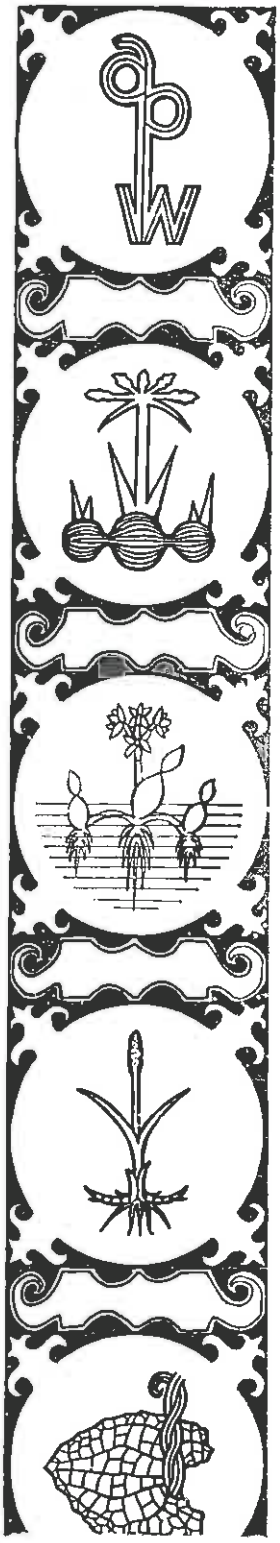
PROCEEDINGS OF THE SIXTH ASIAN-PACIFIC WEED SCIENCE SOCIETY CONFERENCE

Jakarta, INDONESIA
JULY, 11 - 17, 1977

VOL. I



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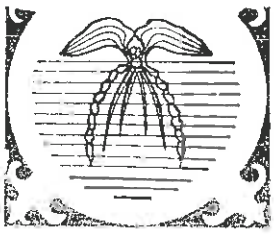

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Welcome Address

H. O. ADIWINATA

It is my great privilege, on behalf of the Organizing Committee, to welcome you to the Sixth Conference of the Asian Pacific Weed Science Society and to extend my sincere gratitude for the enthusiatic participation in it, as witnessed by the considerable number of valuable contribution papers submitted and the large heartwarming attendance.

But then again, this gathering marks quite a few important events and I am particularly honoured to mention them.

Firstly, with its Sixth Conference the Asian Pacific Weed Science Society celebrates its tenth anniversary and all of us present wish it many more decades of success and fruitfulness to come.

Secondly, only yesterday the Weed Science Society of Indonesia completed its Fourth Conference; I congratulate the newly elected officers and wish them an even greater success during their tenure than has been achieved during the six years of the Society's existence.

Thirdly, this conference is also attended by representatives of the International Weed Science Society; their presense provides the opportunity to establish affiliation of the Weed Science Society of Indonesia with the international organization.

To Mr. L. J. Matthews, Dr. Marvin Schreiber and Mr. L. C. Burrill, the first officers of the IWSS, I extend my heartiest congratulations.

Lastly, the city of Jakarta only a few weeks ago celebrated its 450th anniversary and all of us present here, I am sure, wish it more prosperity and happiness in the years and centuries to come.

The Organizing Committee has endeavoured to extend the opportunity of attending this conference and the benefit of participation in a much wider exchange of ideas and information it provides not only to the participants of the preceding Fourth WSSI Conference, but also to a good number of selected faculty members of not less than seventeen universities in Indonesia. With their attendance of the workshop on "Weed Control in Small Scale Farms", a theme aptly chosen by the Programme Committee, the organizers of this conference hope to stimulate the progress of weed science and to extend its benefits to an even greater part of society and mankind.

It is most gratifying to the organizers that their endeavour has succeeded almost to their full expectations, thanks to the generous support of BIOTROP, the Department of Agriculture and the State Plantation Groups, the Directorate General of the Water Resources Development of the Department of Public Works and Electric Power, the LIPI (Indonesian Institute of Sciences), the Directorate General of Higher Education, the Municipality of Jakarta and the Agrochemical Companies.

For this, on behalf of the Organizing Committee, I would like to extend my deepest gratitude; their contribution will be most instrumental in the development of weed science in Indonesia.

I am sure that I am voicing the sentiments of the whole conference in expressing my deep appreciation and gratitude for the presence of Your Excellency the Minister of Agriculture of the Republic of Indonesia and Your Excellency's gracious willingness to deliver the opening address of this conference this morning.

I would also like to thank all my colleagues who have unstintingly dedicated their time and effort to make this meeting a successful one.

In conclusion I wish all participants a pleasant stay in Indonesia and Jakarta, a fruitful discussion and the conference all the success it deserves.

Presidential Address

M. SOERJANI

It is a great honour for me to be given the opportunity on behalf of the Executive Committe members of the Asian Pacific Weed Science Society to welcome you and extend our sincere appreciation for your efforts to participate in this conference which demonstrate your deep interest in and support for the activities of our Society. It is also a particular privilege to me to be President of the Society on its tenth anniversary which is commemorized with the publication of the beautiful book containing a collection of impressions from our past presidents. This publication was organized and done by Dr. L.C. Burrill whom we are all grateful to.

