two-week period, it showed no evidence of cumulative toxicity. When fed to rats and dogs for three months at a dietary level of 1000 ppm it showed no adverse effect on the animals. The 8-day dietary median lethal concentration (LC_{50}) of this compound for both mallard duck and bobwhite quail is in excess of 5000 ppm. The median tolerance limits (TL_{50}) for fish for a 96-hour exposure period are: bluegill, between 370 and 420 ppm; rainbow trout, between 320 and 420 ppm and fathead minnow, 274 ppm with 95% confidence interval values of 207–361 ppm.

DPX 3674 is an exceptionally active herbicide, highly effective when applied on plant foliage as well as when applied to the soil. It has shown maximum effectiveness when applied for post-emergence of weeds during the period of active plant growth. On the other hand, application made when vegetation is dormant or semi-dormant might be less effective. Microbial decomposition appears to be the major factor in its disappearance from the soil.

Apart from exercising herbicidal activity against a broad spectrum of annuals and perennial grasses and broad-leaved weeds, it has also shown exceptional effectiveness against sedges, woody species, herbaceous vines, aquatic weeds and noxious ferns.

Initially introduced in 1972–1973 as an industrial herbicide, it has shown promise also for use in certain crops such as sugar cane and rubber. Experimental work in progress also points out the effectiveness of DPX 3674 as an aquatic weed killer. Recent investigations also indicate that it might become the herbicide " par excellence " in pine forestry because of the exceptional tolerance of *Pinus radiata* to its biological activity.

The present paper highlights in a summarized form the versatile herbicide activity of DPX 3674.

Total Vegetation Control

During 1973–1974 a series of over 20 replicated trials were conducted in Australia and New Zealand to evaluate the effectiveness of DPX 3674 applied post-emergence on a range of weeds occurring in those two countries. Rates of application varied from 2 kg up to 16 kg a.i. per hectare on a wide variety of soil types and at different seasons of the year. From the results obtained in those trials the following information emerged.

1) DPX 3674 showed exceptional herbicidal activity when applied during the active growth of weeds.

2) It showed good contact activity even at low rates of application of 1/2 to 3 kg a.i./ha and speed of top kill although related to rate of application, was also influenced by temperature with maximum effect when it reached 27°C and above.

3) Residual activity was related to rates of application and soil type and depending upon weed species the following general observations were made: (i) Short Term weed control of 3–6 months: 2–5 kg a.i./ha. (ii) Complete weed control for 6 months to 1 year: 5–10 kg a.i./ha. At those rates most woody species, perennial grasses and noxious ferns were killed.

4) It did not appear that the addition of surfactant enhanced herbicide activity. Improvement in weed control obtained in certain cases was attributed to the better coverage that resulted from its use. However, further experimental work is needed before

definite conclusions can be drawn in that respect.

From the DPX 3674 trials laid down in 1973–1974, valuable information was obtained on the effectiveness of the chemical on a wide range of weed species.

CROP USE

Development work carried out with DPX 3674 indicates that at low rates of application this new compound might prove to be an effective herbicide in certain crops because of its broad weed spectrum activity under a varied set of climatic conditions and soil types. Moreover, the fact that it has an excellent post-emergence activity also indicates that the use of this property in mixures with diuron or bromacil as the residual component might prove to be an effective combination for the control of weeds in crop plants. Our experimental work in crop plants may be summarized thus:

Sugar cane. The general trend seems to indicate that DPX 3674 at 0.5 kg–1.0 kg ai/ha could be used with safety in most sugar cane varieties in pre-emergence treatment of the crop. However, certain varieties like Pindar, NCO 310 and some of the South African varieties have shown excellent tolerance to the chemical at rates as high as 4 kg a.i./ha. It was also observed that at low rates of application (0.5–1.0 kg a.i./ha) DPX 3674 has not provided in certain soil types and under certain climatic conditions the duration of weed control expected.

Further experimental work has shown that DPX 3674 used at 0.5–1.0 kg a.i./ha for its post-emergence activity in combination with diuron as the residual component at rates 1–2 kg a.i./ha could give outstanding weed control with excellent crop safety. Further development work in progress seems to confirm that such combinations will find a place in sugar cane weed control practices.

Rubber. Test work in rubber indicates that this plant is fairly tolerant to DPX 3674 as from 2 year old field transplants. From a series of trials conducted in Malaysia, there are good indications that DPX 3674 in combination with diuron could give 4–6 months weed control. The best treatments would appear to be DPX 3674 at 0.5 to 1.0 kg a.i. plus diuron at 1–2 kg a.i./ha. DPX 3674 at these rates in mixtures with diuron, has controlled most of the common weeds found growing in rubber plantations.

Oil-Palm. Exploratory work indicates that DPX 3674 might probably find a place in this crop, particularly in established plantations. Experimental work in progress again seems to point out that DPX 3674 plus diuron would prove an excellent combination in that respect.

Asparagus. This crop has shown good tolerance to DPX 3674 in New Zealand. As the regular use of Bromacil in that crop has led to a *Paspalum dilatatum* problem, there are indications that the use of DPX 3674 would help in eradicating this grass in asparagus.

FORESTRY

Unwanted vegetation in Forestry is a serious problem from the time of replanting until the young trees are well developed and can contest and suppress competition from the undergrowth by casting an increasingly greater shade on the shrubs and weed strata. In most countries of the world chemicals are used in pine forestry to control unwanted vegetation both at replanting and tree releasing.

Because of the need for better and safer chemicals in pine plantations, test plots with DPX 3674 were set out in New Zealand.

Hereunder is presented in a summarized form results of some trials conducted in New Zealand highlighting the tolerance of *Pinus radiata* to DPX 3674.

In a trial carried out by N. Z. Forest Products Co. Ltd. in collaboration with Neill, Cropper & Co. Ltd. to determine *Pinus radiata* tolerance, DPX 3674 was applied at 7.2 and 10.8 kg a.i/ha. The trial included the technique of assessing tolerance by planting one year old seedlings at two month intervals. DPX 3674 produced no phytotoxic effect on seedlings planted in May, July and September, that is, at 2,4 and 6 months after herbicide treatment.

In another tolerance trial conducted by Forest Products, DPX 3674 was applied at 1.8, 3.6 and 7.2 kg a.i./ha with and without a non-ionic surfactant. The trial was laid down in pine seedlings established 3 months in the field. The treatments were applied as a blanket spray over the pines and in post-emergence of the weeds. Heights and diameters of the pine trees measured 7, 12 and 32 weeks after spraying showed no adverse effect of DPX 3674 on pine growth and development. The addition of surfactant caused a slight temporary bronze-like appearance to the pine foliage at the highest rate of application.

Two trials with statistical layout were laid down at Kaingaroa Forest by Neill, Cropper & Co. Ltd. in collaboration with the Forest Service of New Zealand. In those trials the chemical was applied at rates of 1.8, 3.6, 7.2 and 10.8 kg a.i./ha plus a non-ionic surfactant. Briefly they may be described thus:

In the first trial the chemical was applied in early post-emergence of weeds before replanting. At the time of application in October, the experimental plots had 50% weed cover with most weeds at the seedling stage of 2–3 inches high. Broom (*Cytisus* spp.) was at the trifoliate leaf stage. To assess pine tolerance to the chemical one row consisting of ten, 18 month old seedlings from the nursery were transplanted direct into the respective experimental plots 3 days after treatment. This procedure was repeated every two months with such seedlings. From the results obtained there was no evidence of adverse effects on pine development at all rates of application. However, since the second planting was made two months after spraying, that is in December (which is not normal practice because it is generally too dry for this operation) the plants were in general not growing as well as those in the October planting. Weed control at the latest date of assessment (March, 1975) was excellent at all rates. Broom was controlled at all rates and bracken (*Pteridium* spp.) as from the 7.2 kg a.i. rate.

The objective of the second trial was a "tree releasing" operation from a population consisting of broom (*Cytisus* spp.), blackberry (*Rubus* spp.), bracken (*Pteridium aquilinum*), *Holcus* spp., and ragwort (*Senecio* spp.). Broom was 2–3 ft. high. At the time of spraying the pine transplants were 18 months planted out and were about 2 ft high and the chemical was applied as a blanket spray over top of pines and weeds. From the results obtained, DPX 3674 produced no phytotoxic effect on pines at all rates used. Weed control was particularly spectacular on all species at the 10.8 kg a.i/hectare.

In a preliminary, non-replicated toxicity trial laid down by the Forest Research Institute, Rotorua some adverse effects on radiata pine seedlings transplanted into weed-free plots one day after treatment with 16 kg a.i./ha were evident after 6 months. Overall however, tolerance appeared to be satisfactory.

From experimental work carried out in New Zealand and supported by exploratory investigations in the United States, there are good indications that *Pinus radiata* and apparently most conifers have an inherent tolerance to DPX 36724 herbicidal activity.

Owing to the economic significance of controlling unwanted vegetation in pine forestry the above findings should stimulate further research with this chemical in that field.

Aquatic Weed Control

Research work carried out in Australia indicates that DPX 3674 is very effective on most floating and soil rooted emergent species. DPX 3674 applied at 5.5 kg a.i./ha gave excellent control of the following species: *Eichhornia crassipes*, *Ludwigia peploides*, *Paspalum paspaloides*, *Juncus* sp., *Cyperus eragrostis*, *Polygonum lapathifolium*, *Salvinia auriculata*, *Typha domingensis*, *Rumex crispus*, *Ranunculus sceleratus*, *Triglochin procera*, *Polypogon monspeliensis*, *Scirpus validus*.

Studies conducted in a small "tank farm" by the Water Conservation and Irrigation Commission of N.S.W., Australia with DPX 3674 at concentrations of 5, 1 and 0.1 ppm showed that the following species were controlled at rates as low as 0.1 ppm: *Potamogeton tricaranatus*, *Vallisneria gigantea*, *Elodea canadensis*, *Ceratophyllum demersum*.

It must be observed that *Myriophyllum propinquum* (common milfoil) showed some indication of being affected only at the highest concentration level.

From this work it also emerged that DPX 3674 had little or no herbicide activity on all the above species during the winter months and up to early summer. This may indicate its effectiveness is temperature controlled and that at low water temperatures it loses some of its herbicidal activity.

Acknowledgments

The writer is indebted to the New Zealand research workers from Forest Products Ltd., Forest Research Institute and Forest Service for their enthusiasm and collaboration in regard to development work with DPX 3674 in forestry. I am also grateful to Mr. Geoff Sainty of the Water Conservation and Irrigation Commission at Griffith, N.S.W. for his collaboration regarding investigational work with DPX 3674 on aquatic weeds. It is also a great pleasure to acknowledge the assistance received from my friends of Neill, Cropper & Co. Ltd. for valuable information and discussion on the use of DPX 3674 under New Zealand conditions. Finally, the assistance received from my colleagues and friends of the Du Pont Company from the Australasian and South East Asian regions regarding the availability and discussion of their experimental results is also gratefully acknowledged.

Control of Nutsedges (*Cyperus rotundus* and *Cyperus esculentus*) and Other Weeds with K-223 and K-1441

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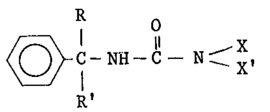
Abstract. K-223 is a selective herbicide with excellent herbicidal effects for the control of several noxious cyperaceous weeds in paddy rice fields. K-223 can also be applied by preplant soil incorporation to control purple nutsedge in upland rice fields. Another excellent herbicide is K-1441, which possesses a somewhat broader herbicidal spectrum than K-223. Preemergence application of K-1441 is particularly effective in controlling various important weeds such as Cyperaceae and Gramineae families. Turf, peanut, sugarcane, potato, tomato, cotton, sunflower, strawberry, and rice were tolerant of K-1441.

Materials and Methods

A number of related benzyl urea derivatives belonging to the general structure I below were synthesized, and the R, R′, X and X′ respectively in the formula were varied systematically. The compounds thus prepared were subjected to herbicidal evaluation tests in greenhouses.



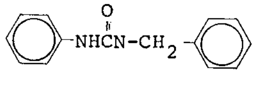
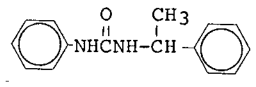
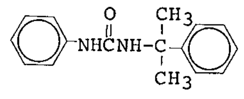
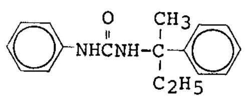
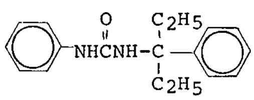
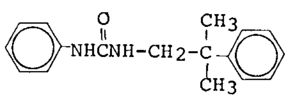
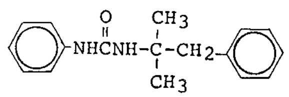
(I)

Two series of evaluation tests were conducted.

Irrigated water treatment. Ceramic pots were packed with soil and watered to obtain paddy conditions. Two rice seedlings at the 4-leaf stage and slender spikerush (*Eleocharis acicularis* R. & S.) were transplanted into each pot. Then seeds of barnyardgrass (*Echinochloa crusgalli Beauv.*), smallflower umbrellaplant (*Cyperus difformis* L.), bulrush (*Scirpus juncoides* Roxb.), monochoria (*Monochoria vaginalis* Presl.) and ammania (*Lythrum anceps* Makino) were sown in the pots. On the next day a suspension of the test compounds was added to the irrigation water at dosages of 1, 2 and 4 kg/ha. Phytotoxicity to barnyardgrass was recorded at 18 days, and the surviving barnyardgrass in each pot was carefully removed by hand. Phytotoxicity to other plants was recorded at 34 days.

Soil-incorporated pre-emergence treatment. A suspension of the test compounds was sprayed at concentrations of 4, 8, and 12 kg/ha onto ceramic pots packed with soil, and the thus treated soil was mixed well to a depth of 10 cm. Four tubers of purple nutsedge

Table 1. Variations in structure of benzyl moiety.

Compound	Irrigated water treatment								soil-incorporated	
	Dosage (kg/ha)	Barnyardgrass	Umbrellaplant	Spikerush	Bulrush	Ammania	Monochoria	Rice	Dosage (kg/ha)	Purple nutsedge
	4	9	0	0	0	0	0	0	12	0
	2	8	0	0	0	0	0	0	8	0
	1	2	0	0	0	0	0	0	4	0
	4	10	10	9	10	5	0	0	12	1
	2	8	10	7	9	0	0	0	8	0
	1	5	10	0	2	0	0	0	4	0
	4	10	10	9	10	3	0	0	12	9
	2	10	10	9	10	0	0	0	8	8
	1	8	10	8	8	0	0	0	4	4
	4	8	10	8	10	0	0	0	12	7
	2	7	10	8	10	0	0	0	8	6
	1	7	10	6	10	0	0	0	4	0
	4	7	0	9	10	0	0	0	12	7
	2	5	0	6	10	0	0	0	8	4
	1	5	9	6	10	0	0	0	4	0
	4	3	0	2	0	0	0	0	12	0
	2	3	0	0	0	0	0	0	8	0
	1	2	0	0	0	0	0	0	4	0
	4	9	10	0	0	0	0	0	12	0
	2	7	8	0	0	0	0	0	18	0
	1	5	2	0	0	0	0	0	4	0

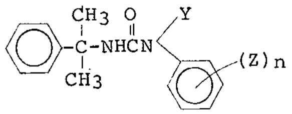
Phytotoxicity ratings: 0=no-toxicity, 10=completely killed

(*Cyperus rotundus* L.) were planted in the soil at a depth of 3 cm. Five weeks after the treatment the plants and parent tubers were removed from the pots and compared with untreated plants.

Structure-Activity Relationship

Seven 1-benzyl-3- phenyl urea derivatives of similar frame-structures are arranged in Table 1, with a view to comparing the effects of varying substituents in the benzyl moiety. The data in Table 1 show that introduction of alkyl substituents into α-position causes great enhancement of herbicidal activity. Maximum activity is reached when both α-hydrogen atoms are substituted with methyl groups. An increase in length of the

Table 2. Variations in structure of compound II.



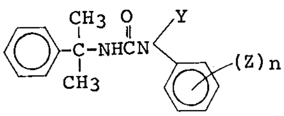
Exp. No.	Substituent Y	(Z) n	Irrigated water treatment: Dosage (kg/ha)	Barnyardgrass	Umbrellaplant	Spikerush	Bulrush	Ammania	Monochoria	Rice	Soil-incorporated: Dosage (kg/ha)	Purple nutsedge
	H	H	4	10	10	9	10	3	0	0	12	9
			2	10	10	9	10	0	0	0	8	8
	H	o-CH_3	4	10	10	9	10	7	7	0	12	9
			2	9	10	9	10	5	2	0	8	9
	H	m-CH_3	4	10	10	9	10	6	0	0	12	8
			2	9	10	9	10	6	0	0	8	8
K-223	H	p-CH_3	4	10	10	9	10	4	0	0	12	10
			2	10	10	9	10	2	0	0	8	9
	H	2,3-$(CH_3)_2$	4	8	10	9	10	4	0	0	12	8
			2	7	10	9	10	2	0	0	8	8
	H	2,4-$(CH_3)_2$	4	10	10	0	10	8	8	0	12	9
			2	10	10	9	10	6	8	0	8	8
	H	o-Cl	4	10	10	0	10	4	0	0	12	5
			2	7	10	8	10	0	0	0	8	5
K-1441	CH_3	H	4	10	10	9	10	10	10	2	12	10
			2	10	10	9	10	9	10	0	8	10
	C_2H_5	H	4	10	10	9	10	10	10	0	12	10
			2	10	10	9	10	10	10	0	8	10
	CH_3	m-Cl	4	10	10	9	10	10	10	0	12	10
			2	10	10	9	10	9	10	0	8	9

Phytotoxicity ratings: 0=no-toxicity, 10=completely killed

alkyl substituents results in a lowering of activity, and increase in benzyl chain length also considerably decreases activity.

In order to obtain more information many other 1-(α, α-dimethylbenzyl)-3-aryl ureas as represented by the general structure II below, where "Y" stands for an alkyl group or a hydrogen atom, and "$(Z)_n$" indicates substituents are treated for herbicidal activity.

Some of the representative compounds are selected and their biological data are



(II)

summarized in Table 2. It is clear from Table 2 that compouhds belonging to this general structure have properties so marked as to inhibit growth of various annual cyperaceous weeds, which have been so difficult to control, while rice and common broad leaf plant are not seriously affected.

In the course of extensive research, K-223 and K-1441 were selected from compounds belonging to the structure II as quite promising new herbicides, and further repeated field trials have been carried out to establish practical application methods for weed control.

K-223

1-(α,α-Dimethylbenzyl)-3-(*p*-tolyl) urea (K-223) is selected from the point of view of use in paddy and upland rice fields, since it has the least phytotoxicity to rice plants and is low in toxicity to fish and mammals. K-223 is odorless and colorless needle crystal, which melts at 203°C. Acute oral toxicity is $LD_{50}>6,500$ mg/kg to mouse and $LD_{50}>4,000$ mg/kg to rat, acute subcutaneous toxicity is $LD_{50}>3,000$ mg/kg to mouse and $LD_{50}>3,500$ mg/kg to rat, and subacute toxicity to rat at feedings of 0.15, 0.75, and 3.75 g/kg per day for 90 days produced no deviation from normal. Toxicity to fish is so low that the TLm value at 48 hours to carp was >300 ppm.

For practical application K-223 can be mixed with other herbicides such as nitrofen or CNP (2,4,6-trichlorophenyl-4′-nitrophynyl ether), in order to broaden the herbicidal spectrum. In particular, treatment with a combination of 7% K-223 and 9% CNP in a granular formulation to transplanted rice fields gave excellent control over a wide range of weeds. For the purpose of controlling purple nutsedge in upland rice field, 2 to 10 kg/ha of K-223 can be applied in wettable powder by preplant soil-incorporation treatment.

K-1441

3-Methyl-1-(α,α-dimethylbenzyl)-3-phenyl urea (K-1441) is odorless and colorless crystal, which melts at 76°C. Acute oral toxicity is $LD_{50}>7,660$ mg/kg to mouse and $LD_{50}>9,000$ mg/kg to rat, and acute subcutaneous toxicity is $LD_{50}>10,700$ mg/kg to mouse and $LD_{50}>11,400$ mg/kg to rat. Toxicity to fish is low. The TLm value at 48 hours to carp was 15 ppm. K-1441 exhibits herbicidal activity against weeds at the time of germination or in the initial growing stage of the roots. It is mainly taken up through the roots. Pre-emergence application or soil incorporation is, therefore, most effective. The following are examples of noxious weeds which can be controlled by pre-emergence or soil incorporation treatment at a rate of 2 to 10 kg/ha: Purple nutsedge, yellow nutsedge (*Cyperus esculentus* L.), green kyllinga (*Kyllinga brevifolia* Rottb.), umbrellaplant, wild oats (*Avena fatua* L.), annual bluegrass (*Poa annua* L.), barnyardgrass, crabgrass (*Digitaria sanguinalis* Scop.), and yellow foxtail (*Setaria glauca* Beaux.). The following crops have shown high tolerance to K-1441: turf, beans, peanut, potato, sugarcane, sunflower, tomato, cotton, corn, strawberry, and rice.

Thiochlormethyl, an Interesting Compound for Herbicide Mixture with Broad Spectrum Weed Control in Rice Culture

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Abstract. Thiochlormethyl with the chemical name 3-(3-chloro-4-chlorodifluoromethylthiophenyl)-1,1-dimethylurea displays excellent pre- and post-emergence efficacy on various kinds of broad leaf weeds and certain grasses as a paddy herbicide. Thiochlormethyl can be used in soil incorporation and water service treatments. Its excellent plant compatibility permits application, irrespective of rice variety and warm temperature when triazin herbicides can not be used. The mixtures of thiochlormethyl and herbicides for grass control give more consistent control of grasses and extend the effective period of application from pre-emergence to the early growing stage of the weeds.

INTRODUCTION

Many excellent herbicides for grass control in paddy rice are well known while there are only a few paddy herbicides for broad leaf weed control with high selectivity on rice.

With the modernization of agriculture, machinery transplanting using young seedlings has become more popular year by year. These seedlings are more sensitive to herbicide than ordinary transplanted seedlings.

The experience has shown that under certain climate and soil conditions, 2,4-D, MCPA and simetryne reveal insufficient plant compatibility to rice seedlings under such circumstances, it is necessary to develop a herbicide not only which shows long lasting efficacy to a wide range of weed species but which is safe to rice seedling in all transplanting stages and when directly seeded.

CLEARCIDE, a substituted phenylurea (suggested common name: thiochlormethyl code No.: KUE-2079A) with the chemical name 3-(3-chloro-4-chlorodifluoromethylthiophenyl)-1,1-dimethylurea has an excellent efficacy to broad leaf weeds on both pre- and early post-emergence water service treatments with good tolerance to machinery transplanted rice and direct sown wet rice.

The compound has been developed cooperatively by Bayer AG in West Germany and Nihon Tokushu Noyaku Seizo K.K. in Japan.

Thiochlormethyl and its combinations with grass control herbicide such as benthiocarb, molinate, chlomethoxynil, NTN-5810 and NTN-9625 have been officially tested throughout Japan by the Japan Association for Advancement of Phytoregulators (JAPR) Since 1971.

Biological Properties of Thiochlormethyl

a) Selectivity of Substituted Phenylurea on Paddy Rice Plant

As described in Table 1, substituted phenylurea generally do not have any selectivity in rice seedling. Out of this group, however, only thiochlormethyl shows outstanding plant compatibility to rice and excellent control to paddy weeds.

b) Herbicide Performances

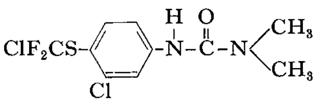
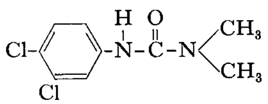
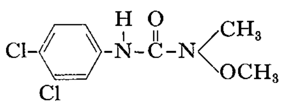
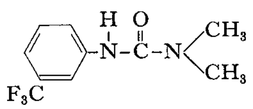
As described in Table 2, thiochlormethyl displays excellent pre- and post-emergence efficacies to various kinds of broad leaf weeds and certain grasses as *Monochoria vaginalis, Dopatrium junceum, Elatine triandra, Lindernia pyxidaria, Rotala indica, Aneilema japonica, Cyperus difformis* and *Scirpus juncoides.* In pre-emergence application it also controls *Echinochloa Crus-galli* and *Eleocharis acicularis,* however the post-emergence efficacy to these weeds is not quite sufficient.

It gives excellent control also to a number of emerged perenial weeds such as *Potamogeton distinctus, Marsilea quadrifolia.* Floating weeds and algae as *Azolla sp., Salvinia natans, Spirodela sp., Chara Braunii* and *Spirogyra crassa* are well controlled.

c) Plant Compatibility to Paddy Rice under Various Conditions

The application of 2,4-D and MCPA for broad leaf weeds control is limited to the period between the end of the effective tillering stage and the young head forming stage or rice seedling. Under warm climate conditions simetryne tends to cause plant toxicity.

Table 1. Herbicide performance of substituted phenylurea on paddy rice.

Chemical	Chemical Structure	kg/ha	Herbicide Performance (%)					
			ECHC	ELOA	CYPD	MONV	Dicot	RIS
Thiochlormethyl		2.0	100	100	100	100	100	0
		0.5	70	50	100	100	100	0
Diuron		0.5	100	80	100	100	100	80
Linuron		0.5	100	75	100	100	100	80
Fluometuron		0.5	100	80	100	100	100	85

ECHC: *Echinochloa Crus-galli,* ELOA: *Eleochalis acicularis,* CYPD: *Cyperus difformis,* MONV: *Monochoria vaginalis,* Dicot: Several kinds of broad leaf weeds, RIS: Rice seedling, Rating: 100; 100% kill, 0; 0% kill, Treated time: 6 days after transplanting (DAT), Assessed time: 30 DAT.

Table 2. Herbicide performance of thiochlormethyl for the various applications.

Chemical	kg/ha	Herbicide performance (%)						
		ECHC	ELOA	CYPD	MONV	Dicot	D-RIS	T-RIS
PPI								
Thiochlormethyl	1.5	100	85	100	100	100	100	0
	0.5	40	50	100	100	100	50	0
Simetryne	0.45	40	30	70	70	60	60	20
3DAT		pre	pre	pre	pre	pre	pre	3 LS* 14 cm**
Thiochlormethyl	1.0	100	100	100	100	100	100	0
	0.25	50	30	100	100	100	60	0
Simetryne	0.45	70	60	100	100	80	100	60
12DAT		1.5		1.0	1.5	2.0	2.0	6.0 LS
		5.0	2.0	0.7	2.0	0.5	8.5	23 cm
Thiochlormethyl	1.5	60	20	100	100	100	5	0
	0.5	10	0	100	100	100	0	0
Simetryne	0.45	10	0	70	85	80	20	0

PPI: Pre-plant soil incorporation, D-RIS: Direct sown rice, T-RIS: Transplanted rice.
* LS: Leaf stage, ** cm: Plant height.

Table 3. Plant compatibility of thiochlormethyl under tropical conditions.

Chemical	kg a.i./ha	Plant height % of untreated control			Number of stem % of untreated control		
		IR-8	G.M.	C-4-63	IR-8	G.M.	C-4-63
Thiochlormethyl	2.4	95.6	102.5	92.3	105.8	116.4	86.9
2% GR.	1.6	103.0	96.3	95.8	103.9	103.0	90.0
	1.2	103.0	99.4	110.0	101.9	97.9	122.8
	0.8	107.5	98.4	103.5	114.5	102.1	124.5
Simetryne	0.6	101.0	71.2	—*	55.3	20.5	—
1.5% Gr.	0.45	93.0	99.4	—	81.5	46.6	—
Untreated check		100	100	100	100	100	100
		47.9 cm	51.9 cm	34 cm	20.6**	29.2	11.4

Application time: 6 DAT, Assessed time: 25 days after chemical application, Rice seedling ages at the transplanting time: IR-8; 28 day old, G.M.; Glutinus miracle; 16 day old, C-4-63; 15 day old,
* Plant died, ** The number of stem per one plant.

Under such circumstance, thiochlormethyl is an interesting compound with similar weed control properties and excellent plant compatibility to transplanted and direct sown wet rice seedling under temperate and tropical conditions proved by trials in Japan, Taiwan and the Philippines.

Table 3 reviews a plant compatibility test carried out in the Philippines. It can be demonstrated that thiochlormethyl applied at different application rates to three rice varieties does not influence growth and tillering of plants negatively under tropical conditions.

Practical Use of Thiochlormethyl in Combination with Grass Control Herbicides

The experience has shown that benthiocarb, molinate and others are not effective enough to control the whole weed spectrum. Especially for the control of broad leaf weeds such as *Monochoria*, *Elatine*, *Dopatrium* many combination products have been introduced.

Thiochlormethyl can be used in combination with grass herbicides to extend the control effectiveness toward all important weeds in paddy rice.

Some mixtures have been officially announced to be practicable as paddy herbicide and can be applied during a long period.

CLEARTURN (benthiocarb+thiochlormethyl) can be used in ordinary and in machinery transplanted rice from pre-plant soil incorporation to post-emergence water service treatments, up to the 2.5 leaf stage of *Echinochloa Crus-galli*. Ordram K (molinate

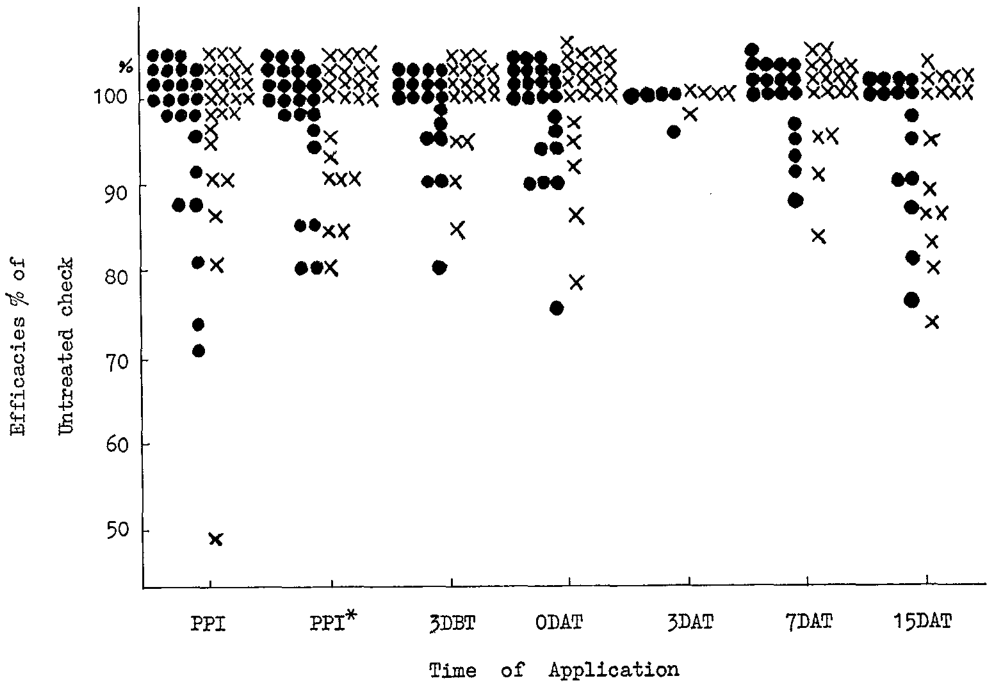


Fig. 1. Efficacies of benthiocarb/thiochlormethyl (30 kg/ha) to *Echinochloa Crus-galli* and *Monochoria vaginalis* on the official tests since 1972

PPI : Pre-plant soil incorporation application

PPI*: Pre-plant soil surface application directly after puddling

●: *Echinochloa* ×: *Monochoria*

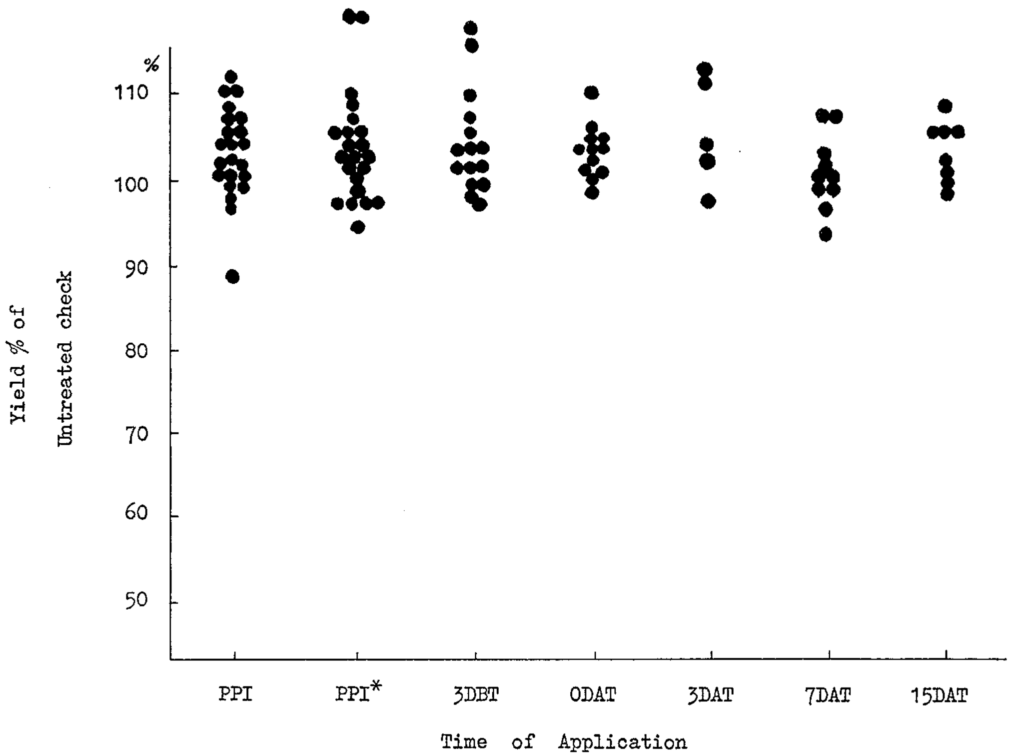


Fig. 2. Influence of benthiocarb/thiochlormethyl (30 kg/ha) on the yield of rice on official test since 1973.

+thiochlormethyl) can be used up to 1 day before transplanting and from 2 to 18 days after transplanting.

The control of CLEARTURN to *Echinochloa* and *Monochoria* is plotted in Fig. 1. It can be demonstrated that more than 85% of the experiments carried out since 1972 show more than 90% control.

In Fig. 2 the yields of rice after treatment with CLEARTURN are plotted in the same way. This shows that in almost all tests the yield was increased after the use of CLEARTURN for wide spectrum weed control.

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Effect of Undisturbed Soil Period on Glyphosate Control of *Cyperus rotundus* L.

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Abstract. Purple nutsedge (*Cyperus rotundus* L.) plants were treated in the field at 2, 4, 6, 12, and 24 weeks after tilling, with glyphosate [*N*-(phosphonomethyl) glycine] at 1, 2, and 4 kg/ha, to determine the optimum rate and period of non-disturbance for good nutsedge control. In most cases, 2 kg/ha gave as good control as 4 kg/ha. Glyphosate applied after 12 weeks of non-disturbance gave almost complete mortality of foliage and more than 75% mortality of tubers. Glyphosate applied at 2, 4, 6, and 24 weeks gave insufficient control of tubers and had to be repeated.

Introduction

Purple nutsedge (*Cyperus rotundus* L.) is a serious weed pest in most warm areas of the world (Holm and Herberger, 1969). Until recently, no herbicide has given sufficient post-emergence control to greatly reduce or eradicate a nutsedge infestation. In 1971, the Monsanto Company introduced glyphosate [*N*-(phosphonomethyl) glycine], which appeared to be very toxic to many hard-to-control perennials. (Baird *et al.*, 1971; Derting *et al.*, 1973). Several workers reported successful control of nutsedge with glyphosate. Wills reported 95% control of nutsedge with 2 kg/ha in Mississippi (Wills, 1973). In Tanzania, a mature stand of nutsedge was controlled with 1 application of glyphosate at 2 kg/ha for 26 weeks (Magambo and Terry, 1973). Under dry conditions, they were able to extend control with 4 and 6 kg/ha for 88 weeks (Terry, 1974).

We undertook the present study to determine the most effective period of soil non-disturbance for nutsedge control with glyphosate.

Materials and Methods

This experiment was conducted at the Waimanalo Research Station, Oahu, Hawaii. A field heavily infested with purple nutsedge was rotovated to a depth of 15 cm, and harrowed to prepare a smooth seedbed. Three kg/ha (a.i.) each of trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) and chloramben (3-amino-2,5-dichlorobenzoic acid) granules were applied to control other weed species. These herbicides were reapplied 2 and 4 months after initial application. The field was irrigated twice weekly by overhead sprinklers. Weeds other than nutsedge that emerged were removed by hand.

Half of the field was rotovated again 10 weeks later. Two weeks later, the first applications of glyphosate were made to 3 ×6 m plots. All applications were made with a 1-wheel, hand-propelled sprayer, applying 375 l/ha spray solution at 2.1 kg/cm^2 pressure. Glyphosate was applied at 1, 2, and 4 kg/ha (a.i.) every 2, 4, 6, 12, or 24 weeks after the last tilling, until no regrowth appeared. Thus, 2, 4, and 6 week treatments were applied at 2, 4, or 6 weeks after tilling, and repeated every 2, 4, or 6 weeks, respectively. The 12 week treatments were applied only once, since the population dropped to nearly zero, and remained there until the soil was worked up again. Applications at 24 weeks were not repeated, since the experiment terminated before another 24 weeks passed.

The number of nutsedge shoots in 0.3 m^2 was counted every 2 weeks, for the duration of the experiment. Every 4 weeks tubers were dug from each plot. The experiment was set up as a randomized complete block design, with 3 replications. The data was analyzed by analysis of variance and differences between means were compared by Duncan's multiple range test.

The tubers dug from the plots were washed and trimmed of roots and rhizomes. Twenty tubers from each plot were placed on filter paper in 15 cm diameter petri dishes, and 15 ml of 100 ppm benzyl adenine solution was added to each dish to test for viability (Teo and Nishimoto, 1973). Then the number of sprouted tubers per dish was recorded after incubation in the dark at 23 C for 3 weeks.

Results and discussion

Two and 4 kg/ha rates provided equal nutsedge control in most cases. One kg/ha was applied every 2 weeks, and after 3 months it did not differ from 2 or 4 kg/ha applied every 2 weeks. Thus, 2 kg/ha gave as good control of nutsedge as 4 kg/ha, and with

Table 1. Effect of glyphosate treatment on purple nutsedge plant density.

Glyphosate (kg/ha)	No. of Plants in 0.3 m^2*				
	At application	1 month after initial application	3 months after initial application	5 months after initial application	7 months after initial application
1 every 2 weeks	138.0 ab	147.0 ef	12.0 ab	7.0 a	6.7 abcd
2 every 2 weeks	140.3 ab	90.0 d	5.0 a	1.3 a	2.3 abc
4 every 2 weeks	143.0 ab	63.0 cd	3.0 a	1.3 a	5.3 abcd
2 every 4 weeks	140.7 ab	165.7 f	18.3 bc	9.3 a	14.7 d
4 every 4 weeks	179.0 abc	131.7 e	12.7 ab	7.7 a	11.0 bcd
2 every 6 weeks	269.0 cd	33.3 abc	11.7 ab	10.0 a	11.3 cd
4 every 6 weeks	239.3 cd	23.0 ab	10.7 ab	8.7 a	13.3 d
2 at 12 weeks	278.0 d	47.0 bc	0.3 a	0.9 a	1.3 ab
4 at 12 weeks	190.0 bcd	21.3 ab	0.5 a	0.3 a	0.7 a
2 at 24 weeks	86.7 a	11.3 a	42.7 d	67.0 b	
4 at 24 weeks	96.3 a	6.0 a	28.0 c	46.0 b	

* Means in a column followed by the same letter are not significantly different at P=0.05 by Duncan's multiple range test.

frequent sprayings, 1 kg/ha gave as good control as 2 and 4 kg/ha.

There was some variation in the number of plants present at initial application (Table 1). Six and 12 week old plots had the greatest number, since maximum density is reached about then as reported (Hauser, 1962). At 24 weeks, the population had receded. One month after initial application, the 6, 12, and 24 week plots showed the most reduction in stand. At 3 months, nutsedge in the 24 week plots were increasing rapidly in numbers, while all others were decreasing. The population of the 12 week treatments had dropped to nearly zero, and remained there up to 7 months after treatment. This did not differ from several of the other treatments, but glyphosate was applied only once to 12 week plots. At 7 months after initial application, the 12 week treatments (1 application) and 2 week treatments (14 applications) did not differ. More plants were present in the 4 and 6 week treatments than others, but in some cases, were not different from 2 week treatments.

Regermination of tubers from these plots gave an indication of the effectiveness of the glyphosate treatments in killing the tubers. Tubers dug 1 month after initial applications showed the 12 week treatments to be the most effective (Table 2). At 3 months, the 2, 4, and 6 week treatments caused around 50% mortality of tubers, while 12 week treatments gave better than 75% mortality. The 24 week treatment showed no difference from controls at all dates.

At 5 months, the same general pattern was present. One kg/ha every 2 weeks did not give as good control as 2 and 4 kg/ha. Four kg/ha every 6 weeks gave better kill than other shorter term treatments.

It appears that purple nutsedge is most susceptible to glyphosate treatment at 12 weeks after tilling. Thus, where possible, soil should be tilled and left undisturbed for this period of time to obtain optimum control with a minimum amount of glyphosate.

Table 2. Regermination of nutsedge tubers after treatment with glyphosate.*

Glyphosate (kg/ha)	1 month after initial application (%)	3 months after initial application (%)	5 months after initial application (%)
1 every 2 weeks	75.0 de	48.3 bcd	78.3 de
2 every 2 weeks	31.7 abc	41.7 bcd	55.0 cd
4 every 2 weeks	48.3 cd	45.0 bcd	41.7 bc
2 every 4 weeks	85.0 e	58.3 cd	58.3 cd
4 every 4 weeks	76.7 de	66.7 de	40.0 bc
2 every 6 weeks	46.7 cd	41.7 bcd	53.3 cd
4 every 6 weeks	35.0 bc	38.3 bc	25.0 ab
2 at 12 weeks	15.0 ab	23.3 ab	10.0 a
4 at 12 weeks	3.3 a	5.0 a	5.0 a
2 at 24 weeks	83.3 e	90.0 ef	93.3 e
4 at 24 weeks	76.7 de	88.3 e	91.7 e
0 (Control)	98.3 e	95.0 f	95.0 e

* Means in a column followed by the same letter are not significantly different at $P=0.05$ by Duncan's multiple range test.

If time is limited, control can be achieved with more frequent applications. A higher rate at a shorter time period will give a slight increase in control over lower rates.

When glyphosate is used for long-term nutsedge control, it will be easier to maintain control. Once the nutsedge has reached maximum density (12 weeks), 2 kg/ha should give good long-term control. If the plants pass maturity and the population declines before application, susceptibility to glyphosate also declines.

The optimum control at 12 weeks is probably due to two factors: 1. Most non-dormant tubers will have sprouted by 12 weeks, thus having an aerial connection, and making them susceptible to herbicide application. 2. The plants reach physiological maturity about this time, thus allowing translocation to all parts of the plant. Soon afterwards, senescence sets in.

In conclusion, 2 kg/ha glyphosate seems to be the optimum rate for purple nutsedge control. About 12 weeks of non-disturbance and vigorous growth provides purple nutsedge plants most susceptible to glyphosate.

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C 288 (A Mixture of Piperophos and Dimethametryn) in East Asia

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Abstract. The selective herbicide C 288 or CG 102 (AVIROSAN) containing piperophos (C 19490; *S*-2-methylpiperidinocarbonylmethyl *O*,*O*-di-*n*-propylphosphorodithioate) and dimethametryn [C 18898; 2-(1,2-dimethylpropylamino)-4-ethylamino-6-methylthio-1,3,5-triazine] and the mixture (RILOF H) containing piperophos and 2,4-D IPE have been successfully developed in East Asian rice growing countries.

Broad spectrum weed control with C 288 was achieved in both temperate and tropical countries. The optimum rate of application tended to be lower in the tropics. C 288 was well tolerated by both *Indica* and *Japonica* type of rice in Korea and Taiwan.

INTRODUCTION

This paper presents the summary of progress of the development with C 288 in East Asia, that is Korea, Japan, Taiwan, Philippines and Indonesia. Another related mixture called RILOF H which contains piperophos and 2,4-D isopropylester (2,4-D IPE) has been also developed only in tropical Asia. Successful weed control and high selectivity was achieved with these herbicide in rice.

MATERIALS AND METHODS

As shown in Table 1 many different formulations have been developed for use under different climatic conditions, as a result of the different rates of application needed to achieve good weed control. Secondly, the weed flora is different from that in Japan,

Table 1. C 288 (CG 102) related rice herbicides.

Name	Formulation	Contents		Developed in
AVIROSAN	5.5% Gr.	Piperophos+dimethametryn	(4:1)	Korea, Japan
(C288 or CG102)	3.3% Gr.	,, ,,	,,	Taiwan, Philippines
RILOF H	4 % Gr.	Piperophos+2,4-D IPE	(3:2)	Philippines, Indonesia
	5 % Gr.	,, ,,	(2:1)	,,
	50 % EC	,, ,,	(2:1)	,,
WAIDA	15.5% Gr.	Piperophos+dimethametryn	(4:1)	Japan only
(TH63)		+bentazon 10%		

although major troublesome weeds in rice fields are basically the same in East Asian countries.

C 288 5.5% granules are in the registration phase in Korea and Japan; 3.3% granules have already been made commercially available in Taiwan and 50% EC is available in the Philippines. RILOF H is available in the Philippines and Indonesia. TH 63 or WAIDA which is a mixture of C 288 and bentazone, is available only in Japan.

Results and Discussion

Average monthly temperature in major cities in rice growing area were indicated in Fig. 1 in relation to average temperature at the time of transplanting. Japan and Korea belong to the temperate zone. The 1st crop in Taiwan, transplanted in January and February, also belongs to the temperate zone, but 2nd crop which is transplanted in mid-summer is grown at higher temperature than in the Manila area. In the Manila area the temperature is high enough to plant rice all year round when irrigation water is available. Such different climates resulted in different rates of application of C 288 being necessary.

With the rates recommended in the following sections for the individual East Asian countries, control of annual grasses, sedges and broadleaved weeds has been consistently excellent, with a highly positive influence on yield.

Taiwan. In the 1st crop which is transplanted under temperate climate conditions, 30 kg/ha of C 288 3.3% granules applied 4–6 days after transplanting successfully controlled the major annual weeds. In the 2nd crop, a lower rate, 15 kg product/ha was apparently sufficient to achieve good weed control.

Water and soil temperature measured in 1974 summer trials in the southern part of Taiwan, indicated that the maximum was 42–44 degrees C in the day time. Under such extremely high temperature, there was no difference in susceptibility between *Indica* and *Japonica* varieties to C 288. In sandy soil, however, slight stunting was observed regardless of variety.

Korea. A large number of trials has been carried out in the past few years in Korea. The weed flora in Korea was almost the same as the one in the northern part of Japan. AVIROSAN 5.5% granules at 20 to 30 kg/ha, applied 5–15 days after transplanting gave good control of all annual weeds and some perennial weeds such as *Potamogeton distinctus*, which is a major problem weed in Korea. *Cyperus serotinus* was considerably depressed by the application of 30 kg, but *Sagittaria pygmaea* was not controlled.

It is known that some of the triazine herbicide such as simetryne are phytotoxic to *Indica* rice. Therefore, crop tolerance of C 288 was closely evaluated using *Japonica* rice varieties such as Sadominori, Mankyung, Akibare and new high yielding *Indica* cross varieties such as IR 667 and IRI 317. The results clearly demonstrated that there was no varietal difference in susceptibility and that C 288 was well tolerated also by *Indica* cross varieties.

Philippines. Trial work carried out since 1972 in the Philippines has established that both C 288 and RILOF H can be safely and effectively applied 4–6 days after transplant-

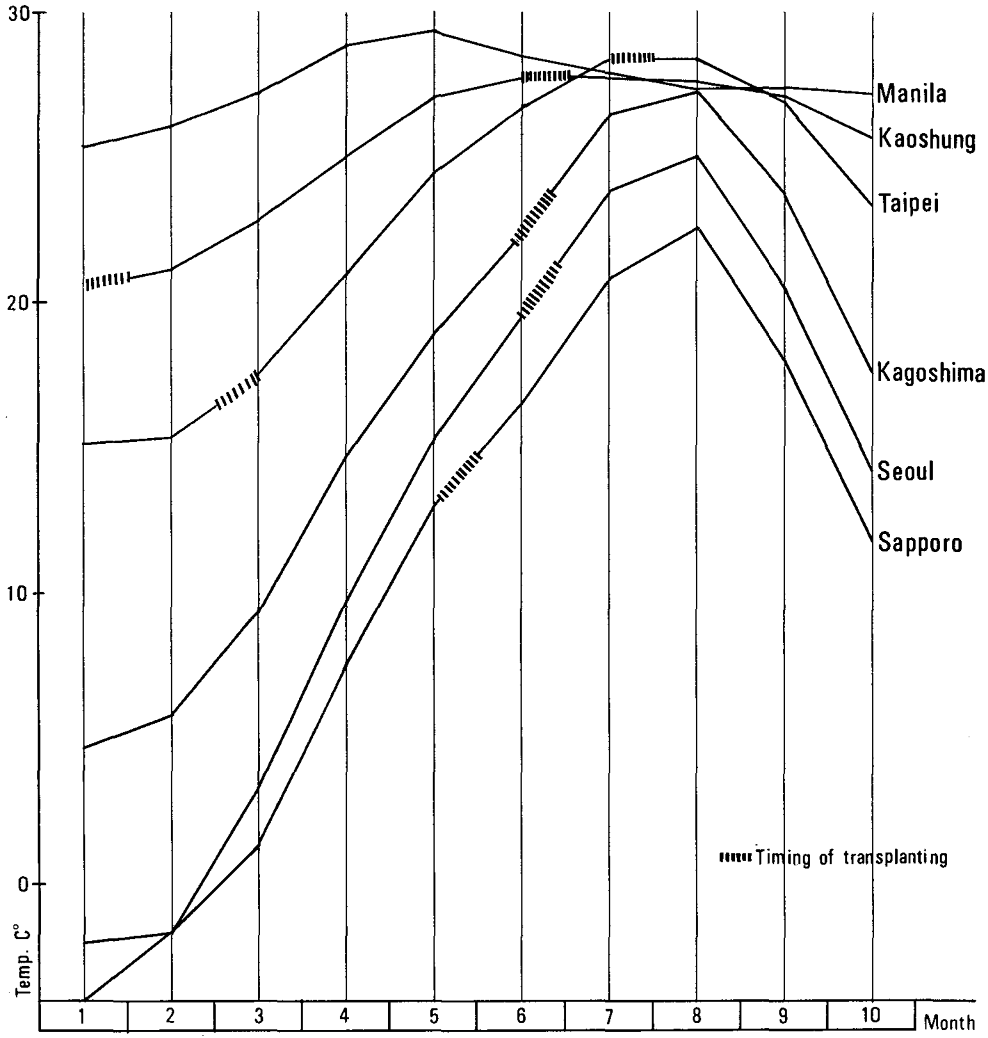

Fig. 1. Average temperature and timing of rice transplanting in East Asia.

ing in hand transplanted rice. Promising results have been obtained also in direct seeded flooded rice and in rainfed direct-seeded rice, that is rice grown on natural rainfall without having continuous irrigation water; these results require confirmation in practical applications on farmers' fields. In dapog rice, however, initial stunting was sometimes observed. In direct seeded flooded rice, it was demonstrated by De Datta at IRRI that C 288 gave the best yield among rice herbicides tested under various different water management, for example deep water, 5 cm, shallow water, 1 cm, or various depths of water at different periods. These results clearly indicated that even with the poor water management, such as is generally present in farmers' fields in the tropics, C 288 can be safely and effectively used in tropical rice. Varietal differences in susceptibility among IR varieties and C-4 varieties have not been noted. Both C 288 and RILOF H have been officially recommended by the Filipino government for their Masagana 99 project.

Japan. C 288 5.5% granules, coded CG 102 were extensively developed throughout Japan. The recommendation is 30 to 40 kg of granules applied 7–15 days after transplanting, before 2.5 leaves stage of *Echinochloa* species. Sequential treatments of pre-emergence herbicides such as diphenylethers followed by the application of C 288 15 to 25 days after transplanting was also successful, particularly in mechanically transplanted rice. There is no *Indica* rice grown in Japan, and no varietal difference within *Japonica* varieties was detected in the field trials.

ACKNOWLEDGMENTS

The authors acknowledge with gratitude the co-operation of the IRRI, the government stations in the Philippines, Korea, Taiwan, Japan, and untiring assistance of their colleagues in the Ciba-Geigy groups in the East Asian countries.

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Amiprophos-Methyl, A New Herbicide in Upland Crops

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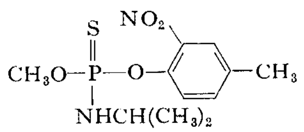
Abstract. Amiprophos-methyl [*N*-isopropyl *O*-methyl *O*-(2-nitro-*p*-tolyl) phosphoramidothioate] is a new organophosphorous herbicide which exerts its efficacy by attacking the meristem of germinating plants. Soil surface treatment before or at weed emergence displays excellent efficacy on major upland weeds with good plant compatibility to a wide range of crops. In this paper, the physiological action, herbicide performance and weed controlled are discussed. Some information on the behavior in soil are included.

INTRODUCTION

Amiprophos-methyl [TOKUNOL M; *N*-isopropyl *O*-methyl *O*-(2-nitro-*p*-tolyl) phosphoramidothioate] was discovered during research cooperations at Nihon Tokushu Noyaku Seizo K.K. and Bayer AG.

After several years of testing in our and official field facilities, amiprophos-methyl has been approved for practical use in a wide range of vegetable crops, field crops and turf. The product applied pre-emergence proved to be effective on important annual grasses and broadleaf weeds, in particular on grasses such as *Digitaria adscendens* and *Echinochloa crus-galli*.

The chemical formula of amiprophos-methyl is:



The technical compound is solid with a melting point of 65°C and a water solubility of 10 ppm. It is soluble in cyclohexanone, xylene and chloroform at the rate of 46, 17 and 28%, respectively.

Field research up to now has been conducted with a 60% wettable powder at dosage rates from 2.5 to 5 kg/ha.

The technical compound has a low acute toxicity showing an oral LD_{50} of 1,200 mg/kg and a dermal LD_{50} of >5,000 mg/kg to rats. Its extensive chronic toxicology and environmental studies are now in progress.

Physiological Action

Amiprophos-methyl applied pre-emergence exerts its efficacy by attacking the meristem tissues of germinating plants and inducing an abnormal cell division.

A pre-emergence test was made on *Echinochloa crus-galli*. A series of concentrations from 0 to 1 ppm was applied to the seeds for an exposure of 7 days. Shoot elongation was significantly reduced. Absence of coronal roots and internode rootletes was noted. It seems that the apical meristem is the major site of the action.

A second pre-emergence test was made to determine what influence the placement of amiprophos-methyl has on weed control and selectivity. The test species used were *Digitaria adscendens*, *Echinochloa crus-galli*, *Chenopodium album*, *Portulaca oleracea*, carrot, rice and sugarbeet. Whenever the placement was above or in contact with the seeds, excellent weed control was obtained. Soil surface treatment was most effective. Chemical placement below the seeds resulted in poor control.

Post-emergence treatment on *Digitaria adscendens* was made at dosage rates of 2 and 3 kg/ha to the seedlings at 0, 1, 2 and 3 leaf stage. Up to 1 leaf stage, complete growth suppression was obtained. At 2 leaf stage, the suppression was not adequate. The induction of anthocyan was observed.

With regard to the structure-activity relationship of amiprophos-methyl derivatives, there was highly specific requirement for pre-emergence efficacy and some modification raised the activity markedly (Aya *et al.*, 1973). The efficacy of the alkylphosphoramidothioates are highest when there are 1–4 carbons on the alkylamino moiety, regardless of the side chain. The efficacy decreases as the number of carbons increases. A change of *O*-lower alkyl does not influence the efficacy. The substitution of phenyl contributes remarkably to the efficacy. The substitution with alkyl and halogen at the 4-position of 2-nitrophenyl raised the efficacy. The substitutions are written according to the order of decreasing efficacy: 2-nitro-*p*-tolyl (amiprophos-methyl)>2-nitro-4-chlorophenyl>2-nitrophenyl>2,4-dichlorophenyl (DMPA)>2,4-dinitrophenyl.

Biological Performance to Crops and Weeds

Amiprophos-methyl is a highly effective pre-emergence herbicide against many grasses and broadleaf weeds. A summary of the weed response is presented in Table 1.

One unique facet of the compound is its wide range of crop tolerance. Crops showing good tolerance in pre-emergence treatment after seeding include bean, cabbage, carrot, cotton, pepper, pea and upland rice. Transplanted crops such as cucumber, egg plant, tomato (furrow application), lettuce, onion and strawberry have shown good tolerance in the treatment before or after planting.

Extensive field tests have been conducted at over 70 Experimental Stations and official organizations, mainly in Japan. Amiprophos-methyl was officially proved practical for use in cabbage, carrot, cucumber, lettuce, onion, peanut, strawberry and turf. The dosage rates of 60% wettable powder ranged from 2.5 to 5 kg/ha for crops and 5 to 10 kg/ha for turf (*Zoysia japonica*). A summary of the herbicidal performance obtained

Table 1. Response of annual weeds to amiprophos-methyl 60% wettable powder.

Weed	Dosage rate	
	2.5 kg/ha	5.0 kg/ha
Alopecurus aequalis	+	+++
Cyperus iria	++	+++
Cyperus microiria	++	+++
Digitaria adscendens	+++	+++
Echinochloa crus-galli	+++	+++
Eleusine indica	+++	+++
Poa annua	++	+++
Setaria viridis	++	+++
Amaranthus ascendens	++	+++
Cardamine flexuosa	++	+++
Centipeda minima	+	++
Chenopodium album	++	+++
Erigeron annuus	+	++
Euphorbia supina	+	+
Galinsoga ciliata	+	+
Lamium amplexicaule	++	+++
Polygonum Blumei	++	++
Portulaca oleracea	+++	+++
Rorippa palustris	+++	+++
Stellaria media	++	+++

Categories: +++ very good effect 90–100% kill
++ satisfactory effect 75–80% kill
+ inadequate effect less than 75% kill.

Table 2. A summary of herbicidal performance of amiprophos-methyl.

Crop and treatment	Dosage rate (kg ai/ha)	Weed control		Plant toxicity	Exp. Stat.
		MONO	DI		
Cabbage	After planting				Hyogo
Amiprophos-methyl	1.8	1	1	no	
	3	1	1	no	
Trifluralin	0.9	1	2	no	
Carrot	After seeding				Ibaraki
Amiprophos-methyl	1.8	1	1	no	
	3	1	1	no	
Linuron	0.75	1	1	no	
Peanut	After seeding				Miyazaki
Amiprophos-methyl	1.8	1	2	no	
	3	1	1	no	
Simazine	0.8	2	2	no	
Zoysia	Before weed emergence in spring and autumn				Tokyo
Amiprophos-methyl	3	1	3	no	
	6	1	2	no	
Bensulide	12	1	3	no	

MONO = grasses, DI = broadleaf weeds

Weed control is expressed by the ratings showing 1 = excellent (90–100%), 2 = acceptable (75–89%) and 3 = unacceptable (less than 75%).

from official tests are presented in Table 2.

BEHAVIOR IN SOIL

Amiprophos-methyl is well tolerant to leaching. In a leaching experiment using soil colum, 90% of the compound applied was retained in 1 cm soil surface layer. A half-life of 25 to 35 days was obtained in tests on clay and sandy loam with 4.5 and 0.8% organic matter incubated at 28°C. A similar test was conducted on sterilized soil and in this case a half-life of more than 50 days was found, regardless of soil type. Based on the result of these tests, micro-organism may take a great part in the degradation. A profile of the metabolism in soil given in Fig. 1. Four metabolites were found: aminoamiprophos-methyl (I), amiprophos-methyl oxygen analog (II), *O*-methyl *N*-isopropylamino-phosphorothioic acid (III) and *O*-methyl phosphorothioic acid (IV). Under upland condition, (I) and (II) which had been formed by reduction of the nitro group and thio-oxidation of amiprophos-methyl were found as major metabolites (Ueyama *et al.*, 1973; Takase, 1974).

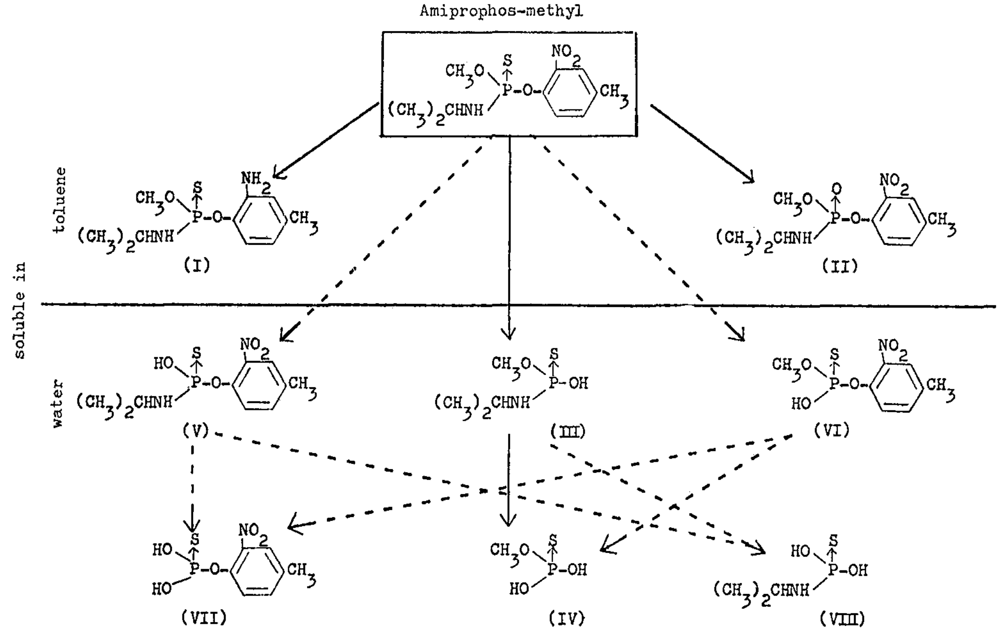


Fig. 1. A proposed metabolism of amiprophos-methyl in soil.

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Characteristics of New Herbicide NK-049

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Abstract. Characteristics of NK-049(3,3′-dimethyl-4-methoxybenzophenone) were studied from the view point of the practical use. Against main annual weeds in paddy field on pre- or post-emergence treatment, NK-049 showed high herbicidal activity to give good efficacy, and the applicability as pre- or post-transplanting herbicide in paddy field was confirmed. The applicability of NK-049S, mixture of NK-049 with bensulide (SAP), was also confirmed. Herbicidal characteristics against upland field weeds and phytotoxicity to crops were studied, and the applicability of NK-049 to onion field and that of NK-049P (mixture of NK-049 with prometryne) to soybean field were confirmed.

INTRODUCTION

In the other part (Ito *et al.*, 1976), we reported some aspects of mode of action of NK-049(3,3′-dimethyl-4-methoxybenzophenone) and its applicability as herbicide in paddy and upland fields (Munakata *et al.*, 1973).

In this paper, characteristics of NK-049 are reported from the view point of the practical use.

AS PADDY FIELD HERBICIDE

Character of weed control. 1) NK-049 showed herbicidal activity against most of annual paddy field weeds in pre-emergence treatment. Experiments were carried out in pot with four species of weeds at three growth stages. They were barnyardgrass (*Echinochloa crus-galli* beauv.), flat-sedge (*Cyperus microria* Steud.), monochoria (*Monocoria vaginalis* Presl), and false pimpernel (*Lindernia pyxidaria* L.).

All the weeds tested were completely controlled by NK-049 at 1 to 3 kg/ha in pre-emergence treatment and at 2 to 4 kg/ha in the 1- to 1.5-leaf stage treatment. Those weeds over the 2-leaf stage were controlled at 6 to 8 kg/ha (Ito *et al.*, 1974).

2) In the outdoor concrete pot test, the herbicidal effect was studied on the pre- and post-transplanting treatment in paddy field condition. In the pre-transplanting treatment, the high efficacy was obtained by the soil surface treatment under flooded condition. In the post-transplanting treatment, the high efficacy was observed, even when NK-049 was applied 7 days after transplanting. In this test, only late emerging false pimpernel was observed 30 days after transplanting (Ito *et al.*, 1974).

3) Herbicidal activity of NK-049 in paddy field was examined at the three treatment times in the experiment stations of six regions in Japan. At the dose of 3 to 4 kg/ha, almost complete weed control and growth suppressing action against weeds were observed as long as 10 to 15 days after transplanting and no effect on growth of rice plant was observed (JAPR, 1972–1974).

Thus, NK-049 has an applicability as an early treatment herbicide in paddy field.

Higher practicability by combination. 1) Although NK-049 completely controls barnyardgrass up to the 1-leaf stage as described in the above test, biodegradable and nonresidual properties are noteworthy characters of NK-049 (Munakata *et al.*, 1973). For complete control of barnyardgrass, main weed in paddy field in Japan, the combination of NK-049 with various herbicides was tested. These studies resulted in finding an excellent mixture of NK-049 with bensulide, which strengthens the action of NK-049 by promoting chlorosis and retarding growth of the weed. This mixture combining NK-049(2.4 kg/ha) with bensulide (0.9 kg/ha) assured the herbicidal effect and the safety to rice plant. In this case, the dose of bensulide (0.9 kg/ha) is equivalent to 1/2 to 1/3 of the conventional dose when used alone.

2) This mixture (NK-049S) was examined in many agricultural experiment stations in Japan. The results showed that NK-049S controlled weeds as long as 15 to 20 days after transplanting by the pre- or post-transplanting treatment using 30 to 40 kg/ha of its granules containing NK-049 (8%) and bensulide (3%) without any influence to the growth of rice.

Thus, the applicability of NK-049S was confirmed at the pre- or post-transplanting treatment in paddy field (JAPR, 1972–1974).

As Upland Field Herbicide

Character of weed control. 1) In the pre-emergence soil treatment, NK-049 was tested against six main upland field weeds. They were crabgrass (*Digitaria adscendens* Henr.), barnyardgrass, foxtail (*Setaria viridis* Beauv.), amaranth (*Amaranthus lividus* L.), common lamb's-quarter (*Chenopodium album* L.), and smartweed (*Polygonum longisetum* De Bruyn).

The results of this experiment showed that NK-049 completely killed carabgrass at 1 kg/ha, barnyardgrass at 3 kg/ha, foxtail at 5 kg/ha, amaranth at 3 kg/ha, common lamb's-quarter at 4 kg/ha, and smartweed at 6 to 9 kg/ha. In general, spring or summer growing weeds were controlled at 1 to 4 kg/ha in pre-emergence treatment, but foxtail and smartweed were resistant a little (Ito *et al.*, 1975).

2) The herbicidal activities of NK-049 were tested at the pre-emergence soil surface treatment and the foliage treatment against the following autumn or winter weeds: water foxtail (*Alopecurus aequalis* Sobol.), annual bluegrass (*Poa annua* L.), shepherd's purse (*Capsella bursa-pastoris* Medicus), bog stitchwort (*Stellaria alsine* Grimm), and chickweed (*Stellaria neglecta* Weihe).

All the five species of weeds described above were killed at 2 kg/ha in pre-emergence treatment, and in foliage treatment competely at 3 to 4 kg/ha except annual bluegrass (Ito *et al.*, 1975).

3) Residual activity of NK-049 was tested at the soil surface treatment under the low temperature (1.5 to 9.5°C) and under the high temperature (17 to 34°C), and the degree of activity was indicated by the control activity to crabgrass and barnyardgrass, whose seeds were sown in every 10 days after treatment of NK-049 into the soil.

Under the low temperature condition, the residual activity was retained, that is, NK-049 was effective even 60 days after its treatment to kill 75% of crabgrass and 50% of barnyardgrass. On the other hand,under the high temperature condition its activity was reduced, that is, although it was effective to kill 100% of crabgrass and 55% of barnyardgrass 30 days after its treatment, a sudden drop of the herbicidal activity was observed 40 days after treatment (Ito *et al.*, 1975).

Applicability to vegetable field. 1) In order to know the susceptibility of vegetable to NK-049 applied in soil in pre- or post-transplanting treatment (Ito *et al.*, 1975), action of NK-049 via root absorption was further studied in the water culture method. As the results, no phytotoxicity was observed at 320 ppm for onion, at 120 ppm for cabbage and strawberry. Phytotoxicity at higher concentration than those has not been observed yet.

2) At seven horticultural experiment stations, NK-049 was successfully applied on onion field in post-transplanting treatment at 3 to 4 kg/ha, and it was effective against autumn and winter weeds. Furthermore, additional spring treatment assured controlling spring weeds. No influences on growth and yield of onion were observed (JAPR, 1973, 1974b).

Applicability to soybean and peanut fields. 1) Effect of NK-049 on soybean at emergence was further studied by the sand culture method, as soybean is known to be highly resistant to NK-049. As the results, only slight chlorosis was observed at a dose higher than 10 kg/ha. Even at 30 kg/ha, chlorosis was slight as well. On the other hand, barnyardgrass showed strong chlorosis, followed by death at 1 kg/ha.

2) In the practical soybean and peanut fields, the mixture of NK-049 and prometryne "NK-049P" was examined in oder to kill completely summer weeds at seven (soybean) and three (peanut) agricultural experiment stations in Japan. As the results, the combination of NK-049+prometryne (2.8+0.4 kg/ha, or 4.2+0.6 kg/ha) completely killed weeds without any damage to growth of soybean and peanut (JAPR, 1973, 1974a).

As mentioned above, the applicability of NK-049 in paddy field and upland field was confirmed by the tests performed at the official agricultural and horticultural experiment stations in Japan, though the number of crops tested was limited in case of upland field test.

Acknowledgment

In this report, we cited the results of the application test of NK-049, NK-049S, and NK-049P, which were carried out by JAPR.

The authors wish to thank the researchers of agricultural and horticultural experiment stations for their elaborate tests on NK-049 and its mixtures.

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Herbicidal Activities against Weeds and Phytotoxicity on Rice Varieties of Benthiocarb

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Abstract. Fifty-five species of weed and thirty-four varieties of rice plants (*Oryza sativa*) in paddy field were treated by benthiocarb. Annual gramineous and cyperaceous weeds, slender spikerush (*Eleocharis acicularis*) were more sensitive to bentiocarb than other weeds. Varieties of rice plants cultivated in Japan, USA and Italy were more tolerant to benthiocarb than *Indica* varieties such as IR-8, Leuang Tawng, C4–63 and Taichung Native.

Introduction

Since 1965, the herbicidal properties of benthiocarb [S-(4-chloro benzyl)-N,N-diethyl thiolcarbamate] have been tested by the authors. Benthiocarb is effective to control barnyardgrass (*Echinochloa crus-galli* P. Beauv. var. *oryzicola* Ohwi), umbrella plant (*Cyperus difformis* L.) and slender spikerush (*Eleocharis acicularis* Roem. et Schult.), but is less toxic to rice (*Oryza sativa* L.) when applied under flooded condition. Higher selectivity of benthiocarb between rice and barnyardgrass in the same growth stage was observed in the following order; 2-leaf stage > 3-leaf stage > 1-leaf stage > 4-leaf stage > coleoptile stage.

Benthiocarb is taken up mainly through the coleoptile of barnyardgrass which is in the coleoptile stage, however it is taken up through the root of barnyardgrass which is in the 1-leaf stage. It inhibits the cell division and cell elongation at the growing point of barnyardgrass, but does not inhibit photosynthesis of rice plant or barnyardgrass, nor affects respiration of excised roots of rice or barnyardgrass.

This report presents the results of the susceptibility of weeds and tolerance of rice varieties to benthiocarb.

Materials and Methods

Experiment 1. Seeds or rhizomes of weeds were sown in pots filled with the clay loam soil and 3 cm of water. The diluted emulsion of benthiocarb was dripped into the water at the 1st and 10th day after seeding. The weeds treated by benthiocarb were cut after 20 days at ground level for measurement of fresh weight of the aerial parts.

Experiment 2. Pots of 100 cm were filled with the clay loam soil and watered. Then varieties of rice seeds were sown in pots. The diluted emulsion of benthiocarb was dripped into the water at the 1st and 10th day after seeding. The fresh weight of rice plants was measured at the 20th day after the treatment.

RESULTS AND DISCUSSION

Susceptibility of weeds. Table 1 showed results on suceptibility of weeds to benthiocarb. The susceptibility decreased in the following order; *Echinochloa*, *Cyperus*, *Eleocharis* spp.>*Leptochloa* spp.>*Fimbristylis* spp.>*Eriocaulon* spp.>*Limnophila* spp.>*Aneilema*, *Monochoria*, *Juncus*, *Ammannia*, *Lindernia*, *Dopatrium*, *Vandellia*, *Gratiola*, *Deinostima*, *Rotala* spp.>*Polygonum*, *Callitriche* spp.>*Scirphus*, *Mosla*, *Elatine*, *Bidens* spp.>*Sagittaria*, *Spirodela*, *Lemna* spp.>*Spirogyra*, *Hydrodictyon*, *Marsilea*, *Paspalum* spp.> *Lobelia* spp.> *Solvina*, *Azolla*, *Ricciocarpus*, *Ludwigia* spp.>*Alisma*, *Oenanthe*, *Potamogeton* spp.

Annual gramineous and cyperaceous weeds, slender spikerush were more sensitive to benthiocarb than other weeds.

Tolerance of rice varieties. As shown in Table 2, the phytotoxicity of benthiocarb varied markedly among rice varieties. At the emergence stage, IR-8, Leuang Tawng and C4–63 were very sensitive, Taichung Native was a little sensitive. But twenty four varieties of rice plants cultivated in Japan and Tainan-3, Bluebonnets, Bluebell, Caluro, Calrose and Rafaello were tolerant to benthiocarb. At the 2-leaf stage, every variety was very tolerant to benthiocarb.

Therefore, we considered that *Indica* was more sensitive to benthiocarb than the other varieties.

Table 1. Herbicidal activities of benthiocarb against weeds.

Weeds		ED_{90} (g/a)	
Family name	Botanical name	Emergence statge	2-leaf sage
Marsileaceae	*Marsilea quadrifolia**	20	60
Salvinaceae	*Salvinia natans*	—	80
Potamogeton	*Potamogeton distinctus**	160	200
Alismataceae	*Sagittaria pygmae**	45	100
	S. trifolia	45	100
	*S. aginashi**	160	200
	Alisma canaliculatum	160	200
Gramineae	*Leptochloa chinensis*	6	15
	*Baspalum distichum**	60	240
	Echinochloa crus-galli	5	15
	E. crus-galli var. *formosensis*	5	15
	E. crus-galli var. *oryzicola*	5	15
	E. crus-galli var. *caudata*	6	15
	Oryza sativa	20	240

Continued . . .

Table 1. (Continued.)

Weeds		ED_{90} (g/a)	
Family name	Botanical name	Emergence stage	2-leaf stage
Cyperaceae	*Cyperus sanguinolentus*	5	15
	C. tenuispica	5	15
	C. difformis	5	15
	C. hakonensis	5	15
	*C. brevifolius**	15	30
	*C. serotinus**	20	60
	Fimbristylis dichotoma	7.5	20
	F. miliacea	7.5	20
	Eleocharis pellucida	5	15
	*E. acicularis**	4	8
	*E. kuroguwai**	50	200
	Scirpus juncoides	40	100
	*S. maritimus**	60	240
Lemnaceae	*Spirodela polyrhiza*	—	45
	Lemna paucicostata	—	45
Eriocaulaceae	*Eriocaulon sieboldtianum*	10	20
Commelinaceae	*Aneilema japonicum*	20	50
Pontederiaceae	*Monochoria vaginalis*	10	35
Juncaceae	*Juncus leschenaultii*	20	35
Polygonaceae	*Polygonum hydropiper*	30	60
Callitrichaeceae	*Callitriche verna*	30	60
Elatinaceae	*Elatine triandra*	40	80
Lythraceae	*Rotala pusilla*	20	50
	R. indica	20	50
	Ammannia multiflora	20	50
Onagraceae	*Ludwigia prostrata*	80	120
Umbelliferae	*Oenanthe javanica**	160	200
Labiatae	*Mosla dianthera*	40	120
Scrophulariaceae	*Lindernia pyxidaria*	20	80
	Limnophila sessiliflora	15	30
	Dopatrium junceum	20	50
	Vandellia angustifolia	20	50
	Deinostema violacea	20	50
Campanulaceae	*Lobelia chinensis**	70	100
Compositse	*Bidens frondosa*	80	150
	B. tripartita	40	100
	Eclipta prostrata	40	100

* Rhizome.

Table 2. Phytotoxicity of benthiocarb on rice varieties.

Rice varieties		Main cultivated areas	Percent of phytotoxicity	
			Emergence stage*	2-leaf stages**
1.	Mutsunishiki	Japan	11.6	18.5
2.	Kiyonishiki		11.8	16.2
3.	Fujiminori		13.5	18.7
4.	Reimei		11.9	19.5
5.	Sasanishiki		12.1	18.5
6.	Honenwase		12.9	18.5
7.	Toyonishiki		11.5	16.6
8.	Koshihikari		11.6	19.2
9.	Yomomasari		12.4	19.0
10.	Kusabue		13.8	16.6
11.	Norin-29		11.9	16.1
12.	Norin-35		11.5	19.1
13.	Hokuriku-90		12.1	18.7
14.	Tsukushibare		12.0	18.8
15.	Kuju		11.3	19.2
16.	Mineyutaka		11.9	18.4
17.	Toyotama		12.4	18.2
18.	Asominori		12.0	16.9
19.	Nankai-55		11.8	18.3
20.	Reiho		12.5	19.1
21.	Nihonbare		13.3	18.5
22.	Kinmaze		11.5	18.3
23.	Otomemochi		13.3	16.4
24.	Mangetsumochi		12.6	17.8
25.	IR-8	Tropics	28.2	19.3
26.	Leuang Tawng	Thailand	45.4	18.5
27.	C4-63	Philippines	46.8	18.1
28.	Taichung Native	Formosa	31.8	18.6
29.	Tainan-3		12.7	17.3
30.	Bluebelle	U.S.A.	13.9	18.7
31.	Bluebonnet		12.6	19.4
32.	Caluro		11.5	16.6
33.	Calrose		12.8	16.7
34.	Rafaello	Italy	12.5	19.1

* 5 g/a, ** 100 g/a.

Synergism in Benthiocarb-Propanil Combination

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Abstract. Combination of benthiocarb [*S*-(4-chlorobenzyl)*N*,*N*-diethylthiolcarbamate] 50 E.C. with propanil (3,4-dichloropropionanilide) 35 E.C. synergistically enhanced herbicidal activity both in pre-emergence application and in post-emergence application and extended range of selectivity. The effectiveness of combination treatment was always higher than that of single treatment by either benthiocarb or propanil under various environmental conditions; rainfall, light intensity, temperature, or degree of irrigation. The preferable combination ratio should be 4 to 5 kg active ingredient of benthiocarb plus 1 to 2 kg of propanil per hectare.

Introduction

Benthiocarb is a selective pre-emergence or early post-emergence herbicide in direct-seeded rice. It acts as a growth inhibitor on germinating weeds and partly as a contact herbicide on emerged weeds. Propanil, on the other hand, is a selective post-emergence herbicide. It acts as a photosynthetic inhibitor. The combination of these two chemicals originated simply to add the residual action of benthiocarb to the contact effect of propanil, but the effectivebess was found to be higher than expected. The authors studied the synergism in pre-emergence or post-emergence application and the stabilization of herbicidal effectiveness under various environmental conditions to confirm the increase in activity by combination.

Materials and Methods

Weeds used were barnyardgrass (*Echinochloa crusgalli*), and *Polygonum nodosum. Cyperus Iria* and *Leptochloa chinensis* in field test were naturally occuring. *Japonica* rice (var. Kinmaze) was used generally and *indica* variety bluebelle was added in field test. Chemicals used were SATURN 50 EC for benthiocarb and STAM 35 EC for propanil. These were mixed in tank prior to application. Only in field test, experimental combination product 30+30 EC and 40+20 EC were used. In greenhouse test, weeds and rice were seeded in a 11 cm × 11 cm pot respectively, covered with sandy loam soil 5 mm thick pressed, than sprayed with test chemicals pre-emergence or post-emergence 2.5–3 leaf stage of barnyardgrass. Spray volume was equivalent to 1 kl/ha for each treatment. Effects were investigated 2 to 3 weeks after treatment by visual assessment or measuring fresh weight. In field test, rice were seeded with drill seeder. Barnyardgrass and *poly-*

gonum seeds were broadcast before cultivation. They were sprayed 14 days after seeding with a spray volume of 1 kl/ha. In rainfall test, artificial rain of 8 mm in 15 minuts was given by rainfall machine 1, 5, 6 and 24 hours respectively after treatment. In light intensity test, low light intensity was given by shading sunlight by cotton net after treatment. In temperature test, day temperature of 35, 28 and 20°C with 5°C night differential were given in KOITO growth cabinet. In irrigation test, wet condition was made by immersing the bottom of pots into water, and flooding was made 2 to 3 cm deep prior to treatment.

RESULTS AND DISCUSSION

Synergism. As shown in Fig. 1 herbicidal activity on barnyardgrass was enhanced by combination of benthiocarb with propanil either by soil treatment or by foliage treatment. Rice was not affected by pre-emergence application, but slightly injured by post-emergence application at the dosage sufficient to control barnyardgrass, however, the increase in phytotoxicity by combination was not so much as in case of barnyardgrass. To expect both pre-emergence activity and post-emergence activity, combination ratio of 5: 1 to 4: 2 is preferable. This ratio corresponds to Yamane's recommendation (1972), or Goto's introduction (1973). To confirm the synegism, pre-emergence application and post-emergence application were repeated. Results are shown in Fig. 2 and Fig. 3. In

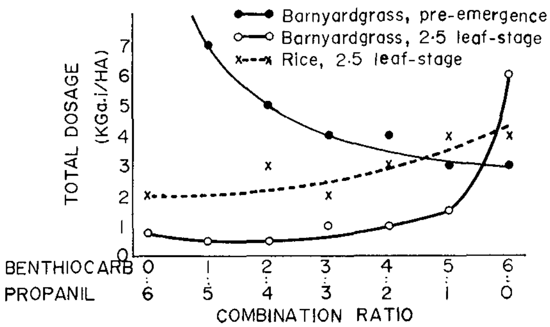

Fig. 1. Barnyardgrass control and rice injury at various benthiocarb-propanil combination ratios. Required dosages to give severe damage to barnyardgrass or slight injury to rice are plotted.

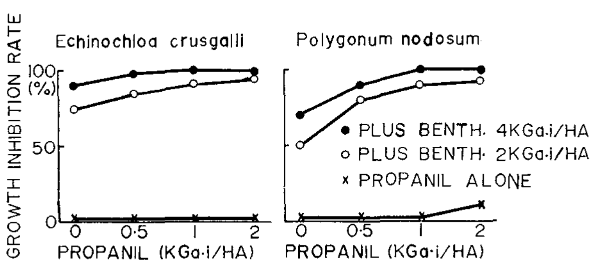

Fig. 2. Synergism of benthiocarb and propanil by pre-emergence application.

pre-emergence application, activity of benthiocarb was enhanced by addition of propanil, which has low activity in itself. In post-emergence application, the activity of combination of 1: 1 was superior to that of each alone. Probit analysis of this synergism was reported previously (Kawano *et al.*, 1974).

Field trial. Combination product of benthiocarb with propanil applied at 2 to 3 leaf-stage of weeds gave excellent control (Table 1). In this experiment, 3+3 kg/ha was as effective as 4+2 kg/ha. The former ratio is recommended by Smith and other reseachers in U.S.A.

Influence of environmental condition. In the rainfall test, addition of benthiocarb

Table 1. Benthiocarb-propanil combination in dry-seeded rice field (Kikugawa 1975).

Herbicide	Dosage (l/ha)	Number of weeds/m²				Rice injury
		E	C	P	L	
Propanil 35 EC	8	20	132	0	120	—
Benthiocarb-Propanil						
30+30 EC	8	19	7	4	4	—
40+20 EC	8	7	12	4	1	—
Untreated		153	242	42	154	—

Seeding; May 14th. Treatment; May 28th.
E: *Echinochloa crusgalli*, C: *Cyperus Iria*, P: *Polygonum nodosum*, L: *Leptochloa chinensis*.

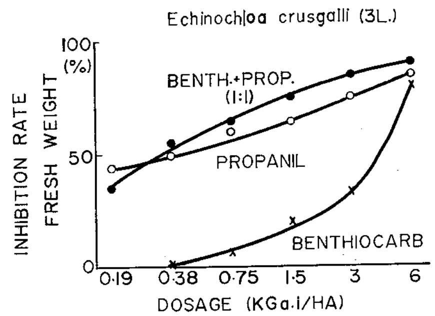

Fig. 3. Synergism of benthiocarb and propanil by post-emergence application.

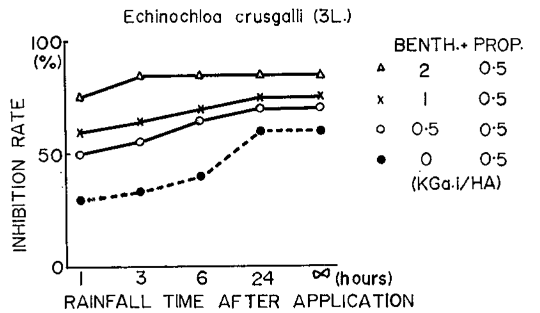

Fig. 4. Influence of rainfall on benthiocarb-propanil activity.

prevented the decrease in activity of propanil by rainfall in proportion to the amount of benthiocarb added (Fkg. 4). In light intensity test, benthiocarb was more effective under low light intensity, and propanil under high light intensity. The activity was increased by combination under both light intensity (Fig. 5).

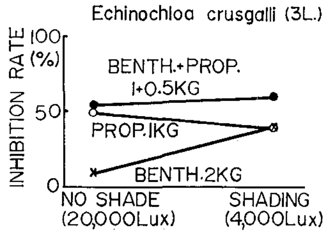

Fig. 5. Relationship between light intensity and benthiocarb-propanil activity.

In temperature test, benthiocarb was more effective under low temperature, and propanil under high temperature. The activity was increased by combination under both temperature (Fig. 6) In irrigation test, water decreased the activity of both benthiocarb and propanil by post-emergence application. The effectiveness was stabilized by combination under dry, wet and flooded condition (Fig. 7).

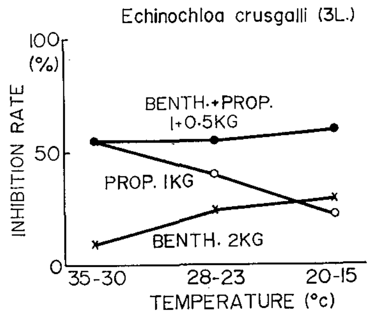

Fig. 6. Relationship between temperature and benthiocarb-propanil activity.

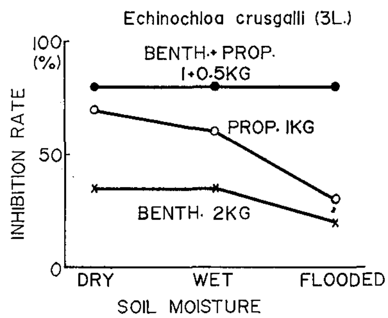

Fig. 7. Influence of irrigation on benthiocarb-propanil activity.

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Influence of Soil Properties on the Herbicidal Activity of Oxadiazon under Flooded Condition of Paddy Field

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Abstract. A study was carried out to evaluate the effect of soil properties on the herbicial activities of 2-*t*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazoline-5-one (oxadiazon) using 29 types of soil of Japan. Results obtained revealed that the herbicidal activities of oxadiazon varied to a great extent on different types of soil. The higher the oxadiazon adsorptive ability of soil, the lower was the weed control effect and vice versa. The higher the adsorptive capacity of soil, the lower was the phytotoxicity against transplanted rice plant which meant that the phytotoxicity preventive capacity of soil (to rice plant) increased with the increase in oxadizaon adsorptive capacity of the soil. Organic matter content, both quantitative and qualitative, of soil influencing the adsorption was an important factor in determining the herbicidal activities of oxadiazon under flooded condition of paddy field. Each of soil pH, clay content, cation exchange capacity (CEC) and volume weight of soil had marked effect, although in different way, on herbicidal activities of oxadiazon.

MATERIALS AND METHODS

15 g of each of the 29 types of soil collected from Agricultural Experiment Stations (paddy field) of all over Japan as shown in Table 1, was taken in a 50 ml glass tube. And, 30 ml of 1.2 ppm oxadiazon solution which is equivalent to the concentration of oxadiazon at the rate of 60 g a.i./10 are, under field condition of 5 cm of submerged water, was added to each tube. Tubes were then, shaken for 15 minutes and kept undisturbed until equibrium was attained (48 hrs). Following centrifugation, oxadiazon was extracted from supernatant by n-hexane and analyzed with gas chromatography, and the concentration of oxadiazon in the supernatant obtained was used to explain oxadiazon adsorption by soil (low concentration means high adsorptive ability of soil and vice Versa). Total carbon content, estimated by a nitrogen analyzer of Coleman Co., was termed as organic matter content in this paper. As to the clay content, the data of 20 types of soil sent by Agri. Exp. Sts. were referred. CEC was determined by semimicro Shollenberger's method. Volume weight of soil was calculated by measuring weight of 100 ml air dried fine soil.

Herbicidal activities expressed as ED_{90}, the amount of oxadiazon required to reduce the fresh top weight of *Echinochloa crus-galli* (barnyardgrass), and phytotoxicity against rice palnt which was measured by the length of leaf sheath browing in the mm per plant by pot test.

Seven kinds of adsorbents were determined to compare the adsorptive ability of organic matter and clay. Powders of rice plant compost, bark compost, peatmoss and cellulose were used as organic matter. Bentonite, zeeklite and kanuma soil which includes much allophane, were used as clay. 15 g of the mixtures of each these adsorbents with river sand were taken in 50 ml glass tube and the oxadiazon adsorptive ability was determined in the same procedure as in case of the test soils.

Results and Discussion

Table 1 shows the properties of each type of soil and the influence of each soil on

Table 1. Soil properties and herbicidal properties under paddy field conditions on twenty-nine soils.

No.	Location of test soils	Soil properties						Herbicidal properties	
		OCW	TCC	CC	CEC	pH	VWS	ED_{90}	PAR
1	Chuo	0.027	4.38	34.7	25.6	5.2	0.95	0.64	0
2	Kamikawa*	0.041	4.88		24.2	4.9	0.90	0.22	4.0
3	Akita	0.046	2.27	27.3	23.8	5.9	0.91	0.10	6.0
4	Toyama	0.040	1.64		22.4	4.6	0.97	0.32	0.5
5	Furukawa	0.050	2.39	31.8	26.7	5.0	0.88	0.21	0
6	Noji (Konosu)	0.052	2.78	38.6	20.3	5.6	0.93	9.11	6.8
7	Shizuoka	0.053	2.18		12.6	5.9	1.07	0.14	16.8
8	Saga	0.054	1.67	35.1	21.5	5.3	0.99	0.14	34.2
9	Tochigi	0.058	2.62		14.3	4.9	0.93	0.25	15.5
10	Shiga	0.068	1.50	10.1	11.9	5.9	1.25	0.16	25.6
11	Shimane	0.069	1.75	21.6	16.9	5.8	0.98	0.08	6.0
12	Hyogo	0.071	1.50	31.9	10.5	5.5	1.10	0.10	30.6
13	Ohita	0.077	1.93	37–40	13.4	6.1	1.08	0.15	29.9
14	Okayama	0.079	1.34		11.1	5.0	1.21	0.11	9.5
15	Tottori	0.083	2.17		12.3	4.9	1.13	0.26	17.7
16	Aichi	0.088	1.46	23.1	14.6	6.1	1.13	0.06	166.7
17	Fukuoka	0.089	1.71	8.5	7.5	5.0	1.10	0.07	129.5
18	Nagasaki	0.090	1.29	13.3	9.7	4.9	1.90	0.26	42.a
19	Kagawa	0.094	1.35		7.8	5.9	1.27	0.16	126.7
20	Chiba	0.097	1.24	21.0	14.8	5.9	1.05	0.07	21.1
21	Donan	0.097	1.22	12.6	16.2	4.8	1.16	0.14	233.0
22	Hiroshima	0.099	1.05	11.3	5.6	5.2	1.24	0.04	122.5
23	Ehime	0.100	0.95	19.6	7.5	5.6	1.21	0.06	82.3
24	Kagoshima	0.109	1.55	14.7	10.6	5.7	1.09	0.07	118.3
25	Ibaragi*	0.110	3.55		24.2	5.6	0.82	0.16	8.2
26	Tochigi*	0.112	7.93	18.4	36.2	5.8	0.83	0.12	107.3
27	Ishikawa	0.114	1.35	22.5	10.8	5.4	1.06	0.04	158.0
28	Miyazaki	0.114	1.81		14.0	5.7	1.08	0.15	165.4
29	Gifu	0.148	0.88	20.6	10.6	5.7	1.25	0.02	242.5

* Black volcanic ash soil

Abbreviation: OCW: Oxadiazon concentration (equilibrated) in water (ppm), TCC: Total carbon content (%), CC: Clay content (%), CEC: Cation exchange capacity (me/100 g soil), pH: pH (H_2O), VWS: Volume weight of soil, ED_{90}: amount of oxadiazon required to reduce the fresh top weight of barnyardgrass by 90%, PAR: Phytotoxicity against rice plant [length (mm) of leaf sheath browning] herbicidal activities. The soil properties varied widely depending on the soil types as follows: 0.88 to 7.93% on total carbon content, 8.5 to 40% on clay content, 5.6 to 36.2 me/100 g on CEC, 4.6 to 6.1 on pH and 0.82 to 1.27 on volume weight of soil. The ED_{90} value and phytotoxicity against the rice plant, and the adsorption of oxadizaon by different soils were different. Chuo soil having highest adsorptive ability had lowest weed control effect and Gifu soil having lowest adsorptive ability had highest weed control capacity. This indicated that adsorptive ability of soil is negatively correlated with weed control effect of oxadiazon. On the other hand, the highest adsorptive ability of Chuo soil was associated with highest capacity to prevent phytotoxicity against rice plant, and the lowest adsorptive capacity of Gifu soil was associated with lowest capacity to prevent it indicating that the adsorptive ability of soil was positively correlated with phytotoxicity preventive capacity of the soil. Data presented in Table 2 will substantiate

Table 2. The correlation (r) of six soil properties and two herbicidal properties among themselves calculated from experimental data from twenty nine soils (upper value) and twenty six soils except black volcanic ash soils (under value).