In the past two years the Executive Committee has tried to contribute a little to the foundation of long term programs of our Society for promoting weed science in the region. To achieve this, the following Committees were continued or instituted during the period of 1975 - 1977: Committee on Membership (Dr. R. K. Nishimoto), Committee on Newsletter (Dr. T. Motooka), Committee on Education and Training (Dr. B. L. Mercado), Committee on Compilation of Registered Herbicides (Dr. S. R. Obien), Committee on Nomenclature and Standardization (common names of plants; common names of herbicides and related chemicals and standard experimentation: Dr. P. W. Michael). The Committee on Compilation of Registered standard Herbicides chaired by Dr. S. R. Obien was particularly outstanding in carrying out its mission. We all will soon be made aware of the registered herbicides in the region by the manuscript organized by Dr. S. R. Obien. This is an activity which is perpetual in nature and the list will require a review each year. The list will be able to offer information and to record the historical fate of various herbicides in various countries. I would be happy to see the activities of this Committee be continued.

Education and Training is without doubt, an important mean to promote Weed Science. I suggest that this important Committee organize a program for a pooling of funds to be used for granting scholarships to students working in Weed Science. I believe that the funds can be made available and what we will have to do is to coordinate.

I am happy to learn that the Weed Science Club of Thailand has been formed and is now affiliated with our APWSS. Recently the Malaysian Plant Protection Society was also formally instituted to include a weed control program. The promotion of weed science in the Southeast Asian region seems to be gaining momentum, and in fact the recognition of weed problem as an important aspect of crop production and as an integral part of a regional development is now world wide. The introduction of a Weed Science Program under FAO proves this point. With the formation of IWSS the activities of weed science will surely be better coordinated. I propose that our Society establish cooperation not only with IWSS but also with FAO. I would like to take this opportunity also to congratulate the initation of the International Weed Science Society with the first officers Mr. L. J. Matthews as the President, Dr. Marvin Schreiber as the Elected President, and Mr. Larry Burrill as the Secretary.

As the complexity of weeds is realised, it seems that we are not facing only a single problem of weed control, but many interconnecting problems in the human environment as well. The problem seems to be ecological in nature. Weeds have existed in the human environment despite men's incredible efforts to eradicate and control them. They seem to have powerful survival abilities. Weed management is, therefore, more appropriate than weed control as a solution of weed problems. We have to learn to live with weeds, and we have to learn to keep them from causing any diversion of energy in our activities by an integrated control approach. We have also to learn to keep the output of our activities high, with the least ecological imbalance.

The interconnected problems are exemplified by a case where a weed may constitute a habitat for vectors of diseases. Weeds on the other hand may be efficient solar energy fixers on areas which would otherwise be bare. It is our task then to utilize this energy for our benefit, for example as feeds for livestock or fish, as soil additives, etc. This forces us to rely on a multiple approach to the problem rather than trying to compartmentalize various interconnected problems.

In conclusion, I hope that the conference will provide a useful stage for further development of weed science, weed management and will directly or indirectly contribute to the solution of food problem and the improvement of the environment throughout the world. I sincerely wish the conference every success.

We also hope that you will enjoy your stay in Indonesia and if we can be of any help we will be only too pleased to do what we can.

Finally I would like to thank deeply the Weed Science Society of Indonesia for co-hosting the conference and the workshop, BIOTROP for sponsoring the workshop, the Minister of Agriculture of the Republic of Indonesia, the Directorate General of Water Resources Development of the Ministry of Public Works and Electric Power, the Chairman of LIPI, the Directorate General of Higher Education of the Ministry of Education, the former Governor of Jakarta, the Plantations' Directors and the Agrochemical companies for their valuable contributions to these meetings.

I wish to acknowledge with thanks the tireless and dedicated work of my colleagues, the members of the Organizing Committee, the Program Committee, the Editorial Committee and the Local Organizing Committee in making this conference and workshop a success.

Opening Address

The Minister of Agriculture of the Republic of Indonesia

TOYIB-HADIWIJAYA

On behalf of the Government and the people of Indonesia I thank the Executive Committee and members of the Asian Pacific Weed Science Society for having chosen Jakarta as the venue for their Sixth Conference — which I understand also marks the tenth anniversary of the Society.

Many weed species transcend national boundaries and to control effectively the problems they created to agriculture, to economic and other aspects of human life, calls for concerted efforts of plant protectionists in many countries. Hence, I welcome the opportunity to exchange information and knowledge this Conference provides.

The development of the science of plant protection during the last few years has been most gratifying. Being a plant pathologist myself, I can remember the days not so long ago when plant protection was compartmentalised into Entomology, Phytopathology, Nematology, Weed Science, etc. Now the concept of Pest Management has been universally accepted where the problem of pests and diseases in a given agrosystem has to be comprehended in an integral manner under an ecosystem approach. While in the past one could proceed to become a phytopathologist or entomologist, now one has to be a plant protectionist first before specializing in a particular field of pest problem such as weeds.

As an administrator responsible for regulating the use of pesticides I have keenly followed the increasing volume of pesticides used in Indonesia and the also increasing proportion of herbicides in the total volume of all pesticides combined: while it amounted to only 9% in 1969 it rose to no less than 30% in 1974.

While this fact would point to an increasing awareness and appreciation for the benefits derived from using herbicides, there is also cause for concern over their effects and possible hazards to the environment and the quality of our life.

And if this would call for more emphasis on weed research than heretofore the question arises on how to define priorities and allocate resources among the various aspects of weed research itself.

The estates plantation industry has readily accepted the use of herbicides in its quest for higher yields and higher efficiency. However, the incorporation of herbicides into the limited inputs of the small-scale farm,

without aggravating the already existing disguised unemployment of the farmer family, while deriving the full benefit of higher yields, poses many problems.

And yet, the need for ever higher agricultural production to feed — and feed better — the 135 million population, increasing with some three million annually, is very acute.

Although every opportunity and many incentives are offered to develop rice and other food crops estates on the outer islands, the brunt of food production will most certainly fall on the small farmer. That is why enthusiastically approve the initiative to organize a workshop on "Weed Control in small-scale farms".

There is still scope for expansion of wet rice cultivation — where the weed problem may be restricted to aquatic species — but in the long run we will have to resort to upland conditions where the weed problem is, and losses are, much more serious. All these problems will tax our ingenuity and resources, and it is here that Society will look at you for solutions.

I could name a few of the most pressing problems, such as the occurrence of wild rice and parasitic weeds, weeds serving as host plants for diseases and pests such as the notorius brown plant hopper, the possible shift in weed population due to the resistency mechanism of some weeds, the occurrence of any possible allelopathic substances in a more concentrated — and thus more potent-form due to water shortage, the effects of herbicides to the physical and chemical properties of — and to the microbial life in — the soil, their possible leaching and consequent hazards to the whole environment, and so on.

I am happy to note the interdisciplinary approach as exemplified in the organisation of the workshop; in conclusion I wish you all a successful Conference and a happy sojourn in Indonesia and Jakarta.

Agriculture in Indonesia

A. T. BIROWO [1]

INTRODUCTION

Agriculture is the most important sector of the Indonesian economy, as it contributes most of the national income, and provides employment for the majority of the population. Stressing development programs on agriculture creates employment opportunities for the rural sector and ultimately brings about a more equitable income distribution, and hence determines the level of welfare of the population.

The Five Year Development Plan, the Indonesian acronym of which is PELITA, is a program of development in which strategies for development are formulated within the frame work of the Broad Outline for the State Policy, enacted by the National Assembly for government guidance for policy formulation. We are currently in the middle of the Second PELITA 1973/1974 - 1978/1979, and have passed through the First PELITA during the period 1969/1970 - 1973/1974.

In the agricultural sector, the development objectives are a) a sufficient food supply for all groups of the population, b) the improvement of farm economics, especially those of the small farmers, c) increasing foreign exchange earnings, d) the conservation of natural resources and increasing their productive capacity in harmony with sound environment policy, and e) increasing employment opportunity.

Having passed through the development process in PELITA I and carrying on into the PELITA II period, despite many difficulties encountered in the Plan's implementation, the improvements achieved have on the whole been very encouraging.

The national economy has been successfully brought to a favorable condition. The country's Gross Domestic Products (GDP) has, during the PELITA I period increased in real terms by 42% or 7% per year on the average. With a population increase of around 2.6% annually, it means an annual growth of per capita income of around 5.5%.

The growth in the agricultural sector during PELITA I was estimated at 3.5% annually as shown in Figure 1; its share, however, in the total national product has declined from 51% in 1968 to around 40% in 1975. This indicates the progress of the economy made in the process of development.

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[1] Chief, Bureau of Planning, Ministry of Agriculture, Jakarta, Indonesia.

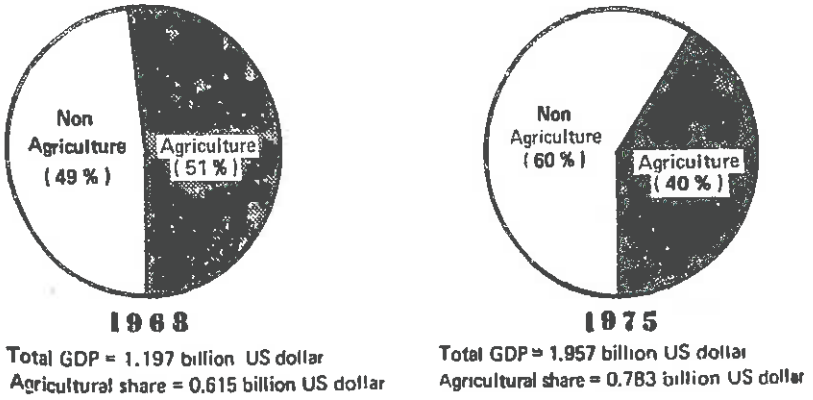

Figure 1. The Agricultural share to the Indonesia GDP (1968–1975) at constant 1960 market prices.

The inflation rate (based on 1966 index of cost of living) has been brought down from 171.1% in 1967 to 12.3% in 1970 and 6.4% in 1972. Then in 1973 it reversed up to 31.0% and further up to 40.6% in 1974, but again down to 19.0% in 1975. This uptrend in the rate of inflation during 1973 and 1974 was generated by the sharp increase in the price of rice in 1973 due to the world wide shortfall in output of this staple commodity as a result of the severe drought in 1972; and also it was affected by the world economic inflation during that period.

Despite the unusual long dry spell in 1972 which affected the agricultural production and caused a severe setback, a significant improvement in the sector of agriculture was achieved.