	OCW	TCC	CC	CEC	pH	VWS	ED_{90}	PAR
OCW		−.204	−.574**	−.402*	.359	.430*	−.580**	.753**
TCC	−.727**		.196	.802**	−.043	−.694**	.359	−.250
CC	−.566**	.587**		.449*	.179	−.533*	.320	−.512*
CEC	−.703**	.656**	.652**		−.094	−.844**	.398*	−.356
pH	.176	−.112	.241	−.135		.075	−.457*	.054
VWS	.671**	.669**	−.651**	−.803**	.165		−.329	.505**
ED_{90}	−.599**	.759**	.320	.517**	−.419*	−.381		−.441*
PAP	.808**	−.516**	−.507**	−.455*	.087	.553**	−.432*	

Abbreviation: same as Table 1.
*, **: Significant at 0.05 and 0.01 level respectively.

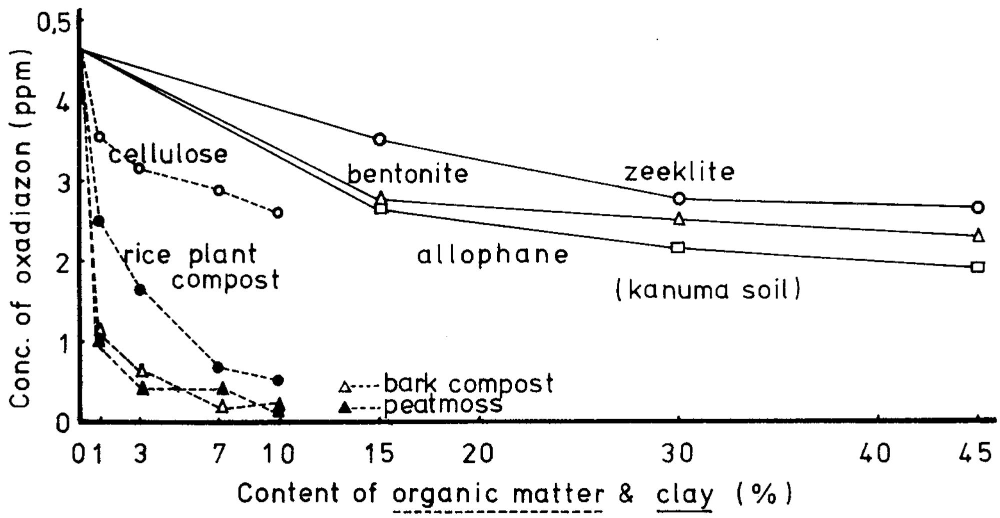

Fig. 1. Adsorption of oxadiazon by organic matter and clay.

the above statement. From Table 2, it would be very clearly observed that the ED_{90} value of oxatiazon was significantly correlated with CEC and soil pH whereas phytotoxity to rice plant had significant relation with clay content and volume weight of soil, so far as all the 29 soils were concerned as one group. However, aparting three black volcanic ash soils aside, a different correlative trend was observed with the rest 26 types of soil where ED_{90} value was significantly correlated with organic matter, CEC and pH, and phytotoxicity was significantly correlated with all soil properties except pH. It was, therefore, evident that the two groups of soil (29 soils as one group and all the soil types except three back volcanic ash soils as another group) differed in the correlation of herbicidal activities and organic matter content. This difference in the correlation of herbicidal activities of oxadiazon with organic matter among the two groups seemed to be the difference of adsorptive ability of soils caused by quantitative and qualitative difference in organic matter. In the present study, the qualitative analysis of the organic matter were not done, but to prove above hypothesis, another experiment was designed with seven kinds of adsorbents results of which have presented in Fig. 1 which shows that oxadiazon adsorptive ability of organic adsorbents were higher than those of clay adsorbents. Among the organic adsorbents, peatmoss, bark compost and rice plant compost having higher adsorptive ability than the cellulose, and as to the clay adsorbents, kanuma soil was little superior than bentonite and zeeklite.

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The authors wish to thank all Agricultural Experiment Stations for supplying the paddy field soils used in this study.

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Some Aspects of Mode of Action of New Herbicide NK-049

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Abstract. Concerning the new herbicide NK-049 (3,3′-dimethyl-4-methoxybenzophenone) with chlorosis inducing herbicidal activity, the chlorosis induction was found to be the primary factor for its herbicidal action, and it is different from the so-called photosynthesis inhibiting herbicide. Obvious differences were found on chlorophyll formation and suppression of growth between rice and barnyardgrass (*Echinochloa crus-galli* Beauv.). Susceptibility of plant to NK-049 was suggested to depend not on family of plant and size of seed, but on morphological and physiological properties peculiar to seed at germination.

Introduction

In the 4th conference of APWSS (New Zealand, 1973), we reported (Munakata *et al.*, 1973) briefly that (1) NK-049 (3,3′-dimethyl-4-methoxybenzophenone) induced chlorosis and killed weeds, (2) its action varied with the species of plant, and (3) in some cases, it induced chlorosis on crops too, but its symptoms were slight and recovered to normal growth.

The mechanism of chlorosis induction, which is the most characteristic activity of NK-049, is not clear yet, but now we would like to report the results that chlorosis is thought to be a primary factor for the control of weeds, and that the susceptibility of plant depends on the morphological and physiological properties of the individual plant at the germination of the seed.

Influence to Photosynthesis

The action of NK-049 to the photosynthesis of barnyardgrass was compared with that of prometryne[2,4-bis(iso-propylamino)-6-methylthio-*s*-triazine], which is regarded as an inhibitor of photosynthesis. After either NK-049 or prometryne was applied to barnyardgrass at the 2-leaf stage in pot under flooded condition, the degree of chlorosis was surveyed and the rate of photosynthesis was measured by use of an infrared analyzer (Horiba: ASSA-1).

Chlorosis appeared 2 days after the treatment of NK-049, and was observed to reach its maximum on the 5th to 6th day. The reduction of the rate of photosynthesis was proportional to the degree of chlorosis. On the other hand, in case of prometryne treatment, the reduction of the rate of photosynthesis appeared in several hours after the application, followed by the complete stoppage of photosynthesis after a day, while appearance of barnyardgrass was normal even after a day, and it died several days after the application.

Thus, it may be concluded that NK-049 is quite different from the photosynthesis-inhibiting herbicide, and reduces the photosynthetic activity by reducing the content of chlorophyll.

Influence to Chlorophyll

It has been reported that the degree of chlorosis-inducing activity of NK-049 varies with the kind of plant. From this fact, rice and barnyardgrass were used in this test. The rice and barnyardgrass were treated with NK-049 in pre-emergence. After their germination, their chlorophyll content was measured and compared with that of the untreated.

The definite amounts of seed of rice and barnyardgrass were sown to the soil in pot placed in the growth cabinet (day: 15 klux, illuminated by fluorescent lamp, at 25°C, night: at 20°C–12 hrs. cycle system), and covered with soil 5 to 10 mm in depth. Then, NK-049 was applied at the dose of 0.5, 1.0, 2.0, 4.0, and 8.0 kg/ha. The soil was kept wet during the experiment.

Chlorophyll was measured by the conventional method: the whole plant was extracted with hot ethanol (80%) and the absorbance was measured at 665 mμ.

These results were indicated by use of ratio of chlorophyll content of the treated plants to the untreated. At the lower rate application (0.5 and 1.0 kg/ha), chlorophyll content of barnyardgrass reduced to 40% (at 0.5 kg/ha) and 5% (at 1 kg/ha) in the early period. It reduced to 70% (at 0.5 kg/ha) and 50% (at 1.0 kg/ha) after 3 weeks. At the dose of more than 2.0 kg/ha, chlorophyll formation was clearly inhibited and the barnyardgrass was killed through strong chlorosis. Growth of barnyardgrass was slightly inhibited at lower rate (0.5 kg/ha), but completely at more than 1.0 kg/ha.

On the other hand, chlorophyll content of rice plant reduced somewhat at all the rates tested in the early period, too, but at the dose of less than 2.0 kg/ha, it recovered to 90% of the control in 2 weeks, and at higher rate (8.0 kg/ha) to 80% in 3 week after application.

Top fresh weight of rice was normal in every case.

Thus, clear difference of chlorophyll formation and growth inhibition was observed between rice and barnyardgrass.

Physiological Influence to Seed Germination

NK-049 showed no influence to germination at pre-emergence treatment in our preceding test. In this test, the consumption of the reserve substance of rice-seed treated with NK-049 in pre-emergence was studied, comparing with the control in natural condition and in the dark condition where no chlorophyll is formed.

The changing patterns of the content of the reserve substance of rice seed were all the same to the control.

Thus, NK-049 is suggested to have no influence to the germination of seed from the physiological view point.

ACTION SITE IN PLANT

In pre-emergence treatment against barnyardgrass with NK-049, chlorosis was observed when NK-049 was applied to the plumule or simultaneously to the plumule and radicle, slight chlorosis through the radicle only, and no chlorosis through young root (Ito *et al.*, 1974).

In foliage treatment against transplanted rice-seedling (2.5-leaf stage) in flooded condition, slight chlorosis was observed, and in root treatment, no chlorosis. However, no other growth influencing action was observed in rice at any route of application (Ito *et al.*, 1974).

As mentioned above and NK-049 exhibits its herbicidal activity when applied at plumule or foliage. For example, in the experiment on the action of NK-049 against foxtail (*Setaria viridis* Beauv.) and smartweed (*Polygonum longisetum* De Bruyn), which are different in their types of germination, by the action to plumule foxtail was killed in the period of up to emergence, and smartweed at emergence. These facts are easily explained by their morpholotical and physiological characteristics (Ito *et al.*, 1975).

DEGREE OF SUSCEPTIBILITY OF PLANT

Various kinds of crops and weeds were studied on their susceptibility to NK-049. The test plants were Poaceae (23 spp.), Fabaceae (7 spp.), Brassicaceae (6 spp.), Compositae (6 spp.), Solanaceae (4 spp.), Chenopodiaceae (3 spp.), Cucurbitaceae (2 spp.), Malvaceae (2 spp.) and Apiaceae (1 sp.)

In pre-emergence treatment, 6 species of plants showed resistance, 23 species slight resistance, and 12 species high susceptibility.

In foliage treatment (at 3- or 4-leaf stage), 12 species showed resistance and 11 species susceptibility.

Above results suggest that difference of susceptibility is caused by that of morphological and physiological properties, being independent of the family and the size of the seed.

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Effects of Phosphorus on the Phytotoxicity and Residual Activity of Trifluralin

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Abstract. Glasshouse experiments were conducted to study the interaction between phosphorus and trifluralin (2,6-dinitro-*N*,*N*-dipropyl-4-trifluoromethylaniline) using German millet (*Setaria italica* (L.) Beauv.), a species susceptible to trifluralin. The addition of low rates of phosphorus (up to 300 ppmw) had either no effect or slightly enhanced the phytotoxicity of trifluralin. However, at high rates of application, phosphorus significantly reduced the toxicity of the herbicide. Phosphorus concentration of plant tops increased with each increment of phosphorus at 0 and 0.25 ppmw of trifluralin, but such increases occurred only at the high rates of phosphorus in plants treated with 0.45 ppmw of the herbicide. Bioassay results indicated that phosphorus has very little effect on the persistence of trifluralin.

INTRODUCTION

The amount of phosphorus in the soil has been reported to influence the phytotoxity of several herbicides including trifluralin (Wilson and Stewart, 1973), simazine (2-chloro-4,6-bisethylamino-1,3,5,-triazine) (Adams, 1965), atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) (Doll *et al.*, 1970, Stolp and Penner, 1973), amitrole (3-amino-1,2,4-triazole), and diuron [*N*-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea] (Selman and Upchurch, 1970). Wilson and Stewart (1973) found that trifluralin caused greater reduction of tomato roots at lower rates of phosphorus than at high phosphorus rates. They also reported that phosphorus was less effective in promoting root growth as the rate of trifluralin increased. Trifluralin has been shown to inhibit the uptake of phosphorus by tomatoes (Wilson and Stewart, 1973), cotton, and soybeans (Cathey and Sabbe, 1972). On the other hand, an increased uptake of nitrogen and phosphorus by soybeans was found by Meyer *et al.* (1973). Added nutrient materials have been reported to increase degradation of some herbicides in the soil but had no effect on the decomposition of others (Hance, 1973).

In view of the widespread use of fertilizers on New Zealand soils, this project was initiated to determine the influence of phosphorus on the phytotoxicity and residual activity of trifluralin, and to ascertain if trifluralin had any effect on phosphorus uptake by the plants.

METHOD AND MATERIALS

This study consisted of eight glasshouse experiments conducted between 1973 and 1975 using German millet, an extremely susceptible species to trifluralin (Rahman and Cox, 1975). The soil was a Horotiu sandy loam which contained 14.8% organic matter, 53% sand, 25% silt, 16% clay, a pH of 5.5, and a very low amount of available phosphorus. The treatments were arranged in a split-plot randomized block design with four replications. Plastic pots, 15 cm in diameter, were used for all the experiments.

Phosphorus in the form of $Ca(H_2PO_4)_2 . H_2O$ was mixed thoroughly with the soil one or two days before seeding. Other macronutrients and micronutrients were also added at concentrations estimated to produce optimum growth. Phosphorus levels included in various experiments varied between 0 and 1000 parts per million by weight of oven-dry soil (ppmw). The concentrations of trifluralin were 0, 0.25, 0.35, and 0.45 ppmw. These concentrations were selected so that the middle rate was close to the GR_{50} value—the rate which would result in a 50% reduction in the shoot growth as compared to the untreated control. Trifluralin was mixed only with a portion of the soil which provided a top layer in each pot to a depth of 5 cm. Ten caryopses of German millet were placed at a depth of 2.5 cm. At the start of each test the soil was brought to field capacity and maintained thereafter between 75 and 100% field capacity. After emergence the seedlings were thinned to five plants per pot. The plants were harvested after a growth period of 5 weeks and dry matter weights of the shoot material were determined.

At the conclusion of each experiment, the pots were reseeded with German millet to find out the residual activity of trifluralin. After allowing the pots to dry for 2 days the upper 2.5 cm of soil was removed, ten caryopses of German millet were seeded into each pot and the soil was replaced. Five plants were established in each pot and moisture was maintained between 75 and 100% field capacity. After 5 weeks the plants were cut off and shoot weights were recorded.

The shoot material used for phosphorus determination was wet digested and analysed colorimetrically by a vanadomolybdate method.

RESULTS AND DISCUSSION

Both phosphorus and trifluralin influenced the dry weight and phosphorus content of German millet shoots. The smallest phosphorus addition produced a significant growth response (Fig. 1), with further marked increases in the dry weight from each increment up to about 700 ppmw. Phosphorus uptake by shoots was not significantly affected by levels of up to 100 ppmw, but further increments in the rate of phosphorus increased the phosphorus content of plant tops. Both the dry weight and phosphorus concentration of shoots decreased with increasing rates of trifluralin (Fig. 2 and 3).

Trifluralin and phosphorus interacted in their effects on the dry weight and phosphorus uptake by shoots. The addition of phosphorus up to 300 ppmw did not have any significant effect on the phytotoxicity of trifluralin, although there was a trend for

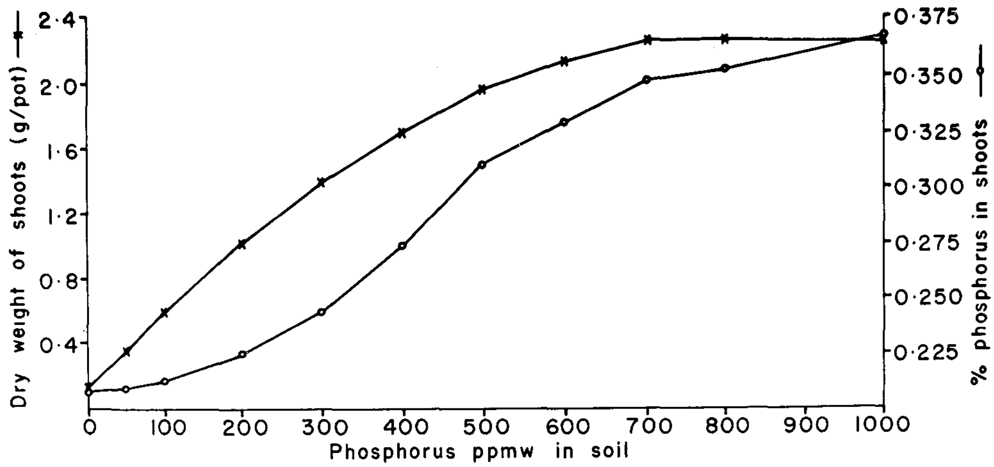

Fig. 1. Effect of different concentrations of phosphorus on the dry weight and phosphorus content of German millet shoots in the absence of trifluralin.

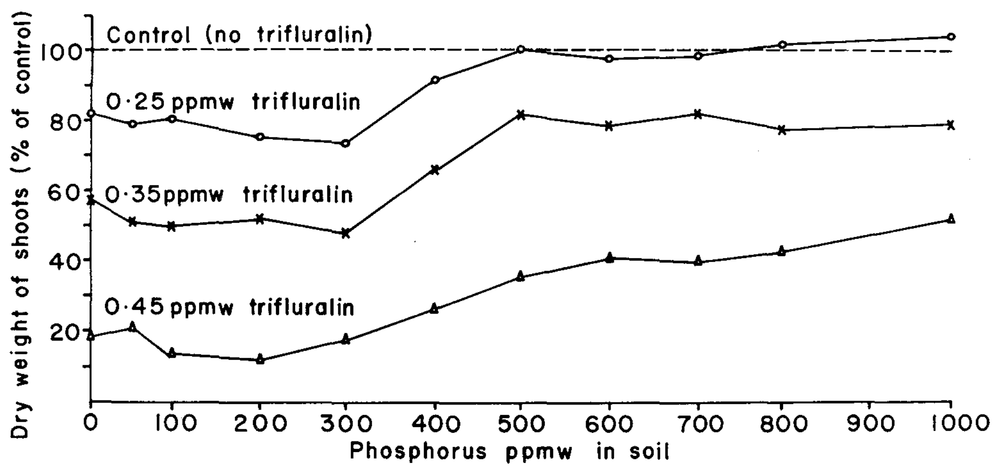

Fig. 2. Influence of phosphorus and trifluralin on the shoot dry weight of German millet.

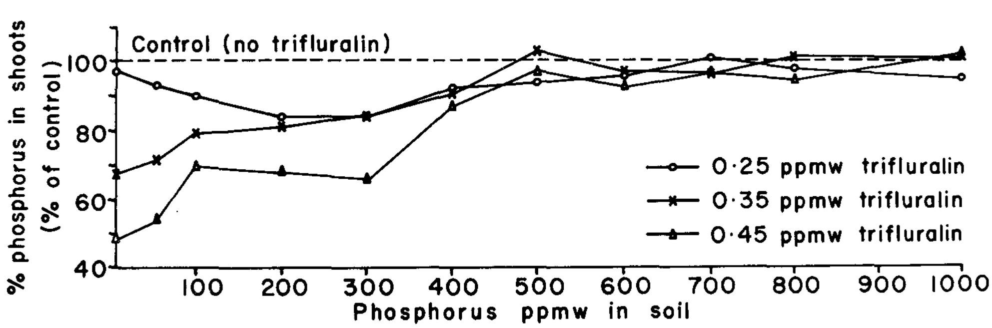

Fig. 3. Influence of phosphorus and trifluralin on the phosphorus content of German millet shoots.

slight decreases in dry weights with each increment of phosphorus up to that level, at all the three rates of trifluralin. At rates higher than 300 ppmw, phosphorus resulted in significant reductions in the herbicide phytotoxicity as is demonstrated by higher shoot dry weights (Fig. 2). This increase in dry weight appeared to reach a maximum between 500 and 600 ppmw and no significant increases occurred with further increments in the phosphorus level.

Phosphorus content of plants receiving none or low rates of phosphorus was reduced significantly by the two higher concentrations of trifluralin but not from 0.25 ppmw when compared with the no herbicide treatment. Trifluralin had no effect on the phosphorus content of German millet shoots in the presence of high levels of phosphorus (Fig. 3).

The results presented here on the effects of phosphorus applications are in agreement with the earlier findings of Cathey and Sabbe (1972) and Stewart and Wilson (1973) on phosphorus-trifluralin interactions, although the soil used in our experiments had a markedly higher organic matter content and thus a greater adsorptive capacity. Barnes and Krieg (1973) found similar relationship between potassium and trifluralin using a nutrient culture system. From a practical point of view, data from this study suggest that the normal rates of phosphorus application, which are commonly used in the cropping and pasture situations in New Zealand, would have no marked effect on the phytotoxicity of trifluralin. However, at high rates a significant negative relationship could be expected between the rate of phosphorus and the phytotoxicity of this herbicide.

The bioassay data for residues of trifluralin at the termination of the experiments indicated that concentrations of active trifluralin remaining in the soil from the two high rates were sufficient to cause significant reductions in the growth of German millet, confirming the relatively long persistence of trifluralin as observed by other workers (Horowitz *et al.*, 1974; Rahman and Ashford, 1973). The degree of persistence was not affected significantly by additions of phosphorus, although results from some experiments showed a trend for less residual activity of trifluralin at high levels of phosphorus application. Hance (1973) reported that the addition of nutrient materials did not affect the degradation of linuron. Results from our work also suggest no apparent relationship between phosphorus levels and the persistence of trifluralin.

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Experience with Metribuzin for Upland Weed Control

G. KÜLPS and M. AYA

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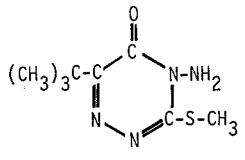
Abstract. Metribuzin [4-amino-6-*t*-butyl-3-(methylthio)-1,2,4-triazin-5(4H)-one] is currently under development by Bayer and Nihon Tokushu Noyaku Seizo K.K.

During the fourth Asian-Pacific Weed Science Conference at Rotorua, New Zealand, a paper regarding the mode of action and general biological properties of metribuzin was presented (Hack et al., 1973).

This paper will discuss the experience gained with metribuzin in asparagus, potatoes, sugarcane and tomatoes in the Asian-Pacific countries. Application methods, dosage rates and weeds controlled are discussed.

INTRODUCTION

Metribuzin (SENCOR) is a new interesting herbicide on the group of asymmetric triazinones, with excellent effects, whether applied pre- or post-emergence (Eue and Lembrich, 1973).



Metribuzin

In the USA, pre-emergence treatment with metribuzin at the dosage rates from 1 to 1.5 kg/ha has been approved for commercial use in soybeans. (The dosage rates given here refer to the 50% wettable powder.) A single application, however, tend to be less selective in light soil and in some trials conducted in the Asian-Pacific countries. For the use in such areas and countries, metribuzin can be usefully mixed with other herbicides such as alachlor and trifluralin. The addition of metribuzin at the dosage rates up to 1 kg/ha improves the selectivity and the efficacy on broadleaf weeds in particular.

In the Western countries, a number of trials have indicated that metribuzin applied post-emergence in carrots has given good weed control with satisfactory crop tolerance (Kampe, 1972). In Japan, however, the crop tolerance are generally negative.

For weed control in alfalfa, metribuzin has been tested for years in New Zealand. Greatest promise has shown for weed control during the crop establishment period

(Fellowes, 1972).

Weed control with metribuzin in asparagus, potatoes, sugarcane and tomatoes has been tested extensively in the Asian-Pacific countries and proved highly effective with good crop tolerance.

The chemical, physical, biological properties and toxicological investigations were described in detail elsewhere (Eue and Lembrich, 1973; Löser and Kimmerle, 1972).

Field Results with Metribuzin

Potatoes. Extensive field tests have been conducted mainly in Australia, Japan and New Zealand (Table 1). Chemical weed control by linuron, triazine herbicides and a mixture of paraquat/linuron has become routine. However, the treatments before sprouting of potatoes has limitations which have prevented their general uses. Further, in some areas grass weeds can not be adequately controlled with above-mentioned chemicals.

Metribuzin applied pre- or post-emergence at dosage rates from 1 to 1.5 kg/ha was highly effective on all major grasses and broadleaf weeds in potatoes. Metribuzin displayed at least 90% control to *Commelina communis* which was a hard kill weed by the standard herbicides in Japan. In many cases, metribuzin possessed better efficacy when

Table 1. Weed control with metribuzin in potatoes.

Treatment	kg a.i./ha	Weed control rating (0–9)[a]						Yield[b]
Japan								
Preemergence		DIGA	ECHIC	CHEA	COMC	POLB	STEM	
Metribuzin	0.5	8	9	9	8	9	9	101
	0.75	9	9	9	9	9	9	97
Linuron	1.0	3	8	7	1	5	9	88
Postemergence								
Metribuzin	0.5	9	9	9	9	9	9	106
	0.75	9	9	9	9	9	9	106
Linuron	1.0	6	8	8	4	8	9	89
Australia								
Postemergence		IUNF	POAA	AROC	CHEA	FUMS	POLA	
Metribuzin	0.35	9	9	9	9	9	9	105
	0.7	9	9	9	9	9	9	99
New Zealand								
Postemergence		AGRR	DIGS	AMAR	CHEA	CONA	SOLN	
Metribuzin	0.35	9	9	9	9	8	9	126
	0.7	9	9	9	9	8	9	130

a) 0 = No weed control, 9 = Complete weed control. b) % in comparison to handweeded plot.

Weed species: AGRR, *Agropyron repens;* AMAR, *Amaranthus retroflexus;* AROC, *Cryptostemma calendula;* CHEA, *Chenopodium album;* COMC, *Commelina communis;* CONA, *Convolvulus arvensis;* DIGA, *Digitaria adscendens;* DIGS, *Digitaria sanguinalis;* ECHC, *Echinochloa crus-galli;* FUMS, *Fumaria* sp.; IUNF, *Juncus bufonius;* POAA, *Poa annua;* POLA, *Polygonum aviculare;* POLB, *Polygonum blumei;* SOLN, *Solanum nigrum;* STEM, *Stellaria media.*

applied post-emergence at or after sprouting of potatoes. Metribuzin is absorbed via the roots as well as the leaves of weeds.

In pre-emergence treatment with metribuzin, many varieties of potatoes were treated with no difference in susceptibility at dosage rates of 3 and 6 kg/ha, double and four times higher than normal dosage rates. The post-emergence treatment after sprouting of potatoes resulted in chlorosis in a few cases, but disappeared rapidly and no difference could be detected a couple of weeks following treatment. A total of 22 varieties from the group of disease and nematode resistant, high starch, white and red skinned potatoes was tested for the susceptibility in overtop spray. Two varieties, May Queen and Hokkai-Aka (red skinned) tolerated less well. No significant evidence on the susceptibility-breeding history was found.

The yield obtained with metribuzin was at least equal to those recorded for standard herbicides and in machinery weeded field.

Sugarcane. Generally, there are three plantation systems; ratooning, planting of top cuttings and transplanting of incubated cuttings according to the local climate conditions, labor management and financial reasons. In any cases, the pre-emergence herbicides should be long lasting as to clean for at least 4 to 5 months until ploughing filed for banking the cane rows and tolerant to unfavorable weather conditions, too much and too little rainfall according to the time of planting, wet and dry seasons.

Metribuzin has been tested in Japan, the Philippines, Taiwan and Thailand. Sugarcane tolerates very well to the treatment with metribuzin in any plantation systems.

Table 2. Weed control with metribuzin in sugarcane.

Treatment	kg a.i./ha	Weed control rating (0–9)[a]							Plant toxi.
Japan									
Ratooning, Preemergence		DIGA	ECHC	ELEI	OXAM	POLS			
Metribuzin	0.5	7	9	7	9	9			0
	1.0	9	9	9	9	9			0
Diuron	1.2	5	8	7	8	7			0
	1.6	6	9	8	8	8			0
Philippines									
Planting, Postemergence		CYPR	DDTA	ELEI	ALCV	PASI	ROOE		
Metribuzin/MCPA	0.5/4.48	6	6	7	6	5	5		0
	0.7/4.48	7	7	7	9	8	9		0
Diuron/MCPA	1.28/4.48	7	8	8	8	8	8		0
Taiwn									
Planting, Postemergence		CYPR	DIGA	ECHC	ELEI	AMAP	PHYA	PORO	
Metribuzin/2, 4-D	1.6/1.6	8	9	9	9	9	9	9	0
Diuron/2, 4-D	1.6/1.6	8	9	9	9	9	9	9	0

a) 0 = No weed control and no plant toxi., 9 = Complete weed control.

Weed species: ALCV, *Alchemilla vulgaris;* ELEI, *Eleusine indica;* AMTP, *Amaranths spinosus;* OXAM, *Oxalis martiana;* CYPR, *Cyperus rotundus;* PASI, *Paspalum dilatatum;* DIGA, *Digitaria adscendens;* PHYA, *Physalis angulata;* DTTA, *Dactyloctenium aegyptium;* POLS, *Polygonum* sp.; ECHC, *Echinochloa crus-galli;* ROOE, *Rottboellia exaltata.*

Metribuzin applied pre- and post-emergence up to 3 kg/ha has displayed good efficacy on annual weeds. The residual efficacy was satisfactory even under unfaborable weather conditions. An obstinate perennial broadleaf weeds in Japan, *Oxalis martiana* propagating with underground nuts was controlled completely by metribuzin at 1 kg/ha. For the control of *Cyperus rotundus* which is a particular hazard to the cane in the Philippines and Taiwan, a combination of metribuzin of 3 kg/ha with 2,4-D of 1.5 kg/ha has provided good results (Table 2).

Tomatoes. For weed control in transplanted tomatoes, metribuzin has been tested in Japan and New Zealand (Fellowes, 1972).

Post-transplanting application of metribuzin at dosage rate of 1.5 kg/ha occasionally produced transient chlorosis and slight marginal leaf burn, but caused no significant yield decrease. The best weed control was obtained from application made 7 to 14 days after planting and the weeds were in the 2 to 4 leaf stage (Table 3).

Metribuzin should not be used in tomatoes grown under plastic cover or in greenhouse. It has a risk of plant damage and carry-over to following crops.

Asparagus. Metribuzin has been tested mainly in Japan (Table 4). The weed flora is similar to that in potatoes. Weed control in asparagus, however, requires longer lasting and more broad spectrum activity than that in potatoes, because asparagus is havested for years.

Metribuzin has been tested for two application times; before emergence of the first spear of asparagus and at the end of cutting season. The applications of metribuzin at dosage rates from 1 to 1.5 kg/ha achieved sufficient broad spectrum weed control

Table 3. Weed control with metribuzin in field tomatoes[a].

Treatment	kg a.i./ha	Weed control rating (0–9)[b]								Plant toxi. (0–9)[b]
Japan										
Preemergence		CYPI	DIGA	ECHC	AMAA	CAPB	CHEA	GASC	PORO	
Metribuzin	0.35	7	4	4	7	9	9	9	7	0
	0.7	8	9	7	8	9	9	9	9	1
Trifluralin	1.5	8	9	9	9	7	9	6	9	1
Postemergence										
Metribuzin	0.35	9	7	7	9	9	9		9	0
	0.7	9	9	9	9	9	9		9	2[c]
Diphenamid	3.0	7	6	6	9	9	9		9	0
New Zealand										
At emergence		COPD		SETV	AMAR		CHEA	SOLN		
Metribuzin	0.35	9		9	9		9	8		2[c]
Trifluralin	1.0	8		8	8		8	0		0

a) Transplanted. b) 0=No weed control and no plant toxi., 9=Complete weed control and death of crop. c) Transient slight chlorosis.

Weed species: AMAA, *Amaranthus ascendens;* DIGA, *Digitaria adsendens;* AMAR, *Amaranthus retroflexus;* ECHC, *Echinochloa crus-galli;* CAPB, *Capsella bursa-pastoris;* GASC, *Galinsoga ciliata;* CHEA, *Chenopodium album;* PORO, *Portulaca oleracea;* COPD, *Coronopus didymus;* SETV, *Setaria viridis;* CYPI, *Cyperus iria;* SOLN, *Solanum nigrum.*

Table 4. Weed control with metribuzin in asparagus in Japan.

Treatment	kg a.i./ha	Weed Control rating (0–9)[a]					Plant toxi.
After making ridge,							
Preemergence		CHEA	COMC	POLB	SENV	STEM	
Metribuzin	0.5	9	8	8	9	9	0
	1.0	9	9	9	9	9	0
Diuron	0.8	9	5	8	8	9	0
Postemergence							
Metribuzin	0.5	9	8	9	9	9	0
	1.0	9	9	9	9	9	0
Diuron	0.8	8	6	9	9	9	0
After levelling ridge							
Preemergence		CHEA	COMC	DIGA	POLB		
Metribuzin	1.0	9	8	9	8		0
Diuron	0.8	9	6	8	8		0
Postemergence							
Metribuzin	1.0	9	9	9	9		0
Diuron	0.8	9	6	9	9		0

a) 0 = No weed control and no plant toxi., 9 = Complete weed control.

Weed species: CHEA, *Chenopodium album;* POLB, *Polygonum blumei;* COMC, *Commelina communis;* SENV, *Senecio vulgaris;* DIGA, *Digitaria adscendens;* STEM, *Stellaria media.*

and adequate residual activity. *Commelina communis* and some grasses which are tolerant to the standard herbicides were controlled by metribuzin. No damage and no reduction of the stem weight with metribuzin has been noted. Sown asparagus tolerates to the treatment of metribuzin at 1 kg/ha applied directly after seeding.

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The Control of Paspalum (*Paspalum dilatatum*) and Kikuyu (*Pennisetum clandestinum*) with Tetrapion

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Abstract. Two field trials were conducted in northern New South Wales to determine the activity of tetrapion (sodium 2,2,3,3-tetrafluoropropionate) on paspalum (*Paspalum dilatatum*) and kikuyu (*Pennisetum clandestinum*). Rates of 2.8, 5.6 and 11.2 kg ae/ha reduced the cover of paspalum in the spring following application from 100% to 30.6%, 8.3% and 2.8% respectively 44 weeks after application and of kikuyu from 100% to 83.3%, 13.9% and 19.4% for the same rates, 51 weeks after application. These results are compared to 2,2-DPA at various rates including 16.6 kg ae/ha which resulted in green plant covers of 83.3% for paspalum and 72.2% for kikuyu in the following spring.

Introduction

The use of residual and knockdown herbicides for annual weed control in agricultural and non-agricultural situations has, in many instance, led to a change in the weed flora to a perennial grass dominant situation. The need for a perennial grass herbicide is particularly pronounced in the non-agricultural situations where cultivation is not possible and long term residual herbicides have been effective in preventing the re-establishment of annual species. As a consequence, there has been rapid establishment and spread of perennial grasses such as paspalum and kikuyu.

The control of problem perennial grasses currently involves repeated applications of either amitrole or 2,2-DPA and in some cases both are applied in combination. Alternatively, very high rates of 2,2-DPA (28 kg ae/ha) are used. However, these treatments rarely prevent re-invasion of the perennial grasses in the following season.

Tetrapion is a halogenated aliphatic acid with low mammalian toxicity (Yamade and Ando, 1971) which is chemically related to 2,2-DPA. Its herbicidal activity in terms of weed spectrum is similar to 2,2-DPA but unlike the related material, tetrapion is slower to take effect but more long term. The material is both soil and to a much lesser extent, foliar active and appears to remain in the plant for some considerable time.

Materials and Method

Two trials were carried out in northern New South Wales on a clay loam soil type. A randomized block design with 4 replications was used in both trials. Plot size was 3 × 3 metre. Treatments were applied with knapsack sprayer incorporating a 4 nozzle boom with 73077 'Spraying Systems' T-jet nozzles at 35.5 cm spacings and operating at 138 kPa. Spraying was carried out at 3.2 kph to give a volume of application of 112 litres per hectare of spray mix. The boom was kept at a height of 46 cm above the foliage. The surfactant 'Agral' 60 was added at 0.1% ai w/v to all tetrapion treatments. Both trials were conducted in pure stands of the target species, trial 1 on paspalum and trial 2 on kikuyu. In both trials treatments were applied in October/November during the spring flush.

Assessments were carried out using a 0–9 whole plot eye score for green cover on a linear scale where 0=nil cover and 9=total cover, at intervals following treatment application. The scores were transformed for statistical analysis by scaling Y=1.1111X and transformed by Y=arcsine $\sqrt{x/10}$. The actual scores have been converted to percentage cover for ease of interpretation. Both percentage cover and transformed data are presented.

Results and Discussion

Trial 1. As expected, the 2,2-DPA treatments were showing signs of control before tetrapion, the latter being very much slower to act. However, six weeks after application the tetrapion treatments were giving better control of paspalum than the 2,2-DPA treatments. Eight weeks after treatment tetrapion at 11.2 kg ae/ha was giving significantly better control than 2,2-DPA. The two lower rates of 2,2-DPA showed a levelling off in control eight weeks after application, while the tetrapion treatments showed an increase in the control of paspalum. During the winter while the paspalum was dormant, no assessments were made. The assessment in the following spring (44 weeks after treatment) showed that tetrapion was still controlling the potential new growth of paspalum. The 2,2-DPA treatments did not show any long term control and these plots were similar in paspalum cover to the untreated control plots. Table 1 shows that the cover of paspalum following tetrapion at 2.8, 5.6 and 11.2 kg ae/ha assessed the following spring, had been reduced to 30.6%, 8.3% and 2.8% respectively compared to 2,2-DPA 16.6 kg ae/ha 83.3% and untreated with a 100% ground cover. The areas treated with tetrapion were however invaded by broadleaf weeds.

Trial 2. The results show a similar pattern of control for kikuyu as seen in trial 1 for paspalum. Again, the quick knockdown from 2,2-DPA was evident, with tetrapion taking longer to show any visual signs of control. During January (approximately 7 weeks after application) heatwave conditions caused dormancy in the kikuyu sward. However, heavy rain shortly after this period produced normal growth on all plots except those treated with tetrapion. A mild winter allowed the kikuyu to continue to grow when normally low temperatures would cause growth to cease. The assessment 51 weeks after application showed that tetrapion was giving acceptable control of kikuyu at all but the lowest rate. At this time (Table 2) percentage ground cover for tetrapion at 2.8, 5.6, 11.2 and 2,2-DPA at 16.6 kg ae/ha were 83.3%, 13.9%, 19.4% and 72.2% respectively. This result is at variance with previous comparative work reported by Parker (1970) where tetrapion performed relatively poorly compared to 2,2-DPA in a glasshouse trial on kikuyu. As in trial 1, a broadleaf weed succession followed in the tetrapion plots

Table 1. Trial 1: The effect of tetrapion on paspalum. Percentage green cover, error-free transformed data shown in brackets.

Treatment kg ae/ha		Weeks post-spraying					
		1	8	16	22	26	44
Tetrapion	2.8	81.1 (64.4)	41.7 (40.1)	41.7 (40.2)	38.9 (38.3)	33.3 (35.1)	30.6 (32.6)
	5.6	61.1 (51.7)	27.8 (31.3)	19.4 (22.9)	19.4 (22.4)	13.9 (18.9)	8.3 (11.9)
	11.2	64.4 (53.3)	19.4 (25.6)	8.3 (11.9)	2.8 (4.9)	0.0 (0.0)	2.8 (4.9)
2,2-DPA	4.4	63.9 (53.2)	61.1 (51.5)	66.7 (54.9)	69.4 (56.5)	66.7 (54.7)	91.7 (81.0)
	8.3	61.1 (51.5)	44.4 (41.8)	61.1 (51.6)	69.4 (57.0)	66.7 (54.7)	100.0 (89.8)
	16.6	52.8 (46.6)	47.2 (43.4)	27.8 (31.7)	33.3 (34.5)	33.3 (31.3)	83.3 (72.3)
Control		100.0 (89.8)	100.0 (89.8)	100.0 (89.8)	100.0 (89.8)	66.7 (54.7)	100.0 (89.8)
LSD	5%	(10.2)	(8.5)	(14.1)	(14.6)	(13.9)	(20.2)
	1%	(13.8)	(11.6)	(19.4)	(20.1)	(19.1)	(27.6)
	0.1%	(18.8)	(15.8)	(26.4)	(27.4)	(26.0)	(37.7)

Table 2. Trial 2: The effect of tetrapion on kikuyu. Percentage green cover, error-free transformed data shown in brackets.

Treatment kg ae/ha		Weeks post-spraying					
		3	5	7	15	26	51
Tetrapion	2.8	66.7 (54.9)	50.0 (45.0)	11.1 (16.8)	2.8 (4.9)	0.0 (0.0)	83.3 (72.3)
	5.6	50.0 (45.0)	19.4 (22.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	13.9 (15.3)
	11.2	16.7 (23.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	19.4 (19.1)
2,2-DPA	4.4	52.8 (46.6)	36.1 (36.2)	19.4 (26.0)	33.3 (35.1)	52.8 (46.6)	97.2 (85.0)
	8.3	0.0 (0.0)	8.3 (11.9)	5.6 (9.7)	11.1 (19.5)	19.4 (26.0)	91.7 (75.3)
	16.6	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	8.3 (11.9)	16.7 (17.5)	72.2 (64.4)
Control		100.0 (89.8)	100.0 (89.8)	22.2 (28.1)	44.4 (41.8)	66.7 (54.7)	100.0 (89.8)
LSD	5%	(5.2)	(15.7)	(10.2)	(10.9)	(12.0)	(35.4)
	1%	(7.2)	(21.5)	(13.9)	(14.9)	(16.5)	(48.5)
	0.1%	(9.8)	(29.3)	(19.0)	(20.3)	(22.5)	—

where the kikuyu had been eliminated.

It is evident from these trials that tetrapion controls both paspalum and kikuyu for an extended period. However, there is evidence that paspalum is more susceptible to tetrapion than kikuyu when the amount of spring regrowth for each of the individual species is compared following tetrapion at 2.8 kg ae/ha. This indication that susceptibilities of various perennial grasses to tetrapion varies, is shown by the poor activity on paragrass (*Brachiaria mutica*) reported by O'Bien *et al.* (1973) and confirmed by work conducted in northern Queensland by a co-worker of the authors Matthews (1975).

Rainfall after application has been reported as being influential on the result obtained with tetrapion Aelbers *et al.* (1969) and Blair (1972). The excellent results obtained in these two trials were obtained under relatively dry conditions with only light falls of rain being recorded for some eight weeks after spraying. Such conditions would allow for good root uptake of tetrapion before any appreciable leaching out of the root zone could take place.

Future work with the material should be aimed at increasing the speed of control, increasing the spectrum of weed control to include broadleaf weeds and defining more precisely the rate susceptibility of other problem perennial grasses to tetrapion.

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Structure-Activity Relationship of Cyclic Imide Herbicides

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Abstract. In the context of development of cyclic imide herbicides, information has been obtained on the structural characteristics required for herbicidal activity and a hypothesis that the alkylene ring, the electron-donating moiety, the imide ring and the *p*-substituted aryl ring are the prerequisite for activity is presented.

INTRODUCTION

The discovery of the herbicidal properties of a series of compound (I), by Matsui *et al.* (1974), gave a new impetus to the search for imide herbicides.

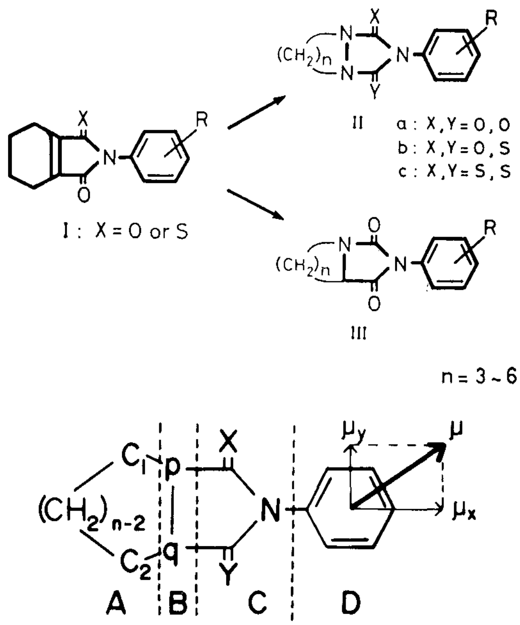


Fig. 1. Structures and Moieties of cyclic imide compounds.

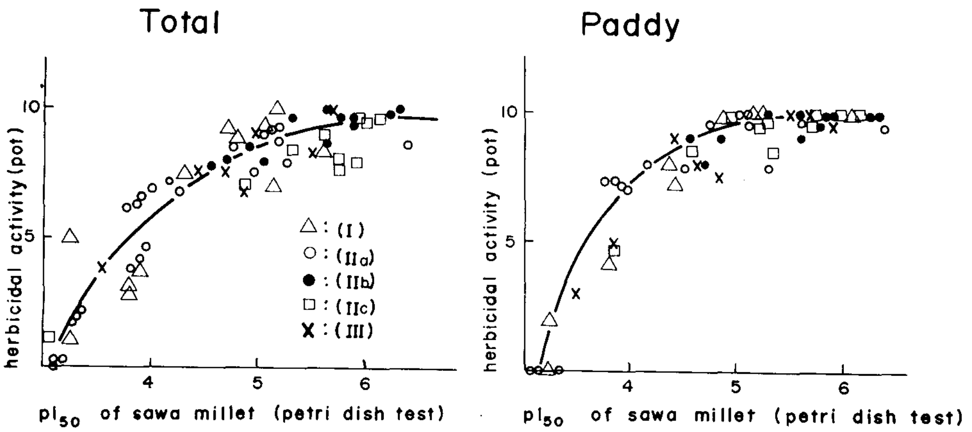
Subsequent research in imide type of compounds (I, II and III) has shown the tonic effect of this discovery. The work reported in brief here had the following three objectives;

1) To find out what stuructural modification may be made to the parent series (I) without losing its hitherto unique biological properties. This information could elucidate a feature of its molecule, either in whole or in part, which is associated with the herbicidal activity.
2) To find out whether the parent series (I) and its relatives (II and III) are active *per se*, or whether their activity results from modification within, or in the vicinity of, the plant. This information might be helpful to predict their mechanism of action, metabolism and so on, before starting the biochemical study.
3) To design new compounds with similar or improved activity by making use of the information obtained.

BIOLOGICAL

All the compounds used in this work were synthesized in our laboratory. Biological tests, which measure inhibition of root growth of sawa millet by the Petri dish test, herbidal activity by pot test and influence of light or site of absorption against activity, were performed by the methods described in our previous paper (Ohta *et al.*). The biological and biochemical response of plants to all series of compounds, such as browning of shoots, growth retardation, requiring light for activation, absorbing the compounds mostly from coleoptile and mesocotyl parts of plant and so on, is quite similar (Jikihara *et al.*).

As shown in Fig. 2, a good correlation was found to exist between results obtained



Evaluation

Application	Pre-emergence in upland	Foliar spray	Pre-emergence in paddy
Weeds	crab grass, Common purslane, hairy galinsoga	sawa millet, radish	barnyard grass, umbrella plant, toothcup, monochoria
Dose	20 g / a		
Activity	10 : complete kill ~ 0 : no weed control		

Fig. 2. Correlation between Petri dish test and pot test.

in the Petri dish test and those in the pot test. Especially, this correlation shows a better fit in a paddy condition. Therefore, our discussion about structure-activity relationship is made mainly using pI_{50} values; negative logarithm of the molar concentration which produces a 50% inhibition of root growth.

General Consideration of the Compounds

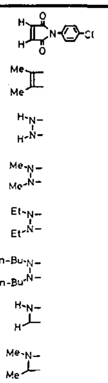
A closer look at the structure of the compounds in Fig. 1 shows a number of ineresting features (Moiety A-D), all of which could be responsible for their herbicidal activity in the form of the following three hypothetical points; 1) They are alkylene compounds, some of which are herbicides of long standing: for example, lenacil, decazolin, and others. In many cases, the alkylene group brings about an increase of lipophilicity. 2) They have electron-donating moiety and are imide types of compounds, which might contribute to polarity or hydrophilicity of compounds. 3) Another possibility to be considered is that of the proper balance of lipophilicity and hydrophilicity, which may be responsible for herbicidal activity. If this is the case, the question arises as to what features are responsible for its unique properties.

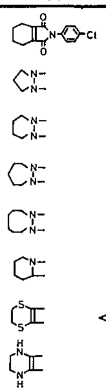
Having these purely chemical consideration in mind, a series of compounds was made in order to get some idea why these imide types of compounds exhibit so potent herbicidal activity and, also, to find out whether variation in their structure would be permissible.

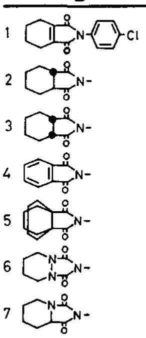
Importance of alkylene ring (moiety A). The first concerns the alkylene group in all series (Table 1).

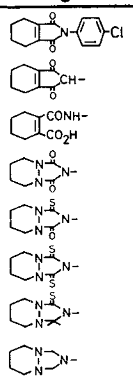
Introduction of the alkylene group having 3–5 carbon atoms at *p* and *q* position brought about remarkably high activity (Compds. 9–12 and 14), whereas the alkylene group of more than 6 carbon atoms gave less active compounds (e.g., Compd. 13). Hetero-atom(s) in the alkylene ring leads to inactive relatives (Compds. 15 and 16). This shows that a suitable lipophilicity of the alkylene group plays an important role in producing high activity. Dimethyl analogues (Compds. 2, 4 and 8) were considerably

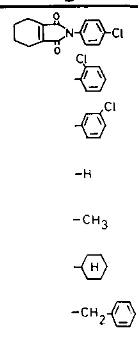
Table 1. Importance of Moiety A, B, C and D.











No.	A	pI_{50}	No.	A	pI_{50}	No.	B	pI_{50}	No.	C	pI_{50}	No.	D	pI_{50}
1		2.67	9		5.25	1		5.25	1		5.25	1		5.25
2		4.65	10		5.25	2		3.80	2		3.75	2		3.49
3		2.72	11		5.15	3		3.92	3		4.85	3		3.92
4		4.22	12		5.16	4		2.79	4		5.15	4	–H	2.84
5		2.04	13		3.69	5		3.05	5		6.32	5	$-CH_3$	3.01
6		2.78	14		5.68	6		5.15	6		6.16	6		2.87
7		2.82	15		<2.57	7		5.68	7		3.96	7		4.07
8		3.78	16		2.59				8		3.12			

active, while other open chain analogues, such as diethyl or dibutyl derivatives, were inactive. The carbon atoms (C_1 and C_2) in the active Compound 9 are on the same plane with the imide ring and the carbon atoms on the trimethylene and tetramethylene urazoles or hydantoin which are also active (Compds. 10, 11 or 14) have *cis*-configuration. This fact appears to be responsible for hearbicidal activity. The less active diethyl, dibutyl or hexamethylene analogue (Compds. 5, 6 or 13) by implication has a *trans*-configuration. In the case of dimethyl analogues, the existence of *cis*-isomer could be responsible for their rather high activity.

Importance of electron-donating moiety (Moiety B). The next question is what is the importance of electron-donating moiety B (Table 1). When the two hydrogenated geometrical isomers of Compound 1 were tested, both (Compds. 2 and 3) were found to be less active than their parent. Likewise, introduction of one more of tetramethylene group to the double bond leads again to the inactive decalin-analogue (Compd. 5). However, the replacement of the bridgehead carbon atom(s) in Compound 1 by nitrogen(s) to give urazole or hydantoin (Compds. 6 or 7) did not change the strong herbicidal activity of the parent Compound 1.

Importance of imide ring (Moiety C). Next question is about Moiety C (Table 1). Replacement of the nitrogen in Compound 1 by methine gave less active indandione derivative (Compd. 2). The herbicidal activity of the triazolidine (Compd. 8) was greatly reduced. However, conversion of urazole (Compd. 4) into its corresponding thiono or

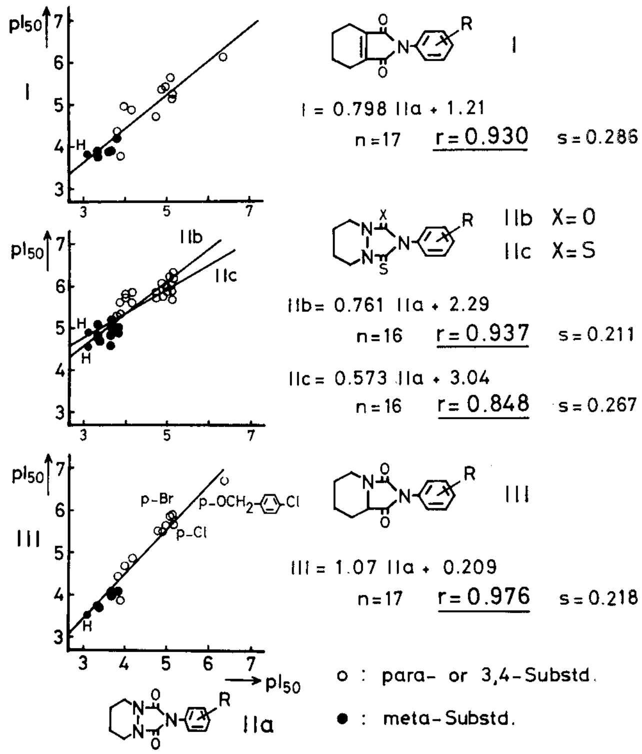


Fig. 3. Substituent effect on herbicidal activity.

dithiono analogues (Compds. 5 or 6) leads to more than a tenfold increase of activity. While the triazolidinethione (Compd. 7), which has no imide structure, showed to be less active. These facts indicate that Moiety C should be a planar and preferably have the imide ring. The rather high activity of Compound 3 might suggest that this compound is converted to the Compound 1 within the plant.

Importance of Aryl ring (Moiety D). The next question arising is that of the importance of aryl ring (Table 1). It was found that the activity of the Compound 1 was greatly reduced when the *p*-chlorophenyl group was replaced by hydrogen, alkyl, cycloalkyl, or *o*- or *m*-substituted aryl group (Compds. 2–7).

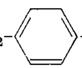
Fig. 3 shows the activity-correlations between the series of compound IIa and the other series. From these linear equations, it is evident that, amongst all series of compounds, change of the herbicidal activity coming from the modification of aryl group is well correlated, thus suggesting the similarity of biological response in all series of compounds. These equations, also, characterize the aryl group required for activity as follows; 1) *p*-Substituent on benzene ring is necessary for activity. 2) As a substituent, halogen (especially Cl or Br), lower alkyl, lower alkoxyl of benzyloxy is desirable.

Quantitative structure-activity relationship. However, it was very difficult to discuss this substituent-effect on herbicidal activity in the monistic conception: for example, these activities correlated poorly with the Hammett σ constants. So, we tried to determine whether the multi-parameter Hansch analysis could be used to provide meaningful structure-activity relationship amongst members of our series. The successful results obtained so far are shown in the following equations, which were calculated using the parameters in Table 2;

			n	r	s	F
Eq. 1	$pI_{50}(I)$	$=3.98+0.334\pi+0.984\mu_X-0.251\mu^2$	16	0.927	0.283	24.412
Eq. 2	$pI_{50}(IIa)$	$=3.36+0.811\pi+0.701\mu_X-0.143\mu^2-0.253\mu_Y$	16	0.955	0.250	28.306
Eq. 3	$pI_{50}(IIb)$	$=4.90+0.387\pi+0.667\mu_X-0.117\mu^2-0.239\mu_Y$	16	0.925	0.260	16.294
Eq. 4	$pI_{50}(IIc)$	$=5.07+0.806\mu_X-0.182\mu^2$	16	0.896	0.232	26.421
Eq. 5	$pI_{50}(III)$	$=3.71+0.741\pi+1.09\mu_X-0.259\mu^2$	16	0.920	0.380	21.957
Eq. 6	$pI_{50}(I)$	$=4.33-0.981\sigma+0.088\pi+0.501\pi^2$	16	0.627	0.588	2.595

As shown in Eq. 6 derived from the series of compound I, regression analysis using σ and π system gave only a non-significant correlation. Each parameter in Eq. 1–5 is significant of more than a 95% confidence level. Hydrophobicity parameter, π, is insignificant in Eq. 4 and its influence on activity varies rather greatly also in other equations. This fact may indicate that π does not play as the hydrophobic binding force at the site of action, but closely related to the hydrophobic transfer of the molecule in absorption or translocation. By the explanation of Tute (1971) about μ and μ^2, because of the negative signs of μ_Y and μ^2 terms respectively, μ_Y may be interpreted as a trap by a

Table 2. pI_{50} values and parameters used in regression analysis.

SUBSTITUENT	pI_{50}(I)	pI_{50}(IIA)	pI_{50}(IIB)	pI_{50}(IIC)	pI_{50}(III)	σ	π	π^2	μ_x	μ_y	μ^2
H	3.81	3.10	4.54	4.90	3.52	0.00	0.00	0.00	0.00	0.00	0.00
3-F	3.87	3.33	4.74	5.08	3.74	0.34	0.13	0.0169	0.80	1.39	2.56
3-Cl	3.92	3.67	5.03	5.22	4.01	0.37	0.76	0.578	0.85	1.46	2.86
3-Br	4.22	3.82	5.01	4.88	4.07	0.39	0.94	0.884	0.85	1.47	2.89
3-Me	3.78	3.36	4.71	4.84	3.72	−0.07	0.51	0.26	−0.18	0.31	0.13
3-CF_3	3.88	3.62	4.86	4.59	4.10	0.43	1.07	1.15	1.43	2.48	8.18
4-F	4.96	3.99	5.75	5.80	4.70	0.06	0.15	0.0225	1.60	0.00	2.56
4-Cl	5.25	5.15	6.32	6.16	5.68	0.23	0.70	0.49	1.69	0.00	2.86
4-Br	5.63	5.11	6.24	5.98	5.90	0.27	1.02	1.04	1.70	0.00	2.89
4-I	5.17	5.13	5.87	5.68	5.87	0.30	1.26	1.59	1.70	0.00	2.89
4-Me	4.34	3.84	5.26	5.26	4.42	−0.17	0.52	0.27	−0.36	0.00	0.13
4-OMe	4.90	4.15	5.61	5.87	4.86	−0.27	−0.04	0.0016	1.14	0.00	1.64
4-NO_2	3.76	3.88	5.62	5.28	3.86	0.78	0.24	0.0576	4.22	0.00	17.8
3,4-Cl_2	4.70	4.75	5.87	5.75	5.50	0.60	1.46	2.13	2.17	1.25	7.25
3-Me,4-Cl	5.35	4.91	6.09	5.76	5.49	0.16	1.21	1.46	1.53	0.32	2.43
3-Me,4-Br	5.34	5.02	5.91	5.94	5.64	0.20	1.53	2.34	1.52	0.31	2.41
4-OCH_2--Cl	6.11	6.39	—	—	6.69	—	—	—	—	—	—

dipole-charge interaction or an interference against a dipole-charge interaction by μ_X on the X-axis and μ^2 as a trap by a dipole-induced dipole interaction or a restriction to give an optimal μ value. From the parabolical nature of μ term in all equations, it is evident that μ should have a proper size and direction for activity. This fact reflects that a dipole-charge interaction along the X-axis may be a critical step in the toxophoric reaction. And also, it is possible to say that μ is one of the most important keys to the designing new highly herbicidal imide compounds. From the data presented, it appears that a large number of imides can be herbicidal. The incidence of this activity is very high amongst compounds whose structure conforms to the following rules; 1) C_1 and C_2 carbons in the alkylene ring should form part of planar or have *cis*-configuration against the imide ring in Moiety A and B. 2) Moiety C should be a planar and preferable have imide ring. 3) The *p*-substituent on benzene ring should have a proper size and direction of a dipole moment for activity in Moiety D.

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Glutathione Conjugation of Herbicides in Plants and Animals and its Role in Herbicidal Selectivity

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Abstract. Plants are capable of metabolizing some herbicides by a mercapturic acid-like pathway. The terminal product, however, does not appear to be the mercapturic acid found in animals. The initial reaction with glutathione in the mercapturic acid pathway has been reported to occur in both plants and animals. Glutathione conjugation is a detoxication mechanism which is important in herbicide selectivity.

Introduction

Glutathione conjugation is the first step in the mercapturic acid pathway leading to the detoxication and elimination of toxic xenobiotic (foreign) compounds in mammals (Boyland *et al.*, 1969). Herbicide metabolism by glutathione conjugation in plants and its significance in the formation of insoluble residues have been reviewed [Shimabukuro, in press (a)]. This review presents more recent results on comparative metabolism of herbicides by glutathione conjugation in animals and plants and the role of this reaction in herbicidal selectivity in plants.

Mercapturic Acid Biosynthesis in Mammals

Nucleophilic displacement of a functional group by glutathione (glutathione conjugation) is the first reaction in mercapturic acid (*N*-acetyl-L-cysteine residue) biosynthesis (Boyland *et al.*, 1969). Intermediate steps involve the successive hydrolysis of the glutamyl and glycine residues to give the *S*-cysteine conjugate followed by *N*-acetylation to yield the mercapturic acid which is excreted in the urine. The number of herbicides reported to be metabolized by the above process in both animals and plants is limited. However, recent reports indicate that the initial reaction with glutathione occurs in both animals and plants, but the terminal product in plants is not the mercapturic acid.

Herbicide Metabolism by Glutathione Conjugation

A major metabolite of atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine), first detected in sorghum (*Sorghum bicolor* (L.) Moench) (Shimabukuro *et al.*,

1969) was characterized as the glutathione conjugate [*S*-(4-ethylamino-6-isopropylamino-*s*-triazinyl-2)glutathione] (GS-atrazine) (Lamoureux *et al.*, 1970). This was the first report of a herbicide undergoing such a reaction in plants. In contrast to the metabolic pathway shown in mammals, glycine and glutamyl residues were removed in that order from GS-atrazine to give the *S*-cysteine conjugate. The *S*-cysteine conjugate was not metabolized to the mercapturic acid, but a rearrangement occurred to give the *N*-cysteine derivative which was metabolized to the lanthionine conjugate [*N*-(4-ethylamino-6-isopropylamino-*s*-triazinyl-2)lanthionine] (Lamoureux *et al.*, 1973).

In the rat, glutathione conjugates of atrazine and its *N*-dealkylated derivatives were formed only *in vitro* (Dauterman *et al.*, 1974). Atrazine administered orally to the rat was *N*-dealkylated and hydroxylated with no mercapturic acid intermediates being formed (Bakke *et al.*, 1972). However, the chloro-*s*-triazine herbicide, cyanazine [2-chloro-4-ethylamino-6-(1-cyano-1-methylethylamino)-*s*-triazine], was metabolized to the mercapturic acid in rat (Crayford *et al.*, 1972). In contrast to atrazine, the glutathione conjugate of cyanazine was not characterized in plants grown in cyanazine-treated soil (Beynon *et al.*, 1972). No direct studies of cyanazine metabolism in plants have been reported.

Cyprazine (2-chloro-4-cyclopropylamino-6-isopropylamino-*s*-triazine) metabolism was similar to that of atrazine. The glutathione and γ-glutamylcysteinyl conjugates of cyprazine were identified in several plant species (Lamoureux *et al.*, 1972). In the rat, glutathione conjugation of cyprazine did not occur but it was primarily *N*-dealkylated and hydroxylated (Larsen *et al.*, 1975).

The metabolism of atrazine, cyanazine, and cyprazine indicates that a given herbicide or its closely related herbicide may or may not be metabolized by a mercapturic acid or mercapturic acid-like pathway in both animals and plants. The chemical properties of each herbicide appear to determine whether glutathione conjugation will be an important reaction in either the animal or plant or in both.

Glutathione conjugation and subsequent metabolism of fluorodifen (2,4′-dinitro-4-trifluoromethyl diphenylether) appear to occur in both animals and plants. The metabolite, *S*-(2-nitro-4-trifluoromethylphenyl)-glutathione, was isolated only from peanut (Shimabukuro *et al.*, 1973), but 2-nitro-4-trifluoromethylphenyl mercapturic acid was isolated from the urine of fluorodifen-treated rats (Lamoureux *et al.*, in press). In peanut, the *S*-cysteine conjugate is not metabolized to the mercapturic acid or the lanthionine conjugate as reported for atrazine (Lamoureux *et al.*, 1973), but acylation occurs to give *S*-(2-nitro-4-trifluoromethylphenyl)-*N*-malonylcysteine [Shimabukuro *et al.*, in press (c)]. This metabolite may be an intermediate in the formation of insoluble residues.

The glutathione conjugate of propachlor (2-chloro-*N*-isopropyl-acetanilide) has been identified (Lamoureux *et al.*, 1971) and the glutathione-like conjugates of CDAA (*N*,*N*-diallyl-2-chloroacetamide) and barban (4-chloro-2-butynyl-*m*-chlorocarbanilate) have been detected in several plant species [Lamoureux *et al.*, 1971; Shimabukuro *et al.*, in press (b)]. The mercapturic acids of both propachlor and CDAA have been identified in rats (Lamoureux *et al.*, in press).

The limited studies indicate that plants are capable of metabolizing herbicides by a mercapturic acid-like pathway. However, some of the reactions after initial glutathione conjugation differ between plants and animals and result in terminal products other than mercapturic acid.

Glutathione Conjugation and Herbicide Selectivity

Herbicide selectivity is relative and is directly related to dosage applied to plants. Generally, at a reasonable physiological concentration, some plants will be killed while others remain uninjured. To be effective, the herbicide must reach the sensitive site or sites in its toxic form at a concentration (effective internal concentration) sufficient to cause severe disruption of normal growth. Many barriers such as absorption by roots or leaves, translocation, inherent morphological variations, spray retention, etc. ,are believed to influence the effective internal concentration of a herbicide. The effects of these barriers are usually determined by applying ^{14}C-labeled herbicides and measuring the ^{14}C activity absorbed, translocated, or retained on plant surfaces. Generally, these methods do not account for the dynamic chemical changes which the parent herbicide undergoes from the moment it penetrates the epidermal layer of the root or leaf surface until it reaches the site of action. Results of metabolism or detoxication studies measure directly the internal concentration of the herbicide at a given time.

Metabolism of herbicides is probably the most important and effective means by which plants can reduce the concentration of a toxic herbicide to prevent irreversible damage. Glutathione conjugation is a major detoxication mechanism which effectively protects plants from atrazine injury (Shimabukuro *et al.*, 1971). The recovery of atrazine-inhibited photosynthesis in both sorghum and corn leaf discs occurred within 6 hours with a 77 to 80% conversion of atrazine to GS-atrazine. In corn, the nonenzymatic benzoxazinone-catalyzed conversion of atrazine to hydroxyatrazine was a significant factor in total detoxication only when atrazine was absorbed through the roots. This pathway is not significant in sorghum. The enzyme, glutathione-S-transferase, was active in shoots but not in roots of corn (Frear *et al.*, 1970). The results on atrazine metabolism, enzyme concentration, tolerance to atrazine, and benzoxazinone concentration in 8 lines of corn indicated that most corn plants would be totally resistant to atrazine even if benzoxazine were absent. Glutathione conjugation was sufficiently active to detoxify atrazine very rapidly in all corn lines except one with extremely low glutathione-S-transferase activity. Atrazine concentration in the one susceptible line was 5 times and 12 times that of the resistant isogenic line after 48 hours when atrazine was introduced through the root and leaf, respectively. This large difference in atrazine concentration was due to differential metabolism and not to differences in any of the barriers mentioned above (Shimabukuro *et al.*, 1971).

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Selective Action of 3-(3-Chloro-4-chlorodifluoromethyl-thiophenyl)-1,1-dimethylurea (Thiochlormethyl) on Growth of Plants

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Abstract. In an attempt to survey a selectivity of 3-(3-chloro-4-chlorodifluoromethylthio-phenyl)-1,1-dimethylurea (thiochlormethyl) with a wide plant spectrum and to clarify the mechanisms of its selectivity, absorption, translocation and chemical transformation of thio-chlormethyl in plants, as well as effects on plant growth, were investigated in both root and shoot application. In root application, rice, barnyardgrass (*Echinochloa crus-galli* Beauv.) and cucumber plants were found tolerant, whereas tomato plant was shown susceptible. From the results of absorption, translocation and chemical transformation, it is suggested that selectivity of root-applied thiochlormethyl between those species of plants is apparently due to the differential concentrations of thiochlormethyl translocated in shoot parts. In shoot application, it was shown that rice plant was tolerant while tomato, cucumber and barnyard-grass plants were susceptible, and it is also suggested that the selectivity of shoot-applied thiochlormethyl was caused by the difference in concentrations of thiochlormethyl in shoot tissues. The concentrations were caused by the differential rates of both absorption and metabolism in shoots.

INTRODUCTION

Thiochlormethyl is a new herbicide that is practically used for weed control in rice. Since its effect of growth have not been widely investigated, we attempted to survey a selectivity of thiochlormethyl with wide plant spectrum and to clarify the mechanism of its selectivity.

MATERIALS AND METHODS

1-Methyl ^{14}C-labelled thiochlormethyl was used in the present study. 1) Growth test: Thiochlormetyl in definite concentrations was applied either directly to shoots or roots of plant grown under upland condition. Each species of plants used was at the 2 to 3 leaf stage. In the case of water culture, thiochlormethyl was applied either to roots through nutrient solution or to shoot parts by means of dipping method. Ten days after each application, plant was harvested and the fresh weight of shoot parts was measured. 2) Absorption, translocation and metabolism: For the root application, root parts of various species of plants were dipped in nutrient solution containing 2 ppm of ^{14}C-

thiochlormethyl. For the shoot application, shoot parts of intact plants were dipped in 2 ppm of thiochlormethyl solution for definite hours, then the plants were transferred into nutrient solution to keep further growth. After plant tissues were prepared by wet combustion method (modified Van Slyke's method), ^{14}C-radioactivities in them were estimated by a liquid scintillation spectrophotometer. For the quantitative determination of metabolic products, each preparation of roots or shoots was extracted with 80% acetonitrile. After the extracts were concentrated in vacuum, remaining aqueous solution was partitioned with chloroform and water. Then the chloroform soluble fraction was separated with TLC using chloroform and acetone (9: 1) as a developing solvent. ^{14}C-radioactivities of thiochlormethyl and its metabolites were determined.

Results and Discussion

Effects of thiochlormatyl on growth of various species of plants were shown in Fig. 1. In root application, rice, barnyardgrass and cucumber plants were found tolerant for thiochlormethyl, whereas tomato plant was shown susceptible. In shoot application, it was shown that rice plant was tolerant while tomato, cucumber and barnyardgrass plants were susceptible. As shown in Fig. 2, in studies with root-applied ^{14}C-thiochlormethyl, it was clarified that tomato and cucumber plants absorbed more than rice and barnyardgrass plants. Furthermore, the resulting concentrations of thiochlormethyl in shoots by absorption and translocation were remarkably different among those plants. Its concentrations in shoots of tomato and barnyardgrass plants were higher than rice and cucumber plants. These results suggest that the selectivity of root-applied thiochlor-

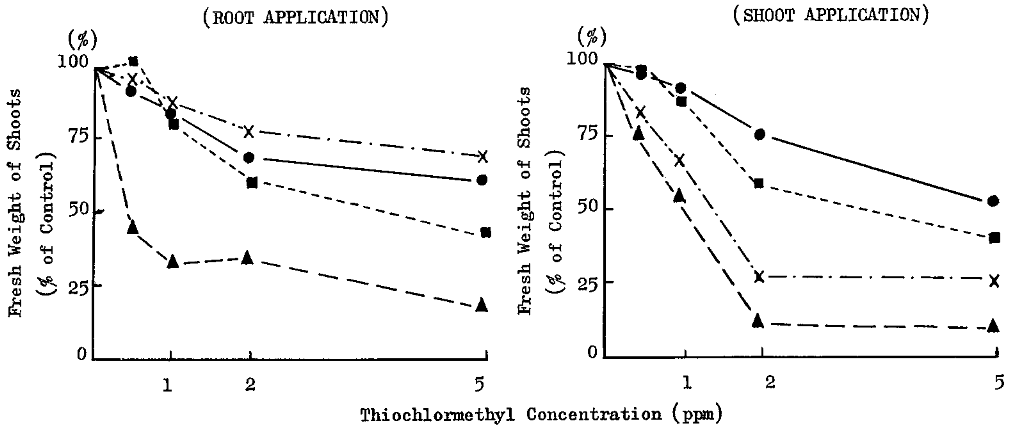

Fig. 1. Effect of thiochlormethyl on growth of rice, barnyardgrass, cucumber and tomato seedlings 10 days After application in water culture.

Root application: Plant roots were dipped in nutrient solution containing thiochlormethyl for 10 days.

Shoot application: Shoot parts of intact plants were dipped in thiochlormethyl solution for 3 hours, then the plants were transferred into nutrient solution to keep further growth.

—●— Rice, —■— Barnyardgrass, —×— Cucumber, —▲— Tomato

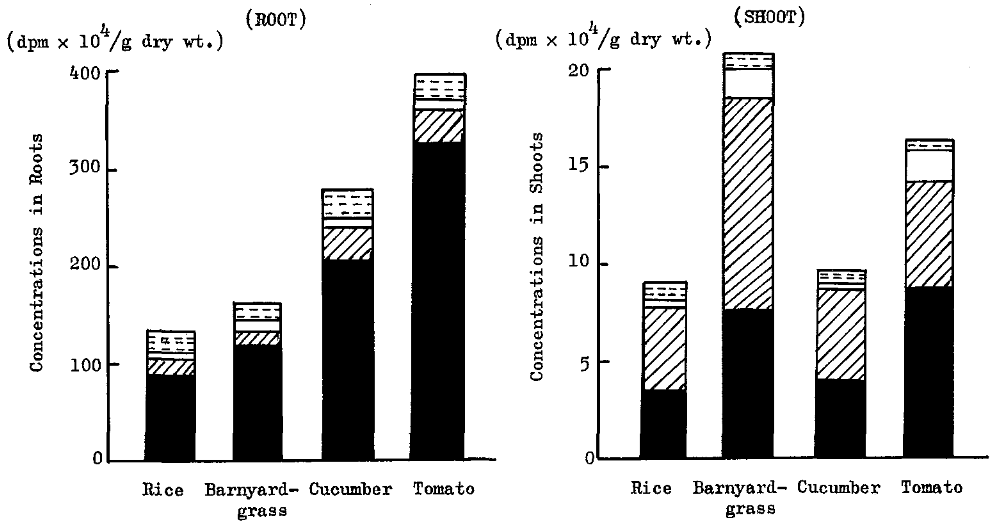

Fig. 2. Concentrations of thiochlormethyl and its metabolites in roots and shoots of rice, barnyardgrass, cucumber and tomato plants after root application.

Plant roots were dipped in nutrient solution containing ^{14}C-thiochlormethyl for 24 hours. ■ Thiochlormethyl, ▨ Chloroform soluble fraction (Others than thiochlormethyl), □ Water soluble fraction, ⊟ Unextracted fraction.

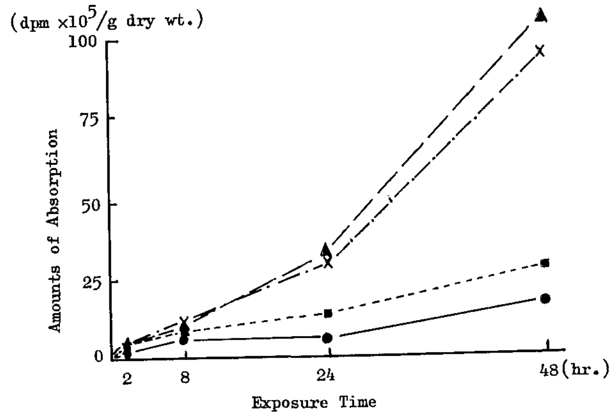

Fig. 3. Absorption of thiochlormethyl by plant shoots.

The shoot parts of intact plants were dipped in ^{14}C-thiochlormethyl solution for definite hours.

—●— Rice, —■— Barnyardgrass, —×— Cucumber, —▲— Tomato

methyl is apparently due to the difference in thiochlormethyl concentrations in the shoot tissues. The concentrations were caused by the differential rate of absorption and translocation. Absorption of thiochlormethyl in shoots of various speices of plants after shoot application was shown in Fig. 3. It was clarified that tomato, cucumber and barnyardgrass plants absorbed more than rice plant. The rates of metabolism of thiochlormethyl in shoots of various plants were shown in Fig. 4. The rate of rice plant (tolerant)

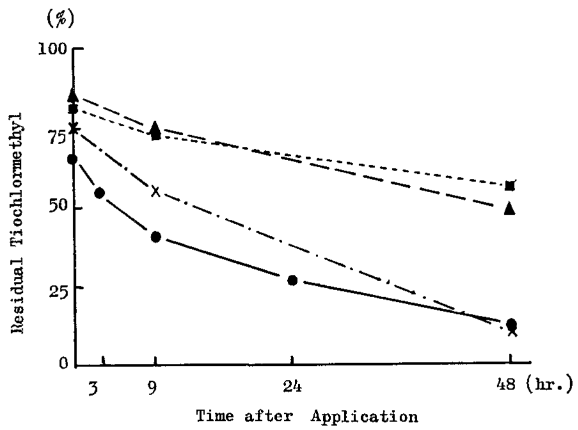

Fig. 4. Persistence of thiochlormethyl in shoots of plants after shoot application.
Shoot parts of intact plants were pre-treated by dipping in ^{14}C-thiochlormethyl solution for 3 hours.
—●— Rice, —■— Barnyardgrass, —×— Cucumber —▲— Tomato

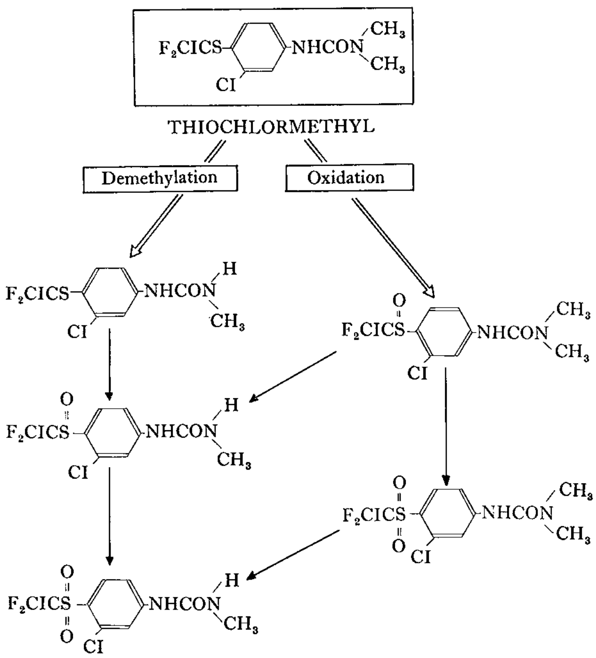

Fig. 5. Proposed metabolic pathways of thiochlormethyl in plants.

was more rapid than barnyardgrass and tomato plants (susceptible). In cucumber plant (susceptible), it was metabolized rapidly in shoots as well as rice plant. However, the concentration of thiochlormethyl in cucumber plant was obtained higher than in rice plant. These results suggest that the selectivity of shoot-applied thiochlormethyl is apparently due to the difference of concentrations in shoot tissues. In this case, its concentrations were caused by the difference in rates of absorption and metabolism in the shoot tissues. Metabolic pathways of thiochlormethyl in various species of plants were investigated. The metabolites were almost of the same kind in various species of plants, but the rates of metabolism were different among those plants. Desmethyl-thiochlormethyl, thiochlormethyl sulfoxide, thiochlormethyl sulfone, desmethyl-thiochlormethyl sutfoxide and desmethyl-thiochlormethyl sulfone were identified as metabolites. In the time course studies, desmethyl-thiochlormethyl was found as a major metabolite and formed very rapidly. The fact indicates that N-demethylation is a major metabolic process in the plants. Thiochlormethyl sulfoxide and sulfone were also detected in about a half quantity of desmethyl-thiochlormethyl. The fact indicates that thio-oxidation is one of major processes in the plants. Phytotoxicological activity of metabolites was investigated. Sulfoxide and sulfone of thiochlormethyl showed remarkably herbicidal activities, while other metabolites detected showed little. It is concluded that the selective action of thiochlormethyl is apparently due to the differential concentrations of thiochlormethyl in shoot tissues. In root application, differential rates of absorption by roots and of translocation to shoots are considered to be the dominant factors determining the shoot concentrations. In shoot application, differential rates of incorporation directly into shoots and metabolism in shoots are the dominant factors.

Selective Action of 2, 4, 6-Trichloro-4′-nitro-diphenylether (CNP) on Rice and Barnyardgrass

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Abstract. The selectivity of 2,4,6-trichloro-4′-nitro-diphenylether (CNP) in rice and barnyardgrass (*Echinochloa crus-galli* var. *oryzicola*) was studied. CNP was applied by the double pots method to the shoot and root zones separately. In shoot zone treatment, the growth of barnyardgrass seedlings was greatly inhibited, whereas that of rice seedlings was not affected much. In root zone treatment, the growth of both plants was little retarded. CNP in lower concentrations greatly stimulated oxygen uptake of rice shoots but decreased that of barnyardgrass shoots. The photosynthetic activities of chloroplasts isolated from both species of CNP-treated plants, show that in both species photosystem II was not affected and photosystem I was stimulated, but that cyclic photophosphorylation was inhibited remarkably only in barnyardgrass. The mechanism by which CNP selectively destroys barnyardgrass may be by interfering cyclic photophosphorylation, stimulating photosystem I, and decreasing oxygen uptake when the plants are exposed to light.

INTRODUCTION

CNP is extensively used as a preemergence herbicide in paddy rice fields. However, neither the mode of action of CNP nor the basis of the selectivity between rice (tolerant) and barnyardgrass (susceptible) has been explained. The objectives of the present studies were to explain the selectivity between rice and barnyardgrass in terms of their biochemistry.

MATERIALS AND METHODS

Pure CNP was used at serial concentration calculated on the basis of 100 g of oven dry soil, and 0.5 mg and 1.0 mg correspond to 5 g/a and 10 g/a in terms of field application, respectively. The herbicide was applied as a fine spray and then mixed thoroughly with the corresponding amount of auto-claved, volcanic ash soil, sieved through a 2-mm screen. Rice (var. Nihonbare) and barnyardgrass were the plant species used. Uniform seedlings, having a shoot 1 mm in length, were planted in the double plastic pots of 9 cm in diameter reported by Eshel *et al.* (1967), such that their root systems were exposed to soil in the lower pot and their shoots to soil in the upper pot. This study was conducted under controlled greenhouse conditions with a daytime temperature of 23°C and a nighttime temperature of 18°C. Oxygen uptake was determined at 30°C by the conventional Warburg method reported by Umbreit *et al.* (1957). Photosystem I activity was estimated from the rate of O_2-linked $DCIPH_2$ photooxidation measured by the method reported by Izawa (1968). Photosystem II activity was estimated from the rate of DPIP photoreduction. Cyclic photophosphorylation was measured using a modification of Avron's method (1960). Carbon dioxide fixation was determined by exposing plants to $^{14}CO_2$ and light for 3 hours in a plastic chamber in the green house.

Results and Discussion

Shoot zone treatment greatly inhibited the growth of barnyardgrass seedlings after emergence, whereas it did not affect much that of rice seedlings (Fig. 1). However, root zone treatment did not affect the growth of either plant as compared with controls (Table 1). Furuya *et al.* (1966) reported the same results. The growth of both plants, especially the rice shoots, was stimulated rather than inhibited by CNP. Therefore, CNP selectivity acts on barnyardgrass by affecting its shoots.

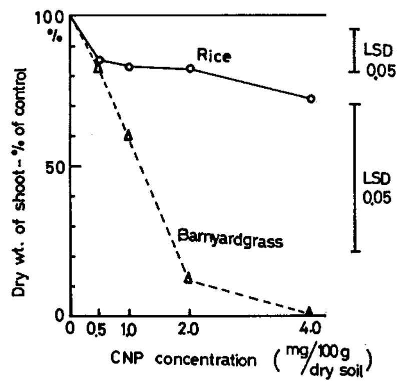

Fig. 1. Effect of exposing only the shoots of rice and barnyardgrass seedlings to CNP-treated soil using double-pot to prevent movoment of herbicide.
In this experiment the depth of the treated soil above the seeds was 2 cm.
Dry weight were taken 12 days after planting.

To clarify the biochemical mechanism of action of CNP, the difference in plant metabolism caused by CNP was investigated. Since CNP causes a rapid wilting of the shoot after the emergence, oxygen uptake was measured as a first step. Fig. 2 shows, in darkness CNP stimulates the rate of oxygen uptake in both rice and barnyardgrass, but CNP does not cause any difference in their rates of growth. The oxygen uptake of rice shoots increased with increasing hours of illumination except when a high concentrations of CNP was used, but oxygen uptake of baryardgrass shoots decreased with increasing hours of illumination. This is similar to the behaviour of the shoots of plants which have been infected with a disease: the shoots of those plants which are resistant to the disease increase their oxygen uptake but those susceptible to it decrease their oxygen uptakes. However, although oxygen uptake of the shoots of rice increased and

Table 1. Effect of exposing only the roots of rice and barnyardgrass seedlings to CNP-treated soil using a double-pot to prevent movement of herbicide.

Plant	CNP concentration (mg/100 g dry soil)	Growth		Oxygen uptake of excised roots		
		10 days after planting		Days after planting		
		Shoot wt. (%)	Root wt. (%)	5 (%)	10 (%)	10* (%)
Rice	1.0	126	106	104	104	104
	2.0	120	111	107	92	73
	4.0	128	103	121	100	59
Barnyardgrass	1.0	114	114	104	101	94
	2.0	116	98	98	75	52
	4.0	104	102	115	78	53

Data are expressed as % of control.

* After washing off the soil, intact seedlings in distilled water were exposed to the sunlight for 8 hours.

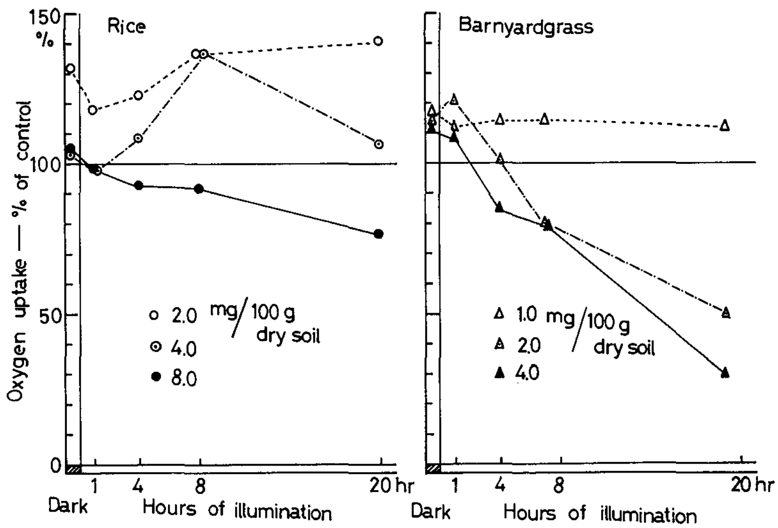

Fig. 2. Time-course of oxygen uptake of the excised shoots exposed to CNP-treated soil. Rice and barnyardgrass whose shoots were exposed to CNP-treated soil, were germinated in darkness, and were then continuously illuminated by metal haloid lamps.

that of the shoots of barnyardgrass decreased with increasing time of illumination, the oxygen uptake of the roots of both these plants always decreased after the direct illumination to root for 8 hours (Table 1). From these results, we conclude that CNP exerts herbicidal activity in the presence of light. Arai *et al.* (1966) and Matsunaka (1969) reported that 2,4-dichlorophenyl-4′-nitro-phenyl ether (nitrofen) required light for herbicidal activity. Matsunaka (1969) also reported that diphenylether herbicides, such as nitrofen and CNP having ortho-substituent(s) on one benzene ring, required light for phytotoxicity. CNP showed increasing herbicidal activity with increasingly intense

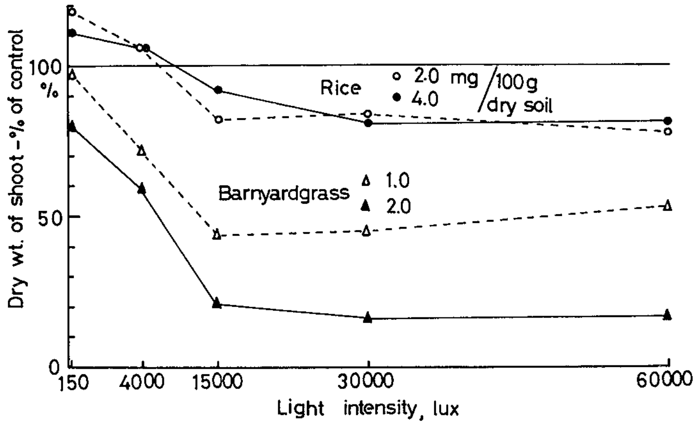

Fig. 3. Effect of light intensity on rice and barnyardgrass grown in soil treated with CNP in shoot zone.

Dry weights of foliage were taken 15 days after planting and are expressed as a percent of the dry weights of plants not treated with the herbicide but grown under the same conditions.

illumination as shown in Fig. 3. Light with an intensity of from 150 to 4,000 lux stimulated the growth of CNP-treated rice. Light with an intensity in the range from 15,000 to 60,000 lux slightly decreased the growth of CNP-treated rice, but by the same amount at all intensities in this range. However, increasing light intensity greatly decreased the growth of CNP-treated barnyardgrass. The authors (1975) reported the longer the exposure to the light after seedling emergence, the greater the phytotoxicity to barnyardgrass. This phytotoxicity could hardly be detected immediately after the emergence of CNP-treated rice and barnyardgrass. After the rice and barnyardgrass have been illuminated for some time, the barnyardgrass wilts rapidly. The phytotoxicity of CNP

Table 2. Effect of exposing only the shoots to CNP-treated soil on photosynthetic activities of chloroplasts isolated from rice and barnyardgrass.

Plant	CNP concentration (mg/100g dry soil)	Relative Activities-% of control			Dry wt. of shoot
		PS-I* (%)	PS-II* (%)	Cyclic P.P.* (%)	(%)
	1.0	95	136	80	94
Rice	2.0	119	125	69	84
	4.0	157	134	79	78
Barnyardgrass	0.5	161	100	85	85
	1.0	169	87	35	61

* PS-I, PS-II, and cyclic P.P stand for photosystem I, photosystem II, and cyclic photophosphorylation, respectively. Chloroplast was isolated 10 days after planting.

Non-treated, chloroplast (i.e. control) activities of PS-I, PS-II, and cyclic P.P in rice were 430 μmloes O_2/mg chl/hr., 110 μmoles DPIP reduced/mg chl/hr., and 220 μmoles of ATP formed/mg chl/hr., respectively and in barnyardgrass 200 μmoles O_2/mg chl/hr., 70 μmoles DPIP reduced/mg chl/hr., and 130 μmoles of ATP formed/mg chl/hr., respectively.

Table 3. Effect of exposing only the shoots of rice and barnyardgrass seedlings to CNP-treated soil on $^{14}CO_2$ fixation and dry weight of shoots.

Plant	CNP concentration (mg/100 g dry soil)	8 days after planting (1.4 L)		11 days after planting (2.0 L)	
		$^{14}CO_2$ fixation (%)	Dry wt. of shoot (%)	$^{14}CO_2$ fixation (%)	Dry wt. of shoot (%)
Rice	1.0	126	103	100	94
	2.0	54	100	71	96
	4.0	47	81	69	88
		6 days after planting (1.4 L)		10 days after planting (2.3 L)	
Barnyardgrass	0.5	104	79	113	97
	1.0	85	69	86	56
	2.0	24	37	87	24

Data is expressed as a percent of fixation and growth of controls.

requires the formation of chlorophyll. Matsunaka (1969) reported that a natural albino mutant was tolerant to nitrofen in light.

The effects of CNP on the photosynthetic activities were investigated with chloroplasts isolated from CNP-treated rice and barnyardgrass. Photosystem II was stimulated approximately 30% in rice as compared with the control, while in barnyardgrass a slight inhibition was observed. Photosystem I was stimulated greatly as the amount of CNP increased, and cyclic photophosphorylation was inhibited remarkably in barnyardgrass, but slightly in rice (Table 2). $^{14}CO_2$ fixation of intact plants is shown in Table 3. Although $^{14}CO_2$ fixation of both rice and barynardgrass at the 1.4 leaf stage was inhibited by higher concentrations of CNP, the dry weight of the rice shoot did not decrease much at these CNP concentrations, but that of barnyardgrass did. And this decrease of dry weight was caused by factors other than the inhibition of $^{14}CO_2$ fixation. $^{14}CO_2$ fixation of barnyardgrass returned to the control level after the 2.0 leaf stage.