RESOURCE BASE IN AGRICULTURE

As shown in Figure 2, there are in Indonesia, approximately 190.4 million ha of land. Out of this total, 35.4% are primary forest, 28.8% secondary forest and tidal swamp water areas and 8.6% arable land. From the 8.6% arable land, there are 4.84 million ha of irrigated rice fields, 9.33 million ha of upland areas and 2.23 million ha covered by estate crops.

There is, geographically, an uneven distribution of natural resources. As shown in Table 1, Java and Madura which have a total land area of 13.2 million ha or 6.9% of the Indonesia's total land area, are occupied by 576 people/km^2. The agricultural area in the other islands is relatively small compared to their total land area. The agricultural area in

Java and Madura is 73,5% of their total land area. Where is in the other islands it is 30,9% of their total land area.

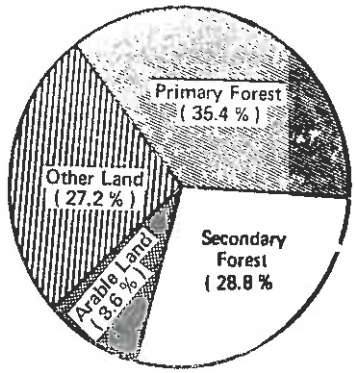

Figure 2. Relative proportion of Land area in Indonesia 1973.

Table 1. Geographical distribution of agricultural resources in Indonesia 1971.

Items	Java and Madura	Total of Indonesia
1. Total land area, million hectare	13.2	190.4
2. Population/km²	576.0	63.0
3. Wooded area, million hectare	3.2	121.7
4. Agricultural area, million hectare	9.7	15.6
5. Agricultural area per capita, hectare	0.128	0.131
6. Farm food crop area, million hectare	8.3	12.3
7. Wet rice land, total, million hectare	2.5	4.1
8. Wet rice land, harvested, million hectare	3.02	4.5
9. Cropping intensity for rice (8)/(7) × 100%	120.0	110.0

Source: Central Bureau of Statistics.

ACHIEVEMENT IN THE AGRICULTURAL SECTORS

Food production. During the period of PELITA I from fiscal year 1969/70 through fiscal year 1973/74, rice production annually increased by 4.8%. The harvested area for rice increased from 8.02 million ha in 1968 to 8.40 million ha in 1973, and further up to 8.77 million ha

in 1975. It means an annual increase of about 0.84%. The yield level for rice increased from 2.79 ton/ha of paddy in 1968 to 3.34 ton/ha in 1973, and 3.37 ton /ha of paddy in 1975, or an annual increase of about 3.8%. The increase in yield and harvested area raised the total rice production from 11.70 million ton in 1968 to 14.60 million ton in 1973 and 15.3 million ton in 1975. This means an annual increase in production of rice of about 4.6%. Compared with the annual population growth of about 2.6%, it results in an annual increase in per capita production of 2.4%.

The achievement in rice production was attributed mostly to the intensification program, the Indonesian acronym of which is Bimas Program. Bimas program is simply a credit package containing the provision of cash, fertilizers, seed, pesticides as well as the provision of intensive extension by the government to the farmers. The intensification program in 1968 covered an area of about 1.60 million ha which increased to 3.99 million ha in 1973 or a total increase of 146% during the PELITA I. In 1975 Bimas area slightly declined to 3.74 million ha which was mainly due to more farmers becoming self supporting in financing their rice growing. The yield in the Bimas program increased from 3.63 ton paddy/ha in 1973 to 4.30 ton/ha in 1975 or up by 21.8%. In 1975 Bimas area covered an area 42.7% of the total rice area. In this program the use of HYV (high yielding variety) covered around 34.2% of the total rice, or about 80.2% of the total Bimas area. The institutional vehicle for the Bimas program is the so called Village Unit. In 1968 there were 1,854 Village Units and increased to 2,557 in 1973, and around 3,000 were estimated in 1975. The credit system for the Bimas program is implemented by the Bank Rakyat Indonesia (Rural Agricultural Bank) abbreviated as BRI-, through the BRI Village Bank unit. Currently there are about 2,500 BRI Village Bank Units and 233 BRI mobile Bank Units to serve the farmers all over the country.

The production of other food crops, such as maize, cassava, sweet potato, soybeans and peanut, varied considerably from year to year depending on weather conditions and market situation. The trend of production of these other food crops, as shown in Table 2, has been upward but at a slower rate than that of rice production. The production of maize and cassava has substantially increased in the last five years, due to the increasing demand for exports.

Table 2. The production of food crops in Indonesia 1969 - 1975.

Commodity	Production (million tons)			Annual rate of increase (%)	
	1969	1973	1975a	1969-1973	1969-1975
1. Rice	12.25	14.60	15.28	4.8	4.1
2. Maize	2.29	3.69	2.64	12.67	2.40
3. Cassava	10.92	11.18	12.32	0.59	2.03
4. Sweet potato	2.26	2.39	2.48	1.41	1.56
5. Soybean	0.39	0.54	0.56	2.09	6.36
6. Peanuts	0.27	0.29	0.33	8.6	3.59
7. Vegetables	1.80	2.30	2.02	2.9	1.9
8. Fruits	2.27	4.25	5.17	15.7	13.7

Source: Central Bureau of Statistics.
a: preliminary figure.