The actions of CNP are quite complex and cannot be explained easily and completely without conducting experiments on absorption, translocation, and chemical transformation in plants. Additional studies such as on the effect on oxidative phosphorylation are required before the site of action of CNP can be comprehended completely. From this report, however, we conclude that strong interference with cyclic photophosphorylation accompanied with stimulation of photosystem I and a decline of oxygen uptake by the illuminated barnyardgrass could be one of the mechanisms through which CNP selectively destroys barnyardgrass.

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Basis for Selectivity of K-223 among Several Plants

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Abstract. The comparative studies on absorption, translocation and metabolism of the new urea herbicide, 1-(α,α-dimethylbenzyl)-3-*p*-tolylurea (K-223), were conducted to determine factors associated with the selectivity among several tolerant and susceptible plants. The results may be briefly summarized in the following three: (1) the tolerance of pea and cucumber plant may be attributable to their capacity for metabolize the herbicide to polar conjugates, (2) the differential distribution which lowered the effective concentration of the herbicide in the shoot and root meristems may be closely related to the tolerance of rice plant, (3) the susceptibility of purple nutsedge (*Cyperus rotundus* L.) appears to be correlated with a combination of factors of accumulation within meristematic sites of tuber and the ability to metabolize the herbicide.

INTRODUCTION

A new urea herbicide, K-223, controls effectively many Cyperaceous weeds, such as umbrellaplant, slender spikerush and bulrush in paddy field and purple nutsedge on uplands, while it is ineffective against most broad-leaved weeds. Field tirals showed marked tolerance of many useful crops (Takematsu *et al.*, 1975). Although specific reports concerning the mode of action of this chemical are not found, it appears to exerting its effects on meristematic sites in some way which may be related with cell division (Takematsu *et al.*, 1974). The purpose of this investigation was to determine the basis for the selectivity among plants by studying absorption, translocation and metabolism of K-223 by three tolerant plants; rice, pea and cucumber plant and a susceptible plant; purple nutsedge.

MATERIALS AND METHODS

^{14}C-K-223. K-223 labeled at carbonyl carbon with carbon-14 was synthesized. Its radiochemical purity was above 99% and the specific activity was 5.6 μCi/mg.

Plant materials and treatments. Rice plant, pea, and cucumber seeds were germinated, transplanted and grown in an environmental chamber. Purple nutsedge tubers were obtained from stock plants in pots outdoor and sprouted in a growth chamber. Seedlings at the 3 to 4 leaf stage were treated with ^{14}C-labeled K-223 by soaking the roots in culture solution containing the herbicide. The treatment of purple nutsedge was done by soaking about half part of tuber with roots in the herbicide solution. All experiments were carried out without aeration.

Radiochemical assays. At different time intervals, the test plants were harvested and sectioned into desired fractions. Each part was homogenized with methanol. After filtration, the amounts of radioactivity in each extract was determined. The insoluble residue was dried and combusted by oxygen flask method. Quantitative measurement of radioactivity was made on a liquid scintillation spectrometer. The methanol extracts, after radioassay, were concentrated under reduced pressure and redissolved in a small volume of 90% methanol suitable for TLC analysis. The radioactive materials were separated by thin-layer chromatography using 20×20 cm glass plates precoated with 250 μ Merck silica gel GF_{254}. Authentic synthesized compounds were co-chromatographed on each chromatogram for comparison with unknowns in plant extracts. After development, the plates were radioscanned to locate radioactive areas and autoradiographed. Individual spots were scraped from the plates into counting vials and assayed.

Results and Discussion

Uptake and distribution study. i) *Time-course experiments.* Fig. 1 shows the amounts of ^{14}C-radioactivity uptaked from the roots and ^{14}C-distribution patterns in the plant parts. K-223 was uptaked easily and translocated into the shoots of all tested plants. Aerial parts of rice and pea plant contained more quantities of ^{14}C than root parts, but distribution of ^{14}C in the intercalary meristem zones of rice plant was of slight extent (Table 1). Autoradiographic data also indicated the translocation patterns characteristic of an acropetal translocation following root absorption, but ^{14}C-distribution patterns in

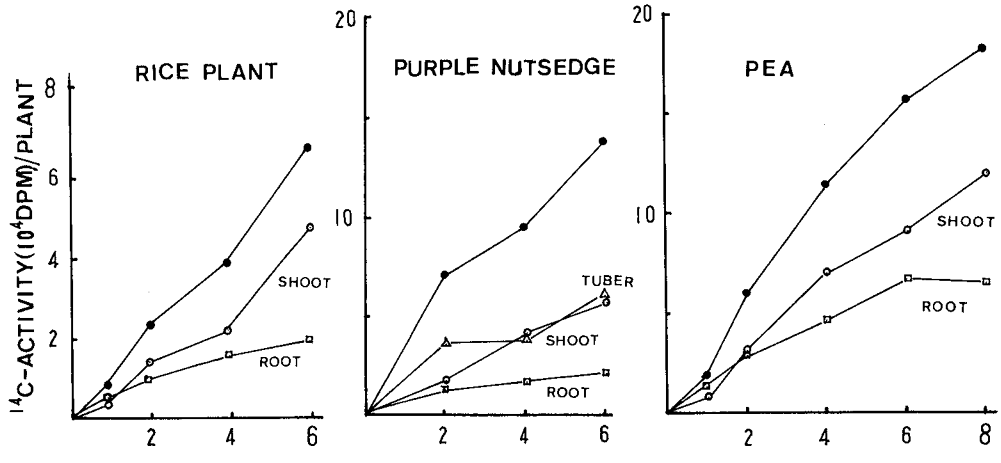

Fig. 1. Uptake and translocation of ^{14}C-labeled K-223 by rice, pea and purple nutsedge plants root-treated with 0.4 ppm concentration[a].

[a] The amounts of ^{14}C-radioactivity was determined by combining the radioactivity found in methanol extract and insoluble residue.

tissues were different among species. Rice plant exhibited an unique distribution of ^{14}C in lower leaves and stems with an accumulation in the intercellular spaces. Pea plant also exhibited similar distribution with a tendency to accumulate at the leaf margins. The ^{14}C-label incorporated into purple nutsedge tuber was detectable only at or near the surface.

ii) *Pulse time-course experiments.* A noticeable phenomenon was the leakage of ^{14}C-label from rice roots into the external culture solution (Table 2). Additional experiments indicated that loss of ^{14}C-label by leakage was maximum during the first 2 day interval and about half of the initialy uptaked radiocarbon was lost by leakage (Table 3). On the other hand, the underground organs of nutsedge have been retained a large portion of ^{14}C during experiment period. Thus, the differences of absorption could not explain wide difference in susceptibility among the plants, but the differential distribu-

Table 1. Percentage distribution of ^{14}C in rice plants at different time intervals following root uptake from nutrient solution containing 0.4 ppm of ^{14}C-labeled K-223.

	Plant parts	Days of treatment			
		1	2	4	6
Rice plant	Rest of shoots	36.7	58.8	55.8	69.6
	Intercalary meristem zones	4.9	1.7	2.9	2.3
	Roots	58.4	37.5	41.3	28.3

Table 2. Percentage distribution of ^{14}C in rice and purple nutsedge plants pretreated with ^{14}C-labeled K-223 for 3 days.

Species	Plant parts	Days after treatment			
		0	2	4	8
Rice plant	Shoots	63		65	63
	Roots	37		16	13
	Culture solution			19	24
Purple nutsedge	Shoots	25	18	14	29
	Tubers	47	59	54	47
	Roots	28	23	32	24

Table 3. Radioactivity released in culture solution from rice roots[a].

Time interval days	^{14}C released[b] ($\times 10^4$ cpm/two plants)	% of initially uptaked ^{14}C
0—2	2.58	41.8
2—4	3.00	48.6
4—6	3.23	52.4

[a] The ^{14}C-K-223 (0.4 ppm) Kasugai's solution was removed and replaced with fresh solution after 3 days.

[b] Radioactivity released in 100 ml of culture solution from two rice plant roots was determined at 2 days interval. Values are the mean of seven experiments.

tion appeared to be an important factor for the species selectivity. The ^{14}C-leakage phenomenon may play a significant role in the tolerance of rice plant under paddy field condition.

Qualitative and quantitative metabolic study. TLC autoradiograms of methanol soluble ^{14}C-materials of various plant parts exhibited several radioactive spots. Among these, compounds of Rf 0.16, 0.26 and K-223 were tentatively identified by thin-layer co-chromatography with authentic standards (Table 4). The major polar component (Rf 0) was fractionated from pea root methanol extracts by a modified Bligh-Byer extraction procedure (Still *et al.*, 1971; 1973) and partly purified through XAD-2 (Amberite) ad-

Table 4. Percentage distribution of ^{14}C-labeled compounds in various plant sections[a].

Rf [b]	Compound	Cucumber		Pea		Rice plant		Purple nutsedge		
		Root	Shoot	Root	Shoot	Root	Shoot	Root	Tuber	Shoot
0.93	Unknown	2.0				0.9**				
0.85	Unknown	3.4								
0.79	K-223	56.2	61.5	40.9	64.3	94.5	44.4	75.1	87.0	61.7
0.48	Unknown	2.4								
0.26	Hydroxymethyl derivative[c]	1.3	3.4	3.5*	2.6*	1.5*	5.2	11.0*	2.3*	6.7*
0.16	*p*-Tolylurea	5.7	3.9				5.1			
0.00	Polar materials	29.1	31.1	55.6	33.1	3.2	45.3	13.7	10.6	31.5

[a] Determined by TLC of methanol extracts from the plants after 3 days root absorption of ^{14}C-labeled K-223.
[b] Solvent system: n-hexane-toluene-acetone (1 : 1 : 1).
[c] This represents 1-(α, α-dimethylbenzyl)-3-*p*-hydroxymethylphenylurea.
*, ** The ^{14}C-activity in area of Rf 0.16–0.26 and Rf 0.85–0.93 was determined.

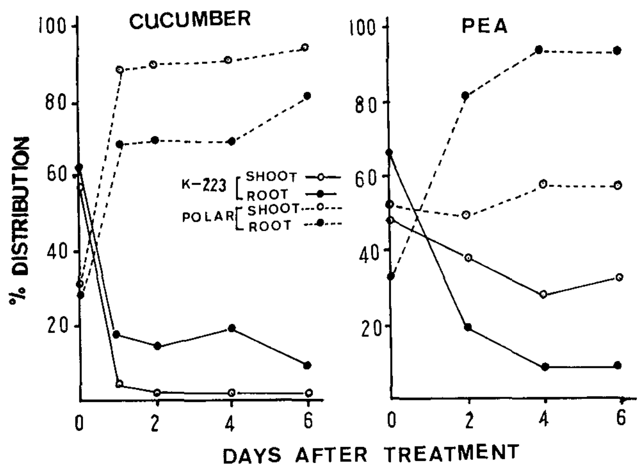

Fig. 2. Pulse time-course of distribution of ^{14}C between K-223 and polar metabolites in pea and cucumber plants[a].

[a] The ^{14}C-labeled K-223 Hoagland's solution was removed and replaced with fresh nutrient solution after 3 days.

Table 5. Time-course of degradation of K-223 in rice and purple nutsedge plants[a].

Species	Plant parts	Days after treatment				
		0	2	4	6	8
Rice plant	Shoots	59	53	54	48	
	Roots	87	83	80	79	
	Culture solution		14		28	
Purple nutsedge[b]	Shoots	60		41		25
	Tubers	86		61		49
	Roots	75		70		57

[a] The plants were pretreated for 3 days with 1.5 ppm of ^{14}C-K-223. Values given under each part are expressed in terms of percentage of K-223 in methanol extractable ^{14}C-materials.
[b] The observed symptoms of purple nutsedge was an extreme inhibition of root growth, but the growth of shoot was not so inhibited as a control.

sorption, Sephadex LH-20 column chromatography and preparative TLC using silica gel. Enzymatic hydrolysis with β-glucosidase gave an aglycone. Identification of the aglycone was established by thin-layer co-chromatography and the comparative study of its chemical property with a synthesized authentic compound, 1-(α,α-dimethylbenzyl)-3-*p*-hydroxymethylphenylurea.

Pulse time-course experiments indicated that pea root tissues metabolize K-233 rapidly to polar conjugates. The degradation of the herbicide was much more rapid in cucumber tissues. The results are shown in Fig. 2. Thus, the ability to metabolize the herbicide to polar materials appeared to play an important role in the tolerance of pea and cucumber plant.

The tolerance of rice plant appeared not to be attributable to metabolism within the limit of the present experimental data (Table 5). However, we presume K-223 was rapidly metabolized after absorption, but metabolites was not tightly held in the root tissues, because sizable amounts of ^{14}C-materials other than the parent herbicide were detected in the external culture solution. Further detailed study will be required to evaluate the ability of rice plant root to metabolize K-223. Although purple nutsedge tuber has a mechanism capable of metabolize K-223, the rate of degradation was slow. The susceptibility of purple nutsedge appeared to be correlated with a combination of factors of accumulation within meristematic sites of the tuber and the ability to metabolize the herbicide.

Acknowledgments

We wish to thank Dr. Y. Omura for many useful suggestion during the course of this work, we also would like to acknowledge the considerable assistance of Mr. N. Seki.

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Fate of Oxadiazon in Rice Plants

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Abstract. Absorption, translocation and metabolism of 2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazolin-5-one (oxadiazon) in rice plants were investigated. Oxadiazon was applied a day before transplanting to soil under submerged conditions in 1/2000 are-sized pots. Supplementarily water culture of rice plants was conducted. Root-applied oxadiazon was translocated to shoots and accumulated in the lower leaves and stems more heavily than in the upper. Oxadiazon was chemically transformed to several metabolites in rice plants, main of which were identified as dealkylated and oxidized compounds of side-chains (alcohols or carboxylic acids) and cleaved compounds of oxadiazolin-ring. In harvest time a extremely small portion of oxadiazon was translocated to ears. Metabolites of oxadiazon in ears were quantitatively estimated and a cleaved compound of the oxodiazolin-ring was found most. Translocation barriers for these compounds are postulated inbetween stems and ears.

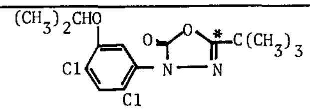
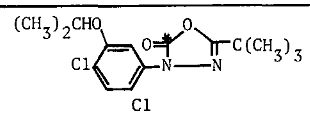
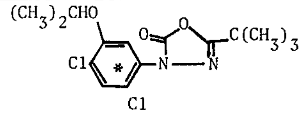
Introduction

Oxadiazon which contains a N-heterocyclic ring structure, is a new type of herbicide in regard to chemical structure and few works have been published on its behavior in plants. In the present work the fate of oxadiazon in rice plants is studied with respect to its absorption, translocation and metabolic transformation concerned with the development and growth of the rice plants.

Methods and Materials

Three types of oxadiazon labelled with carbon-14 at the different positions in the molecule were used (Table 1). Three mg of the oxadiazon (Oxa-1, Oxa-2 or Oxa-3) were applied to 1/2,000 are-sized pots which were filled with submerged soil and tried to be distributed evenly in soil of 5 cm below the surface by stirring the soil layer. A day after the application of oxadiazon, rice seedlings at the 4 to 5 leaf-stage were transplanted and submerged water was kept 3 cm deep. The plants were grown to the ripening stage in a controlled phytotron. Plants were sampled for preparations of radioautography and metabolism studies 1, 2, 3 and 4 weeks and 2, 4 and 5–6 months after transplanting. Metabolic products were investigated quantitatively and qualitatively by means of TLC, GLC and ^{14}C-radioactivity determination in addition to MS, NMR, IR and chemical synthesis.

Table 1. Radiochemical properties of ^{14}C-labeled oxadiazon.

Abbreviation	^{14}C-Labeled oxadiazon		Specific-activity	Radiochemical purity
O x a - 1	oxadiazolin-2-^{14}C		1.8 mCi/m mole	99 %
O x a - 2	oxadiazolin-5-^{14}C		42 mCi/m mole	97.5%
O x a - 3	phenyl-U-^{14}C		0.57mCi/m mole	99 %

* Indicates the position labeled with carbon-14.

Results and Discussion

It was observed that oxadiazon once intaken into root tissues was considerably translocated to shoots. In shoots oxadiazon was distributed in aged leaves more heavily than in younger leaves. Acropetal translocation was observed, while a little basipetal translocation was detected in both blades and sheaths. A heavy accumulation of compounds was found in the areas of brown spot symptoms on the young leaf-sheaths. Total amounts of oxadiazon included metabolites in plant tissues at various stages of growth and development are shown in Table 2. Concentrations of oxadiazon decreased in the plant parts in the order: leaves and stems $\gg$ husks $\gg$ hulled grains. Metabolic transformation of oxadiazon once incorporated into plants was surveyed and the 4-phenyl-1,3,4-oxadiazolin-5-one structure of oxadiazon was found to be fairly stable. Metabolic reactions in plants occurred mainly in the side-chains of oxadiazon. Amounts of oxadiazon and its metabolites at harvest time are shown in Table 3. Since M-1, a cleaved metabolite of the oxadiazolin-ring, was clarified as one of the major metabolites in ears, distribution of oxadiazon and M-1 was investigated in detail (Table 4). In field experiments, the amounts of M-1 as well as oxadiazon existing in hulled grains was confirmed

Table 2. Total amounts (ppm) of oxadiazon included metabolites in plant tissues at the various growth stages.

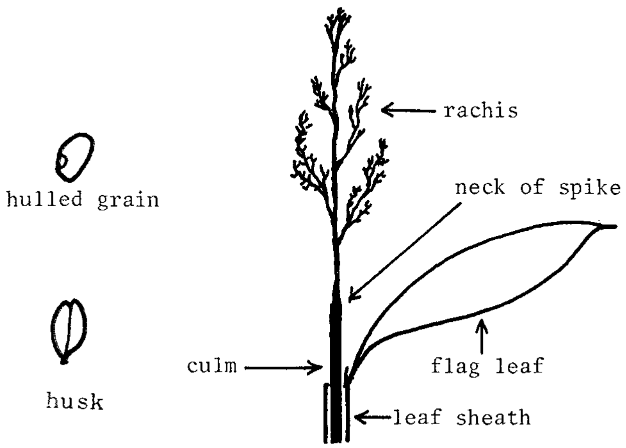
Oxadiazon	Months after transplanting 1	2	At harvest time		
	Shoot	Shoot	Straw	Husk	Hulled grain
Oxa-1	0.56	1.31	0.74	0.040	0.0099
Oxa-2	1.27	1.29	1.14	0.022	0.0039
Oxa-3	1.79	1.21	0.81	0.045	0.0080

Table 3. Accumulation of oxadiazon and its metabolites in rice plants.

Compounds	Percentage of radioactivities of oxadiazon and its metabolites (%)						
	Oxa-1		Oxa-2			Oxa-3	
	Straw	Husk	Straw	Husk	Grain	Straw	Husk
Oxadiazon	84.3	52.7	78.0	32.6	22.0 (19.6)*	76.0	48.2
A-2	—	—	2.0	5.6	—	—	—
A-3	4.6	—	3.6	5.0	—	4.6	—
A-6**	3.4	5.0	7.0	3.3	22.9	3.5	3.4
A-8	—	—	2.5	4.8	—	—	—
M-1	4.9	31.1	5.6	46.2	46.5	9.8	36.1
M-2	—	—	1.3	2.5	—	—	—
Others	2.8	11.2	—	—	—	6.1	12.3

* Determined by isotope dilution method (oxadiazon in grains).
** A-6 is a fraction found in the origin-locationin TLC.

Table 4. Distribution of oxadiazon and its metabolites M-1 in tissues of rice plants.



Compounds	Concentration (ppm) of oxadiazon and its metabolite M-1				
	Leaf sheath + flag leaf	Culm	Rachis	Husk	Hulled grain
Oxadiazon	0.479	0.216	0.129	0.008	0.001
M-1	0.018	0.008	0.012	0.010	0.002

less than 0.5 ppb (the detectable limit by GLC). It was concluded that oxadiazon and M-1 were translocated from stems to ears at different rates from each other. Metabolic transformation of oxadiazon in rice plants are proposed as shown in Fig. 1.

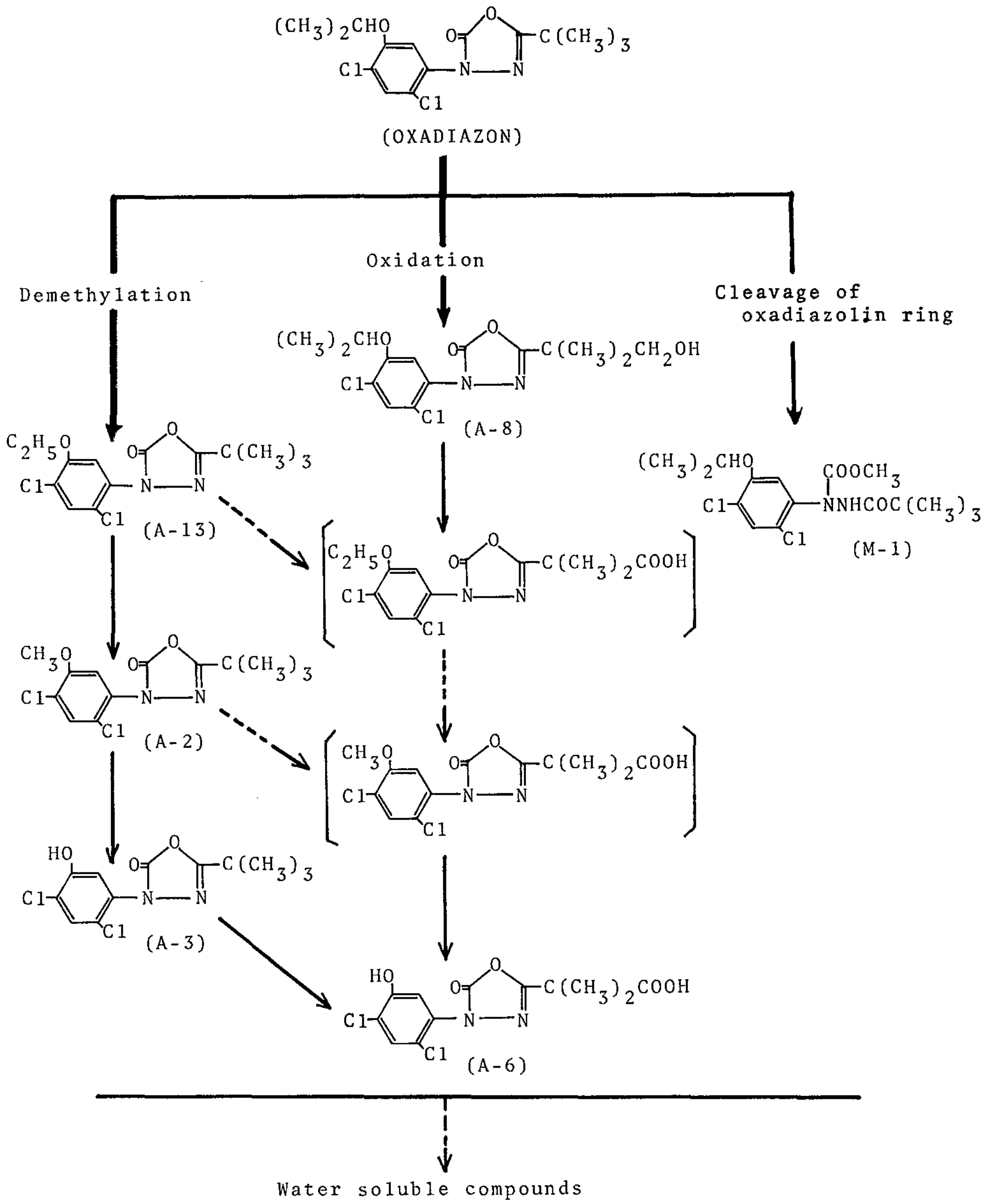


Fig. 1. Proposed metabolic pathways of oxadiazon in rice plants.
——→, identified; -----→, assumed; [compounds], assumed.

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Evolution of Residual Oxadiazon in Crops (Rice and Soybean) and in a Weed (*Echinochloa crus-galli* Beauv.)

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Abstract. Plants growing in soil treated with labelled oxadiazon (2-*tert*-Butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazoline-5-one) absorb only small amounts of the herbicide (1 to 5% of the applied material). The herbicide can be absorbed by any parts of the plants in contact with treated soil. Compound taken up by aerial part can induce phytotoxic reactions (herbicidal action) but is not translocated; on the contrary oxadiazon absorbed by roots is well translocated to the rest of the plant but generally no phytotoxic reactions occur.

Oxadiazon is accumulated in older parts of the plant and very little is found in the growing point; quantities present at harvest in seeds are very low (0.01 to 0.02 ppm).

Qualitatively, oxadiazon represents more than 90% of total residues, and the main metabolite, 26,806 R.P., 50 to 70% of the remaining radioactivity.

INTRODUCTION

Oxadiazon is a polyvalent herbicide active both pre- and post-emergence (Burgaud *et al.*, 1969). It has proved to be selective in several crops for exemple rice and soybean.

We have carried out studies in greenhouse in order to examine the behaviour of the herbicide in plants and soil. Our work was conducted with three types of ^{14}C labelled oxadiazon:

Spec. act. 39 mCi/mMol labelled on $\overset{*}{C}{=}O$ position (27,185 R.P.).

Spec. act. 1.78 mCi/mMol labelled on $\overset{*}{C}{-}C(CH_3)_3$ position (27,667 R.P.).

Spec. act. 25.87 mCi/mMol labelled on the phenyl ring (29,873 R.P.).

For the treatments, labelled material was diluted with "cold" oxadiazon.

In this report we have only studied the uptake and the translocation of radioactive materials in two crops: rice and soybean and a weed: *Echinochloa crus-galli* grown in treated soil.

MATERIALS AND METHODS

Soils. Three soils were used. Analyses are shown in Table 1. Soil 1 is a clay loam,

Table 1. Granulometry of soils used in tests.

		(% of fine soil)		
		Soil 1	Soil 2	Soil 3
Clay	<2 microns	23	6.0	13.0
Silt	2–20 microns	16	11.0	11.0
Fine sand	20–50 microns	27.8	19.6	22.3
Sand	50–200 microns	15	46.0	6.0
Coarse sand	>200 microns	15	16.0	34.0

Remark: The complement to 100% correspond to organic matter and total carbonates.

soil 2 a sandy loam and soil 3 a garden soil with a high organic matter content (7%).
Plants. Rice—variety IR 8, Soybean—variety Clark K 63. *Echinochlos crus-galli* Beauv. were collected in the south of France.

Plants and soils were kept in a green house in the following conditions:

—Natural and artificial light giving 6,000 lux on the surface of the soil or on the plants.

—Illumination 16 hours every day.

—Temperature: during the day 24±2°C, during the night 18±2°C.

The soils were watered every day and maintained at about 80% of their maximum water capacity.

Treatments. Soils were treated by incorporation, sprinkling or spraying of water emulsions of labelled mixture of oxadiazon.

Extraction. Plants were carefully collected, and fractionnated into the different samples: roots, stems, leaves, shoots for instance. Each sample was ground and extracted with a mixture of acetone and methyl alcohol. The organics solutions were dried on anhydrous sulfate, evaporated to dryness at medium temperature (30 to 40°C) and the residues dissolve in methyl alcohol for radioassays:

—Thin layer chromatography and autoradiography.

—Counting by scintillation—Tri-carb liquid scintillation spectrometer.

—Combustion—when direct countings were not possible because quenching was too important, extracts were burnt in an oxidizer Model 306 and $^{14}CO_2$ trapped and counted by usual methods.

Results

Rice and Echinochloa. Important studies on metabolism of oxadiazon in rice have been conducted in Japan by Ishizuka and Hirata (1976), so we have only compared the uptake and translocation of the herbicide in the two species.

Soil (No. 3) was treated by incorporation or sprinkling of water emulsions of labelled oxadiazon. The final concentrations of herbicide in the soil were:

—1.2 and 3.6 ppm when incorporated,

—1 and 3 ppm when sprinkled.

The plants (15 cm high, 4 leaves) were transplanted in the treated soil and were

Table 2. Oxadiazon in plants grown in treated soil.

Treatment	Oxadiazon in soil (ppm)	Interval (a)	ng/plant and ppm of total oxadiazon							
			Rice				*Echinochloa* (c)			
			Roots		Shoots		Roots		Shoots	
			ng	ppm (b)	ng	ppm	ng	ppm	ng	ppm
Inc.	1.2	21	35	0.015	36	0.012	45	0.015	510	0.171
		28	22	0.013	75	0.025	40	0.018	820	0.216
	3.6	21	45	0.025	58	0.030	47	0.021	250	0.311
		28	42	0.021	60	0.028	61	0.029	125	0.250
Spr.	1	21	80	0.036	39	0.016	55	0.027	160	0.160
		28	55	0.031	44	0.015	47	0.021	55	0.121
	3	21	40	0.015	40	0.025	52	0.015	255	0.515
		28	42	0.021	65	0.031	73	0.031	440	0.914

(a) Interval=days between transplantation and sampling.
(b) ppm are expressed in terms of $\mu g/g$ freshweight.
(c) Phytotoxic reactions were very important and plants were moribond even at the low concentration.

kept in the green house for 21 and 28 days. At sampling, plants where extracted for counting. Results are shown in Table 2.

Discussion: Oxadiazon was absorbed by roots and translocated in to the shoots and the leaves; however concentrations are generally very low: about 0.03 ppm. In rice we found this same concentration in roots and in aerial parts; on the contrary, in *Echinochloa*, we also found this same concentration in the roots but in the leaves concentrations in oxadiazon were 5 to 10 times higher (generally 0.2 ppm but even 0.9 ppm). So, in a susceptible plant, translocation from roots to shoots is very important: a such phenomenon can explain the susceptibility of this weed to oxadiazon.

Soybean. Three different experiments were conducted in order to determine the relative importance of uptake by cotyledons and roots, the translocation and the distribution of oxadiazon in the roots, the leaves, the pods and the seeds.

Uptake and translocation of oxadiazon: Incorporation. Soils (Nos. 1, 2 and 3) were treated by incorporation of oxadiazon in order to obtain a concentration of 4 ppm of herbicide in the soils. Treated soils were partitioned between 180 ml plastic pots in three differents ways (Fig. 1):

—A—treated soil under et above the seeds,

—B—treated soil above the seeds,

—C—treated soil under the seeds.

Pots were kept in the green house and at about 1 week intervals soybean plants were picked up and extracted in order to measure radioactivity in:

1—aerial part above the cotyledons=the *shoot,*

1—the *cotyledons,*

3—aerial part under the cotyledons=the *hypocotyl,*

4—the *roots,*

Results are summarized in Table 3.

We have studied the distribution of oxadiazon in "the shoot" at the last sampling.

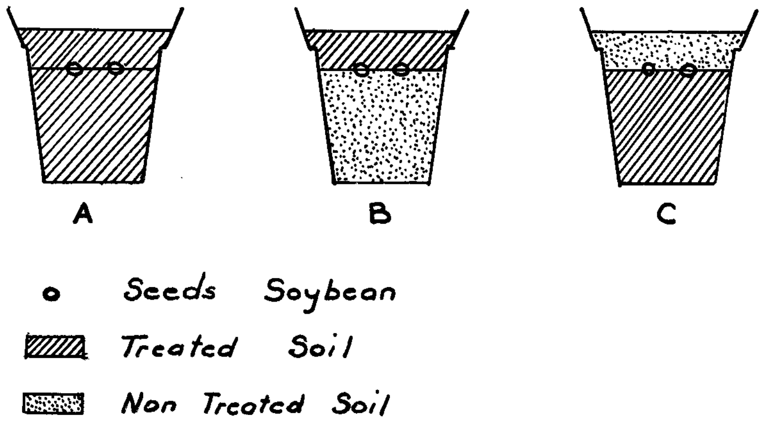


Fig. 1

Table 3. Treatment by incorporation—concentrations and distributions of oxadiazon amounts in various organs of soybean.

Soil &	Trt.	Organ	D=8 (a)		D=14 (a)		D=20 (a)		D=27 (a)		D=33 (a)	
			ng	% (b)	ng	% (b)	ng	% (b)	ng	% (b)	ng	% (b)
Soil I:	A	Shoot	10	2	159	13	542	25	1,527	40	1,694	32
		Cotyledons	159	28	254	20	189	9	—	0	—	0
		Hypocotyl	79	14	209	17	347	16	377	10	341	6
		Roots	316	56	639	50	1,050	50	1,926	50	3,317	62
		Total	564	100	1,261	100	2,128	100	3,830	100	5,352	100
	B	Shoot	8	2	60	17	39	9	211	28	169	30
		Cotyledons	234	60	167	48	181	40	—	0	—	0
		Hypocotyl	86	22	76	23	102	23	62	8	64	11
		Roots	61	16	40	12	131	28	474	64	326	59
		Total	389	100	346	100	453	100	747	100	559	100
	C	Shoot	23	3	179	13	477	20	1,134	37	1,064	37
		Cotyledons	104	14	108	8	265	11	—	0	—	0
		Hypocotyl	134	18	235	18	320	14	304	10	215	7
		Roots	470	65	813	61	1,312	55	1,605	53	1,592	56
		Total	731	100	1,335	100	2,374	100	3,043	100	2,871	100
Soil II:	A	Shoot	24	2	497	18	1,485	30	2,166	35	2,944	36
		Cotyledons	540	36	759	27	1,037	21	—	0	—	0
		Hypocotyl	385	25	636	22	948	19	1,203	20	683	8
		Roots	559	37	935	33	1,440	30	2,734	45	4,613	56
		Total	1,508	100	2,827	100	4,910	100	6,903	100	8,240	100
	B	Shoot	12	2	66	9	293	26	304	30	391	29
		Cotyledons	336	67	414	58	380	34	—	0	—	—
		Hypocotyl	103	21	158	22	180	16	300	30	140	10
		Roots	47	10	76	11	274	24	396	40	838	61
		Total	498	100	714	100	1,127	100	1,000	100	1,369	100

Table 3. (Continued.)

Soil &	Trt.	Organ	D=8 (a)		D=14 (a)		D=20 (a)		D=27 (a)		D=33 (a)	
			ng	% (b)	ng	% (b)	ng	% (b)	ng	% (b)	ng	% (b)
	C	Shoot	29	3	417	24	979	40	1,948	29	1,739	36
		Cotyledons	169	18	196	11	105	4	—	0	—	0
		Hypocotyl	50	5	198	11	259	10	328	5	348	7
		Roots	667	74	921	54	1,125	46	4,505	66	2,793	57
		Total	915	100	1,732	100	2,468	100	6,781	100	4,880	100
Soil III:	A	Shoot	10	22	205	19	372	26	978	33	953	36
		Cotyledons	149	27	249	23	134	9	171	6	—	0
		Hypocotyl	97	18	130	12	192	13	205	7	205	8
		Roots	289	53	508	46	738	52	1,517	54	1,494	56
		Total	545	100	1,092	100	1,436	100	2,931	100	2,652	100
	B	Shoot	3	2	49	19	84	24	161	32	318	27
		Cotyledons	98	49	114	44	118	33	61	12	—	0
		Hypocotyl	81	41	61	24	57	16	44	9	100	9
		Roots	17	8	33	13	96	27	239	47	746	64
		Total	199	100	257	100	355	100	505	100	1,164	100
	C	Shoot	18	5	172	23	485	31	754	36	908	43
		Cotyledons	71	18	82	11	78	5	47	2	—	0
		Hypocotyl	32	8	144	19	165	10	167	8	171	8
		Roots	271	69	347	47	844	54	1,144	54	1,031	49
		Total	392	100	745	100	1,572	100	2,112	100	2,110	100

a) D=interval in days between treatment and sampling.
b) Distribution (%) per plant in various parts (organs).

The shoot was cut into 4 parts according to Fig. 2. Results are shown in Table 4.

Spraying. With the soils treated in pre-emergence, the results are in total agreement with those obtained by incorporation.

Discussion. Uptake of oxadiazon by plants may occur through all the organs which may happen to be in contact with treated soil.

The amounts extracted depend upon the length of contact and the nature of the soil; clay (soil I) and principaly humic (soil III) colloids checked the absorption of the herbicide, but even in the most favorable case (soil II) the absorbed amounts only represent a very small part (lesser 2%) of the product applied to the soil.

If we consider the distribution of the chemical in the plant during the first days, the organs which contained more herbicide were those which had been in contact with the treated soil (some phytotoxic reactions occured in soil II on hypocotyls and cotyledons). Later the herbicide found in the shoots came from the roots but there was a continous and more or less regular decrease of the oxadiazon concentration from the base towards the top of the aerial part, in the proportion of 1 to 10 as an average in our test conditions.

Residue at harvest: Soybean were cultivated in soils (1 and 2) treated in pre-emer-

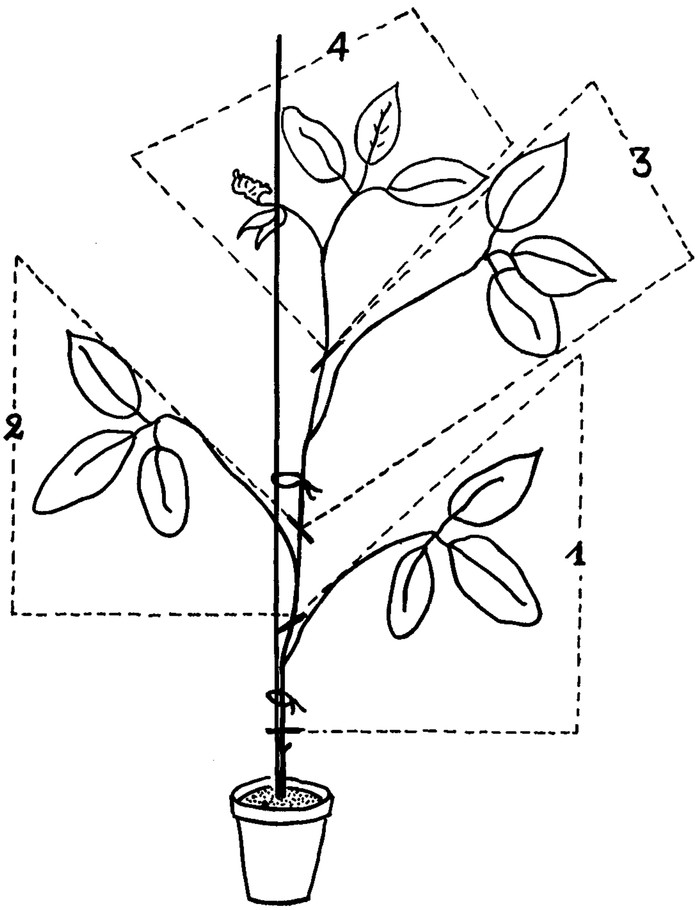


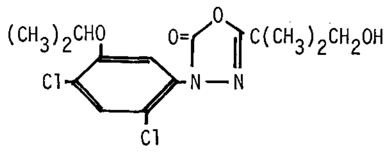
Fig. 2

gence by spraying (2.6 kg/ha a.i. in soil 1, 1.6 kg/ha a.i. in soil 2). After 4 months, seeds were ripened and all the plants were hervested and partitioned in three samples: seeds, pods and the rest of the shoot. Extractions were conducted as before and all the fractions obtained (organic extracts, water extract and solid residues) were counted. Results are shown in Table 5.

Discussion of results. More than 90% of the absorbed radioactivity remained in the vegetative part, less than 5% was translocated into pods and less than 2% was found in seeds. The autoradiographs indicate that this radioactivity consisted mostly of oxadiazon itself; no metabolite was detectable.

Metabolism in soybean: At the moment we have in progress new studies with soybean grown in soils treated with 29,873 R.P. For metabolic studies we have selected radioactive oxadiazon labelled on the most stable part of the molecule (i.e. the phenyl ring).

This new study confirms the previous results we have obtained with other kinds of labelled oxadiazon (27,185 R.P. or 27,667 R.P.). Furthermore we have identified one metabolite in green parts of the plants:



=26 806 R.P.

Table 4. Treatment by incorporation. Oxadiazon amounts in shoot fractions (results for 1 plant).

Treatment	Fractions	Soil I				Soil II				Soil III			
		Q(b)	%(a)	P(c)	C(d)	Q(b)	%(a)	P(c)	C(d)	Q(b)	%(a)	P(c)	C(d)
A	1	557	47	308	1.81	1,068	40	500	2.14	390	46	285	1.37
	2	302	26	315	0.96	1,096	41	538	2.04	227	27	315	0.72
	3	243	20	377	0.64	398	15	563	0.71	183	22	485	0.38
	4	81	7	508	0.16	95	4	500	0.19	49	5	554	0.09
	Average or total	1,183	100	1,508	0.78	2,657	100	2,101	1.26	849	100	1,639	0.52
B	1	453	64	443	1.02	133	46	450	0.30	70	41	518	0.14
	2	108	15	371	0.29	70	24	275	0.25	80	46	591	0.14
	3	117	16	464	0.25	62	21	325	0.19	17	10	636	0.03
	4	35	5	421	0.08	27	9	400	0.07	5	3	500	0.01
	Average or total	713	100	1,699	0.42	292	100	1,450	0.20	172	100	2,245	0.08
C	1	724	60	391	1.85	1,016	49	371	2.74	254	40	400	0.64
	2	304	25	318	0.96	672	32	336	2.00	203	32	438	0.46
	3	166	14	355	0.47	328	15	357	0.92	126	20	554	0.23
	4	20	1	245	0.08	78	4	329	0.24	49	8	454	0.11
	Average or total	1,214	100	1,309	0.93	2,094	100	1,393	1.50	632	100	1,846	0.34

(a) distribution (%) of total radioactivity in the shoot.
(b) Q=oxadiazon amount (ng).
(c) P=weight of the fraction (mg).
(d) C=concentration (ppm).

Table 5. Amounts in soybean plants (radioactivity expressed as total oxadiazon).

Part	Soil 1				Soil 2			
	Weight of each fraction (g)	Amount (μg)	Concent. (ppm)	% of total (%)	Weight of each fraction (g)	Amount (μg)	Concent. (ppm)	% of total (%)
Shoots	135	52.8	0.39	98.1	103	16.2	0.16	93.2
Pods	29	0.74	0.026	1.4	43.6	0.84	0.019	4.8
Seeds	12.1	0.29	0.024	0.5	18.6	0.34	0.018	2.0
Total	176.1	53.83	0.31	100.0	165.2	17.38	0.11	100.0

Quantitatively, oxadiazon itself represents more than 90% of the radioactive residues and 26,806 R.P. about 50 to 70% of the remaining radioactivity.

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Residues of Nitrofen (NIP) and CNP in Paddy Fields

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Abstract. The residues of a herbicide, CNP (*p*-nitrophenyl 2,4,6-trichlorophenyl ether), and its derivatives: *p*-aminophenyl 2,4,6-trichlorophenyl ether, 2,4-dichlorophenyl *p*-nitrophenyl ether (NIP; nitrofen), and *p*-aminophenyl 2,4-dichlorophenyl ether in the paddy field soils were determined. In the paddy field soil sprayed with CNP-granules about ten months ago, large quantities of these amino compounds which combined chemically with the soil organic matters were left over, and they were altered to the free amino compounds by the strong alkaline treatment of the soil samples. The survey of the residues of CNP and NIP, including respective amino derivative, in the paddy field soils in Japan revealed considerably heavy pollution by them, especially in the northern districts.

Introduction

Since 1965, a herbicide, CNP (MO®) have been widely used in Japan for the control of weeds in paddy fields. Ichihashi *et al.* (1971) reported the formation of the amino derivatives of CNP, NIP, and chlomethoxynil by the microbes in the soil. Kuwatsuka (1972) and Shimotori *et al.* (1975) showed extensively that these amino derivatives and other metabolites were formed in the soils under the flooded condition at their laboratory. Tatsukawa *et al.* (1973) reported that large quantities of CNP and its amino derivative were detected from the paddy field soils in Ehime prefecture.

In this paper, it is reported that large quantitatives of CNP-A (*p*-aminophenyl 2,4,6-trichloropheyl ether) chemically combined with the soil organic matters were contained in the paddy field soils sprayed with CNP-granules about ten months ago, and much more quantities of CNP-A than that obtained by the method of Tatsukawa *et al.* were determined by the more strong alkaline treatments of the soil samples, and in this case, NIP-A (*p*-aminophenyl 2,4-dichlorophenyl ether) was also detected appreciably. In addition, the results of the determinations of the residues of CNP and NIP, including respective amino derivative, in the paddy field soils and rice grains in the whole country are described.

Methods and Materials

Determination of the Nitro Compounds (CNP and NIP) in Soil. A sample (40 g) of soil which contained about 50% of dry matter, was shaken with 100 ml of acetone fortified with dilute hydrochloric acid (2.5 N, 0.8 ml) for 30 minutes. An aliquot (50 ml) of the supernatant was taken into the aqueous solution (300 ml, which contained 0.1 N KOH and 2% Na_2SO_4) and shaken with 50 ml of hexane. The hexane layer was washed with 50 ml of 0.5 N HCl and dried over Na_2SO_4. CNP and NIP in the hexane were determined by glc equipped with ECD.

Determination of the Amino Compounds (CNP-A and NIP-A) in Soil. CNP-A in soil had been extracted with organic solvents under the weak alkaline conditions (Kuwatsuka, 1972: Tatsukawa *et al.*, 1973), But, as shown in Fig. 3, the quantity of the determined CNP-A in the soil increases as the alkaline treatment is strengthened. The highest values of CNP-A were obtained by the very strong alkaline treatment.

Table 1 shows the values determined by the method described below. A sample (40 g) of soil which contained about 50% of dry matter, was heated with 30 ml of 10 N KOH and 1–10 g of $Na_2S \cdot 9H_2O$ for 4 hours at 80°C. The sludge was shaken with 100 ml of acetone for 20 minutes. An alquot (30 ml) of the supernatant was taken into the aqueous solution (300 ml, which contained 0.1 N KOH and 2% Na_2SO_4) and shaken with 80 ml of hexane. After washing with water, the hexane layer was shaken with 60 ml of 0.5 N HCl, twice. The aqueous layer was neutralized with KOH solution to pH 10 and shaken with 30 ml of hexane. The hexane layer was trifluoroacetylated with triethylamine and anhydrous trifluoroacetic acid, and it was determined by glc. The determined value of the amino compound was converted to the nitro equivalent and reduced the value of the nitro compound which was transformed to the amino compound during the alkaline treatment.

Soil Samples. In the period of the autumn in 1973 to the spring in 1974, soil samples were taken 10 cm depth from 64 paddy fields of the spots illustrated in Fig. 1. These fields were well investigated of the spray history of the herbicides, and was clear that most of them had been sprayed conventionally with 3–4 kg/10 are of 9% CNP-granules every year before or after the transplant of rice seedlings (May–July). The soil samples were determined of the densities, dry matters, and contents of the herbicides. The residue of the herbicide per 10 are was calculated as follow:

$$\text{herbicide (g/10 a.)} = \text{depth (cm)} \times \text{density (g/cm}^3) \times \text{dry matter (\%)} \times \text{herbicide (ppm)} \times 1/10$$

RESULTS

Table 1 shows the results of the determination of CNP and NIP in 35 paddy field soils sprayed with CNP-granules about ten months ago. It is arranged by each district in Japan. Residues of CNP and NIP are expressed as the total of the nitro compound and the amino compound. Residue ratio of CNP means the residual CNP to the CNP sprayed in 1973, which includes the accumulation of CNP sprayed before 1972.

Mean residue ratio of CNP is 89% in Hokkaidō district and 50% in Tōhoku district. These values exceed 32% in Kinki-Chugokū district and 31% in Kyūshū district. These results show the significant relation between the residue of CNP and the climate in each district: exceedingly high level residue in cold Hōkkaido, and low in warm Kyūshū.

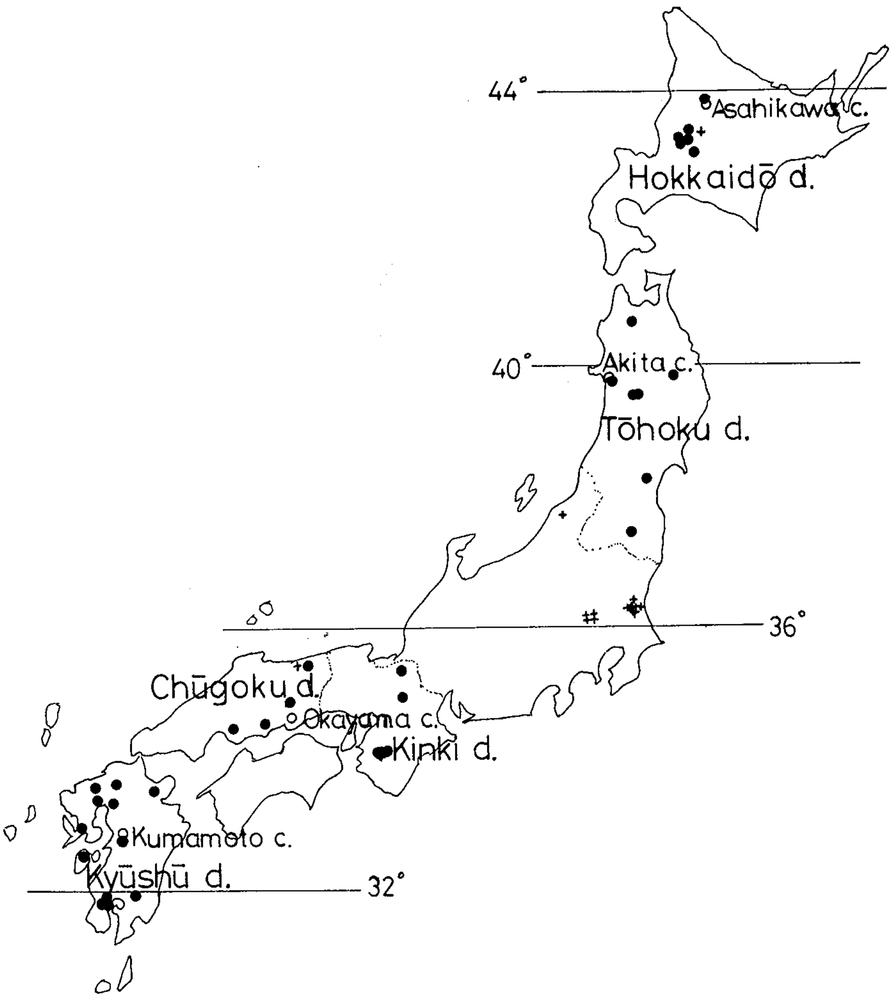

Fig. 1. Sampling spots of the paddy field soils.
●: Sampling spots of the soils shown in Table 1
+: Other sampling spots

The wide range of residue values suggests that other factors than the climate are related to the residues of CNP. The main component of the residues in soil is CNP-A. NIP and NIP-A are considered as the reductive dechlorination products derived from the sprayed CNP.

Discussion

The studies up to the present on the residues of CNP and NIP in the paddy field soils show the next facts (Yamada *et al.*, 1974, 1975). As shown in Fig. 2, CNP sprayed conventionally to the paddy fields decreases rather fast and is transformed to the amino

Table 1. Residues of CNP and NIP in the paddy field soils sprayed with CNP-granules in relation to destricts.

	Hokkaidō d.	Tōhoku d.	Kinki-Chūgoku d.	Kyūshū d.
Year average temp. (°C) (City)	6.2 (Asahikawa)	10.9 (Akita)	14.5 (Okayama)	15.9 (Kumamoto)
Number of fields	6	7	10	12
Sprayed CNP (g/10 a.)	300 (270–360)	309 (270–360)	320 (270–540)	330 (180–540)
Residue of CNP (g/10 a.)				
Nitro compound	53 (18–133)	19 (1–110)	7 (1–18)	19 (1–39)
Amino compound*	214 (116–336)	134 (32–300)	94 (29–202)	83 (27–185)
Total	267 (133–406)	153 (99–308)	101 (42–215)	102 (29–189)
Residue ratio of CNP (%)	89 (42–136)	50 (28–85)	32 (13–69)	31 (11–61)
Residue of NIP (g/10 a.)				
Nitro compound	2 (0–11)	0 (0–1)	0 (0–2)	0 (0–2)
Amino compound*	22 (5–73)	14 (2–32)	8 (5–14)	18 (4–53)
Total	24 (5–75)	14 (2–32)	8 (5–14)	18 (4–53)

These values are mean values of each district and the range values are shown in a parenthesis. CNP spray: May-July in 1973 (CNP had been sprayed in most fields before 1972). Soil sampling: 10 cm depth, March-May in 1974.

* Values converted to the nitro equivalent

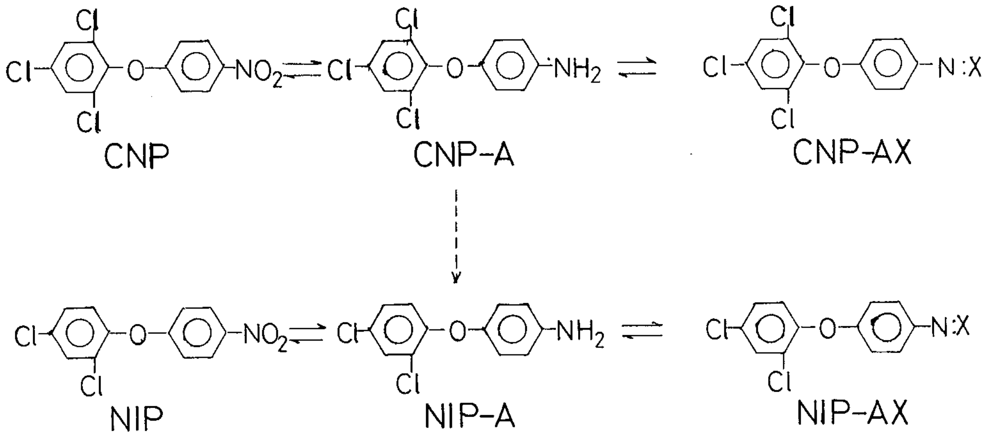

Fig. 2. Degradation pathway of CNP in the paddy field soil.

derivative (CNP-A) in the soils. CNP-A in the free state also decreases gradually and is further altered to the conjugates, CNP-AX, combined chemically with the soil organic matters. CNP-AX in the soil are considered to be very stable and remain for many years, and be able to return to CNP-A and CNP. In some cases, considerably large quantities of NIP and NIP-A are detected from the paddy field soils sprayed only with CNP-granules. In the case of NIP-granules spray, the same residue patterns of NIP as CNP are observed.

As shown in Fig. 3, by the increasing alkaline treatments on the soil, CNP-AX and NIP-AX were hydrolized gradually to free CNP-A and NIP-A extractable with acetone. The soil samples from the whole country were treated under the alkaline condition close to the treatment obtainable the maximum quantities of CNP-A and NIP-A.

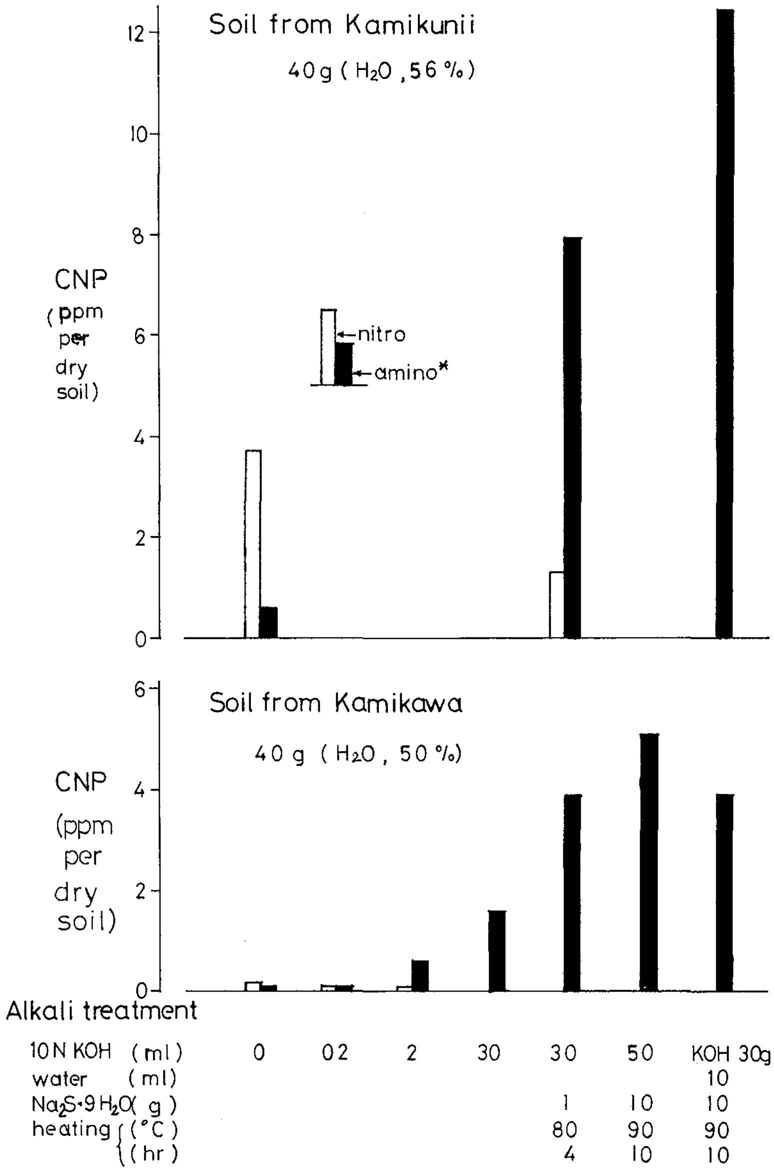

Fig. 3. Determinted CNP in soil in relation to various alkaline treatments.
* Values converted to the nitro equivalent.

The results of the present study show the high level residues of CNP-AX in the soil, especially in Hokkaidō district. It is suggested that the activities of the microbes in soil to the organic compounds are generally weak in Hokkaidō district owing to the cold climate. Meanwhile, in the unpolished rice grains harvested from the fields contaminated with CNP and its derivatives, neither CNP, CNP-A, NIP, nor NIP-A was detected more than 0.01 ppm of the detectable limit by the method applied.

ACKNOWLEDGMENT

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Fate of Diphenyl Ether Herbicides in Soils and Plants

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Abstract. The fate and behavior of diphenyl ether herbicides, mainly CNP (2,4,6-trichlorophenyl 4′-nitrophenyl ether), chlomethoxynil (2,4-dichlorophenyl 3′-methoxy-4′-nitrophenyl ether) and bifenox (2,4-dichlorophenyl 3′-carbomethoxy-4′-nitrophenyl ether) in soils and plants were studied in laboratory by using ^{14}C-labelled compounds. These herbicides were rapidly degraded to form their amino derivatives in soils under flooded conditions, but not under upland conditions. Many degradation products were identified. The mechanism of amino formation and the stable complex of amino derivatives are discussed. Behavior of uptake, translocation and metabolism in plants were different among these herbicides. Their degradation pathways in soils and in plants were proposed from their degradation products identified.

Introduction

Diphenyl ether herbicides such as CNP (MO®), chlomethoxynil (X-52), nitrofen (NIP, TOK®, 2,4-dichlorophenyl 4′-nitrophenyl ether) and bifenox (MC-4379, MODOWN®) are pre-emergence herbicides, mainly used in flooded rice fields. Of all pesticides, the amount of CNP used in Japan is the largest during the past several years in particular. Chlomethoxynil is used in a large amount in recent two years.

Among the diphenyl ether herbicides, the methabolism in plants and the photodegradation of fluorodifen (Preforam®, 4-(α,α,α-trifluoromethyl)-2-nitrophenyl-4′-nitrophenyl ether) and nitrofen have been studied. The fate and behavior in soil have not been studied.

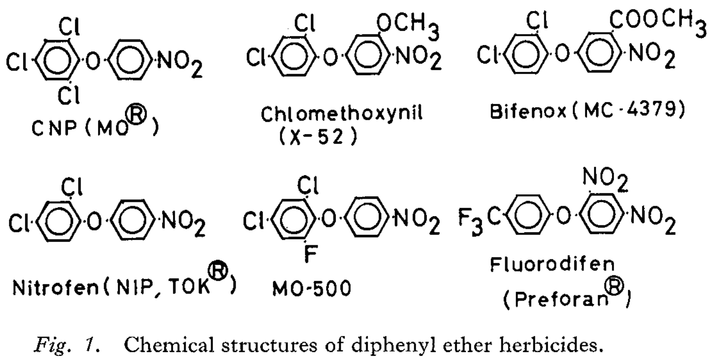

Fig. 1. Chemical structures of diphenyl ether herbicides.

This presentation is a summary of our study dealing with the fate and behavior of diphenyl ether herbicides, mainly CNP, chlomethoxynil and bifenox, in soils and plants. The details on bifenox will be presented elsewhere in this Conference. Nitrofen and MO-500 (2,4-dichloro-6-fluorophenyl-4'-nitrophenyl ether) were also used in the comparative studies.

The experiments were carried out in the laboratory. ^{14}C-labelled compounds of CNP, chlomethoxynil and bifenox were mainly used. Two radioactive compounds of each herbicide were prepared, labelled at one or the other benzene ring. Nitrofen was labelled at the chlorobenzene ring.

The chemical structures of the diphenyl ether herbicides are shown in Fig. 1.

Degradation in Soils

The degradation of the herbicide chemicals in several soils were compared under upland and flooded conditions. The soil samples were placed in flasks and pre-incubated for 2 weeks under simulated upland or flooded conditions before the chemicals were added. The chemicals were rapidly degraded in flooded soils to produce fair amounts of their amino derivatives, but very slowly under upland conditions, where amino derivatives were not detected.

In soils under flooded conditions, many degradation products were detected. For instance, CNP produced the amino analogue and its acylamides, the hydroxy derivatives at the nitro and the chloro positions, nitrofen derivatives produced by dechlorination, and several phenols produced by cleavage of the ether linkage. The identified products and the proposed degradation pathways in soils are shown in Fig. 2.

In the case of nitrofen which is a 2,4-dichlorophenyl derivative instead of a 2,4,6-trichlorophenyl derivative of CNP, the same analogues such as the amino analogue and its acetoamide and formamide, the hydroxy analogues at each of the nitro, 2-chloro, 4-chloro and 6-hydrogen positions, and phenols cleaved at the ether linkage were detected. Chlomethoxynil, which has a methoxy group adjacent to the nitro group of nitrofen,

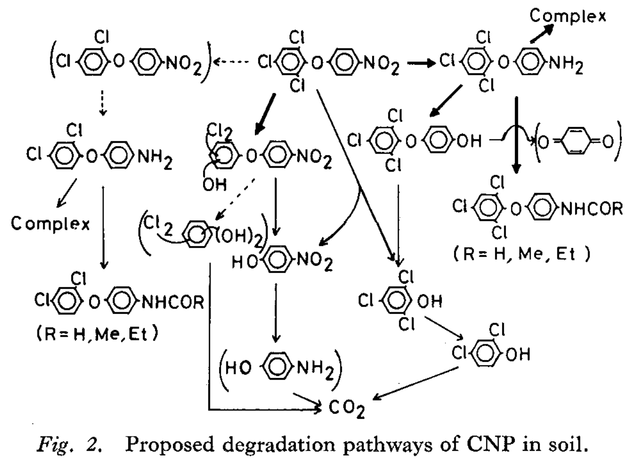

Fig. 2. Proposed degradation pathways of CNP in soil.

yielded compounds which were analogous to nitrofen degradation products with the methoxy group and additionally their demethylated compounds. Bifenox, which has a carboxymethyl group instead of a methoxy group, produced carbomethoxy analogues of nitrofen derivatives and the free acid derivatives hydrolyzed at the ester linkage, and nitrofen produced by decarboxylation.

The reduction of the nitro group to amino group was highly correlated with the redox potential of soils among the three soils studied under 5 different conditions. There was a linear relationship between the degradation rate and ferrous content for each soil sample pre-incubated under different conditions for different periods of time. CNP in aqueous suspension was easily reduced to its amino derivative by ferrous salts or hydrogen sulfide, but not by manganous salts. All nitrate-reducing bacteria and other bacteria also reduced the nitro group of CNP in the water suspension within 24 or 48 hours. When the soil was sterilized before pre-incubation, the diphenyl ether remained stable in the soil. When the soil was sterilized after pre-incubation under flooded conditions and before application of the chemical, it was degraded to a fair extend. Soils under flooded conditions, in general, contains a large amount of ferrous ion, which is produced by iron-reducing bacteria. Nitrate-reducing bacteria are also common in flooded soils. These results suggest that the reduction of the amino group in flooded soils is due to chemical reaction with the ferrous ion produced by bacteria and is also due to microbial action.

The amino compounds were persistent in soils, whether in the laboratory or in the field, for rather long periods. The compounds were found to be strongly adsorbed on soil particles, especially on humic substances, both by ionic adsorption and by covalent bonding with radicals such as the quinone group of humic substances. To some extent, the amino compounds of various diphenyl ether herbicides in soils behaved differently.

Uptake and Metabolism in Plants

The absorption, translocation and metabolism of CNP, chlomethoxynil and bifenox in seedlings of rice and barnyardgrass (*Echinochlor crus-galli* L.) at the 2- and 4-leaf stages were studied by using ^{14}C-labelled compounds in water and soil cultures.

Both plants absorbed these chemicals through the roots. CNP, however, was hardly translocated from the roots to the stems and leaves in rice, and a little more easily in barnyardgrass. The translocation of CNP absorbed through the bottom part of stems was easier than that absorbed through the roots. Chlomethoxynil was translocated more easily from root to upper parts than CNP, and more easily in barnyardgrass than in rice. Bifenox itself was hardly translocated in plants, but the free acid produced by the hydrolysis of bifenox in plants or that applied through the roots was easily translocated. Amino derivatives of diphenyl ether herbicides were not uptaken by plants from the soil. Also, they were not translocated from the roots even if they were absorbed through the roots from the aqueous solution.

On metabolic studies, when ^{14}C-CNP was supplied through roots, most of the radioactive substances found in the upper parts contained only small amount of CNP itself even after 16 days of treatment, although water soluble radioactive substances and tissue-bound ones increased gradually with time. In roots also, the parent ^{14}C-CNP possessed about 90% of the total radioactivity after 16 days of treatment. The other metabolites were identified as the amino compound and its formamide and N-β-D-glucoside, and the hydroxy derivatives at the 4′-position, *p*-nitrophenol and *p*-aminophenol, and their conjugates.

Chlomethoxynil and bifenox were not only translocated from roots to the upper parts but were metabolized rapidly in leaves. The metabolic products of chlomethoxynil included considerable amount of the amino derivative and the demethylated derivative and their conjugates. They were detected in the upper parts as well as in the roots of both plants. The metabolic rate was more rapid in the rice plant than in barnyard-grass.

Bifenox was degraded also rather rapidly, and many metabolites were found to correspond with the metabolites of CNP or chlomethoxynil.

Fate of Bifenox (MC-4379) in Rice Plant and Soil Environment

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Abstract. Bifenox [methyl 5-(2′,4′-dichlorophenoxy)-2-nitrobenzoate] is a new herbicide that has been tested widely in paddy fields in Japan. Its photodegradation in aqueous solution, degradation in soils, and uptake, translocation and metabolism in the rice plant were studied in laboratory. The main photodegradation pathway was the cleavage of the ether linkage. In flooded soils, it was degraded rapidly. Microbial hydrolysis and chemical reduction were the principal pathways in soils. In the rice plant, it was metabolized rapidly and ring hydroxylation followed by conjugation or binding was the principal pathway. Bifenox absorbed by the root was hardly translocated, but the free acid was translocated. The amino derivatives were not translocated.

INTRODUCTION

Bifenox (MC-4379) is a new herbicide developed by Mobil Chemical Company. Its herbicidal activity in paddy fields was described in another part of this proceeding. The absorption, translocation and metabolism of bifenox in weeds were stated elsewhere (Ohyama *et al.*, 1975). This paper deals with laboratory studies on its photodegradation in aqueous solution, its degradation in paddy soils under flooded and upland conditions, and its uptake, translocation and metabolism in the rice plant.

PHOTODEGRADATION

Materials and Methods. Aqueous solutions (0.2 ppm) of ^{14}C-labeled bifenox and the free acid were irradiated with a high pressure mercury lamp at pH 3,6 and 9, and with a low pressure mercury lamp at pH 6. Samples were extracted with ether and degradation products were identified and quantitatively determined by tlc-autoradiographic techniques.

Results and Discussion. Bifenox was photodegraded rapidly. Cleavage of the ether linkage, hydrolysis, reduction and hydroxylation of the benzene rings occurred. A small amount of nitrofen was also detected. By estimation of the amounts of degradation products, the major degradation pathway was presumed to be the cleavage of the ether linkage. At higher pH values, the formation of the free acid increased, because bifenox is an o-nitrobenzoic acid ester, in which the nitro group has a positive substituent effect for alkaline hydrolysis and a negative one for acid hydrolysis (Taft, 1952). The amounts of nitrofen were proportional to the amounts of the free acid formed and nitrofen was probably produced by decarboxylation of the free acid. Actually, irradiation of the free acid produced a sizable amount of nitrofen.

Degradation in Soils

Materials and Methods. Three soil samples Anjyo (mineral soil, kaolin), Tochigi (volcanic ash soil, allophane) and Nagano (mineral soil, montmorillonite) soils, were collected from dried paddy fields in winter and passed through a 2 mm sieve. Fifty grams each (oven-dried base) of soil was placed in a flask and water was added to flood the soil up to a depth of 1 cm (flooded condition), or to make up to 60% of the maximum water holding capacity (upland condition). The soils were pre-incubated in the dark at 30°C for 2 weeks. Acetone solution (0.5 ml) of labeled compounds of bifenox or the free acid at 10 ppm level based on oven -dried soil, and of amino derivatives at 5 ppm level, were applied into the soils. At appropriate intervals, the whole sample in each vessel was extracted with acetone. The acetone solution was condensed and extracted with ether. The ether layer was condensed and analyzed by tlc-autoradiograpy and the radioactivity of each degradation product was determined.

Results and Discussion. Time course studies of the degradation of bifenox in Anjyo soil under flooded conditions and under upland conditions are shown in Fig. 1. The amounts of acetone-extractable radioactive materials decreased with time. Bifenox was degraded rapidly and the half life was about 4 days in flooded Anjyo and Tochigi soils, and within 2 days in flooded Nagano soil. In the early stages of degradation, the hydrolysis of ester bond and reduction of nitro group to amino group were occurred principally and the free acid formed was also reduced subsequently. When flooded soil was sterilized by autoclave before pre-incubation, both the hydrolysis of ester bond and the reduction of nitro

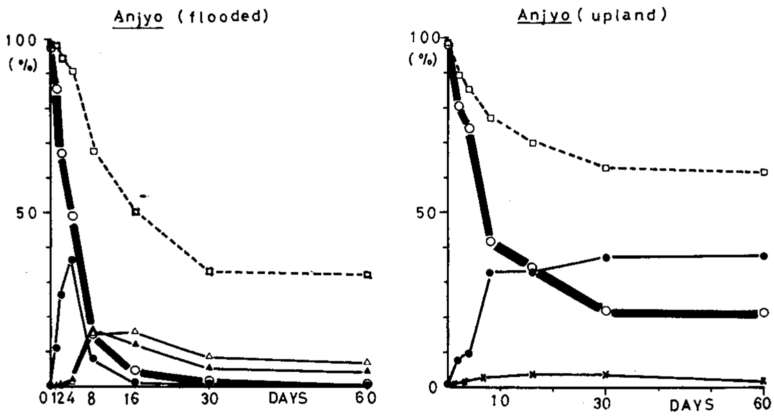

Fig. 1. Degradation of bifenox in Anjyo paddy soil. (^{14}C-nitrophenyl ring labeled bifenox, 10 ppm)

□ Acetone exts.; ○ Bifenox; ● 5-(2′,4′-Dichlorophenoxy)-2-nitrobenzoic acid; △ Methy 5-(2′,4′-dichlorophenoxy)-anthranilate; ▲ 5-(2′,4′-Dichlorophenoxy)-anthranilic acid.

group did not occur. When the soil in the reduced state was sterilized, only the reduction occurred and the hydrolysis did not. There results suggest that the hydrolysis was caused by microbial reaction, but that much of the reduction was caused by chemical reaction with ferrous ion which is produced microbially in anaerobic soil. Under upland conditions, bifenox was also degraded rapidly and the half life was about 6 days. The main process involved was hydrolysis. The free acid was also easily reduced in soils under flooded conditions but was fairly stable under upland conditions. A part of the free acid was reverted to bifenox by methylation. The amino compounds, in part, were acylated, but most of them were strongly adsorbed by the soil. Many minor degradation products of bifenox were detected in the soils. The proposed degradation pathways are shown in Fig. 2.

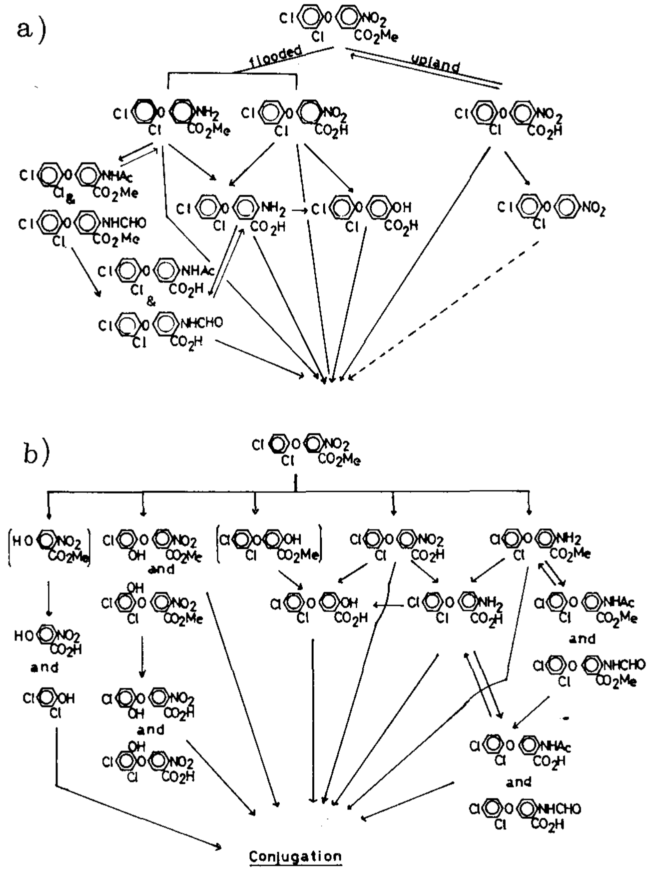

Fig. 2. Major degradation pathways in soils and major metabolic pathways in rice plant.
a) Major degradation pathways in soils
b) Major metabolic pathways in rice plant

Uptake, Translocation and Metabolism in the Rice Plant

Materials and Methods. In uptake and translocation experiments, roots of 30 rice plants at 3-leaf stage were supported with a metal net, dipped into Kasugai's solution containing 5 ppm of the labeled compound and placed under 10,000 lux of artificial light at 30°C. At appropriate intervals, plants were taken up, washed with water and then with benzene, and divided into roots and upper parts. Each part was extracted with 80% acetone. The acetone was evaporated and the residues were extracted with ether. The ether extracts were condensed and the residues were spotted on tlc plates. The ether-unextractable radioactive materials were hydrolyzed with acid and enzyme. Plant-bound radioactivity was measured by combustion with a sample oxidizer. In metabolism experiments, the same treatments were done except that the stems dipped up to a depth of 3 cm into the solution.

Results and Discussion. The amounts of radioactive ester-type compounds absorbed by roots were larger than those of acid-type compounds. This is supposed to be caused by the difference in polarity. A small amount of radioactive bifenox absorbed through the roots was translocated. Bifenox itself was hardly translocated except in the form of the free acid. The free acid applied to the roots was translocated easily. Radioactivity applied in the form of amino compounds were translocated in very small amounts but the parent compounds were hardly detected. These results reveal that the ultimate soil degradation products in flooded soil, the amino compounds, were absorbed by the roots, but they were not translocated to the upper parts. Bifenox was metabolized rapidly in the rice plant. The ether-extractable metabolites detected were the free acid, the amino compounds, ring hydroxylated compounds and phenols produced by the ether-linkage cleavage. When ether-unextractable and plant-bound materials were hydrolyzed with hydrochloric acid or β-glucosidase, a large amount of 5–(2′–hydroxy–4′–chlorophenoxy)–2–nitrobenzoic acid and 5–(2′–hydroxy–4′,6′–dichlorophenoxy)–2–nitrobenzoic acid were detected. Hydroxylation of the benzene ring followed by conjugation or binding was supposed to be the principal degradation pathway for bifenox. The metabolic products of the free acid were the same as those of bifenox. The amino compounds were rapidly bound by plant tissue. The proposed metabolic pathways of bifenox in the rice plant are shown in Fig. 2.

Acknowledgments

The authors wish to thank Professor K. Kumada for his valuable advice. Thanks are also due to Mobil Chemical Company for supplying labeled bifenox and Yashima Chemical Co., Ltd for their encouragement throughout this work.

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Fate and Behavior of Benthiocarb Herbicide in Soil Environment and Plants

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Abstract. The fate and behavior of benthiocarb [SATURN, *S*-(4-chlorobenzyl) *N*,*N*-diethylthiolcarbamate] in soil environment and plants were studied in laboratory, using ^{14}C-benthiocarb. Benthiocarb in aqueous solution was degraded photochemically. In soils, benthiocarb was degraded more rapidly under aerobic conditions than under anaerobic conditions. Most of the radioactivity of phenyl carbon was recovered as $^{14}CO_2$. The uptake, translocation and metabolism in plants were also studied. The degradation products by irradiation, in plants and in soils were identified. Two major routes were found in the degradation pathways in common, and the specific pathway was also existed. Its volatilization from water and soil was also investigated.

INTRODUCTION

Benthiocarb has been used mainly for the control of paddy weeds in Japan.

The present presentation is a review of our study on photodegradation and volatilization of benthiocarb, its uptake and metabolism in plants, and its degradation in soil. Most of the experiments were carried out in the laboratry using non-radioactive benthiocarb and ^{14}C-benthiocarb labeled either at the methylene carbon of the benzyl group or at the benzene ring.

PHOTODEGRADATIOH

Benthiocarb in aqueous solution was rapidly degraded under ultraviolet rays and sunlights. Irradiation with ultraviolet rays or exposure to the sunlight formed many degradation products such as benthiocarb sulfoxide, 4-chlorobenzyl alcohol, 4-chlorobenzaldehyde, 4-chlorobenzoic acid, 4-hydroxy analogues of the alcohol, the aldehyde and the acid. Among these, 4-chlorobenzyl alcohol and 4-chlorobenzaldehyde were the major products. The proposed pathways are shown in Fig. 1. The degradation process included oxidation and hydrolysis.

VOLATILLIZATION

When ^{14}C-benthiocarb in aqueous solution was placed in an open vessel and ex-

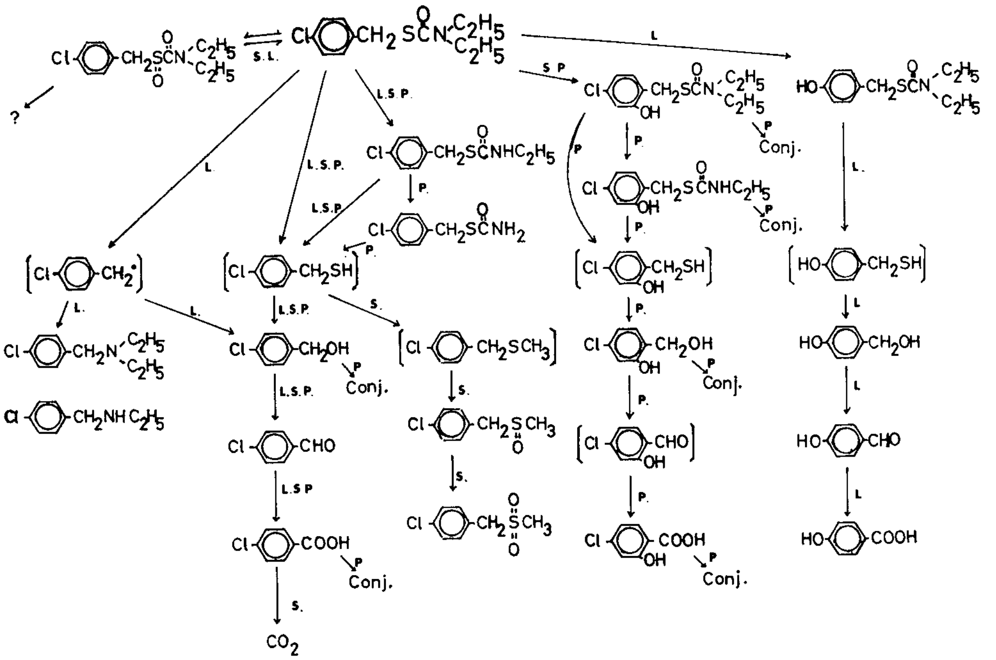

Fig. 1. Possible degradation pathways of benthiocarb herbicide.
L: photodegradation pathways, S: degradation pathways in soils, P: metabolic pathways in plants.

posed to sunlight, the radioactivity in the solution remarkably decreased with time proportionally, accompanied by the evaporation of water. However, presence of soil in aqueous solution suppressed volatilization, because benthiocarb was rapidly adsorbed on soil. The volatilized radioactive substances consisted mainly of parent benthiocarb itself and several minor photodegradation products. Benthiocarb applied on the soil surface of unflooded soil volatilized to a lesser extent than that applied on flooded soil. Furthermore, when it was incorporated into upland soils, the volatilization was negligible.

Degradation in Soils

When the rates of degradation of benthiocarb in various soils were compared, the rate varied according to the kind of soil. But there was little corelation between the rate and soil properties. On the contrary, when benthiocarb was degraged in soils under different conditions, its redox state largely affected the degree of degradation. Three soil conditions: upland (40% of maximum water holding capacity), oxidatively flooded (5 mm water depth over 5 mm of soil layer enough to supply air well), and reductively flooded (5 cm water depth over 7.5 cm layer of soil, with almost little air), were simulated. The degradation rate was fastest under upland conditions, followed by that under oxidatively flooded conditions, and the slowest was that under reductively flooded conditions

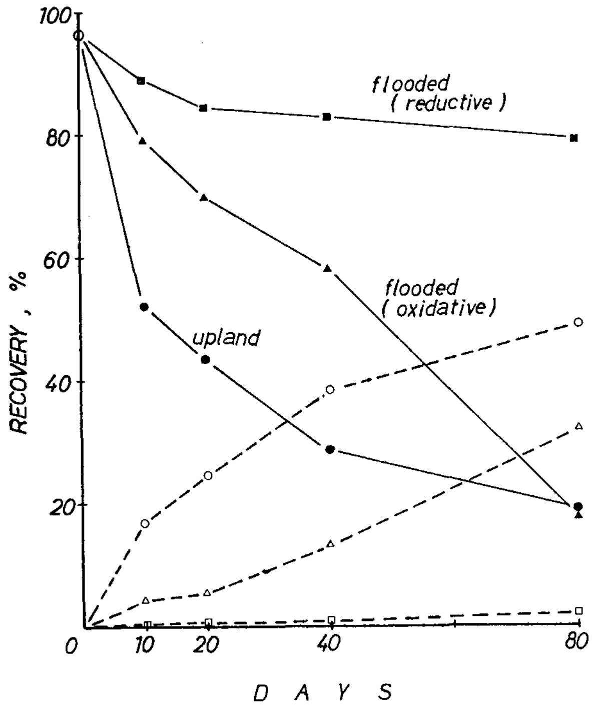

Fig. 2. Decomposition of benthiocarb and evolution of $^{14}CO_2$ from benzene ring labeled benthiocarb under different soil conditions in Anjo soil.
—— benthiocarb; - - - $^{14}CO_2$; ●○ upland; ▲△ oxidatively flooded; ■□ reductively flooded.

(Fig. 2).

A large amount of degraded radioactive materials was recovered as $^{14}CO_2$ from benzene ring carbon. The evolution rate agreed well with the degradation rate in soil. In sterile soil, little degradation of benthiocarb and no evolution of CO_2 occurred. From these results it was presumed that aerobic microorganisms degraded benthiocarb in the early stage and rapidly catabolised it to CO_2.

Radioactive materials extracted with acetone or methanol consisted mainly of benthiocarb itself and small amounts of degradation products. More than 20 intermediate metabolites were detected, and none of them were over 3% of the applied radioactivity. Relatively major products were benthiocarb sulfoxide, desethyl benthiocarb, 4-chlorobenzoic acid and 4-chlorobenzyl methyl sulfone. The possible degradation pathways are shown in Fig. 1.

Degradation in Plants

^{14}C-Benthiocarb was rapidly absorbed through the roots and stems of various plants. The radioactive substances were translocated throughout the whole plants. Absorption and translocation occurred more efficiently in barnyardgrass (*Echinochloa* *crus-galli* Beauv.) than in rice plant. Benthiocarb was rapidly degraded by rice plant and barnyardgrass within a few days after absorption. The metabolism was faster in rice plant than in barnyardgrass. Large amounts of the radioactive materials in plants were extracted with aqueous acetone. However, the amounts of unextractable radioactive materials increased with time. In the lipophlic fraction, the metabolic products were identified as 2–hydroxy benthiocarb, 2–hydroxy desethyl benthiocarb, 4–chloro–2–hydroxybenzyl alcohol, 4–chloro–2–hydroxybenzoic acid, desethyl benthiocarb, 4–chlorobenzyl thiocarbamate, 4–chlorobenzyl alcohol, 4–chlorobenzoic acid. These products did not exceed 3% of the total radioactivity in plants.

The radioactivity in the polar fraction increased with time and it reached over 50% of the extracted material. More than half of the radioactive material in the fraction was converted to extractable substances by hydrolysis with β-glucosidase or hydrochloric acid. Among the hydrolyzates, 6 compounds were identified as 4-chlorobenzyl alcohol, 4–chlorobenzoic acid, 2–hydroxy benthiocarb, 2–hydroxy desethyl benthiocarb, 4–chloro–2–hydroxybenzyl alcohol and 4–chloro–2–hydroxybenzoic acid. These materials are thought to exist as conjugates with sugars and/or amino acids. The proposed metabolic pathways are shown in Fig. 1.

General Discussion

In actual paddy fields, herbicides applied should dissipate by the action of many factors in the field environment. Some portions of benthiocarb herbicide are considered to dissipate from the treated fields by runoff, leaching, and volatilization. Large portions are degraded by biological activities and lights. Benthiocarb in the flooded water in rice fields dissipates by photodegradation and volatilization, by microbial degradation and by uptake and metabolism in plants. In this study, these degradation processes were described. From the results obtained, the proposed degradation pathways are summarized in Fig. 1. Two major routes exist in common among the degradation pathways; the first involves deethylation, hydrolysis and stepwise oxidation of benzene ring moiety of benthiocarb and the second involves an additional step of hydroxylation at the 2–position of the benzene ring preceding the above processes. Dealkylation and hydrolysis of the thioester linkage were ascertained in the degradation of thiocarbamate compounds by lights and in plants and soils.

The hazard of benthiocarb herbicide in the environment is not thought to be serious, because it is rapidly degraded photochemically in flooded water and microbially into CO_2 in the soil. Furthermore, in plants, it is rapidly metabolised into the conjugates of 4–chlorobenzoic acid and other substances. No benthiocarb was detected in rice grains in this study.

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Photodecomposition and Some Behavior of Herbicides, Benthiocarb and DCPA in Soils

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Abstract. Herbicides benthiocarb [*S*-(4-chlorobenzyl) *N*,*N*-diethylthiocarbamate] and DCPA (dimethyl-2,3,5,6-tetrachloroterephthalate) were photodecomposed under sunlight. 4-Chlorobenzyl *N*-ethylthiocarbamate, 4-chlorobenzylmercaptan, 4-chlorobenzylalcohol, and 4-chlorobenzoic acid were identified from the photodecomposed products of benthiocarb. 1,2,4,5-Tetrachlorophthalic acid and 1,2,4,5-tetrachlorobenzene were detected from DCPA. Benthiocarb persisted longer in autocleaved soil than nonautoclaved soil. The degradation was assumed to proceed by microbial and chemical reactions. DCPA remained stable on surface of dry soils for many weeks after application, but the moisture seemed to be an important factor affecting the degradation of DCPA in the soil.

INTRODUCTION

Benthiocarb (SATURN) has been officially recommended in Taiwan for the control of weeds in paddy rice fields since 1971. DCPA (Dacthal) is first recommended for the control of weeds in onion field (1972) and then in the other upland field crops such as garlic (1973), soybeans (1974), and peanut (1975) in Taiwan.

In order to study the environmental degradation of these herbicides after their application in the field and to seek further for the safe and more correct use, experiments have been done on the photodecomposition under sunlight or UV irradiation as thin film on glass, and some behavior of the herbicides in soils was also investigated.

MATERIALS AND METHODS

Materials. Benthiocarb is the product of Kumiai Chemical Industry Co., Ltd., Japan. Pure compound was prepared by column chromatography from the technical product. DCPA is the product of Diamond Shamrock Corporation, U.S.A. Pure material was prepared by extracting with acetone from commercial product and recrystallized from methanol (m.p. 156°C).

Soils used for the experiments of benthiocarb were collected from the paddy fields of Ying-Ko (Soil A) of Tapipei prefecture, Chung-Lih (Soil B) of Tauyuan prefecture and Shin-Zuan (Soil C) of Taipei prefecture respectively. Soils used for the experiments of DCPA were collected from the upland fields of Tong-Shan (Soil D), Shan-Hua (Soil E), Pei-Lienchen (Soil F) of Tainan prefecture, respectively. The

Table 1. Some physico-chemical properties of the soils.

Soils	pH Soil: H_2O = 1 : 1	CEC meq./100 g	Organic matter %	C/N ratio	Texture
Soil A	4.8	7.11	1.53	7.05	Sandy loam
Soil B	5.2	4.71	0.69	6.38	Sandy clay loam
Soil C	5.3	9.70	1.98	10.2	Silty clay loam
Soil D	5.8	14.33	1.66	8.23	Silty clay loam
Soil E	6.2	12.19	2.48	13.2	Silty loam
Soil F	7.1	10.72	1.47	7.68	Silty clay loam

major physico-chemical properties of these soil samples are given in Table 1.

Apparatus and condition. ECD gas chromatography was performed through the experiment with Shimadzu Gas Chromatograph Model GC-5A type. TLC was carried out with silica gel 254 pre-coated plate, a product of E. Merck, Germany, with the thickness of 0.25 mm. The location of the spots was observed under the UV lamp (254 nm) or detected either with iodine vapor, bromophenol blue or a mixture of silver nitrate and 2-phenoxyethanol. IR was performed with Perkin-Elmer Model 457 Infrared Spectrophotometer.

Methods. Each 200 mg of pure benthiocarb or DCPA was dissolved in acetone in a Petri-dish. The solvent was evaporated at room temperature and the uniform thin film was exposed to sunlight for 2, 4, 8, 16, 32, 48, 64 and 96 hrs respectively. It was then washed out with acetone and evaporated to an appropriate small volume for the further experiments. Certain amounts of benthiocarb or DCPA were also dissolved in acetone, and spotted in a band on the TLC plate, irradiated with UV lamp (254 nm) for 4, 8, 12, 24, 48 and 96 hrs respectively.

Soil samples were air dried, and passed through a 2 mm sieve. Each 50 g of six soil samples were placed in a 250 ml Erlenmyer flask with 16 duplicates for the purpose of different treatment and storage period. Soil A, B and C were placed in a room temperature under the flooded condition for one week. After then 50 ppm of benthiocarb in hexane solution was added, shaken well, and kept at room temperature. At 0, 5, 10, 20, 30, 40, 50 and 60 days, the remained benthiocarb was determined by GC. Under the flooded condition, Soil C was also autoclaved at 121°C for 30 min, and compared with nonautoclaved sample with a same condition by adding 100 ppm of benthiocarb. Soils D, E and F were treated with 100 ppm of DCPA in two ways, flooded and dried conditions, and the residues were analyzed after 0, 1, 5, 10, 15 and 20 days.

Results and Discussion

Benthiocarb was photodecomposed as thin film on glass and analyzed by TLC. First photodecomposed product appeared after exposed for 2 hrs, but the products seemed to be almost the same after 24 hrs, though there was some change in amount of each spot, unchanged benthiocarb decreased and the spot remained in origin increased. No significant difference was observed between irradiation with sunlight and

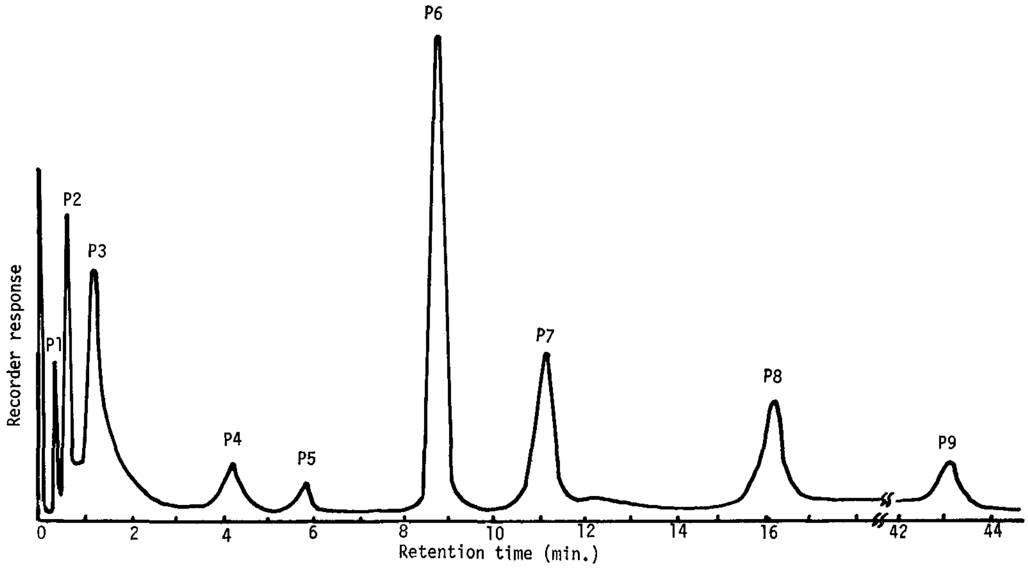

Fig. 1. Gas chromatogram of degradation products formed from benthiocarb exposed as thin films to UV light for 32 hrs by column DC-200.