Since 1973 the intensification program has also been extended to include maize, soybean and peanut. In 1974 the area under the intensification program was 201,700 ha of maize or 7.9%, 85,954 ha of soybean or 15.2%, and 48.742 ha of peanut or 13.2% of the total area planted for the respective crops.

The intensification program has increased the yield of maize by 56%, soybean by 84% and peanut by 69%.

The production of horticultural crops such as fruits and vegetables, as shown in Table 2, also increased during the PELITA I and during the first two years of PELITA II. This increase of production was mainly brought about by the increased market absorption with favorable prices, good weather conditions as well as an improvement in crop culture.

Estate crop production. In general, as shown in Table 3, all estate crop production also showed an increased trend. For the smallholder crops, rubber and coffee have increased steadily, whereas for the estate plantations, almost all crops have increased their production.

During the period of 1974 - 1975 the combined production of smallholders and estates for rubber increased by 0.5%, palm oil 3.1%, copra 2.8%, coffee 0.6%, tea 14.6% and sugar cane by 3.8%.

Table 3. The Production of main estate crops in Indonesia (both large-scale and smallholder) 1973 - 1975.

Commodity	1973	1974	1975a	Annual rate of increase (%) 1974 - 1975
	in thousand tons			
1. Rubber	844	812	823	0.5
2. Palm oil	289	347	374	3.1
3. Copra	1,280	1,423	1,464	2.8
4. Coffee	150	158	159	0.6
5. Tea	67	65	74.5	14.6
6. Clove	27	15.5	16.6	7
7. Pepper	29	27	27	0
8. Tobacco	78	NA	NA	—
9. Sugar cane	1,015	1,210	1,257	3.8
10. Cotton	2.6	6.5	5.9	— 9.2

Source: Department of Agriculture.
NA: not available.
a: Preliminary figures.

Efforts to improve the production of smallholders have been taken through many ways such as intensified extension programs, crop rehabilitation through the provision of high yielding planting materials, and demonstration plots so that farmers can directly observe the advantage of the use of new technology. The results of these efforts were reflected in the substantial increase in demand for high yielding planting materials by the farmers.

The estate plantations have demonstrated remarkable improvement. During PELITA I, as shown in Table 4, rubber production increased 2.8%, palm oil 10.6%, palm kernels 11.7%, tea 7.0%, and sugar cane 3.6%. These increases in estate crop production were mainly attributed to the improvement in the overall managerial operation, heavy rehabilitation and intensive replanting programs.

The exports of the estate crops have been favourable. Despite a slight decline in the exports of rubber and tobacco in 1975 resulting from price stagnation in the world market during the first half of 1975, other commodities such as palm oil, tea and coffee increased over the PELITA I level by 46.0%, 3.1% and 38.7% respectively.

Table 4. Production of estate plantation crop, 1969 - 1975 (only large-scale).

Commodity	1969	1973	1974	1975	annual increase (%) 1969 - 1973
	in thousand tons				
1. Rubber	220	246	246	246	2.8
2. Palm oil	189	289	348	397	10.6
3. Palm kernels	40	64	74	81	11.7
4. Tea	40	53	51	56	7.0
5. Coffee	13	10	17	16	— 6.5
6. Sugar cane	702	811	987	1,012	3.6
7. Copra	2	6	8	8	27.5

Source: Department of Agriculture.

Fishery production. Both marine and inland fisheries were expanding during PELITA I. Marine fishery production increased by 3.5% and inland fishery production increased by 0.2% and the total increase of fishery production during PELITA I was 2.4%.

Total fish production, as shown in Table 5, was 1.16 million ton in 1968 it increased to 1.30 million ton in 1973 and to 1.40 million ton in 1975. This increase in production of fish was mainly due to the increase in the marine fishery. Fish harvest and catches from the marine fisheries have been improved through the modernization of fishing equipment and an increased number of motorised fishing boats. On the other hand, the production of inland fishery has also indicated an improvement particularly through the improvement of culture management.

The exports of fish and fish products have increased sharply since 1967. In that year, total exports were 7,782 ton valued at US$ 1.7 million, which then rose to 52,145 million ton valued US$ 68.09 million in 1973, and 40,713 ton valued US$ 88.8 million in 1975. The main commodity responsible for the increase was frozen shrimp which accounted for about 60% of the total fish exports. Skipjack and tuna fish are expected to increase in future exports.

Table 5. Fishery production in Indonesia 1968 - 1975.

Year	Sea fishery	Inland fishery	Total
	in thousand tons		
1968	723	437	1,160
1969	785	429	1,214
1970	808	421	1,229
1971	820	424	1,244
1972	836	433	1,269
1973	860	440	1,300
1974	893	449	1,342
1975a	996	393	1,389
Annual rate of increase (%) 1968 - 1973	3,5	0,2	2,4

Source: Department of Agriculture.

a: Preliminary figure.

The development program in fisheries aims to increase fish production up to 2.0 million ton from the present level of about 1.3 million ton. The program includes modernization of fishing gear, motorization of fishing boats, and training and upgrading of fishermen to improve their catching technique.

Livestock production. Development in the livestock sector has been characterized by an upward trend in production. During the period of 1973 - 1975, as shown in Table 6, the production of ruminant meat increased 4.9% for beef, 9.3% for buffalo meat, 7.1% for mutton and 17.6% for lamb. The production of pork increased 6.5% and poultry meat 9.6% during that period. In 1975, as shown in Table 7, the production of meat increased 7.5% over 1974 level, where as the production of eggs and milk increased by 28.6% and 10.6% respectively.