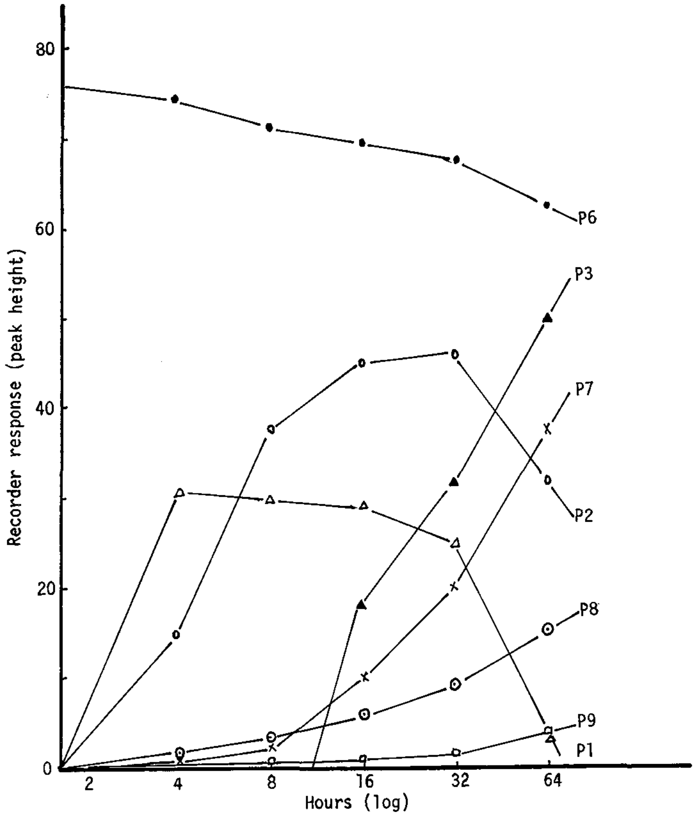

Fig. 2. Change of benthiocarb and degradation products under various photodecomposed period.

UV lamp. When the photodecomposed product (32 hrs) were analyzed with DC-200, nine peaks were obtained on gas chromatogram as shown in Fig. 1. Change of benthiocarb and degradation products under various photodecomposed period was shown in Fig. 2. When compared the retention time to authentic compounds, P_1, P_2, P_3, P_6 and P_9 were identified to be 4-chlorobenzaldehyde, 4-chlorobenzylalcohol, 4-chlorobenzyl N-ethylthiocarbamate, unchanged benthiocarb and 4-chlorobenzylmercaptan, respectively.

At least ten components were detected with photodecomposed benthiocarb by TLC analysis. When compared the Rf value to authentic compounds, five compounds were identical to unchanged benthiocarb, 4-chlorobenzyl N-ethylthiocarbamate, 4-

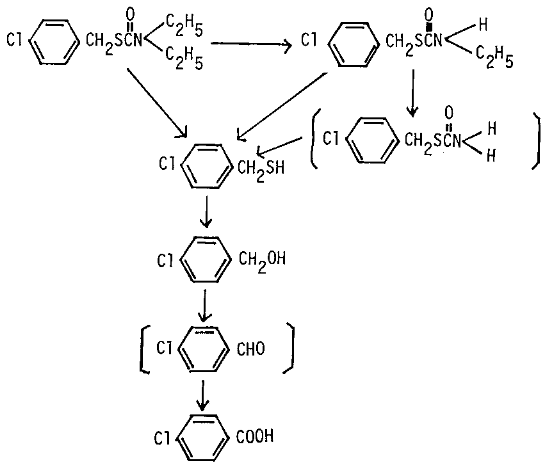

Fig. 3. Partial pathways involved in the photodecomposition of benthiocarb.

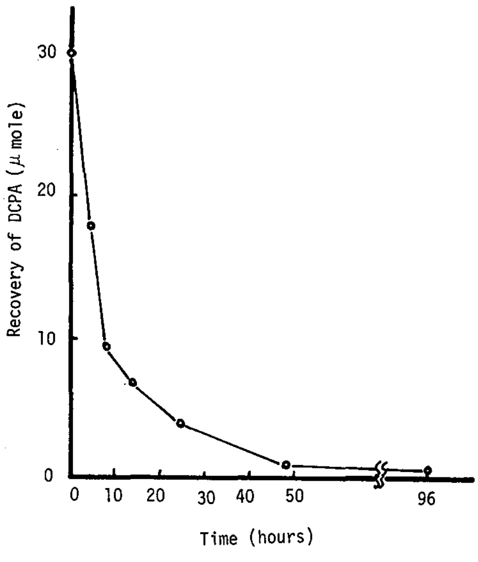

Fig. 4. Recovery of DCPA after photodecomposition for different time to UV lamp.

chlorobenzylmercaptan, 4-chlorobenzylalcohol and 4-chlorobenzoic acid. For the further identification of the compounds, each band on the TLC plate was scraped out and determinated by IR. Thus the partial pathways involved in photodecomposition of benthiocarb are proposed as shown in Fig. 3.

DCPA was also photodecomposed and analyzed in same way. The thin layer

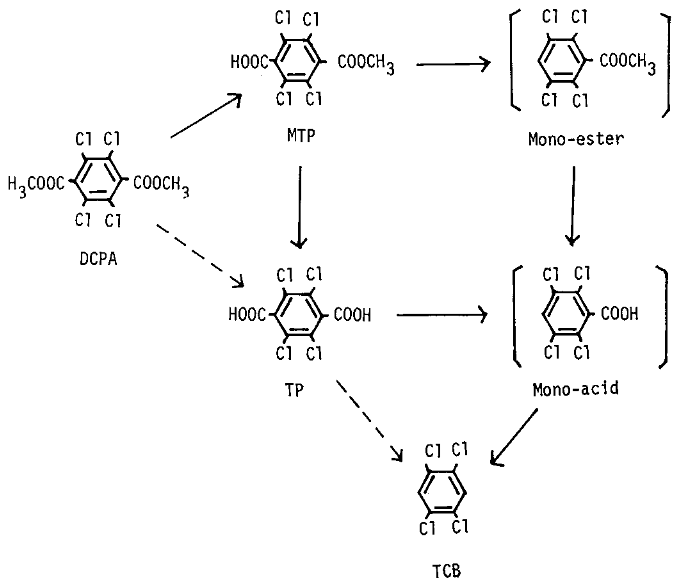

Fig. 5. Partial pathways involved in photodecomposition of DCPA.

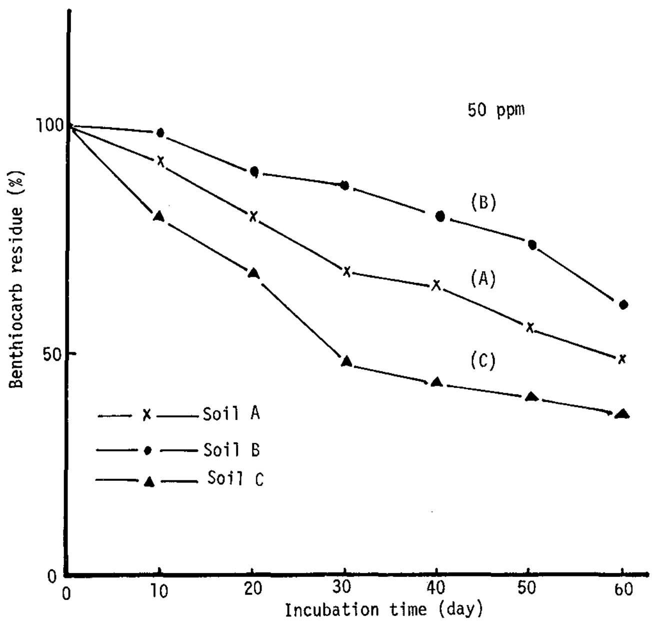

Fig. 6. Degradation of bentiocarb in various soils under flooded condition.

chromatogram showed that DCPA was photodecomposed to MTP (monomethyl tetrachloroterephthalate) and TP (tetrachloroterephthalic acid) after exposed for 2 hrs and TCB (1,2,4,5-tetrachlorobenzene) was formed after exposed for 4 hrs. When exposed period was between 4 to 48 hrs, the products seemed to be almost the same, but if the exposed period was prolonged for more than 64 hrs, certain unidentified products were formed. The quantitative analysis of DCPA by gas chromatography showed the decomposition of DCPA was very fast, 50% decomposed after exposed for 5 hrs, and above 95% after 48 hrs as shown in Fig. 4. The major photodecomposed products of DCPA were TP, MTP and TCB. TP and TCB were identified by IR. Therefore the partial pathways involved in photodecomposition of DCPA are proposed as shown in Fig. 5.

Degradation of benthiocarb in various soils under flooded condition are shown in Fig. 6. Fifty per cent of benthiocarb decomposed within one month in Soil C, 60% remained in Soil B for 2 months, and 50% in Soil A for 2 months. The decomposition rate was different from the types of soil. Soil organic matter may be one of the factors influencing the persistence of benthiocarb in soils. Larger amount of organic matter in Soil C than in Soil B showed the fast decomposition rate in Soil C than in Soil B. In order to study the effect of the decomposition of benthiocarb by soil microorganisms, Soil C was treated in two different conditions, namely autoclaved and nonautoclaved.

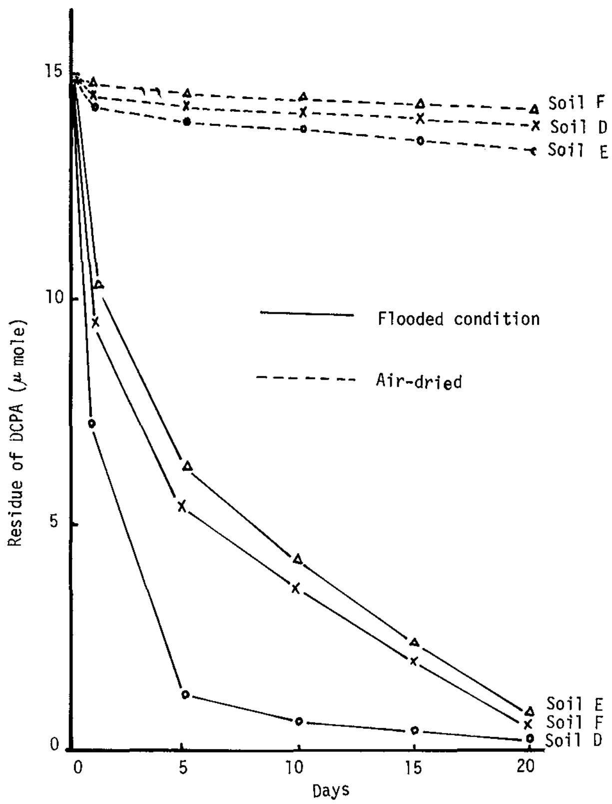

Fig. 7. The residue of DCPA in soils.

Fifty-six per cent remained after one month in the nonautoclaved soil, but 80% remained in the autoclaved soil. Twenty per cent of benthiocarb lost in the autoclaved soil suggested that the decomposition of benthiocarb in soil was not only due to the soil microorganisms but also by chemical reaction.

DCPA remained in soils was also decreased as exposed period increased. No significant loss of DCPA was found in the air dried soil, but a very fast degradation rate was observed with flooded condition as shown in Fig. 7. The result suggested that DCPA may hydrolyze with the soil water, and the decomposition of DCPA in flooded soil seemed to be mainly by hydrolysis and soil microorganisms play a minor role.

ACKNOWLEDGEMENTS

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Effect of Leaf Mulch from Picloram Injected *Eucalyptus* spp. on Establishment and Growth of *Trifolium subterranean* and *T. repens*

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Abstract. Control of unwanted mature *Eucalyptus* spp. with picloram (4-amino, 3,5,6-trichloropicolinic acid) based herbicides is widely practised in Australian in association with pasture improvement. Field and glasshouse bioassay experiments show that leaves from picloram injected *Eucalyptus* spp. were not phytotoxic to subterranean clover (*Trifolium subterranean*) or white clover (*T. repens*). No allelopathic effects from the leaves of mountain gum (*Eucalyptus dalrympleana*) or white sallee (*E. pauciflora*) in field or pot bioassay comparable to those described by del Moral and Muller (1969) for southern blue gum (*E. globulus*) and red river gum (*E. camaldulensis*) were evident.

INTRODUCTION

Picloram based herbicides (the amine salt of picloram plus the amine salt of 2,4-D or 2,4,5-T in a ratio of 1: 4) are used commercially for killing a variety of tree genera by direct placement of chemical into the vascular system of the tree, and have been used in this way to improve livestock grazing areas in Australia for a decade. *Eucalyptus* are normally left standing after treatment and legume, grass seeds and fertilizer may be broadcast into treated areas for pasture improvement.

This paper describes an experiment to determine if picloram injected into *Eucalyptus* trees could be phytotoxic to pasture legumes growing within the area of injected trees.

The writer presented part of this experiment in the proceedings of the Fourth Asian-Pacific Weed Science Society Conference (1973) and experimental procedure and portion of that data is presented again.

Relatively little is known about the metabolism and fate of picloram in plants. It appears that picloram in plants is very stable with most of the picloram remaining unchanged (Meikle *et al.*, 1966; Redemann *et al.*, 1968; Maroder and Prego, 1971).

Research has shown that picloram is taken up by roots of a variety of plants from nutrient solution and from soil and via foliage.

After foliar application, Reid and Hurtt (1970) found 6.2% of the picloram applied was exuded into the nutrient solution from the roots of red maple (*Acer rubum*) and 1.6% from the roots of green ash (*Fraxinus pennsylvanica*). Reid *et al.* (1971) found that the quantity of picloram exuded from red maple, green ash and white ash (*Fraxinus americana*) was not related to the tolerance of these species.

Australian studies (R. M. Moore) have shown ^{14}C picloram placed into the vascular system of the stem of three metres high bimble box (*Eucalyptus populnea*) and red river gum translocated in plants in less than 24 hours with the greatest concentration in the foliage within a few hours.

The following experiment was carried out to measure effect of picloram or any allelopathic effect from leaves on legume establishment or growth.

Materials and Methods

Mature mountain gum and white sallee trees growing near Oberon in Australia were injected at the trunk base with an aqueous solution of picloram potassium salt. Rates of injection were 1 ml of 2% and 2 ml of 2% picloram per injection pocket. Injection centres were spaced 15 cm apart and the pocket width was 4.5 cm. Collar ringbarked and untreated control were included.

Four 460 m^2 randomised plots of each treatment were laid down February 25, 1971. Average number of trees per plot was 47 (1,022/ha) and mean total basal circumference per plot was 4,048 cm (880 m/ha). Variation of tree size distribution in the experimental area was not significant.

With such a dense tree population, the rates of picloram injected into trees in the plots were equivalent to an overall dose of 231 g/ha or 0.26 g picloram/m of tree circumference (for 2 ml of 2% picloram) and 115 g/ha or 0.13 g picloram/m of tree circumference (for 1 ml of 2% picloram).

These injection rates closely represent peak use rate practised in a few areas only. Normal average injection use rates are between 70 and 90 g picloram/ha.

Seeds of subterranean clover and white clover were broadcast with molybdenum-superphosphate 49 days after picloram injection and ringbarking.

Two qualitative bioassays were carried out between January and April 1972 for observational purposes.

Bioassay Procedure. A quantitative bioassay using leaf mulch and clay loam soil both collected from the Oberon experimental area, commenced in June 1972. Soil samples were prepared which contained a series of concentrations of picloram in the soil maintained at a moisture content of three-quarters field capacity.

Three leaf mulch treatments were representative of light (123 g/m^2), medium (246 g/m^2) and heavy (492 g/m^2) leaf fall as observed on the soil surface in the experimental area at Oberon.

Pre-soaked subterranean and white clover seed was sown into weighted amounts of soil maintained at approximately three-quarters field capacity in plastic pots without drainage holes. Treatments were replicated five times.

Results and Discusstion

In the Oberon field plots good legume germination occurred in all treatments but low survial and slow growth were evident in all plots in 1971. Quadrat counts of white clover and subterranean clover throughout 1971 showed no significant differences in

Table 1. Legume measurements, August 1972, following treatment of *Eucalyptus*.

Treatment of trees (Feb., 1971)	Mean area of clover plants (cm^2)	Mean area of mature trifoliate leaf/plant (cm^2)
A. Picloram injected 115 g/ha*	7.27	1.13
B. Picloram injected 231 g/ha**	8.08	1.28
C. Collar ringbarked	8.22	1.19
D. Not treated	3.44	0.77
LSD (P=0.05 for means)	1.04	0.34

* 0.13 g picloram/m tree circumference. ** 0.26 g picloram/m tree circumference.

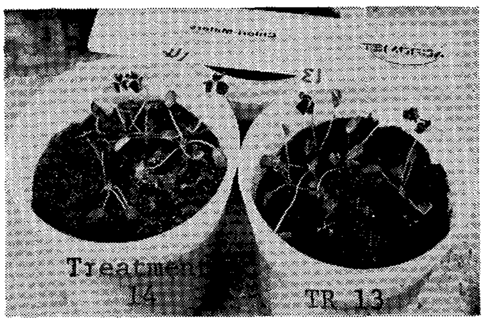
Measurements are the mean area per plant from 24 quadrats (0.36 m^2)/plot. Treatments A-D were replicated 4 times.

legume distribution and no visual growth differences were evident throughout the experimental area. A large proportion of legumes in the plots flowered and set seed in 1971 when only 3.8 to 5.1 cm high due to climatic conditions. Legume yield was not taken in the field in 1971. Leaf mulch was collected from the trial area in August 1971 (six months after picloram injection) and placed in cool dry storage until used for preliminary observation pot tests and then quantitative bioassay.

Legume measurements in the plots during 1972 indicated that the mean area of clover plants and mature trifoliate leaf area of these plants was significantly different only in untreated control plots where competition from trees was maximum (Table 1).

Bioassay can be a sensitive quantitative method for detection of small concentrations of picloram. Marley (1970), using soybean (*Glysine max* var. Java) as the test plant, found that for concentrations greater than 0.002 ppm a good index of measurement was the length of the unifoliate leaves. For concentrations of 0.002 ppm or less the more sensitive index was length of the centre leaflet of first or second trifoliate leaf. The limit of sensitivity in the test soil was 0.0005 ppm.

In this quantitative bioassay records of foliar appearance, plant height, mature trifoliate leaf diameter and finally dry weight at the conclusion of the experiment were recorded.



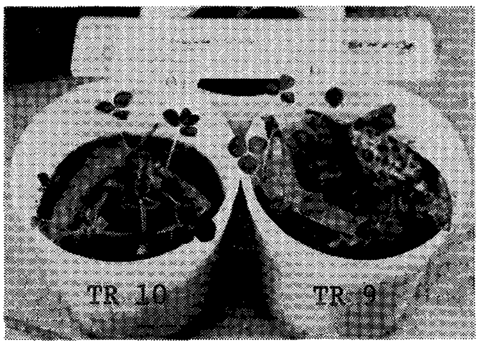


Fig. 1. Photographs to show effect of picloram on trifoliate leaf diameter of subterranean clover from 4 treatments in Table 2.

Table 2. Bioassay to determine the effect of picloram and leaf mulch on white and subterranean clovers.

Treatment	Mean leaf diameter (mm)	
	White clover	Subterranean clover
1: no picloram or leaf mulch	4.08 ef	15.5 c
2: 0.13 g* picloram/m, 492 g** leaf mulch/m^2	4.32 ef	17.0 ab
3: 0.13 g picloram/m, 246 g leaf mulch/m^2	5.98 bcd	18.0 a
4: 0.13 g picloram/m, 123 g leaf mulch/m^2	5.30 bcde	16.1 bc
5: 0.26 g picloram/m, 492 g leaf mulch/m^2	4.84 bcde	17.3 ab
6: 0.26 g picloram/m, 246 g leaf mulch/m^2	5.18 bcde	16.9 ab
7: 0.26 g picloram/m, 123 g leaf mulch/m^2	5.32 bcde	17.5 a
8: no picloram, 492 g leaf mulch/m^2	5.30 bcde	16.9 ab
9: no picloram, 246 g leaf mulch/m^2	6.14 bc	17.1 ab
10: no picloram, 123 g leaf mulch/m^2	4.62 def	17.5 a
11: picloram 0.01 ppm in soil	1.90 h	4.4 g
12: picloram 0.005 ppm in soil	2.34 gh	5.0 g
13: picloram 0.003 ppm in soil	2.64 gh	6.4 f
14: picloram 0.002 ppm in soil	3.36 fg	8.8 e
15: picloram 0.001 ppm in soil	6.26 b	9.9 e
16: picloram 0.0005 in soil	10.00 a	11.8 d

* Picloram injected per m of tree circumference.

** Leaf mulch per m^2 of soil surface.

Means in columns followed by a common letter are not significantly different at the 5% level of significance as determined by Duncan's Multiple Range test.

The effect of sublethal doses of picloram on legumes vary from gross stunting and thickening of stem tissue to varying degrees of leaf and stem distortion. In this experiment it was found that lateral diameter of mature trifoliate leaf area was the most sensitive measure of picloram effect (Fig. 1).

Results in Table 2 were recorded 48 days from the commencement of bioassay.

Picloram in soil (treatments 11–16, Table 2) reduced trifoliate leaf diameter of clover in order with each successive increase in concentration of picloram. With white clover 0.0005 ppm picloram has increased leaf area. It is not uncommon to see plant growth stimulation with very low concentrations of picloram in soil. Bauer *et al.* (1970) found picloram increased dry weight of corn, sorghum, cotton and soybean at 0.00025 ppm in soil and cowpea with 0.001 ppm in soil. In contrast dry weight of cowpea and soybean were reduced with 0.01 and 0.001 ppm picloram in soil respectively.

No visual picloram symptoms or allelopathic effects from leaf mulch were observed with white clover, and leaf measurements show no significant reduction between leaf mulch treatments and the series containing no leaf mulch.

With subterranean clover the standard series of picloram in soil have significantly smaller leaf diameters than leaf mulch treatments and soil above; and leaf mulch treatments gave bigger leaf diameter than no picloram or leaf mulch. This suggests that picloram, leaf mulch, or both, stimulated growth.

It can be concluded from this study that picloram injected into mature *Eucalyptus* trees in the field will not result in phytotoxicity on clover pasture establishment.

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Thickening Agent Useful for Reducing Spray Drift

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Abstract. A commercial "thickner" used as a flocculating agent for purification of industrial water has been found to be capable of reducing the formation of small droplets if added to made-up aqueous spray fluids containing amine 2,4-D. Spray drift downwind from target areas was markedly reduced in developmental trials with both ground and aerial spraying equipment, and more precise spray patterns were produced. The additive used is a synthetic high molecular weight polymerised blend of sodium acrylate and acrylamide which forms a viscous (thixotropic) emulsion when added slowly to water with stirring. No significanct inrease in spray pressure is necessary when this additive is used with aqueous sprays containing amine 2,4-D.

Introduction

When compared with other agricultural sprayers, the aeroplane cannot be challenged where speed, economy in use of fuel, and uniform delivery of a low volume of spray are the limiting factors in low cost treatment of large areas of land.

Herbicides when properly used can help greatly in the production of larger and cleaner yields of many crops. The key words are "properly used". To be effective as well as economically acceptable, a herbicide must be applied at the correct dose level to the most vulnerable part of the target during the most susceptible period of growth.

On every occasion that herbicides are used, spray contractors must check carefully the factors of wind direction, location of susceptible crops, suitability and efficiency of equipment, as well as personal spraying techniques. These factors are particularly important with the 2,4-D type herbicides when applied by spray equipment, and become vitally important where legal restraints are in force.

As human frailty qualifies the influence and importance of some of the abovementioned factors, an acceptable "safening agent" which can be added to made-up sprays has been sought by research workers throughout recent years. The basic requirement has been the ability to reduce the formation of very small spray particles and, by so doing, to minimise the risk of drift of potentially hazardous chemicals into susceptible crop areas.

Materials and Methods

Local trials were conducted in South East Queensland during 1973 and 1974, based upon the lead given by Akesson *et al.* (1964) of the Agricultural Engineering Department of the University of California. The experimental designs of Akesson *et al.* (1971) and test procedures designed by Yates *et al.* (1966, 1967) were used as guidance, as also some of their techniques for analysing dispersion of drift deposits.

A Grumman "Ag Cat" aircraft was used in these trials. Spraying Systems nozzles were fitted at eight inch (20 cm) intervals, and the aircraft was flown with the boom

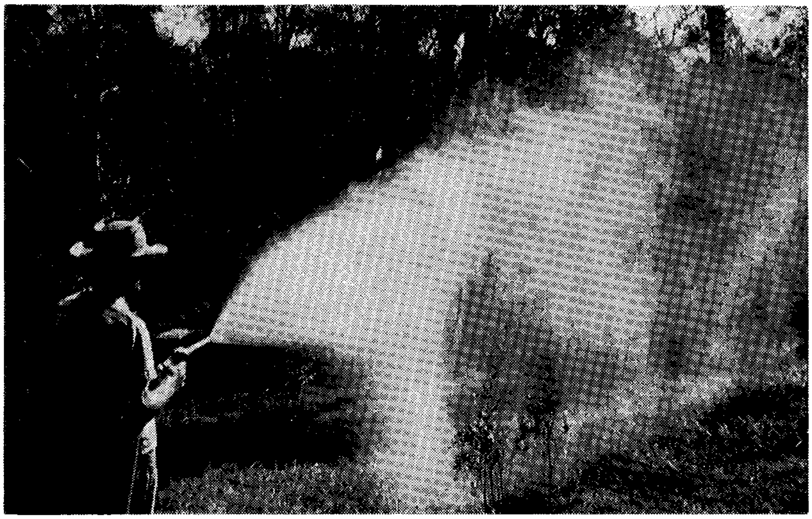

Fig. 1. High-volume ground spraying of amine 2,4-D in water at pressure of about 250 p.s.i. Note the production of a dense cloud of very small droplets which are slow to settle and liable to drift on wind currents.

Fig. 2. The same spraying operation as in Fig. 1 but with thickener added to the spray liquid. Relatively coarse droplets are produced and these display very little tendency to drift.

about one semi-span (approximately five metres) above the ground. The spray output varied between 2½–3 gallons/acre (28–34 litres/hectare).

Flight paths were orientated at right angles to the wind direction, and each spray mixture was coloured with a dye. Rolls of paper (blank newsprint 90 cm wide) were rolled out at right angles to the line of flight for recovery of droplet patterns. Samples of these droplet patterns were taken at semi-span intervals from the paper strips after each spray run, so that closer visual comparisons could be made.

Field experience in ground spraying showed that several "viscosity additives" or "thickeners" could be used to minimise drift (Figs. 1 and 2). With amine 2,4-D the most promising additive was a synthetic liquid polymer, formulated as a syrupy water-miscible concentrate and used for water purification in various industries. This particular polymer is known in agricultural circles as "Lo-Drift" and is a high molecular-weight blend of polyacrylamide and sodium acrylate which on mixing with water forms a thixotropic emulsion, i.e. a thin "gel". This thickener must be added slowly with stirring to the made-up spray fluid (to which any necessary wetter has already been added). Agitation should be continued for a minute or more, to ensure that thorough mixing has taken place. The thickened spray mixture is not seen to be "thick"; however droplets fall in strands rather than drops from the finger tips, i.e. the spray fluid has become slightly more viscid than water.

Results and Discussion

Observations and assessments from various field trials conducted during 1973 and 1974 are summarised as follows:—

1) With all nozzles and normal configuration, the quantity of fine droplets blown

Fig. 3. Low volume aerial spraying of amine 2,4-D in water at pressure of about 40 p.s.i. Note the cloud of small droplets, some of which are moved upwards and outwards by the wingtip vortices.

Fig. 4. Low volume spraying as in Fig. 3, but with thickener added to spray fluid and last three nozzles (nearest wing tips) removed. Note concentrated spray composed of relatively coarse droplets.

downwind was seen to be reduced considerably (by some 75%–90%) by the addition of thickening agent to amine 2,4-D sprays applied by aircraft (Figs. 3 and 4).
2) In crosswinds between 5–10 knots, the downwind edge of a thickened aerial spray swathe was brought approximately one semi-span closer to the line of flight.
3) Blanking-off the three nozzles nearest each wingtip reduced the amount of spray taken into the wing tip vortices and reduced the effective overall width of the spray swathe by about one semi-span. This reduction in width of swathe appeared to take place irrespective of addition of thickener.
4) Minimal production of fine spray droplets occurred when commercial thickener was added to an amine 2,4-D spray mixture in the aircraft tank at a dilution of 1 in 1,500, or 1 in 600 for ground spraying. These rates appear to be commercially acceptable.
5) With thickener but without 2,4-D, an increase of some 50% in spraying pressure was needed to offset increased viscosity; however the addition of amine 2,4-D reduced this tendency to increased viscosity and no alteration in pressure was necessary.

Associated with this examination of additives was a modest study of spray patterns from standard cone nozzles placed at various angles across the air stream, and jet-type nozzles (eg. "Solid-Stream") directed into the air stream. As expected, relatively coarse sprays were produced when both types of nozzles were directed to the rear and when the last three nozzles nearest the wing tips were blanked off, a markedly precise spray pattern was produced. When compared with the results using a normal nozzle configuration, this modified spray swathe is appreciably narrower, and up to 30% more flying time would be needed to cover any given area.

Acknowledgements

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Herbicidal Activity of Bifenox in Transplanted Rice Paddies

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Abstract. Bifenox [methyl 5-(2′,4′-dichlorophenoxy)-2-nitrobenzoate] was applied at a dosage of 20 kg/ha of granule (7%) when weeds were before, just-after and after the germination stage. A phytotoxicity test for transplanted rice plants was conducted by applying forty kg/ha of bifenox granule (7%) four days after the transplantation.

Bifenox showed outstanding herbicidal activities against various weeds such as barnyard-grass (*Echinochloa crus-galli*), monochoria (*Monochoria vaginalis*), toothcup (*Rotala ramosior*), false-pimpernel (*Lindernia procumbens*), waterpurslane (*Ludwigia palustris*), nutsedge (*Cyperus serotinus*), slenderspikerush (*Eleocharis acicuiaris*), hardstem-bulrush (*Scirpus hotarui*), and arrowhead (*Sagittaria pygmaea* and *S. trifolia*) when it was applied at an early growth stage of those weeds after the germination.

Bifenox was more effective than other diphenylether type herbicides in controlling hard-stem-bulrush and arrowhead. Like the above herbicides bifenox occasionally gave a brownish discoloration to the leaf-shearth of rice plants. However, it soon disappeared and no adverse effects was observed during the growth of rice plants. It is concluded that bifenox has a broader selectivity between transplanted rice and weeds at the early growing stage.

INTRODUCTION

Bifenox (MC-4379, MODOWN) was synthesized by Mobil Chem. Co., Ltd., in U.S.A. and Kruger and Fry (1973) reported that this compound was useful for protection of upland crops such as barley, wheat, soybean, corn and rice.

In Japan, bifenox has been evaluated as a herbicide for weed control in transplanted rice paddy since 1971. Bifenox has a broader spectrum of weed control when this compound applies from 3 days before to 8 days after transplantation, it is less harmful to rice than chlornitrofen, which is widely used. Bifenox isn't harmful to rice seedling by absorbing through the rice root.

It is not active when the treared plant is in the dark. Bifenox adsorbs to the surface soil and kills germinating weeds by being absorbed through their plumules.

Thus, it has a very good selectivity to transplanted rice, especially when it is applied before transplantation. Acute oral LD50 of bifenox is 4,566 mg/kg for mouse and more than 6,400 mg/kg for rat. Its fish toxicity for carp (TLM 48 hr) is 1.2 ppm of active ingredient. The present report describes the herbicidal effect on various weeds and the injury to transplanted rice.

Materials and Methods

Bifenox granule (7%) formulation was used in the experiments.

Experiment-1 (*Field tests*). Plant material: Rice seedlings at 2.5 leaf stage were transplanted. Bifenox was applied when the weeds were at an early growing stage. Plot size: 4 m ×5 m, 3 replicates. Soil type: Kanagawa alluvial silty loam soil. Date transplanted: June 2, 1972. Weed control and an injury to rice were observed at 35 days after application. Results are given in Tables 1 and 2.

Experiment-2 (*Pot tests*). Plant material: Rice seedlings at 2.5 leaf stage were used. Plot size: 1/200,000 ha. 3 replicates. Dates transplanted and observed: June 3, 1974 and July 16, 1974 respectively. Results are given in Table 3.

Results and Discussion

As shown in Tables 1 and 2, bifenox was very effective on main weeds in rice paddy such as hardstem-bulrush, barnyardgrass, monochoria, nutsedge, toothcup, water purslane and slender-spikerush. It was more effective on weeds than nitrofen and chlornitrofen by being applied 4 and 8 days after transplantation. Hardstem-bulrush was susceptible to bifenox, while chlornitrofen, nitrofen and chlomethoxynil were not effective on it. As for toxicity to transplanted rice, slightly brownish discoloration of leaf-sheath began to be recognized at about one week after application of bifenox as

Table 1. Weed control indices of bifenox granule applied in transplanted rice paddy (20 kg/ha).

Herbicide	Application time*	Weed control index**						
		H.b.	B.g.	M.c.	T.c.	N.s.	W.p.	F.p.
Bifenox	−3	10	10	10	10	10	10	10
(7% G)	+4	10	10	10	10	10	10	10
	+8	8	8	9	10	10	10	10
Chlornitrofen	−3	1	9	10	10	10	10	8
(9% G)	+4	1	8	9	9	9	9	7
	+8	0	3	4	6	6	5	4
Nitrofen	−3	2	9	10	10	10	10	10
(7% G)	+4	2	9	9	10	9	9	8
	+8	0	4	5	6	7	7	6
Chlomethoxynil	−3	5	10	10	10	10	10	10
(7% G)	+4	2	10	10	10	10	10	10
	+8	0	6	7	9	9	8	9
Untreated		0	0	0	0	0	0	0

* −3 = applied 3 days before transplantation, +4 = applied 4 days after transplantation.
** H.b. = hardstem-bulrush, B.g. = barnyardgrass, M.c. = monochoria, T.c. = toothcup, N.s. = nutsedge, W.p. = waterpurslane, F.p. = false pimpernel.
Activity of weed killing is marked on the basis of 10.

Table 2. Indices of bifenox granule to weed control and toxicity to rice at various intervals after application (20 kg/ha).

Herbicide	Application time	Days after application											
		7 days				21 days				35 days			
		S.t.*	S.p.	S.s.	R.	S.t.	S.p.	S.s.	R.	S.t.	S.p.	S.s.	R.
Bifenox	−3	10	10	10	0	10	10	10	0	4	7	8	0
	+4	10	10	10	1	10	10	10	1	5	8	8	0
	+8	8	9	9	1	7	8	9	1	3	6	6	0
Chlornitrofen	−3	4	4	9	0	0	0	9	0	0	0	6	0
	+4	2	3	9	1	0	0	9	1	0	0	6	0
	+8	0	0	6	1	0	0	5	1	0	0	3	0
Nitrofen	−3	4	4	9	1	0	0	9	1	0	0	6	0
	+4	2	3	9	2	0	0	9	2	0	0	5	0
Chlomethoxynil	−3	8	10	10	0	6	8	10	2	0	6	8	0
	+4	8	10	10	1	6	8	10	1	0	6	8	0
Untreated		0	0	0	0	0	0	0	0	0	0	0	0

* S.t.=arrowhead (*Sagittaria trifolia*), S.p.=*Sagittaria pygmaea*, S.s.=slender-spikerush, R.=rice. Activity is marked on the basis of 10 (0=not effective, 1=slightly brownish discoloration on the leaf-sheath without influencing to rice growth, 10=completely killed).

Table 3. Average plant height, number of tillers and brownish discoloration indices of leaf-sheath of transplanted rice treated with bifenox granule (40 kg/ha).

Herbicide	Application time	Tochigi diluvial volcanic ash silty loam soil			Kanagawa alluvial silty loam soil			Kagoshima shirasu grayish sandy loam soil		
		P.H.	T.N.	B.D.I.	P.H.	T.N.	B.D.I.	P.H.	T.N.	B.D.I.
Bifenox	−1	61.2 cm	7.3	0	61.0	7.0	1	63.0	7.0	1
	+4	60.0	7.7	0	61.3	7.7	1	62.0	8.0	1
Chlornitrofen	−1	61.0	7.3	0	61.0	6.7	1	63.2	7.3	1
	+4	60.3	7.0	0	60.0	7.7	1	62.7	8.0	1
Simetryne	−1	0**	0**	10	0**	0**	10	0**	0**	10
	+15	61.0	6.7	0	60.2	6.3	0	62.0	7.0	0
Untreated		60.7	7.0	0	62.0	7.0	0	63.0	7.3	0

* P.H.=plant height (cm), T.N.=number of tillers, B.D.I.=brownish discoloration index of leaf-sheath (0=not effective on rice, 1=slightly brownish discoloration of leaf-sheath, 10=completely killed).
** transplanted rice was completely killed.

well as nitrofen, chlornitrofen and chlomethoxynil, but they did not influence rice growth. It is concluded that bifenox has a broader spectrum of weed control and a broader selectivity between transplanted rice and weeds at an early growing stage.

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New Results with Bentazon in the Rice Growing Areas of Europe and the Americas (Sown Rice)

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Abstract. The paper deals with the use of bentazon (3-Isopropyl-1H-2,1,3-benzothiadiazin-(4)3H-one-2,2-dioxide) as a postemergence herbicide in sown rice.

The normal practice is to precede the bentazon foliage treatment with a preliminary treatment of the rice field with a herbicide effective against grasses, such as *Echinochloa* spp. Before foliage application, which is carried out during the 3- to 5-leaf stage of the weeds, the water has to be drained from the rice fields. The application rates of bentazon are 1.5, 2.0 and, in special cases, 3.0 kg/ha a.i. They give excellent control of *Alisma*, *Ammannia*, *Butomus*, *Commelina*, *Cyperus*, *Sagittaria*, *Scirpus* and many other weed species. Bentazon is selective in all growth stages of rice.

Introduction

At the Fourth Asian-Pacific Weed Science Society Conference in New Zealand, the author presented a paper on "Trials with bentazon in rice". The paper dealt with the initial trial results for bentazon active ingredient of the commercial product: BASAGRAN during 1970–1972 and earlier publications, in which the chemistry, range of effectiveness, and selectivity were reported.

At this year's conference in Tokyo, our Japanese colleagues will be speaking on the application of bentazon as a granular in transplanted rice. This paper, however, is concerned with the results from trials and practical usage, in which bentazon was used as a foliage-applied herbicide in sown rice.

Materials and Methods

Foliage application in small plot, replicated trials was carried out with knapsack sprayers. In large-scale trials and in practical usage, the material was applied by ground equipment, fixed-wing aircraft or helicopters. Before foliage application, which took place during the 3- to 5-leaf stage of the weeds, the water always was drained from the rice fields.

In the regions of Europe and the Americas where sown rice is grown, the normal practice was to precede the bentazon foliage treatment with a preliminary treatment of the rice field with a herbicide effective against grasses, such as *Echinochloa* spp. The application rates of bentazon were 1.5, 2.0 and, in special cases, 3.0 kg/ha a.i. The

Table 1. Percentage control of dicotyledonous weeds in sown rice using bentazon at the 3–5 leaf stage of the weeds (number of trials in brackets).

Weed species	Bentazon kg/ha	
	1.5	2.0
Ageratum conyzoides	92 (2)	98 (3)
Alternanthera sessilis	78 (3)	91 (5)
Ammannia spp.	99 (13)	99 (24)
Bacopa spp.	99 (1)	99 (1)
Bergia aquatica	98 (3)	99 (3)
Eclipta alba	—	94 (2)
Jussiaea abyssinica	98 (3)	99 (3)
Sesbania exaltata	—	98 (6)
Sphenoclea zeylanica	—	95 (2)

Table 2. Percentage control of monocotyledonous weeds in sown rice using bentazon at the 3–5 leaf stage of the weeds (number of trials in brackets).

Weed species	Bentazon kg/ha	
	1.5	2.0
Alisma spp.	96 (21)	97 (45)
Butomus umbellatus	94 (6)	93 (20)
Commelina spp.	100 (5)	99 (19)
Cyperus difformis	95 (9)	94 (13)
C. esculentus	—	95 (2)
C. flambristilis	—	100 (1)
C. iria	—	100 (1)
C. rotundus	88 (2)	93 (2)
C. spp.	100 (1)	96 (5)
Eleocharis spp.	96 (2)	98 (4)
Fimbristylis dichotoma	99 (2)	99 (3)
Heteranthera limosa	100 (1)	93 (4)
Mariscus longibracteatus	97 (2)	98 (3)
Sagittaria spp.	95 (8)	99 (9)
Scirpus maritimus	97 (28)	96 (61)
S. mucronatus	94 (15)	96 (33)
Typha spp.	—	98 (5)
Echinochloa spp.	no control	no control

volumes of aqueous carrier used were approx. 400 l/ha for knapsack sprayers and ground equipment, 75–150 l/ha for fixed-wing aircraft and 35–150 l/ha for helicopters.

Results

Small-scale trials. From a total of about 130 small plot, replicated trials on sown rice in Europe and the Americas, the herbicidal effect of bentazon, applied at the 3- to 5-leaf stage of the weeds, is summarized in two tables. These two tables contain the most important weeds found in the trials. From these tables it can be seen that bentazon gave very good control of *Alisma* spp., *Ammannia* spp., *Butomus umbellatus*, *Commelina* spp., *Cyperus difformis*, *Eleocharis* spp., *Sagittaria* spp., *Scirpus maritimus*, *Scirpus mucronatus*, etc. As is known, bentazon has no herbicidal effect on Gramineae.

Large-scale trials and practical usage. In 1973, 1974 and 1975 bentazon at 2 kg/ha (4 l/ha BASAGRAN) in 300–400 l water was applied for weed control on more than 150,000 hectares of rice in Italy, Romania and Spain. Ground equipment was used for most of the treatments. These applications in practical usage confirmed the results obtained in the previous trials. Applications made by helicopter and fixed-wing aircraft at a volume of aqueous carrier of 50–150 l/ha were also satisfactory and in most cases equal to the treatments with ground equipment.

However, in 1975 it was shown again that with aircraft, in comparison to ground equipment, more attention must be given to carrying out the application technique accurately. The volume of aqueous carrier, therefore, should range between 100–150 l/ha for airplanes and slightly less for helicopters. The helicopter normally enables more accurate and quicker application. To ensure effectiveness, it is advisable not to use less than 2.5 kg/ha bentazon for aerial application.

Discussion

Rice herbicides must control Gramineae, Cyperaceae and broadleaved rice weeds. In areas with intensive growing, a single application very seldom is adequate. Growers, therefore, have switched to the practice of using several herbicides in sown and transplanted rice.

As a herbicide in sown rice, bentazon will be used mainly where 1) the rice herbicides normally applied do not sufficiently control certain weeds, 2) phenoxy herbicides can not be applied at a particular time due to reasons of selectivity or 3) phenoxy herbicides can not be applied because of the danger of drift to sensitive neighbouring crops.

Bentazon serves the above purposes well, since it has a very broad range of effectiveness as a rice herbicide, is selective in all growth stages of rice and does not present the danger of drift, which is so common among the phenoxy herbicides.

The use of bentazon requires particular attention to application techniques. If fixed-wing aircraft is used for a bentazon foliage treatment in sown-rice, special care must be taken to ensure uniform distribution of the spray mixture. This can be accomplished by using high volumes of aqueous carrier (e.g., 150 l/ha) and a double flight over the area, each time changing the flight course by 50%. Experience indicates that, if the weeds have passed the optimal 3- to 5-leaf stage, the application rate of bentazon must be increased to 2.5 or 3.0 kg/ha if fixed-wing aircraft is used for application.

For ground equipment this higher dose is not necessary, as ground equipment operates at pressures above atmospheric pressure and guarantees better penetration of the rice crop by the spray mixture.

As most of the participants at this conference are from areas in Asia with transplanted rice, the purpose of this slide series is to give you an idea of how bentazon is applied in sown rice and what results are obtained.

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Weed Control in Rice with CG 102

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Abstract. An investigation was made of a granular formulation of CG 102 or C 288, a herbicide combination of 4.4% (w/w) piperophos plus 1.1% (w/w) dimethametryn. The herbicide applied into paddy fields at 30 and 40 kg granules per hectare gave very promising results for control of *Echinochloa oryzicola* up to the 2.5 leaf stage, as well as for other types of mono- and dicotyledonous weeds without injury to rice but failed to control *Sagittaria pygmaea*. This perennial weed was remarkably controlled with TH 63, a granular formulation of the mixture of 5.5% (w/w) CG 102 and 10.0% (w/w) bentazon.

INTRODUCTION

The labour shortage in Japan causes difficulty in the use of rice herbicides effective over only a very short application period. The present authors examined the effect of a granular formulation of CG 102 or C 288 (AVIROSAN), a herbicide combination of 4.4% (w/w) piperophos plus 1.1% (w/w) dimethametryn invented by Ciba-Geigy Ltd. (Green and Ebner, 1972; Green and Uchida, 1974; Uchida *et al.*, 1976) on crop and weeds, to develop a rice herbicide effective over 2 weeks from the early time after rice transplanting to the 2–3 leaf stage of *Echinochloa oryzicola* Vasing.

The present authors also conducted an experiment on simultaneous control of annual and perennial weeds with a granular formulation of TH 63 (WIDER) developed by Iwasaki, Watajima and Hagimoto (1976), a combination of 5.5% (w/w) CG 102 and 10.0% (w/w) bentazon invented by BASF A. G. (Luib *et al.*, 1973).

MATERIALS AND METHODS

The experiments were conducted with rice (var. *japonica*) and various weeds growing in 60 ×60 ×50 cm concrete pots outside the glasshouse in the Kyoto section and in a paddy field in the Fukuchiyama section of the Takeda Pesticide Research Laboratories. The pot experiments were replicated three times and the field experiment was replicated four times. The experimental results were expressed by mean values of the repetition.

Piperophos, dimethametryn, bentazon, CG 102 and TH 63 were formulated as granules of 4.4, 1.1, 10.0, 5.5 and 15.5% (w/w) respectively. The doses of these herbicides were expressed by the amount of granules per hectare. The effects of the treatments were determined by the percent reduction in dry weight of the shoots. Full details of the materials and methods are given in the results and discussion section.

Results and Discussion

The effect of varying doses of CG 102 was tested on rice and various weeds growing in a sandy loam soil in the concrete pots to determine the relation between the doses and the effects. CG 102 treated 13 days after transplanting of rice controlled practically *Cyperus difformis* L., *Lindernia procumbens* Philcox, *Dopatorium junceum* Hamilt., *Rotala indica* Koehne, *Elatine triandra* Schk. and *Eleocharis acicularis* Roem. et Schult. at a rate of 20 kg/ha, *Echinochloa oryzicola* (12.9$\pm$2.32 cm with 2.6$\pm$0.39 leaves) at 30 kg/ha, *Monochoria vaginalis* Presl at 35 kg/ha and *Cyperus serotinus* Rottb. at 40 kg/ha under a water leakage condition at the rate of 2.8 cm/day in depth for 2 days from the treatments. But it failed to control *E. oryzicola* (17.6$\pm$2.65 cm with 3.6$\pm$0.73 leaves), *M. vaginalis* and *C. serotinus* at the treatment 17 days after transplanting and *Sagittaria pygmaea* Miq. at both the treatments 13 and 17 days after transplanting even with the highest dose of 50 kg/ha.

On the other hand, CG 102 increased the number of stems and dry weight of shoots of rice with increasing of dose of the herbicide but only those of rice plants treated with CG 102 at more doses than 35 kg/ha 13 days after transplanting were over 100% or those of the hand-weeded control. The great reduction in rice growth observed in the other plots seemed to be based on weed competition, because any symptom of herbicide injury was not observed on rice. Thus, CG 102 applied at doses of 30 and 40 kg/ha gave very promising results for control of *E. oryzicola* up to the 2.5 leaf stage, as well as for other types of mono- and dicotyledonous weeds.

Furthermore, information on practical usages of CG 102 and TH 63 was obtained in an experiment with rice and various weeds growing in a diluvial clay loam soil in the agricultural experiment farm of their laboratories. An experimental field was begun to irrigate and puddled on 27th May 1974. Young seedlings of rice (strain Nihonbare) of average height 12.3$\pm$1.34 cm with 2.1$\pm$0.09 leaves (omitting the first imperfect leaf) were mechanically transplanted 3 cm deep on 30th May. Each plot was enclosed with pine boards in 5 m^2 for preventing outflow of applied herbicides. Water was kept 5 cm deep after transplanting. The granular formulations of CG 102 and TH 63 were applied into water at a dose of 30 kg/ha 4, 8, 12, 14, 16 and 18 days after transplanting. The minimum, maximum and mean air temperatures recorded during 10 days after each treatment were 11–13, 32–33 and 21–22°C respectively and the minimum and maximum water temperatures were 16–19 and 32–34°C respectively. The rate of vertical water leakage in the field was 0.7 cm in depth per day. The herbicidal effects and rice yields were assessed on 31st July to 3rd August and 4th to 14th October respectively.

The weed population in control plots at the conclusion of the experiment is shown in Table 1. *E. oryzicola* had a majority in the field, that is, it formed 65% of the total dry weight of weeds. As shown in Table 2, CG 102 killed completely *Hymenachne indica* Büse forma *oryzetorum* T. Koyama, *Vandellia crustacea* Benth., *Vandellia*

Table 1. Weed population in untreated plots at conclusion of experiment.

Weed species	No./m^2	Dry weight of shoot (g/m^2)
Monocotyledons		
Echinochloa oryzicola (*E.o*)	182	178.5
Hymenachne indica forma *oryzetorum*	46	1.4
Cyperus difformis (*C.d*)	121	3.2
*Cyperus serotinus** (*C.s*)	14	4.0
*Scirpus juncoides** (*S.j*)	9	1.5
*Eleocharis acicularis** (*E.a*)	—	9.2
Eleocharis congesta subsp. *japonica* (*E.c*)	56	3.2
Monochoria vaginalis (*M.v*)	417	45.3
*Sagittaria pygmaea** (S.p)	101	3.4
Dicotyledons		
Vandellia crustacea	222	0.6
Vandellia angustifolia	396	2.6
Dopatrium junceum	638	4.7
*Limnophila sessiliflora**	28	0.3
Rotala indica	1190	16.5
Total	3420	274.4

* Perennial weeds.
( ): Abbreviation of scientific name used in Table 2.

Table 2. The effects of CG 102 and TH 63 applied at a dose of 30 kg/ha on rice and weeds.

Herbicides	Time of application*	Weed species** and % reduction in dry weight of shoots								% of control in wt. of winnowed paddy***
		E.o	*C.d*	*C.s*	*S.j*	*E.a*	*E.c*	*M.v*	*S.p*	
CG 102	4	100	100	100	100	100	100	100	−176	229
	8	100	100	100	100	100	100	100	−8	236
	12	98	100	100	93	100	100	100	26	247
	14	88	100	80	87	100	100	96	71	227
	16	47	100	74	73	100	91	86	−29	153
	18	−39	91	70	60	99	63	76	−100	126
TH 63	4	100	100	100	100	100	100	100	91	259
	8	100	100	100	100	100	100	100	88	253
	12	91	100	100	100	100	100	100	100	233
	14	20	100	100	100	100	100	100	94	178
	16	3	100	100	100	100	100	100	97	150
	18	−9	100	100	100	100	100	99	97	150

* Days after rice transplanting.
** Abbreviated scientific name of weeds (cf. Table 1). *H. indica* forma *oryzetorum* and the dicotyledons in Table 1 were completely eliminated at all the treatments.
*** 1735 kg/ha in mean value in control plots. 239% in mean value in hand-weeded plots.

angustifolia Benth., *D. junceum*, *Limnophila sessiliflora* Blume and *R. indica* at all the growth stages in this experiment and controlled practically *E. oryzicola* (at the 2.4±0.70 leaf stage), *Scirpus juncoides* Roxb. and *C. serotinus* treated within 14 days and *Eleocharis congesta* D. Don subsp. *japonica* T. Koyama treated within 16 days, *C. difformis*, *E. acicularis* and *M. vaginalis* treated within 18 days from transplanting. The effect on *S. pygmaea* was only observed by the treatment 14 days after transplanting but not practical. TH 63 controlled practically all the annual and perennial weeds at all the growth stages except *E. oryzicola*. This weed was remarkably controlled by the treatment within 12 days from transplanting or at the earlier stages than the 2.3±0.55 leaf stage but not 14 days after transplanting. It was based on the slow release of the active ingredients from the granules that the application period of TH 63 for *E. oryzicola* was shorter than that of CG 102. The effect has been improved so that TH 63 is effective in the same degree as CG 102.

The effects of these herbicides against transplanted rice are also shown in Table 2. The number of rice plant per square meter and thousand-kernel-weight were little affected by these herbicides. The number of panicle and winnowed paddy were increased with increasing the herbicidal effects. Thus, the weight of winnowed paddy or grain yields of rice applied with CG 102 and TH 63 4 to 14 days and 4 to 12 days after transplanting respectively were about 2.3 to 2.6 times as much as those of control. Any visible symptom was not observed on rice plants in all the plots. Both CG 102 and TH 63 gave also very promising results in the cooperative field trials with the Japan Association for the Advancement of Phytoregulators at many agricultural experiment stations from Hokkaido to Kagoshima for 4 years from 1972 to 1975.

An experiment on the effects of piperophos, dimethametryn and bentazon and their combinations was conducted in the afore-mentioned concrete pots irrigated to a depth of 5 cm under a water leakage condition at the rate of 1.5 cm/day in depth for 2 days from the treatments. The granular formulations of each herbicide and the mixtures (1: 1 or 1: 1: 1, w/w) of these granules are applied into water at 30 and 40 kg/ha of each herbicide. Piperophos was active to *E. oryzicola* and *E. acicularis* by inhibiting the growth. But the growth inhibition of *E. oryzicola* was partially restored with the lapse of times. Dimethametryn was very effective against *L. procumbens* and *R. indica*, and moderately effective against *M. vaginalis*. Bentazon was remarkably effective against *R. indica* and moderately effective against *M. vaginalis*, *L. procumbens*, *S. pygmaea* and *E. acicularis* at a dose of 40 kg/ha. The combination of 30 kg/ha piperophos and 30 kg/ha dimethametryn was very effective against all the weed species except *S. pygmaea* and *S. juncoides*. *S. pygmaea* was remarkably controlled with the combination of dimethametryn and bentazon. *S. juncoides*, however, was remarkably controlled only by the combination of piperophos, dimethametryn and bentazon at 40 kg/ha of each herbicide. Hagimoto and Yoshikawa (1972) suggested that growth inhibitors were synergistic on *E. oryzicola* with inhibitors of photosynthesis and all herbicides of which time of application was less critical would be combinations of both inhibitors. Piperophos is a typical growth inhibitor, and dimethametryn and bentazon are inhibitors of photosynthesis. The effects of CG 102 and TH 63 on *E. oryzicola* were explainable by the prevention of "growth-dilution". The synergistic effect of TH 63 on *S. juncoides* seemed to be based on the same principle. But the synergistic effect of the combination of dimethametryn and bentazon on *S. pygmaea* can not be understandable in the same point of view.

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Effect of a New Herbicide TH 63 in Rice

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Abstract. TH 63, a granular formulation of the mixture of 4.4% (w/w) piperophos, 1.1% (w/w) dimethametryn and 10.0% (w/w) bentazon was examined for simultaneous control of both annual and perennial weeds. TH 63 was more effective than bentazon alone not only against perennial weeds but also against nongraminaceous annual weeds. The difference of their effects was very prominent under a water leakage condition at the rate of 3 cm per day. Thus, it appeared that TH 63 was capable of controlling a wide range of annual and perennial weeds without injury to rice when applied 7 to 15 days after transplanting.

Introduction

Recently, some kinds of perennial weeds such as *Sagittaria pygmaea* Miq., *Alisma canaliculatum* A. Br. et Bouché, *Cyperus serotinus* Rottb. and *Scirpus juncoides* Roxb. have become a serious problem in Japanese paddy fields. They have been spreading as a result of the repeated application of herbicides which have little or no effect on these weeds. Bentazon is effective against many kinds of annual and perennial weeds without injury to rice (Luib *et al.*, 1973). The effect, however, is remarkably reduced by water leakage (Iwasaki and Watajima, 1973) and there is hardly any effect on graminaceous weeds. On the other hand, CG 102 (AVIROSAN), a granular formulation of 4.4% (w/w) piperophos plus 1.1% (w/w) dimethametryn has an excellent effect against various kinds of annual weeds and some kinds of perennial weeds (Hagimoto *et al.*, 1976). So TH 63 (WIDER), a granular formulation of the mixture of 5.5% (w/w) CG 102 and 10.0% (w/w) bentazon has been developed for simultaneous control of both annual and perennial weeds. The present report gives the experimental results.

Materials and Methods

In all experiments, TH 63 was used in granule form. The granules contained 4.4% (w/w) piperophos, 1.1% (w/w) dimethametryn and 10.0% (w/w) bentazon. Single bentazon was also used in granules containing 10.0% active ingredient. The doses of these herbicides were expressed by the amount of granules per hectare. A pot test was carried out in a greenhouse using 1/5,000 are Wagner's pots. The tubers of *S. pygmaea* were sprouted at 30°C and 5 tubers were planted in the pot 3 cm deep. Both granules of TH 63 and bentazon were applied in the pots irrigated to a depth of 3 cm.

The water leakage was continued for 2 days after application.

A field test was conducted with TH 63 in a diluvial clay loam soil in the Fukuchiyama Experimental Farm of our research laboratories in 1973. Water was kept 5 cm deep after transplanting. The rate of vertical water leakage in the field was 0.7 cm in depth per day. The area of each plot was 5 m^2.

The JAPR (Japan Association for the Advancement of Phyto-regulators) cooperative field tests were carried out at many agricultural experiment stations located from Hokkaido to Kyushu for 3 years from 1973 to 1975.

Results and Discussion

The effects of TH 63 and bentazon on *S. pygmaea* are shown in Table 1. Bentazon gave an excellent effect under the nonleakage condition. The effect, however, was remarkably reduced by water leakage. Because bentazon is rather water soluble and is not absorbed by soil (Abernathy and Wax, 1973), leaching of bentazon seemed to occur. On the other hand, TH 63 showed an excellent effect not only under the non-

Table 1. The effects of TH 63 and bentazon on *S. pygmaea* with 6 leaves under water leakage condition.

Herbicide	Dose (kg/ha)	Reduction in dry weight of whole plant: Nonleakage condition (%)	Reduction in dry weight of whole plant: Leakage condition* (%)
TH 63	20	91	62
	30	99	81
	40	99	94
Bentazon	20	99	23
	30	91	66
	40	95	77
LSD	(p=0.05)	N.S.	29.3

* 3 cm/day in water depth.

Table 2. Growth stages of rice and weeds at each application time in field trial in 1973.

Plant species	Days after transplanting: 6		13		20	
	Leaf number	Plant height (cm)	Leaf number	Plant height (cm)	Leaf number	Plant height (cm)
Rice	6.1	25.8	8.2	29.4	—	36.5
Echinochloa oryzicola	0.3	1.7	2.3	6.9	3.4	13.4
Monochoria vaginalis	—	—	2.1	2.2	3.6	3.5
Sagittaria pygmaea	1.6	2.5	4.1	4.0	5.3	6.1
Cyperus serotinus	—	—	3.9	7.0	6.0	16.8
Eleocharis kuroguwai	—	—	4.2	3.9	4.2	5.8

Table 3. The effect of TH 63 in field trial in 1973.

Application time (Days after transplanting)	Dose (kg/ha)	Reduction in dry weight of shoots (%)						
		Weed species*						
		E.o	M.v	S.p	C.s	E.k	E.a	Total
6	20	100	100	−189	100	68	96	85
	30	99	100	27	100	92	100	96
	40	100	100	69	100	86	100	98
13	20	97	100	68	100	27	100	96
	30	99	100	88	100	78	100	98
	40	100	100	86	100	100	100	99
20	20	−58	96	98	94	30	100	19
	30	15	100	100	100	14	100	52
	40	66	100	99	100	92	100	80

* E.o=*Echinochloa oryzicola*, M.v=*Monochoria vaginalis*, S.p=*Sagittaria pygmaea*, C.s=*Cyperus serotinus*, E.k=*Eleocharis kuroguwai*, E.a=*Eleocharis acicularis*.

leakage condition but also an effect significantly superior to bentazon alone under a leakage condition at the rate of 3 cm in depth per day. This result suggested that the mixing of CG 102 and bentazon is advantageous not only for the simultaneous control of both annual and perennial weeds but also for the stability of the efficacy of bentazon under water leakage conditions.

The effect of TH 63 in a paddy field was examined in 1973. The growth stages of rice and weeds at each application time are shown in Table 2. TH 63 showed an excellent effect against many kinds of weeds at all the treatments without injury to rice. The effect on *Echinochloa oryzicola* Vasing. was high at the applications 6 and 13 days after transplanting, but the effect on *S. pygmaea* was best at the treatments 13 days and especially 20 after transplanting (Table 3).

The results of the co-operative field tests by arrangement of JAPR in 1973 were similar to the above (Table 4). No reduction of grain yield was found at any application. The effect of TH 63 on *S. pygmaea* in the co-operative field tests is summarized in Fig. 1. Consequently, it appeared that the effect of TH 63 on *S. pygmaea* was reduced when applied at the 2-leaf or less advanced stages below about 20°C, and the reduction of the effect was increased by heavy water leakage more than 2.5 cm in depth per day.

The sequential application of two herbicides is generally used to secure herbicidal effect under inadequate conditions for herbicidal activity such as heavy water leakage, low temperature, longterm successive emergence of weeds and less advanced plant growth stages. The effect of TH 63 at the sequential application with chlornitrofen, chlomethoxynil or butachlor was confirmed in our research laboratories and the JAPR co-operative field tests in 1974 and 1975.

Through the above mentioned results, TH 63 is very promising for control of both annual and perennial weeds, but in the case of temperatures below about 20°C or heavy water leakage conditions, it should be applied at the 3-leaf or more advanced stages of *S. pygmaea* and before the 2.5-leaf stage of *E. oryzicola*. If this is impossible, TH 63 should be applied several days after application of chlornitrofen, chlomethoxynil or butachlor.

Table 4. Summary of JAPR co-operative field test results on TH 63 in 1973.

Application time (Days after transplanting)	Dose (kg/ha)	Grade of herbicidal efficacy*	Number of trials on each grade: Weed species** E.o	B.L	E.a	S.p	C.s	S.j	Average of grain yield (% of hand-weeding)
7–13	30	E	43	51	45	21	9	14	102
		G	5	0	1	6	0	2	
		F	4	1	1	5	1	1	
		P	1	0	1	10	0	3	
7–13	40	E	9	10	7	8	1	3	104
		G	1	0	0	0	0	0	
		F	0	0	0	0	0	0	
		P	0	0	0	0	0	0	
14–20	30	E	19	30	27	13	5	7	99
		G	3	1	1	3	0	3	
		F	7	1	0	6	1	1	
		P	3	0	1	2	1	1	
14–20	40	E	25	32	28	14	5	8	102
		G	2	1	2	5	1	3	
		F	4	0	0	2	0	2	
		P	3	0	0	0	0	1	

* E=excellent (less than 10% of weedy control), G=good (11–20%), F=fair (21–50%), P=poor (more than 51%).

** E.o=*Echinochloa oryzicola*, B.L=broadleaf weeds, E.a=*Eleocharis acicularis*, S.p=*Sagittaria pygmaea*, C.s=*Cyperus serotinus*, S.j=*Scirpus juncoides*.

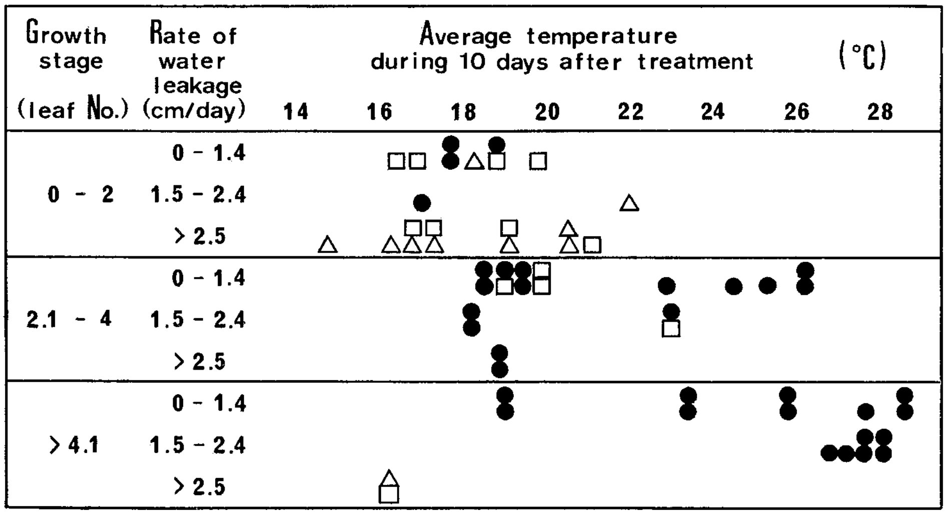

Fig. 1. Summary of the effect of TH 63 on *S. pygmaea* at JAPR co-operative field tests in 1973.
(● =less than 10% of weedy control, □=11–20%, △=more than 21%)

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A Multi-location Test of Granular Herbicides on Transplanted Rice

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Abstract. In a multilocation test on the effectiveness of several granular herbicides for transplanted rice during 1972–1974 wet season at six Experimental Stations of CRIA Bogor no severe phytotoxicity of the rice plant was observed. Effective control of the existing weed species was obtained with piperophos+2,4-D IPE (G) and trifluralin/2,4-D IPE (G). Benthiocerb (G) and TCE-styrene/2,4,-D IPE (G) controlled grasses and sedges well and broadleaved weeds moderately; 2,4-D IPE (G), nitrofen (G), butachlor (G) and MCPA (EC) followed by handweeding had moderate effects. No significant differences in yield between the traditional method, i.e., handweeding two times, and one application of the granular materials tested were obtained. Weeds in the untreated plots commonly reduced yields by 800–1000 kg/ha dry grain compared to plots receiving herbicide application.

Introduction

Most tropical Asian farmers practice transplanting in rice cultivation. During the early growth from transplanting to 4 weeks, weed competition is important because weeds can greatly affect the development of the number of tillers (IRRI, 1967). It is important to keep the fields as weed-free as possible during early growth. In recent years use of herbicides on rice in developing countries has become more and more popular, mainly using 2,4-D and MCPA in liquid formulation (De Datta, 1974). Sprays of these herbicides could be toxic to the rice plant with time, thereby influencing its growth and development. To minimize direct contact of the solution with crop leaves and stems, use of granular formulations may prove more useful. Application of granules is easier and simpler, sprayers and other equipments are not needed, and time of broadcasting may be less when compared to time of spraying. Under these conditions, toxic effects to the crop will be minimized.

Experiments to evaluate effectiveness of granular herbicides on rice were initiated by the Central Research Institute for Agriculture in Bogor in 1968. Promising granules were further tested in a multilocation test with different weed densities and species.

Materials and Methods

The experiments were conducted in 6 Experimental Stations of CRIA which had different weed populations and weed species. A randomized block design was used with

4 replications. IR 5 rice variety was used in the first year, while in the 2nd and 3rd years an improved variety Pelita I/2 was used. The plants were spaced 25 ×25 cm with 3 plants per hill. Twenty one day old seedlings were used. The experimental plots were 3 ×5 m. All experiments were fertilized with 120 kg N plus 45 kg P_2O_5 per ha. One third of N and all P fertilizers were applied at transplanting. The rest of N was applied 1/3 at tillering stage (21 DAT) and 1/3 at primordia initiation stage (60 DAT). Scorings from 0–10 were used to evaluate phytotoxicity and weed control effectiveness.

Results and Discussion

Phytotoxicity. In general no severe symptoms of toxicity were observed after granule applications. With MCPA (EC) as a standard 2,4-D IPE and nitrofen granules showed slight toxicity for about two weeks. Thereafter normal growth was observed. Piperophos, butachlor, benthiocarb and TCE-styrene (in combination with 2,4-D IPE or as a single herbicide) were selective and did not show any remarkable symptoms of toxicity. Data from observations for phytotoxicity are shown in Table 1.

Weed control. The herbicides tested in these experiments belong generally to grass killer group. The exceptions were MCPA and 2,4-D IPE which are mostly effective against broadleaf weeds and sedges. But pre-emergence applications of these phenoxy compounds have the ability to inhibit germinating weed seeds. On the average piperophos+2,4-D IPE, trifluralin/2,4-D IPE, benthiocarb+2,4-D IPE or benthiocarb alone can kill most of the existing weeds in the experimental plots. At Pusakanegara Experimental Station, where *Monochoria vaginalis* is dominant, benthiocarb alone was moderately effective in controlling this broadleaf and should have done better if combined with 2,4-D IPE. Butachlor and nitrofen granules were effective for grasses, but not for *M. vaginalis* and *Marsilea crenata,* especially at Pusakanegara and Kendalpayak Experimental Stations, where these weeds are dominant. To increase the efficacy of those herbicides it would be better to combine them with 0.5–0.8 kg/ha a.i. of 2,4-D IPE (G). Gramineae species, which can be controlled with granules, consisted of *Echinochloa crusgalli, E. colonum, Leptochloa chinensis.* But several grasses like *Paspalum vaginatum,* grew from rhizomes left in the mud during land preparation could not be controlled effectively. Also, growing from rhizomes and rather difficult to eradicate were *M. crenata* and *Salvinia molesta* (Pusakanegara and Kendalpayak Experimental Stations). Other weed species like *Scirpus lateriflorus, Fimbristylis miliacea, Cyperus difformis, M. vaginalis, Gratiola juncea* were fairly well controlled. In several plots piperophos+2,4-D IPE (G) eradicated *M. crenata* well. In Table 2, Column S, high ratings do not always mean effective control for sedges. In some Experimental Stations there were low populations of sedges.

Percent weed cover. Observations at 19 DAT showed that all herbicides could suppress weed growth. But, on the other hand, at 60 DAT several weed species had developed and percent weed coverage increased to about 42% for 2,4-D IPE compared to 73–95% for the untreated plots. Piperophos+2,4-D IPE, trifluralin/2,4-D IPE and benthiocarb showed the lowest percent weed coverage. For handweeding twice and MCPA followed by handweeding, the percentage was low since observations were made at two weeks

Table 1. Effect of herbicides on the phytotoxicity, weed coverage and yield of transplanted rice. CRIA. Wet Season, 1972–1974.

Treatment	Rate kg/ha a.i.	Toxicity 71/72 DAT 19	Toxicity 71/72 DAT 60	Toxicity 72/73 DAT 19	Toxicity 72/73 DAT 60	Toxicity 73/74 DAT 19	Toxicity 73/74 DAT 60	Toxicity Average DAT 19	Toxicity Average DAT 60	Percent weedcover 71/72 DAT 19	Percent weedcover 71/72 DAT 60	Percent weedcover 72/73 DAT 19	Percent weedcover 72/73 DAT 60	Percent weedcover 73/74 DAT 19	Percent weedcover 73/74 DAT 60	Percent weedcover Average DAT 19	Percent weedcover Average DAT 60	Dry grain yield 71/72 (kg/ha)	Dry grain yield 72/73 (kg/ha)	Dry grain yield 73/74 (kg/ha)	Dry grain yield Average (kg/ha)
2, 4-D IPE (G)	0.8	1.7	1.0	1.9	0.8	1.4	0	1.7	0.6	4	11	7	42	7	38	6	30	4,637	4,953	3,471	4,354
TCE-styrene/ 2, 4-D IPE (G)	0.75/ 0.5	1.5	1.0	1.4	0.8	1.0	0.2	1.3	0.7	3	12	5	27	6	36	5	25	4,485	4,811	3,702	4,333
Trifluralin/ 2, 4-D IPE (G)	0.6/ 0.5	1.6	1.0	1.4	0.9	—	—	1.5	1.0	4	14	5	23	—	—	4	18	4,499	5,175	—	4,837
MCPA (L)+ weeded 1x	0.6	1.5	1.1	1.6	0.5	1.8	0	1.6	0.5	5	12	5	8	8	34	6	18	4,443	5,198	3,727	4,456
Nitrofen (G)	2.0	1.9	1.1	1.6	0.7	2.3	0.1	1.9	0.5	4	16	5	27	9	30	6	25	4,415	5,041	3,721	4,392
Benthiocarb (G)	1.5	1.3	1.0	1.2	1.0	0.9	0.4	1.1	0.8	4	5	6	28	8	28	6	21	4,670	5,230	3,566	4,489
Butachlor (G)	1.0	1.3	1.0	0.9	0.7	0.4	0	0.9	0.6	8	21	8	39	17	31	11	30	4,415	4,906	3,669	4,330
Piperophos+ 2, 4-D IPE (G)	1.0+ 0.5	1.5	1.0	1.4	0.9	0.9	0.1	1.3	0.7	3	5	4	17	5	21	4	14	4,669	5,302	3,953	4,661
Piperophos+ 2, 4-D IPE (G)	1.5+ 0.5	1.9	1.1	1.4	1.3	0.9	0.1	1.4	0.8	3	4	3	12	3	6	3	7	4,663	5,120	3,882	4,555
Benthiocarb (G) +2, 4-D IPE (G)	1.0+ 0.5	—	—	—	—	1.0	0.1	—	—	—	—	—	—	7	35	—	—	—	—	3,628	—
Weeded 2x	—	—	—	—	—	—	—	—	—	36	7	42	8	27	3	35	6	4,615	5,189	3,807	4,537
Control	—	—	—	—	—	—	—	—	—	38	95	40	92	21	73	33	87	3,579	3,751	3,316	3,555

Toxicity scoring: 0=no toxicity, 1–3=slight toxicity, 4–6=moderate toxicity, 7–9=heavy toxicity, 10=crop completely killed.
DAT=days after transplanting.

Table 2. Effectiveness of herbicides on transplanted rice. CRIA. Wet Season, 1972–1974.

Treatment	Weed Control																							
	71/72						72/73						73/74						Average					
	19 DAT			60 DAT			19 DAT			60 DAT			19 DAT			60 DAT			19 DAT			60 DAT		
	G	S	B	G	S	B	G	S	B	G	S	B	G	S	B	G	S	B	G	S	B	G	S	B
2,4-D IPE (G)	8.6	8.8	8.3	8.0	7.1	8.2	8.9	9.5	8.0	7.2	6.3	6.6	5.5	9.0	6.2	6.8	6.2	4.8	7.5	8.8	7.5	7.3	6.5	6.5
TCE-styrene/ 2,4-D IPE (G)	8.0	9.0	8.6	8.1	7.5	7.8	8.9	9.3	8.6	7.6	7.2	6.2	6.0	8.2	5.9	7.4	6.8	5.1	7.6	8.8	8.8	7.7	7.2	6.4
Trifluralin/ 2,4-D IPE (G)	8.0	8.8	8.6	8.2	7.7	7.9	8.4	9.3	8.6	7.4	7.1	7.0	—	—	—	—	—	—	8.2	9.1	8.6	7.8	7.4	7.5
MCPA (L)+ weeded 1x	7.6	9.0	8.4	8.5	7.9	7.9	8.7	9.3	8.5	8.2	8.2	7.9	6.0	8.1	5.2	7.0	6.5	4.6	7.4	8.8	7.4	7.9	7.5	6.8
Nitrofen (G)	8.2	8.5	8.2	8.1	7.0	7.0	8.7	9.2	8.1	7.5	7.1	6.5	6.4	7.8	6.5	7.2	7.2	5.6	7.8	8.5	7.6	7.6	7.1	6.4
Benthiocarb (G)	8.0	8.9	8.1	8.6	8.6	8.0	8.9	9.4	8.0	7.9	8.2	8.9	6.4	7.3	6.4	7.8	7.3	5.7	7.7	8.7	7.5	8.1	8.2	6.5
Butachlor (G)	7.3	8.5	7.0	7.9	7.8	6.3	8.3	9.0	7.3	7.1	7.5	5.4	5.7	7.2	6.0	7.2	7.3	5.4	7.1	8.2	6.8	7.4	7.5	5.7
Piperophos+ 2,4-D IPE (G)	8.0	8.8	8.6	8.7	8.2	8.1	9.1	9.5	9.1	7.8	7.9	7.5	7.1	8.4	7.4	7.6	7.6	6.6	7.4	8.9	8.4	8.0	7.9	7.4
Piperophos+ 2,4-D IPE (G)	8.6	9.0	9.0	8.6	8.4	8.6	9.5	9.5	9.5	8.1	8.3	8.0	8.2	8.8	7.8	8.1	8.6	7.5	8.8	9.1	8.8	8.3	8.4	8.0
Benthiocarb(G) +2,4-D IPE(G)	—	—	—	—	—	—	—	—	—	—	—	—	7.0	8.3	5.8	6.7	7.2	5.3	—	—	—	—	—	—
Weeded 2x	—	—	—	—	—	—	—	—	—	—	—	—	1	3	2	9.1	9.0	9.0	—	—	—	—	—	—
Control	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	0	0	0	—	—	—	—	—	—

Weed control scoring: 0=no weed control, 10=weeds completely killed DAT=days after transplanting, G=Gramineae, S.=sedges, B=broadleaved weeds.

after handweeding.

Grain yield. In general high yields were obtained from trifuralin/2,4-D IPE (G), piperophos+2,4-D IPE (G), benthiocarb (G), handweeding 2x and MCPA followed by handweeding. Other treatments gave lower yields than handweeding 2x although the differences were not significant. The yields were reduced in untreated plots by about 1000 kg dry grain compared to handweeding 2x.

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A New Nitrofen Granular Formulation for Mechanical Application

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Abstract. A new nitrofen (2,4-dichlorophenyl-4′-nitrophenyl ether) granular has been successfully formulated. This new nitrofen granular (7%) will enable growers to control various weeds in paddy rice fields with reduced dosages (20 to 30 kg-product/ha). Soil residues will be reduced as a result, thus eliminating herbicide pollution problems. This new nitrofen granular is highly adaptable to mechanical application with pipe dusters, and also for hand application in paddy rice fields. Mechanical application of new nitrofen granular is advantageous to reduce labor requirements usually necessary for rice herbicide applications.

INTRODUCTION

Nitrofen (TOK) is a herbicidal composition introduced into Japan from Rohm and Haas Company. When introduced it represented the first preemergence herbicide having desirable efficacy coupled with a low order of fish toxicity. Nitrofen granular (7%) and nitrofen EC (25%) were commercially released in 1967 to control weeds in paddy rice fields and in upland fields, respectively.

Fundamental studies with nitrofen granular in paddy fields demonstrated that the young shoots of germinating weeds were killed on contact with the nitrofen active ingredient. Contact with nitrofen occurs as shoots pass through the nitrofen inpregnated soil layer formed on the surface of treated paddy fields. Herbicidal activity is improved overall by better coverage of nitrofen active ingredient corresponding to more uniform distribution of nitrofen particles applied on the soil surface.

Various tests have been carried out in a continuing effort to improve the herbicidal performance of nitrofen granular, and to establish the optimum effective dosage level for nitrofen. As a result of a recent discovery, we have succeeded in decreasing the dosage of nitrofen active ingredient required per hectare by a new granular formulation of smaller particle size. This new nitrofen granular has been modified not only in particle size but also in formulation process techniques. New nitrofen granular is particularly suited for mechanical application equipment. The mechanical applicator, commonly called a pipe-duster, showed better performance of the new nitrofen granular as a result of more uniform particle distribution and better application efficiency. These properties are very important in reducing environmental pollution, and in reducing the accumulation of herbicidal residues in the soil by effectively applying lower dosages of nitrofen to the paddy field. Fig. 1 presents the results of preliminary

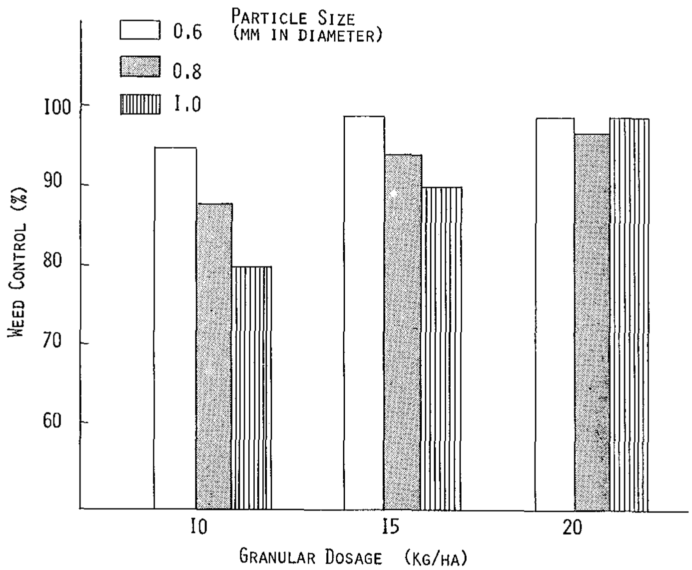

Fig. 1. Efficacy comparison of nitrofen granular depending on particle sizes. (TOCIL, Exp. Sta., 1970)

field pot tests comparing herbicidal activity of pre-emergence application of 3 experimental formulations of nitrofen granular. These tests were carried out during the growing season of 1970.

Materials and Methods

Using concrete pots, nitrofen granular formulations were carefully hand applied to paddy soil 3 days after transplanting rice. Three formulations of nitrofen granular were prepared by TOCIL laboratory using the same adjuvants, carriers, and other raw materials. Only the active ingredient and particle size were varied.

The results indicate that there is no difference in the herbicidal efficacy between the 3 particle size samples in the higher dosage range, but a nitrofen granular of particles size 0.6 mm in diameter has promising efficacy in the lower dosage range as compared with the samples of larger particle size.

Following these concrete pot tests, small scale secondary field plot tests were carried out to compare various nitrofen granular formulations with different active ingredient levels but with the same particle size (0.6 mm diameter) as found most effective in pot tests. The nitrofen granular formulations were carefully hand applied 4 days after transplanting adult rice seedlings.

Results and Discussion

Results are presented in Table 1.

Table 1. Comparison of herbicidal activities among various nitrofen granular formulations.
(TOCIL, Exp. Sta., 1970)

Granular formulation	Timing of appl. (days)	Dosage (kg a.i./ha)	Weed Control			Relative rice plant growth (fresh weight) (%)
			Barnyard-grass (%)	Broad leafed (%)	Total (%)	
Nitrofen G-A (7%)	−2	1.4	100	90	93	107
	+4	,,	94	95	95	126
Nitrofen G-B (9%)	−2	1.8	100	91	95	103
	+4	,,	97	90	92	118
Nitrofen G-C (12%)	−2	2.4	100	100	100	95
	+4	,,	100	100	100	93
Regular nitrofen G (7%)	−2	2.1	93	88	91	109
	+4	,,	90	87	89	108

The efficacy of nitrofen granular Type A (7%, 0.6 mm diameter) and nitrofen granular Type B (9%, 0.6 mm diameter) were essentially equal and both were superior to the standard nitrofen granular (7%, 0.9 mm diameter). Nitrofen granular Type C (12%, 0.6 mm diameter) showed almost complete weed control activity, but resulted in severe browning of rice stems and slight growth retardation.

In the following growing season (1971), nitrofen granular Type A was mechnically applied to paddy rice fields 5 days after transplanting. Mechanical application of nitrofen granular Type A at a dosage of 20 kg-product/ha, and regular nitrofen granular at a dosage of 20 kg-product/ha, and hand application of regular nitrofen granular at a dosage of 30 kg-product/ha controlled weeds by 93%, 87% and 91%, respectively. The mechanical application of new nitrofen granular Type A at the reduced dosage of 20 kg-product/ha provided the same weed control efficacy as the hand application of regular nitrofen granular at a dosage of 30 kg-product/ha.

From 1971 to 1973, various tests with new nitrofen granular formulations were performed by 12 prefectural experiment stations and other test organizations. These experiments were designed to ascertain the most effective application technique. Best results were obtained using the pipe-duster—a machine consisting of a long plastic hose with many holes equally spaced along its length and a motor driven blower. This machine affords good and uniform particle distribution. The practical efficacy of new nitrofen granular Type A has been satisfactorily demonstrated for both mechanical application and hand application to paddy rice fields.

Recommendation for Use

Followings are our best recommendations for the application of new nitrofen granular in paddy rice fields to control weeds. These use recommendations are very similar to those for regular nitrofen granular, hence no drastic changes in grower practices will be necessary. Weed control will however be remarkably improved, and labor requirements and environmental pollution will be greatly reduced.

Dosage: 20 to 30 kg-product/ha.

Timing: Hand transplanted rice (adult seedlings)

2 to 3 days before transplanting or 4 to 8 days after transplanting.

Machine transplanted rice (young seedlings)

1 to 3 days before transplanting or 4 to 7 days after transplanting.

When applying new nitrofen granular with a mechanical applicator (pipe-duster) care should be taken to select the proper equipment and calibrate it properly. According to field tests with several pipe-dusters, it was found that a combination of 7,800 rpm blower rotations and a 8/10 shutter opening was the best combination for the DM-9 model of Kyoritsu, and a combination of 7,500 rpm blower rotations and a 2/8 shutter opening was the best for the MD-140 model of Maruyama. Though not tested, other models may be suitable for application of new nirtofen granular if properly calibrated.

Weed Control in Broadcast-seeded Rice on Upland Field after Flooding

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Abstract. Barnyardgrass (*Echinochloa crus-galli*), one of the most problematical weed, always comes out earlier than rice plants and the weed reaches at 3.5-leaf stage when the rice plant reaches at 1.5-leaf stage. There was no yield decrease due to weed competition when weeds were controlled for about 40 days (until 7-leaf stage of rice) after seeding. Therefore, the sequential application of tank mixtures of propanil (3,4-dichloropropionanilide) and benthiocarb (*S-p*-chlorobenzyl *N,N*-diethylthiolcarbamate) (firstly: at 1 to 1.5-leaf stages of rice. secondly: at 3.5 to 4.5-leaf stages or 2–10 days before flooding) gave excellent weed control until harvest. The second application showed some phytotoxicity to rice plant but prevented over-vegetative-growth and finally gave high yield.

INTRODUCTION

The direct-seeded rice cultural method in which plowing, harrowing, and seeding are carried out under the upland condition is now prevailing in Japan. In this method two different seeding procedures are used. In the broadcast seed procedure, seeding is carried out by hand or sprayer and shallow plowing from 3 to 5 cm by a rotary type machine follows. In the drill-seed method, a power or hand-operated drill seeder is used. When 4 to 5 leaves develope from seedling, field is irrigated and brought to flooded condition.

Utilization of this method has increased yearly but yet occupied only 2% of the total acreage of Japanese paddy field in 1974. The strong reason why this labor-saving rice culture which have been expected to become a main stream does not extend rapidly is that the weed problems are not yet resolved.

The objective of this study is to establish the weed control in this direct-seeded rice cultivation.

METHODS

The results described in this paper have been obtained from a large number of field experiments for the last 15 years, so detailed experimental methods are omitted.

Results

Weeds and their control before seeding. Water foxtail (*Alopecurus aequalis* var. *amurensis*) is the main species before seeding in most field. This weed disturbs harrowing and often causes poor stand and low yield of rice. Various herbicides and their application methods have been tested. Application of paraquat (0.6–0.75 a.i. kg/ha) for 10–20 days before seeding gave an excellent result. But in the case of the continuous direct-seeded cultivation for three years this treatment becomes unnecessary because this weed is killed before fructification and its seed logevities are nearly one year.

In some cases Dropwort (*Oenanthe javanica*) and *Cyperus serotinus* which propagate with stolons and tubers respectively increase yearly by the rotary tillage before seeding. But Dropwort is completely controlled by 2,4-D (1–1.5 kg/ha) applied for 20–50 days before seeding. Control of *Cyperus serotinus* will be described later.

Required weed-free period after seeding. Harmful effect of weeds on the rice becomes greater as weeds grow earlier and weeds which come out in a certain period after seeding will no longer affect the yield of rice. The present experiments were carried out to decide how long weed-free period after seeding are necessary.

Weed eradication was carried out carefully by application of paraquat preventing drill-seeded rice plants from contact injury. When plots were not weeded after seeding, weeds exceeded rice in the plots due to the light competition. But when plots were kept weed-free until 6 weeks (7-leaf stage of rice) after seeding, the yield did not reduce like the plot which was weed-free through the whole cultivation time. Consequently rice should be raised in weed-free condition up to about 7-leaf stage or 40 days after seeding.

The period of emergence of main weeds. To decide the optimum timing of herbicide application the author investigated the period of emergence of main weeds and compared early vegetative growth of each weed with that of rice.

The period of emergence of weeds becomes longer by early seeding (lower temperature) than later one (higher temperature), but relative relationship between rice and weeds remain unchanged. The most problematical weed, Barnyardgrass, always emerges earlier than rice and when rice plants reach 1.5-leaf stage, barnyardgrass come to almost final stage of emergence and early emerged ones reach 3.5-leaf stage at this time. When rice plants reached 2 to 3 leaf stage, the emergence of other major weeds, Large crabgrass (*Digitaria sanguinalis*), Sprangletop (*Leptochloa chinensis*), annual sedges and broad-leaved weeds had drawn to a close. Height of each species except barnyardgrass at an early stage was much shorter than rice plant.

Cyperus serotinus which had increased rapidly under direct-seeded condition in recent years emerged with rice, and its sprouting from tubers terminated when rice plants reached 3-leaf stage. The height of early emerged ones became taller than rice after 5-leaf stage of rice.

After flooding, such hydrophytic and hygrophytic weeds as *Monochoria vaginalis*, Toothcup (*Rotala indica*), Arrowhead (*Sagittaria pygmaea*) etc. begin to emerge but almost stop to emerge within two weeks. In many cases, these weeds did not affect on the rice growth because water was apt to leak and shading by rice plants became greater.

Weed control after seeding. As a result of these investigations, complete weed control for the upland period, above all at the early stage of the period is of great importance.

Many soil treatment (residual pre-emergence) herbicides such as PCP (pentachlorophenol), nitrofen (2,4-dichloro 4′-nitro diphenylether), linuron [3-(3,4-dichlorophenyl) 1-methoxy 1-methylurea], swep [methyl *N*-(3,4-dichlorophenyl) carbamate], benthiocarb and so on were tested, but these herbicidal effects were changeable due to soil moisture content, fineness or coarseness of harrowing and compactness of soil etc.

For this reason, selective foliage (contact post-emergence) and soil treatment herbicides became necessary. We tested combinations of propanil and soil persistent herbicides, and found that a mixture of propanil and benthiocarb was most effective among them. The combination rate of these herbicides was evaluated. Application of propanil (1.75 kg/ha) and benthiocarb (5.00 kg/ha) to the 1 to 1.5-leaf stage of rice resulted in the best control of weeds, and phytotoxicity to rice was very low. The effectiveness of these mixtures was not reduced by rainfall after one hour from application. In a heavily infested field, a single treatment of high dosage of propanil (3.5 kg/ha) plus benthiocarb (7.5 kg/ha) applied at the 2-leaf stage of rice failed to show complete control of weeds, but two sequential application of these mixtures [at first: propanil (1.5–2.0 kg/ha)+benthiocarb (4–5 kg/ha) to 1 to 1.5 leaf stage of rice; then: at 3.5–4.5 leaf stage or 2–10 days before flooding, propanil (2 kg/ha)+benthiocarb (3 kg/ha)] gave excellent weed control until harvest. The second application caused some phytotoxicity to rice plant but prevented over-vegetative-growth and gave a high yield. When *Cyperus serotinus* came into existence, bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-(4)3H-one 2,2-dioxide] (2–3 kg/ha) applied 25–30 days after seeding controlled the weed completely. When bentazon was mixed with propanil and benthiocarb in the second application, all kinds of major weeds were completely controlled simultaneously. In some cases, Knotgrass (*Paspalum distichum*) invades into paddy fields from the dikes, but glyphosate [*N*-(phosphonomethyl) glycine] (2.5–3.5 kg/ha) applied at the early stage of elongation controlled this species for about 2 months.

A Survey of Commercial Direct-Drilling of Rice in the Murrumbidgee Irrigation Area of South-Eastern Australia

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Abstract. Two seasons' results from farmer sown direct-drilled rice in the Murrumbidgee Irrigation Area are given. Approximately 45 per cent of the area direct-drilled using the bipyridyl herbicides was surveyed in both years. The results are compared with sod-seeded and conventionally sown rice. The role of the bipyridyls, other herbicides and grazing stock is discussed in relation to the management practices currently adopted in the area.

Introduction

Reduced cultivation techniques for rice establishment using the bipyridyl herbicides have been carried out in Malaysia (Seth *et al.*, 1971), Sri Lanka (Mittra and Pieris, 1968) and the Philippines (Moomaw *et al.*, 1968). The development of minimum cultivation techniques, including direct planting is reported to be gaining acceptance in Japan (Brown and Quantrill 1973). However, most of this work refers to transplanted rice.

Four methods of rice establishment have been used in the Murrumbidgee Irrigation Area (MIA) with varying degrees of success (Boerema and McDonald, 1967; Boerema, 1969). The most common method is drill sown, followed by aerial sown on flooded bays, both into conventionally prepared seed beds. Sod-seeding has a relatively limited following (see Table 1) and very few crops are established by aerial seeding

Table 1.