Table 6. Meat Production 1968 - 1975.

Items	1973	1974	1975	Average annual increase (%)	
				1973-75	1974-75
	in thousand tons				
1. Beef	202.6	212.8	223.3	4.9	4.9
2. Buffalo meat	59.6	62.4	71.1	9.3	13.9
3. Pork	41.2	44.5	46.8	6.5	5.2
4. Horse meat	0.9	0.9	0.9	0.0	0.0
5. a. Mutton	11.7	12.0	13.3	7.1	10.8
b. Lamb	14.9	15.4	20.2	17.6	31.2
6. Poultry	48.5	55.2	58.1	9.6	5.3

Source: Department of Agriculture.

The exports of livestock have substantially increased during PELITA I. In 1968 about 52,508 head of cattle and buffalo were exported which then increased to 62,601 head in 1973. But in 1975 the exports sharply declined to 36,054 head due to the unfavourable prices in the importing countries. However, the export of animal products including hides and bone, continuously increased during PELITA I and during the first two years of PELITA II.

The development program in livestock, focused on the improvement of breeding. Recently an Artificial Breeding Centre was opened, and it has served the farmers with artificial insemination for both beef and dairy cattle. In 1974 about 21,636 ampules of frozen semen were imported. The number was increased to 32,217 ampules in 1975 or an increase of 49%. This program is introducing high yielding strains into the traditional breed to improve its production.

Forestry production. Despite the fact that the production and exports of timber and other forest products were affected by the recent world wide economic recession in the last three years, the production of timber has experienced a boom during PELITA I. In 1968, as shown in Table 8, the production of timber (including indigenous timber and teakwood) totalled 5.25 million m^3 and increased to 25.8 million m^3 in 1973 or 31.8% annual increase.

Table 7. The Production of meat, milk and egg 1973 - 1975.

Items	1973	1974	1975	Average annual increase (%)	
				1973-75	1974-75
	in thousand tons				
1. Meat	379.4	403.1	433.6	6.9	7.5
2. Milk	35.4	56.9	50.7	25.8	10.9
3. Egg	81.4	98.1	126.0	24.5	28.6

Source: Department of Agriculture.

The exports of timber were 1.24 million m^3 in 1968 up to 19.40 million m^3 in 1973, or an increase of 38.6% annually during PELITA I.

Table 8. Timber production in Indonesia 1969 - 1975.

Year	Teakwood	Non-teakwood	Total
	in thousand m^3		
1968	468	4,783	5,251
1969	520	7,587	8,107
1970	568	11,856	12,424
1971	770	11,968	13,738
1972	579	17,120	17,717
1973	676	25,124	25,800
1974	680	22,600	23,280
1975a	660	18,340	19,000
annual increase (%) 1968 - 1973	7.4	33.2	31.8

Source: Department of Agriculture.
a: Preliminary figure.

During the period 1969 - 1973 the exports sharply increased and reached their peak in 1973 when a total of 19.4 million m^3 valued at US$ 583 million were exported. However, since 1974 the exports slowed down and declined to 13.9 million m^3 valued at US$ 500 million in 1975. In spite of this, due to the effect of the world economic recession, this decrease in exports coincided with the government policy to cut down the exports of logs, so as to encourage the establishment of a wood industry in this country to produce wood products for export.

The development program in forestry emphasizes the increase production of timber and other forest products for both domestic consumption and for exports. Special attention is given to forest exploitation, that is, the strict control of logging operations in order not to damage natural resources. Rehabilitation and replanting of forests is a priority program being undertaken in PELITA II.

AGRICULTURAL TRADE

Indonesia has continued to maintain a favourable agricultural trade balance. During PELITA I, as shown in Table 9, agriculture accounted roughly for half of Indonesia's total export earnings. Agricultural exports amounted to US$ 660 million in 1969. In 1973 this almost tripled to US$ 1,905 million. In 1974 and 1975 the value of agricultural exports further increased to US$ 1,699 million and US$ 1,429 million respectively.

Forestry and fisheries were the major subsectors, which increased substantially in the total agricultural exports. The share of traditional products such as rubber, coffee and palm oil have steadily increased, whereas other commodities including palm kernels, tobacco and pepper decline slightly in the last three years.

Food imports, mainly rice, wheat and sugar increased from US$ 234 million in 1970 to US$ 786 million in 1974. Agricultural imports accounted for about 43.5% of the total imports during that period. The composition of agricultural imports in the last two years has shown a notable shift from imports of food to imports of fertilizers. Food imports dropped from 62.2% in 1973 to 46.0% in 1974, whereas fertilizer imports increased from 13.6% in 1973 to 39.2% in 1974, of the total agricultural imports. The shift to high imports of fertilizers indicates the growing demand for fertilizers especially for rice crop.

Table 9. Indonesia's export value in 1969 - 1975.

Sector	Average 1969 - 1973		1974		1975	
	Value	%	Value	%	Value	%
	in US $ million					
1. Total	775	47.3	1,852	24.9	1,230	17.5
Agriculture	18		52		32	
a. Food crops	498		960		608	
b. Estate crops	9		17		17	
c. Livestock	26		92		70	
d. Fisheries	224		730		503	
e. Forestry	766	46.8	5,211	70.2	5,281	75.0
2. Petroleum Products	96	5.9	363	4.9	527	7.5
3. Other Sector						
T O T A L	1,637	100	7,426	100	7,038	100

Source: Wahyudi Sugianto and Paul J. Avontroodt, 1976. "Policies and Analysis to Support Decisions Made in the Indonesian Agricultural Sector."

DEVELOPMENT STRATEGY

During PELITA I the major development program was dictated especially by the urgent problem of food supply. Accordingly policy priorities were focused on an increase in the supply of specific food commodities, especially rice. The priority choice in maximizing rice production entailed a strategy to favour the farmers with well irrigated land and sufficient resources to enable them benefit from the new rice technology to the maximum. Rice output has increased to reach the national target. However, the development program faced a variety of problems.

The problems of development originated from the fact that the farming community were mostly small farmers. These small farmers operate small units of land, spread out over many regions with numerous differences in physical as well as social structures. Hence, there is a wide variety of farming types and techniques between regions, among villages in one region and even among farmers within one village.

The complex problems of the small farmers, were more clearly identified during PELITA I and it was planned to solve them through appropriate policy objectives and strategic programs in the current PELITA II.

This involves (a) diversification of intensification programs to include other non-rice food commodities such as coarse grains and pulses, poultry and fishery for small-holders, (b) proper credit policy through appropriate interest rates and simpler loan procedures to reach a larger segment of the poorer farming community, and (c) various government projects to stimulate rural participation in agricultural development.

Various programs of replanting, estate rehabilitation and improvement of managerial capability are being carried out to cope with the problem of neglected estates during the pre-PELITA period. In the field of marketing and credit, the solutions to the problems were (a) appropriate credit policy to reach the lower income group, (b) the creation of credit insurance such as ASKRINDO STATE CORPORATION (Credit Insurance Public Corporation) and Cooperative Insurance called Lembaga Jaminan Kredit Koperasi (LJKK in Indonesia) to help the economically weak group, and (c) to intensify the effort to establish Rural Credit Cooperatives within the Village Unit system.

In the field of unemployment, the approach to tackle the problem has been (a) transmigration schemes with comprehensive regional development patterns in sparsely populated areas, (b) special schemes to stimulate labor intensive activities in the rural areas, (c) training to improve the various technical skills of the unemployed labor, and (d) establishment of more diversified agro-allied industries and agrobusiness.

In solving the forestry problem the following measures have been taken: (a) in implementing the control of the forest exploitation, the forest concession holders are required to make annual, five yearly and 2-yearly development plans, (b) to work out an effective marketing strategy, a timber producer's association has been established and its operation is being intensified; (c) to cope with the problems of establishing wood-based industries, an interdepartmental team has been set up, and (d) resettlement of the shifting cultivator as a priority project in the conservation of the forest resources.

The problems in the field of planning are being solved through more appropriate training to improve the technical as well as managerial skill, and through the provision of better data and statistics.

Climate of Indonesia

L. R. OLDEMAN [1]

ABSTRACT

The climate of Indonesia is governed by the monsoons, which bring heavy precipitation during the period October through April, the wet season, while the remainder of the year is characterized by dry and sunny wether. The monsoonal pattern is disturbed by mountain chains, which may either cause high monthly rainfall throughout the wet seasons, or heavy intensity rainfall, concentrated in the afternoon hours, while on the other hand mountain chains may shelter leeward slopes. Since Indonesia is located near the equator the climate is also typical isothermal. This implies that seasonal variations in air temperature are small. Although slightly higher temperatures are observed during March and April and again during September and October, the vertical gradient is of much greater importance. The air temperature drops 0.5C per 100 m increase in altitude. In general the diurnal difference in air temperature increases during the dry season and is much smaller during the wet season. The other climatic factors like solar radiation, relative humidity, and evaporation are closely related to the alternating wet and dry seasons. During the wet season the light intensity is near or below 300 g cal/cm²/day, the relative humidity is about 80% during day-time, while evaporation values are between 2 and 3 mm/day. During the dry season, solar radiation will often reach values of 400 cal/cm²/day or more, the relative humidity may drop to values around 50% during the day, while daily evaporation may be as high as 6 mm. The wind speed finally is in general not more than 2 m per second, but may increase to values of 5 m/s in afternoons or during periods of heavy thunderstorms, which occur mainly during the transition periods between the dry and wet season. With the exception of North Sulawesi and Timor, cyclones are unknown in the Indonesian archipelago.