	1973/74	1974/75
Total rice area in MIA (ha)	25218	26757
Area direct-drilled (estimated, ha)	600	600
Average rice yield (dry paddy, t/ha):		
Conventionally sown	6.8	5.6
Direct-drilled	7.3	6.5
Number of MIA rice growers:		
Conventionaly sown	601	603
Direct-drilled (estimated)	25	25
Survey sample size:		
Number of growers	12	13
Area direct-drilled (ha)	280	290

direct into flooded pasture.

The first attempt to establish rice in the MIA by reduced cultivation was conducted at Leeton in 1955 (Hood, 1961). Hood describes the sod-seeding technique as "the placing of seed in a narrow slit in the soil which falls back over the seed immediately following the operation leaving the surface otherwise undisturbed". Direct-drilling is a widely accepted term for a similar technique but where the bipyridyl herbicides are used for weed control prior to sowing. With sod-seeding, sowing takes place into an untreated pasture which is subsequently irrigated to promote rice plants germination. Sheep are then allowed to graze the paddock until the rice begins to emerge.

The success of sod-seeding has been limited (Clough, 1974) by insufficient sheep to handle pasture growth after sowing, slime resulting from decaying subterranean clover, delayed crop maturity caused by pasture competition and nitrogen build-up and high blood worm (*Chironomus tepperi*) populations resulting in a reduced crop stand.

Using a knockdown herbicide overcomes many of these problems (Clough, 1974) as well as reducing the number of irrigation flushes necessary for complete rice emergence prior to the application of permanent water.

In 1973 a number of rice growers who had adopted the practice of sod-seeding replaced sheep with the bipyridyl herbicides paraquat and diquat for pasture control. The success of direct-drilling in this season resulted in growers adopting the technique the following year.

Results and Discussion

Growers who had used the technique of direct-drilling in either year were asked to complete a questionnaire in which they were to list the main advantages and disadvantages of direct-drilling compared to both sod-seeding and conventional establishment. The percentage response to each comment is given in Tables 2 and 3. Within the 1974/75 survey nine growers were asked to list in order of priority their opinions on the various advantages and disadvantages between the three techniques. The resulting priority score is given in Tables 2 and 3.

The main advantages of direct-drilling over conventional establishment appear to be greater pasture utilization, fewer harvesting problems associated with firm ground and better barnyardgrass (*Echinochloa* spp.) control.

The ability with direct-drilling to make better use of pastures was stressed in many instances. Approximately 45 hectares (the rice quota per farm) of pasture are made available for grazing out of an average of 200 hectares per farm. This area would normally be ploughed in early spring when available grazing is at a low level.

Reduced harvesting problems with direct-drilled crops through better drainage once the permanent water is taken off, less bogging during harvesting and fewer delays during wet weather were benefits stressed by many growers.

Boerema and McDonald (1964) pointed out that attempting to overcome harvesting problems by earlier drainage could result in moisture stress during the maturation period if water is removed before the late dough stage of development. Haying-off, lodging, reduced yield and poor milling quality can often result.

Table 2. Survey results from the MIA 1973/74 and 1974/75 seasons on rice establishment by direct-drilling. Grower response—percentage of total comment and comment priority score 1974/5.

Grower comment	% response		Total priority* score (max. 36)
	1973/74	1974/75	1974/75
Advantages of direct-drilled over conventionally sown rice.			
1. Greater pasture utilization.	35.3	85.6	29
2. Fewer harvesting problems.	47.0	85.6	19
3. Reduced *Echinchloa* spp. problem.	29.4	71.4	8
4. Less ground preparation and ease of establishment.	23.5	28.6	5
5. Higher grain yield and grain quality.	17.6	28.6	6
6. Less fertilizer necessary.	23.5	58.2	12
Advantages of direct-drilled over sod-sown rice.			
1. More effective pasture control.	41.3	58.2	14
2. Less slime problems.	53.0	100.0	30
3. Superior *Echinchloa* spp. control.	47.0	85.6	9
4. Less stock management required.	29.4	71.4	14
5. Reduced bloodworm infestation.	41.3	58.2	17
6. Higher yield.	29.4	14.3	2

* (Tables 2 and 3)
A score of 4, 3, 2, 1 was given for the first, second, third and fourth priorities respectively for comments from each grower. The above is total from nine growers giving a maximum possible score of 36.

Table 3. Survey results from the MIA 1973/74 and 1974/75 seasons on rice establishment by direct-drilling. Grower response—percentage of total comment and comment priority score 1974/75.

Grower comment	% response		Total priority* score (Max. 36)
	1973/74	1974/75	1974/75
Disadvantages of direct-drilled over conventionally sown rice.			
1. Poor perennial weed control.	47.0	100.0	33
2. Need for improved land levelling and contour grading.	23.5	58.2	9
3. Poor availability of direct-drilling equipment.	17.6	43.0	8
4. Herbicide cost.	17.6	43.0	16
Disadvantages of direct-drilled over sod-sown rice.			
1. Herbicide cost.	35.3	71.4	28
2. No disadvantages.	—	35.7	8
3. Timing of herbicide application and pre-spray management.	—	14.3	6

Comments on barnyardgrass control refer to observations by growers that the germination of barnyardgrass is reduced under direct-drilling and that control with post-emergence herbicides such as molinate appeared superior compared to conventionally sown rice crops. The average yields from direct-drilled in both seasons appear to be above those from conventional crops (Table 1). Further work would be needed to determine whether in fact the higher yields were due solely to better weed control.

The ability of direct-drilled rice to overcome the slime problem associated with sod-sown rice was the most frequent advantage commented on by growers. This is a very major plus for direct-drilling since slime can completely smother the crop.

The superior barnyardgrass control under direct-drilling compared to sod-seeding is associated with slime and organic matter. With sod-seeded crops decaying vegetative material prevents post-emergence herbicides such as molinate and propanil from reaching the site of uptake for adequate barnyard grass control.

These advantages of direct-drilling over sod-seeding together with less competition from the pasture and reduced bloodworm levels are all associated with the effective removal of the pasture vegetation prior to sowing.

The major disadvantage of direct-drilling relative to conventional rice establishment was the lack of control of perennial weeds such as dock (*Rumex* spp.) and water couch (*Paspalum paspaloides*). This undoubtedly is one of the main limitations of the technique. However, with closer attention to pre-sowing management some of these weed problems can be overcome by the use of selective herbicides in the pasture phase e.g. dicamba for broad leaf weed control and the use of herbicides which are more effective for perennial grass control than the bipyridyls, such as glyphosate.

Growers felt greater attention will have to be paid to land levelling and contour grading one or two years prior to direct-drilling rice for optimum direct-drilling results.

The poor availability of suitable direct-drilling equipment and herbicide cost were also mentioned as being disadvantages of direct-drilling. Steps are being taken to have more suitable direct-drilling equipment based on the triple disc system made available to growers in the area. A number of growers however felt that the herbicide cost was offset by cultivation and labour costs associated with conventional establishment.

The cost of the bipyridyl input was the only real disadvantage levelled against direct-drilling relative to sod-sowing. In the second year many growers stated that there were no disadvantages, discounting the herbicide cost as minor compared to the many advantages of direct-drilling over sod-seeding.

Work on the fertilizer requirements of rice has shown that both conventional (Boerema and McDonald, 1965) and sod-seeded (Boerema, 1965) crops benefit from small quantities of nitrogen at sowing even after a pasture involving a nitrogen fixing legume such as clover. Therefore the opinion of a number of growers that less fertilizer is required with direct-drilling, which ranked third in priority (Table 2), would need verification.

The results of this survey show that direct-drilling of rice in the MIA is a very viable technique relative to conventional establishment and certainly compared to sod-seeding. However the results also indicate that further work is needed to optimize this method of rice establishment. Work is warranted on the comparative yield performance of conventional and direct-drilled crops and an analysis of the factors which contribute to an apparent yield advantage with direct-drilling; the relative fertilizer requirements of both types of establishment; the real cost benefits of extra grazing and fodder conservation available with direct-drilling; means of overcoming some of the perennial weed problems by herbicides and management practices; the timing of the paraquat/diquat herbicide application relative to sowing; the relative performance of post-emergence herbicides such as molinate for barnyardgrass control in conventional and direct-drilled crops and the relative merits of existing machinery for direct-drilling rice.

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Effect of Repeated Annual Application of Preemergence Herbicides on Paddy Field Weed Populations

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Abstract. Repeated annual application of butachlor [*N*-(butoxymethyl)-2-chloro-2′, 6′-diethylacetanilide], benthiocarb·simetryne [*S*-(4-chlorobenzyl)-*N*,*N*-diethylthiol carbamate plus 2-methylthio-4, 6-bisethylamino-*s*-triazine], nitrofen (2,4-dichlorophenyl-*p*-nitrophenyl ether), and 2,4-D IPE (2,4-dichlorophenoxy isopropyl ester), normally recommended for annual weeds, increased yearly weed dry weight and created a predominance of the perennial sedge, *Eleocharis kuroguwai* Ohwi and *Cyperus serotinus*, and annual sedge, *Scirpus juncoides*. After the first year's application these sedges comprised 45% of the total weed population, but after the fourth year's application, they increased markedly to 69%. Broadleaf weeds decreased from 45% to 10% over the same period. The population shift is due to the successive elimination of herbicide-sensitive species and their gradual replacement by resistant species.

INTRODUCTION

The fast industrialization has resulted in a rapid increase of herbicide application since 1967. Since then, herbicides consumption steadily increased and to date has reached a consumption of about 20,000 t/year covering over 40% of paddy field in Korea. Farmers have repeatedly used these herbicides intended for the control of wide spectrum of weeds. These herbicides are exclusively nitrofen and butachlor.

The continued use of a herbicide has been reported to raise the level of tolerance within weed populations. The incidence of incomplete weed control is often observed as a shift to more tolerant weed species. Then, tolerant weed species often became the dominant weed problem. Shooler *et al.* (1972) reported a genetic basis governing tolerance of foxtail barley (*Hordeum jubatum* L.) to siduron [1-(2-methyl cyclohexyl)-3-phenylurea]. Similarly, Wiemer observed variability in tolerance of 20 strains of bermudagrass [*Cynodon dactylon* (L.) Pers.] to TCA (trichloroacetic acid) and dalapon (2,4-dichloropropionic acid).

The characterization and identification of weed population shift to more tolerant weed species may be worthwhile in developing applicable weed control system. Thus, this study was initiated to identify and analyze shift of weed species by repeated annual application of herbicides in paddy field.

Materials and Methods

The experiment was conducted on a loam soil of the paddy field at the Crop Experiment Station, Suweon, from 1971 through 1974. Rice variety, Jinheung (pure indica cross) was transplanted in the spacing of 30 by 15 cm in early June of every year. One half of each plot was transplanted with rice, but another half was left without rice. However, both parts received the same amount of fertilizer and the same level of management.

Nitrofen at 2.1 kg a.i./ha, butachlor 1.5 kg a.i./ha, benthiocarb•simetryne 2.55 kg a.i./ha and 2,4-D IPE 0.9 kg a.i./ha were applied at 4,6,6 and 4 days after transplanting, respectively. The same amount of herbicides were applied annually in the same plot over four years. Treatments were replicated three times in a randomized complete block design. At the time of herbicide application, approximately 3 cm of water depth was maintained. Rice received 100–50–60 kg/ha of N, P_2O_5 and K_2O of fertilizer each year. In the first year, area tested contained 2.3% of OM, 7.65 meq/100 g of CEC with a pH of 5.3. Percolation rate was less than 1 cm/day. The dry weight of weeds was determined at the maturity of rice and analyzed statistically.

Results and Discussion

Weed infestation. In the first year, predominant weeds infested in experiment area, were barnyardgrass, *Monochoria vaginalis*, *Rotala indica*, *Polygonum hydropiper*, and some *Potamogeton distinctus*, some *Eleocharis kuroguwai*, some *Cyperus serotinus* and some *Scirpus juncoides* etc. Weed infestation was relatively higher than in farmer's fields.
Total dry matters of weeds. Regardless of treatments, total dry weight of weeds steadily increased yearly (Table 1). More or less 100% of increase in weed dry weight was observed over four years period. The similar increased trend was noticed in both the rice cultured and no rice cultured plot (Table 1). However, steep and significantly higher increases were observed in no rice cultured plots. In rice culture, annual broadleaf weeds were gradually replaced by the perennial sedge like *E. kuroguwai* and to some extent by the annual sedge like *S. juncoides*. The population of *E. kuroguwai* and *S. juncoides* increased from 21.4 and 3.2 gr/m^2 in 1971 to 109.0 and 20.6 gr/m^2 in 1974, respectively. These figures are average of all treatments in 1971 and in 1974, respectively. The population of these two weeds in 1974 was several times greater than that of their weed population in 1971. Sedges, *E. kuroguwai* and *S. juncoides*, are mainly responsible for the annual increase of weed dry weight in all treatments. However, the major contribution to dry matter increase was attributed to *E. kuroguwai*.
The portion of annuals and perennials. As shown in Fig. 1, annual weed population in six treatments was relatively stable during the four years period, while remarkable increase were noticed in the perennial weeds. In fact, there was an increase and a decrease among annual weeds. Most of the annual weed species yearly decreased while instead annual sedge, *S. juncoides*, increased markedly to substitute other annuals.

The untreated control revealed the same trend of weed shift as chemical treated

Table 1. Total dry matter of weeds in repeated annual application of herbicide in both rice culture and no rice culture.

Herbicides	Dry weight of weed (gr/m²)			
	1971		1972	
	Rice cultured	No rice cultured	Rice cultured	No rice cultured
Nitrofen	78.7[bcd]	414.7[bc]	141.3[b]	452.2[bc]
Butachlor	86.2[bcde]	383.4[bc]	41.8[a]	512.6[c]
Benthiocarb·simetryne	143.1[e]	361.8[b]	8.5[a]	415.7[abc]
2,4-D IPE	127.9[de]	351.8[b]	29.9[a]	341.3[ab]
Hand weeding	0.4[a]	142.7[a]	7.7[a]	287.5[a]
None	98.4[cde]	505.4[c]	105.2[b]	719.5[d]

Herbicides	Dry weight of weed (gr/m²)			
	1973		1974	
	Rice cultured	No rice cultured	Rice cultured	No rice cultured
Nitrofen	194.6[c]	561.8[b]	178.1[b]	588.7[cde]
Butachlor	172.6[bc]	594.5[b]	147.6[b]	539.0[bcde]
Benthiocarb·simetryne	135.8[b]	749.6[c]	127.4[d]	632.2[e]
2,4-D IPE	249.7[d]	876.2[c]	337.9[c]	619.5[de]
Hand weeding	6.2[a]	313.9[a]	23.1[a]	325.1[a]
None	406.2[d]	755.5[c]	335.5[c]	573.1[bcde]

* In each column, means followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test. Dry weight determined at maturing stage of rice.

ones, its pattern was more obvious and steep one than that of herbicide treated ones. *E. kuroguwai*, resistant to herbicides, becomes easily established and spreads rapidly because of the biological adaptability of its vegetative parts. Our preliminary study showed that one single mother tuber of *E. kuroguwai* multiplied more or less 50 new plants within 60 days. New tubers formed in deeper depth of soil (mainly 5 to 20 cm) which is their advantage for long survival because they may avoid damage from tillering and coldness. In addition, tuber has dormancy. Perennial sedges, *C. serotinus* and *P. distinctus* have active mechanism of propagation, but their lower population in comparison with *E. kuroguwai* may not be easily explained, however, they appeared to be biologically more sensitive to herbicides tested.

Taking look at classification of weeds in rice cultured plot shown in Fig. 2, broadleaf weeds significantly decreased from 45% to 10% in four years period, instead sedges markedly increased from 45% to 69% in 1974. Increase of sedges was mainly due to increases in the population of *E. kuroguwai* and to some extent *S. juncoides*. However, grasses seemed to be no significant change either rice cultured or no rice cultured plot. At the starting year, grasses were minor weeds. However, grasses were not eliminated by repeated annual application of herbicides because soil has a large source of seeds which germinate irregularly, escaping herbicidal toxicity.

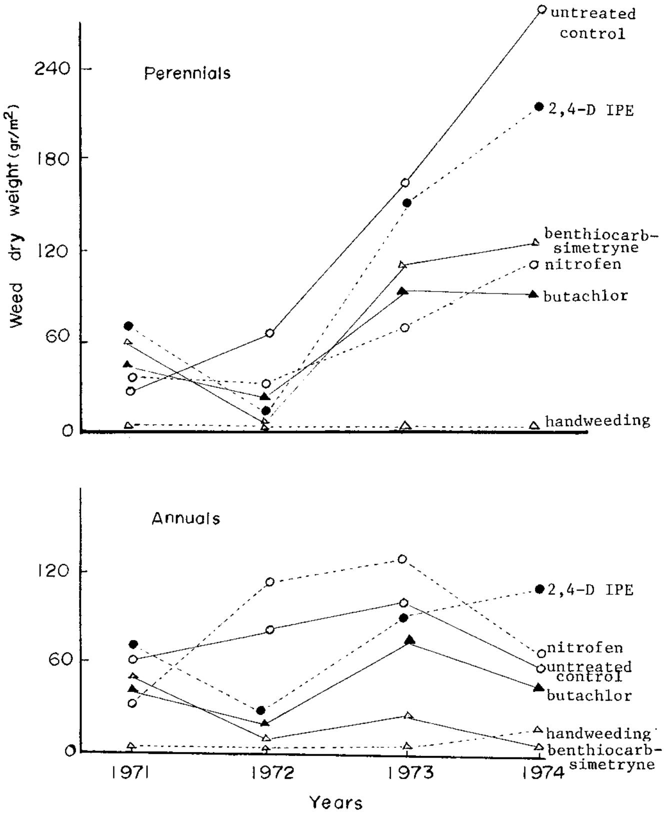

Fig. 1. Weed population shift of annuals and perennials in the repeated annual application of herbicides over four years.

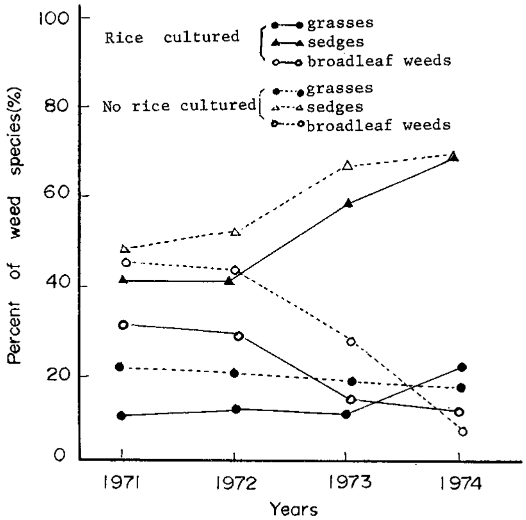

Fig. 2. Weed population changes in both rice cultured and no rice cultured plot in repeated annual application of herbicides nitrofen, butachlor, benthiocarb-simetryne, 2, 4-D IPE, handweeding and untreated control

Table 2. Rice yield in repeated annual application of herbicides in paddy field.

Herbicide	Rate (kg a.i./ha)	Yield*					
		1972		1973		1974	
		Brown rice (t/ha)	Index (%)	Brown rice (t/ha)	Index (%)	Brown rice (t/ha)	Index (%)
Nitrofen	2.1	4.7[b]	89	4.3[b]	77	4.0[b]	69
Butachor	1.5	4.9[bc]	93	4.5[b]	80	4.2[b]	72
Benthiocarb•simetryne	2.55	5.4[c]	102	4.6[b]	82	4.8[bc]	83
2,4-D IPE	0.9	5.2[bc]	98	4.0[b]	61	3.8[b]	67
Hand weeding	15+30 DAT**	5.3[bc]	100	5.6[c]	100	5.8[c]	100
Untreated control	—	3.5[a]	66	1.9[a]	34	2.4[a]	41

* In each column, means followed by the same letter are not significantly different at 5% level using Duncan's multiple range test.
** DAT: Days after transplating.

Grain yield. The increased weed population reduced significantly grain yield of rice as shown in Table 2. In 1972, the grain yield of rice in all herbicide treatments was not significantly different with handweeded one. However, in 1974, approximately 30% of yield reduction compared with handweeding treatment was observed in all herbicide treatments. Furthermore, untreated control over four years yielded only 41% of handweeded one. The decreased yield was mainly due to a high infestation of sedges, especially *E. kuroguwai* and *S. juncoides.* Benthiocarb•simetryne treatment among chemicals treated resulted in the highest yeild since this chemical was to some extent effective to sedges.

Based on results and observation, it is obvious that chemicals are a very strong selective mechanism which influence populations of various weed species. Many researchers (Vega *et al.*, 1971; Ryan, 1970) reported inter or intraspecific selectivity of weeds to herbicides. Herbicides treatment like 2,4-D IPE, nitrofen and butachlor shifted weed population to the similar direction. However, it was unpredictable with benthiocarb•simetryne treatments. Its effectivity varied; most probably due to climatic and soil conditions at the time of herbicide application. The results in this study clearly suggest that the high degree of resistance to one chemical and susceptibility to another would allow control of unwanted plants by one herbicide and elimination of the susceptible species by the other herbicide. The results obtained in this study agreed with other's reports on weed population shift by herbicide in various plant species in different locality.

Several possible conslusion may be derived from this study. First, the repeated annual application of herbicides is the major component responsible for the existing weed population shift in paddy fields. Secondly, the magnitude of the effect on repeated annual herbicide application is great enough to increase the resistant weed species and to decrease rice yeild in proportion to dry weight increase of weeds. Finally, results obtained in this study clearly suggests either the immediate need of herbicide rotation or herbicide combination to manage weeds not to be harmful to crop plants. Chemical alone may not be a perfect control method although we rotate herbicides. Therefore, results obtained suggest that intergrated weed control method including chemicals ecological and mechanical means should be altogether evaluated to manage effectively weeds in paddy field.

Further studies on competitive ability of difficult weeds may shed more light on the build of effective weed control system in paddy fields.

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Control of Perennial Weeds in Paddy Rice in Korea

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Abstract. About 22% of the total paddy field acreage of Korea is infested with perennial weeds, and the most dominant species are *Cyperus serotinus* Rottb.>*Spirodela polyrhiza* Schleid.>>*Potamogeton Franchetii* A. Benn. et Baag.>*Eleocharis acicularis* Roem. et Schult.>*Sagittaria pygmaea* Miq.>*Eleocharis Kuroguwai* Ohwi., and can be arranged in the above order according to their distribution density. *N*-(phosphonometyl) glycine (glyphosate) 36EC as a foliage application at 2.0 kg a.i./ha was excellent for controlling *C. serotinus* (4 to 5 leaf stage) before transplanting prior to land preparation. Excellent control of these perennials with relatively little damage to rice plants was obtained by 5 days after transplanting (DAT) treatments of 1,1,1-trifluoro-*N*-[2-methyl-4(phenylsulfonyl)phenyl] methanesulfonamide (perfluidon) 5G at 1.0 to 1.5 kg a.i./ha, 15 DAT treatments of 3-isopropyl-1H-2,1,3-benzothiadiazin-4-(3H)-one 2,2-dioxide(bentazon) 10G at 3.0 to 4.0 kg a.i./ha, and 7 DAT treatments of α-(β-naphtoxy) propionanilide+*S*-(4-chlorobenzyl)*N*,*N*-diethylthiocarbamate(MT 101+ benthiocarb) 10/7G at 2/1.4 to 3/2.1 kg ai./ha. Control of *P. Franchetii*, *E. acicularis* and *S. polyrhiza* was most excellent with 1.32/0.33 kg a.i./ha of *S*-(2-methyl-1,1-piperyl-carbonyl- methyl)-*O*,*O*-di-*n*-propylthiophosphate + 2-methylthio-4-ethylamino-6-(2, 1-dimethylpropylamino)-*s*-triazine(piperophos+dimetametryn) 4.4/1.1G, 1.5/0.36 kg a.i./ha of *s*-ethyl hexahydro-1 H-azepine-1-carbothioate+2-methylthio-4,6-bis(ethylamino)-*s*-triazine(molinate+simetryne) 5/1.2G and 2.1/0.45 kg a.i./ha of benthiocarb+simetryne 7/1.5G, when treated 10 to 15 DAT each.

Introduction

As of the end of 1974 the acreage of herbicide application in Korea extended to about 49% of the total paddy field acreage. After the introduction of herbicides it has become relatively easy to control annuals effectively by application of *N*-(butoxymethyl)-2-chloro-2′,6′-diethylacetanilide(butachlor), 2,4-dichlorophenyl *p*-nitrophenyl ether (nitrofen), 2,4,6-trichloro-4′-nitrodiphenyl ether (CNP) or benthiocarb+simetryne, but control of some perennials is still difficult, and besides their remarkably strong ability of propagation is a real stumbling block to control.

In order to establish an integrated control measures for these perennials a nationwide survey of the present status of their infestation and distribution along with chemical control experiments has been made for three years since 1973.

Materials and Methods

1) Relative density of distribution of perennials by species in paddy fields was investigated by means of field survey and enquete from 800 farm households selected by random sampling on a nationwide scale.

2) Field experiments were conducted on silty clay soil (organic matter 2.5%) and sandy loam soil (organic matter 1.3%).

Rice seedlings of Mangyeong (japonica type) and Tongil (IR667) varieties raised in a lowland seed bed for 50 days were transplanted, three seedlings each per hill at a space of 15 ×30 cm.

In case of foliage treatments glyphosate 36EC or dimethylamine salt of (2,4-dichlorophenoxy) acetic acid (2,4-D amine) 40EC were applied to the established weeds 5 to 10 days before transplanting prior to ploughing and harrowing; in soil treatments a proper quantity of tubers and/or bulbs of major perennials which passed the winter in paddy fields were planted after land preparation prior to the transplanting of rice seedlings followed by herbicide applications as shown in Table 2. Other cultural practices including fertilizer applications and insect and disease controls were applied correspondingly to the conventional methods.

Weeding effect and crop damage were measured several times by visual estimation, yields were also measured.

Results and Discussion

Distribution of perennials. *C. serotinus*, *P. Franchetii*, *S. pygmaea* and *E. Kuroguwai* are the species which are found most difficult to control and high in distribution density. Regional distribution of these perenninals is characterized by latitudinal difference in relative distribution density of *C. serotinus* and *P. Franchetii*. In case of *C. serotinus* the lower the latitude from middle to south of Korean peninsula, the higher the distribution density, while that of *P. Franchetii* is quite the reverse. Thus *C. serotinus* is most predominant in the south, and *P. Franchetii* is most predominant in the mid-north. No reginonal difference in distribution is found in the other species (Table 1).

Chemical control.

1) Weeding effect (Table 2): Glyphosate 36EC; When applied 5 to 10 days before transplanting at 2.0 kg a.i./ha at a volume of 600 *l*/ha it gave excellent control of *C. serotinus* (4 to 5 leaf stage) and *Aneilema japonica* Kunth. (annual weed; 8–12 leaf stage) without any crop injury (Ryang, 1974b).

Perfluidon 5G; All of the five perennials tested as well as annuals were effectively controlled. Control of *C. serotinus*, *S. pygmaea* and *P. Franchetii* was exceptionally excellent. 5DAT treatments rather than 10–15 DAT treatments, and treatments with little leaching rather than much leaching were more effective (Ryang, unpublished).

Bentazon 10G; *C. serotirus* and *Scirpus hotarui* Ohwi. were excellently controlled. Also, strong inhibition effect against *S. pygmaea*, *E. Kuroguwai* and *P. Franchetii* was observed. However, annuals such as *Echinochlora crusgalli* showed tolerance, and less

Table 1. Distribution of perennials in paddy fields.

Province	Infested area (%)	Distribution density of perennials (%)							
		C. serotinus	*P. Franchetii*	*S. pygmaea*	*E. Kuroguwai*	*S. hotarui*	*S. polyrhiza*	*E. acicularis*	Others
Total average	22.58	25.15	15.18	10.46	4.51	3.8	17.72	10.56	11.99
Gangwon	25.35	18.4	32.08	1.52	5.26	6.78	25.42	6.74	3.76
Kyonggi	16.26	21.87	26.43	8.53	5.76	3.92	10.03	12.05	11.41
Chungbug	23.08	19.33	17.3	15.63	7.3	2.27	19.99	7.4	10.77
Chungnam	21.91	19.34	13.0	7.6	8.28	5.33	19.22	8.75	18.48
Jeonbug	20.92	22.36	10.78	12.41	2.83	8.63	15.3	15.85	11.84
Jeonnam	20.97	34.3	11.42	7.02	1.78	1.49	27.86	4.62	11.51
Kyongbug	23.75	28.6	4.95	18.86	3.85	2.17	21.96	7.3	12.32
Kyongnam	26.91	31.39	8.84	7.36	2.83	1.1	20.7	14.75	13.03
Jeju	24.03	31.74	12.7	0.05	6.2	5.64	22.28	9.22	12.17

effective control was observed with the increase of leaching (Mine *et al.*, 1974a, 1974b; Ryang, unpublished). The optimum time of application is 15DAT, and treatments of butachlor (5DAT) followed by bentazon (25DAT) and bentazon+allyl MCP (15DAT) were more effective (Ryang, unpublished).

MT 101+benthiocarb 10/7G; *S. pygmaea*, *S. hotarui* and *E. acicularis* as well as annuals were excellently controlled. Relatively strong inhibition effect against *C. serotinus*, *P. Franchetii* and *E. Kuroguwai* was also observed. 7DAT treatments rather than 12DAT treatments were more effective. Little effect of leaching and soil texture on weeding effect was observed (Ryang, unpublished).

Piperophos+dimetametryn 4.4/1.1G; *P. Franchetii*, *S. polyrhiza*, *S. hotarui* and *E. acicularis* as well as annuals were excellently controlled. Inhibition effect against *S. pygmaea*, *E. Kuroguwai* and *C. serotinus* was found. Little effect of leaching and soil texture on weeding effect was observed (Ryang, unpublished).

Molinate+simetryne 5/1.2G and benthiocarb+simetryne 7/1.5G; *E. acicularis*, *P. Franchetii*, *S. polyrhiza* and *S. hotarui* as well as annuals were effectively controlled, but control of *S. pygmaea*, *C. serotinus* and *E. Kuroguwai* was less effective.

2) Crop damage and yields (Table 2): Among the chemicals tested, bentazon, bentazon+allyl MCP, piperophos+dimetametryn and MT 101+benthiocarb were relatively safe to rice plants with little yield reduction regardless of soil texture, application dosage, amount of leaching, variety of rice, growth stage of rice seedlings and temperature. But MT 101+benthiocarb, when applied at fewer than 4 leaf stage, caused crop damage which increased with the increase in application dosage. When treated to old seedlings (6–7 leaf stage) crop damage of perfluidon was slight with little effect on yields regardless of soil texture, but when treated to young seedings (fewer than 4 leaf stage) crop damage increased and yields were reduced as the application dosage and temperature increased, and amount of leaching decreased on both soil textures (Ryang, unpublished).

Benthiocarb+simetryne and molinate+simetryne were considerably safe to japonica type variety regardless of soil texture, but they become much less safe to Tongil

Table 2. Field test results on crop tolerance and perennial weeds control in transplanted.

Chemicals		Rate (kg a.i./ha)	Application time	Weeding effect (1–5)[a] sandy loam soil						Sandy loam soil 6–7 LSG (40DAT)		Silty clay soil 6–7 LSG (40DAT)	
				Ann.	C.s	S.p	E.K	P.F	E.a*	Crop injury (1–10)[b]	Yield (%)	Crop injury (1–10)[b]	Yield (%)
Weedy check		—	—	1	1	1	1	1	1	1.0	75	1.0	73.5
Hand weeding		—	—	5	5	5	5	5	5	1.0	(6,670 kg/ha)	1.0	(6,300 kg/ha)
Glyphosate	36EC		5DBT fb 5DAT[c]	4	5	—	—	—	—	1.0	99.1	1.0	103.1
fb butachlor	6G	2 fb 1.8	10DBT fb 5DAT	4	5	—	—	—	—	1.0	100.1	1.0	104.3
2,4-D	40EC												
fb butachlor	6G	0.28 fb 1.8	5DBT fb 5DAT	5	2	—	—	—	—	1.0	96.2	1.0	96.5
Perfluidon	5G	1	5DAT	3	3.5	4	3	4	5	1.2	99.8	1.2	99.8
		1.5	5 ,,	3	4.5	4.5	4	5	5	1.5	100	1.5	100
		2	5 ,,	3	5	5	4	5	5	2.0	99	2.0	99.7
		1.5	10 ,,	3	3.5	5	3.5	3.5	5	1.5	100	1.5	100
		2	10 ,,	3	5	5	3.5	4.5	4	2.0	100	2.0	100
		2	15 ,,	3	3	3	2	2	2	1.0	93.2	1.5	95
Bentazon	10G	2	15 ,,	2	3.5	3.5	1.5	2.5	2	1.0	100	1.0	100.1
		3	15 ,,	2	4	4	2	3	3	1.0	100	1.0	100
		4	15 ,,	3	4.5	4.5	3	3.5	3.5	1.0	100	1.2	100
Bentazon+	10G/	4/0.48	15 ,,	4	5	5	2	5	4	1.5	98.9	1.0	100
allyl MCP	1.2G	3/0.36	25 ,,	4	5	4.5	2	4	3	1.0	101.2	1.0	100
MT-101+	10G/	3/2.1	7 ,,	5	4	4.5	3	3	5	1.0	100	1.0	99
benthiocarb	7G	3/2.1	12 ,,	4	3.5	4	3	2	4.5	1.5	98	1.5	100
Piperophos+	4.4G/	1.32/0.33	10 ,,	4	2	3	3.5	5	5	1.0	100	1.0	99.9
dimetametryn	1.1G	1.32/0.33	15 ,,	4	2	2.5	2	4.5	4.5	1.0	100	1.0	100
Benthiocarb+	7G/	2.1/0.45	10 ,,	4	2.5	3.5	2.5	4.5	5	3.0	95.0	1.5	98.0
simetryne	1.5G	2.1/0.45	15 ,,	4	2	3.5	2	4.5	5	2.0	98.9	2.0	98.5
Molinate+	5G/	1.5/0.36	12 ,,	4	2	3.5	2.5	4	4	2.0	99.5	2.0	99.7
simetryne	1.2G	1/0.24	15 ,,	4	2	3	2	4	4.5	1.5	100	1.5	100
		1.5/0.36	15 ,,	4	2.5	2.5	2	4.5	4.5	1.5	99	1.5	99.4

Note: [a] Weeding effect rating=1, no effect; 5, all weeds killed.
[b] Injury rating=1, no toxicity; 10, all plants completely killed.
[c] DBT=Days before transplanting, DAT=Days after transplanting.
* Ann=Annual weeds, C.s=*Cyperus serotinus*, S.p=*Sagittaria pygmaea*, E.K=*Eleocharis Kuroguwai*, P.F.=*Potamogeton Franchetii*, E.a=*Eleocharis acicularis*.

variety (IR 667) causing crop damage on such conditions as high temperature, sandy loam soil (fewer than 2% organic matter) and high rate of application (Ryang, 1974a; unpublished).

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Rice Varietal Response to Various Preemergence Herbicides

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Abstract. Four preemergence herbicides were applied to greenhouse-grown seedlings of varieties Tongil (hybrid between indica and japonica crosses), Jinheung (pure Japonica cross) and IR24 (pure indica cross) of different ages at varying water depths. Butachlor [*N*-(butoxymethyl)-2-chloro-2′, 6′-diethyl acetanilide] was slightly injurious to all the varieties under all conditions tested. CNP (2, 4, 6-trichlorophenyl-*p*-nitrophenyl ether) and nitrofen (2,4-dichlorophenyl-*p*-nitrophenyl ether) caused similar injury symptoms to all the varieties, more severe with nitrofen. These injuries were however not permanent. CNP was most tolerant to all the varieties. Benthiocarb-simetryne [*S*-(4-chlorobenzyl)-*N*, *N*-diethylthiol carbamate plus 2-methylthiol-4, 6-bisethylamino-*s*-triazine] caused severe injury to Tongil at the higher temperature, less at the higher water level, but slight injury to Jinheung and IR24. The difference may be explained by the shallower root system of Tongil, allowing more contact with the herbicide, or different varietal metabolic rates.

INTRODUCTION

Paddy field area in Korea is 1,275,000 hectares. In 1975, 450,000 hectares were planted with Tongil rice variety (indica-japonica cross), a high yielding variety. Further expansion of acreage covered by indica-japoinca crosses is inevitable because these selections yielded 30% higher than the traditional leading japonica types.

Labor shortage problems resulted in the use of herbicides for controlling wide weed spectrums, causing chemical weed control in paddy field to become a popular practice in Korea. As of today, more than 40% of paddy field received herbicide treatment. However, the recent rapid increase of herbicide application has, in some cases, resulted in undesirable injury to rice plants. This has resulted in some difficult to dissemination and extension of agricultural technology to farmers of varied educational levels.

Differential responses within weed species to herbicides also have been reported in barnyardgrass (*Echinochloa crus-galli* Beauv.) (Roché and Muzik, 1964), wild oats (*Avena fatua* L.) (Jacobson and Anderson, 1968), and canada thistle (*Cirsium arvense* Scop.) (Hodgson, 1970), among cultivars in sorghum (Burnside and Wicks, 1972), corn (Anderson, 1964; Eastin, 1971), barley (Derscheid *et al.*, 1952) and sugarcane (Peng and Yeh, 1970).

The identification of these differences may be worthwhile in preventing substantial crop injuries and in developing more tolerant lines or in screening more safe herbicide for the rice production in future. This paper summerizes some of our results along this line.

MATERIALS AND METHODS

Greenhouse experiments was conducted in 1974 to evaluate the response of three rice varieties including Jinheung (pure japonica cross), Tongil (indica-japonica cross) and IR24 (pure indica cross) to granular form of preemergence herbicides, nitrofen, butachlor, CNP and benthiocarb-simetryne. These experiments were conducted in the agronomy greenhouse at the Crop Experiment Station, Suweon, Korea. Loam soil of 2.5% organic matter (Table 1) was used to fill up to two third of 1/5000 a Wagner pot. 0.5 gr. of N, P_2O_5 and K_2O fertilizer was incroporated into each pot just before transplanting.

Effect of herbicides on rice injuries in different leaf stages at different water depths. Seedlings grown on seed bed were pulled at 1, 3, 5 and 7 leaf stages, and four seedlings/pot were transplanted in the Wagner pots. Immediately, 1, 5 and 9 cm of water depth were applied and maintained, and a commercial rate, 60 mg of each herbicide was applied. Treatments were replicated three times in a randomized complete block design. Air temperature in greenhouse varied between 20°C to 35°C. Rice injury was visually evaluated on a 0 to 10 scale, where 0 is no effect, and 10 is death of all plants. Plants from all three replications were harvested 20 days after herbicide treatment. Dry weight of entire plant were determined and statistically analyzed.

Effect of temperature on phytotoxicity of benthiocarb-simetryne. This experiment was conducted in the phytotron. Four rice seedlings of Jinheung, Tongil and IR24, at three leaf stages were transplanted in 1/5000 Wagner pots. Temperature range of glass room used was 14°C–10°C, 20°C–18°C and 30°C–20°C in day and at night. Shortly after transplanting, 60 mg/pot of benthiocarb-simetryne was applied and 3 cm of water depth was maintained. Plants from three replications were harvested 20 days after the herbicide treatment. Dry weight of entire plants were determined and analyzed statistically.

Table 1. Analysis of soil used in this experiment.

Soil texture	Mechanical property (%)				pH	Chemical property		
	Coarse sand	Fine sand	Silt	Clay		OM (%)	N (%)	CEC (meq/100 g)
Loam	11.9	34.2	40.7	13.2	4.7	2.5	0.18	8.6

RESULTS AND DISCUSSION

Crop injuries and dry weight of rice. All the herbicide tested showed differential injuries to various stages of different rice varieties on average of three water levels (1, 5, 9 cm) (Table 2). This injuries was markedly higher at the younger stage, particularly one leaf stage. However, the plants tolerated gradually as they became older. At the seven leaf stage, all varieties were tolerant to herbicides used except for slight injuries by benthiocarb-simetryne. Younger stage of rice seedling showed delicate varietal difference to herbicides tested. Jinheung followed by IR24 were most tolerant to herbicides used.

Regardless of the leaf stage of varieties, the greatest injuries was observed in the benthiocarb-simetryne treatment followed by nitrofen. Tongil, indica-japonica crosses, appeared to be most sensitive to the herbicides applied. As shown in Table 2, Tongil seedlings treated with benthiocarb-simetryne at 5 leaf stage caused great injury (toxicity rate: 7), but other varieties showed negligible injuries (toxicity rate: 1 and 2, Jinheung and IR24, respectively). As shown in Fig. 1, insignificant differences were observed at the 7 leaf stage treatment compared with the one and three leaf stages. This indicated that regardless of varieties, age of rice plant is an important selective mechanism to escape herbicidal toxicity.

Table 2. Rice varietal responses to herbicides in different growth stage[a].

Herbicides \ Leaf stage	Jinheung				Tongil				1R 24			
	1[b]	3[c]	5[c]	7[c]	1[b]	3[c]	5[c]	7[c]	1[b]	3[c]	5[c]	7[c]
Nitrofen	8	6	3	0	10	7	5	0	9	6	3	0
Butachlor	5	5	1	0	3	1	0	0	2	1	0	0
CNP	1	1	0	0	3	0	0	0	1	0	0	0
Benthiocarb•simetryne	10	7	1	1	10	9	7	3	9	6	2	2
Untreated control	0	0	0	0	0	0	0	0	0	0	0	0

a) Toxicity rating: Scale 0—10; 0—no toxicity, 10—complete kill.
b) One leaf stage had 3 cm of water depth.
c) Average of three different water depths treatment: 1, 5 and 9 cm.

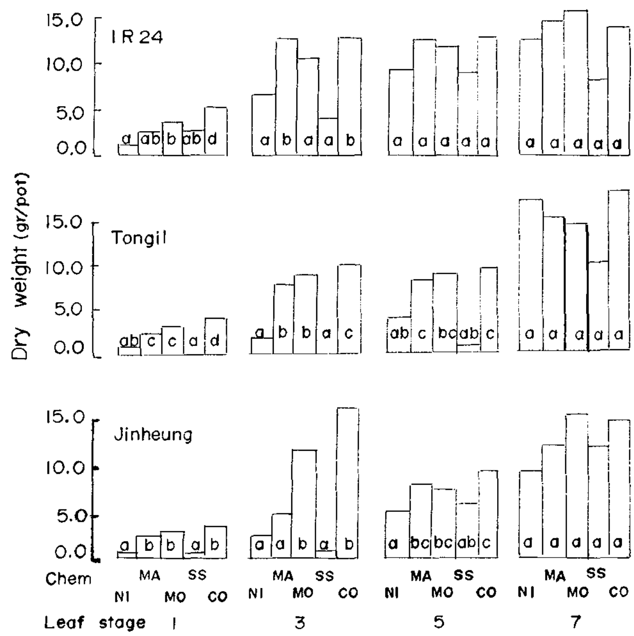

Fig. 1. Effect of herbicides treated at different leaf stages in average of three water depths on rice dry weight. Water depths used: 1, 5 and 9 cm.
NI: nitrofen, MA: butachlor, MO: CNP, SS: Benthiocarb•simetryne, CO: control.

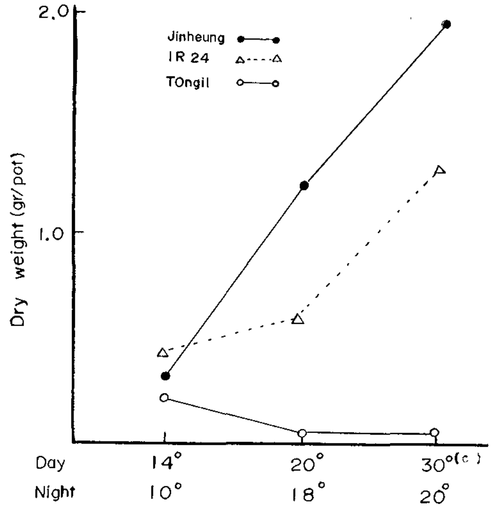

Fig. 2. Effect of temperature on dry weight of various varieties treated with benthiocarb simetryne at 3 leaf stage.

Effect of temperature on herbicide activity. Temperature treatment resulted in different degree of injuries among varieties and higher temperature retarded growth significantly compared with the untreated control one (Fig. 2). Within the range of temperature treatments, most serious injuries were marked on Tongil rice variety. Injury increased as temperature rose from 10°C to 30°C. The high temperature treatment (30°C–20°C in day and at night) caused severe injury and growth reduction of rice varieties tested, almost killing of Tongil variety. This indicated that the absorption and probably translocation of chemical to site of action may be accelerated by the higher temperature. Ibaraki (1967) reported that at high temperature (26.7°C), prometon absorption was increased to a level to cause 50% growth reduction within 36 hours of solution exposure. Arakawa *et al.* (1973) also reported similarly that herbicides combined with simetryne generally increased rice injury as temperature rose from 20°C to 30°C. In addition to this, they suggested that rice injuries to simetryne was closely related to the clay content of soil.

Based on results of this study, it is clear that rice varieties tested reponsed differently to herbicides. Of the herbicides used, benthiocarb-simetryne treatment resulted in the obvious differential response among varieties. Huruya and Kataoka (1970) reported that movement of benthiocarb in soil was negligible and benthiocarb itself was relatively safe to rice. In this study, similarly, crop injury occuring in benthiocarb-simetryne treatments may be mainly attributed to simetryne. Many researchers (Anderson, 1964; Huruya, 1969; Ryang, 1973) reported that temperature and clay content in soil are two major factors responsible for the phytotoxicity of simetryne. The sensitive response of Tongil to benthiocarb-simetryne is of particular interest. This differential varietal response to benthiocarb-simetryne may be due in large to an inherent physiological difference among varieties. Particularly, Tongil has some different characteristics from Jinheung and IR24. Most of Tongil's roots were distributed in 0 to 5 cm of the soil depth, near the soil surface, while Jinheung had more in 5 to 10 cm of soil depth. Furthermore, root weight per tiller was greater in Jinheung than in Tongil (Park *et al.*, 1972). Benthiocarb-simetryne, particularly simetryne is mainly absorbed through roots and then moved upward to the leaf tip, the site of herbicide action. This treatment primarily retarded root growth and induced simultanious toxicity symptom in the leaves. The obvious visual symptom of phytotoxicity became light green and finally drying of leaves. This difference may explain, to some extent, selective injury between varieties.

Several explanations of differential varietal response may be derived from this study.

First, different varietal response may be attributed to inherent physiological characteristics. Tongil which has funnel type of root distribution is easily exposured to benthiocarb-simetryne. While Jinheung that has barrel type has less chance to be exposured to herbicide. Particularly, seedlings are made up mainly of meristematic and young expanding tissues with a rapid growth rate. When these seedlings are more exposured to herbicide, their roots may be easily damaged by external chemicals.

Secondly, different uptake and translocation rate may be closely related to toxicity. The faster movement of herbicide to functional site, the more crop injuries at that site can be expected.

Thirdly, some biochemical difference among varieties may detoxify external compound at different rates which result in death of susceptible plants.

Finally, the response of Tongil rice varieties to benthiocarb-simetryne was not exactly the same in the field and greenhouse conditions based on the preliminary observation.

Further study on physio-biochemical response of Tongil to benthiocarb-simetryne may shed more light on the mechanism of varietal response to chemical herbicides.

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Effect of 3-Hydroxy-5-methylisoxazole on the Reduction of Herbicide Injury to Rice Seedlings

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Abstract. 3-Hydroxy-5-methylisoxazole (HMI) is a highly effective fungicide against damping-off organisms in rice and sugar beet seedlings. HMI is not only a fungicide, but it has a direct growth-promoting activity in rice seedlings. The pre-treatment of rice seedlings with HMI reduces the phytotoxic action of five of seven herbicides applied three days after transplanting. The five herbicides whose phytotoxic action is reduced are simetryne, swep-MCPA, nitrofen, CNP and propanil. The reduced herbicidal injury observed in rice seedlings may be due to increased seedling vigor induced by HMI. The improved physiological condition in these rice seedlings may increase their resistance to some injurious herbicides.

INTRODUCTION

The isoxazole homologue, HMI, is one of the most effective fungicides for controlling soil-borne plant diseases (Takahi *et al.*, 1974). HMI not only controls damping-off organisms in rice, sugar beet and other crop plants, but it is also a promising growth stimulant (Ogawa and Ota, 1973; Ota and Ogawa, 1974).

This paper reports the effect of HMI on the reduction of herbicide injury to rice seedlings.

MATERIALS AND METHODS

HMI was applied to the soil immediately after sowing of rice (*Oryza sativa* L. var. Nihonbare) seeds in the nursery beds as previously described (Ogawa and Ota, 1973). The plants reached the 2.4 to 2.5-leaf stage after 20 days. These seedlings were transplanted manually into a plastic tray (10 cm high, 5.5 cm wide, and 15 cm long) containing approximately 650 ml of paddy soil. Ten seedlings were placed in each tray with two replications for each concentration of herbicide. Water was added to maintain a 1 cm layer above the soil level. Seven commercial herbicides shown in Table 1 were applied at approximately one to ten times the recommended rate. The herbicides except propanil, were added to the water. Propanil was sprayed on the foliage with a compressed-air hand sprayer after water was drained. Water was added again 2 days after propanil treatment. The experiment was repeated several times at Konosu from May to June, 1973. The results of the experiments were similar and, therefore, the data from only one of the experiments are presented.

Table 1. A list of herbicides tested.

Common name	Chemical name	Trade name	Content of active ingredient	Practical dosage (kg or *l*/10 a)
Propanil	3′,4′-dichloropropionanilide	Stam E.F. 35	35%	1 *l*
Simetryne	2,4-bis(ethylamino)-6-(methylthio)-*s*-triazine	Gy-bon granule	1.5%	3–4 kg
Nitrofen	2,4-dichlorophenyl-*p*-nitrophenyl ether	NIP granule	7%	3–4 kg
CNP	2,4,6-trichlorophenyl-*p*-nitrophenyl ether	MO granule	9%	3–4 kg
Swep-MCPA	methyl 3,4-dichloro-carbanilate, [(4-chloro-*o*-tolyl)oxy] acetic acid ethyl ester	Swep M granule	Swep 20% MCPA 0.7%	3 kg
Benthiocarb·CNP	*S*-*p*-chlorobenzyl *N,N*-diethylthiolcarbamate, 2,4,6-trichlorophenyl-*p*-nitrophenyl ether	Saturn M granule	Benthiocarb 7% CNP 6%	3–4 kg
Benthiocarb·simetryne	*S*-*p*-chlorobenzyl *N,N*-diethylthiolcarbamate, 2,4-bis(ethylamine)-6-(methylthio)-*s*-triazine	Saturn S granule	Benthiocarb 7% Simetryne 1.5%	3–4 kg

Results and Discussion

Plant injury was rated daily after herbicide treatments. No visual symptoms of injury developed on rice plants for several days. First signs of seedling injury were observed 9 days after treatments.

Simetryne injury to rice seedlings was observed 10 days after treatment. Desiccation of the leaf tips was typical of simetryne injury to rice seedlings. Simetryne stunted plant growth and caused leaf desiccation even at the recommended rate of 3 kg/10 a after 13 days. Simetryne injury increased significantly with increased rates. However, pre-treatment with HMI significantly reduced the injury to rice seedlings at all rates of simetryne, although the degree of protection was less as the rate of simetryne applied increased. At 3 to 4.5 kg/10 a, the practical dosage of simetryne, rice seedlings pre-treated with HMI showed a slight yellowish discoloration of older leaves without reduction in shoot weight. Even at 30 kg/10 a, the highest rate of simetryne applied, HMI pre-treatment reduced slightly simetryne injury to rice seedlings. The shoot weight of rice seedlings after 13 days of treatment demonstrated that pre-treatment with HMI reduced the injury by simetryne at all dosages (Fig. 1).

HMI generally appeared to promote the growth of shoots or roots in the control plants not treated with herbicides.

Nitrofen injury to rice seedlings produced a brownish discoloration of the leaf sheath (basal stem) and growth reduction. Nitrofen was significantly more phytotoxic to rice seedlings than CNP, a closely related analog. Injury to rice seedlings occurred at all dosages of nitrofen 16 days after treatment, and the degree of injury was relatively constant for all dosages. However, rice seedlings pre-treated with HMI showed normal

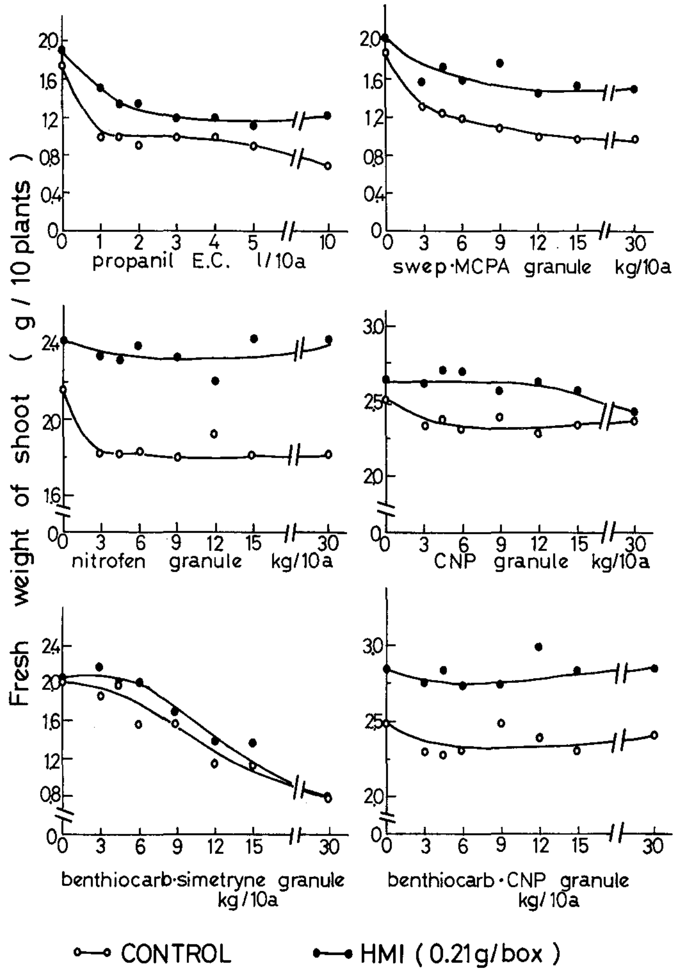

Fig. 1. Effect of 3-hydroxy-5-methylisoxazole on the phytotoxicity of herbicides on rice seedlings.

growth with little or no stem damage by nitrofen at all dosages after 16 days (Fig. 1).

Rice seedlings treated with CNP showed the same brownish discoloration of leaf sheath as in nitrofen treatment. Pre-treatment with HMI reduced the browning injury caused by CNP at all dosages, although minor phytotoxic symptoms were observed. No reduction in shoot or root weight occurred in both HMI-treated and untreated control seedlings at all dosages.

No injury symptoms were observed within 7 days after treatment with propanil and swep-MCPA which are photosynthetic inhibitors. However, some injury to rice seedlings was observed after 11 days when propanil was applied at the recommended field rates of 1.0 and 1.5 *l*/10 a. Shoot growth was reduced approximately 45% at these rates. The injured plants showed leaf burning. Shoot growth was inhibited 60% at the highest dosage level of 10 *l*/10 a. Pre-treatment with HMI reduced the inhibition of shoot growth by propanil to 15% and 30%, at the rates of 1.0 *l*/10 a and 10 *l*/10 a, respectively (Fig. 1). The protective effects of HMI on rice seedlings treated with swep•MCPA, 13 days after treatment, were similar to that observed with propanil treatment (Fig. 1).

HMI showed no protective effects on rice seedlings treated with herbicide combinations of benthiocarb•simetryne and benthiocarb•CNP 18 days after treatment (Fig. 1).

In summary, the pre-treatment of rice seedlings with HMI reduced the phytotoxic action of five of seven herbicides applied after transplanting. The five herbicides whose phytotoxic action was reduced were simetryne, nitrofen, CNP, propanil and swep-MCPA.

Preliminary experiments indicated that herbicidal injury was not reduced when HMI was applied simultaneously with the herbicides at time of rice transplanting. HMI was effective as a protectant only when applied as a pre-treatment to rice. Therefore, the reduction of herbicidal injury in rice seedlings per-treated with HMI may be due to increased seedling vigor induced by HMI. The increased vigor may increase the resistance of rice seedlings toward herbicidal injury. HMI treatment also reduced overhead flooding damage immediately after transplanting of rice plants (Ogawa and Ota, 1974).

The reported results are from laboratory experiments only. Therefore, further research under field conditions will be required to evaluate critically the practical use of HMI as a herbicide antidote.

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The Application of Methazole for Early Post-Emergence Weed Control in Onions

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Abstract. Trials were conducted in the Lockyer Valley, Queensland to determine the crop tolerance of onions to early and sequential applications of methazole [2-(3,4 dichlorophenyl-4-methyl-1,2,4-oxadiozolidine-3,5-dione)]. There were no yield depressions following a single application of 1.7 kg a.i./ha methazole applied at the 1–2 leaf stage of the crop. No yield depressions compared to handweeded control were evident following methazole at rates up to 1.0 kg a.i./ha applied at the 1–2 leaf stage of the crop, followed by 2.0 kg a.i./ha at the 5–6 leaf stage. High ambient temperatures at the time of application did not affect the crop tolerance of onions to methazole. The results are discussed in relation to the possibilities of using methazole for early post emergence weed control of onions in the Lockyer Valley.

Introduction

The competitive ability of crops varies over a wide range, but few crops lack competitive ability to the extent demonstrated by onions. Shadbolt and Holm (1956) working with rainfed onions, carrots and beets found that onions tolerated weed competition to a much lesser extent compared to the two latter crops. Not only were the competitive effects from weeds greater but the effects tended to be irreversible. The onions did not appear to have the ability to make compensative growth following the removal of the weed growth. In their study, the period from crop emergence to 4 weeks post-emergence was the most critical for weed competition. Wicks, Johnston *et al.* (1973) working with irrigated onions, where it would be likely that the crop would have a greater opportunity to recover from any weed competition once removed, showed that a weed-free period of 12 weeks after onion emergence is necessary to prevent a yield loss from weeds. Williams and Crabtree *et al.* (1973), in studying the interactions of row spacing and weed competition in a number of crops, including onions, indicated that the crop must be free of weeds for the entire growing season for maximum yield. Hazard (1967) based on work from the Gatton Research Station, Lockyer Valley, confirms the findings of other workers that weeds compete with onions in the early stages of crop development for moisture, nutrients and light, and in the latter stages can prevent full bulb formation and ripening as well as interfering with harvest.

Some of the initial work with methazole was carried out by Griffith and Baker (1970). They showed that methazole applied to onions at 2.2 kg a.i./ha should be delayed until the crop had reached the 2 leaf growth stage. Working on a similar growth stage Cassidy and MacNaeidhe (1970) reported good tolerance of onions to 2.2 kg methazole/

ha applied at the crook to 1 leaf stage grown on medium loam soil. The findings of Griffith and Baker have since been confirmed by Edwards (1971), Lake and Griffith (1971), Baker and Edwards (1972) and Robert and Bond (1972). Plumbe (1974) from trial work in southern Australia, reports damage following methazole application to onions grown on a light sand at rates above 1.1 kg a.i./ha. However, on a medium loam, yields from onions treated with rates up to 3.6 kg a.i./ha were not significantly different from those of the hand weeded control treatment. The aims of this study were: a) To determine the rate of methazole which could be tolerated by onions at the 1–2 leaf stage grown under field conditions in the Lockyer Valley and b) To determine if a subsequent application of methazole had an effect on crop tolerance. c) To determine whether high temperatures at the time of application affect the tolerance of onions to methazole.

Materials and Methods

The trials were carried out in commercial onion crops grown in the Lockyer Valley under normal fertilizer and spray irrigation frequency. A randomised block design with 4 replications was used throughout. Spray treatments were applied with a knapsack sprayer fitted with a 2 metre boom incorporating 4 'Spraying Systems' 8003 T jets nozzles operating at 140 kpa to deliver 250 l water per hectare.

Trial 1 was conducted on a brown podzolic loam at Tenthill. Plot size was 2 ×6 m. The treatments involving chlorthal at 7.5 kg a.i./ha were sprayed post plant pre-emergence and followed by sprinkler irrigation for incorporation. All the initial post-emergence treatments were applied when the crop was at the first true leaf (the second true leaf was 1–3 cm long) on 14/6/73. The control plots which were to receive no post herbicide treatment were hand weeded shortly afterwards. The second ioxynil treatment was applied in mid July because of a heavy weed burden on these plots. The second methazole application was made on 13/8/73 when the crop was at the 5–6 leaf stage. At this time the grass weeds, barnyardgrass (*Echinochloa crus-galli*) and liverseed grass (*Urochloa panicoides*) in the plots which had already received the initial methazole treatment were at the 2–4 leaf stage. Broadleaved weeds in these plots were relatively insignificant at this time. Weed counts were made at harvest when crop yield was estimated by weighing the total number of onions from an area of 1 m (2 rows) ×3 m.

Trial 2 was also conducted on a podzolic loam at Tenthill. Plot size was 2 ×10 m incorporating 4 double rows. The area was pre-treated with chlorthal 7.5 kg a.i./ha prior to crop emergence. The application times for the 1–2 leaf stage was made on 9/4/74 when 90% of the onions had the second true leaf at 2.8 cm in length. The shade temperature at the time of application was 30°C. The second methazole application was made on 24/7/74 when 90% of the crop had the fourth true leaf emerging. The shade temperature during the second application was 25°C. The predominant weed at both times of application was potato weed (*Galinsoga parviflora*), 15 cm high at T1 and 55 cm high at T2. The number of onions per metre of row were counted on 14/5/74 and the yield of marketable onions from an area of 1 m (2 double rows) ×8 m from each plot were taken on 12/7/74.

Trial 3 was conducted at Gatton on a block clay loam. Chlorthal was applied as a pre-emergence treatment. Methazole was applied post emergence as a split application, early and late, and compared with a single application at both times of spraying. The early spray treatments were applied on 12/6/74 when the crop was at the 1–2 leaf stage (90% of the crop had the second true leaf emerged). The late spray treatments were applied on 19/8/74 when the crop was at the 6–7 leaf stage. The whole trial area was kept weed free throughout the duration of the trial by hand weeding. The crop was harvested on 14/10/74 and the marketable onions from 1 m (2 rows) ×6 m from each plot were weighed for yield estimation. Yields from this trial were depressed by a severe attack of downy mildew (*Perenospora destructor*) late in the growing season.

RESULTS AND DISCUSSION

Trial 1. The yield data from this trial showed no differences between treatments. All treatments, including the handweeded control, effectively eliminated weeds early in the crop. However, in treatments where weeds were allowed to establish later in the season there were also no yield differences apparent (Table 1). Similarly, the second

Table 1. Weed population—percentage cover at harvest (transformed data in brackets) and total onion (cv. Lockrose white) yield following methazole application alone or following chlorthal pre-emergence.

Treatment (kg a.i./ha)	Percentage weed cover E	G	C	Mean onion yield kg/plot (t/ha)
Chlorthal 7.5 T1 fb. methazole 0.8 T2	58.3 (50.2)	22.2 (27.7)	5.6 (9.7)	5.3 (17.7)
Chlorthal 7.5 T1 fb. methazole 1.0 T2	52.8 (47.2)	30.6 (33.3)	13.9 (21.6)	4.8 (16.0)
Chlorthal 7.5 T1 fb. methazole 1.2 T2	55.6 (48.2)	47.2 (43.9)	0.0 (0)	4.5 (15.0)
Chlorthal 7.5 T1 fb. ioxynil 0.2 T2 fb. 0.4 T3	55.6 (48.1)	47.2 (43.7)	11.1 (14.1)	4.3 (14.3)
—methazole 1.0 T2	52.8 (47.2)	33.3 (37.1)	2.8 (4.9)	4.7 (15.7)
—methazole 1.0 T2 fb. 1.2 T4	2.8 (4.9)	0.0 (0)	0.0 (0)	5.3 (17.7)
—methazole 1.0 T2 fb. 2.0 T4	0.0 (0)	0.0 (0)	0.0 (0)	5.7 (19.0)
Chlorthal 7.5 T1 fb. handweeding at T2	47.2 (43.2)	63.9 (54.5)	8.3 (11.9)	4.3 (14.3)
LSD 5%	(14.6)	(19.4)	(12.5)	NS
1%	(19.8)	(26.4)	NS	—
0.1%	(26.8)	(35.7)	—	—

Data transformed from whole plot score of 0–9 where 9=complete cover by Y=arcsin $\sqrt{x/10}$ and scaled by Y=X×1.1111 to give a range of 0–90. The actual 0–9 scores have been converted to percentage cover.

fb.=followed by; E=*Echinochloa crus-galli*; G=*Galinsoga parviflora*; C=*Chenopodium album*.

Harvest area 1×3 m. T1, pre-emergence; T2, 1–2 stage of crop; T3, 3–4 leaf stage of crop; T4, 5–6 leaf stage of crop.

application of methazole at the 5–6 leaf stage did not reduce the marketable yield of onions. A weed assessment taken at harvest, Table 1 shows that only two treatments, both involving split applications of methazole, gave effective weed control for the duration of the crop. This result suggests that early competition only, is of importance in affecting onion yield.

Trial 2. The purpose of this trial was to evaluate the crop safety of methazole when applied early and late under weed-free and weedy conditions, as well as assessing the effect of high ambient temperatures at application. There were no differences in the onion population following methazole (Table 2). There were marked reductions in yield when weeds were present if no weed control measures were taken, as in the unsprayed control, or when the post-emergence application of methazole was delayed until the 3–4 leaf stage. There was a slight fall in yield at the lowest rate of methazole in the applications made at the 1–2 leaf stage due to lack of weed control. Since there were no differences between the various methazole rates, time of application, and the no post-emergence spray treatment in the weed free plots, it is assumed that high temperatures at application do not increase crop phytotoxicity of onions to methazole.

Trial 3. To confirm the crop tolerance results obtained in Trials 1 and 2, a further trial was conducted in which methazole was applied to onions maintained under weed free conditions. There were no significant differences in yield (Table 3) between the various methazole treatments and the no post-emergence spray treatment. The treatment involving a single application of 1.7 kg a.i./ha methazole at the 1–2 leaf stage of the crop, while causing very slight leaf scorch, did not reduce onion yield. A single application of 2.5 kg a.i./ha methazole at the 6–7 leaf stage was completely safe to the crop.

Table 2. The effect of methazole at two times of application on onion plant number and on onion (cv. early Lockyer white) marketable yield in handweeded and non-handweeded situations.

Treatment (kg a.i./ha) chlorthal 7.5 pre-emergence followed by	Mean no onion plants per metre of row[a]		Mean onion yield kg/plot (t/ha)[b]	
	Handweeded	Non-handweeded	Handweeded	Non-handweeded
Methazole 0.8 T1	19.9	21.7	29.2 (36.5)	19.6 (24.5)
Methazole 1.0 T1	22.6	21.2	29.6 (37.0)	26.3 (32.9)
Methazole 1.2 T1	18.8	21.1	27.4 (34.3)	27.7 (34.6)
Methazole 1.7 T1	18.9	19.7	33.8 (42.3)	29.3 (36.6)
Methazole 2.2 T2	22.8	19.9	31.5 (39.4)	14.1 (17.6)
Methazole 4.4 T2	21.0	20.4	24.7 (30.9)	14.4 (18.0)
No post-emergence spray	21.3	21.1	28.2 (35.3)	5.8 (7.3)
LSD 5%	NS		9.0 (11.3)	
1%	—		12.2 (15.3)	
0.1%	—		16.2 (20.3)	

T1, 1–2 leaf stage of crop; T2, 3–4 leaf stage of crop.

[a] Mean of 8 counts per plot assessed 35 days after treatment for T1, 20 days after treatment for T2.

[b] Harvest area 1 m (4 rows) ×8 m. Marketable yield—Standard No. 1 grade onion >4 cm, <6 cm diameter.

Table 3. The effect of methazole on the yield of marketable onions (cv. Lockrose white) under weed free conditions.

Treatment (kg a.i./ha)	Mean onion yield kg/plot (t/ha)
Chlorthal 7.5 T1 fb. methazole 1.2 T2+HW	11.7 (19.5)
Chlorthal 7.5 T1 fb. methazole 1.7 T2+HW	12.1 (20.2)
Chlorthal 7.5 T1 fb. methazole 1.2 T3+HW	12.1 (20.2)
Chlorthal 7.5 T1 fb. methazole 2.5 T3+HW	13.1 (21.8)
Chlorthal 7.5 T1 fb. methazole 1.5 T2 fb. 1.2 T3+HW	11.9 (19.8)
Chlorthal 7.5 T1 fb. — +HW	12.5 (20.8) NS

fb.=followed by; HW=handweeded; Harvest area 1×6 m.
T1, pre-emergence; T2, 1–2 leaf stage of crop; T3, 6–7 leaf stage of crop.
Marketable yield—standard No. 1 grade >4 cm, <6 cm diameter.

The results show that methazole applied at the 1–2 true leaf stage of the crop (once the second true leaf has emerged) is safe to onions at rates up to 1.7 kg a.i./ha. High temperatures at spraying do not appear to alter this tolerance.

When used after a pre-emergence application of chlorthal, methazole will control weeds escaping from the chlorthal treatment. This includes grasses and a range of broadleaved weeds. Hazard (1969) lists among the weeds which are not controlled by chlorthal as slender celery (*Apium leptophyllum*), prairie grass (*Bromus uniloides*), potato weed (*Galinsoga parviflora*), bitter cress (*Coronopus didymus*), bell-vine (*Ipomoea plebeia*), hairy jo-jo (*Soliva anthemaifolia*), shepherd's purse (*Capsella bursa-pastoris*), caltrop (*Tribulus terrestris*) and Bathurst bur (*Xanthum spinosum*).

Other trial work and field observations have shown that all these weeds are controlled by methazole, particularly at the seedling stage. However, two weeds which are not controlled by either chlorthal or methazole are burr medic (*Medicago polymorpha*) and common fumitory (*Fumaria officianlis*).

The early application of methazole in the Lockyer Valley can be expected to give weed control for about 6–8 weeks. This gives protection to the crop when weed competition is most damaging. A second application of methazole may be made, according to when the next weed germination occurs. In the Lockyer Valley the early onion crops are more likely to be troubled by broadleafed weeds, whereas in mid and late season crops grass weeds are more likely to be dominant.

The ability of methazole to control grass weeds pre-emergence and at the seeding stage is of great significance to onion crops in the Lockyer Valley. In past seasons the early appearance of grasses has created major harvesting problems. Grass weeds are difficult to cultivate or control by hand chipping. Early weed emergence with the crop is a common occurrence, it is therefore felt that methazole has a very useful role to play in grass and broadleaf weed control of onions in the Lockyer Valley.

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The Use of Trifluralin and Alachlor for Weed Control in Soybeans

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Abstract. In a series of experiments on weed control in soybeans (cv. Lee) at Camden, New South Wales, the following mean yields (kg/ha) were obtained: no weed control—2,090; hand-weeded—2,740; herbicides (trifluralin at 1.1 kg/ha or alachlor at 2.2 kg/ha)—2,370. L.S.D. (5%)-450. Though substantial losses in yield due to weeds were recorded, statistically significant increases after the use of the two herbicides were not.

In order to approach more closely the yields which can be attained under weed-free conditions more attention must be given to non-herbicidal control methods such as pre-sowing cultivations, time of sowing, inter-row cultivation and crop rotation.

Introduction

Along with the recent world interest in the production of oilseed crops, the area of soybeans [*Glycine max* (L.) Merrill] sown in Australia increased from about 1,000 ha in 1966–67 to about 50,000 ha in 1974–75. Workers in the Faculty of Agriculture, University of Sydney, have been engaged in much of the developmental research which has made successful growing of soybeans possible.

At the University of Sydney Agronomy Farm, Camden, New South Wales, we have carried out a series of weed control experiments in spray-irrigated soybeans from 1969–1970 to 1973–74 using the following pre-emergent herbicides-alachlor (2-chloro-*N*-2,6-diethylphenyl-*N*-methoxymethylacetamide), chloramben (3-amino-2,5-dichlorobenzoic acid), metribuzin [4-amino-6-*tert*-butyl-3(methylthio)-1,2,4-triazine-5(4H)-one], oxadiazon [4-(2,4-dichloro-5-isopropoxyphenyl)-2-*tert*-butyl-1,3,4-oxadiazolin-5-one] and trifluralin (2,6-dinitro-*N*,*N*-dipropyl-4-trifluoromethylaniline).

The use of pre-emergent herbicides was based on the expectation that they would bring about adequate control of susceptible weeds in the first six weeks of growth of soybeans.

The most important weeds in soybeans at Camden are *Echinochloa crus-galli* (L.) Beauv. and *E. crus-pavonis* (H.B.K.) Schult. (barnyardgrasses), *Digitaria sanguinalis* (L.) Scop. and *D. ciliaris* (Retz.) Koeler (summer grasses), *Amaranthus hybridus* L., *A. powellii* S. Wats. and *A. viridis* L. (amaranths), *Chenopodium album* L. (fat hen), *Solanum nigrum* L. (black-berried nightshade), *Galinsoga parviflora* Cav. (potato weed) and *Sonchus oleraceus* L. (common sowthistle). Scattered dense infestations of *Datura stramonium* L. (common thornapple) and *Nicandra physalodes* (L.) Gaertn. (apple of Peru) occur also.

The only herbicides tested which are commercially available in New South Wales are trifluralin and alachlor and it is these two which have shown most promise in our experiments in terms of weed control and apparent safety to the crop.

We have developed a weed control programme in large-scale plantings on the Agronomy Farm, using trifluralin at 1.1 kg/ha for one or two seasons followed by use in later seasons of alachlor at 2.2 kg/ha especially for control of the composites, potato weed and common sowthistle. Under favourable conditions both herbicides give good control of grasses.

In this paper I intend to concentrate on the effects of these herbicides on yield of soybeans, summarizing the results of experiments over the 5-year period in which trifluralin and alachlor at the abovementioned rates were used. Weed control was satisfactory in all experiments.

Materials and Methods

All experiments were laid out in complete randomized blocks with at least four replicates. Treatments included no weed control, handweeding and the appropriate herbicide. Soybeans cv. Lee were sown at 25 seeds per metre with a precision planter in rows spaced 50 cm apart. This row spacing was chosen because of earlier work in U.S.A. (Peters *et al.*, 1965; Wax and Pendleton, 1968) demonstrating its advantage over wider rows in terms of weed control. Sowing date varied from mid-November to early January. Plot size was 1.8 m by 6.1 m. Herbicides were applied with an AZ carbon dioxide sprayer. Trifluralin was incorporated as shallowly as possible with a rotary hoe just before sowing and alachlor was applied immediately after sowing. Plots were first irrigated with 12 mm within two days of sowing and kept moist by subsequent spray irrigation whenever necessary. The hand-weeded plots were kept clean by hoeing and hand-pulling until canopy closure of the beans, six to eight weeks after sowing. The plots were harvested in May or early June by cutting and threshing two adjacent metre lengths of row from the centre of one half of each plot.

Results

The mean yields for each season and overall means are presented in Table 1. The overall means show that there were substantial losses in yield (about 20%) due to the presence of weeds but that there were no statistically significant increases in plots treated with the herbicides over those plots which received no weed control.

Discussion

The use of herbicides for weed control in soybeans, as in any other crop, must surely be based on the expectation that their use will be profitable. But, here in an overall treatment of a 5-year series of experiments we are faced with the reality that

Table 1. Yield of soybeans cv. Lee in kg/ha.

Season (mean yields)	No weed control	Handweeded	Herbicide
1969–70	2,780	2,670	2,660 (1.1 kg/ha trifluralin)
1970–71	2,780	3,050	2,580 („ „)
1971–72	1,930	2,640	2,380 (2.2 kg/ha alachlor)
1972–73*	1,020	2,070	1,560 („ „)
1973–74	1,940	3,260	2,690 („ „)
Overall mean	2,090	2,740	2,370

L.S.D. (between overall means)—5%—450.

* The low yields in 1972–73 were at least partly caused by the rot fungus, *Sclerotinia sclerotiorum*.

statistically significant increases in yield due to herbicides have not been recorded. How is it that we were unable to approach the yields in the hand-weeded plots by the use of herbicides which gave satisfactory weed control? There are, I think, two important considerations. Firstly it is possible that the yields of hand-weeded plots are stimulated by the cultivation coincident with hoeing and hand-pulling of weeds and secondly there may well be hidden harmful effects of the herbicides on the crop. In these experiments, although there were no measurable adverse effects of the herbicides on establishment and height of the soybean plants it may well be that there were inhibitory effects of trifluralin on lateral root development, as reported by Oliver and Frans (1968) and on nodulation, as reported by Kust and Struckmeyer (1971), which affected the complex processes involved in flowering, seed setting and pod-filling. Similarly, alachlor has been shown by Milică *et al.* (1972) in field studies and by Wibowo (1975) in glass-house studies to inhibit nodulation and root growth in soybeans.

It is necessary to test these ideas in further intensive field studies.

Meanwhile, in order to approach more closely the yields which can be attained under weed-free conditions more attention must be given to non-herbicidal control methods such as pre-sowing cultivations, time of sowing, inter-row cultivation and crop rotation. It seems to me that it is unrealistic to expect that any herbicide or combination of herbicides will give the complete answer to our weed problems in soybeans.

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Bentazon, a Post-emergence Herbicide in Soybeans and Other Crops

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Abstract. Soybean herbicides (mainly soil-applied herbicides) used so far generally prove effective against annual grasses. Control of many broadleaved weeds is mostly poor. The selectivity of the available post-emergence herbicides is marginal.

Our trial results and the results from practical usage in Brazil, Canada, Eastern Europe and the USA show that the post-emergence herbicide bentazon [3-isopropyl-1H-2,1,3-benzothiadiazin-(4)3H-one-2,2-dioxide] is highly effective against *Abutilon*, *Amaranthus*, *Ambrosia*, *Bidedens*, *Brassica*, *Datura*, *Helianthus*, *Ipomoea*, *Polygonum*, *Raphanus*, *Sida*, *Sinapis*, *Xanthium* and other weed species found mainly in soybeans. The optimal application rate lies in the region of 1 kg a.i./ha Application should be carried out between the formation of the first and third trifoliate leaves of the crop, which is when the weeds are at a very susceptible stage.

In addition to soybeans, bentazon is also selective in other crops belonging to the Leguminosae and Gramineae Families and is suited for aerial application.

INTRODUCTION

The biological properties of bentazon (BASAGRAN) have been described in a number of previous publications. In soybeans bentazon is used as a foliage-applied herbicide. The weeds, therefore, must have emerged at the time of application. For complete kill, adequate spray coverage of the weeds is essential. Growth-promoting climatic conditions (e.g., high temperatures and high humidity) accelerate kill of the weeds. There should be no rainfall for several hours after application.

Bentazon is selective particularly in crop plants belonging to the Leguminosae and Gramineae Families (e.g., soybeans, peanuts, cereals, rice and maize). It has already been introduced as a herbicide in the USA, Brazil and other important soybean-growing countries. This paper will report on the most important results from trials and practical usage.

MATERIALS AND METHODS

Bentazon was applied post-emergence at rates of 0.5–2 kg a.i./ha during different growth stages of the weeds and soybeans. Application was carried out by knapsack sprayers in the replicated trials. In actual agricultural practice, ground equipment, fixed-wing aircraft and helicopters were used

Results

Good tolerance of bentazon at practically all growth stages was shown in more than 200 replicated trials and in agricultural practice. Dependent on the variety and climatic conditions, slight leaf scorching can occasionally occur. However, the crop quickly recovers; and there is no adverse effect on the yield performance. True intolerance was observed only with some Japanese varieties.

Bentazon is selective in a whole range of other crops. The product can be applied at any growth stage of peanuts and after formation of the first trifoliate leaf of beans. Bentazon can also be used in rice, maize, cereals, peas and other crops.

Bentazon's range of effectiveness in soybeans is shown in Table 1. Belonging to the most important weeds in soybeans are the species of *Abutilon*, *Amaranthus*, *Ambrosia*, *Bidens*, *Brassica*, *Datura*, *Helianthus*, *Ipomoea*, *Polygonum*, *Raphanus*, *Sida*, *Sinapis* and *Xanthium*. As can be seen in the table, they are controlled very well. The best weed control at the lowest application rates is obtained when the soybeans have developed 1–3 trifoliate leaves. As a rule, this is when the weeds also are in an early stage of growth and, hence, are very susceptible to bentazon.

Table 1. Herbicidal activity of bentazon in soybeans.

Weed species	Dose in kg a.i./ha		
	0.75	1.0	1.5
Abutilon theophrasti	93 (16)	92 (18)	98 (8)
Acanthospermum hispidum	100 (1)	100 (2)	—
Amaranthus retroflexus	83 (12)	85 (19)	90 (5)
Ambrosia artemisiifolia	97 (10)	96 (15)	99 (3)
Bidens pilosa	—	98 (25)	—
Brassica kaber	94 (7)	99 (4)	85 (1)
Chenopodium album	77 (11)	93 (15)	89 (4)
Cyperus esculentus	81 (5)	84 (4)	88 (1)
Datura stramonium	89 (2)	99 (1)	94 (2)
Galinsoga parviflora	—	98 (3)	—
Helianthus annuus	—	97 (5)	—
Hibiscus trionum	97 (5)	89 (4)	100 (3)
Ipomoea hederacea and *purpurea*	77 (8)	88 (25)	99 (2)
Ipomoea aristolochiaefolia and others	—	98 (11)	—
Polygonum pensylvanicum	99 (11)	98 (11)	100 (6)
Polygonum persicaria	97 (1)	100 (3)	—
Raphanus raphanistrum	—	96 (21)	—
Sida spinosa	98 (4)	97 (8)	99 (1)
Sida rhombifolia	—	98 (17)	—
Sinapis arvensis	—	94 (12)	—
Xanthium pensylvanicum	96 (23)	96 (35)	100 (8)

( )=No. of trials.

Application carried out after formation of 2–4 trifoliate leaves of soybeans.

Bentazon can also be applied by airplane or helicopter. Good results are obtained with rates of 50–100 l/ha water. The application technique must be carried out accurately so as to ensure uniform coverage of the weeds.

Discussion

As a rule, the weeds and grasses occurring in soybeans can not be controlled with one single herbicide. Soil-applied herbicides used to control grasses are only effective against a few weeds. By using a soil-applied herbicide pre-sowing or pre-emergence and bentazon post-emergence (systematical treatment), a very broad range of weeds and grasses can be controlled, including almost all of the important weeds and grasses found in soybean crops. As bentazon is very selective in soybeans and can be applied at practically any growth stage of the crop plants, the application time is determined by the growth stage of the weeds. Generally, the weeds are at a very susceptible stage (3–6 leaves) when the soybeans have formed 1–3 trifoliate leaves. On the average 1 kg a.i./ha is used at this point for good herbicidal activity.

Bentazon is translocated only to a very slight degree in the plant; and its systemic activity is, thereofre, negligible. In the case of perennial weeds like *Cirsium arvense*, *Convolvulus arvensis* and *Cyperus esculentus* growing under upland conditions, a bentazon application normally kills only the aerial part of the weeds, which means that regrowth will occur. Good herbicidal activity against these weeds can be obtained by a split application of bentazon at an interval of 10–14 days. The dose required per application is 0.75–1 kg a.i./ha.

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Weed Control in Barley in Korea

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Abstract. Excellent control of *Alopecurus aequalis*, the most dominant weed in barley, with little crop damage was observed with pre-emergence treatments of *N*-(butoxymethyl)-2-chloro-2′, 6′-diethyl acetanilide (butachlor), 3-methyl-4′-nitrodiphenyl ether (TOPE), *S*-(4-chlorobenzyl) *N,N*-diethylthiocarbamate (benthiocarb), 2,4-dichlorophenyl *p*-nitrophenyl ether (nitrofen) and 2,4,6-trichloro-4′-nitrodiphenyl ether (CNP) regardless of soil texture and weather and in case of *A. aequalis* which is developed up to 3 to 4 leaf stage at the time of barley seeding, 1,1′-dimethyl-4,4′-bipyridinium dichloride (paraquat) and/or *N*-(phosphonomethyl) glycine (glyphosate) fb butachlor, and 2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine (terbutryn) were very effective, while butachlor (5DAS) fb dimethylamine salt of (2,4-dichlorophenoxy) acetic acid (2,4-D amine) (140DAS) was most effective for controlling broadleaves.

INTRODUCTION

Barley is an important staple food crop next to rice in Korea, and is planted to as large as 1.0 million ha. Of the areas planted to barley 43 per cent is double cropping at paddy after rice and the rest is upland barley.

In barley culture, there are several difficulties in the attempt of expanding area planted to barley, namely 1) low profitability, 2) severe labor shortage owing to the overlap of seed time and harvest time of barley and rice, and 3) time and labor-consuming conventional weed control practices after seeding barley. Therefore, it is imperative to introduce mechanization and chemical weed control practices into barley in order to save labor and reduce production cost. Among the weeds found in barley at drained paddy, *Alopecurus aequalis*, winter annual, alone constitute about 79–88% of the total weeds, and the remaining weeds are composed mainly of broadleaves such as *Stellaria uliginosa* Ohwi, *S. media* Villars, while in an upland barley such broadleaves are of dominant (Park, 1972; Ryang, 1974c).

In order to select suitable herbicides for use in barley which possess excellent weeding effect with little or none crop damage to barley, pot, green house, and field experiments were conducted for 6 years.

MATERIALS AND METHODS

The experiments were conducted on barley under two different soil types; silty clay (O.M 2.4%) and sandy loam (O.M 1.7%).

Two varieties of naked barley, *Hordeuu sativum* Jessen, Baegdong and Wanju bomsal were used.

Herbicidal properties of the chemicals were tested through the methods as described by Takematsu (1964), and the methods adopted by Miyahara (1970), field experiments were carried out through the methods adopted by the Crop Experiments Station, ORD, Korea (Kim, 1971).

Results and Discussion

Weeding effect. Butachlor, alachlor, chlorpropham, benthiocarb, TOPE, nitrofen and terbutryn were excellent for controlling *A. aequalis*, and could be controlled even at one third to half recommended dosage with little variation in the weeding effect regardless of the environmental conditions including soils, and CNP, simazine and swep were next to above chemicals (Table 1).

PCP, linuron, and simetryne were relatively less effective for controlling *A. aequalis*.

Linuron, PCP, simazine, swep, diuron and 2,4-D were very effective for controlling broadleaves, while butachlor, alachlor, nitrofen, CNP and benthiocarb were a little less effective.

Butachlor, benthiocarb, simazine and terbutryn were effective for controlling *A. aequalis* and *S. uliginosa* at its 2 leaf stage (Table 1).

Paraquat, glyphosate and terbutryn were very effective for controlling *A. aequalis* even at its 3 to 4 leaf stage (Table 1).

At optimum soil moisture, butachlor, alachlor, benthiocarb and simazine were effective regardless of the formulation types, while granular formulation of nitrofen and CNP was much less effective (Ryang, 1970).

Crop tolerance. In the tolerance tests in a sandy loam soil, soil surface and rootzone applications of CNP, nitrofen, TOPE, butachlor, benthiocarb, swep, and PCP caused very little crop damage (Ryang, 1971).

Foliage applications, when applied at 2 to 3 leaf stage of barley, of butachlor, alachlor, norea and benthiocarb caused slight contact injury (Ryang, 1971) (Table 1).

Crop damage of CNP, nitrofen, TOPE, benthiocarb and butachlor did not necessarily increase in proportion to the increase in application dosage, and temperature varied (Ryang, 1973a).

In contrast these chemicals, alachlor, diuron, chlorpropam, terbutryn, linuron and the other chemicals caused little crop damage on silty clay soils high in organic matter at recommended rates each, while on sandy loam soils low in organic matter, severe crop damage was caused as the application dosages and rainfalls increased regardless of the depth of seed cover (Ryang, 1973a).

Behavior in soils. When applied in November, the herbicidal longevity of butachlor, TOPE, linuron and alachlor persisted for 120 to 160 days to be found the longest, and those of simazine, benthiocarb, nitrofen and CNP persisted for 100 to 110 days to be found quite long, and those of PCP and 2,4-D persisted for about 70–80 days to be found rather short, while those of paraquat and glyphosate was found the shortest, and

Table 1. Weeding effect and crop injury according to various conditions.

Chemicals		Application rate (kg a.i./ha)	Leaching grade in soil		Difference of weeding effect (1–5)*		Weeding effect by application time (1–5)*			Test on tolerance of barley (SL) (1–5)**			Crop injury (1–5)** Siol texture		Crop injury (1–5)** Depth of seed covering	
			SiC	SL	SiC	SL	Pre-emer. A.a.	2 LSG A.a	3–4 LSG A.a	SA	RZ	FA (2-3LSG)	SiC	SL	SiC (1.5 cm)	SL (3–5 cm)
Nitrofen	50WP	1.5	nar	nar	4	5	5	3	1	2	1	2	1	2	1.5	2.5
CNP	20EC	1.5	,,	,,	4	5	5	3	1	1	1	2	1	1	1	1.5
TOPE	25EC	2.5	,,	,,	5	5	5	5	1	1	2	3	1	1	1	1
Butachlor	60EC	1.5	,,	mid	5	5	5	5	1	1	2	1	1	2	1	1.5
Alachlor	48EC	1.5	mid	wide	5	5	5	5	1	2	4	1	2	4	2	5
Diuron	78.5WP	0.8	nar	,,	4	5	5–4	5	4	2	3	3	2	3	2	3
Linuron	50WP	0.75	,,	mid	4	5	5–4	4	3	2	1	4	1	2	1	2.5
Chlorpropham	45.8EC	0.8	,,	wide	5	5	5	—	—	2	4	2	1	3	1	3
Swep	40WP	4.0	,,	mid	4	5	5	—	—	1	2	3	1	2	1	2
Benthiocarb	7G	1.5	,,	nar	5	5	5	4	2	1	2	1	1	1	1	1.5
Simazine	50WP	0.5	,,	wide	5	5	5	4	3	2	4	1	1	3	1	3
Terbutryn	50WP	1.5	,,	mid	5	5	5	5	4	1.5	—	3	1	3	1	3
Simetryne	50WP	0.5	,,	nar	3	3	3	4	2	1	2	3	1	1.5	1	1.5
PCP	86WP	10.0	,,	mid	3	4	3	1	1	1	2	3	1	2	—	—
Benthiocarb +simtryne	7/ 1.5G	2.1/ 0.45	,,	nar	5	5	5	4	2	1	2	—	1	2	—	—
2,4-D	40EC	0.28	mid	wide	2	3	3	3	2	—	—	—	—	—	—	—
Paraquat	24.5EC	0.4fb 2.0	nar	nar	—	—	1	5	5	1	1	5	1	1	—	—
Glyphosate	36EC	2.0fb 2.0	,,	,,	—	—	1	5	5	1	1	5	1	1	—	—

mid: middle, nar: narrow, SiC: silty clay soil, SL: sandy loam soil, A.a.: *Alopecurs aequalis*, LSG: leaf stage.
* Weeding effect scale: 1, no effect; 5, all weeds killed.
** Injury rating: 1, no toxicity; 5, all plants completely killed.
SA: soil surface application, RZ: root zone application, FA: folliage appication.

Table 2. Weeding effect, initial crop injury and yields.

Chemicals		Application rate (kg a.i./ha)	App. time	Sandy loam soil				Silty clay soil			
				Initial crop injury (1–5)*	Weeding effect (1–5)**		Yield index (%)	Initial crop injury (1–5)*	Weeding effect (1–5)**		Yield index (%)
					G.	B.			G.	B.	
Weedy check		—	—	1	1	1	72.6	1	1	1	74.1
Hand weeding		—	—	1	4	4	100	1	4	4	100
Nitrofen	50WP	1.5	2–4DAS	2	5	3	95	2	4	3	98
CNP	20EC	1.5	”	1.5	4	3	96	1.5	4	3	97
TOPE	25EC	3.75	”	1	5	4	97	1.5	4	3	100
Butachlor	60EC	1.5	”	1.5	5	3	98	1.5	5	3	100
Butachlor	6G	1.8	”	1.5	5	3	99	1.5	5	3	100
Alachlor	48EC	1.5	”	4	5	3	65	2	5	3	90
Benthiocarb	50EC	1.5	”	1	5	3	97	1	5	3	100
Chlorpropham	45.8EC	0.687	”	3	4	3	75	2	4	3	95
Linuron	50WP	0.75	”	3	4	5	93	1.5	3	5	94
Benthiocarb+simetryne	7/1.5G	2.1/0.45	”	2	5	4	95	1.5	5	4	100
Simazine	50WP	0.5	”	2.5	5	4	85	1.5	4	5	96
Butachlor	60EC	1.5	2DAS fb								
fb 2,4-D	40EC	fb 0.28	140DAS	1.5	5	5	98	1.5	5	5	99
Paraquat	24.5EC	0.4	4DBS fb								
fb butachlor	60EC	fb 2	2DAS	1.5	5	4	97	1.5	5	3	98
Glyphosate	36EC	2									
fb butachlor	60EC	fb 2	”	1.5	5	5	97	1.5	5	3	98
Terbutryn	50WP	1.5	0–4 DAS	2	5	4	94	1.5	5	5	98

G.: grasses, B.: broadleaves, DAS: days after seeding, DBS: days before seeding.
* Injury rating: 1, no toxicity; 5, all plants completely killed.
** Weeding effect rating: 1, no effect; 5, all weeds killed.

they became inactivated immediately after the application (Ryang, 1973b; 1974a).

The leaching ranges of CNP, nitrofen, benthiocarb, PCP, and butachlor were found narrow, and relatively little difference in leaching ranges was observed regardless of soil textures, while those of 2,4-D, alachlor, diuron, chlorpropham and simazine varied considerably depending on soil texture (Ryang, 1973b; 1974a).

Field experiments. As shown in the Table 2, it was safe to apply alachlor, chlorpropham, diuron, simazine and terbutryn to barley in silty clay soils, high in adsorption capacity, but it was almost impossible to apply them in sandy loam soils, low in adsorption capacity because of severe crop damage and yield reduction (Ryang, 1970; 1972)

Therefore, even if they have a wide weeding spectrum, the chemicals whose leaching range varied considerably as soil textures and rainfalls varied must be strictly limited to only a small acreage in case the adsorption capacity to soils is low as in Korea (Ryang, 1974b).

On the contrary, butachlor, benthiocarb, nitrofen, CNP and PCP (less effective to *A. aequalis*) caused relatively little crop damage and yield reduction regardless of soil texture, and thus can be applied widely to barley fields of Korea, even if some broadleaves show tolerance to these chemicals.

For several reasons butachlor is most widely used in barley in Korea. These include 1) excellent control of *A. aequalis* as well as some broadleaves, 2) enough residual activity with good crop tolerance, 3) application convenience of granule formulation with equal weeding effect as emulsion under upland field conditions.

However, in some double cropping barley at paddy after rice in the southern area *A. aequalis* reaches up to 3 to 4 leaf stage at the time of barley seeding, and besides a broadcast seeding without plow is mostly employed. In this case it was very effective to control the top-growth weeds first with paraquat or glyphosate before seeding, and then to apply pre-emergence treatment herbicides such as butachlor, to control newly emerged weeds.

Also, in case quite a number of broadleaves are still remained after herbicide treatments in upland barley fields, it was very effective with no yield reduction to apply 2,4-D amine at 280 g a.i./ha as post-emergence treatments at the fully tillered stage of barley when 4–8 in. high, prior to boot stage in spring.

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Effects of Cultivation and Herbicide Usage in Successive Wheat Crops

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Abstract. A field experiment was conducted in N.E. Victoria, Australia to study the effects of cultivation and repeated use of herbicides, di-allate, alachlor, paraquat and amitrole-T (amitrol+ammonium thiocyanate), on the weed flora and grain yields of five successive wheat crops after a pasture ley.

Cultivation resulted in good weed control in the first year crop, but with successive cropping, weed populations increased from year to year, due mainly to an increase in annual ryegrass (*Lolium rigidum* Gaud.) Ryegrass was also present with other weeds on direct-drilled (uncultivated) plots.

Wheat grain yields were negatively correlated with weed density and the repeated herbicide applications caused no apparent crop damage.

Introduction

It is both environmentally and agronomically important to know the possible consequences of long-term herbicide usage in any cropping system. Approximately 35% of the wheat area in Victoria, Australia is sprayed annually for weed control. In 1974 this would have amounted to 400,000 hectares of treated crop.

This paper reports a study of the changes in weed flora under five successive wheat crops following a pasture ley. The effects of cultivation and repeated use of herbicides, on changes in species composition of the weed flora, resultant effects on grain yield, and possible long-term reductions in weed populations were examined.

Experimental Details

Site. The experiment was conducted from 1969–1973 at the Rutherglen Research Station in North-Eastern Victoria, Australia; longitude 146°30′ and latitude 36°05′.

Six years of annual pasture preceeded the five successive wheat crops. Total soil nitrogen in the 0 to 20 cm layer was 0.145 percent w/w, just prior to sowing.

The soil type was Rutherglen loam (Poutsma and Skene, 1961), Dr 3.13 (Northcote, 1965), which is transitional between a red-brown earth and a yellow podsol.

Five treatments were sown in a randomized block with eight replicates: Conventionally cultivated (conv. cult.), unsprayed; Conv. cult. plus di-allate; Conv. cult. plus alachlor; Not cultivated, sprayed with paraquat; Not cultivated, sprayed with amitrole-T.

Di-allate and alachlor were applied at 1.12 kg/ha each year to a finely cultivated, level seed bed immediately after sowing of the wheat. One pass with a set of heavy harrows was used to incorporate di-allate; alachlor was not incorporated. The control treatment was cultivated similarly to the di-allate and alachlor plots and sown without herbicide application.

Paraquat and amitrole-T were applied to uncultivated soil at rates of 0.28 kg/ha (of the ion) and 1.12 kg/ha respectively, in order to kill weeds just prior to direct-drilling of wheat. In all years both cultivated and direct-drilled plots were sown with a rigid-hoe Shearer drill. Wheat cv Olympic was seeded at 85 kg/ha and fertilised with 15 kg/ha of phosphorus (applied as superphosphate).

The herbicide treatments were applied to the first four crops only. In the fifth year the whole experimental site was uniformly cultivated and wheat with superphosphate, but no herbicide treatment was sown on all plots to investigate any carryover effects from the previous applications.

Measurements. Each year, the frequency with which weed species occurred was measured using an inclined point quadrat. Fifty points, in five groups of ten, which were permanent throughout the experiment, were used per plot. In addition annual ryegrass populations were counted in ten quadrats (each 0.4 m^2) randomly selected per plot.

All plots were harvested for grain yield using a commercial harvester.

In 1969, 1970 and 1971, areas of the experiment were affected by eyespot lodging, caused by the fungus *Cercosporella herpotrichoides*, and the extent of this was visually assessed at maturity of the crop by two independent observers.

RESULTS

Weed populations (Fig. 1). Cultivation resulted in extremely good weed control in the first-year crop; weed populations were very low and consisted mainly of silver grass [*Vulpia bromoides* (L.)] and *Poa annua* L. plus scattered plants of annual ryegrass (Table 1). However, with successive cropping, weed populations increased from year to year due mainly to an increase in annual ryegrass. This effect was greatest on the unsprayed, cultivated control treatment. Applications of di-allate were very effective in reducing ryegrass infestations and smaller reductions were obtained with alachlor. The changes in annual ryegrass populations on direct-drilled plots were similar to those

Table 1. Ryegrass densities under crop 1969–1973.

Treatment	Ryegrass density plants/m^2				
	1969	1970	1971	1972	1973
Conv. cultivated	12a*	101a	108a	396a	516b
Conv. cult. + di-allate	1b	12c	16c	60c	338c
Conv. cult. + alachlor	1b	21c	18c	86c	442bc
Direct-drilled + paraquat	18a	50b	32b	199b	738a
Direct-drilled + amitrole-T	15a	36bc	38b	144b	696a

* Letters in the one column with the same postscript letters do not differ significantly ($P>0.05$).

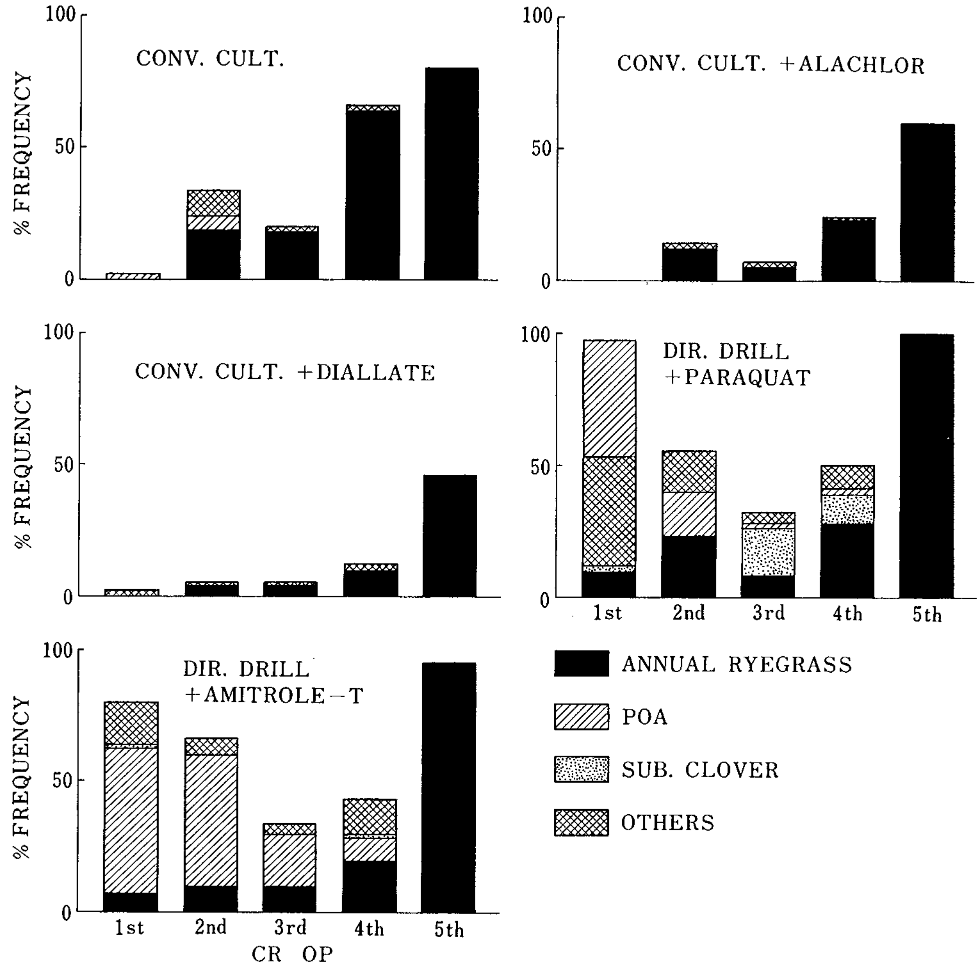

Fig. 1. Composition of weed flora under crops, 1969–73.

under cultivation, but approximately equal proportions of other weeds were also present.

Carryover effects of the various treatments in the fifth year crop were not large and there were marked increases in annual ryegrass populations on all plots.

Grain yield. Grain yield was negatively correlated with weed incidence, as weed populations increased, grain yields decreased. Yields of the control treatment were 2.99 t/ha, 2.16 t/ha, 4.13 t/ha and 1.77 t/ha in 1969, 1970, 1971 and 1972 respectively (Figs. 2 and 3).

In the first crop weeds were negligible and the resultant yields from all cultivated treatments were similar. High weed populations and well above average rainfall, in 1973 resulted in extremely poor crop growth and gain yields were not obtained for that year.

Incidence of lodging. In 1970 and 1971, lodging of wheat tillers due to *Cercosporella herpotrichoides* was greatest on the unsprayed, cultivated treatment ($P<0.05$). Direct-drilled wheat did not lodge.

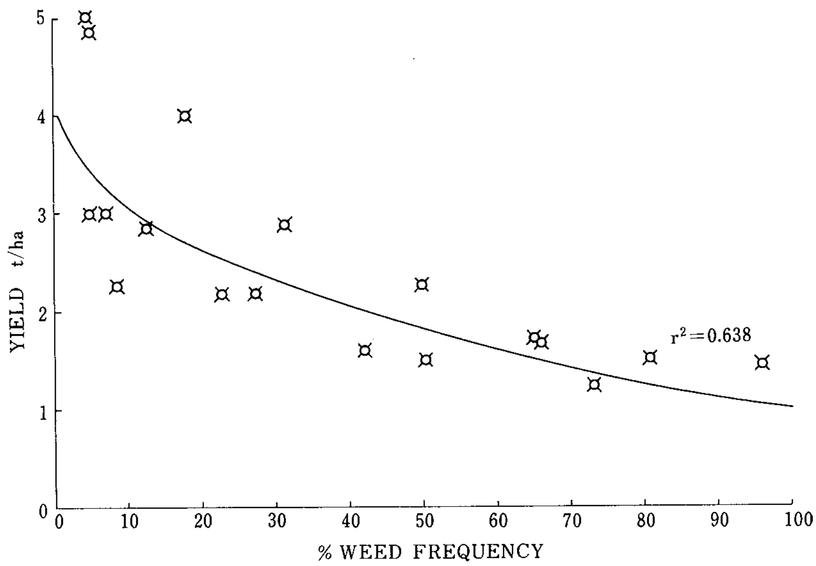

Fig. 2. Relationships of grain yield to percentage weed frequency, 1969–1972.

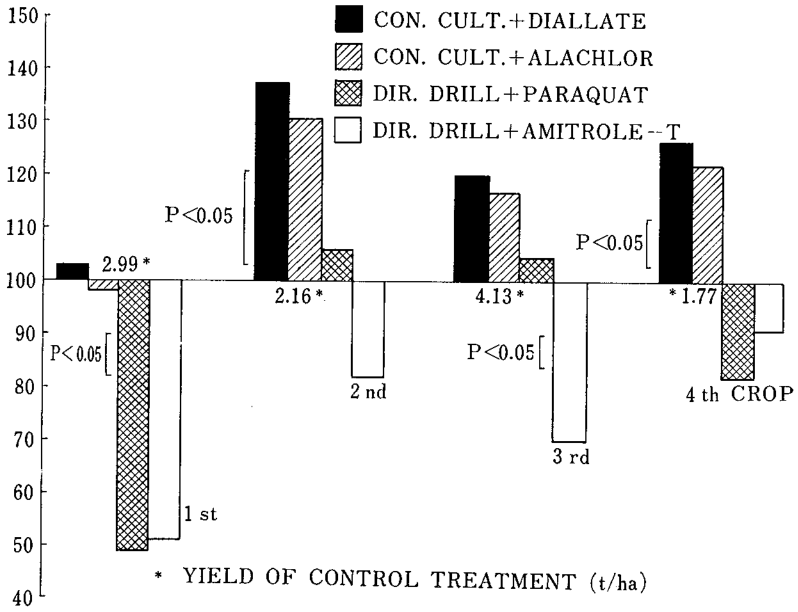

Fig. 3. Wheat grain yield as percentage of unsprayed control (100%).

Discussion

Populations of weeds changed in both density and botanical composition under the particular cropping program in this experiment. Weed numbers which emerged on cultivated plots increased from year to year resulting from the rapid build-up of annual ryegrass. This multiplication of ryegrass with successive cropping is a reflection of the copious seeding ability of the species (McGowan, 1967). Changes in annual ryegrass populations on the two direct-drilled treatments were similar but were accompanied by a decline in the populations of other weeds, mainly *Poa annua* and subterranean clover.

Weed populations were lowest where cultivation was followed by application of di-allate or alachlor, but despite repeated use of these herbicides sufficient ryegrass plants survived to increase the populations from year to year and when spraying was discontinued in 1973, there was a resultant ryegrass 'explosion'.

Direct-drilling generally resulted in lower yields than cultivation, but in other experiments at Rutherglen similar yields were obtained from the two systems (Reeves and Ellington, 1974). In the present experiment the increased incidence of weeds under direct-drilling compared to cultivation possibly caused the lower yields.

Gross crop damage from any possible build-up of herbicide residues was not apparent. Year to year persistence was not anticipated as tri-allate, a closely related compound to di-allate, had no effect on barley yields in Britain when applied at higher rates than in this experiment for a period of six years (Fryer and Kirkland, 1970). Similarly, Freed and Furtick (1961) in the U.S.A. showed that amitrole at 1–2 kg/ha persisted for only 2–6 months in a range of soils, whilst paraquat (Burns and Audus, 1970) and alachlor (Sarfaty 1968) also had short persistences in soil at similar rates to those used in this experiment.

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Performance of Difenzoquat (AC-84777) for Post-emergence Wild Oat Control in Wheat in Southern Australia

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Abstract. A field trial is reported which demonstrates the general performance of difenzoquat (1,2-dimethyl-3,5-diphenyl-1 H-pyrazolium methyl sulphate) for wild oat (*Avena fatua*) control in wheat in southern Australia. The results demonstrate the importance of removing wild oats during the early stages of the crop and in this respect difenzoquat 0.75 kg a.i./ha gave mean yield increases of 28.8% when applied at the 3 leaf stage of wheat compared to 16.9% at the mid-tillering stage. This was so despite superior wild oat control at the later timing.

Temporary crop chlorosis and stunting was observed following difenzoquat application of 0.75 and 1.5 kg a.i./ha. This damage was within acceptable limits at 0.75 kg. However, the wild oat infestation was moderate to high (>200 pl/m^2) and the crop very vigorous, and this would most probably have prevented the damage from being expressed in the final yield. Other work is mentioned which showed differences in varietal susceptible of wheat and the relatively greater tolerance of barley to difenzoquat. Finally, evidence is presented which shows that difenzoquat activity increases with the concentration of the wetting agent, in this case Teric N8.

Introduction

Chemical control of wild oats in Australia is largely dependent on di-allate and tri-allate. Post-emergence control has great farmer appeal but to date barban is the only registered chemical. Difenzoquat formally coded AC-84777, was reported by Shafter (1974) as effectively controlling several species of wild oat, including *Avena fatua* and *A. ludoviciana* the predominant species in Australia, at growth stages ranging from 2 leaf to early stem elongation. Under ideal growing conditions and good crop competition, 0.6 kg a.i./ha was sufficient to control 3–4 leaf stage wild oats, whereas 0.9 to 1.2 kg a.i./ha was required with late applications or during cold weather. Spring wheat was damaged by difenzoquat in some of Shafer's trials, there being marked differences in varietal susceptibility. Barley was reportedly more tolerant. These findings, although based largely on the northern hemisphere experience, did include some Australian work.

Materials and Methods

A number of field trials were conducted in 1974 to evaluate difenzoquat under Australian conditions. One of these trials has been selected as representative of the general findings.

The trial was conducted in wheat (var. Olympic) in the Wimmera district of Victoria. *Avena fatua*, the dominant species in southern Australia was the target. The site was virtually a pure wild oat stand and the infestation was moderate to heavy (>200 pl/m²). Chemical treatments were difenzoquat 0.75 and 1.5 kg a.i./ha plus Teric N8 0.3 and 0.5% a.i. and barban 0.14 kg a.i./ha. Two times of application were evaluated, 1½ and 3 leaf stage of the wild oats. The wheat at these times was at the 3 leaf and mid-tillering stages respectively. The trial was a randomised block design with 4 replications and plot size of 2.5×25 m. It was sprayed with an Oxford Precision Sprayer mounted on bicycle wheels and operated at a speed of 4 kph, a volume of 100 l/ha and pressure of 190 kPA using 'Spraying Systems' T-jet size 730077 nozzles placed 46 cm above the ground.

Wild oat counts were made in the controls on both spraying dates. Assessments of wild oat panicle cover, which included panicles both above and below the canopy, and crop vigour were made thereafter using visual ratings on a 0 to 9 linear scale where 0=no panicles (i.e. complete control) and no crop vigour (i.e. crop death) and 9= maximum panicle cover (i.e. no control) and maximum crop vigour, the word maximum referring to the plot containing the most wild oat panicles and the plot possessing the most crop vigour. The scores were scaled Y=1.111X and transformed Y=Arcsine $\sqrt{x/10}$ for statistical analysis. The actual scores on the 0 to 9 scale have been converted to percentages for ease of interpretation. Both percentages and transformed data are presented.

Results and Discussion

The wild oat population increased from 156 pl/m² at T1 to 240 pl/m² at T2, an increase of 62% during the 4 week period between the 2 spraying dates. It is not surprising therefore that wild oat control was better at T2 with virtually complete control being obtained with all difenzoquat T2 treatments (Table 1). The T1 treatments of difenzoquat presumably controlled most of the wild oats which were present at the time of application, but as the compound does not possess soil activity subsequent germinations were not controlled. However, the majority of these late germinations apparently did not survive as the wild oat panicle cover scores for T1 indicate. If these later germinated wild oats had survived to produce panicles, the scores at T1 would almost certainly have been higher (3 to 4 cf. 1.4 to 2.5). The crop was very vigorous and dense by normal Victorian standards and presumably strong crop competition prevented the late germinations from becoming established.

Despite superior wild oat control at T2, the T1 difenzoquat treatments produced the better yield responses, in fact, every T1 outyielded the T2 treatments. Average yield increases for T1 and T2 treatments were 28.8 and 16.9% respectively. The highest grain yield, 3,601 kg/ha, was obtained with difenzoquat 1.5 kg a.i./ha+Teric N8 0.5% a.i. This compared with 2,651 kg/ha for control (Table 1).

Temporary crop chlorosis and some stunting was evident in the early growth stage with some difenzoquat treatments (Table 1). This was not very evident at 0.75

Table 1. Performance data for difenzoquat showing the effect on the wheat, the degree of wild oat control and the resultant yield responses.

Treatment (kg a.i./ha)					Crop vigour score (%) 8 wks after T1; 4 wks after T2	Wild oat panicle cover score (%) 15 wks after T1; 11 wks after T2	Grain yield (kg/ha)
Difenzoquat	0.75 +	Teric N8	0.3% a.i.	T1	99 (87.4)*	26 (31.7)	3,241
,,	1.5	,,	0.3 ,,	T1	89 (73.2)	17 (24.5)	3,429
,,	0.75	,,	0.5 ,,	T1	90 (74.3)	17 (24.2)	3,391
,,	1.5	,,	0.5 ,,	T1	84 (71.0)	15 (19.8)	3,601
,,	0.75	,,	0.3 ,,	T2	90 (74.3)	11 (18.1)	3,192
,,	1.5	,,	0.3 ,,	T2	72 (58.3)	0 (0)	3,149
,,	0.75	,,	0.5 ,,	T2	87 (71.9)	5 (7.3)	3,015
,,	1.5	,,	0.5 ,,	T2	76 (61.4)	4 (4.9)	3,042
Barban	0.14			T1	93 (79.1)	27 (31.2)	3,112
Control					100 (89.8)	100 (89.8)	2,651
LSD	5%				(9.9)	(9.3)	397
	1%				(13.2)	(12.4)	532

* Figures in brackets are transformed data.
T1 = 3 leaf stage wheat; 1½ leaf wild oats. T2 = mid-tillering wheat; 3 leaf wild oats.
Wild oat population at T1 = 156 pl/m²; T2 = 240 pl/m².

kg a.i./ha but was quite noticeable at 1.5 kg a.i./ha which, incidently, is double the proposed commercial rate for Australia. The scores in Table 1 show the T2 treatments as being more phytotoxic but the time of application must be born in mind when interpreting these data.

The trial was inspected at earlier growth stages and crop damage at T1 was evident but again only the high rate was obvious. Despite this crop damage, the yield responses were very encouraging. However, the site had a reasonably heavy wild oat infestation, but with low infestations this damage may have resulted in yield depression. Evidence from glasshouse studies (unpublished) has indicated certain wheat varieties as being more susceptible to difenzoquat damage than others. Olympic, the variety in the present trial, was moderately susceptible, while Halberd, another common commercial variety in southern Australia was one of the most sucseptible. Barley was more tolerant than wheat.

Difenzoquat is very dependent on the presence of a wetting agent for activity. Previous work had shown Teric N8 as a suitable surfactant for use with the chemical. In the present study, there was evidence in the T1 application for improved difenzoquat performance as the concentration of Teric N8 was increased from 0.3 to 0.5% a.i. However, although not really apparent here, evidence from other trials has indicated that the degree of crop damage also increases with the wetter concentration.

The trial shows the importance of removing wild oat competition during the early stages of crop growth. However in Australia, farmers like to see paddocks which are free of wild oat panicles after having spent money on chemical control. In this respect, later applications (3 leaf stage wild oats), while they may not give the optimum yield response, would likely appeal to farmers more than early applications. Of course, very late applications are likely to become less effective against wild oats if for no other reason the crop becomes a shield against spray penetration to the target species.

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Chemical Weed Control in a Ratoon Cropping System for Sorghum

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Abstract. Growing sorghum [*Sorghum bicolor* (L.) Moench] in ratoon systems leads to weed buildup in the succeeding non-cultivated ratoon crops. Standard preemergence herbicides used in single-crop sorghum are not adequate alone in ratoon systems. Paraquat [1, 1′ dimethyl-4, 4′-bipyridilium] applied over the fresh stubble the first 5 days after stover harvest provided improved weed control and higher stover yields. Paraquat at 0.28 kg/ha was as effective as 0.58 kg/ha which caused some crop injury. Applying paraquat more than 5 days after stover harvest injured or killed young sorghum tillers and led to poor ratoon stands and yields. Coupling of preemergence and contact herbicides is considered necessary for weed control in non-cultivated ratoon sorghum.

Introductin

Sorghum is usually grown as an annual, but it can be grown perennially in the tropics with year-round growing conditions. In sorghum, following harvest of the original sown crop (called the plant crop), the stubble produces new tillers which grow to form the ratoon crop. Sorghum is not commonly ratooned, but ratooning of sorghum is receiving increased attention as a cropping system (Plucknett *et al.*, 1970, 1971; Escalada and Plucknett, 1975a, 1975b).

Ratoon cropping minimizes plowing-planting operations after harvest, reducing costs and field time. However, the system may lead to build-up of insects, diseases and weeds which limit yields and number of ratoon crops (Plucknett *et al.*, 1970, 1971). Weeds in ratoon systems are especially severe, for certain perennials or hardy annuals can escape and build up in the sorghum rows, where they cause difficulty in succeeding ratoons.

Suitable herbicides for annual sorghum crops are numerous, including: atrazine [2-chloro-4-(ethylamino)-4-(isopropylamino)-*s*-triazine]; propazine [2-chloro-4,6-bis (isopropylamino)-*s*-triazine]; propachlor [2-chloro-*N*-isopropylacetanilide]; norea [3-(hexahydro-4,7-methanoindan-5-yl)-1,1-dimethylurea]; linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea]; and 2,4-D (2,4-dichlorophenoxy acetic acid) (Burnside *et al.*, 1972; Chamberlain *et al.*, 1972; Wicks, 1966; Phillips, 1970; Nieto, 1970; Chenault *et al.*, 1970). The authors are not aware of weed control research for ratoon sorghum; this work was initiated to find a suitable weed control system for ratoon sorghum in Hawaii.

Methods and Materials

Two previous experiments confirmed that atrazine, propachlor, and propazine were about equally effective for weed control in sorghum plant crops, although atrazine caused some stover yield reduction at higher rates. Therefore, experiments were conducted to find herbicides for ratoon crops which followed plant crops in which these herbicides had been used. The experiments were: 1) comparative effects of atrazine, propachlor, and propazine with and without paraquat on subsequent ratoon crops, and 2) effects of paraquat, atrazine, and diuron [*N'*-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea] on sorghum treated with atrazine in the plant crop.

Experiments were conducted on a Halii soil series (typic gibbsihumox, pH 4.9, organic matter 4–6%) at the Hawaii Agricultural Experiment Station on Kauai. Annual rainfall (200–250 cm) is well distributed throughout the year, so the crops were not irrigated.

Fertilizers were broadcast on the soil and worked in at the final harrowing. Sorghum (cv. savannah) was drilled at 10 kg/ha at 3–5 cm depth with a corn planter, in 4 rows spaced 50 cm apart.

The experimental design was a randomized complete block with 3 replications. Herbicides were applied before weed emergence in plant crops and at appropriate schedules after stover harvest in ratoon crops. Two center rows were harvested for yield; stover was cut 5–7 cm above the ground. Subjective ratings of weed control and sorghum stover dry matter yields were main evaluation criteria for herbicide performance. Weed control, growth and stand reduction ratings (0=no control, no growth or stand reduction; 100=complete control or stand reduction) of sorghum were based on visual observations; grain yields were not recorded because of extensive bird damage. Treatment effects on stover dry matter yields were analyzed statistically by analysis of variance and Duncan's multiple range test.

Results and Discussion

Effects of atrazine, propazine, and propachlor with and without Paraquat on ratoon crops. Atrazine, propazine and propachlor were about equally effective in weed control in the plant crop (weed ratings and crop growth reduction data not shown). These herbicides were then used in the succeeding ratoon crops at the same rates used in the plant crop (Table 1). In addition, paraquat applications (0.56 kg/ha) were superimposed on half of each plot, including the untreated control, to control those weeds which escaped the preemergence herbicide treatments.

Adding paraquat to initial atrazine, propazine and propachlor treatments greatly improved weed control and generally resulted in higher yields than treatments without paraquat (Table 1). Weed populations were greater in ratoons 2 and 3 than in the plant crop and ratoon 1. Weed buildup with time was attributed to poor post-emergence activity of atrazine, propazine, and propachlor.

The dominant weed in the plant crop was *Eleusine indica* (L.) Gaertn. In the

Table 1. Effects of herbicide treatments on sorghum stover yield (dry matter, MT/ha); plant crop vs. ratoon crops, Kauai, 1971–1972*.

Herbicide	Rate applied (kg/ha)	Paraquat, 0.58 kg/ha applied to ratoon	Plant crop[a] (Jan.-June)	Ratoon 1 (June-Sept.)	Ratoon 2 (Sept.-Jan.)	Ratoon 3 (Jan.-May)	Mean yield of: Plant crop+ratoon crop	Mean yield of: Ratoon crop only
Atrazine	2.24	–	5.8	5.9	4.0	5.6	5.3	5.2
		+	—	9.3	4.6	7.4	6.8	7.1
	3.36	–	6.2	6.7	3.4	6.1	5.6	5.4
		+	—	8.5	4.8	7.3	6.7	6.8
	4.48	–	5.2	8.3	3.6	5.3	5.6	5.7
		+	—	7.8	4.2	7.5	6.2	6.5
Propachlor	5.60	–	6.4	6.5	4.1	4.3	5.3	5.3
		+	—	9.0	4.4	6.0	6.5	6.6
Atrazine	1.12+4.48	–	6.2	8.0	4.3	5.7	6.1	6.0
Propachlor	4.48	+	—	9.3	4.8	7.8	7.1	7.3
	2.24+3.36	–	5.4	7.6	3.9	6.7	5.9	6.0
		+	—	9.6	5.4	6.1	6.6	7.0
Propazine	2.24	–	5.6	7.1	3.4	5.4	5.3	5.1
		+	—	7.2	4.3	6.7	6.0	6.1
Control-unweeded		–	5.2	6.7	2.9	2.6	4.5	4.0
		+	—	6.5	4.2	5.4	5.5	5.3
LSD 5%				1.19	0.76	0.98		
1%				1.60	1.02	1.32		

[a] In the ratoons, half of the original plots were sprayed with paraquat (subplot=2×3 m). There were no significant differences among yields of treatments in the plant crop.

ratoons, *Digitaria sanguinalis* (L.) Scop. became the major weed problem. In the control subplots treated with paraquat only, *Borreria laevis* (Lam.) Griseb., *Euphorbia hirta* L., and *Cynodon dactylon* (L.) Pers. populations increased. When atrazine, propazine, or propachlor only were used, *C. dactylon* and *D. sanguinalis* were the dominant weeds. Propachlor alone led to a buildup of *C. dactylon, D. sanguinalis, B. laevis* and *E. hirta.*

Atrazine alone controlled broadleaf weeds quite well, but did not control grasses effectively. By ratoons 2 and 3, *D. sanguinalis* and *C. dactylon* had increased considerably in atrazine plots. Propachlor was quite effective against grasses but was relatively ineffective against broadleaf weeds. Propazine showed similar activity as atrazine. In ratoons 2 and 3, heavy populations of *D. sanguinalis* and *Cyperus rotundus* L. resulted.

Effects of atrazine, diuron, and paraquat on ratoon crops. Ratoons of a plant crop that received preemergence atrazine (2.24 kg/ha) were treated with herbicides to study their effects on weeds and sorghum yields (Table 2). A wetting agent (X-77) was added at 1% to some treatments to increase herbicide activity. Rates and times of paraquat application were also studied. When paraquat was applied within the first 5 days after harvesting of the sorghum stover, only temporary injury to sorghum resulted. However, serious damage to sorghum and significant yield reduction resulted when spraying was delayed to 14 days after harvest. Paraquat at 0.58 caused some injury to sorghum tillers; how-

Table 2. Effects of herbicides on sorghum stover yield (dry matter, MT/ha) of ratoon crops which developed from a plant crop previously treated with preemergence atrazine (2.24 kg/ha). Kauai, 1971–1972.

Herbicide	Rate (kg/ha)	Plant crop yield	Ratoon 1		Ratoon 2		Ratoon 3		Mean yield of:	
			DAH[a]	Yield[b]	DAH[a]	Yield[b]	DAH[a]	Yield[b]	Plant crop+ ratoon crop	Ratoon crop only
Paraquat	0.28	6.6	1	9.9	2	5.7[ab]	2	8.1[a]	7.6	7.9
	0.58	6.1	1	8.8	2	4.9[b]	2	7.3[ab]	6.8	7.0
	0.28	5.9	5	8.8	14	2.1[c]	—	—	5.6	5.4
	0.58	6.4	5	9.6	14	2.7[c]	—	—	6.2	6.9
Paraquat+ Atrazine	0.58+ 3.36	6.1	1	8.6	2	5.3[b]	2	6.7[bc]	6.7	6.9
Atrazine	3.36	5.6	1	9.6	2	5.2[b]	2	6.0[c]	6.6	6.9
Atrazine+WA[c]	3.36	6.1	1	10.7	2	5.6[ab]	2	7.8[ab]	7.6	8.0
Diuron[d]	1.12	5.9	1	9.8	2	5.7[ab]	2	7.5[ab]	7.3	7.7
Diuron+WA[c]	1.12	5.6	1	9.2	2	6.5	2	8.2	7.4	8.3
Control-unweeded		6.0	—	8.7	—	5.9				

[a] DAH=Days after harvest when treatments were applied.
[b] Within a column, values with different letters after them differed significantly (1% level) based on Duncan's multiple range test. There were no significant differences in yields among treatments in the plant crop and in ratoon 1. Mean yields (plant crop+ratoon crop, ratoon crop only) were not analyzed.
[c] Wetting agent, X-77, applied at 1% of solution.
[d] Rate of diuron was increased to 2.24 kg/ha in ratoons 2 and 3.

ever, a rate of 0.28 kg/ha provided satisfactory weed control with little or no persistent injury to sorghum. Atrazine plus paraquat gave no advantage over paraquat alone. Use of a wetting agent (X-77) with atrazine and diuron generally improved weed control.

As in the other experiments, there was a gradual buildup of weeds in ratoons 2 and 3. *D. sanguinalis*, *C. dactylon*, *B. laevis*, and *E. hirta* populations increased in ratoons 2 and 3.

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Herbicide and Crop Rotation Effects on the Weed Complex

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Abstract. A four-season trial was conducted using continuous maize and soybean with the continuous use, rotation or combination of various herbicides to determine weed species shifts. No weed species increased in maize treated for four seasons with atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] or the combination atrazine+alachlor [2-chloro-2′,6′-diethyl-*N*-(methoxymethyl)acetanilide]. Four seasons of alachlor allowed a 6 and 21% increase in broadleaf weeds in maize and soybeans, respectively, while maintaining excellent grass weed control. In soybeans a 21% increase in broadleaf weeds occurred after four seasons of linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea]. Linuron combined with alachlor gave the best weed control in soybeans while the rotation of herbicides was less effective. In both crops, two hand weedings for four seasons tended to reduce the weed population the following year.

Introduction

The use of preemergence herbicides in Latin America is increasing rapidly. Often claims are made that weeds are becoming resistant to herbicides when in fact an ecological shift is taking place with secondary weed problems becoming primary ones.

Horowitz *et al.* (1974) observed species shifts by applying ten herbicides in the same plots during four years. *Anagollis coerula* (Gouan.) was eliminated by substituted urea herbicides while *Convolvulus arevenis* L. tended to increase. Species which were only partially controlled by the initial applications persisted even after repeated applications.

Using a rotation of cotton, peanuts and maize and various intensities of chemical and mechanical weed control measures, Hauser *et al.* (1974) obtained a great reduction in *Cyperus esculentus* L. infestations. *Digitaria sanguinalis* (L.) Scop. and *Xanthium pensylvanicum* Wallr. populations also decreased, while *Euphorbia maculata* L. increased. All treatments significantly reduced the total number of weeds after three years.

In a similar study, Weber *et al.* (1974) found that after three seasons of trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) *D. sanguinalis* and *Dactyloctenium aegyptium* (L.) Richter were controlled, but *C. esculentus* had completely infested the area. This shows how rapidly dramatic species shifts can occur.

Another aspect of effectively controlling weeds during many seasons is the overall weed population reductions which should result. Roberts and Dawkings (1967), in a 6-year study observed 22, 30 and 36% decreases in the number of viable weed seeds in the upper 23 cm of the soil with 0, 2 or 4 tillage operations per year, respectively. This indicates that by preventing weed seed production, weed infestations can be greatly reduced over time. However, Weber *et al.* (1974) found the total weed density unaffected after applying prometryne and trifluralin for three years without planting a crop.

No such information has been reported for tropical Latni America. Therefore, a four season trial was designed to study the weed species shifts which occur with the continued use, rotation or combination of herbicides in maize and soybeans, and to compare the effects of hand weedings and chemical control on the weed population after four seasons of intensive control.

Materials and Methods

Atrazine (2 kg/ha) and alachlor (2.5 kg/ha) were applied repeatedly, in combination (half rate of each) or in rotation, during four consecutive seasons in maize (a while brachytic line). Linuron (1.5 kg/ha) and alachlor (2.5 kg/ha) were similarly applied in soybeans (var. ICA-Lily). The plantings and applications were made in a clay soil with 3.9% O.M. and a pH of 7.2. A split-plot design with four replications was used where the crop was the main plot and the weed control treatment the split-plot. After each harvest, the entire area was tilled and the plots relocated in exactly the same position as in the first planting.

Herbicides were applied with a CO_2 plot sprayer equipped with four 8003 Teejet nozzles at 2.1 kg/cm^2 pressure in 215 l/ha of water. Percentage weed cover by species was determined 30 and 60 days after planting with the line intercept method (Phillips, 1959). The principal grasses were *Leptochloa filiformis* (Lam.) Beauv., *Echinochloa colonum* (L.) Link, *Eleusine indica* (L.) Gaertn. and *D. sanguinalis* and the broadleaves were *Amaranthus dubius* Mart., *Portulaca oleracea* L., *Ipomoea tiliacea* (Willd.) Choisy, *Euphorbia hypericifolia* L. and *Cucumis melo* L. All except *Ipomoea* were broadcast seeded at the time of the first planting only. Percentage weed cover was also determined during the fifth season when neither crops were sown nor herbicides applied after plowing and double-disking in order to determine the long-term effects of the control measures on the weed population.

Results and Discussion

The consecutive use of atrazine for four seasons gave excellent weed control without reducing maize yields (Fig. 1 and Table 1). Alachlor controlled all the grasses but a trend toward a buildup of broadleaf species was observed, especially of *I. tiliacea* and *C. melo*. Both the combination or rotation of the two herbicides were effective in controlling nearly all the weeds and not allowing any resistant species buldups.

Chemical weed control was less effective in soybeans after the first season (Fig. 1). Linuron permitted both broadleaves (primarily *E. hypericifolia*) and grasses to increase while alachlor maintained excellent grass control but allowed buildups of *I. tiliacea* and *C. melo*. The combination of linuron and alachlor during four seasons gave

Table 1. Maize and soybean grain yields during four seasons with the continued use, combination, or rotation of herbicides and the percent weed cover during the fifth season without a crop.

Crop	Herbicide	Comparative yield* Season 1st	2nd	3rd	4th	X̄	Weed cover** 5th season B.L. (%)	Gr. (%)
Maize	Atrazine	85	83	105	103	94	38	16
Maize	Alachlor	103	100	95	101	100	87	1
Maize	Atraz+Alac	94	109	113	99	104	64	1
Maize	Atr/Alac/Atr/Alac	87	84	99	99	92	73	8
Maize	Weedy Check	75	53	74	60	66	81	5
Soybeans	Linuron	89	97	85	84	89	67	12
Soybeans	Alachlor	88	87	107	93	94	72	1
Soybeans	Lin+Alac	85	144	109	88	106	83	3
Soybeans	Lin/Alac/Lin/Alac	99	139	79	83	100	77	1
Soybeans	Weedy Check	76	17	36	43	43	65	15

* Yield expressed as a percentage of hand-weeded plots.
** Sixty days after preparing the land.

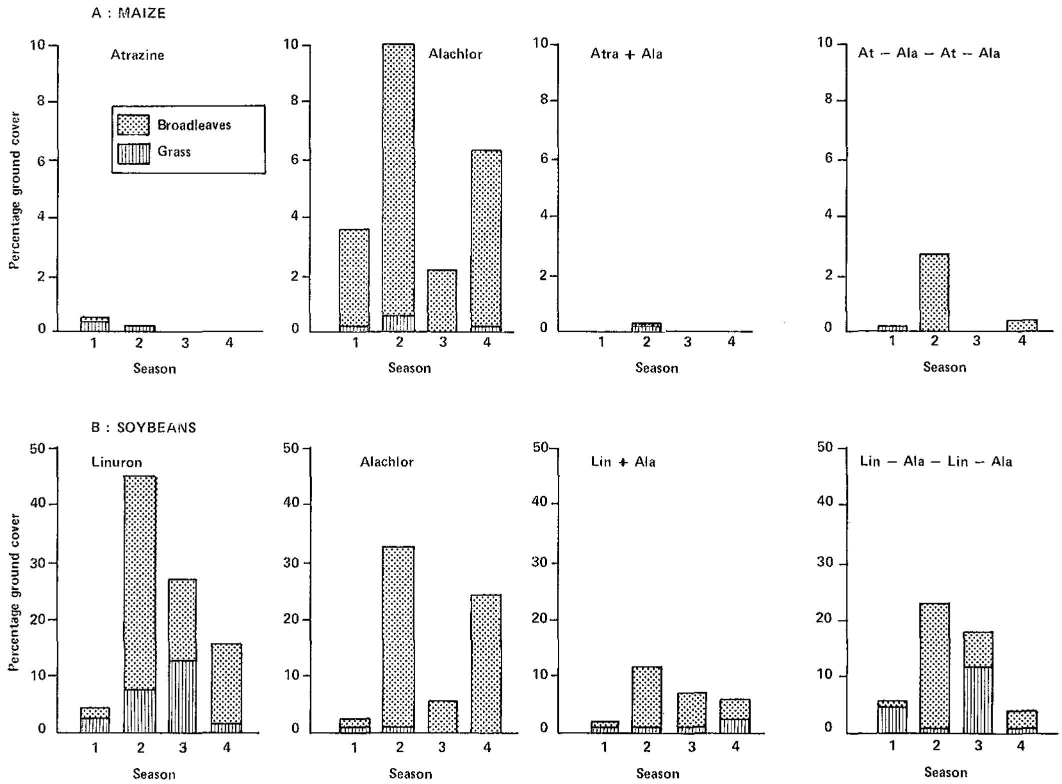

Fig. 1. Effect of the continued use, combination or rotation of atrazine and alachlor in maize and linuron and alachlor in soybeans on the percentage of cover by grass and broadleaf weeds 60 days after planting (A) maize and (B) soybeans during four seasons.

the best weed control in soybeans. Rotating these products allowed higher grass coverage in the seasons linuron was applied and higher broadleaf coverage in those with alachlor. Both mixing or rotating linuron and alachlor prevented a buildup of resistant species and tended to increase soybean yields more than did the continuous use of either product (Table 1). Soybean yields were not affected by apparently high weed infestations probably due to the creeping nature of the resistant broadleaves which made them poor competitors for light.

A relationship was found between the degree of weed cover and the crop species when herbicides are used. Comparing the effectiveness of alachlor in maize and soybeans, one observes that the first season's broadleaf coverage results are very similar but in subsequent seasons alachlor allowed three times more broadleaf coverage in soybeans than in maize. Thus, the buildup of resistant species is crop dependent.

Two hand weedings 30 and 60 days after planting for four seasons reduced both grass and broadleaf coverage in maize but only the broadleaf coverage in soybeans (Fig. 2). Hand weedings were consistently more effective in maize than in soybeans. Thus the effectiveness and long term effects of manual or mechanical control are also crop dependent. Considerable seasonal variation in the weed coverage occurred in the non-weeded plots, principally due to weather fluctuations. After the first season, there was more total weed coverage in the non-weeded soybeans than in non-weeded maize and proportionately more grasses in soybeans and more broadleaves in maize. Thus, for the weed species in this study, monocot weeds adapted better to the dicot crop and vice versa.

Observations made during the fifth season, when no crops were planted or herbicides applied after land preparation, show that there was little beneficial effect of ex-

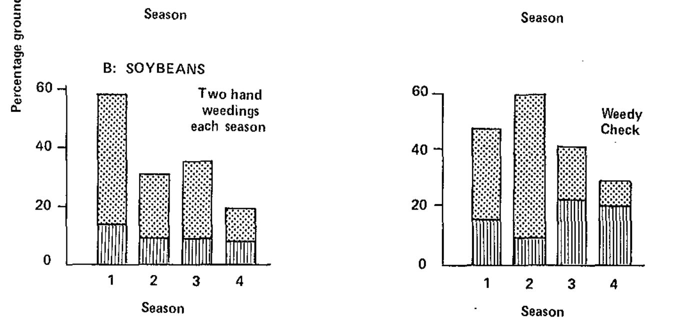

Fig. 2. Effect of two hand weedings and no weedings on the percentage of cover by grass and broadleaf weeds 30 days after planting (A) maize and (B) soybeans during four seasons.

cellent weed control during four previous seasons (Table 1). All treatments were more than half-covered with weeds 60 days after the land was tilled. Continuous atrazine or linuron use had the greatest grass coverages. Four seasons of atrazine gave the lowest total weed infestation while no soybean treatment gave significant reductions the fifth season. In the non-weeded plots, three times more grass was present after four seasons of soybeans as compared to four seasons of non-weeded maize.

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Preliminary Effects of Different Husbandry Regimes on Some Vegetable Crops

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Abstract. Over a period of 18 months a cropping sequence of peas, transplanted cabbages, broadbeans amd sweetcorn were compared under three husbandry regimes. Cabbage yields were reduced but broadbeans and sweetcorn increased with minimum cultivation and herbicides. These results and the accompanying changes in weeds and soil conditions pointed to the need for further work on minimum tillage techniques.

Introduction

The development of chemical weed control in the present century has, for the first time, given agriculturalists the opportunity of re-assessing traditional standards of soil cultivation. In some crops clear advantages for reduced tillage have been realised already using systems which include herbicides. Recent reviews quote, for example, direct drilled areas approaching 2×10^6 ha in the USA (Young, 1973) and 1×10^5 ha in England (Scott Russell and Fryer, 1975). In terms of total energy requirements, cropping with less cultivation and more chemical weed control is generally less costly than traditional tillage systems. It has been estimated that the energy balance of a crop can favour direct drilling by a factor of at least two (Price Jones, 1975).

To date the possibilities of such novel techniques have been explored most thoroughly in grain crops, including rice in Japan (Brown and Quantrill, 1975) and fodder brassicas. An initial investigation with a series of vegetable crops is described here.

Experimental Methods

A uniform seedbed was prepared initially and duplicate 5 m$\times$10 m plots marked out to compare cropping under three growing systems as follows:

Treatment 1—Intensive cultivation without herbicides. Conventional ploughing and seed bed preparation. Mechanical cultivation for weed control in the growing crop.

Treatment 2—Modified cultivation with herbicides. Conventional ploughing and seedbed preparation. A herbicide programme for weed control.

Treatment 3—Minimum cultivation with herbicides. No ploughing and only the minimum soil disturbance required to place seed or transplants in the soil. A herbicide

Table 1. Cropping sequence, cultivations and herbicides (kg a.i./ha) applied.

Crop	Treatment 1	Treatment 2	Treatment 3
Peas, sown	Hoed twice	Trifluralin 0.8	Trifluralin 0.8
11 Oct–28 Dec '73		Methabenzthiazuron 2.0	Methabenzthiazuron 2.0
Cabbages, transplanted	Hoed once	Simazine 0.4	Aziprotryne 1.5
1 Mar–30 May '74	Weeds dug*	Weeds dug*	Asulam 1.5*
Broad beans, sown	Hoed twice	Simazine 1.0	Simazine 1.0
14 Jun–14 Dec '74	Weeds dug*	Asulam 1.5*	Asulam 1.5*
Sweetcorn, sown	Hoed twice	Cyprazine 0.8	Paraquat/diquat 0.6
19 Dec '74–10 Mar '75			

* Spot treatments to control RUobt.

programme for weed control.

Details are given in Table 1 of the cropping sequence, cultivations and herbicides applied. Densities of 90 plants/m² for peas and 6 plants/m² for cabbages, beans and sweetcorn were chosen. The main weed species occurring were: *Amaranthus hybridus* (AMhyb), *Portulaca oleracea* (POole), *Capsella bursa-pastoris* (CAbur), *Rumex obtusifolius* (RUobt), *Coronopus didymus* (COdid), *Solanum nigrum* (SOnig), *Lolium multiflorum* (LOmul), *Veronica persica* (VEper).

Result

In the pea crop the main weed species, CAbur and COdid, were little affected by trifluralin applied to treatments 2 and 3. However, a post-emergence application of methabenzthiazuron was effective and eventual yields (Table 3) were slightly greater than of treatment 1 which was inter-row hoed.

In the cabbage crop the main resistant weeds after application of simazine (treatment 2) and aziprotryne (treatment 3) were SOnig and CAbur, respectively. Weed populations were generally much lower than on treatment 1. Plants which had been slit-planted in treatment 3 established irregularly and the poorer growth which resulted was reflected in lower yields (Table 3).

After the cabbage harvest, and again during the life of the following broad bean crop, control measures were taken against RUobt, (Table 1). The level of infestation on each occasion (Table 2) showed the first hand-digging in the cultivated treatments 1 and 2 was much less effective in holding the infestation than the spot treatment with herbicide in treatment 3.

At broad bean harvest, an analysis of weed foliage showed that different species had become significant in each treatment and a much lower weight of weeds occurred in the uncultivated treatment 3. As the weed infestation decreased in order through treatment 1, 2 and 3 (Table 2) so pod yield increased (Table 3).

Weeds which occurred in the sweetcorn seedbeds were mainly AMhyb and POole, and in addition on treatment 3, CAbur (although the overall weed density was much lower on this treatment). Weed control measures were taken after crop emergence in

Table 2. Weed patterns in each crop according to treatment.

Crop	Weeds		
	Treatment 1	Treatment 2	Treatment 3
Peas			
total weeds, plants/m²	659	590	557
main spp.	CAbur, COdid	CAbur, COdid	CAbur, COdid
Cabbages			
total weeds, plants/m²	368	90	50
main spp.	CAbur, COdid, SOnig	SOnig	CAbur
RUobt, plants/m²	0.1	0.3	0.6
Broad beans			
weed fresh wt, g/m²	59	41	15
main spp.	LOmul	VEper	COdid
RUobt, plants/m²	0.9	0.9	0.6
Sweetcorn			
main spp.	AMhyb, POole	AMhyb, POole	AMhyb, POole, CAbur

Table 3. Yields of marketable produce, tonnes/ha.

Crop, marketable produce	Treatment		
	1	2	3
Peas, pods	19.1	22.1	22.2
Cabbages, heads	77.8	78.9	48.2
Broad beans, pods	25.6	27.7	29.6
Sweetcorn, cobs	21.5	28.9	29.2

treatments 1 and 2 and before crop emergence in treatment 3. Total yields of sweetcorn cobs increased from treatment 1 to treatments 2 and 3 (Table 3) as did the number and weight of large sized cobs.

After the first three crops had been taken, differences in soil characteristics were recorded in the sweetcorn seedbeds. Treatments 1 and 2 gave a soil pH of 6.2 and a bulk density of 1.0 kg/dm³ to a depth of 8 cm, whereas treatment 3 gave a pH increasing from 6.0 at the surface to 6.3 at 8 cm and an average bulk density of 1.2 kg/dm³.

Slightly higher levels of the major nutrients P and K occurred in the surface layer of treatment 3.

Discussion

There was little difference in the yields of peas, the first crop. Transplanted cabbages did not establish very successfully in the uncultivated plots, perhaps because of the planting technique used, and gave poor yields. The succeeding crops of broad beans and then sweetcorn produced better yields from the plots with reduced or no cultivation. In the 'cultivated only' treatment, where inter-row hoeing was practised and weeds within the row survived, it is likely that weed competition generally affected crop growth. In 'herbicide' treatments, weeds were always adequately controlled.

Without cultivation, weed infestations tended to diminish, although it was noted that at different times of year CAbur, COdid, AMhyb and POole germinated very successfully on the surface of the uncultivated plots.

Soil characteristics which were examined showed that the uncultivated soil developed a slightly higher bulk density and wider range of pH from the surface down to 8 cm depth than the other treatments. Other physical and biological properties of uncultivated soil monitored on nearby sites have shown higher organic carbon levels and higher populations of some soil animals e.g. nematodes (G. W. Yeates, pers. comm.). Penetrometer investigations showed no difference in resistance to 10 cm depth in uncultivated soil (K. Moore, pers. comm.).

The relative importance of these changing properties in terms of crop and weed growth cannot be fully assessed at this stage. However, the success so far achieved justifies further investigation of the value of minimum tillage in a range of vegetable crops especially in intensive cropping areas where the preservation of good soil structure is often of urgent concern.

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Weed Control on Apple Orchard by Two Granular Herbicides

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Abstract. Granule types of trifluralin (α, α, α-trifluoro-2,6-dinitro-*N*, *N*-dipropyl-*p*-toluidine) and dichlobenil (2,6-dichlorobenzonitrile) were treated singly or in mixture on apple orchard. The sufficient result was not obtained by single treatment of trifluralin or dichlobenil, but synergistic effect was gained by the combined treatment of these two herbicides. The best combination was 1.25 kg/ha trifluralin and 2.01–3.35 kg/ha dichlobenil. The effect was enhanced by soil incorporation treatment.

Introduction

Apple is the principal fruit next to citrus in Japan. The apple growing area is about 55,000 ha. Most of apple orchards are located in slopes or places where are a shortage of water and are unsuitable for rice cultivation.

At present, herbicides are scarcely used in apple orchard. The first reason is in difficulty to get water for spraying of herbicides and many growers do not have spraying apparatus.

Apple growers become experienced in using rotary cultivator attached to garden-tractor or handy grass-cutter for weed control. However these weed control procedures require a great deal of labor, because they have to do grass-cutting or cultivation 5 to 7 times in a growing season. Recently, labor is hardly obtainable yearly. In apple orchards, granular type herbicides are advantageous because they are easy to handle and their application does not require water and any special equipment. Granular type herbicides, trifluralin and dichlobenil are recognized to be effective in apple orchard. These two herbicides are not toxic to apple trees in comparison with other translocation type herbicides. But they also have some problems. They have vapor action and selectivity to weeds and their application on the surface of the ground is not sufficient to exert their effect. We studied more effective procedures to control weeds in the apple orchard by using these herbicides.

Materials and Methods

The experiments were conducted at the test apple orchard of Nagano Prefecture Horticultural Experiment Station, Suzaka, Nagano in 1974 and 1975. The soil type of the orchard is clay loam with pH 5.5 and this soil contained 2.2% organic matter. Trifluralin granule (2.5% a.i.) and dichlobenil granule (6.7% a.i.) were used singly and in mixture. After spraying these herbicides by hand, the land was cultivated by rotary cultivator about 6 cm in depth. Each test was conducted under trees with 50 m^2 (5 × 10 m) plot. Tests conducted were as follows.

Test on May 2, 1974; 1.5 kg/ha trifluralin, 4.02 kg/ha dichlobenil.

Test on July 1, 1974; 1.5 kg/ha trifluralin, 4.02 kg/ha dichlobenil, 1.25 kg/ha trifluralin+3.35 kg/ha dichlobenil, 1.25 kg/ha trifluralin+2.01 kg/ha dichlobenil, 0.75 kg/ha trifluralin+3.35 kg/ha dichlobenil.

Test on May 7, 1975; 1.5 kg/ha trifluralin, 4.02 kg/ha dichlobenil, 1.25 kg/ha trifluralin+3.35 kg/ha dichlobenil, 1.25 kg/ha trifluralin+2.01 kg/ha dichlobenil, the test plot was brought under cultivation on August 3.

Herbicidal injury test; the herbicides were incorporated into the soil on June 10, 1974 where 2 year seedling of apple trees were planted. Application rate of the herbicides; trifluralin—2.00 kg, 2.50 kg, 3.00 kg (/ha), dichlobenil—5.36 kg, 6.70 kg, 8.04 kg (/ha).

Results and Discussion

Test on May 2, 1974. Weeds were controlled perfectly for 3 weeks after single treatment of trifluralin and dichlobenil. Four weeks after treatment, large crabgrass [*Digitaria sanguinalis* (L.) Scop.] germinated in the area treated with dichlobenil, and broad leaf weeds germinated in the area treated with trifluralin. Thereafter, these weeds grew normally and cultivation or weed cutting was required in the middle of July. Weed species in the herbicide treated area varied according to herbicides used. The area treated with dichlobenil was covered completely with large crabgrass, while the area treated with trifluralin was covered with broad leaf weeds such as dayflower (*Commelina communis* L.), groundsel (*Senecio vulgaris* L.), purslane (*Portulaca oleracea* L.), sowthistle (*Sonchus oleraceus* L.) and dandelion (*Taraxacum officinale* Weber).

Test on July 1, 1974. In the combination test of both chemicals, the weeds were controlled very well. Combinations of 1.25 kg/ha trifluralin+3.35 kg/ha dichlobenil and of 1.25 kg/ha trifluralin+2.01 kg/ha dichlobenil controlled the weeds perfectly until fall of the year, but combination of 0.75 kg/ha trifluralin+3.35 kg/ha dichlobenil was not effective and the area was covered with large crabgrass.

Test on May 7, 1975. In the area treated with herbicides singly the weeds were controlled perfectly for about 3 weeks after treatment, but 5 weeks after treatment, the areas treated with trifluralin and dichlobenil respectively were covered with weeds. While weeds in the area of combined treatment were controlled until fall of the year by cultivation early in August. Combination of 1.25 kg/ha trifluralin+3.35 kg/ha dichlobenil was more effective than that of 1.25 kg/ha trifluralin+2.01 kg/ha dichlobenil but the difference was very little between two combinations.

Herbicidal injury test. Herbicidal injury appeared in 2 year seedling plants area where the soil incorporation treatment test with 6.7 kg/ha and 8.04 kg/ha dichlobenil was conducted. Yellowing symptom caused by the injury was recognized at leaf margin but

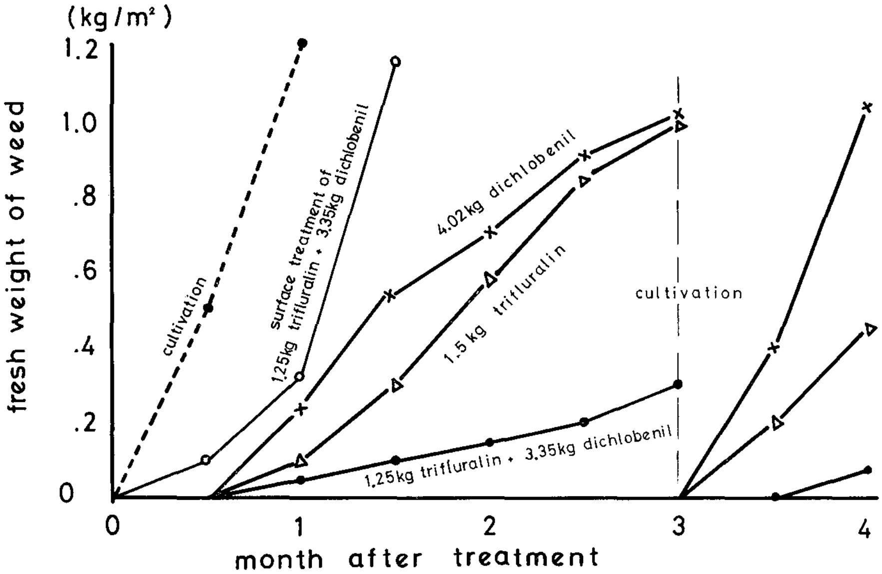

Fig. 1. Effect of weed control on apple orchard by granule type trifluralin and dichlobenil (treatment on May 7, 1975).
Dosage: kg a.i./ha.

defoliation or reduction of shoot growth was not found. However the injury was not observed by treatment of 5.36 kg/ha dichlobenil or 3.0 kg/ha trifluralin.

Conclusion. Single treatment of trifluralin or dichlobenil did not show sufficient herbicidal effect, since both herbicides have their own selectivity. Therefore, trifluralin treated area was covered with broad leaf weeds and dichlobenil treated area was covered with grass weeds. Synergistic effect was obtained by the combined treatment of trifluralin and dichlobenil. The best combination was obtained by the treatment of 1.25 kg/ha trifluralin+3.35 kg/ha–2.01 kg/ha dichlobenil and cultivation after treatment. The effect was enhanced by soil incorporation treatment early in August when weeds started to germinate.

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Some Aspects of Weed Control in Fruit Trees

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Abstract. The history of soil management in fruit tree culture including recent increase of so-called "sod culture with weeds" and the importance of the management of weed as natural green cover were described. As the troublesome weed in orchard, 81 species in 30 families were recognized and more than a half were the perennials. Some studies were made to estimate the effect of weed management on the growth of young orange tree (*Citrus Unshiu*). The results suggest that not only the weeding effect but also the soil surface condition after control would be the important factors affecting tree growth.

History of Soil Management in Fruit Tree Culture in Japan

Soil management of orchard can be essentially clasified to the clean culture, sod culture and mulch. In our country orchards have conventionally managed with clean culture at first. In apple growing region, however, sod culture with grass and legume has started since thirty years ago and mulching has also been employed for the recovery from the decreased soil fertility caused by the continuous clean culture and for the prevention from soil erosion. Thereafter, owing mainly to the recent deficiency of labours, orchards of clean culture, sod culture and also mulch have often been left without sufficient management. Thus so-called "sod culture with weeds" came to increase widely, and the problems how to manage the weeds as natural green cover and how to eradicate the troublesome weeds are now very important.

Weeds Observed in Orchard in Japan

To summarize the answers to the questionnaire to each prefecture in 1973, 81 species in 30 families including 20 Compositae, 10 Graminaceae and 7 Polygonaceae were found to be the important weeds according to the high degree in dominance and the difficulty in control. Among them 49 species, more than a half, were the perennials. The list of most important weeds is shown in Table 1. Many of these species are found to be the plants that grow usually on the wayside or on uncultivated area. The soil management of non-tillage or without deep tillage may contribute to the increase of these species. Chemical weed control in these days would often be the cause of the shift of weed species. Troublesome perennial weeds are to become dominant with successive applications of a certain herbicide.

Table 1. Species of common weeds observed in orchard in Japan.

Whole country		Northern region (apple zone)		Southern region (citrus zone)	
1.	*Artemisia princeps**	1.	*Artemisia princeps**	1.	*Artemisia princeps**
2.	*Digitaria adscendens*	1.	*Equisetum arvense**	1.	*Digitaria adscendens*
3.	*Equisetum arvense**	1.	*Rumex obtusifolius**	1.	*Cyperus rotundus**
4.	*Imperata cylindrica**	1.	*Trifolium repens**	4.	*Imperata cylindrica**
5.	*Stellaria media*	5.	*Dactylis glomerata**	5.	*Erigeron sumatrensis*
5.	*Polygonum longisetum*	5.	*Stellaria media*	5.	*Calystegia japonica**
5.	*Amaranthus lividus*	5.	*Taraxacum officinale**	5.	*Polygonum longisetum*
8.	*Erigeron sumatrensis*	8.	*Digitaria adscendens*	8.	*Amaranthus lividus*
9.	*Commelina communis*	8.	*Chenopodium album*	9.	*Cayratia japonica**
9.	*Cayratia japonica**	8.	*Commelina communis*	9.	*Miscanthus sinensis**
9.	*Calystegia japonica**	8.	*Senecio vulgaris*	9.	*Commelina communis*
12.	*Cyperus rotundus**	8.	*Rumex acetosella**	9.	*Oxalis martiana**
13.	*Setaria faberi*	8.	*Plantago asiatica**	9.	*Oxalis corniculata**
14.	*Erigeron canadensis*	8.	*Kalimeris yomena**	9.	*Pueraria lobata**
14.	*Miscanthus sinensis**				
14.	*Oxalis martiana**				
17.	*Oxalis corniculata**				
17.	*Chenopodium album*				
17.	*Rumex japonicus**				
20.	*Hydrocotyle sibthorpiodes**				
20.	*Rumex obtusifolius*				

* Perennial.
Each number indicates the order determined by two factors; the degree of dominance and the difficulty in control.

Some Aspects of Weed Management in Orchard

The management of weed as a natural green cover should be considered in the prevention from soil erosion and elimination of undesirable effects of weeds though it has not yet been known which species could be the better components of natural green cover. From this point weeds would be allowed to grow during a rainy season from June to the middle of July and need to control to alleviate water competition during a dry season following.

Studies were made to estimate the effect of weed management on fruit trees. Growth and development of young (three-four year old) orange tree were observed under the weed control varied in timming, duration and means including the application of herbicides. Results are summarized as follows:

1) As shown in Table 2 if the weeds were allowed to grow during the period from the middle of July to August, the shoot growth of orange trese in the year and also in the next year, and the fruiting in the next year were heavily reduced. The result suggests that weeds need to be depressed in their growth for a month, at least, just after the rainy season.

Table 2. Effects of the timming of weed control on the shoot growth and the fruiting of young orange tree. The effects lasted to the next year were also determined.

Time of mowing	Increase in shoot length*		Fruiting (in the next year)	
	In the year	In the next year	Number of** fruits per tree	Diameter of young fruit (cm)
(A) July 15, Aug. 8, Sept. 3	100	100	more than 7	2.64
(B) July 15	94.1	59.0	5.5	2.75
(C) Aug. 8	16.9	44.5	5.7	2.58
(D) Sept. 3	19.3	46.5	5.3	2.23
No treatment	10.9	17.5	4.0	2.21

* Indicated as % of (A) value. ** Counted after fruit thinning.

Table 3. Effects of various means of weed control on the shoot growth of orange tree. The effect lasted to the next year were also determined.

Treatment	Soil surface condition*			Shoot growth in length**	
	Cover	Weed-top	Weed-root	In the year	In the next year
Mowing	−	−	+	100	80
Mowing—Grass mulch	+	−	−	181	126
Herbicide (paraquat 30 ml/a)	−	−	+	55	—
Herbicide (asulam 100 g/a)	+	−	−	131	92
Hand weeding***	−	−	−	100	100
No treatment	+	+	+	18	22

* For two months after treatment. ** As % of hand weeding value. *** To remove completely

2) With the various means of weed management the condition surrounding the soil surface varied. The application of paraquat (1,1′-dimethyl 4,4′-bipyridylium) made the condition similar to that after mowing and asulam [methyl(4-aminobenzenesul-phonyl)carbamate] made that similar to grass mulch. The result presented in Table 3 indicates that the growth of the trees would be promoted when the soil surface are covered with degradated weeds. The promotion of growth may be due to the conservation of soil moisture and nutrition, less fluctuation of soil temperature and also to depression of weed emergence and regrowth. In another experiment, immediate elonagtion of tree roots after weed control was observed when weed roots were killed, while with paraquat application slight elongation was observed (Fig. 1). The competition between the root of the tree and that of the weed seemed to be apparent.

Above results suggest that not only the weeding effect but also the soil surface condition after control would be the important factors affecting the growth and development of trees. Herbicides, means to manage the natural green cover, thought to have the ability to make various soil surface conditions such as under mulching, clean culture or after mowing. The condition like mulch could be obtained with almost all

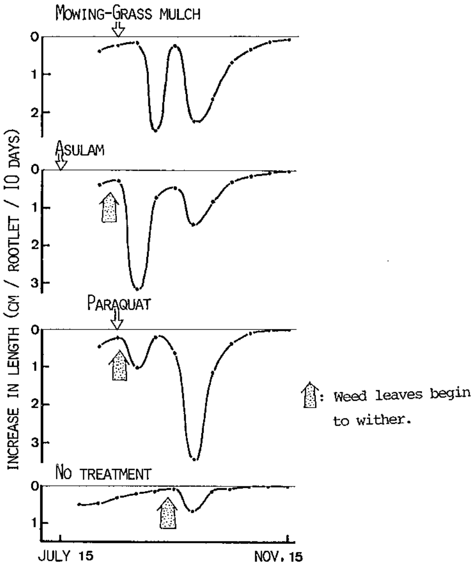

Fig. 1. Effect of various means of weed control on the root growth of young orange tree.

the herbicides commonly used in orchard if applied in autumn where the grass weeds were dominant, while only with asulam could be obtained in summer application.

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Research of a New Diphenyl Ether
B) Weed Management in Orchards and Non-agricultural Fields by New Diphenyl Ether Including Combinations

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Abstract. A new diphenyl ether herbicide, RH-2915 (2-chloro-4-trifluoromethylphenyl-3′-ethoxy-4′-nitrophenyl ether) shows fairly good herbicidal activity to control grown-up weeds in itself. But the effectiveness is not perfect in several different conditions even at a dosage of 30 g a.i./are. When applied in combination with a low dosage each of diuron [3-(3,4-dichlorophenyl)-1,1-dimethyl urea], ametryne (2-ethylamino-4-isopropylamino-6-methylthio-1,3,5-triazine), paraquat (1,1′-dimethyl-4,4′-bipyridinium ion), DSMA (disodium methanearsonate), or several other herbicides in orchard and non-agricultural field, however, RH-2915 shows excellent herbicidal activity to grown-up weeds and also prevents weed development for a long period at a lower dosage of 5–15 g a.i./are. Especially, a combination of RH-2915 and diuron is the best of all conbinations for this purpose.

INTRODUCTION

Rohm and Haas Company invented a new diphenyl ether herbicide. Its code number is RH-2915. Several diphenyl ether herbicides have been practically used as pre-emergence herbicide mainly in paddy fields but also in upland fields in Japan. RH-2915 also has the same mode of herbicidal action as nitrofen (2,4-dichlorophenyl-4′-nitrophenyl ether) and other diphenyl ether herbicides. But, RH-2915 has a stronger contact activity by several ten times, a longer residual efficacy and a wider herbicidal spectrum than the established similar type herbicides. In order to utilize those advantages of RH-2915, we tried to expand the application of RH-2915 for controlling weeds in orchards and non-agricultural fields.

MATERIALS AND METHODS

In Experiment I (Table 1), 2 leaf stage (14.5 cm height) of barnyardgrass (*Echinochloa crus-galli*) planted in pots were used. In Experiment II, which evaluates non-selective herbicidal action of RH-2915 EC, barnyardgrass of 35 cm height planted in pots were used. In Experiment III, IV and V, RH-2915 EC was applied on the upland fields almost covered with crabgrass (*Digitaria* spp.) of more than one meter height. The experiment conditions of combination test with various other herbicides were the same as Experiment III. In Experiment VI, RH-2915-diuron combination was treated in 1/2,000 are pots where crabgrass (75 cm height), barnyardgrass (60 cm) and French weed (*Galinsoga parviflora*, 50 cm) were grown. In Experiment VII, crabgrass and barnyardgrass of average 41 cm height grown in 1/2,000 are pots were used. In Experiment VIII, upland field was used where crabgrass and other various weeds of 45 to 60 cm height were grown. The above experiments were replicated for 2 to 3 times. Spray volume was 20 liter/are (in Experiment I, 10 liter/are), a small pressure sprayer was used. No spreader-sticker was used in Experiment I. Commercially available spreader-sticker was used at 10–30 ml/are in the other Experiments. RH-2915 EC has 24% a.i. and RH-2915 WP has 50% a.i. RH-2915D WP is a mixture of RH-2915 and diuron (30% each as a.i.). In the plots of foliage only spray in Experiment VII, husks of rice grain were placed entirely to cover the soil surface and were removed after spray. The results were generally collected about 30 to 50 days after the application. Those Experiments were conducted between May to September of 1973 and 1974.

Results and Discussion

Table 1 summarized the foliar contact efficacy of RH-2915 and other diphenyl ether herbicides. RH-2915 presented a contact herbicidal efficacy stronger by about 25 times than nitrofen. RH-2915 developed stronger herbicidal efficacy by 20 to 25

Table 1. Comparison of contact activity of RH-2915 and other diphenyl ether herbicides.

Composition	About 55% weeding dosage (g a.i./are)	Comparison of weeding activity
RH-2915 EC	1.0 (53)	1
Nitrofen EC	25.0 (57)	ca. 1/25
TOPE EC	45.0 (55)	ca. 1/45

Weeds—2 leaf stage (14.5 cm height) of barnyardgrass. * Herbicidal ratio

Table 2. Activity of RH-2915 EC as non-selective foliar herbicide.

Composition	g a.i./are	Exp. II (%)	Exp. III (%)	Exp. IV (%)	Exp. V (%)
RH-2915 EC	5.0	35	5		
	10.0	97	15	8	25
	15.0		35		55
	20.0			70	
	25.0	98			
	30.0		63		79
Paraquat	9.6	98	95	91	90
Ametryne EC	39.5		98	58	94
Check	—	0	0	0	0

Exp. II used pots with mainly barnyardgrass (35 cm height).
Exp. III, IV, V used field with mainly crabgrass (1 m height).

Table 3. Herbicidal activity of RH-2915 and combination with other herbicides.

Composition	g a.i./are	Weeding ratio		
		15 days (%)	28 days (%)	40 days* (%)
RH-2915 EC	5	20	15	5
	10	50	28	15
	15	65	43	35
	30	88	78	63
RH-2915 EC+PCP-Na	5+10	80	70	38
	10+10	83	76	55
RH-2915 EC+propanil EC	5+20	68	86	38
	10+20	85	78	53
RH-2915 EC+SK-432 EC	5+10+2	85	86	53
	10+10+2	94	95	79
RH-2915 EC+paraquat	5+1.44	75	75	55
	10+1.44	90	88	80
RH-2915 EC+diquat	5+1.8	75	60	15
	10+1.8	83	73	65
RH-2915 EC+ametryne EC	5+7.5	88	84	83
	10+7.5	95	98	97
RH-2915 EC+diuron WP	5+15	88	90	85
	10+15	99	99	98
RH-2915 EC+DSMA	5+15	87	98	98
	10+15	88	94	94
RH-2915 EC+24-D-Na	5+10	70	59	50
	10+10	88	87	93
Paraquat	7.2	93	97	95
Diquat	9	35	30	5
Ametryne EC	37.5	97	90	88
SK-432 EC	62.5+12.5	40	90	78
Check	—	0	0	0

* Days after application. SK-432 EC is product of propanil 25% a.i. and phenkapton 5% a.i.

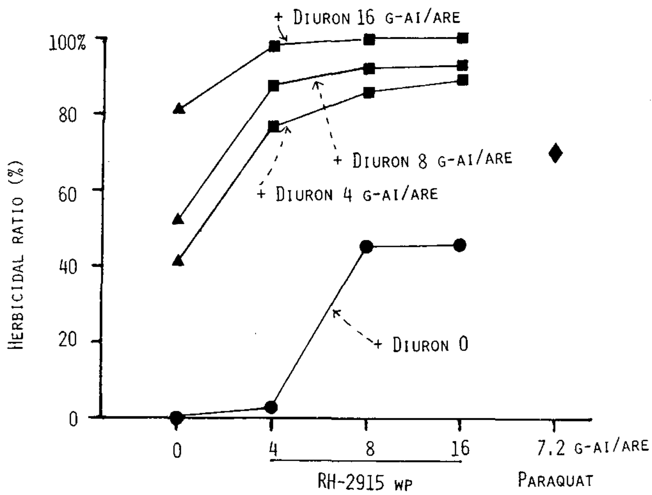

Fig. 1. Efficacy of mixture of RH-2915 WP and diuron WP.

times than nitrofen as an upland pre-emergence herbicide on the other experiment. Table 2 presents the results of the non-selective herbicidal efficacy of RH-2915 EC. When RH-2915 EC was applied at a dosage of within 30 g a.i./are, its herbicidal activity was not so stable depending on the variety and growth stage of weeds. The reason is that RH-2915 is poor in permeating into the plant tissues. Therefore, the single application of RH-2915 has a limited application in complex weed population in the orchards and non-agricultural fields. Then the mixtures of RH-2915 with other herbicides were ex-

Table 4. Active part of a mixture of RH-2915 and diuron.

Application Part*			Weeding ratio** (%)	Application part*			Weeding ratio** (%)
RH-2915		Diuron		RH-2915		Diuron	
F•S		—	37	F•S	+	S	57
F		—	38	F	+	F•S	86
S		—	6	F	+	F	80
—		F•S	56	F	+	S	60
—		F	44	S	+	F•S	64
—		S	7	S	+	F	56
F•S	+	F•S	90	S	+	S	20
F•S	+	F	86	Check			0

Dosage: 8 g a.i./are, Weed: crabgrass, barnyardgrass, height: 41 cm in average
* Application Part: F . . . Foliage, S . . . Soil
** 36 days after application

Table 5. Efficacy of a mixture of RH-2915 and diuron (RH-2915D) in complex weed populations.

Treatments		Weeding Ratio			Effect to various weeds**					①*** (%)
Herbicides	g a.i./are	19 days (%)	32 days (%)	52 days* (%)	C.G.	D.F.	H.W.	F.H.	O.W.	
RH-2915D WP	9+ 9	73	86	70	⧻	–	‡	‡	⧻	46
”	18+18	88	94	81	⧻	‡	‡	⧻	⧻	84
RH-2915D WP+24-D	9+9+15	83	86	80	‡	⧻	⧻	⧻	⧻	0
RH-2915 WP	18	49	50	58	+	–	–	‡	+	34
”	27	53	77	65	+	–	–	‡	+	24
Diuron WP	18	23	43	51	+	+	–	–	+	0
”	27	40	70	65	+	+	+	+	‡	27
Paraquat	9.6	75	63	65	–	⧻	⧻	+	‡	0
Propanil+carbaryl	50+10	88	93	76	‡	+	–	–	⧻	0
Bromacil WP	24	68	84	83	‡	⧻	⧻	⧻	‡	0
Check	—	0	0	0						0

① Preventing rates of weed re-establishment
* Weeds weight survived
** Effect at 52 days after treatment; C.G.—crabgrass, D.F.—dayflower, H.W.—horseweed, F.H.—field horsetail, O.W.—other weeds; ⧻ Excellent, ‡ good, + fair, – poor
*** At 43 days after the weeds cutting which did for the inverstigation of weeding efficacy at 52 days after treatment

pected to expand the RH-2915 application. Test results are presented in Table 3. In this case, herbicides commonly used in orchards were applied at 1/2 to 1/5 of their ordinary dosages with RH-2915. Then the foliar contact herbicidal efficacy of RH-2915 was greatly improved by the low dosages of diuron, ametryne, DSMA, Paraquat, 2,4-D (2,4-dichlorophenoxy acetic acid) and SK-432 (propanil 25%+phenkapton 5%). At the same time, the dosage of RH-2915 could also be considerably decreased. Diuron, ametryne and DSMA were the suitable compositions in combination with RH-2915. Among them, a mixture of RH-2915 and diuron was the best in herbicidal efficacy and stability in consequence of the followed few experiments. Fig. 1 presents the herbicidal

Table 6. Herbicidal efficacy of RH-2915D WP in citrus orchards (official field data—1974).

Weeding efficacy in experiments of spring time.

Treatments		Weeding efficacy					
Chemicals	g a.i./are	A	B	C	D	E	F
RH-2915D WP	10.5+10.5	×	×	×	×	×	×
	18 +18	×	×	×	×	×	×
Paraquart	3.6		⧺−×				×
	4.8			×			
	7.2	×	⧺−×	×			
Ametryne EC	25		+−⧺				
	37.5	×	⧺−×				
Propanil+carbaryl EC	50+10			⧺		⧺	+−⧺
	75+15			⧺		×	⧺
Diuron WP	30				×		

Weeding efficacy in experiments of summer time.

Treatments		Weeding efficacy						
Chemicals	g a.i./are	A	B	C	D	E	F	G
RH-29I5D WP	10.5+10.5	×	×	×	⧺−×	⧺	⧺−×	
	18 +18	×	×	×	×	⧺	⧺−×	⧺−×
Paraquart	4.8			⧺−×				
	7.2	×		⧺−×			⧺	⧺−×
Proparil+ carbaryl EC	50+10		×	⧺−×		+	+	
	75+15		×	×		⧺	⧺	+−⧺
Bromacil WP	16		×					
	32				⧺			
	42		×					
Ametryne EC	37.5	×						
	50				⧺			

Degree of weeding: complete weeding ×, ⧺, +, ±, − none weeding
Weed height: spring time 20–40 cm, summer time 25–75 cm
Water valume: 15 to 20 liter/are, sticker added
A, B, . . . F, G: experiment station

efficacy of a mixture of RH-2915 and diuron for crabgrass and barnyardgrass. The mixture of RH-2915 and diuron exhibited synergistic effect. When diuron (fixed dosage level) and RH-2915 (changed dosage level) were mixed, herbicidal efficacy was not so much improved with the increase of RH-2915 dosage levels if it exceeds over a 8 g a.i./are in this experiment. On the other hand, diuron exhibited an increased activity with the increase of its dosage independent to the RH-2915 dosage level. Therefore, in this combination, diuron should be applied at the same or more dosage level than RH-2915. The activity development location and herbicidal function mechanism of a mixture of RH-2915 and Diuron were studied. Table 4 presents the results. Both of RH-2915 and diuron gave a herbicidal action on the foliar part treatment. The mixture of two components gave almost the same action, too. But, the component applied on the soil surface increased the foliar treatment activity of the other component. As a result,

Table 7. Herbicidal spectrum of RH-2915D WP (1974 official experiments).

Common Name	Scientific Name	Efficacy
Crabgrass	*Digitaria* spp.	Excellent
Western wheatgrass	*Agropyron smithii* Ohwi	Excellent
Green foxtail	*Setaria viridis* Beauv.	Good
Barnyardgrass	*Echinochloa crus-galli* Beauv.	Excellent
Italian rye grass	*Lolium multiflorum* L.	Excellent to good
Rescue grass	*Bromus catharticus* Vahl	Good
Foxtail grass	*Alopecurus aequalis* Sobol var.	Excellent
Annual bluegrass	*Poa annual* L.	Excellent
Bermuda-grass	*Cynodon dactylon* Pers.	Good to fair
Narrowleaf vetch	*Vicia angustifolia* L.	Excellent
Bedstraw	*Galium aparine* L.	Excellent
Smartweed	*Polygonum* L. spp.	Excellent to good
Chickweed	*Stellaira media* (L.) Cyrillo	Excellent
Dayflower	*Commelina communis* L.	Good to fair
Livid amaranth	*Amarnthus lividus* L.	Excellent
Lawn pennywort	*Hydrocotyle sibthorpioides* L.	Excellent
Cogongrass	*Imperata cylindrica* P. Beauv. var. *koenigii*	Poor
Curly dock	*Rumex japonicus* Houtt	Poor
Common lambsquarters	*Chenopodium album* L.	Excellent
Yabugarashi	*Cayratia japonica* Gagn.	Poor
Field horsetail	*Equisetum arvense* L.	Good
Purple nutsedge	*Cyperus rotundus* L.	Poor
Annual sowthistle	*Sonchus oleraceus* L.	Good
Oriental hawksbeard	*Youngia japonica* L.	Excellent
Annual fleabane	*Erigeron annuus* L.	Excellent
Horseweed	*Erigeron canadensis* L.	Good
Fleabane	*Erigeron bonariensis* L.	Excellent to good
Wormwood	*Artemisia princeps* Panp.	Fair to poor
Marshcress	*Rorippa islandica* Borbas.	Good

main part of herbicidal activity of this composition has in the foliar action, but the composition dropped on the soil is supposed to help the activity of the composition applied on the foliar part. Table 5 summarizes the activity of a mixture of RH-2915 and diuron in relatively complex weed populations. In this experiment, RH-2915D WP, equal mixture of RH-2915 (30% a.i.) and Diuron (30% a.i.), was used. RH-2915D WP exhibited a higher herbicidal efficacy than the single application of RH-2915 or diuron. The herbicidal efficacy of RH-2915D was the same or better than paraquat, propanil-carbaryl combination or bromacil (5-bromo-3-*sec*-butyl-6-methyluracil). Only dayflower (*Commelina communis*) was not controlled completely by RH-2915D. Table 6 summarizes the 1974 official field data of RH-2915D which were obtained in various Japanese official experiment stations in controlling weeds in the citrus orchards. As is obvious from the results, RH-2915 D WP showed advantageous herbicidal activity to the herbicides usually applied for this purpose. Table 7 shows the weeding activity for various weeds of RH-2915 D WP in the official field experiments.

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New Herbicides for Hawaiian Sugarcane

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Abstract. Four new herbicides of diverse activity show promise for weed control in Hawaiian sugarcane (*Saccharum* spp. hybrids). Metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-1,2,4-triazine-5(4H)one] applied pre- or postemergence, selectively controls a broad spectrum of grass and broadleaf species. Asulam (methyl sulfanilylcarbamate) applied postemergence, selectively controls certain perennial grass species such as paragrass (*Brachiaria mutica*) and johnsongrass (*Sorghum halepense*). Glyphosate [*N*-(phosphonomethyl)glycine] applied postemergence controls most perennial grass species as a directed spot treatment. And GS-14254 [2-*sec*-(butylamino)-4-(ethylamino)-6-(methoxy)-*s*-triazine] applied preemergence controls most broadleaf and grass species in high rainfall regions (>200 cm annual rainfall).

These new herbicides, when registered for use in Hawaiian sugarcane, will replace or supplement five highly effective herbicides: diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea]; ametryn [2-(ethylamino)-4-(isopropylamino)-6-(methylthio)-*s*-triazine]; atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine]; dalapon (2,2-dichloropropionic acid); and 2,4-D [(2,4-dichlorophenoxy)acetic acid].

Introduction

Although weed control programs differ widely among Hawaiian sugarcane plantations they are based on five herbicides: diuron, ametryn, atrazine, dalapon and 2,4-D. In irrigated sugarcane, residual weed control is obtained with ametryn at 4.5 to 11.2

Table 1. Present uses for herbicides in Hawaiian sugarcane.

Herbicide	Preemergence		Postemergence		Irrigated	Unirrigated
	BL	GR	BL	GR		
Ametryn	+	+	+	+	+	+[1]
Diuron		+	+[2]	+[2]	+[3]	+
Atrazine	+		+		+	+
Dalapon				+[4]	+	+
2, 4-D			+		+	+

+ Denotes condition where herbicide may be used. BL=broadleaves, GR=grasses.

[1] Good post activity but less active than diuron preemergence in unirrigated cane.

[2] Surfactant required at 0.25%.

[3] Good post activity but less active than ametryn preemergence in irrigated cane.

[4] Directed applications only.

Table 2. Proposed uses for new herbicides in Hawaiian sugarcane.

Herbicide	Preemergence		Postemergence		Irrigated	Unirrigated
	BL	GR	BL	GR		
Asulam				+[1]	+	+
Metribuzin	+	+	+	+	+	+
Glyphosate			+	+[2]	+	+
GS-14254	+	+				+

+ Denotes condition where herbicide may be used. BL=broadleaves, GR=grasses.

[1] Highly selective. Especially active on paragrass and johnsongrass.

[2] Highly toxic to young cane, must be carefully directed.

kg/ha or ametryn+atrazine at 4.5+4.5 kg/ha. Postemergence spot treatment of mixed broadleaves and grasses is accomplished with directed applications of ametryn or diuron combined with 2,4-D or dalapon or both. Application in irrigated sugarcane is by aircraft for preemergence or early postemergence treatments, or by hand knapsack for spot postemergence treatments. In unirrigated sugarcane (more than 200 cm annual rainfall), pre- and postemergence weed control programs more often are based on diuron at 4.5 kg/ha and diuron+atrazine at 2.8+2.8 kg/ha. Spot weeding programs are similar to those in irrigated fields. Pre- and postemergence broadcast treatments in unirrigated fields are sprayed by tractor and spot treatments are sprayed by hand knapsack. A summary of present herbicide uses is given in Table 1.

Weed control operations are carried out for the first 4 to 6 months of the 24 to 36 month crop at a cost (including labor) averaging $6.36 per metric ton of sugar ($175.00 per hectare).

Four new herbicides of diverse activity: metribuzin, asulam, glyphosate and GS-14254 are promising for weed control in Hawaiian sugarcane. A summary of the proposed uses is given in Table 2.

Metribuzin

Metribuzin, most versatile of the new herbicides, has both pre- and postemergence activity on broadleaves and grasses in irrigated and unirrigated cane. Metribuzin is especially active on guineagrass (*Panicum maximum*), the most serious weed problem in Hawaiian sugarcane fields. Metribuzin is selective for sugarcane and can be applied aerially over most Hawaiian sugarcane cultivars. Cultivars showing tolerance to ametryn are tolerant to metribuzin (Hawaiian Sugar Planters' Association, unpublished data). Effective rates of application for irrigated cane range from 4.5 to 6.7 kg/ha, while 2.2 to 4.5 kg/ha are required for unirrigated cane.

Asulam

Asulam can replace dalapon for some uses because of its high degree of selectivity for sugarcane and its activity on several perennial grasses such as johnsongrass, paragrass, and torpedograss (*Panicum repens*). An assigned tolerance of 0.1 ppm in raw sugarcane is established for asulam, and full registration for its use is expected in September 1975.

Asulam can be broadcast over the crop, broadcast as a directed spray, or spot sprayed on grasses. Rates of application for broadcast treatment are 3.4 to 5.6 kg/ha.

Glyphosate

Glyphosate provides outstanding postemergence control of perennial grass species such as guineagrass, paragrass, and napiergrass (*Pennisetum purpureum*). Care must be taken not to contact sugarcane foliage because the crop is highly sensitive, especially during periods of rapid growth. Proposed uses for glyphosate in Hawaiian sugarcane include irrigation ditch treatment, spot treatment of perennial grass within fields, and preplant broadcast applications. For spot treatments of most perennials, glyphosate is effective at 9 kg/1000 *l* of water. In dense stands of weeds such as paragrass, 926 *l* or more per hectare is needed. For light stands of dallisgrass (*Paspalum dilatatum*), 227 *l*/ha is sufficient.

GS-14254

GS-14254 is active primarily as a preemergence herbicide in high rainfall regions. A tolerance of 0.25 ppm has been established. However, because of formulation problems, no material has been made available by Ciba-Geigy Corporation.

Control of Mosses in Tea

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Abstract. In some areas of tea-plantation where radiation is limited and humidity is relatively high throughout the year, moss become a nuisance. They cover not only the soil surface under the tea bushes, but also a large part of the tea-trunk and branches. So far, no special effort is made to control these mosses at the soil surface, while moss on the tea trunk and branches are usually scraped off manually soon after deep-pruning.

Preliminary trials to control moss by chemicals, were conducted at Pagilaran ten-estate in Central-Java.

Glyphosate (isopropylamino salt of *N*-phosphonomethyl glycine), paraquat+diquat, 2,4-D+MSMA+diuron and captafol [*cis-N*-(1,1,2,2-tetrachloroethyl) thiol-4-cyclohexene 1,2-dicarboximide] were tested to control moss covering the soil surface. So far, only glyphosate seems to be promissing, while 2,4-D+MSMA+diuron and captafol gave only moderate control.

Captafol alone was used to control moss covering the tea trunk and branches. Captafol at 0.5% gave better control than the lower concentrations and no disadvantageous symptoms on the tea plant were observed.

There are indications that the stage of growth of the moss, determines its susceptibility towards chemicals.

INTRODUCTION

Tea plantations in hilly areas in Java have always some spots where radiation is limited and humidity is relatively high throughout the year, usually on the western and southwestern slopes or in dales. In such areas moss become a nuisance because of their rapid and abundant growth so that not only the soil surface under the tea bushes is covered, but also a large part of the tea trunk and branches. So far no special effort is made to control these mosses at the soil surface except the routine shallow soil cultivation which is not specially meant to control moss. Moss on the tea trunk and branches are usually scraped off manually soon after deep pruning using coconut fiber or bamboo slices. Research reports on the effect of moss cover on the growth or yield of tea is scarce, but many tea planters are of the opinion that it may harm the tea plant.

It was observed that during dry months tea bushes in such areas were less healthy looking and tea bushes with moss covering the trunk and branches had a very poor appearance. It was reported that in some tea plantations in west Java, soil under a cover of moss for long times develop a characteristic profile (Isa Darmawidjaja, 1975). A few centimeters of the most upper layer have a marked darker color, than the lower layers which is separated by a yellowish compact layer indicating a high iron accumulation. The darker color of the upper layer is probably due to a high soil moisture content. Further observations should confirm whether this phenomena is common or only a local occasion.

Assuming that moss should be controled, a preliminary trial was conducted at Pagilaran tea-estate in Central Java, to evaluate the effect of some chemicals in controling moss at the soil surface and on tea trunks and branches.

Materials and Methods

The experiment was conducted at Pagilaran tea estate, Central Java, at an elevation of about 1,100 m a.s.l. The tea-bushes were more than 30 years old and were in the 2nd year after deep pruning. The mosses present were not identified yet but presumably many of them represent the genus of *Fissidens*, *Mneodendron*, *Dicranum* and *Marchantia*.

In the first experiment only captafol was tried, using concentrations of 0.1, 0.3 and 0.5 percent of the commercial product. The plots sprayed were 10 sq.m each including 7 tea-bushes, with 3 replications. To assure an even application on soil surface and on the tea trunks, a spray volume of 1,000 l/ha was employed.

The second experiment was meant to test some herbicides against moss beside captafol. The treatments were captafol 0.5%, glyphosate 1%, paraquat 0.3%+diquat 0.3%, 2,4-D-amine 0.45%+(MSMA+diuron) 0.25% (the concentrations were calculated for the commercial product). Plot size was 20 sq.m with 3 replications for each treatment. A spray volume of 400 l/ha was chosen for this trial.

The two experiments used a complete randomized block design.

Visual assessment of the killing effect of the treatments was done at weekly intervals. Taking fresh or dry weight as a parameter of assesment is considered dubious, and too elaborate. Based on the change of color and appearence it is easier to recognize dead or living tissue of moss.

The extent of kill is expressed as percentage kill in relation to the total area.

Results

The results of the first experiment shows that spraying captafol had a significantly better response on moss at the soil surface than it had on the tea-trunk and the higher the concentration of captafol the better its effect. Generally speaking, the percentage kill increased significantly with time, up to the fourth week after spraying which then stayed almost constant till the end of the observation. Increasing concentrations of captafol had a significant better effect on the percentage kill particularly on moss at the soil surface (Fig. 1). On tea-trunk moss, the 0.3 and 0.5 percent concentration did not differ significantly (Fig. 2).

At the beginning the 0.1 percent concentration did not show a significant effect, but at the third week its effect became significant and after the 11th week it became

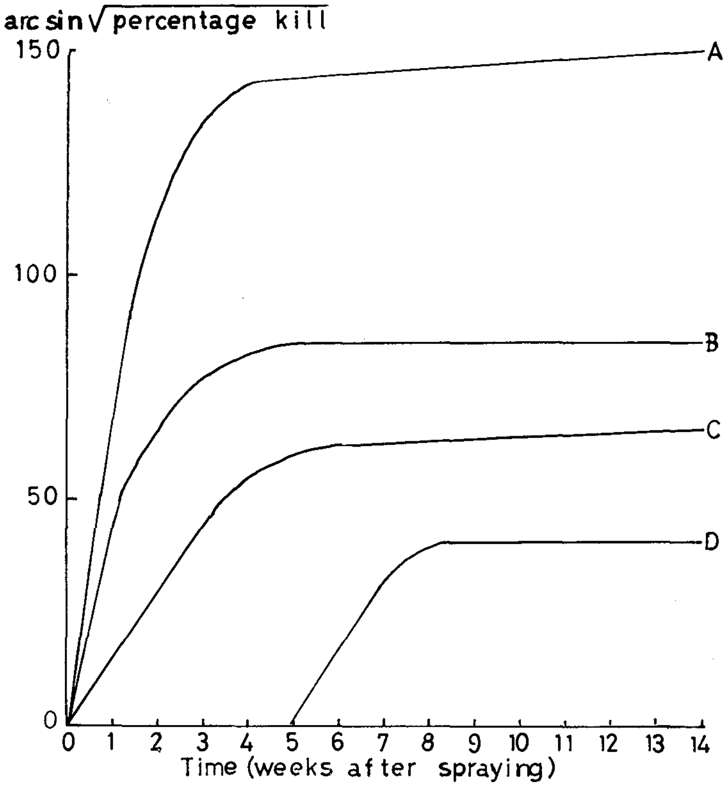

Fig. 1. The effect of increasing concentrations on captafol on moss at the soil surface. A—captafol 0.5%; B—captafol 0.3%; C—captafol 0.1%; D—control.

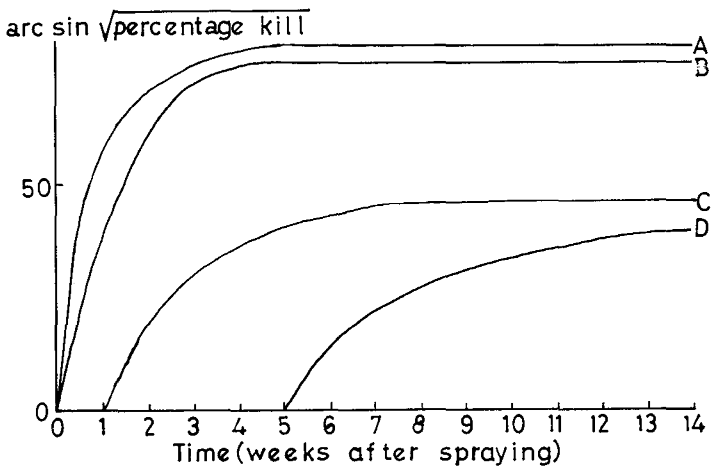

Fig. 2. The effect of increasing concentrations of captafol on moss at the tea-trunk. A—captafol 0.5%; B—captafol 0.3%; C—captafol 0.1%; D—control.

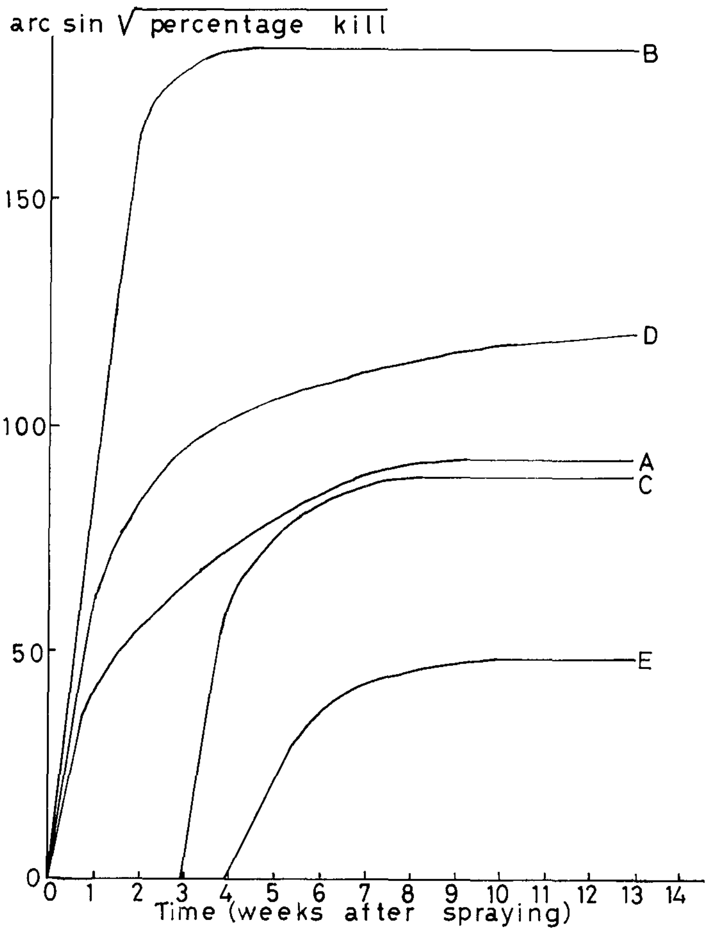

Fig. 3. The effect of various chemicals on moss at the soil surface.
A—captafol; B—glyphosate; C—paraquat+diquat; D—2,4-D+MSMA+diuron; E—control.

unsignificant again. The 0.3 percent concentration had a significant effect from the first week and remained so until the end of the observation, but after the 11th week its effect did not differ significantly from the 0.1 percent concentration. The highest concentration, 0.5 percent had a significant better effect than the two lower concentrations throughout the time of the experiment.

The second experiment showed that glyphosate gave the best control of moss on the soil surface, although it was not a complete control. This was followed by a mixture of 2,4-D-amine and MSMA+diuron, captafol and paraquat+diquat (Fig. 3). Looking at the interaction between treatment and time, it is interesting to note that glyphosate gave a highly significant better control than all other treatments from the second week after spraying on throughout the time of the experiment (14 weeks). Only the first week it was not significantly different to the 2,4-D-amine+(MSMA+diuron) treatment. The 2,4-D-amine+(MSMA+diuron) treatment was not consistently significant better than the paraquat+diquat, and captafol treatment but at the end of the observation it gave a significantly better percentage of kill. Captafol and paraquat+diquat caused about the same percentage kill at the end but overall speaking captafol was better than paraquat+diquat.

Discussion and Conclusions

Beside efforts to control moss in tea, investigations should be made to estimate the loss of tea-leaf and the inhibition of growth of the tea bush, in order to be able to recommend sound control methods. Studies on the influence of continueous moss cover to the soil profile development will be interesting and may be of use in explaining some of the effects of moss in tea.

The results of this preliminary study shows that chemicals can be used to control moss in tea, but further experimentation is needed before it can take over the time consuming and elaborate manual mechanical control.

Captafol at a concentration of 0.5 percent and a spray volume of 1,000 l/ha was able to cause almost 60 percent kill to moss the soil surface, but moss on the tea-trunk and branches were not sufficiently controled. This may be due to an improper application of the spray because spraying was done in one operation with the soil surface treatment using a flood jet nozzle. The lower percentage kill obtained in the second experiment with the same concentration of captafol is presumably due to the much lower spray volume used. Spraying of 0.5% captafol on the tea trunk branches and older leaves did not show any detectable adverse effects.

Glyphosate at 1% concentration and a spray volume of 400 l/ha, equivalent to approximately 1.5 kg a.i./ha, gave more than 75 percent kill of the moss cover. Using a higher dose or repeating the spray would probably give a better control.

2.4-D-amine (1.25 kg a.i./ha)+(MSMA+diuron) (0.4 kg a.i./ha) was less effective, causing only about 41.7 percent kill. The other two treatments, paraquat+diquat and captafol were poor in their performance.

In this experiment it was observed that moss in the sporophyt phase were more affected by the chemicals used, especially the genus *Marchantia* and *Dicrauum*. Further studies will be conducted to confirm this observation.

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Preliminary Studies on the Use of Maleic Hydrazide for the Control of Leguminous Cover Crop Encroachment in Rubber and Oil Palm

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Abstract. The leguminous creepers *Pueraria phaseoloides*, *Centrosema pubescens*, *Galopogonium mucronoides* and *Galopogonium caeruleum* are widely used as covers on rubber and oil palm plantations. The rapid and profuse growth of these covers has lead to the undesirable encroachment into weeding circles. A control measure by using 1,2-dihydro-3,6-pyridazinedione (maleic hydrazide) is being developed as a possible retardant for slowing down the encroachment. At the rate of 1.0 kg/ha the encroachment can be effectively checked for a period of 3 to 4 months. Phytotoxicity aspects are still under investigation. Our data so far indicates that the chemical can be used safely.

Introduction

The normal upkeep method in immature rubber and oil palm is by keeping relatively weed-free circles or strips. This is done by either manual weeding or by using selected herbicides like monosodium acid methane arsonate+3-(3,4-dichlorophenyl)-1,1-dimethyurea (MSMA+diuron), monosodium acid methane arsonate+sodium chlorate (MSMA+sodium chlorate), 1,1′-dimethyl-4,4′-bipyridinium dichloride+3-(3, 4-dichlorophenyl)-1,1-dimethyurea (Paraquat+diuron) etc. In areas where a pure leguminous cover of *P. phaseoloides*, *C. pubescens*, *C. mucronoides* and *C. caeruleum* are maintained, weed regeneration in the weeding zones is generally slow especially on the inland soils.

In such areas, upkeep is therefore aimed at controlling the rapid encroachment of these covers into the weeding zones. Herbicide spraying will normally give control for about 4–5 weeks before a respray is necessary. If hand-weeding is chosen, a follow-up is required 2–3 weeks after. This method is expensive.

Leguminous covers are desirable for rubber and oil palm plantations. Advantages include prevention of soil erosion because of their profuse growth and rapid coverage, improvement of soil conditions and nutrient status especially nitrogen and weed suppression as well as pest control to a certain extent. The rapid growth has however been costly to plantation management in preventing the covers from climbing over the young trees resulting in growth retardation.

This paper reports some of the preliminary findings on using maleic hydrazide, a growth retardant to slow down the encroachment of these covers.

EXPERIMENTS

Two experiments were conducted on two estates, one on rubber and one on oil palm. Pure stand of leguminous covers were maintained in these experimental areas.

Experiment 1. The objective of the experiment is to compare the effectiveness of maleic hydrazide in controlling the encroachment of leguminous covers to some of the most commonly used herbicides. This experiment was conducted on an oil palm estate on coastal clay soil. The leguminous covers were mainly *P. phaseoloides* intermingled with traces of *C. pubescens* and *C. caeruleum*. The covers were vigorously growing and the age of the palms was $1\frac{1}{2}$ years.

The weeds and the enroached covers in the circles were first removed by manual means. The circle size was about 1.5 m in radius. The major weeds were *Borreria latifolia*, *Digitaria longiflora*, *Asystasia coromandeliana*, sedges of *Cyperus* species. Chemical applications were then carried out by spraying a 0.75 m band on the periphery of the circles. A knapsack hand-operated sprayer fitted with 9504 even-flat nozzle tip was used. Walking speed was maintained at 3.2 km/hr. The experiment was a randomised complete block design replicated five times. Each plot consisted of 2 palms. Assessment on the extent of the encroachment was done by placing a 1.2 metre radius ring round the palm base and the encroached covers within the ring were chipped, air-dried and weighed. A total of 3 readings was taken throughout a period of 3 months.

The control received no chemical treatment. Results are shown in Table 1.

The results showed that: 1) 30 days after treatment, all treatments except the control gave good results. 2) 55 days after treatment, maleic hydrazide provided better encroachment control than the rest. 3) 89 days after treatment, results of maleic hydrazide were satisfactory. Encroachment in other treatment plots was high.

Other observations: 1) The addition of diuron at 2.4 kg to maleic hydrazide appeared to reduce the efficacy of the chemical. Scorching of leaves was observed which did not occur in plots treated with straight maleic hydrazide. 2) Weed regeneration in

Table 1. Air-dried weight of encroached leguminous cover crops.

Treatment	Rate/180 litres water (kg)	Average weight (g) of 5 replications		
		Days after treatment		
		30	55	89
Maleic hydrazide	1.0	53	141	425
Maleic hydrazide	1.5	77	91	434
MSMA+diuron	2.5+0.5	27	378	757
MSMA+sodium chlorate	2.8+5.6	31	350	831
Paraquat+diuron	0.56+0.56	61	329	604
Paraquat	0.56	118	343	595
Maleic hydrazide+diuron	1.5+2.4	20	184	544
Control		397	428	581
Min. 5% sig. difference		64.6	164.5	

this particular experiment was rapid. Satisfactory upkeep must include clean circles as well as checking the encroachment of cover crops. 3) Leaf elongation of cover crops was noticed after maleic hydrazide application at 1 kg and 1.5 kg/180 litres water. Thickening of young leaves coupled with slight chlorosis was evident.

Experiment 2. The objective of the experiment was to find an optimum rate for the control of the encroachment of *C. caeruleum*. This cover crop is very useful as it is very prolific and tolerates shade well.

The experiment was conducted in rubber of $1\frac{1}{2}$ years old on inland soil on a slight sloping terrain. During the experimental period, the weather was dry, but the cover crop was growing well. The area was in an open situation as the canopy of the rubber was still small. The weeds in the circles were removed and encroached vines chipped to a 1.2 metre diameter circle. The method of spraying was the same as in Experiment 1.

The experimental design was a simple completely randomised block with 4 treatments replicated 3 times. Eight circles were used in one plot. Assessment were made by measuring the length of the encroached covers and the percentage coverage.

The control plots received no chemical treatments. Results are shown in Tables 2 and 3.

It was obvious that all maleic hydrazide treatments gave good control. The encroachment in the control plots was very high and in view of this, the encroached covers were pulled back to the initial circle size.

Subsequent to this assessment, the method was changed. Instead of taking length measurement, visual scoring of the percentage of encroached covers was taken.

Satisfactory control up to about 3 months was observed on all maleic hydrazide treatments even at the lowest rate. Encroachment was very high in the controls. Most rubber trunks were entangled with covers. Weed regeneration in the experimental plots

Table 2. Length measurement of encroached *C. caeruleum* 28 days after treatment.

Treatment	Rate/180 litres water (kg)	Average length (cm)
Maleic hydrazide	1	0
Maleic hydrazide	2	3.8
Maleic hydrazide	3	0
Control	—	255.7

Table 3. Percentage coverage of encroached *C. caeruleum* in circles.

Treatment	Rate/180 litres water (kg)	% coverage	
		Days after treatment	
		65	94
Maleic hydrazide	1	12.0	45.0
Maleic hydrazide	2	13.3	36.6
Maleic hydrazide	3	8.7	42.0
Control	—	50.0	75.0

was low, only traces of broadleaf-weeds like *B. latifolia* and *Cleome burmani* were found.

From this experiment a preliminary conclusion can therefore be drawn that weeding cost can be substantially reduced. The weeding rounds can be reduced if the encroachment can be controlled for a period of about 3 months.

Problems and Future Development

As maleic hydrazide does not control weeds at the effective rate against cover encroachment, possible combinations with other post-emergent herbicides were explored. The objective was to find out whether a dual purpose programme of controlling weeds and encroachment can be achieved.

Observational trials showed that the effects of maleic hydrazide were nullified when post-emergent herbicides were incorporated. The use of pre-emergent herbicides will therefore be explored. This is aimed at maintaining relatively clean circles with the use of a pre-emergent herbicide and control the encroachment of leguminous covers with the use of maleic hydrazide. The extent of weed control of the pre-emergent herbicide should be about 3 months. Substantial saving in labour can be achieved if such a technique can be devised.

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"Alang-alang" [*Imperata cylindrica* (L.) Beauv.] Control in Immature Rubber

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Abstract. One of the most troublesome weeds in plantation crops in South East Asia is *Imperata cylindrica* (alang-alang). Its complete eradication in immature rubber is of primary importance in ensuring the normal growth of the trees. Mechanical eradication by hand or by tractor ploughing is difficult and costly. Chemical control has proved to be the most efficient method of eradication.

This paper describes an experiment on alang-alang control in immature rubber. Four translocated herbicides 2,2-DPA (dalapon), amitrole, glyphosate and TFP were tested, straight or in mixtures, usually with an initial followed by a subsequent application.

The best control was observed on plots which had received tank mixtures of TFP and 2,2-DPA sprayed in two subsequent applications with eight week intervals. The best ratio was 4.0 kg TFP+6.0 kg 2,2-DPA/ha. Glyphosate applied once at 2.0 kg/ha or twice at eight week intervals at a lower dose, and 2,2-DPA fb 2,2-DPA each at 7.0 kg/ha at four-week intervals were intermediate in their effect. The least effective treatments were amitrole at 2.5 kg/ha followed by 2,2-DPA at 7.0 kg after four weeks, and hand-weeding at four-week intervals.

Introduction

Alang-alang is widely recognized as one of the most troublesome perennial grass weeds in the tropics. Holm (1969) listed alang-alang among the world's ten worst weeds in major agricultural areas in warmer regions. In Indonesia alang-alang is distributed widely from 0–2,700 m above sea level and, not including Java, occupies about 15–20 million ha (Anon., 1975).

The grass is found in arable land, deforested and reafforested areas, in shifting cultivation, upland farms and plantations especially in rubber, oil palm, coconut and cinchona (Soerjani, 1970).

A survey over more than five years shows that alang-alang has a severely retarding effect on the growth of young rubber, about 40–50% retardation (Anon., 1938); in an extreme situation, yellowing of the foliage will occur, followed by defoliation.

Chemical control of alang-alang in rubber plantations in North Sumatra has been practised for many years, and 2,2-DPA used on a large scale (Mangoensoekarjo, 1975). 2,2-DPA is one of the herbicides recommended for alang-alang both in Indonesia (Anon., 1974; Soedarsan *et al.*, 1975) and in Malaysia (Anon., 1957; Seth, 1970; Ho *et al.*, 1975).

In efficacy tests of new herbicides for alang-alang control, 2,2-DPA is usually the reference herbicide. This paper deals with an efficacy test of glyphosate and TFP two new translocated herbicides for alang-alang.

TFP applied alone was very slow acting on alang-alang (Anon., n.d.; Seth and Fua, n.d.; Mangoensoekarjo and Kadnan, 1973); but if mixed with 2,2-DPA (Anon., n.d.; Mangoensoekarjo and Kadnan, 1973) or with paraquat (Seth and Fua, n.d.) it gave a rapid and good effect.

Materials and Methods

The trial was conducted at Deli Muda estate, P. T. Indah Poncan (private rubber estate) Medan, Indonesia, during the period of June 1974 to March 1975 on poorly drained alluvial soil, pH 5.5.

An area of heavy sheet alang-alang between the rows of immature rubber trees was divided into 6 m × 8 m plots. The alang-alang was 1.50–1.80m high.

The trial had a randomized block design, with thirteen treatments and four replications (Table 1).

Spraying was with a knapsack sprayer fitted with a red (.078) polijet tip nozzle. To ensure equal spray per plot, the pressure was kept constant at 15 lb p.s.i. by use of a gauge and a walking-speed of 3 km per hour controlled by stop-watch. The spray

Table 1. Treatments.

	Treatment*	Rate (kg a.i./ha)*	Interval between applications (weeks)
1.	Glyphosate	2.0	—
2.	Glyphosate fb glyphosate	1.0 fb 1.0	8
3.	Glyphosate fb glyphosate	1.5 fb 1.5	8
4.	Glyphosate fb glyphosate	1.5 fb 1.0	8
5.	Glyphosate/2, 2-DPA fb Glyphosate/2, 2-DPA	(1.0/4.0) fb (1.0/4.0)	8
6.	Glyphosate/2, 2-DPA fb Glyphosate/2, 2-DPA	(0.5/4.0) fb (0.5/4.0)	8
7.	TFP/2, 2-DPA fb TFP/2, 2-DPA	(4.0/6.0) fb (4.0/6.0)	8
8.	TFP/2, 2-DPA fb TFP/2, 2-DPA	(4.0/3.0) fb (4.0/3.0)	8
9.	TFP/2, 2-DPA fb TFP/2, 2-DPA	(2.0/6.0) fb (2.0/6.0)	8
10.	Amitrole fb 2, 2-DPA	2.5 fb 7.0	4
11.	2, 2-DPA fb 2, 2-DPA	7.0 fb 7.0	4
12.	Hand-weeding	—	4
13.	Non- weeding	—	—

* fb=followed by (sequential) . . . weeks after first application. glyphosate=Roundup=3 lbs a.e/ U.S. gallon, 2, 2-DPA=Basfapon=74% a.e., TFP=Frenock 60 AC=60% (W/W), amitrole= Weedazol T.L.=27.8%.

volume was maintained at 800 l water per sprayed hectare.

The effects on the alang-alang were recorded from two to eighteen weeks after spray as visual estimates of the percentage scorch relative to the unsprayed control: 0-indicating no effect and 100-complete dessication (Tables 2 and 3). After eighteen weeks the percentage of regrowth was recorded up to the thirty-fifth week. The effect of treatments on rubber leaves was assessed visually.

Data were analysed using Duncan's multiple F and range test. Because of accidents fourteen weeks after spraying, the values for treatments No. 7 repl. I and No. 2 repl. III were obtained by using the missing data formula.

Results and Discussion

Phytotoxicity. No toxicity symptoms were observed in any of the treatments on the rubber leaves ten days after spray or at the final observation.

Herbicidal activity. Glyphosate: The effect of glyphosate on alang-alang began to appear about five days after spray. After ten days the blades became dull in colour, and about 50–75% of them in yellow. After five weeks 60–80% became desiccated and the remainder yellow. Glyphosate applied at 1.5 fb 1.5 kg/ha was significantly different from glyphosate applied at 1.0 fb 1.0 kg/ha, but not with other glyphosate treatments as well as glyphosate/2,2-DPA mixture (Table 2). Trials conducted by Monsanto Far East Ltd., showed that one spray of 2.0 lb a.e./acre glyphosate on sheet alang-alang on wet, low-lying soils, provided maximum control of 88% from 60–120 days after spray, and on well-drained soils of 91–94% from 60–150 days (Wong, 1975).

Regrowth at 35 weeks (Table 3) showed that glyphosate treatments were highly significantly different from the control plots (both on hand-weeded and non-weeded plots). It seemed that glyphosate 1.5 fb 1.5 kg/ha was comparable to that of 7.0 fb 7.0 kg/ha 2,2-DPA. At Curug estate, Indonesia, the shoot-count (regrowth) four months after spray, indicated that 3.0 kg/ha glyphosate was comparable with 25.5 kg/ha 2,2-DPA applied 3 times (12.75 fb 8.5 fb 4.25 kg/ha, at one month intervals) (Soedarsan *et al.*, 1975).

TFP/2,2-DPA mixture: The effect of TFP/2,2-DPA mixture on alang-alang appeared after about one week. After two weeks 60–80% of the foliage was yellow, and after five weeks desiccation began. In a previous trial (Mangoensoekarjo and Kadnan, 1973) TFP applied alone at 4.0 and 6.0 kg/ha had very little effect, giving only 10% and 20% control respectively at nine weeks after spray.

All the TFP/2,2-DPA mixtures reached 82.5–90% control level at eighteen weeks after spray (Table 2), whereas TFP 4.0/2,2-DPA 6.0 kg/ha gave better control than other herbicides tested.

Also the regrowth at thirty five weeks after spray was the lowest and was highly significantly different from other treatments, except glyphosate 1.5 fb 1.5 kg/ha, 2,2-DPA 7.0 fb 7.0 kg/ha and other TFP/2,2-DPA mixtures (Table 3). It was indicated that TFP/2,2-DPA mixtures had the ability to prevent the regrowth of alang-alang for quite a long period.

Amitrole fb 2,2-DPA and 2,2-DPA fb 2,2-DPA: The effects of amitrole fb 2,2-

Table 2. Mean percentage control of alang-alang.

Treatments	2 weeks			5 weeks			10 weeks			14 weeks			18 weeks		
	%*	.05	.01	%*	.05	.01	%*	.05	.01	%*	.05	.01	%*	.05	.01
1. Glyphosate 2	78.8	ab	a	78.8	ab	a	80.0	a-d	a-c	81.3	a-d	ab	80.0	bc	ab
2. Glyphosate 1 fb 1	55.0	de	cd	63.8	cd	bc	70.0	a-c	a-c	76.3	b-d	ab	75.0	c	bc
3. Glyphosate 1.5 fb 1.5	62.5	cd	bc	71.3	bc	ab	73.8	b-d	a-c	83.8	a-c	ab	86.3	ab	ab
4. Glyphosate 1.5 fb 1	70.0	bc	ab	73.8	a-c	ab	75.0	b-d	a-c	78.8	a-d	ab	76.3	bc	a-c
5. Glyphosate/2,2-DPA 1/4 fb 1/4	71.3	bc	ab	70.0	bc	ab	77.5	a-d	a-c	81.3	a-d	ab	77.5	bc	ab
6. Glyphosate/2,2-DPA 5/4 fb 5/4	46.3	e	de	55.0	d	c	68.8	cd	bc	71.3	d	b	76.3	bc	a-c
7. TFP/2,2-DPA 4/6 fb 4/6	78.8	ab	a	77.5	ab	ab	86.3	a	a	86.3	ab	a	90.0	a	a
8. TFP/2,2-DPA 4/2 fb 4/2	61.3	cd	bc	55.0	d	c	67.5	d	c	75.0	cd	ab	82.5	a-c	ab
9. TFP/2,2-DPA 2/6 fb 2/6	73.8	ab	ab	71.3	a-c	ab	81.3	a-c	a-c	82.5	a-c	ab	85.0	a-c	ab
10. Amitrole fb 2,2-DPA 2.5 fb 7	35.0	f	e	81.3	a	a	85.0	ab	ab	87.5	a	a	81.3	a-c	ab
11. 2,2-DPA 7 fb 7	82.5	a	a	80.0	ab	a	86.3	ab	ab	86.3	ab	a	86.3	ab	ab
12. Hand-weeding	82.5	a	a	40.0	e	d	47.5	e	d	21.3	e	c	61.3	d	c
13. Non-weeding	2.0	f	f	2.8	e	d	4.3	e	d	3.8	e	c	5.0	d	d
C.V. %	8.2			7.5			9.7			8.3			8.1		

* Original data, ANOV based on values transformed to arcsin $\sqrt{\%}$.

Any two means followed by the same letter are not significantly different at the 5% level (left) and not highly significantly different at the 1% level (right) (Duncan's multiple range test).

Table 3. Mean percentage regrowth of alang-alang.

Treatments	22 weeks			27 weeks			31 weeks			35 weeks		
	%*	.05	.01	%*	.05	.01	%*	.05	.01	%*	.05	.01
1. Glyphosate 2	31.3	bc	bc	31.3	cd	b-e	45.0	bc	b-d	52.5	b	b
2. Glyphosate 1 fb 1	41.3	b	b	50.0	b	b	57.5	b	b	60.0	b	b
3. Glyphosate 1.5 fb 1.5	26.3	b-d	b-d	35.0	bc	b-d	40.0	b-d	b-e	40.0	bc	bc
4. Glyphosate 1.5 fb 1	31.3	bc	bc	40.0	bc	bc	50.0	b	bc	50.0	b	b
5. Glyphosate/2,2-DPA 1/4 fb 1/4	32.5	bc	bc	38.8	bc	b-d	51.3	b	bc	57.5	b	b
6. Glyphosate/2,2-DPA 5/4 fb 5/4	26.3	b-d	b-d	30.0	cd	b-e	37.5	b-d	b-e	50.0	b	b
7. TFP/2,2-DPA 4/6 fb 4/6	16.3	de	cd	13.8	e	e	17.5	e	e	17.5	d	c
8. TFP/2,2-DPA 4/2 fb 4/2	11.3	e	d	12.5	e	e	21.3	de	de	18.8	d	c
9. TFP/2,2-DPA 2/6 fb 2/6	16.3	de	cd	17.5	de	de	17.5	e	e	20.0	cd	c
10. Amitrol fb 2,2-DPA 2.5 fb 7	26.3	b-d	b-d	27.5	cd	b-e	40.0	b-d	b-e	57.5	b	b
11. 2,2-DPA 7 fb 7	20.0	c-e	cd	25.0	c-e	c-e	27.5	c-e	c-e	40.0	bc	bc
12. Hand-weeding	86.3	a	a	88.8	a	a	90.0	a	a	89.5	a	a
13. Non-weeding	97.3	a	a	100.0	a	a	97.0	a	a	92.5	a	a
C.V. %	16.1			16.8			18.6			19.8		

* Original data, ANOV. based on values transformed to arcsin $\sqrt{\%}$.

Any two means followed by the same letter are not significantly different at the 5% level (left) and not highly significantly different at the 1% level (right) (Duncan's multiple range test).

DPA or 2,2-DPA fb 2,2-DPA did not differ significantly either in degree of control at eighteen weeks or the regrowth of the alang-alang at thirty five weeks. But there was less regrowth in the 2,2-DPA fb 2,2-DPA treatments than in the amitrole fb 2,2-DPA treatment (Table 3).

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Bracken Control with Asulam in Relation to the Rhizome and Frond Development

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Abstract. The rhizomes of one bracken (*Pteridium aquilinum* Kuhn) plant had a total length of 30 m, a diam. of 1 cm and a depth in the soil of 7–25 cm. New fronds emerged in late April and growth of rhizomes slowed down in early autumn. At the end of a growing season, the majority of secondary rhizomes carried 1–2 frond buds. Asulam (*N*′-methoxycarbonylsulfanylamide), applied to foliage, killed the fronds within 2 months and prevented regrowth. Asulam appeared to be translocated to the growing point of rhizomes, and ^{14}C-asulam tended to concentrate in frond buds and rhizome apicies.

INTRODUCTION

Among the compounds known to be effective to bracken, asulam was found to have the greatest herbicidal activity in 1968, inducing deleterious effects on the rhizome system when applied as a foliage spray. This report will present observations on rhizome and frond development of field bracken and the effects induced by asulam upon rhizome of the plant when applied to foliage. Also the distribution of ^{14}C-labelled asulam will be reported.

MATERIALS AND METHODS

Rhizome system. The rhizome sample was taken from a native infestation of bracken on May 8, 1970, in Koka-cho, Shiga-prefecture, in the central part of Japan. The rhizome system of one bracken plant was dug up, and rhizome length, branch system and number of frond buds were recorded.

Effect of asulam on field bracken. Field studies were carried out on a natural stand of bracken. The chemical was applied to the stand (5×10 m) by means of a power sprayer in September 1970 (autumn treatment) and July 1971 (summer treatment). Amount of asulam used was 60 g/a, diluted in water to 10 l/a. The bracken stand averaged 1.8 m in height and 35 fronds per square meter. Rate of injury to fronds and rhizomes was recorded on a scale of 0 to 5.

Distribution of ^{14}C-asulam. Test plants were grown from sporelings in a greenhouse. For fronds, 3.0 μci of ^{14}C-asulam (specific activity 43.5 μci/mg) in 0.1 ml of water was applied to the upper surface of laminae using a hair pen. Plants were harvested after 10 days following treatment, air-dried, mounted, autoradiographed and radioassayed

by liquid scintillation spectrometry.
TTC-reaction. The rhizomes of the treated area were sampled and separated according to various organs. Fragments were washed in water, suspended in a TTC-solution for 2 hrs at 37°C, and enzymatic activity was checked according to the color reaction.

RESULTS

Rhizome system. One bracken plant had a total length of rhizomes of 30 m; length of the main rhizome was 3.7 m, the average length of the primary branches 1.25 m, and the secondary branches 0.29 m. A rhizome varied in depths from 7 to 25 cm, but the main rhizome run at a uniform depth; maximum depth of about 20–25 cm (Table 1).
Effect of asulam on field bracken. In the experiment in summer season, bracken fronds were very susceptible to injury by asulam, and practically eliminated with 60 g/a of asulam (Table 2). Young fronds were most susceptible, dying within 20 days and mature fronds within 60 days after treatment. Emergence of fronds from the treated area was

Table 1. Rhizome system of one bracken plant which was taken from a native infestation of bracken in the central part of Japan.

Total length of rhizome system		30.3 m
Main rhizome	Length	3.7 m
Primary branch	Total length	15.0 m
	Length per branch	1.25 m
	Total no. of buds and apicies	112
Secondary branch	Total length	11.6 m
	Length per branch	0.29 m
	Total no. of buds and apicies	160
Occupied area		3×4 m
Depth of rhizome in the soil	Main rhizome	17–25 cm
	Primary branch	7–13 cm
	Secondary branch	7–13 cm

Table 2. Effect of asulam summer treatment on fronds and rhizomes of field bracken.

Stage of frond	Injury rating[a]					Resprouting activity after treatment		
	Days after treatment					Days after treatment		
	10	20	30	45	60	20	30	300
Fully expanded	0	1	1	3	5			
Half expanded	1	3	3	5	5			
Primary expanded	1	4	5	5	5			
Before expanding	1	5	5	5	5			
						+[b]	—	—

[a] Scale 0: no injury, 5: all fronds dead; rating accounted for necrosis and chlorosis. [b] +: resprouted, —: not sprouted

observed within 20 days after treatment, but the growth was inhibited severely and they died soon after.

The experiment in autumn was designed to determine whether regrowth from the treated area in next year could be controlled. The symptoms of injury appeared somewhat later than in summer, probably due to lower temperatures. But all the treated fronds were dead within 2 months after treatment and regrowth from the rhizomes of the treated area was prevented in the following year and in the year after that.

Rhizome samples taken from the asulam treated bracken were grown in a greenhouse, but all resprouted samples died within 35 days of emergence (Table 3). There was no resprouting over a 30 days period. From the data, asulam appeared to be translocated within 7 days of treatment to the growing point of rhizomes and frond buds in sufficient quantities to cause decay.

Distribution of ^{14}C-asulam. Uptake was followed by movement and accumulation of ^{14}C-asulam in other parts of the rhizome system. Higher specific activity was accumulated in the growing points of the rhizome (Table 4). In general, apicies and frond buds showed higher specific activity than rhizome internode.

TTC-reaction. Rhizome organs gave a positive response to the Tetrazolium test for viability 15 days after treatment, but the response was negative 60 days of treatment. After 6 months rhizome organs showed symptoms of necrosis and almost all decayed 16 months after treatment.

Table 3. Bud activity[a] of the rhizome segments sampled from the treated area with asulam of 60 g/a[b].

Treatment duration (day)	Resprouting activity	Days of emergence (day)	Maximum frond length (cm)	Days of frond dying after emergence (day)
7	+	14	1.0	18
10	+	17	1.0	20
15	+	23	1.0	35
30	—	—	—	—
Control (untreated)	+	10	30.0	—

[a] Bud activity was checked in greenhouse at 25–30°C. [b] Bracken was treated with asulam on June 1971.

Table 4. Distribution of ^{14}C-asulam in bracken rhizome 10 days after treatment to the laminae of frond.

Plant parts	Count per minute (cpm)	Dry weight (mg)	Degradation per minute (dpm/mg)
Rhizome apex	17,530.3	11.7	2,079.6
Rhizome internode (1)[a]	10,035.1	10.9	1,260.5
Frond bud in soil	1,990.1	1.7	1,609.4
Rhizome internode (2)	5,980.7	19.8	414.3
Rhizome internode (3)	8,059.1	53.8	206.1
Rhizome internode (4)	12,017.0	137.6	118.7

[a] No. indicates order of distance from the rhizome apex.

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Bracken Control with Asulam in New Zealand

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Abstract. Bracken control with asulam (methyl 4-aminobenzene sulphonyl carbamate) in New Zealand is reviewed. Long term control of bracken (*Pteridium aquilinum* var. *esculentum*) has been achieved as in other areas but in New Zealand also a further important use has been developed whereby newly planted trees are released from bracken competition by applying asulam earlier in the season as the fronds are starting to unfurl. Long term control has been achieved in trials when applications were made to bracken fronds which were fully expanded but soft. Both uses of asulam are discussed in conjunction with management aspects in agricultural and forestry situations.

Introduction

Since 1970 a large number of field experiments have been carried out in the United Kingdom, Japan, Australia and New Zealand investigating bracken control with asulam (Holroyd *et al.*, 1970; Soper, 1972; Scragg *et al.*, 1972). These have confirmed that excellent control can be obtained for periods up to two years depending upon rates of application, methods of application and spray timing.

In New Zealand it was recognised that bracken by being a different variety than that commonly occurring in the United Kingdom exhibited distinct morphological differences such as greater cuticle formation, different patterns of emergence and possible different frond/rhizome ratios.

Early trials were thus carried out to establish the degree of long term control that could be obtained and the extent to which asulam could suppress frond emergence or expansion in the season of application. At a later stage, much of this work was conducted in conjunction with forestry organisations as management scale trials. Two main aspects were covered: (a) Long term bracken control- for possible use as a land preparation application prior to planting forest land or in agricultural or amenity areas. (b) The release of newly planted *Pinus radiata* from bracken.

Long Term Bracken Control

At one site only asulam was applied to randomised plots of 0.036 ha replicated three times. Rates employed were 2.2, 4.5, 9.0 kg/ha in 95 litres of water/ha. Different times of application were made through one growing season as shown in Fig. 1. All

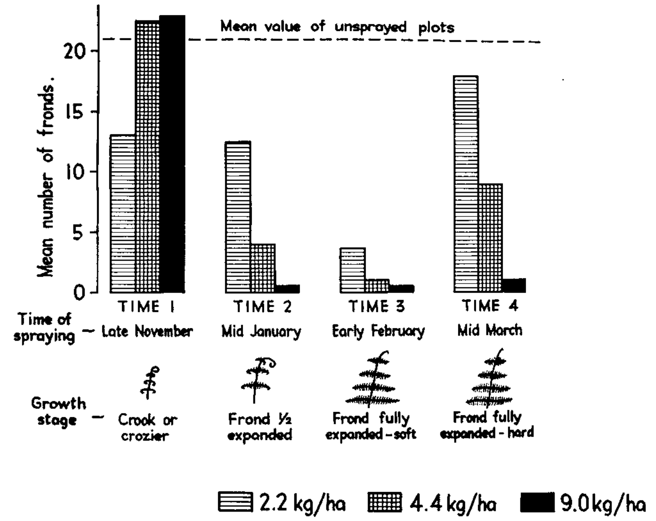

Fig. 1. Long term bracken control. Effect of timing and dose of asulam on frond regrowth 9–12 months after application.

plots were mechanically defoliated in mid-winter before and after the applications to help synchronise frond emergence and remove complications in assessments caused by the presence of overwintered fronds.

The results of this study show that applications of asulam applied when the majority of bracken fronds were fully expanded but soft gave excellent control after twelve months (Time 3 in Fig. 1). At this optimum time even the lowest rate of asulam applied gave very good control.

In an effort to confirm these results, a series of management scale trials commenced in January and February 1974 in both agricultural and forestry situations. Using the information gained in the small plot trials applications were made as closely as possible to "fully expanded but soft" growth stage of bracken. A standard rate of 0.4% asulam was used in the hand lance applications.

In all cases except where defoliation had taken place the winter before application, poor long term control was observed and as a consequence, additional trials are still in progress studying pre-spray management and possible additions to asulam.

Releasing

The activity of asulam at the earlier growth stages, i.e.: when fronds are just starting to unfurl has been reported elsewhere (Wasmuth, 1973a; 1973b).

During January/February 1974 and 1975 commercial applications of asulam for bracken releasing in forestry have been carefully monitored and the results visually assessed on a 0–5 scale, where 0=no effect and 5=complete dessication of bracken fronds. The results obtained are shown in Table 1.

These results indicate that good short term frond suppression has been obtained

Table 1. Releasing

Year	Rating					
	0	1	2	3	4	5
1974	—	1	—	7	11	6
1975	1	—	2	4	16	8

Figures shown are the number of sites where the stated rating has been obtained.

consistently over two seasons although some variations have occurred due mainly to faulty or incorrect timing of applications. Mixtures of asulam and 245-T were employed in some sites where mixed associations of scrub weeds and bracken occurred. No hand releasing was necessary where a rating result of 4 or above was obtained.

Discussion

Long term control. The results of small plot trials for long term control have not yet been duplicated in all management csale applications. Until further work has been completed all the reasons for this cannot be fully explained. The following factors appear to be implicated:

(a) Pre-spray management. In existing bracken communities in New Zealand there is usually an extended period of frond emergence in early summer; correct timing of spraying is difficult. This is further complicated by the fact that existing fronds will often survive for more than one year—thus there is usually a mixture of old and new fronds present early in summer. After removing existing foliage in winter, a more even emergence usually results in summer and thus the majority of fronds are at a similar growth stage at any point in time. A lower frond number to rhizome ratio may also occur.

(b) Frond Expansion. It is a characteristic of the New Zealand variety of bracken that the pinnae expand very quickly and become very hard virtually as soon as they are fully open.

(c) Cuticle Development. The extreme hardness of the fronds, together with a covering of brown scales appears to severely reduce the uptake of asulam. The addition of wetting agents or other adjuvants may assist penetration.

Releasing. The activity of asulam on newly emerging bracken fronds is very consistent in New Zealand and the main limitations on activity are related to timing of spray and spray coverage. Asulam appears to move towards the tips of the expanding pinnae. Thus good spray coverage is very important; if the bracken fronds are well expanded at spraying the quick dessicant effect will not occur and consequent tree release will not be obtained.

The importance of bracken as a competitive weed in newly planted forests in New Zealand has been indicated by the interest shown from forestry workers throughout New Zealand. The fact that *Pinus radiata* is tolerant to asulam and that the compound will give good suppression of bracken fronds has allowed labour to be utilised for other tasks. It is still hoped that long term control of bracken will be confirmed on a management scale as this, if used as a pre-burn/pre-plant spray could obviate the need for releasing after planting.

Bracken is also an extremely important weed infesting vast areas of marginal agricultural land. In the South Island of New Zealand alone, it has been estimated that over 1,000,000 ha are infested (Preest, 1975).

As the need for increased agricultural productivity becomes greater, the use of herbicides coupled with suitable management practices will undoubtedly be necessary. The toxicity of bracken to livestock is not a problem at present except in isolated instances where cattle are forced on to bracken infested country or selectively graze newly emerging fronds after a burn before grasses regenerate.

Acknowledgments

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Control of Kudzu Vine and Brush with 3, 4-DP Butyl, 2-(3′, 4′-Dichlorophenoxy) propionic Acid Butyl Ester

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Abstract. To control Kudzu vine (*Pueraria Thunbergiana*) and brush has been of major importance in Japanese forestry management. This presentation introduces the effectiveness of 3,4-DP butyl, 2-(3′,4′-dichlorophenoxy) propionic acid butyl ester, against Kudzu vine and some of dominant woody plants in forestry, together its selectivity between them and typical useful trees, such as cedar (*Cryptomeria Japonica* D. Don) and Japanese cypress (*Chamaecyparis obtusa* Endl.).

INTRODUCTION

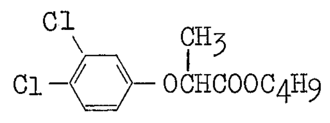
From the value of utilization, cedar and Japanese cypress are most important species of trees in Japanese forestry management. Kudzu vine and brush are very harmful in vegetation of useful trees, with the reasons that they disturb growth of planted seedling of trees through shading sunshine and absorbing nutrients in soils. Thus protection of cedar and Japanese cypress against infestations of Kudzu vine and brush has been of major importance in forestry management, especially afforestation area.

Herbicidal activity of 3,4-DP has not been fully investigated in the past, while 2,4-D, dichlorprop, MCPA, mecoprop, 2,4,5-T, silvex, etc., those which have either chlorine atoms or methyl radical in 2 and 4 positions in their substitutions, have been widely studied.

This repot presents herbicidal activity and selectivity of 3,4-DP butyl.

MATERIALS

3,4-DP butyl has following chemical structure and acute toxicological properties.



The boiling point of this compound is 145–147°C at 2 mmHg, and its acute toxicity LD_{50} for rats are 660 mg/kg (oral), more than 7,680 mg/kg (dermal) and 600 mg/kg (intravenous).

Various experiments were carried out in order to evaluate herbicidal activity and selectivity of this compound, and some of the typical examples of such experiments are shown below.

EXPERIMENTS

Experiment 1. Fundamental assays.

Biological activity of 3,4-DP was evaluated by Avena straight-growth (Tukey *et al.*, 1954), Raphanus test (Takematsu, 1961) and other test method in comparison with other phenoxy compounds.

The following order of auxin activities in Avena test was observed, in which 3,4-DP showed similar activity as 2,4-DP.

2,4-D(Na)>2,4,5-T(Na)>2,4-DP(Na)≒3,4-DP(Na)>3,4-D(Na)

In the test to evaluate biological activity by determing rate of root-growth of rice, a similar tendency as in Avena test was observed.

In Raphanus test however the auxin activity of 3,4-DP was assayed to be the lowest, which was different from the results of the other two tests.

2,4-D>2,4-DP≧3,4-D>3,4-DP

Difference in activity of 3,4-DP according to test methods and species of test plants originated us to proceed further experiments.

Experiment 2. Folia treatment against herbaceous plants.

In order to evaluate activity of 3,4-DP butyl against herbaceous plants, comparison test in pot was carried out by folia treatment with some phenoxy compounds. Chemicals were applied at the concentration of 10 ppm as a.i. respectively. Observation was made 2 weeks after treatment.

As it was shown in Table 1, against most herbaceous plants, activities of the compounds were stronger in the following order, i.e.

2,4-D 2,4-DP 3,4-D 3,4-DP,

except the case of kidney bean, in which the order was;

3,4-D 3,4-DP 2,4-D 2,4-DP.

Table 1. Folia treatment against herbaceous plants. (Conc. 100 pp,)

Test plant	Growth height (cm)	Stage (leaf)	Rating of activity			
			2, 4-D	2, 4-DP	3, 4-D	3, 4-DP
Raddish	10	4	10	10	9–10	2
Tomato	9	1.5	10	8	6	2
Pea	14	5	9–10	7	1	0
Kidney bean	15	1.5	8	5	10	8

Rating; 10, totally killed—0, not affected

Experiment 3. Folia treatment against woody plants.

In order to evaluate activity of 3,4-DP butyl against woody plants, comparison test in pot was carried out by folia treatment with 2,4-D butyl. Test plants were azalea (*Rhododendron obtusum*), persimmon (*Diospyros Kaki*), chestnut (*Castanea pubinenvis*) and *Machilus Thunbergii*. Chemicals were applied at the concentrations of 0.1, 0.2 and 0.4% as a.i. respectively. Observation was made 2 months after treatment.

As it was shown in Table 2, against azalea 3,4-DP showed higher activity than 2,4-D, while its activity against persimmon was lower. Activity of both chemicals against chestnut and *Machilus Thunbergii* were almost same. In spite of the variation of their activities against species of woody plants, persistence of effect of 3,4-DP was observed longer than that of 2,4-D.

Table 2. Folia treatment against woody plants.

Test plant	Height (cm)	Rating of activity					
		2, 4-D			3, 4-DP		
		0.1%	0.2%	0.3%	0.1%	0.2%	0.3%
Azalea	40–50	1	2	4	7	9	10
Persimmon	60–70	8	9–10	10	4	6	8
Chestnut	70–100	7	8	9	6	8	9–10
Machilus Thunbergii	25	0	2	6	1	2	7

Rating; 10, totally killed—0, not affected

Experiment 4. Foliar treatment against conifer.

In order to evaluate phyto-toxicity of 3,4-DP butyl comparison test was carried out against conifer with phenoxy compounds. Chemicals used were emulsifiable concentrates, and they were applied by folia treatment at the concentrations of 0.4 and 1.0% as a.i. respectively. Conifer used were cedar, Japanese cyress and red pine (*Pinus densiflord*). Observation was made 3 months after treatment.

As it was shown in Table 3, phyto-toxicity of 2,4-D and 3,4-D were considerably high and they did not indicate higher selectivity. 3,4-DP showed lower phyto-toxicity and higher selectivity.

Table 3. Folia treatment against conifer.

Test plant	Height (cm)	Rating of activity							
		2, 4-D		2, 4-DP		3, 4-D		3, 4-DP	
		0.4%	1.0%	0.4%	1.0%	0.4%	1.0%	0.4%	1.0%
Cedar	60	3	5	2	3	2	6	0	0
Japanese cypress	40	3	7	1	4	3	6	0	0
Red pine	40	5	6	1	2	2	5	0	0–1

Rating; 10, totally killed—0, not affected

Experiment 5. Field trials of 3,4-DP against Kudzu vine.

In order to evaluate herbicidal effect of 3,4-DP butyl against Kudzu vine, field trials were made by using 7% fine granule formulation of 3,4-DP butyl at forestry areas in Tochigi-, Hiroshima-, Ehime- and Miyazaki-prefecture. Treatments were made by folia treatment at the rate of 100 kg and 150 kg as formulated product per hactare in June–July, 1975. Observations were made 1 and 3 months after treatments, including observation on its effect against some root crowns. The test plots were such areas, where Kudzu vine covered approximately 55–80% at their infestation rates.

As it was shown in Table 4, 3,4-DP butyl adequately controlled Kudzu vine. Effect had started several days after treatment. On observation 3 months after treatment, stem and leaf of Kudzu vine were almost completely killed, and further, severe damage on some root crown was also observed. Application during June and July achieved the highest control.

Table 4. Field trial of 3, 4-DP against Kudzu vine

(Chemical: 3, 4-DP butyl, 7% microgranule)

Plot	Date of application	Dosage (kg/ha)	Mean percent of control		
			Stem and leaf		Root crown
			1 month	3 months	3 months
1	June 20	100	83	95	24
2	July 2	150	92	100	70
3	July 13	100	95	100	—
4	July 27	100	80	90	13

Experiment 6. Field trials of 3,4-DP against brush.

In order to evaluate herbicidal effect of 3,4-DP butyl against brush, several times of field trials were made by folia treatment of 7% a.i. fine granule formulation and 60% a.i. emulsifiable concentrate against dominant species of brush in afforestation area. Locations of the trials were mainly in Tochigi- and Shizuoka-Prefecture. Treatments were made at dosage of either 150 kg/ha of 7% fine granule or 5–8 *l*/ha of 60% EC in spring and summer 1973 and 1974. Observations were made 2–3 months after the treatments respectively.

The following species were adequately controlled by both fine granule and emulsifiable concentrate. They are; *Rhododendron* spp., *Rubus* spp., *Robinia pseudo-Acacia*, *Araliaelata seen*, *Rhus javanica*, *Hydrangea cuspidata* and *Rosa* spp. Species those which were resistant against fine granule, although they were moderately controlled by emulsifiable concentrate were; *Callicarpa japonica*, *Styrax japonica*, *Xanthoxylum piperitum*, *Camellia*, etc.

Discussions

The experiments conducted indicate that 3,4-DP butyl, which has not been fully studied in the past in spite of numerous studies on other phenoxy compounds, having either chlorine atoms or methyl radical in 2 and 4 positions of their substitutions, has the following significant advantages as selective herbicide in Japanese forestry management.

(1) Folia treatment of this chemical in either fine granule or emulsifiable concentrate can control Kudzu vine and brush with minor labour requirement.

(2) Effectiveness of 3,4-DP butyl against Kudzu vine is considerable high, and an adequate application can be possible to prevent regrowth of Kudzu vine.

(3) With its higher selectivity between useful trees and woody plants, overall treatment of both fine granule and emulsifiable concentrate formulations would be applicable.

Acknowledgements

The writers are greatly indebted to the members of forestry experiment stations, those who kindly assisted in offering and managing test plots for this study.

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Effects of Mixture of TFP and Dalapon on Kudzu, *Pueraria lobata* Ohwi

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Abstract. The effects of mixture of TFP (sodium 2,2,3,3-tetrafluoropropionate) and dalapon (sodium 2,2-dichloropropionate) on Kudzu (*Pueraria lobata* Ohwi) were tested.

Foliage application of combined fine granular formulation of TFP (2-3 kg a.i./ha) and dalapon (5–9 kg a.i./ha) exhibited delayed effect on the adult leaves, but elongation of the vines and sprouting of the lateral buds stopped about 10 days after the application. Most of the suberized vines died in the following winter.

In the following year after the application, sprouting of the vines from roots, stolons and stems was strongly inhibited; consequently, the number of vines, their elongation and the growth of leaves were much reduced, and the controlling effect lasted for one year.

INTRODUCTION

Kudzu, one of the important harmful weeds in the forest land, is widely distributed throughout Japan. Vigorous growth of its runner produces a heavy injury to the newly planted trees. Forests infested with Kudzu is estimated to be over three hundred thousand hectare. Lately it is harmful not only to the planted trees but also to the cultivated land such as orchard and mulberry field. The similar trouble by Kudzu is also found in the United States where the control method is under study as well (Couch and Davis, 1966; Dickens and Buchanan, 1971).

Foliage spray of mixture of dalapon and TFP in liquid formulation was found to be effective to Kudzu, a broadleaf weed, although both dalapon and TFP are effective mainly to grass weeds (Kato *et al.*, 1971; Yamada and Ando, 1971). Effect of foliage application to granular dalapon-TFP mixture to Kudzu and its phytotoxicity to Japanese ceder (*Cryptomeria japonica* D. Don) and Japanese cypress (*Chamaecyparis obtusa* Sieb. et Zucc.) were examined in this study.

MATERIALS AND METHODS

Effect by foliage application. Field test was carried out on a well established and dense stand of Kudzu in Hatoyama-mura, Saitama-prefecture. Each test plot was 25 m^2 in size, and replicated three times. Dalapon-TFP fine granular formulation was applicated at the rates as shown in Table 1 in August 1972, and observation on the regrown Kudzu in the former test plots was carried out in June 1973.

Translocation of starch formed by photosynthesis in the treated Kudzu was also studied. The formulated dalapon-TFP mixed fine granule was treated in July 1974, and starch in the petiole and vine was examined respective 1, 2 and 3 months after the treatment. The starch in the sectioned tissue was observed through a microscope after coloured by Iodine potassium iodide method. The petiole and vine of Kudzu for this test was sampled around two to three o'clock in the early morning after a fine day.

Phytotoxicity to the planted trees. Seedlings of Japanese cedar and Japanese cypress of two years old were used in this test. On July 3rd, 1973, fine granular dalapon-TFP was applied carefully onto the crown of seedlings at the rate of 100 kg/ha (a.i. dalapon 5 kg+TFP 2 kg/ha) so as to have good coverage.

The chemical application was made both on unwetted seedlings and on artificially moistened seedlings by water spray in order to ascertain the influence of dew on plant surface on the chemical application. Growth length of the seedling and phytotoxicity to the needle leaves were observed on September 29th, 88 days after the treatment.

Results and Discussion

Effect in the year. Usually Kudzu vines grows 20–30 cm/day under the high temperature condition in July and August. In this test it was observed that all of the Kudzu vines applied with dalapon-TFP stopped growing within 10 days after the application. But the chemicals exhibited a little and slow effect on adult leaves. The leaf burn appeared slowly for regular daytime application, but it appeared quickly for the application in wet condition early in the morning. The adventitious buds, which usually start to sprout after the vines grow in full, did not grow at all. Kudzu vines and leaves cover the surface of the forest floor like a mulch, which is quite beneficial for the forest management because it makes the succession of forest floor vegetation slow and protects the forest soil from erosion.

Complete eradication was aimed in the conventional control practice of Kudzu so far, but the control by dalapon-TFP is quite new compared with the old control methods.

Effect in the following year. Observation on growth of the Kudzu vines sprouted in the next year of dalapon-TFP application is shown in Table 1. The length and fresh weight was extremely small in the dalapon-TFP plots compared with those in the control plot; furthermore, the leaves were small and the petiole and nod interval was short in the same manner. New budding occurred from a little stolons which survived the chemical treatment in the preceding year. Budding from the suberized vines hardly occurred since they were almost dead in the winter. The Kudzu treated with dalapon-TFP did not form bush for one year because the growth of newly budded vines was strongly inhibited. It is quite characteristic that the fine granular dalapon-TFP exhibited its effectiveness much better in the next year than in the year the chemicals were applied.

Translocation of starch. Starch formed by photosynthesis in the daytime is translocated from the leaves in the nighttime. Translocation of the starch from the leaves treated

Table 1. Effects of TFP and dalapon mixture on Kudzu.

Herbicide (kg a.i./ha)	Product dosage (kg/ha)	Application time	Fresh weight		Vine length (cm/m²)	Leaf number (no./m²)	Node interval (cm)	Petiol (cm)
			Vine (g/m²)	Leaf (g/m²)				
TFP 3+ dalapon 9	100	Day	3.0	1.7	20.3	3.5	4.6	4.9
TFP 2+ dalapon 5	50	Morning	40.8	5.3	229.7	10.5	6.0	5.4
	100	Morning	16.8	2.5	155.4	12.0	2.8	2.8
	100	Day	46.3	7.5	237.6	4.0	3.8	5.8
Control*			222.8	199.3	1,589.3	72.0	18.1	16.6
Control**			883.5	823.0	4,901.0	216.5	19.6	26.1

* Some contaminated with herbicide by translocation via vine.
** Normal growth field, near the test plots.

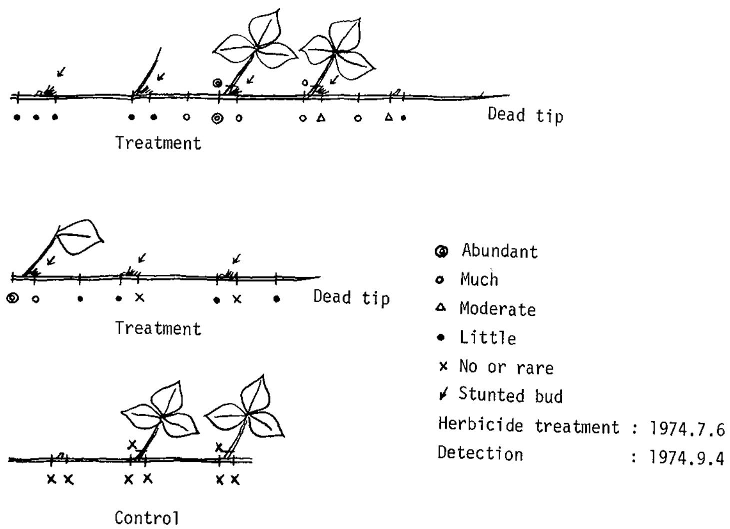

Fig. 1. Detection of starch.

with dalapon-TFP was found in a trend to be heavily inhibited so that large amount of the formed starch was detected in the petioles and soft vines. More starch was detected, not only around the vascular bundle but also in the pith, in August than in September as shown in Fig. 1. Starch was not at all or scarcely detected in the control plot, but detected in all of the treated plot. Amount of the detected starch was closely related to the amount of the existing leaves. Although the mechanism of such activity of dalapon-TFP is still not known in detail, it was quite clear in this test that translocation of the formed starch in the nighttime was remarkably inhibited although photosynthesis was taken place in the treated Kudzu leaves. As an evidence to support this, such an interesting case was found that the treated leaves with dalapon-TFP were attacked by weevils, *Eugnathus distinctus* Roelofs, more often than the untreated leaves. It is estimated that growth of the adventitions buds and vines was heavily controlled

Table 2. Growth of trees treated with TFP and dalapon mixture.

Species	Plot	Crown condition	Number of trees	Growth*	
				Height (cm)	Diameter (mm)
Japanese cedar	Treatment	Dry	28	41.7	6.5
	Treatment	Moist	34	41.9	5.4
	Control	—	26	39.2	5.7
Japanese cypress	Treatment	Dry	42	27.5	3.6
	Treatment	Moist	45	26.2	3.9
	Control	—	46	26.2	3.2

* Period: June 25–September 29

after the chemical treatment because normal starch translocation in the treated Kudzu plant was inhibited as above explained.

Phytotoxicity. Growth inhibition of Japanese ceder and Japanese cypress was not observed in this test as shown in Table 2. When applied on the wet crown, symptom of leaf burning due to the chemicals application was slightly observed, but the symptom itself disappeared about a month after the application.

In view of such unique activities of the fine granular dalapon-TFP on Kudzu together with its little phytotoxicity, low mammalian and low fish toxicity, this fine glanular dalapon-TFP will attract more public attention in the future than any of phenoxy and picloram herbicides.

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Effects of TFP on Eulalia, *Miscanthus sinensis* Anderss.

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Abstracts. Effects of granular TFP (sodium 2, 2, 3, 3-tetrafluoropropionate) on eulalia (*Miscanthus sinensis* Anderss.) were studied. Excellent effects were observed in the soil surface application at the pre-sprouting stage in winter and early spring, and its ws confirmed that the sprouting of eulalia was strongly inhibited for a few years by the application of 3–7 kg a.i./ha.

In the aerial application test conducted at the rate of 5 kg a.i./ha in the afforested land of Japanese cypress (*Chamaecyparis obtusa* Endl.), no phytotoxicity was observed to the planted trees, good herbicidal effect was obtained, and amount of TFP detected in stream water in the test area was extremely small.

INTRODUCTION

Eulalia is one of the most popular perennial grasses in the forest land in Japan to cause a big trouble especially in silviculture. Like dwarf bamboo, Kudzu and ferns, eulalia gives serious damage to the newly planted young trees. Being fond of sunny place, it grows very quickly in the forest land after cutting often to make large plant community. Sodium chlorate, dalapon (sodium 2,2-dichloropropionate) and TCA (trichloroacetic acid) are commonly used to control eulalia, but TFP (Tetrapion, Frenock) was found to be more effective than the formers (Nakamura *et al.*, 1973). TFP controls the growth of grass for a long period by its systemic action even at the small application rate. Since TFP is not a contact herbicide it does not exhibit any quick herbicidal effect when applied in the growth season of eulalia so that application of higher rate is required in order to obtain moderate control. Therefore, it is not practical to apply TFP in such growth season (Yamada and Ando, 1971; Yamada, 1971). In this study, effect of granular TFP applied at small rates during the dormancy period of eulalia and TFP in stream water in the areas, where the aerial application of TFP was made, was determined.

MATERIALS AND METHODS

Pre-sprouting stage application. The test field was heavily covered by eulalia. The field used to be a shrub forest before it was treated with a phenoxy herbicide a few years ago. Thereafter the vegetation was changed into eulalia.

Each test plot was 25 m² (5×5 m) in size, and replicated three times. 10% granular TFP was applied at the rate of 3, 5 and 7 kg a.i./ha in November 1969, and at the rate of 3 and 5 kg a.i./ha in February 1970. The standing dead culms in the test polts at the time of TFP application were not removed.

Observation was made several times on the succession of forest floor vegetation during two years after the application.

Aerial application by helicopter. This test was carried out at Koza-cho, Wakayama-Pref. in November 1972. Test area was about 17 ha with the altitude of 150 to 350 m above sea level, and afforested with young trees of Japanese cypress and Japanese cedar (*Cryptomeria japonica* D. Don). The dominant weed in the forest floor vegetation was eulalia mixed with a few kinds of shrubs and broad leaf weeds.

10% granular TFP was applied at the rate of 50 kg/ha by a helicopter of type Bell 47G-2A. According to the check by granule traps placed in the test area, very good spreading of the applied granular TFP was obtained in the area. After the application, stream water were sampled for TFP analysis at three places, end of the stream in the test area (Point 1) and 500 m (Point 2) and 1,250 m (Point 3) each downstream from Point 1. TFP in the sampled water was analized by FID gas chromatography by Daikin Kogyo Co., Ltd.

The herbicidal effects against eulalia was observed 190 days after the application (June 1973).

Results and Discussion

Result of the test in the pre-sprouting stage of eulalia in winter and early spring is shown in Table 1. TFP exhibited remarkable control of eulalia in each application plot in the following growth season; moreover, the effect was observed to last even in the second growth season. The rate of 5 kg a.i./ha was good enough for practical use

Table 1. Cover degree of floor vegetation.

Time of application and weed	3.0 kg/ha		5.0 kg/ha		7.0 kg/ha		Control	
	'70.10	'71.9	'70.10	'71.9	'70.10	'71.9	'70.10	71.9
Application: 1969.11								
Eulalia	4.0	20.0	0.3	10.0	0	1.7		
White oak (shrub)	19.3	30.0	14.3	23.7	15.0	33.3		
Others (shrubs and weeds)	14.0	31.8	15.6	59.7	11.6	28.0		
Application: 1970.2								
Eulalia	7.3	30.0	3.6	6.0			77.5	82.5
White oak (shrub)	21.0	12.7	21.6	33.3			12.5	9.5
Others (shrubs and weeds)	15.0	12.9	22.3	20.7			9.5	2.0

Eulaia: Japanese pampas grass. White oak: *Quercus serrata* Thunb.

Table 2. Detection of TFP in the mountain stream.

Time of sampling	Measured point		
	1	2	3
Before application	<0.03 ppm	<0.03	<0.03
After application			
0 min.	2.69–2.70	—	—
30 min.	0.70–0.67	<0.03	—
1 hr.	0.48–0.51	<0.03	<0.03
1 hr. 30 min.	—	<0.03	<0.03
2 hr.	0.29–0.30	0.04	<0.03
4 hr. 30 min.	0.05–0.06	0.39–0.40	<0.03
18 hr. 30 min.	0.05	0.06	0.09
23 hr.	<0.03	0.04	0.07
1 day 23 hr.	<0.03	<0.03	<0.03

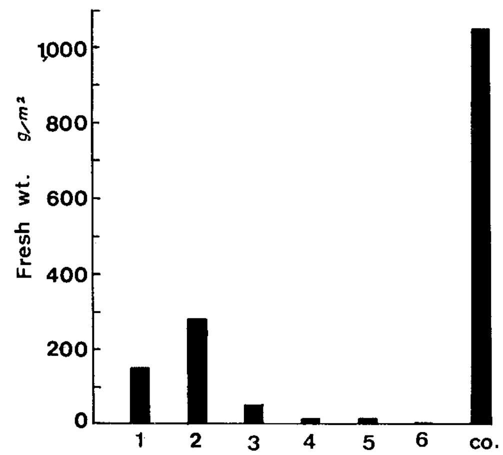

Fig. 1. Effects of TFP on Eulalia in the aerial application by helicopter.
1–6: Check point No. in the applicated area.
CO.: Untreated area near the applicated forest.

of TFP against eulalia. No herbicide has been known to show such long lasting herbicidal effect on eulalia at such small application rates. Especially, it is noteworthy that TFP application in the pre-sprouting stage was practical as a control method of eulalia. Although herbicidal effect of TFP lasted for a few years, TFP residue in soil disappeared within a few months due to the leaching by rain.

As shown in Table 2, amount of TFP detected in the down stream water in the test area was very small, and the detection was limited only in a short time after the application. Since mammalian toxicity and fish of TFP are very low, aerial application of TFP unlikely gives any harmful effect on fishes. Control effect against grasses was as shown in Fig. 1. Cover degree index, length of stem and fresh wieght of grasses were extremely decreased in the test area compared with those in the untreated.

As the above mentioned result, TFP seems to be a very promising herbicide for eulalia control, and application to the other grasses is also expected to be practical.

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Effects of TFP on Dwarf Bamboos, *Sasa* spp. and Allied Genera

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Abstract. Effects of TFP (sodium 2,2,3,3-tetrafluoropropionate) were examined on dwarf bamboos, the main forest floor vegetation of Japan considered to be hazardous weeds in forestry. It was confirmed that the growth inhibition effect of TFP lasted for a few years when soil surface treatment was used at a rate of 1–5 kg a.i./ha.

The plant growth stopped soon after the treatment, but the subsequent defoliation of mature leaves was delayed in the order: *Pleioblastus Chino*, *Sasa nipponica*, and *Pseudosasa purpurascens*. It took less than a year for *P. Chino* and 3 years for *P. purpurascens* for the defoliation of the mature leaves to occur.

INTRODUCTION

Dwarf bamboo, a species of the genus *Sasa* and allied genera, is one of the main forest floor vegetation prevalent throughout Japan. In Hokkaido, approximately 70% of the forest area is covered with dwarf bamboos.

"SUZUTAKE" (*P. purpurascens*) infests the forest ranging from Hokkaido down to Kyushu and is mostly found in the forest lands of the snow scant areas in the western part of Japan. "MIYAKOZASA" (*S. nipponica*) is prevalent in the forest lands from Hokkaido to the central part of Japan, where the snow is not deep. "AZUMANEZASA" (*P. Chino*) is mainly found in the Kanto area, and "NEZASA" (*Pleioblastus variegatus* Makino) in the low forest lands and non-crop lands of the western part of Japan. Because of its great density and height, and because of the fact that it is a perennial weed, it has became one of the most harzardous weeds for reforestation. The height of a large-sized dwarf bamboo can exceed two meters.

Results of research carried on over the past 20 years indicate that sodium chlorate has been practically used for the eradication of the dwarf bamboo. From the standpoint of erosion control of the forest land and the prevention of a sudden variation in the floor vegetation, it is considered that the suppression of the weed's growth is desirable rather than its total eradication. The efficacy of TFP on the dwarf bamboo has already been recognized (Yamada, 1971). In this research, the suppression for long term by applying small amount of TFP was examined.

MATERIALS AND METHODS

Field experiment 1. Efficacy of TFP against the "MIYAKOZASA" and "SUZUTAKE".

Research on the "MIYAKOZASA" was carried out in an area of dense growth in Gumma prefecture, and research on the "SUZUTAKE" in Saitama prefecture. The experimental plot of the "MIYAKOZASA" is located 850 meters above sea level and of the "SUZUTAKE" at 1,100 meters. In Octover 1971, the soil was treated with 3 different grade dosage of the 10% TFP granule as shown in Table 1–2. Treatment of each plot was repeated three times in an area of 25 m^2. Two years later, in September 1973, a 1 m^2 area of the bamboo was mowed from the central part of each plot in order to examine the biomass of the adult culm and the new culm.

Field experiment 2. Efficacy of TFP against the "AZUMANEZASA".

Research on the "AZUMANEZASA" was carried out in an area of dense growth in Saitama prefecture. In March 1972, the soil was treated with the TFP granule as shown in Table 2. The reason for the quantity of the chemical sprayed in Field experiment 2 being lesser than that of Field experiment 1, is due to the higher susceptibility of the experimental plot against TFP. One and a half years later, in September 1973, the plot was examined.

Field experiment 3. Efficacy of TFP against the "NEZASA".

Research on the "NEZASA" was carried out in an area of dense growth in Shiga prefecture. In June 1966, the soil was treated with the liquid TFP of 5 kg a.i./ha after the bamboo was cleared. The size of the plot was 16 m^2 and the treatment was repeated two times. In July 1969, three years after the spraying, the sprouting density of the treated area and non-treated area were examined (Fig. 1).

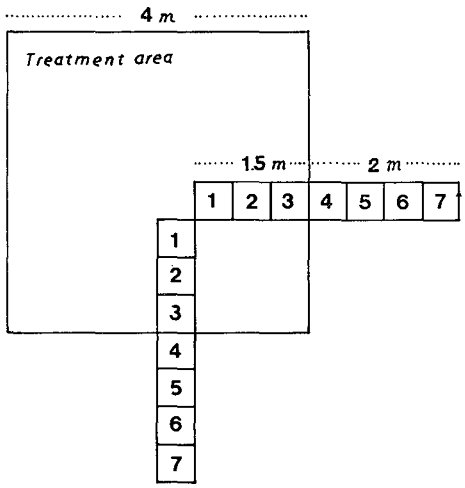

Fig. 1. Disposition of the investigated plots.

RESULTS AND DISCUSSION

The results of the research are shown in Tables 1–3. In all cases, sprouting of the new culm was strongly suppressed for a few years. The number of the culms had decreased extremely and the size of the culms became smaller and gradually they died

Table 1. Effects of TFP on SUZUTAKE. (One shoot)

Rate (kg/ha)	Adult				New culm			
	Height (m)	Fresh weight			Height (m)	Fresh weight		
		Leaf (g)	Culm (g)	Total (g)		Leaf (g)	Culm (g)	Total (g)
1.5	2.0	16.7	47.3	64.0	1.4	1.0	16.3	17.3
3.0	2.0	13.9	46.1	60.0	1.0	0.2	9.4	9.6
5.0	1.8	10.3	32.1	42.4				
Control	2.2	16.2	47.5	63.7	2.4	3.0	44.9	45.2

Table 2. Effects of TFP on AZUMANEZASA and MIYAKOZASA. (One shoot)

Rate (kg/ha)	Adult				New culm			
	Height (cm)	Leaf (g)	Culm (g)	Total (g)	Height (cm)	Leaf (g)	Culm (g)	Total (g)
AZUMANEZASA								
0.5	2.0	6.7	58.8	65.5	1.8	2.6	7.6	20.2
0.8	2.1	7.2	61.7	68.9	2.0	2.1	10.4	12.5
1.0	2.2	6.7	46.9	53.6	1.4	1.4	4.9	6.3
Control	2.8	29.6	98.9	128.5	3.4	2.3	93.2	95.5
MIYAKOZASA								
1.5	1.2	1.7	10.4	11.1	Some sprout			
3.0	1.2	1.7	8.6	10.3	Rare sprout, fail to leaf out and subsequently die			
5.0	1.2	1.3	8.9	10.2				
Control	1.6	6.4	15.7	22.1	Sprout			

Table 3. Sprout suppression of NEZASA at 3 years after TFP treatment.

Shoot condition	Treatment plot			Control plot			
	1	2	3	4 (far 0.5 m)	5 (1 m)	6 (1.5 m)	7 (2 m)
Sprouting density per plot (0.25 m^2)							
Normal	20.0	11.5	14.0	21.5	35.5	71.0	144.5
Suppressed	4.0	1.5	4.0	1.5	3.5	14.0	23.0
Dead	9.0	6.5	2.5	6.5	14.0	30.5	22.0
Total	24.0	13.0	18.0	23.0	39.0	85.0	167.5
(%)	(14.3)	(7.8)	(10.7)	(13.7)	(3.7)	(50.7)	(100)
Fresh weight	29.0g	20.5g	21.0g	27.5g	68.0g	132.5g	290.0g
(%)	(10.0)	(7.1)	(7.2)	(9.5)	(3.4)	(45.7)	(100)

back. The efficacy of the chemical was proportional to the dosage.

The growth of the culm, which sprouted before the treatment, was suppressed, as well as the sprouting of the new culm for a few years after the spraying of the chemical. Efficacy against the culm was slow, but gradually it died back, starting from the tip. Gradually the "SUZUTAKE" leaf burns, and it takes a few years to die back. The leaf and the culm of the "MIYAKOZASA" die back in 1 to 2 years. The leaf of the "AZUMANEZASA" defoliates within a year, but the culm does not die back easily. As mentioned above, according to the variety of the dwarf bamboo, the effect on each leaf is different. The effects also have a close relation to the span of life of the leaf. Because of the effects of TFP, the shape of the leaf is deformed and the number of the leaves is decreased. A quick eradication can not be expected, but an efficacy similar to natural biological control is its special feature. For eradication, the chemical sprayed after mowing and the forest floor vegetation can be controlled for several years.

According to the results of Table 3, it is suspected that TFP moves slightly along the subterranean stem. Similar efficacy is also recognized against the "KUMAIZASA" (*Sasa paniculata* Makino et Shibata) and "NEMAGARIDAKE" (*S. kurilensis* Makino et Shibata) prevalent in the snowy areas.

A method for the long range suppression of the dwarf bamboo by spraying a small amount of herbicide has not yet been discovered. It is likely that the particular characteristics of TFP will be a topic of interest in the future.

Reference

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The Effects of Fertilizer-TFP Combination on Planted Land

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Abstract. As one approach to labour-saving in forestry, studies were carried out on the integrated effects of fertilizer-TFP combination on herbicidal activity and growth of trees. This "combination" was made of fertilizer (20%N, 8%P_2O_5, 8%K_2O) and 2% TFP (sodium 2,3,3,3-tetrafluoropropionate). Experiments were conducted on planted land for testing fertilizer effect and phytotoxicity. This combination was broadcasted in the range of 150–300 kg/ha.

Excellent control result was obtained on dwarf-bamboos and eulalia, and a better fertilizing effect to the Japanese cedar was recognized.

INTRODUCTION

In the forestry of Japan, fertilizers are often given to the young trees. The aim is, of course, to promote their growth and, indirectly, to shorten the weeding period. However, as weeding operation is needed until certain growth stage of the trees, the use of herbicides has become common. As a labor-saving measure, simultaneous application of fertilizer and herbicide is required (Takagi, 1968). However, it is not an easy task: mixture of sodium chlorate and ammonium salts which is effective against dwarf bamboo, involves a risk for causing a fire, and there is no suitable herbicide for control of eulalia (*Miscanthus sinensis* Anderss.) during summer.

Recently, a combination of fertilizer and TFP was produced for trial. TFP shows a high herbicidal effect in small dosage (Yamada and Ando, 1971) and it is stable chemically. This mixture is granular and contains 20%N, 8%P_2O_5, 8%K_2O and 2%TFP.

The present paper describes the relationship between fertilizing and herbicidal activities of this combination and application times.

MATERIALS AND METHODS

Experiment 1. The experiments were carried out on the land planted with four years-old Japanese cedars in Gumma Prefecture. The combination was applied at the dosages of 150 and 200 kg/ha in December 1970 and at the dosages of 75, 100, 150 and 200 kg/ha in May 1971. Area of each plot was 100 m^2 and tests were conducted twice. The forest floor vegetation of the experiment area was a mixed growth of eulalia, dwarf bamboo and some shrubs. The weeding effect was examined in July 1971 and the growth of

Japanese cedar was checked for two years.

Experiment 2. The experiments on the weeding effect against eulalia were carried out. In March 1971, the combination (300 kg/ha) was applied on a 16 m^2 experimental plot with eulalia in Saitama Prefecture. For comparison, TFP (6 kg a.i./ha) and DPA (dalapon) (15 kg a.i./ha) were applied in the same manner. Tests were conducted three times. In August 1971, five months after the application, eulalia was mowed from the central area of 2 m^2 in the plot and its fresh weight was measured to examine the herbicidal effect.

Results and Discussion

The weeding effect is shown in Tables 1 and 2. The combination showed an excellent effect against dwarf bamboo, eulalia and grass weed. The effect was proportional to the amount of the combination applied, but the combination applied in December showed a better effect than that applied in May. Since TFP regulates sprouting and elongation of the grass weed, the application in December before sprouting may be more effective. The combination applied in March was also effective (Fig. 1). An increase of shrub was noticed in those plots where the herbicidal effect was remarkable. This may be explained as the result of accelerated succession of the floor vegetation by the synergistic effect of the herbicide and the fertilizer. This is undesirable from the view-point of cultural work of planted land. Some ecological approaches must be taken

Table 1. Effects of fertilizer-TFP combination on grass weeds.

	Treatment		Control (g/m^2)
	150 kg/ha Fresh wt. (g/m^2)	200 kg/ha (g/m^2)	
Dwarfbamboo	86	63	351
Eulalia	10	—	111
Other monocotyledons	28	14	635
Broadleaf weeds	195	156	258
Shrubs	712	625	312

Treatment: 1970. 12. 18, investigation: 1971. 7. 28

Table 2. Effects of fertilizer-TFP combination on grass weeds.

Treatment (kg/ha)	Dwarfbamboo and eulalia dry wt. (g/m^2)	Shrub and broadleafweeds (g/m^2)	Total (g/m^2)
75	119	131	250
100	107	140	247
150	99	157	256
200	41	225	266
Control	442	205	647

Treatment: 1971.5.18, investigation: 1971.7.29

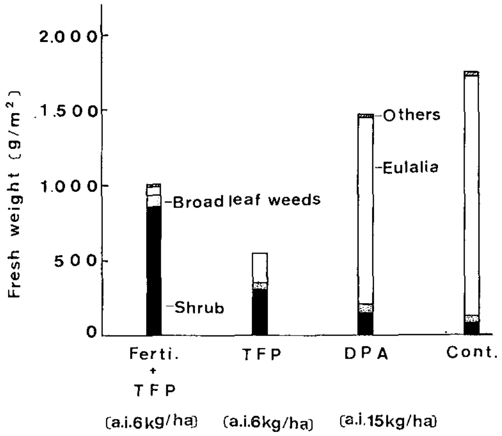

Fig. 1. Effects of fertilizer—TFP combination on eulalia.

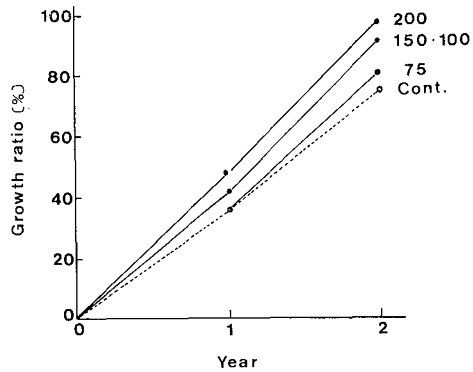

Fig. 2. Growth of Japanese cedar.

to regulate the growth of grass weed to an adquate level, and control the increase of shrub, so the young trees of the plantation will not be covered. The result obtained by the application of the combination in May suggests such an approach.

Effect of the fertilizer on the growth rate of Japanese cedar was found (Fig. 2). From the results mentioned above, both fertilizing and weeding effects of the combination can be expected.

The next research subject will be investigation of the application method by which the grass can be regulated but not entirely eradicated. Application of the combination after sprouting of eulalia can regulate the growth of other grasses in mulch condition, preventing succession of the floor vegetation, and, at the same time, increase the fertilizing effect on the planted trees.

Acknowledgments

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Response of Purple Nutsedge to Applications of TFP and Glyphosate Mixture

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Abstract. The effects of the mixture of TFP (Sodium 2,2,3,3-tetrafluoropionate) and glyphosate [*N*-(phosphonomethyl)glycine] on purple nutsedge (*Cyperus rotundus*) were tested in a tree nursery. Foliar treatment of TFP(3 kg a.i./ha) and glyphosate(1 kg a.i./ha) in June resulted in complete withering of shoots in a month. It gave serious effects of not only blasting the shoots in its growing season but either inhibiting its emergence in the next spring or rarely developing very slender shoots. The dormant tuber dug from the mixture treated area, was controled its sprouting and was inhibited elongation of the shoots.

INTRODUCTION

Purple nutsedge is a world-wide harmful weed. Most of the infested forest nursery in Japan is located in the west of Kanto region. The control of purple nutsedge with herbicides have been studied by various workers. TFP is also effective (Ishii *et al.*, 1971; Ishii and Manabe, 1973), but 10 kg a.i./ha is necessary. However, it is difficult to apply TFP in the tree nursery because of the phytotoxicity to Japanese Cedar (Cryptomeria japonica D. Don) seedling. Purple nutsedge reinfest in a short period even if the density of the tuber is diminished to a very low level. According to the authors (Ishii *et al.*, 1971), it was found that one tuber increased to about two thousand ones in one growing season, and therefore it is desirable to eradicate tubers completely for the control of purple nutsedge. Recently, glyphosate was reported to reduce purple nutsedge stands in Tanzania (Magambo and Terry, 1973) and Hawaii (Zandstra *et al.*, 1974). This studies were carried out in the field to find the synergistic effects when treated with the mixture of TFP and glyphosate.

MATERIALS AND METHODS

Studies were carried out in the infested nursery of the Akanuma Experiment Site, National Forest Experiment Station, from 1973 to 1975. In the first experiment, the single foliar treatment was applied at the dense stand of purple nutsedge with the mixture (TFP 3 kg/ha and glyphosate 1 kg/ha) and glyphosate (1.2 kg/ha) in June 1973. Repeated foliar treatment was done in August of the same year. When the treatment was repeated, the new shoots of glyphosate plots were sparsely and those of the mixture plots were very rarely. Five *l*/a of water and the surfactant were used. Area of each plot was 2.4 m^2, and it was encircled with a vinyl film in the depth of 30 cm to protect the invasion of rhizome from outside plots. Each plot was divided with a wooden board into two compartments, the single treatment and the repeated treatment. Each treatment was replicated three times.

Measurements of nutsedge density were made in October and the following summer by counting emerged shoots from 1 m^2 within every plot. To find the tuber numbers, the top 20 cm of soil from 0.16 m^2 of each plot were excavated in October; and the tubers were counted.

The second experiment was carried out to revaluate the effects of the mixture. The single foliar treatment was done in June 1974, and the repeated foliar treatment was in August. At the start of applications, emerged shoots number of the second experiment were more densely established than the first one. Area of the each plot was 1.5 m^2 and was replicated three times. The measurements were made in October and in June next year. The mortality of tuber was determined to find the discoloration of parenchyma.

Results and Discussion

The result are shown in Table 1–3. In each treatment plot, the shoots died within one month after treatment and its response was rather slow. Regrowth was very inhibited in the mixture and repeated treatment with glyphosate, whereas some growth was observed in the single treatment with glyphosate. Rarely emerged shoots of following growth season indicate that the mixture will suppress the regrowth for long period. In previous study (Magambo and Terry, 1973), it is recognized that glyphosate had induced or prolonged tuber dormancy or inhibited normal sprouting.

The survived tuber treated with the mixture was very few in the following growth season, and it seems that it does not die rapidly but gradually. It may be considered that the winter coldness had affected a little, however this matter is not yet sufficiently examined. From this studies, it is obvious that effects of the mixture is extremely high,

Table 1. Control of purple nutsedge with TFP and glyphosate mixture (1973–'74).

Herbicide	Rate	Shoot			Tuber	
	(kg/ha)	Before treatment '73.6 (no./m^2)	'73.10 (no./m^2)	'74.7 (no./m^2)	Initial '73.3 (no./m^2)	'73.10 (no./m^2)
TFP-glyphosate	3·1	450	5.3	3.7	116.8	713.4
	(3·1)+(3·1)	,,	3.3	0	,,	425.0
Glyphosate	1	527	489.7	668.0	135.6	2,088.7
	1+1	,,	1.3	53.7	,,	1,033.4
	2	490	336.7	276.0	106.2	1,228.1
	2+2	,,	1.0	70.0	,,	1,002.1
Control	—	494	1,210.2	1,529.0	133.1	2,599.0

Table 2. Control of nutsedge with TFP and glyphosate mixture (1974–'75).

Herbicide	Rate	Shoot			Tuber			
		Before treatment '74.6	'74.10	'75.6	Before treatment '74.3	Survive '75.6	Killed '75.6	Mortality
	(kg/ha)	(no./m²)	(no./m²)	(no./m²)	(no./m²)	(no./m²)	(no./m²)	(%)
TFP-glyphosate	3・1	1,445	60	14	909	154	1,406	90.1
	(3・1)+(3・1)	1,019	3	1	990	143	1,714	92.2
Control		988	1,198	636	1,090	3,056	1,025	25.1

Table 3. Tuber mortality of following season.

Herbicide	Rate (kg/ha)	Investigation time	Survive %	Discoloration %	Killed %
TFP-glyphosate	3・1	'73.10	79.4	10.0	10.6
		'74. 7	0	7.0	93.0
Glyphosate	2+2	'73.10	82.5	15.3	2.2
		'74. 7	25.5	22.2	52.3
Control		'73.10	93.2	4.8	2.0
		'74. 7	70.0	15.0	14.6

About 300 tubers were tested in each plot.

but synergistic mechanism of the mixture is not yet studied in details. It is considered that this subject is very interesting for the future study.

Acknowledgment

The authors wish to thank Sankyo Co. for TFP and Monsant Co. for glyphosate used in the investigations.

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Herbage Response to Killing Trees and Shrubs in *Eucalyptus populnea* Woodlands

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Abstract. A previously described study of the effects of trees and shrubs on grass production in *Eucalyptus populnea* woodlands has been continued for a further period. In the experiment, the effects on grass production of killing of trees by ringbarking were compared with those of chemical injection. Throughout the course of the experiment herbage production was always highest on chemically treated, and lowest on untreated plots. Maximum standing biomass on chemically treated plots exceeded 5,000 kg/ha two years after treatment. Comparable yields on ringbarked and untreated areas were 3,763 and 1,550 kg/ha respectively. Grass yields 37 months after tree killing treatments were still double those on untreated plots, but differences in grass production between ringbarked and chemically treated plots had declined.

Introduction

Herbage response to tree and shrub thinning in *Eucalyptus populnea* shrub woodlands was described by Walker *et al.* (1972). Their paper included an experiment comparing the early effects on herbage production of killing trees by ringbarking and by injection with chemicals. This paper records the longer term effects of these treatments on grass yields averaged for 3 month periods for 24 and 57 months after treatments were applied.

The experimental site was at "Quemoi Station", near Cecil Plains (lat. 27°50′S, long. 151°30′E) in southern Queensland on a solodic soil (pH 6.5). Rain falls predominantly in the summer, and averages 600 mm per annum.

Tree density varied from 725 to 780 per ha. Shrubs were few in number (30 per ha) and the common herbs were *Aristida ramosa* and *A. calycina.*

Materials and Methods

Herbage responses to the killing of trees and shrubs were measured and ringbarking and chemical injection were compared on the following treatments applied, June 1969.

(1) Control—no treatment of trees and shrubs
(2) Trees ringbarked, shrubs basal sprayed
(3) Trees injected, shrubs basal sprayed

Mature trees were either killed by injection at stem base with "Tordon 50D

Weedkiller" [4-amino, 3,5,6-trichloropicolinic acid (picloram)+2,4-dichlorophenoxyacetic acid (2,4-D)], or ringbarked one metre from ground. Shrubs were killed by basal stem spraying with 2,4,5-T in diesel distillate.

The experimental design was randomized blocks with two replicates; plot size was 0.4 ha. Herbage was measured by clipping all green material in 10 quadrats of 1 m^2 per plot at a height of 1 cm above ground level. Quadrats were placed at random on each sampling occasion by using coordinates taken from a set of random permutations. Samples were taken monthly between 1969 and 1971, and in March 1974, that is, 57 months after treatment.

Soil samples for moisture determination were taken to a depth of 30 cm at each quadrat site at each harvest. Plots were not grazed or burnt, so material harvested included that surviving from one sampling occasion to another as well as new growth from both old and newly established plants.

Plant material was oven dried at 104°C for 48 hours prior to weighing.

RESULTS

Herbage response to the three treatments is shown in Fig. 1. Rain and soil moisture measured during the first two years of the experiment are shown in Table 1. Monthly data have been averaged for three-monthly periods.

Areas in which trees were treated chemically always produced more herbage than those either ringbarked or left untreated. The herbage response following injection was almost immediate and 4–5 months earlier than on ringbarked areas. The maximum

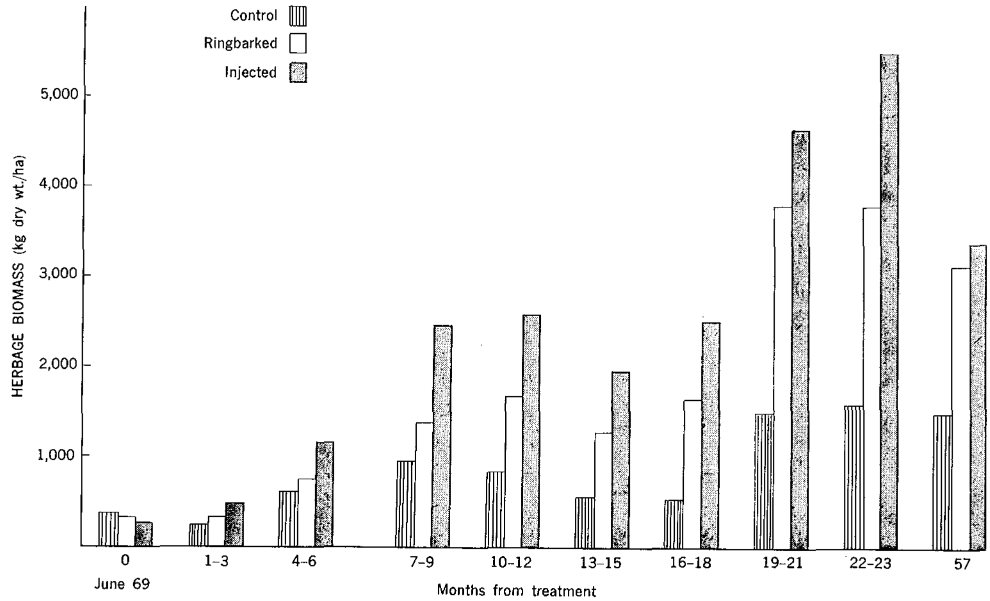

Fig. 1. Herbage yields following ringbarking and injection in *Eucalyptus populnea* woodland.

Table 1. *Eucalyptus populnea* woodland, Quemoi. Effects on soil moisture of ringbarking and of injection with "Tordon 50D". Percent soil moisture 0–30 cm. Means for preceding 3 months.

	Months from treatment								
	0	3	6	9	12	15	18	21	23
Control	5.7	6.7	6.8	7.3	6.1	6.3	6.7	9.3	4.8
Ringbarked	6.1	8.6	8.5	8.8	7.4	6.4	10.6	12.6	6.7
Injected	5.6	9.3	9.6	9.1	7.1	7.2	10.8	12.7	5.9
Rainfall (mm)	31	26	100	45	22	9	72	209	5

yield of herbage of more than 5,000 kg/ha was recorded two years after trees were injected, a reflection of the high rainfall in the preceding 3 months (Table 1). At this time the ringbarked and control treatments also gave their highest yields, these were 3,763 and 1,550 kg/ha respectively.

An analysis of variance of biomass data for the three treatments shows injections to be significantly better than ringbarking which in turn is better than the control (at 1% level) (Fig. 1).

Thinning improved not only herbage yield but also its composition and palatability to livestock. At the commencement of the experiment the unpalatable native grasses *A. ramosa* and *A. calycina* constituted approximately 95% of the herbage present. On plots in which trees were injected the more palatable grasses such as *Bothriochloa decipiens*, *Themeda australis*, and *T. avenacea* appeared within 4–6 months of treatment, and at the end of 2 years these species comprised an estimated 90% of the herbage. A similar change in botanical composition occurred on ringbarked areas, but at a slower rate.

At the end of the first 12 months of the experiment most of the ringbarked trees had produced new shoots below the cut area. Some of these shoots survived but after 2 years only 22% of ringbarked trees had live shoots.

Analysis of soil moisture percentage values showed no significant difference between ringbarking and "Tordon" treatments, but between 3 and 23 months after treatment both were mostly significantly (at 5% level) higher than the control. The difference in soil moisture is seemingly reflected in herbage yields.

Discussion

A substantial and almost immediate increase in herbage production in a *E. populnea* woodland was obtained by killing overstorey trees with "Tordon 50D". Differences in herbage productivity from thinned and unthinned woodlands continued for the 57 months but those between rinbgarked and chemically treated evident 23 months after treatment disappeared during the following 34 months. The higher yields appear to be related with the higher soil moisture in thinned woodlands.

The rather high percentage kills (78%) from ringbarking is unusual. Generally ringbarking of *E. populnea* is followed by regrowth from below the cut and it may take two or more years repeated cutting of regrowth before the trees dies. In the experiment however most new shoots appearing after ringbarking died without further treatment and the slow death of trees is a likely explanation of the continuing increase in herbage production on plots of this treatment.

Acknowledgments

Grateful acknowledgment is made to Mr. V. Barklay of "Quemoi" for his cooperation. My thanks are due also to Messrs. P. Harland, T. Welch and G. Woodward who assisted in all phases of the experiment. Mr. R. Sandland of Division of Mathematics and Statistics, CSIRO kindly analysed the data.

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Selective Use of Sodium Chlorate in Forestry in Japan

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Abstract. Although sodium chlorate has been widely used as non-selective herbicide in the world, selective use of this chemical has been actually practiced in Japan since 1963, and its effectiveness in controlling bamboos in afforested areas has been confirmed. The formulated products of sodium chlorate applied for this purpose are granular and dust with containing flame returdant. In normal practice for controlling of bamboos in afforested areas, 50% granular sodium chlorate formulation is applied at rate between 100 and 300 kg per hectre by aerial spray, while the 50% dust formulation is applied by dust-sprayer. Some considerations relating mechanism of the selectivity of sodium chlorate between crop-trees and bamboos, as well as economical feature of its aerial application are discussed.

INTRODUCTION

Forest land occupies more than 70% of total acreages of Japan, and generally speaking, these forestry lands have been well managed by rotating cutting grown trees for use of construction materials, raw materials for pulp and paper, followed by afforestration with young seedlings.

In forestry lands, as well as afforested areas, weeds bring serious problem for the growth of the crop-trees, and usually such pest weeds had been controlled by manual. 50% of such pest weeds in Japanese forestry is so called Sasa bamboos (*Sasa kurilensis, S. paniculata* and *S. nipponica*, etc.). Both in high mountains and in northern district of Japan, vigorous infestation of Sasa bamboos were often found, paticularly in Hokkaido 90% of pest weeds in forestry lands were Sasa bamboos.

Sodium chlorate has been successfully used to control such Sasa bamboos, and especially the aerial application in forestry lands has been evaluated as one of the most economical methods to control Sasa bamboos.

ACTUAL APPLICATION OF SODIUM CHLORATE

Practical standard of application of sodium chlorate is presented in Table 1.

Mainly granular formulation is used as soil-treatment, while dust is applied as foliar-treatment, controlling Sasa bamboos. The slight difference of susceptibility amongst the species of Sasa bamboos is reported as follows; *S. kurilensis* is the most sensitive species to sodium chlorate, and other species are considered to have the following order of susceptibilities.

S. kurilensis>*S. paniculata*>*Pseudosasa purpurascens*>*S. nipponica*>*Pleioblastus variegatus*.

In spite of the actual selectivity of sodium chlorate, some precaution should be required to apply this chemical against young seedling of crop-trees, for the selectivity of this chemical is based on ecological difference between crop-trees and weeds, and in young seedling of crop-tree do not have any ecological superiority to weeds.

To avoid phytotoxicity to crop-tree, treatment is not allowed for 2 to 3 years after transplanting. The waiting period on application of sodium chlorate from transplanting of crop-tree seedling is shown in Table 2.

In actual practice adjustment of dosage of sodium chlorate in a range between 150 kg and 300 kg per hectre as 50% formulated product should be required according to species of Sasa bamboos to control, age of crop-tree seedlings and soil conditions where Sasa bamboos grow.

Table 1. Practical standard for application.

Formulation	Time of application		Dosage (kg/ha)
50% granular and dust	Soil-preparation:	April-October	150–200
	Weeding:	May-July	100–150

Table 2. Waiting period on application of sodium chlorate from transplanting of crop-tree seedling.

Species	Ground application	Aerial application
Japanese cedar (*Cryptomeria japonica*)	2 years	3 years
White cedar (*Chamaeoyparis obtusa*)	2	3
Pine (*Pinus densifloa*)	3	—
Larch (*Larix gmelini*)	3	—
Picea (*Picea jezoensis*)	3	3
Spruce (*Abies sachalnensis*)	3	3

Table 3. Economical comparison.

	Mannual	Aerial application
Number of workers required; man-day		
Land-preparation	40	17
Plantation	14	14
Weeding	24	18
Total	78 (A)	49 (C)
Total labour cost ¥	104,520	65,660
Sundry expenses ¥	38,672	24,442
Cost for helicopter ¥		6,230
Cost for chemical ¥		20,400
Total ¥	143,192 (B)	117,134 (D)

Percentage of aerial application in man-days to compare with mannual operation; (C)/(A) 62%.
Percentage of aerial application in cost to compare with mannual operation; (D)/(B) 82%.

Economical Features of Aerial Application

Table 3 represents the average cost forestry management per hectre spent in national forestry of Kitami area in Hokkaido in 1970, compared between mannual weeding and aerial application of sodium chlorate. The aerial application of sodium chlorate saved 38% of total man-day in comparison with manual operation and 18% of total costs.

Selectivity of Sodium Chlorate between Crop-Tree and Sasa Bamboos

In spite that foliar treatment of sodium chlorate does not exhibit any selectivity, granular formulation of this chemical has been showing selective herbicidal activity in field condition, presumably caused by difference of depths of the roots between crop-trees and weeds in soil.

Species of crop-trees in Japanese forestries are Japanese cedar (*Cryptomeria japonica* D. Don), Japanese cypress (*Chamaecyparis obtusa* Endl.), larch (*Larix leptolepsis* Murray) and others.

The following two considerations can be considered as the reason of this selectivity.

a) Difference in soil depth.

Roots of the above crop-trees usually grow far deeper into soil than those of bamboos. The roots of bamboos spread widely in sahllow depth under the soil surface, i.e. horizontal net-growth of the roots. To contrary, the roots of the said crop-trees grow vertically into the soil, i.e. vertical development in the soil. This difference obviously offer more chance for bamboos to absorb the chemical through their roots. Further granular formulation increase the posibility of easier dropping from crown-parts of the crop-trees onto soil surface without depositing on their leaves and stems.

b) Difference in sensitivity.

It can be considered that bamboos have higher sensitivity against sodium chlorate than the said crop-trees. From the practice this difference is considered to assist the range of selectivity wider between the bamboos and the crop-trees.

Environmental Problem

Because of several reasons mentioned below, we have no problems about the influence of sodium chlorate on the environment.

a) Sodium chlorate has a very low toxicity for warm blooded animals and fish.

acute toxicity; oral LD_{50} in rats 7,120–7,620 mg/kg

fish toxicity; Tlm 48 hr. rainbow trout 7,000 ppm

So any fish that live in the river and stream near the mountain on which sodium chlorate is applied, receive no effect from chemical.

b) Sodium chlorate is not a persistent soil contaminant.

Table 4. Residue analysis.

Rate (kg/ha)	Sodium chlorate residue in mountain soil (ppm)					
	Days after application					
	8	30	60	90	120	130
150	7	6	3.4	1.5	0	0
200	8.5	5	4	1	0	0

Break-down of sodium chlorate in soil is considerably rapid. In Table 4 the residue of sodium chlorate in mountain soil is presented.

Conclusion

a) In Japan, very large areas of mountain are covered by noxious weed called "Sasa bamboo" and the application of sodium chlorate is very effective in controlling "Sasa bamboo".

b) Among the various control methods, the aerial spraying of sodium chlorate is one of the most practical and economical methods.

c) On the use of sodium chlorate in forests, we are sure that there is no question of "Safe".

Aquatic Weeds in Creeks of the Paddy Area on the Coast of Ariake Sea in Kyushu Island

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Abstract. The main aquatic weeds which are problematic in investigated creeks are waterhyacinth [*Eichhornia crassipes* (Mart.) Solms], knotgrass (*Paspalum distichum* L.), hairly subspecies of knotgrass (*Paspalum* sp.) and parrotfeather (*Myriophyllum brasiliense* Camb.). In 1973, 80% of the water surface of creeks was estimated to be infested with aquatics, mainly waterhyacinth, but, next year, only about one-fourth of the water surface was covered with the weeds, because the growth of waterhyacinth markedly decreased in 1974. In preliminary experiments on chemical control of aquatics, glyphosate [*N*-(phosphonomethyl)glycine] was very promising for controlling knotgrass and its subspecies.

Introduction

In the paddy area of Chikugo and Saga Plains on the northern coast of Ariake Sea in Kyushu Island, there are lots of small creeks (irrigation channels), so the area is usually called as 'creek-paddy region'. In recent years, the overabundant growth of aquatic plants has become serious problem in the area, because many farmers are too busy with working in cities or suburban factories to clear them. These weeds are very troublesome as they impede the flow of irrigation water, disturb fishing, and so on. This work was conducted to investigate kinds of aquatic species in creeks, seasonal or yearly changes of their growth, and methods of their control.

Materials and Methods

Studies were performed in 1973 and 1974, in the central area of 'creek-paddy region' (Fig. 1). The number of investigated creeks was 1,008 (Chikugo Pl.) and 674 (Saga Pl.), and, in each creek, about 0.1 ha of water surface was examined as a unit area to determine names of aquatic species growing there and record their coverages. The emerged and floating weeds were investigated in this study, but the submerged ones were excluded because they were little problematic in utilizing water of creeks. The overall survey of creeks was conducted on the middle of September to that of November, 1974, when the aquatic vegetation stopped growing. Seasonal or yearly changes of weeds were observed every two or three months at fixed seven points, in 1973 to 1974. Preliminary experiments on chemical control of aquatic plants were done in 1973, in

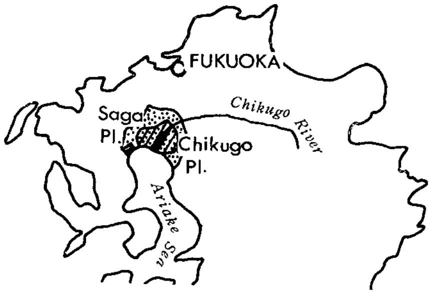

Fig. 1. 'Examined creek-paddy region' in Kyushu Island. The dotted and oblique lines' areas show 'Creek-paddy region' and the examined one, respectively.

pot or field experiments. Glyphosate, paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) and 2,4-D [(2,4-dichlorophenoxy)acetic acid] amine salt were treated to weeds.

Results and Discussion

Thirty four aquatic species were growing in examined creeks. Table 1 shows the most troublesome 4 species and unimportant but widely distributed 11 species. In 1973, it was estimated that 80% of the water surface of creeks was infested with aquatics,

Table 1. Rates of distribution* and coverage of main aquatic weeds in creeks of Chikugo and Saga plains.

Weed species		Distribution		Coverage	
		Chikugo (%)	Saga (%)	Chikugo (%)	Saga (%)
Troublesome weeds;					
Knotgrass	*Paspalum distichum* L.	8	67	1	6
Knotgrass, hairly subspecies	*Paspalum* sp.	31	8	6	2
Parrotfeather	*Myriophyllum brasiliense* Camb.	6	2	2	0
Waterhyacinth	*Eichhornia crassipes* (Mart.) Solms	45	31	12	5
Unimportant, but widely distributed weeds;					
Azolla	*Azolla imbricata* Nakai	2	10	0	1
Cutgrass Ashikaki	*Leersia Sayanuka* Ohwi *Leersia japonica* Makino	12	16	1	1
Duckweed Giant	*Lemna paucicostata* Hegelm. *Spirodela polyrhiza* (L.) Schleid.	9	28	2	5
Frogbit	*Hydrocharis dubia* (Bl.) Backer	15	29	1	2
Lotus	*Nelumbo nucifera* Gaertn.	3	7	1	1
Reed, common	*Phragmites communis* Trin.	5	15	0	1
Waterchestnut Onibishi	*Trapa natans* L. var. *bispinosa* Makino *Trapa natans* L. var. *quadrispinosa* Makino	13	7	3	1
Wild rice	*Zizania latifolia* Turcz.	6	13	0	1

* Number of creeks each species growing/Number of investigated creeks

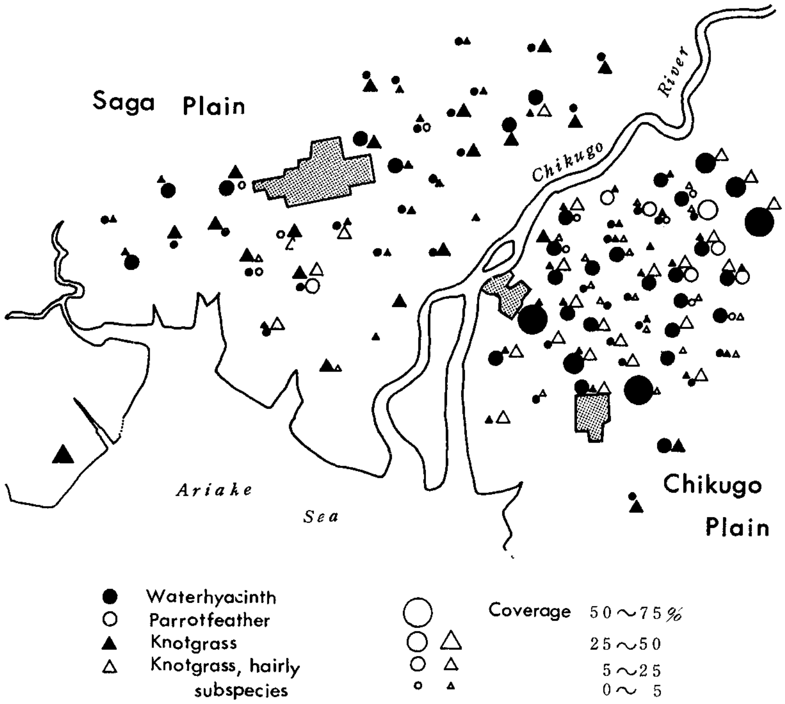

Fig. 2. Local variation of coverages of main aquatic weeds in creeks of Chikugo and Saga Plains. Dotted areas show urban ones.

mainly waterhyacinth. However, in 1974, only 28% (Chikugo Pl.) or 25% (Saga Pl.) of the surface was covered with weed species. The coverages of knotgrass, hairly subspecies of knotgrass and parrotfeather did not change, or sometimes, increased in a small amount, during two years, whereas that of waterhyacinth markedly decreased in 1974, probably because of low temperature in winter season of 1973 to 1974. In 1974, waterhyacinth existed at 45% (Chikugo Pl.) or 31% (Saga Pl.) of examined creeks but its coverages were only 12% (Chikugo) or 5% (Saga) of water surface. Knotgrass mainly infested creeks of Saga Pl., and its thick coverage was usually observed in shallow or newly developed creeks. On the other hand, its hairly subspecies was mainly found in creeks of Chikugo Pl. Parrotfeather formed dense coverages in creeks of a few towns and cities of Chikugo Pl., but it also distributed in several localized area of Saga Pl. (Table 1 and Fig. 2). Fig. 2 shows the local variation of coverages of 4 troublesome aquatic weeds in Chikugo and Saga Pls.

In preliminary experiments on aquatic weed control, glyphosate was treated to knotgrass (1 and 2 kg a.i./ha; pot experiment) and hairly subspecies of knotgrass (4 kg a.i./ha; field experiment in a creek). Knotgrass was completely killed by the chemical. The growth of its hairly subspecies was strikingly inhibited for several months, but, later, the regrowth occurred because of the incomplete application of the herbicide to the submerged part of shoots. Glyphosate (5 kg a.i./ha) and paraquat (0.8 kg a.i./ha) were applied to waterhyacinth in a pot experiment, and both killed the plant. Glyphosate (4 kg a.i./ha) and 2,4-D amine salt (0.7 kg a.i./ha) were treated to parrotfeather plants in pots. The regrowth of the weed was less by glyphosate than 2,4-D. People utilize water of creeks for crop cultivation and fishing in this region, so any herbicide which is toxic to crops or fishes is very difficult to be used practically. Glyphosate seemed promising for controlling weeds, particularly grasses, but further experiments are necessary before appling it to many creeks.

Waterhyacinth and Its Habitats in Japan

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Abstract. Waterhyacinth (*Eichhornia crassipes* Solms) in Japan is found in south up to the Kanto and Hokuriku areas excluding the Chubu area. The northern boundary of distribution corresponds to the zone where the average atmospheric temperature is 1°C in January. The weed has its habitats in irrigation channels and ponds near rice paddy fields and residential areas where the water is fertile with sewages and filthy effluents, also poor in movement and low in clarity. The habitats where waterhyacinth is allowed to spend the winter require such waters as those which are stagnant and shallow in depth, not frozen at the surface in the season, and at the edges of which emerged plants are growing.

INTRODUCTION

Waterhyacinth, a perennial aquatic plant, has a wide distribution in sub-tropical and tropical regions (Penfound and Earle, 1948) and is listed among the ten most important weeds of the world. Though the plant was originally brought into Japan as ornamental in the 1890's (Anonymous, 1972), it was already naturalized in rice paddy fields or irrigation channels in the southern area of Japan in 1911 (Hanzawa, 1911). The invasion of the weedy aquatic plant into many water systems has created a considerable problem today, as the waters have been enriched with various wastes from agriculture fields, residences and from industries in recent years. Domestic sewages and certain industrial wastes were also found to promote the growth of waterhyacinth (Wakefield, 1962). So as to investigate the current situation of waterhyacinth distribution and its habitat in Japan, we sent questionnaires to all (46) of the prefectural agriculture experiment stations in 1974 to 1975, and present here the results along with our analytical results of the waters in which the aquatic weed growed.

DISTRIBUTION

Waterhyacinth is to distribute in the following regions: the Pacific side in south up to the Kanto area (till E 141°, N 37°), the Japan Sea side in south up to the Hokuriku area (till E 137°8′, N 37°), but not in the Chubu area (more northerly than E 137°6′, N 35°2′). Fig. 1 indicates the above areas. At Kochi prefecture (Shikoku area), Hiroshima prefecture (Chugoku area), Ishikawa prefecture (Hokuriku area), Gifu prefecture (Chubu area) and Saitama prefecture (Kanto area) are not known whether at present

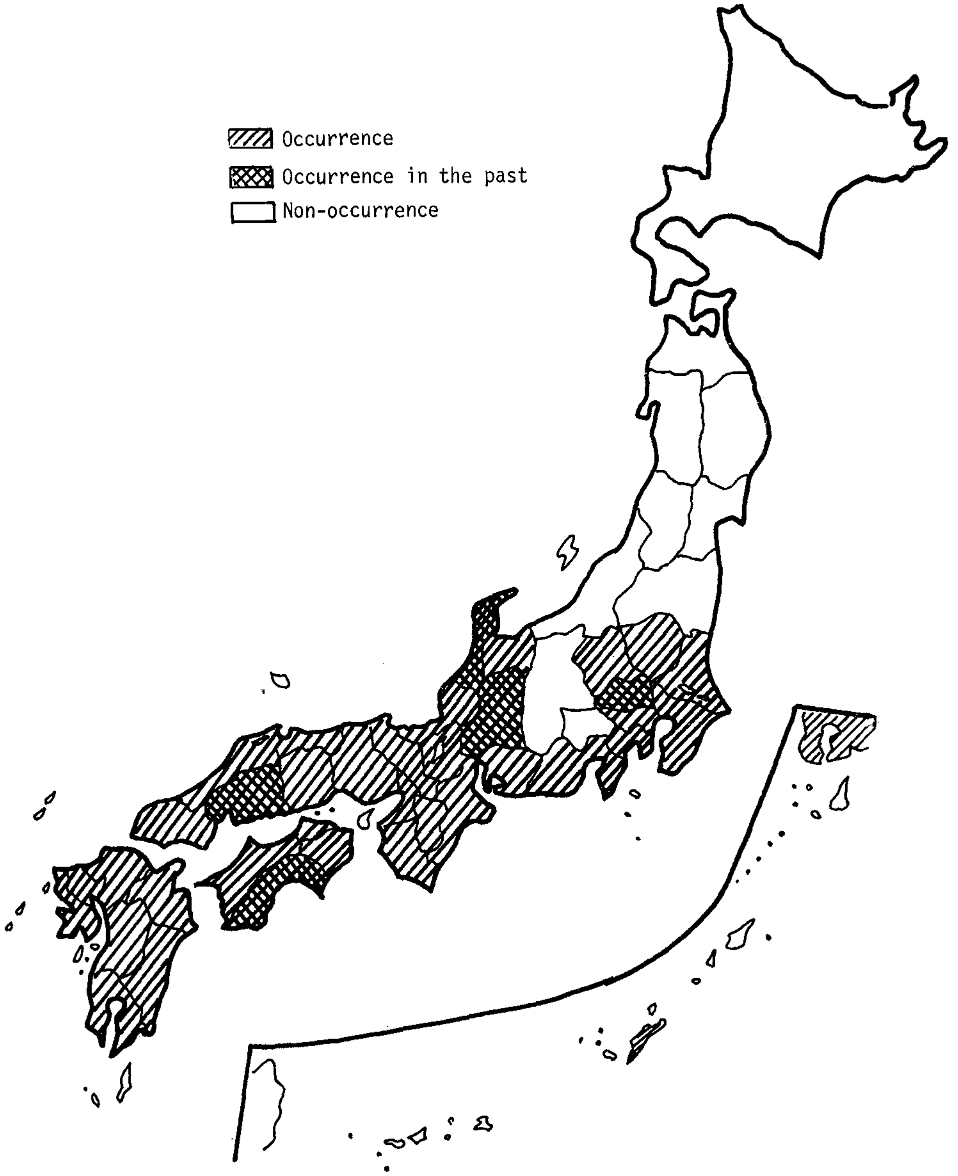

Fig. 1. Distribution of waterhyacinth in Japan.

waterhyacinth occurres, but it is reported waterhyacinth used to be found. No waterhyacinth is reported in Hokkaido, Tohoku and Chubu areas because the plant can not survive in winter but can grow enough in summer.

Habitats

The habitats, in general, are found most in ponds and irrigation channels near rice paddy fields and residential area. The presence of the weed in river was not much reported except the southern area (Table 1). For the above habitats there is a common fact that the waters are heavily enriched by the inflows with filth of hog farms and domestic

Table 1. Habitats of waterhyacinth.

Kind of water system	River	Irrigation channel	Pond	Others*
	18.8%	29.2%	37.5%	14.5%
	* Others Dam for electricity generation. Water pool for timbers. Drainage ditches of factories. Fields of lotus root cultivation.			
The occurrence areas	**Area of residences**	**Area of factories**	**Area of rice paddy fields**	**Others***
	39.5%	10.5%	42.1%	7.9%
	* Others The mouth of a river. The neighborhood of dam.			
Current of water	**Rapid**	**Poor movement**		**Static**
	3.3%	50.0%		46.7%
Clarity of water	**High clarity**		**Low clarity**	
	30.8%		69.2%	

Table 2. Water quality in habitats of waterhyacinth.

Locations of sampling				Water system	NH_4-N (ppm)	Inorg-P (ppm)
Kagoshima	(Oura)		Kyushu	Irrigation	0.58	0.72
	(Nagata River)		"	River	0.41	0.68
Miyazaki	(Oyodo River)		"	River	0.31	0.28
Kumamoto	(Tomiai)		"	Irrigation	2.11	7.35
	(Kase River)		"	River	0.25	1.11
Saga	(Chiyoda)		"	Irrigation	0.50	1.05
Shimane	(Matue)		Chugoku	Pond	1.26	0.33
Osaka	(Takatuki)	No. 1*	Kinki	Drainage ditch	1.73	5.95
		No. 2	"	"	1.39	4.13
		No. 3*	"	"	1.77	2.71
Kyoto	(Amagase)		"	Dam		0.00
	(Yodo)	No. 1	"	Drainage ditch	1.96	3.19
		No. 2*	"	Moat	0.41	0.72
Shiga	(Azuchi)		"	Irrigation	0.13	0.21
	(Omihachiman)		"	Moat	1.62	1.87

* Non-occurrence, pH: 6.6–7.8, Month of sampling: September-November, 1974, NH_4-N: by the Nessler method, Inorg-P: by the Molybdate blue method.

sewages (Table 2). The questionnaire also reveals an interesting habitats of the aquatic plant such as a dom for electricity generation, a water pool for timbers, drainage ditches of factories and fields of lotus root cultivation. And poor movement and low clarity of the water appear to be also important to the habitats (Table 1).

Undesirable Effects and Control

Out of the 46 prefectural stations which the questionnaires were sent to, 70 percent of them reported its undesirable effects: (a) choking irrigations and drainage ditches, (b) interfering with boating and fishing, (c) causing unpleasant odors and flavors, (d) causing water enriched with dead plants in winter, (e) reducing the water level. For the control, only the hand-weeding is the control method employed at present against the troublesome aquatic weed, but the chemical control is under trials with 2,4-D (2,4-dichlorophenoxyacetic acid) amine and paraquat (1,1′-dimethyl-4,4′-bipyridinium dichloride).

Growth Habits

The weed grows and propagates by vegetative reproduction (stolon) which starts around May and ceases its growth in October. Concerning seedlings, it was not known whether in the natural habitats the seeds can be practical means of propagation of the aquatic weed in Japan. But now, in a few habitats of Kyushu area, the seeds are found to be pratical means of propagation. In summer the plant reaches 40 to 100 cm in height. It blooms in August to September in almost all areas. Since November foliage of the weed has been gradually killed by freezing temperature in most areas, but the plant may not completely die until the rhizome is frozen. Fig. 2 indicates the relation between climatic factor and areas where the plant can spend winter. The northern boundary of occurrence is set in the zone with the average atmospheric temperature in January at 1°C, the average annual atmospheric temperature at 13°C, and with the average monthly minimum temperature at −3°C. Even in the above areas, the plants do not always survive in winter. For the habitats where waterhyacinth may spend winter require such waters as those which are stagnant and shallow in depth, not frozen at the surface in the season, and at the edges of which emerged plants, for example, reed (*Phragmites communis* Trin) are growing. Waterhyacinth plants begin regrowth in April to May. Those plants are able to spend winter by means of the following methods: the rhizome survive under other emerged plants, in the peaty mat formed from dead plants, or the seedling may spend winter.

Acknowledgment

The authors wish to thank the staffs of the prefectural agricultural experiment stations for their kind cooperation in response to our questionnaires.

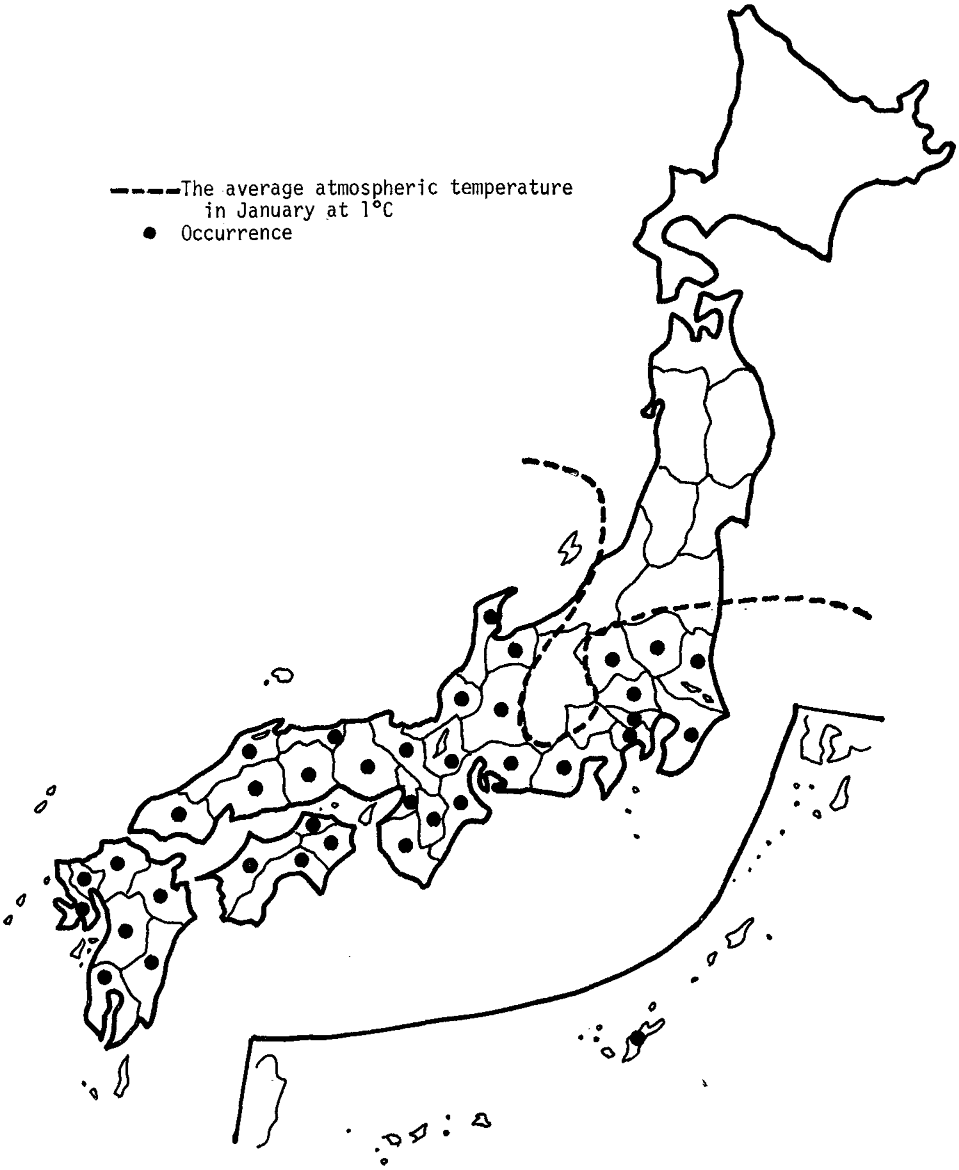

Fig. 2. Effect of climatic factor on distribution of waterhyacinth.

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Studies on the Growth and Control of Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms]

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Abstract. A study was made on the growth of waterhyacinth in a pond located at the Bogor Botanic Garden, Indonesia, where the plant was introduced for the first time into Southeast Asian region in 1894. Quadrats of one sq. meter were made at places with various depths, pH, total N,PO_4,K and Ca. One bulbous-form plant with 6 leaves was planted in each quadrat.

Important factors greatly affecting the growth rate were the water depth and phosphate content. Under this condition the number of leaves was doubled every 7–10 days, and the quadrat was covered with plants in less than 52 days. The mass production was calculated to reach 106 ton/ha/year which absorbed 313.0 kg N and 95.8 kg P/ha/year.

Glyphosate at 2 kg/ha, ametryne at 0.5 kg/ha, diquat+2,4-D at 0.5+2.0 kg/ha and paraquat +2,4-D at 0.5+2.0 kg/ha gave good results to control the plant, in which the herbicides were slightly better absorbed by the roots than by the leaves. The use of different formulation of herbicides, such as the use of rubber based slow release herbicides will be briefly discussed.

The effect of excess nutrient content on waterhyacinth response to herbicide application is included.

INTRODUCTION

Waterhyacinth is the most troublesome of the 10 major aquatic weeds that occur in the 8 Southeast Asian countries (Soerjani *et al.*, 1975). Bock (1969), Penfound and Earle (1948), Westlake (1963), Haller and Sutton (1973), Chadwick and Obeid (1966), Vaas (1951), Widyanto and Soerjani (1974) among others, have studied its growth rate under temperate as well as tropical conditions in the laboratory and in the field. Their studies was focused on its growth rate as affected by nutrient, pH, water-depth, light intensity, etc.

Sheffield (1970) reported that a proper CNP ratio plus micronutrient may promote the growth rate of waterhyacinth. With an increase of particular nutrient elements or a combination of some of the macro and micronutrients (N, P, K, Ca, Cu, Mn, Bo, Fe, etc.), it is possible that massive growth of plant be stimulated. In practise if the critical factors are precisely known, the increase of this particular nutrient can be prevented.

This paper discusses environmental factors affecting the growth of waterhyacinth under field conditions and the effectiveness of some herbicides and their combinations to control it with different methods of (foliar and root) applications. An experiment was conducted to study the effect of some of the nutrients on the effectiveness of the herbicides.

Materials and Methods

Growth of waterhyacinth. Twelve floating bamboo quadrats of one m^2 each were made in four places in the pond at the Bogor Botanic Garden. One plant of waterhyacinth with 5–7 leaves and 10–20 g fresh weight was grown in each quadrat. Each plant has nearly the same SGR (Summed Growth Ratio calculated from leaf number, plant height, % area covered and fresh weight). The plants were observed weekly and the variation of water condition in depth, pH, temperature, $N-NO_3$, $N-NH_4$, $P-PO_4$, $K-K_2O$ and Ca were observed. This experiment was conducted for 52 days, from October to November 1974.

Greenhouse experiments with herbicides. Twenty seven pails of 4.2 l were filled with 4 l pond water and planted with one waterhyacinth each. The water was added with 1.266 cc 1 M $CaCl_2$, 0.162 cc 1 M KOH, 0.067 cc 0.01 M NaH_2PO_4 and 0.779 cc 0.01 M $NaNO_2$ every 3 days. One week after planting, they were treated with glyphosate (2 kg/ha), ametryne (0.5 kg/ha), diquat+2,4-D (0.5+2.0 kg/ha) and paraquat+2,4-D (0.5+2 kg/ha). The herbicides were foliar as well as root applied. It was a completely randomized design, with 9 treatments (including a series of untreated pots) all with 3 replicates. Every 2 days, % damage of plants, pH and dissolved oxygen content of the water were measured. The experiment was terminated after 14 days.

The effect of excess nutrient content on waterhyacinth response to herbicides. Waterhyacinth were grown in plastic pails of 4.2 l with 4 l of pond water with different levels of additional nutrient. $N-NO_3$, $N-NH_4$, $P-PO_4$, $K-K_2O$ and Ca were added at 100% and 200% of the concentration of the respective nutrients in pond water (100% of the nutrients in pond water were; $N-NO_3$: 0.031 ppm; $N-NH_4$: 1.6 ppm; $P-PO_4$: 0.016 ppm; $K-K_2O$: 3.83 ppm and Ca: 10 ppm). Two weeks after growing in these solutions, the plants were sprayed with paraquat+2,4-D at low and high rates, e.g. 0.15+0.4 kg/ha and 0.75+2.0 kg/ha respectively. Two weeks after spraying the plants were harvested for fresh and dry weights.

Results and Discussion

Pond experiment. Table 1 shows that variation of nutrient content of the pond water was so high that it was not possible to get a significant result. However, there was a correlation between $P-PO_4$ with dry weight, increase of fresh weight, increase of leaf number and between pH with the increase of fresh weight, increase of leaf number and shoot number, i.e. in this pH range the higher the pH the better the growth of the plants. It was calculated from this experiment that mass production (fresh weight of waterhyacinth) is 106/ton/ha/year which absorbed 313.0 kg N and 95.8 kg P/ha/year and its relative growth rate (RGR) is 3.69%/day, measured from the increase of fresh weight. This is lower than the result of an experiment at Louisiana by Bock (1969) in which the RGR was 5.8–8.6%/day and 9.9%/day in Jamaica. The value of RGR in Congo river was 4.9%/day (Evans, 1963). Table 2 shows that the nutrient content in this pond is lower than that of other open waters in Java, which is possibly the reason why the RGR of waterhyacinth in the pond is low.

Table 1. Correlation between physical and chemical condition of pond water at the Bogor Botanic Garden and waterhyacinth.

Parameter	Station			
	I	II	III	IV
N—NO_3 (ppm)	0.03 ±0.05	0.03 ±0.03	0.036±0.042	0.035±0.040
N—NH_4 (ppm)	1.54 ±0.03	1.45 ±0.84	1.509±1.00	1.401±1.210
P—PO_4* (ppm)	0.047±0.02	0.061±0.03	0.049±0.50	0.085±0.050
K—K_2O (ppm)	3.76 ±0.22	3.79 ±0.44	3.69 ±0.50	3.54 ±0.43
Ca (ppm)	9.10 ±1.22	10.61 ±1.50	9.34 ±1.50	8.48 ±1.17
pH**	7.30 ±0.3	7.14 ±0.36	7.1 ±0.35	7.73 ±0.64
Depth (cm)	46.59 ±4.17	42.85 ±2.91	38.35 ±3.48	20.99 ±1.43
Fresh weight (g)	1390	1290	780	2600
Dry weight (g)	61.40	75.60	41.23	109.97
Delta SGR (%)	99.5	92.0	68.5	133.0
RGR (%)	4.04	3.71	3.34	3.68

* Correlation with dry weight, delta fresh weight, delta leaf number.
** Correlation with delta fresh weight, delta leaf number, shoot number.

Table 2. Water quality of open water in Java, 1974.

Place of sampling	Ca	N—NO_3	N—NH_4	Tot. N	PO_4	K
			(ppm)			
Bogor Botanic Garden	8.20	0.056	0.405	0.475	0.055	3.69
Swampfaround Krawang (West Java)	19.61	0.034	0.266	0.300	0.041	3.30
Bureng (East Java)	66.0	1.54	0.14	1.68	0.3	5.08
Senggreng (East Java)	53.6	1.12	0.14	1.26	0	3.51
Rawa Pening (Central Java)	30.8	0.56	0.14	0.70	0	3.51

Greenhouse experiment with herbicides. Root application of glyphosate, ametryne, diquat+2,4-D and paraquat+2,4-D is better than foliar application. This is shown in Fig. 2, % damage of waterhyacinth treated with glyphosate and ametryne foliar applied is lower than the root applied. Diquat+2,4-D and paraquat+2,4-D worked very rapidly, one day after application the effect was clearly observed. Diquat combination was slightly better on the first day, but the result was the same after 4 days. After 14 days almost all plants were killed, but the plants treated with glyphosate 2.0 kg/ha were not completely killed. According to Pieterse and van Rijn (1974) at this rate waterhyacinth will be killed after 8 weeks, but at 16 ppm glyphosate, Guritno and Pheang (1975) have shown in their experiments that it only retarded its growth. The use of ametryne 0.5 kg/ha gave a good result on the plant after 14 days. This confirm the result of an experiment conducted by Guritno and Pheang (1975). Dissolved oxygen content decreased lower in root applied plants than in the foliar applied.

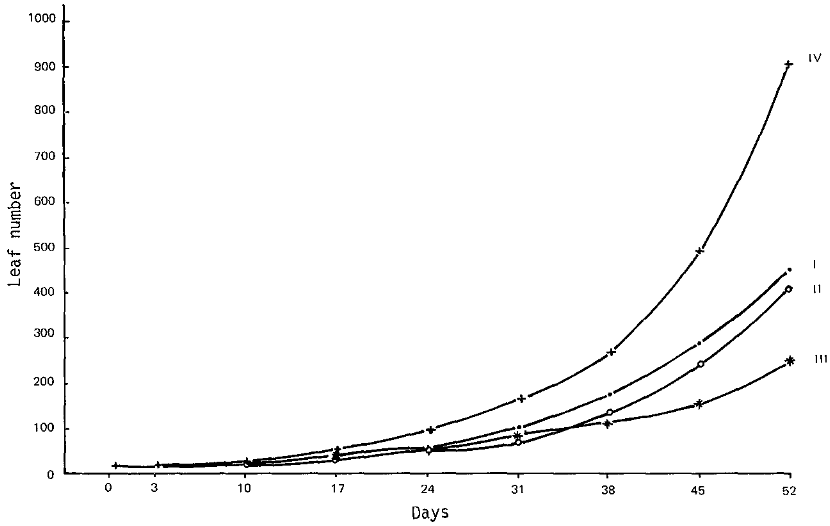

Fig. 1. Increase of leaf number in each station.
I, II, III, IV: increase of leaf number in respective station.

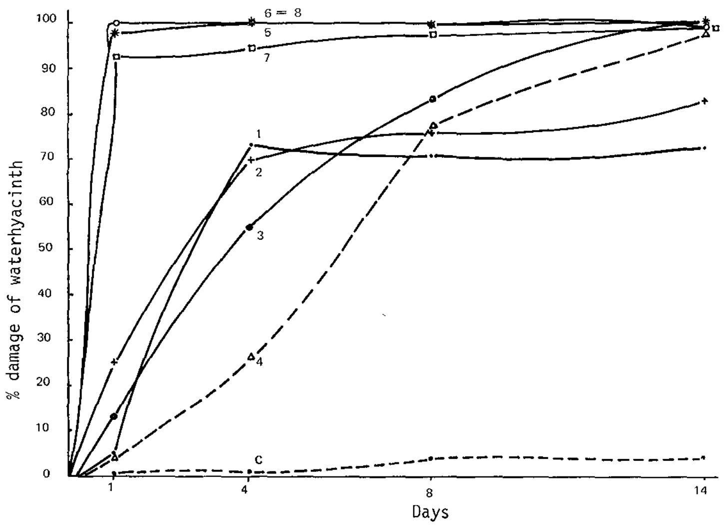

Fig. 2. % damage of waterhyacinth in 14 days.
c=control or untreated pot.
1=foliar application of glyphosate #2.0
2=root application of glyphosate #2.0
3=foliar application of ametryne #0.5
4=root application of ametryne #0.5
5=foliar application of diquat+2,4-D (#0.5+#2.0)
6=root application of diquat+2,4-D (#0.5+#2.0)
7=foliar application of paraquat+2,4-D (#0.5+#2.0)
8=root application of aparaquat+2,4-D (#0.5+#2.0)
(#: kg a.i/ha).

The effect of excess nutrient content on waterhyacinth response to herbicides. Fourteen days after application, all plants treated with higher rate were completely killed, while those treated with lower rate were still alive. These plants were grown in solution added with 100% NO_3, 200% K, 400% Ca. It seems that excess of K and Ca delayed the effect of herbicides to plants, maybe because of their role in the plant metabolism. It is known that K plays an important role in the translocation of assimilates, while Ca may decrease the permeability of the cell membrane to certain ion (such as Na^+) and may decrease the stomatal aperture. However, there was another experiment showing somewhat conflicting result, i.e. no significant difference was observed on the effect of additional 200% and 400% of Ca and N total on waterhyacinth response to 0.5 kg/ha of ametryne. Another experiment conducted to check the performance of ametryne rubber based formulation vulcanized with 1% per hundred rubber of sulphur made by Mr. A. F. S. Budiman, from Research Institute for Estate Crops, Bogor, Indonesia showed that there was no different result with the W.P. formulation applied to the water. (* This rubber based formulation is four days after application the leaves began to dessicate and the plants were completely killed after 14 days.

Conclusion

1) Waterhyacinth at Bogor Botanic Garden, Indonesia has a RGR of 3.69%/day which is rather low as compared with results in other places. Since the pond water has a relatively low content of Ca, N (NO_3) and N total, it will be important to study the RGR of waterhyacinth in other open waters in Indonesia for comparison.

2) Waterhyacinth growth is affected by the depth of water, although no significant difference was observed due to the variations in the water depth during the course of study.

3) Ametryne (0.5 kg/ha), paraquat+2,4-D (0.5+2 kg/ha) and diquat+2,4-D (0.5+2 kg/ha) gave a total kill on waterhyacinth after 14 days. Whereas glyphosate (2 kg/ha) gave only a 75% damage on the plant.

4) The treatments, especially that of ametryne of both foliar and root applications and that of paraquat+2,4-D root application slightly decreased the oxygen content of the water, therefore, precaution has to be made to avoid possible hazardous effect of the herbicides on aquatic biota.

5) The root application of those herbicide gave similar result with foliar application, although the later gave slower response.

6) Rubber based formulation of ametryne (with 1% sulphur) may give a new prospect of the herbicide application into the water with less risk of drift. However, this needs further studies.

Acknowledgements

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Interaction between pH and Nutrient Concentration on the Growth of Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms]

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Abstract. An experiment to study the interaction between pH and nutrient concentration on the growth of waterhyacinth (*Eichhornia crassipes*) shows that waterhyacinth grows better in a medium with pH 7.0 than with pH 4.0 or pH 5.5.

Different levels of nitrogen, phosphorus and potassium gave a highly significant difference on the growth of waterhyacinth. Interaction was found between the effects of different pH and levels of phosphorus, but no interaction between the effects of different pH and levels of nitrogen or potassium. The uptake of phosphorus was more intensive at pH 4.0 while the uptake of nitrogen and potassium was more intensive at pH 7.0.

INTRODUCTION

Waterhyacinth is one of the most noxious aquatic weeds in the world. In most Indonesian open waters, it causes serious problems in irrigation, hydroelectric schemes, water traffic and fisheries (Tjitrosoepomo *et al.*, 1974).

It is important to know what environmental factors may stimulate or prevent waterhyacinth from massive growth, such as the nutrient level of the medium, light intensity, pH and interaction between one factor and others.

Hydrogen ion concentration influences the metabolism of plants. The physiological action of the free hydrogen ion concentration may have a critical effect. In North America the massive infestation of waterhyacinth is found in river waters with a pH of 7.0 and in the Congo river basin very much the same situation prevails (Penfound and Earle, 1948; Berg in Chadwick and Obeid, 1966). In this river, infestation of the species does not develop below pH 4.2. Chadwick and Obeid (1966) and Santiago (1973) reported from their experiments that waterhyacinth yielded best at pH 7.0. Some growth was made at pH 3.0 but both dry weight and plant number were minimal at this value.

The effects of nitrogen, phosphorus and potassium on the growth and reproduction of waterhyacinth have been studied by many investigators (Chadwick and Obeid, 1966; Talatala and Djalil, 1974; Widyanto and Soerjani, 1974; Slamet and Sukowati, 1975). In general the results of their experiments show different yield reactions to variations of nitrogen, phosphorus and potassium with increasing concentrations of the nutrients.

Little experimental data is available on the performance of waterhyacinth under controlled conditions, or its response and interaction with variations in environmental factors. The work reported here is to study the interaction effect of pH and nutrient levels on the growth of waterhyacinth.

Methods and Materials

Plants for the experiment were selected according to similarities in SGR (Summed Growth Ratio) in the number of leaves, height of plants and fresh weight (Numata, 1971).

The selected plants were grown in Hoagland solution with four levels of nitrogen (0%, 25%, 50% and 100% of the normal strength) and with three different pH (4.0, 5.5 and 7.0). A factorial design with three replicates was used in this experiment. The pH of the solution was adjusted every 2 days using sulphuric acid (5%) and sodium hydroxide (10%). After 2 weeks the plants were harvested and the percentages of increase of SGR were measured.

Similar experiments were carried out for various levels of phosphorus and potassium in combination with different pH.

Results and Discussion

Effect of different levels of nitrogen and pH. An analyses of variance of the data indicated that the effect due to the nitrogen levels in the solution is highly significant on the percentage of increase of SGR, but the difference due to the level of pH is not significant.

Waterhyacinth produced a considerably greater number of leaf at pH 7.0 than at pH 5.5 or 4.0. No interaction effect was found between different pH and levels of nitrogen. In the solution with pH 7.0 it shows a positive linear regression, and an increase of SGR in a complete Hoagland solution (100% N level), while with pH 5.5 waterhyacinth shows a quadratic increase. However, the best uptake of nitrogen occured at pH 7.0 (Fig. 1).

In general, a high pH favors uptake of ammonium and a low pH of nitrate. Street (1969) stated that the effects of pH on nitrate and ammonium uptake vary with age and carbohydrate status of the plants, and the length of the periods over which the uptake is followed. In the case of waterhyacinth it is assumed that good nitrate absorption at pH 7.0 was observed because of the short term of the experiment.

Effect of different levels of phosphorus and pH. An analyses of variance of the data indicated that the effect due to the phosphorus levels is highly significant, but the difference due to the level of pH is not significant. Interaction effect was found between different levels of phosphorus and pH on the percentage of increase of SGR. Waterhyacinth shows a linear response at pH 4.0, while at pH 5.5 or 7.0 shows a quadratic response. However, the best uptake of phosphorus occured at pH 4.0 (Fig. 2). This result was supported by the result of Russell (1961) that the phosphate absorption in many plants increased if the pH in the solution becomes lower (4.5–5.5).

Effect of different levels of potassium and pH. The effect of different levels of potassium

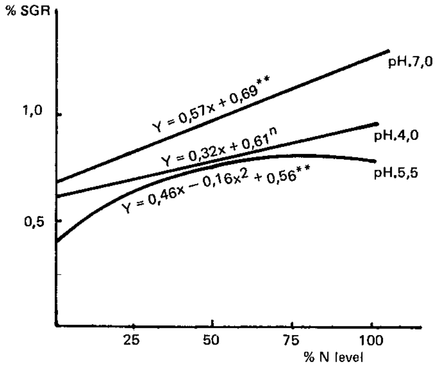

Fig. 1. Regression lines between nitrogen levels and percentage of increase of SGR in different pH.

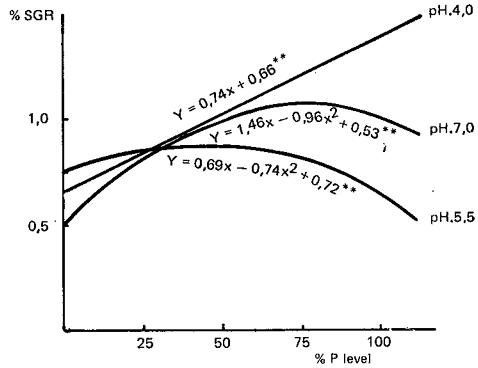

Fig. 2. Regression lines between phosphorus levels and percentage of increase of SGR in different pH.

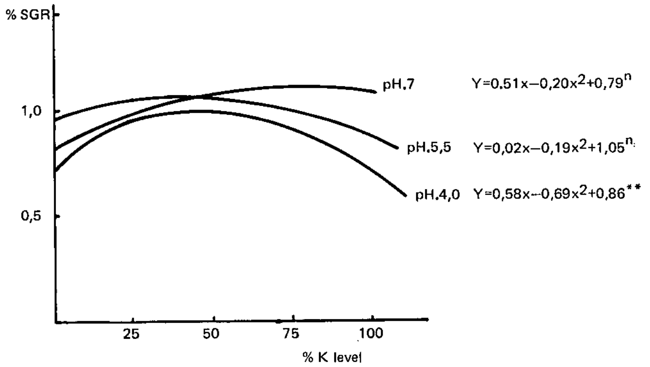

Fig. 3. Regression lines between potassium levels and percentage of increase of SGR in different pH.

and pH on the percentage of increase of SGR is given in Fig. 3.

Different levels of potassium gave a highly significant effect on the percentage of increase of SGR, but the difference due to the level of pH is not significant. There was no interaction effect between different levels of potassium and pH.

Waterhyacinth shows a quadratic response at pH 4.0, 5.5 and 7.0 in the form of SGR. However, the best uptake of potassium occured at pH 7.0 than at pH 5.5 or 4.0.

Similar result was found by Hoagland and Broyer (1940) in the experiment with excised barley roots. They found that the rate of potassium uptake was increased when the pH was raised from 6.0 to 9.0.

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Tadpole Shrimp: a Biological Tool of Weed Control in Transplanted Rice Fields

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Abstract. Three species of tadpole shrimp, *Triopus longicaudatus* Le Conte, *T. granaris* Lucas, and *T. cancriformis* Bosc. can be found in Japan. They can be utilized for weeding in transplanted rice fields. Their leg-like organs agitate the soil and, at the same time, give damage mechanically on just emerged weeds. Soft part of weed will be fed by them. The population of 20–30 tadpole shrimps per square meter may be found to be enough for weeding. Their distribution is limited to well-drained or semi ill-drained paddy fields. The most severe problem, when utilizing tadpole shrimps in more wide scale all over Japan, may be the susceptibility to pesticides, especially to insecticides.

INTRODUCTION

The tadpole shrimp is one of the "living fossils", having about 200 million years' history. It will be a tool for weed control in transplanted paddy fields, although it is really a pest animal in the direct seeded paddy fields as like as in California. In this paper, the general introduction of the tadpole shrimp as a tool of weeding in Japan will be tryed.

TAXONOMICAL POSITION

The taxonomical position of the tadpole shrimp is as follows:

Phylum: Arthropoda, Class: Crustacea, Sub-Class: Branchiopoda,
Order: Notostraca, Family: Triopsidae.

All over the world, we can find out four species; American (*T. longicaudatus* LeConte), Asian (*T. granarius* Lucas), Australian (*T. australiensis* Spencer and Hall), and European (*T. cancriformis* Bosc.) tadpole shrimps (Longhurst, 1955; Katayama, 1973a). In Japan, three of them, American, Asian and European tadpole shrimps distribute, although the last one can be found at a very limited area as described below.

LIFE CYCLE

The life cycle of tadpole shrimps in paddy fields can be illustrated as shown in Fig. 1. Some of the eggs may hatch after the flooding and puddling of the field by a

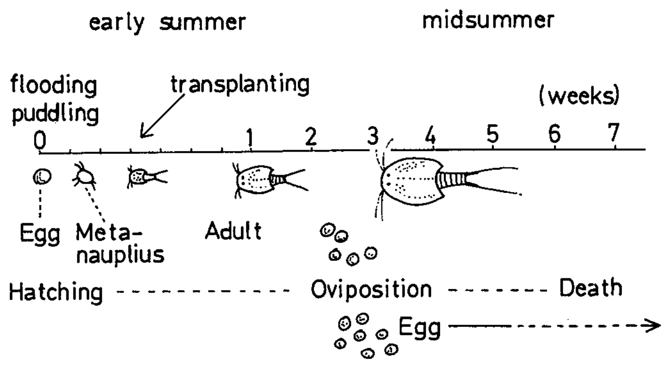

Fig. 1. Life cycle of tadpole shrimps in paddy fields.

help of sunshine (Takahashi, 1975). It takes a lot of days that all eggs will have hatched out. After two or three days of the meta-nauplius stage, they will show the adult form of tadpole shrimp just as like as that of tadpole itself. After several times of ecdyses, they begin to oviposit two weeks after hatching, then they will die 30–50 days after hatching.

It will be easily understood that their living period, from their hatching to death, is just the same as what we need weeding in paddy field. That is to say, they are agitating the soil through the period when weeds give damage on rice plants.

Their eggs are so tolerant against the changes of environments: dry, hot or cold conditions, or against high or low pH and some kind of chemicals (Katayama, 1973a). Then, they can easily overwinter, and next year they will refrain the same behavior in the transplanted paddy fields.

Distribution in Japan

The distribution of tadpole shrimps in Japan was surveyed by the questionaire to the weed specialists in each prefectural agricultural experiment stations, these three years. The results were compiled in Fig. 2.

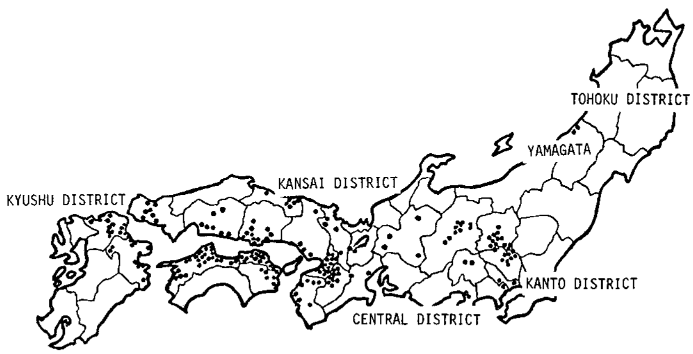

Fig. 2. Distribution of tadpole shrimps in Japan. Points show the places where they were found in 1973–1975. No distribution in Hokkaido and Okinawa areas.

Table 1. Effect of drainage of paddy field on the distribution of tadpole shrimps.

Kind of paddy field	Distribution			
	Survey year			Total average
	1973 (%)	1974 (%)	1975 (%)	(%)
Well-drained	77	82	74	77
Semi ill-drained	11	17	25	19
Ill-drained	11	1	1	4
Actual number of paddy fields surveyed	(79)	(87)	(148)	(314)

In the northern part of Japan, exceptional distribution of European tadpole shrimp was found only in Yamagata Prefecture (Katayama, 1973b). In Kanto and Central districts, we can mainly find out American tadpole shrimps, and from Kansai district to the Northern Kyushu district both American and Asian ones distribute. Southern Kyushu and Okinawa areas have no distribution. Here it may be concluded that both extremely northern or southern parts of Japan have no distribution of tadpole shrimps, except European one in Yamagata Prefecture.

In the questionnaire, the drainage condition of the paddy field, where tadpole shrimps were found, was also asked. Table 1 shows the compiled results. Here, we can say that well-drained paddy field has a preferable conditions. In Kanto district, tadpole shrimps can be found in Gumma or Saitama Prefectures where well-drained paddy fields are dominant. In Ibaraki Prefecture, where ill-drained ones are dominant, we can not find any tadpole shrimps except at the Research Institute of the Japan Association for Advancement of Phytoregulators in Ushiku Town, where soils for experiments were moved from Saitama Prefecture.

The reasons of these difference in their distribution should be clarified in future for the practical use of them in wide areas.

Weeding Mechanism

The weeding mechanism seems to be mainly a mechanical one. They have a lot of leg-like organs under their body. These organs work as agitators, then the mud will be agitated and, at the same time, just emerged weeds are injured mechanically. Here is no selection of weeds. This is a very interesting point as a biological weed control technique, with which usually only a special weed will be controlled owing to the feeding habit of the natural enemy which can not feed other weeds.

Soft part of young weeds will be fed by the tadpole shrimps. Also they feed decomposed animal dead body or humus in the soil.

The most important is that they give no damage to the transplanted rice plants which are already tolerant to such mechanical agitation by tadpole shrimps.

Utility in Weeding

About 50 years ago, weeding efficacy of tadpole shrimps was tested by the researchers of Hyogo Prefectural Agricultural Experiment Station, who found their utility. At that time the farmers called tadpole shrimps as "weeding insects" or "weeding small animals".

At present, in some local area, for instance, Nagano, Osaka and other Prefectures, the practical use of tadpole shrimps for weeding can be found. The farmers are keeping the animals, which naturally hatched and grew in their own paddy fields. In these cases, usually they used to avoid spraying insecticides, especially at the early stage of rice cultivation.

Experimental results (Katayama *et al.*, 1974; Matsunaka and Maehara, 1974) and the answers of the questionaire showed that the population of 20–30 tadpole shrimps per square meter may be found to be enough for weeding.

The judgment by the local extension agents or farmers as to the utility of tadpole shrimps for weeding in the questionaire was compiled in Table 2. Without any additional technical improvement to the present level of utilization of tadpole shrimps, about one quarter of the extension agents or farmers, who found the animals in their fields, seems to recognize the utility and intention for practical use.

Table 2. Judgment* for utility of tadpole shrimps for weeding in transplanted rice fields.

Weeding efficacy	Intention to use	Ratio		
		1974 (%)	1975 (%)	total (%)
Yes	Yes	27	17	22
Yes	No	22	9	15
No	No	51	74	63

* By 136 extension agents and farmers in total.

Problems in Future

There are many problems when we intend to utilize the tadpole shrimps in more wide area and more intensively.

At first we need more fundamental researches on physiology and ecology of tadpole shrimps, especially from the standpoint of effective utilization of them.

Insecticides or some kinds of herbicide will kill the tadpole shrimps. Then, new insecticides having low toxicity to the animal should be developed. On the other hand we should think of integrated control of all pests to crop plants in total.

They also agitate the border of paddy fields, which causes the parcolation of water through the border. Usually in the district of practical use of tadpole shrimps, the farmers made concrete border or plastic-film covered one.

If we intend to use tadpole shrimps in more wide areas, we shall need a lot of eggs to distribute. That is, a technique for the mass production of eggs is needed.

At last, we should think of the minus impacts as like as the plus ones at the time of development and practical use of new techniques from a standpoint of technology assessment. In this case, the checks of the minus impacts to human and to natural ecological balance are very important, although perhaps they may be negligible ones.

ACKNOWLEDGMENTS

The author would like to express his deep thanks for the cooperations by the weed specialists in each local agricultural experiment stations, and for kind advices by Mr. Katayama, Prof. Ueki, and Dr. Takahashi of Kyoto University Group.

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Proxenus sp. (Lepidoptera: Noctuidae), a Promising Natural Enemy of Water Lettuce (*Pistia stratioites* L.)

S. MANGOENDIHARDJO and A. NASROH
SEAMEO Regional Center for Tropical Biology (BIOTROP), P.O. Box 17, Bogor, Indonesia.

Abstract. *Proxenus* sp. attacking water lettuce (*Pistia stratioites* L.) in Java is morphologically similar to *Proxenus hennia* Swinhoe occuring in Sabah. Studies on the bionomics, host specificity and damage potential of *Proxenus* sp. showed that the insect is quite specific to water lettuce. Although its population is restricted by natural enemies in the study area, it may be a useful agent for the biological control of water lettuce in areas where it does not occur.

INTRODUCTION

Water lettuce is one of the ten important aquatic weeds in Southeast Asia (Soerjani *et al.*, 1975). According to Bennett (1975) it could be considered as the third most important weed, after waterhyacinth (*Eichhornia crassipes*) and Kariba weed (*Salvinia molesta*). Several species of natural enemies of water lettuce have been recorded (Sankaran and Ramaseshiah, 1974; Bennett, 1975). A promising leaf feeder, *P. hennia* Swinhoe was reported by Mangoendihardjo and Syed (1974) from Sabah.

In Java, *Proxenus* sp. is the most important natural enemy of the weed. Some aspects of its bionomics, host specificity and damage potentials were studied.

MATERIALS AND METHODS

In the laboratory, egg productivity and viability of *Proxenus* sp. were studied from 18 females in gauze covered plastic containers with water lettuce. Larval duration and mortality were observed from 100 freshly hatched larvae and this observation was replicated five times. Pupae were transfered to another plastic container for emergence of adults.

Host specificity was studied on 27 species of plants belonging to 15 families. More than half of the species used in the test are economic plants.

Damage potential of *Proxenus* sp. and the regrowth of the weed were observed by releasing a number of half-grown larvae on 10 water lettuce plants cultured in cement tanks.

The effect of water depths on survival of larvae was investigated with newly hatched larvae released on somewhat central plant amongst five water lettuce cultured in cement tanks filled with mud so that the water depths of 0; $2\frac{1}{2}$; 5 and 10 centimeter were maintained. Pupation was recorded and the experiment was conducted with five replicates.

Results and Discussion

The infestation of *Proxenus* sp. varied from locality to locality. Larvae of this insect were attacked by two species of unidentified larvae belonging to the orders Diptera and Coleoptera.

Adults of *Proxenus* sp. are nocturnal. They usually emerged and mated at about 7.00–9.00 p.m. Females laid their eggs in groups of 5–90 with brownish wooly covering on both sides of the leaves. Egg productivity was about 355 and nearly 95 percent were viable. Incubation period ranged from 4 to 6 days.

Newly hatched larvae fed on nearest available leaves, but later they prefered to feed on young leaves. The fully grown larvae were about 20 milimeters in length. Shortly before pupation the larvae bored into the swollen parts of the old leaves and pupated after 1–2 days. Larval mortality was about 79 percent and larval duration ranged from 17 to 21 days. Pupal stage lasted for 6–9 days and the entire development was completed in 28–37 days.

The bionomics of *Proxenus* sp. was similar to that *Proxenus hennia* found in Sabah (Mangoendihardjo and Syed, 1974) except that the former laid more eggs but larval mortality was higher.

In starvation test the insects could only survive and completely develop on water lettuce. The newly hatched larvae died after one or two days on *Sorghum vulgare, Oryza sativa, Zea mays, Allium cepa, A. fistulosum, Monochoria vaginalis, Eichhornia crassipes, Limnocharis flava, Salvinia molesta, S. cucullata, S. natans, Brassica oleracea, B. chinensis, Raphanus sativus, Glycine max, Vigna sinensis, Arachis hypogaea, Amaranthus hybridus, Manihot esculenta, Ipomoea aquatica, I. batatas, Marsilea crenata, Ludwigia adscendens, Kaempferia galanga* and *Daucus carota*. The larvae could not survive even on *Colocasia* sp. which belongs to the same family as the water lettuce (Araceae). It seems that *Proxenus* sp. is specific to water lettuce and this phenomenon was supported by the result of oviposition test where it prefered to oviposit on water lettuce amongst other test plants.

Larvae of *Proxenus* sp. were able to destroy about 50–70 percent of leaves and buds at density of one or two halfgrown larvae per plant.

Acknowledgements

The authors are thankful to Prof. Dr. Soeratno Partoatmodjo, Director of BIOTROP and Dr. Mohamad Soerjani, Program Manager of Tropical Pest Biology for their assistance in making the study possible. We are thankful also to Prof. Dr. George E. Allen, University of Florida and the Director of CIE for the identification of insects.

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The Effect of Growth Retardation on Lawns with 2-chloro-9-hydroxy-fluorene-9-carboxylic Acid (CF-125)

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Abstract. The use of chemical growth retardants on grassland is to save labour for mowing and to keep up a fine sight.

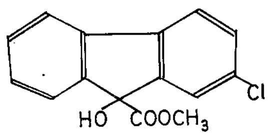
The mixture of 2-chloro-9-hydroxy-fluorene-9-carboxylic acid (CF-215) with Maleic hydrazide (MH-30) proved very effective for lawn-length control. This mixture was very useful of extensive grasslands along roadsides, on the greenbelt of highways, railroadsides, banks, training grounds, airports, etc. At the same time CF-125 gives satisfactory inhibition (herbicidal activity) of broad-leaved weeds.

The most effective application timing is early spring at the time when plant height is 10–15 cm, or just after mowing when plant height grows more than 20 cm. It was possible to inhibit the growth of the most commonly used grass species without mowing through out the growing season.

INTRODUCTION

Since Schneider first published the interesting physiological effects of Morphactins (Chloro-flurenol) in 1964, many workers have described a variety of physiological phenomena caused by these compounds.

Morphactins has many related chemical compounds. Particularly, "methyl-2-chloro-9-hydroxy-fluorene-9-carboxylate" is a high active compound. This compound has been developed for practical use as the commercial name of CF-125.



C F - 1 2 5

Molecular weight : $C_{15}H_{11}O_3Cl$ (M.W. 274.72)

Melting point : 152°C

Water solubility : 21.8 ppm

Morphactins shows various kinds of growth effects against plants. But it has not been made clear the mechanism of action yet. It is suggested that plant hormone, auxin, gibberellin and kinine show mutual activity with Morphactins.

As one of characteristic effects, Morphactins controls the function of cell-division and retards cell-elongation without blighting plants. We make use of this activity for the labor-saving management of mowing, and we recognized its high practicality.

METHODS AND MATERIALS

At first, the basic growth retardant effects of CF-125 was investigated on the representative lawn in Japan.

Concerning the relation between concentration and retardant effect, 500, 1,000, 2,000 and 5,000 ppm of CF-125 were sprayed on lawns of 10 cm stage. Concerning the relation between growing stage and retardant effect, CF-125 was sprayed on each lawn of 10 cm, 15 cm, 20 cm and 30 cm stage. As to the lawn of over 30 cm stage, application was made after mowing until 10 cm stage. Concerning the effect of mixture compounds of CF-125 and MH-30, mixing effect of 1,000 ppm of CF-125 and 3,000 ppm of MH-30 was investigated.

Under the results of investigation above mentioned, the evaluation test on the labor-saving effects of mowing and weed control effects was made on grassland of roadside or the like. CF-125 and MH-30 were mixed by 3 kg a.i./ha each, and application was made at 15 cm stage.

RESULTS AND DISCUSSION

Lawn begins to grow at the end of March and grows flourishingly in May in Japan. Lawn ears up in June, and the height of plant reaches the climax.

The effect of CF-125 on the lawn of 10 cm stage at sprout time is shown at Fig. 1. The growth retardant effect was observed for about one month after application in either case of 500 ppm to 5,000 ppm. In case of over 1,000 ppm, elongation of stalk, which is usually seen in May, and earing was retarded strongly, and the height of plant in July was half to one third (1/2–1/3) in comparison with the case of no application. The

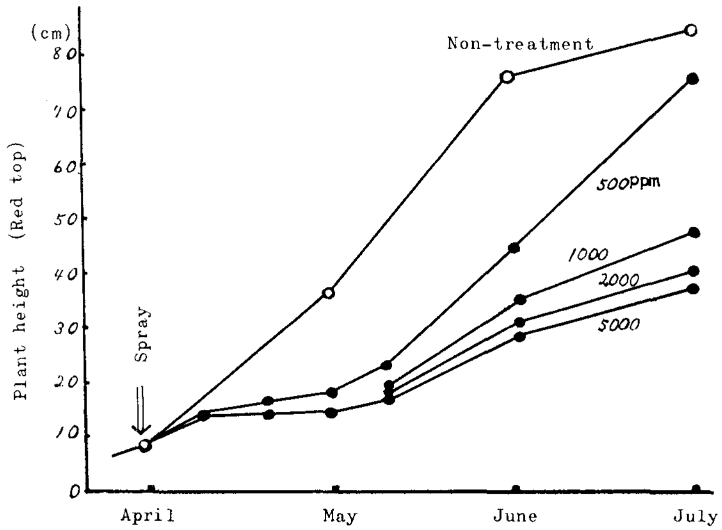


Fig. 1. Plant height regulatory activity of different concentration of CF-125.

characteristic of this compound is that the effect is not influenced by the concentration, in case of over 1,000 ppm. At the low concentration (below 500 ppm), which can not fully retard the function of cell-division, earing was observed and in result, the growth retardant effect was not observed distinctly.

The application timing of CF-125 is the most important condition of good effects. Referring to Fig. 2, CF-125 shows little effect on the plant whose height grows more than 20 cm and little retardant effect on earing. It is considered that CF-125 can not show the retardant activity of cell-division because, differentiation of stalk and heading has advanced already. In case of lawn at over 20 cm stage, practical effects might be achieved by spraying just after mowing (Fig. 3). In this case, it is necessary to spray

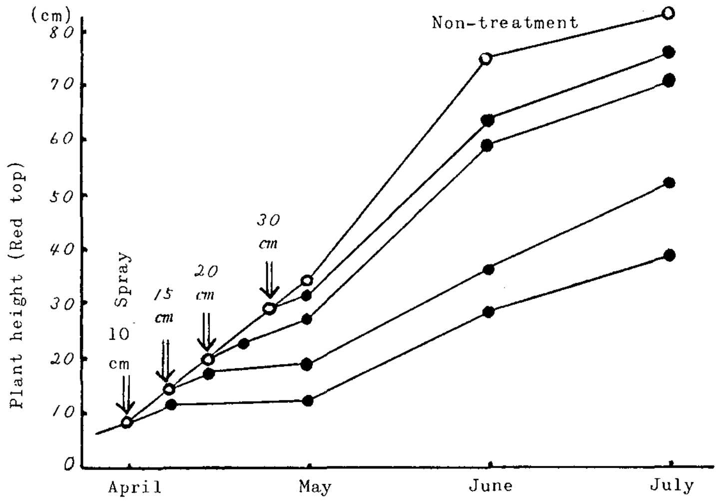


Fig. 2. Effect of CF-125 in different growing stage.

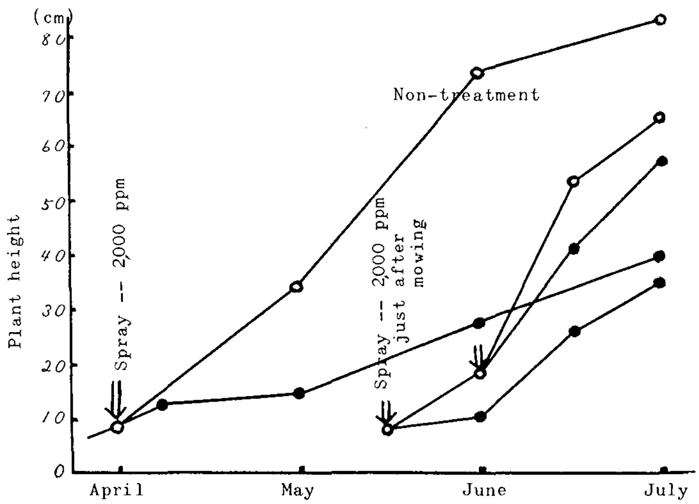


Fig. 3. Effect of CF-125 treatment just after morning.

before regrowth after mowing, that is to say, within 2 or 3 days after mowing.

MH-30 is a retardant which is well known earlier than CF-125. But it is not efficient fully as a growth retardant on the lawn.

Mixture of CF-125 and MH-30 widen active spectrum on various kinds of lawns and increase retardant activity. (Fig. 4, Table 1) Then as the conclusion, CF-125 shows good effects in case that practical concentration is 2,000 ppm to 3,000 ppm and MH-30 is mixtured.

Then, practical evaluation was made on the grassland at roadside or greenbelt of highway. CF-125 and MH-30 were mixtured by 3 kg a.i./ha each.

Usually, the following plants are used on the lawn; Kentucky bluegrass (*Poa*

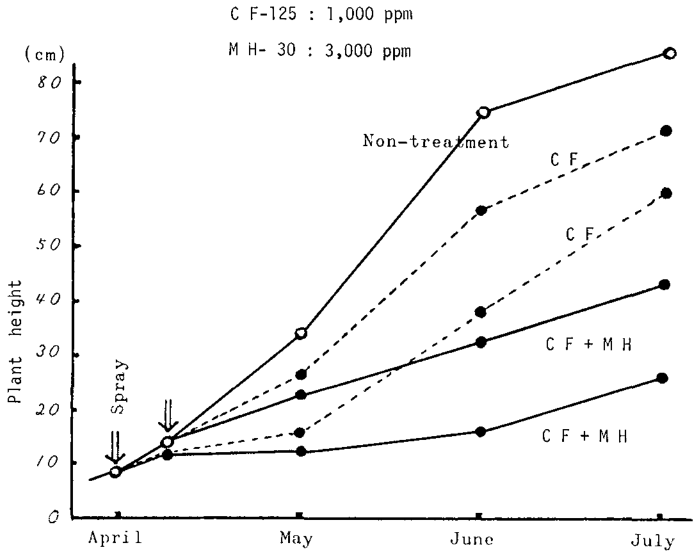


Fig. 4. Plant height regulatory activity of CF-125, MH-30 and mixture.

Table 1. Plant height regulatory activity of CF-125, MH-30 and mixture.

Species	Plant height % against control		
	CF-125 3 kg a.i./ha (%)	MH-30 3 kg a.i./ha (%)	CF-125 3 kg a.i./ha MH-30 3 kg a.i./ha (%)
Poa pratensis	60	85	40
Poa trivialis	75	80	45
Dactylis glomerata	60	90	45
Lolium perenne	55	85	35
Phleum pratensis	60	90	35
Agrostis tenuis	55	85	35
Eragrostis curvula	70	95	40
Lolium multiflorum	60	90	35

Treatment: 15 cm plant height stage.
Data taken 3 months after treatment.

pratensis), Italian ryegrass (*Lolium multiflorum*), redtop (*Agrostis alba*), orchardgrass (*Dactylis glomerata*), *Eragrostis curvula* etc.

By the application of this compound (CF-125+MH-30), earing was not seen until the end of growing season, lawns did not grow over the height of 30 cm, and it was not necessary to control mowing. Therefore, this compound was much helpful to keeping up a fine sight.

At the same time, the mixture of CF-125 with MH-30 showed herbicidal effects on broad-leaved weeds which overgrow in common grassland, as follows; *Taraxacum platycarpum*, *Trifolium* sp., *Rumex japonicus*, *Erigeron* sp., *Plantago* sp., *Artemisia vulgaris*, *Cayratia japonica*, *Capsella bursa-pastoris*, *Cirsium* sp.

This compound inhibited these weeds completely, so it proved very effective for broad-leaved weeds.

CF-125 retards the growth of lawns and grass weeds without blighting, and is of high utility value to save labor for mowing and to keep a fine sight.

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Report on 5th Asian-Pacific Weed Science Society Conference

The 5th Conference was held at the Conference Hall of the Science Council of Japan, Tokyo, Japan from 5th to 11th, October, and cohosted by the Science Council of Japan, the Weed Science Society of Japan, and Japan Association for the Advancement of Phyto-Regulators.

Three hundreds and three delegates attended from Australia, Canada, Colombia, Federal Republic of Germany, France, Hongkong, Indonesia, India, Japan, Kingdom of Tonga, Lebanon, Malaysia, New Caledonia, New Zealand, The Phillippines, Republic of China, Republic of Korea, Singapore, Thailand, United Kingdom and U.S.A., and 101 papers were reported at the general session. Two plenary lectures introducing Japan were also presented.

At the same time, an Symposium "The Integrated Control of Weeds" was held under the auspices of the Ministry of Agriculture and Forestry. The symposium was chaired by Mr. J. R. Fryer, Director of Weed Research Organization, Agricultural Research Council, England, and ten excellent lectures were presented. One day was spent for the field trip and excursion around Kanagawa Prefecture by bus, which were also sponcered by the Ministry of Agriculture and Forestry. The lectures of the symposium will be published as a title of Integrated Control of Weeds by University of Tokyo Press in near future.

Fourth biennial meeting was also held on 11th, October, 1976 and the minutes of the meeting is reported in the following pages by Dr. Donald L. Plucknett, Secretary of APWSS.

Shooichi Matsunaka
Secretary General
Organizing Committee of 5th APWSS Conference

Minutes of Fourth Biennial Meeting, Tokyo, Japan

The Conference Hall, the Science Council of Japan, October 11, 1975

1. *The meeting* was opened by President Kenji Noda, who introduced the officers of the Society.
2. *Minutes of the Fourth Conference* in New Zealand were read by the Secretary.
3. *The report of the Executive Committee* for the period 1973–1975 was read by the Secretary.
4. *The Treasurer's report* was read by R. K. Nishimoto. Dr. Nishimoto expressed thanks to the Japan Association for the Advancement of Phyto-Regulators and to sustaining members for assistance in publishing the third conference proceedings.
5. *Committees and Special Appointments:*

a. *Newsletter*—Dr. Philip Motooka of the East West Food Institute has agreed to take on this responsibility. The Secretary requested that members submit news and photographs for the Newsletter to Dr. Motooka. A quarterly schedule was suggested.

b. *Membership* is low than desired and should increase. All members should encourage individuals to join the Society. Mr. A. Cates (Malaysia) urged commercial firms to become sustaining members, pointing out that they do benefit from activities of the Society.

c. *List of weed workers in the Asian-Pacific area:* The old list needs to be up-dated. Dr. George Mason (New Zealand) suggested that one person be named in each country or local society to work with APWSS.

6. *News business:*

a. *International Weed Science Society*—John Fryer (U.K.), a member of the Steering Committee, presented report on the history and status of the IWSS. There are now about 41 national or regional weed organizations, most of which work locally, with little collaboration or communication with the other groups. The IWSS has been formed to assist in better cooperation between groups, *but is not intended to replace local or regional organizations.*

In February, 1975 at the Weed Science Society of America meetings in Washington, D.C. an eight man steering committee was set up to organize the IWSS. Five of the eight men attended the fifth APWSS conference in Tokyo; these were: L. Matthews, J. Fryer, L. Burrill (Sec. of IWSS), G. Doll and R. Ennis. Neal Shafer is Chairman.

IWSS will issue a brochure by the end of 1975. IWSS would like to prepare a directory of weed workers, and is considering jointly-sponsored meetings or symposia on a world-wide basis.

—Dr. R. Romanowski (USA) moved that APWSS support IWSS in its programs. Second: Dr. M. Soerjani (Indonesia). The motion passed, unanimously.

—Dr. Soerjani then moved that Past President L. Matthews be named APWSS representative to IWSS. Second—A. Cates, Passed.

b. *Honorary Life Membership:* Dr. Y. Baron Goto (USA) was selected as the first recipient of Honorary Life Membership at the Fourth Conference in New Zealand.

Dr. Kenji Noda, (Japan) Dr. Shooichi Matsunaka (Japan) and Mr. L. J. Matthews (New Zealand) were selected for Life Membership at the Fifth Conference.

c. *The report of the Fifth Conference* was given by Dr. S. Matsunaka.

—303 total participants
86 overseas participants
—101 papers
2 plenary papers

d. *Amendments to APWSS rules:* It was moved (Cates/Matthews) that Section III, IV and VI be amended. Carried unanimously. The Rules, as amended, will be mailed to all members.

e. *Sixth Conference*

Indonesia was selected as the venue for the Sixth Conference in 1977.

f. *Seventh Conference*

Australia invited the APWSS to meet there in 1979. Australia was selected as the site for the Seventh Conference.

7. *Election of Officers:* The following officers were elected:

President—Dr. M. Soerjani, Indonesia
Vice President—Dr. Peter Michael, Australia
Executive Committee members:

1. Mr. Wong See Ping, Malaysia
2. Dr. S. K. De Datta, India (IRRI)
3. Mr. L. J. Matthews, New Zealand
4. Mr. Michel Lambert, France (South Pacific Commission)
5. Mr. Larry Burrill, USA (International Plant Protection Center)
6. Dr. Shooichi Matsunaka (Japan)

The Secretary and Treasurer, who are based at the Secretariat in Hawaii, are Dr. Donald L. Plucknett, and Dr. Roy K. Nishimoto, respectively.

8. *Comments—Incoming President:*

The newly—elected President, Dr. M. Soerjani, expressed gratitude to the APWSS for their confidence and trust. He expressed special thanks to the Japanese Organizing Committee for the Fifth Conference; Dr. Noda, APWSS President; Dr. Togari (JAPR); Dr. Numata (WSSJ); Dr. S. Matsumaka, Secretary General of the Conference; and to the government of Japan.

He then announced the following committees and work groups which will begin work during the next biennium. The Committees will be:

a. Newletter (chairman—Dr. Philip Motooka)
b. Membership (chairman—Dr. Roy Nishimoto)
c. Inventory of cleared or registered herbicides (Dr. Santiago Obien)
d. Inventory of weed legislation in the Region.

e. Standardization of:
   (1) common weed names
   (2) chemicals
   (3) methods of research.

The Work Groups will be:

a. Perennial weeds
b. Aquatic weeds
c. Assessment of crop losses
d. Weed control for smallholders and small farmers.

President Soerjani announced that a circular would be sent to the membership asking each person to indicate his interest and preference for the committees and work groups. He stressed that APWSS wishes to maintain relationships with national and regional organizations. He asked for the support and cooperation of all.

9. *Votes of thanks* were extended to:

a. The Secretary and Treasurer

b. Japan and its cooperating Societies who conducted the Fifth Conference in such a fine manner.

c. The interpreters who did an outstanding job of translating.

d. The retiring members of the Executive for their dedication and hard work.

10. *Close of Conference*

Dr. Kenji Noda, Past President, 1973–1975, closed the Conference with words of special thanks to the speakers, delegates, Japanese Ministry of Agriculture and Forestry, Weed Science Society of Japan, the Japanese Association for the Advancement of Phyto-Regulators and to the simultaneous interpreters.

Respectfully submitted:
Donald L. Plucknett,
Secretary, APWSS

November 2, 1975
Washington, D.C. USA

Rules of the Asian-Pacific Weed Science Society (Inc.)

1. Name

The name of the Society shall be the Asian-Pacific Weed Science Society (Incorporated) hereinafter called the Society.

2. Objectives

The objectives of the Society shall be to promote weed science, in particular in the Asian and Pacific regions, by pooling and exchanging information on all aspects of weed science.

3. Membership

There shall be five classes of membership.

(i) Ordinary members
(ii) Sustaining members
(iii) Honorary members
(iv) Associate members
(v) Affiliated national or region societies

4. Mode in which Persons become Members

(i) *Ordinary members:* Any person or organizations interested in the objectives of the Society mey become a member.

(ii) *Sustaining members:* Proprietary companies interested in the objectives of the Society may become sustaining members by biennial financial contributions to the Society.

(iii) *Honorary members:* Any member who has given outstanding service to the Society may be elected as an honorary member at any biennial or special general meeting.

(iv) *Associate members*

(v) *Affiliated societies*—national or regional societies may affiliate with APWSS for purpose of kindred interests, communication, coordination of activities, etc., by letter of intent or requst to APWSS.

5. Mode in which Persons cease to be Members

(i) Any member of the Society may resign by giving notice in writing to the Secretary.

(ii) Any member whose subscription is more than four years in arrears shall be removed from membership and may be readmitted on payemnt of such arrears or an amount decided by the Executive.

6. Officers of the Society

The Officers of the Society shall be:

(i) President
(ii) Vice-President
(iii) Secretary (Permanent position)

(iv) Honorary Treasurer (Permanent position)

and shall be elected at the biennial general meeting. Officers shall hold office until three months after termination of the biennial general meeting next following their election. Newly appointed officers shall take office at the same time.

7. EXECUTIVE COMMITTEE:

The Executive Committee shall consist of:

(i) The President
(ii) Vice-President
(iii) Secretary
(iv) Honorary Treasurer
(v) Immediate Past President
(vi) Six other members

The Executive Committee shall have power to appoint new members to fill any casual vacancy and shall have power to co-opt not more than three other members.

8. ELECTION OF EXECUTIVE COMMITTEE

The members of the Executive Committee shall be elected at the biennial general meeting in the same manner and at the same time as other officers.

9. POWERS OF THE EXECUTIVE COMMITTEE

The Executive Committee shall have all the powers of the Society provided that these powers do not conflict with the rules.

10. DELEGATION OF POWERS BY EXECUTIVE COMMITTEE

The Executive Committee may delegate its powers and duties to subcommittees consisting of such member or members as it may resolve and may grant to any such subcommittee the power to co-opt other persons, whether members or not.

11. EXECUTIVE COMMITTEE—QUORUM

At any meeting of the Executive Committee four shall form a quorum.

12. PATRON OF THE SOCIETY

A patron shall be selected from the country in which the President is resident.

13. BIENNIAL GENERAL MEETING

(i) A biennial general meeting shall be held every two years at the biennial conference or at a time or place decided by the Executive Committee.

(ii) If not to be held at the biennial conference, at least three months' notice shall be given to all financial members of the time and place of biennial general meeting.

(iii) At each biennial general meeting an audited balance sheet and income and expenditure account shall be presented.

(iv) At each biennial general meeting a biennial report shall be presented.

(v) At the biennial meeting (or any special general meeting) a quorum shall consist of 15 members.

14. VOTING

Only ordinary and honorary members are entitled to vote. At all meetings voting shall be on the voices or by a show of hands at the discretion of the Chairman provided that if any member shall so demand voting shall be by ballot. The Chairman shall have a deliberative and casting vote. Except where otherwise stated, a simple majority shall be sufficient to carry a motion.

15. SPECIAL GENERAL MEETING

A special general meeting may be held at any time by resolution of the Executive Committee or on receipt by the Secretary of a requisition signed by at least 20 members specifying the purpose for which the meeting is to be called. At least three months' notice shall be given to all financial members of the time and place of such meeting.

16. FUNDS

All funds of the Society shall be paid to the Honorary Treasurer, who shall keep correct accounts showing the details of the Society's financial affairs and shall disburse monies of the Society under the authority of the Executive Committee.

17. BANK ACCOUNTS

The Society's bank account shall be operated by the Secretary, Honorary Treasurer and any two other members of the Society or other persons appointed by the Executive Committee for that purpose. Cheques and withdrawal warrants shall be signed by any two of the signatories.

18. FINANCIAL YEAR

The financial year of the Society shall end on April 30 in each year, or such other date that may be decided from time to time by the Executive Committee.

19. AUDITOR

At each biennial general meeting an Honorary Auditor shall be elected.

20. SUBSCRIPTIONS

The biennial subscription which is due at the beginning of the financial year and which shall include all privileges including a copy of the *Proceedings* of that year, shall be $4.00 or such other sum as may be decided from time to time at any biennial or special meeting. The fee for associate members would be half that for ordinary members. Non-members may be admitted to conferences on a daily fee which may be decided by the Executive Committee.

21. COMMON SEAL

The common seal shall be kept in the custody of the Secretary and shall be affixed to documents only by the direction of the Executive Committee, in the presence of the Secretary and any one member of the Executive Committee.

22. ALTERATIONS OF RULES

The rules of the Society may be altered, rescinded, or added to at any general meeting provided that two-thirds of the members present vote accordingly, and provided that at least three months' notice of intention is sent by post to members.

23. POWER TO BORROW FUNDS

The Society shall have power to borrow money.

24. DISTRIBUTION OF ASSETS

In the event of the winding up of the Society the funds and the property of the Society shall be distributed to any other body or organization having the same or similar objectives as those of the Society or to such charitable organizations or such charitable purposes as shall be decided by members at the general meeting.

25. OFFICIAL LANGUAGE

The official language of the Society shall be English.

26. CURRENCY

The currency shall be U.S.A. dollars.

(October 11th, 1975)

List of Industry Sustaining Members

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ROHM and HAAS COMPANY
c/o E. N. Irwin
Independence Mall West
Philadelphia, PA. 19105, U.S.A.

ANCOM SDN. BERHAD
Denmark House, 86
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P. O. Box 465
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AUSTRALIAN CHEMICALS CO. (M) SDN. BHD.
P. O. Box 25
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Selanger, Malaysia

KUMIAI CHEMICAL INDUSTRY CO., LTD.
1-4-26, Ikenohata
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Tokyo, 110-91, Japan

DOW CHEMICAL PACIFIC LTD.
P. O. Box 711
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AMCHEM PRODUCTS INC.
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Ambler, Pennsylvania 19002,
U.S.A.

ELI LILLY AND COMPANY
c/o Dr. Glenn C. Klingman
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MONSANTO COMPANY
c/o Dr. R. E. Althans, Manager
International Market Development
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166,
U.S.A.

APPENDIX

Common Names and Abbreviations of Herbicides

amiprophos-methyl *N*-isopropyl *O*-methyl *O*-(2-nitro-*p*-tolyl) phosphoramidothioate
bifenox methyl 5-(2′, 4′-dichlorophenoxy)-2-nitrobenzoate
captafol *cis*-*N*-(1, 1, 2, 2-tetrachloroethyl) thiol-4-cyclohexene 1, 2-dicarboximide
"CF-215" 2-chloro-9-hydroxy-fluorene-9-carboxylic acid
chlomethoxynil 2, 4-dichlorophenyl 3′-methoxy-4′-nitrophenyl ether
chlornitrofen (CNP) 2, 4, 6-trichlorophenyl 4′-nitrophenyl ether
credazine 3-(2-methylphenoxy) pyridazine
cyanazine 2-chloro-4-ethylamino-6-(1-cyano-1-methylethylamino)-*s*-triazine
difenzoquant 1, 2-dimethyl-3, 5-diphenyl-1 H-pyrazolium methyl sulphate
dimethametryn 2-(1, 2-dimethylpropylamino)-4-ethylamino-6-methylthio-*s*-triazine
"3, 4-DP butyl" 2-(3′, 4′-dichlorophenoxy) propionic acid butyl ester
"DPX 3674" 3-cyclohexyl-6-(dimethylamino)-1-methyl-1, 3, 5-triazine-2, 4 (1H, 3H)-dione
glyphosate *N*-(phosphonomethyl) glycine
"GS-14254" 2-*sec*-(butylamino)-4-(ethylamino)-6-(methoxy)-*s*-triazine
"HMI" 3-hydroxy-5-methylisoxazole
"K-1441" 3-methyl-1-(*α*, *α*-dimethylbenzyl)-3-phenylurea
"K-223" 1-(*α*, *α*-dimethylbenzyl)-3-(*p*-tolyl) urea
MCPCA 2-methyl-4-chlorophenoxyaceto-*o*-chloroanilide
metribuzin 4-amino-6-*tert*-butyl-3-(methylthio)-1, 2, 4-triazine-5(4H)-one
"MO-500" 2, 4-dichloro-6-fluorophenyl-4′-nitrophenyl ether
"MT-101" *α*-(*β*-naphthoxy)propionanilide
napropamide *N*, *N*-diethyl-2-(*α*-napthoxy)propionamide
"NK-049" 3, 3′-dimethyl-4-methoxybenzophenone
norea 3-(hexahydro-4, 7-methanoindan-5-yl)-1, 1-dimethylurea
oxadiazon 2-*tert*-butyl-4-(2, 4-dichloro-5-isopropoxyphenyl)-1, 3, 4-oxadiazoline-5-one
perfluidone 1, 1, 1-trifluoro-*N*-[2-methyl-4(phenylsulfonyl)phenyl]methanesulfonamide
piperophos *S*-2-methylpiperidinocarbonylmethyl *O*, *O*-di-*n*-propylphosphorodithioate
"RH-2915" 2-chloro-4-trifluoromethyl-phenyl-3′-ethoxy-4′-nitrophenyl ether
"STOMP" *N*-(1-ethylpropyl)-3, 4-dimethyl-2, 6-dinitrobenzenamine
TCE-styrene *α*-2, 2, 2-trichloroethyl styrene
tetrapion(TFP) sodium 2, 2, 3, 3-tetrafluoropropionate
thiochlormethyl 3-(3-chloro-4-chlorodifluoromethylthiophenyl)-1, 1-dimethylurea
TOPE 3-methyl-4′-nitrodiphenyl ether

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