INTRODUCTION

Climate in general is a function of the geographic location in relation to the solar position on one hand and the distribution of land masses and oceans on the other hand. Indonesia is geographically located between 5°N and 10°S of the equator (see Figure 1). Its land mass, composed of numerous islands is bordered by the Indian Ocean in the southwest and by the Pacific Ocean in the northeast. The Australian continent is located southeast of Indonesia, while the Eurasian continent is on the



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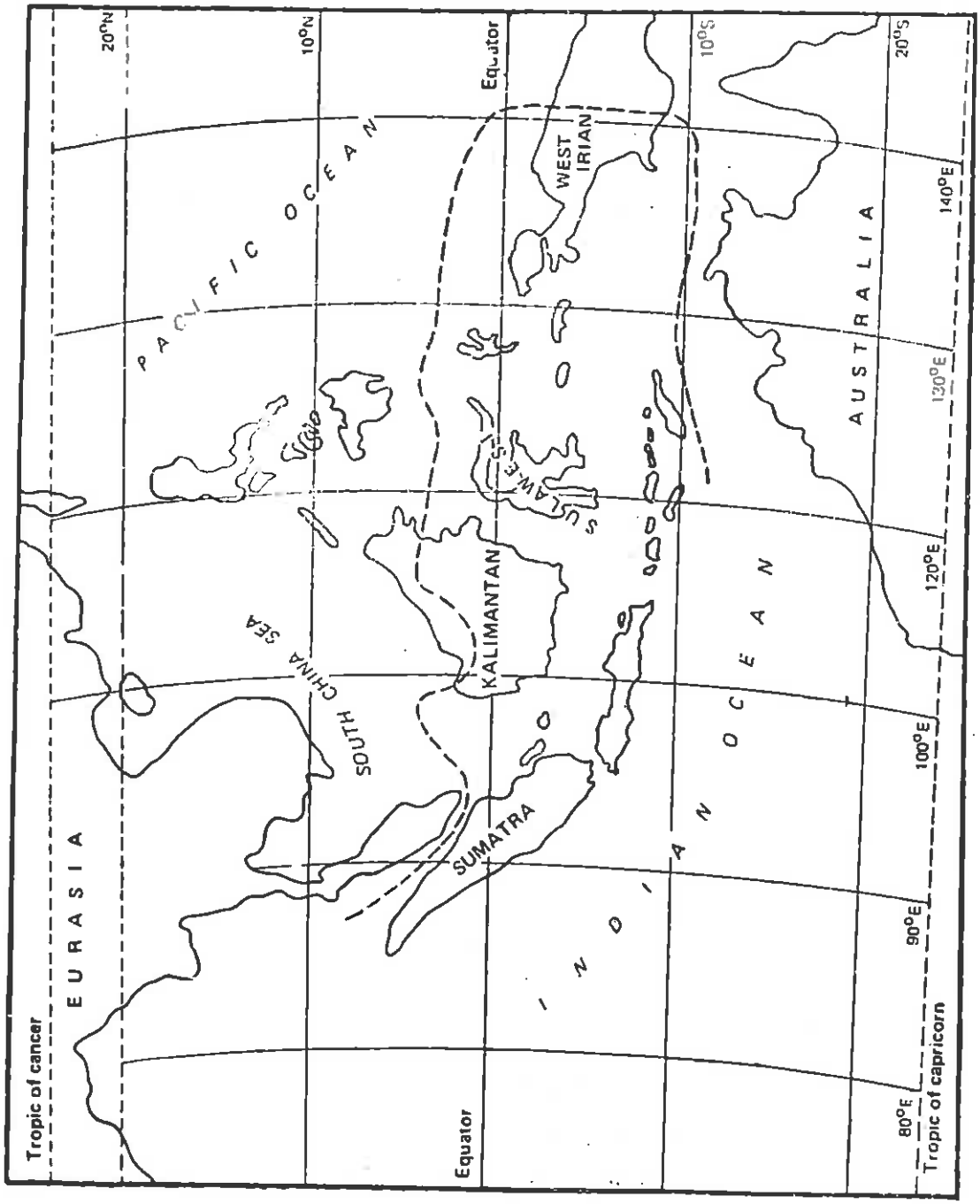

Figure 1 : Geographical position of Indonesia

northwest side. The location of these oceans and land masses are the main factors influencing the typical monsoon type climate of Indonesia. Since the absence or abundance of precipitation is a dominating factor in plant growth, a major section will be devoted to the rainfall patterns as they occur in Indonesia. Its geographical position near the equator is the main reason for a typical isothermic climate. In contrast to the temperate zones, where the seasonal variation in temperature is the major limiting factor in plant growth, seasonal variations in air temperature in the tropics are relatively small. The deviations from the mean annual temperature, either maximum or minimum, are within 5%. On the other hand the vertical component is highly significantly correlated with the air temperature. The topoposition is an important characteristic for the estimation of the air temperature. The second section will be devoted to the air temperatures as they occur in Indonesia.

The other climatic variables, such as light intensity, relative humidity, evaporation and wind speed are certainly important in relation to crop growth, but their values will seldom reach such extremes that plant growth is prohibited. Secondly these factors are all directly or indirectly related to rainfall and temperature. In the third section some average monthly values will be discussed for the sake of completeness.

It is obvious that only generalizations can be presented in this paper. For more details reference is made to the excellent treatise of the climate of the Netherlands Indies by Braak (1929), to the summarized climatic tables of climatic observations made at secondary stations in the Netherlands Indies by Boerema (1946), to the summary tables of monthly rainfall by Berlage (1949), who covered the period 1879 - 1941 and by Sukanto (1969), who summarized the period 1930 - 1960. Finally climatic records of weather stations of the Central Research Institute for Agriculture at Bogor for the period 1972 - 1976 are summarized by Oldeman and Syarifudin (1977) and were used mainly in the third section.

RAINFALL

Rainfall distribution is the most important climatic factor in the humid tropics, particularly for the farming community because success or failure of their food crops depends to a large content on the time of arrival of the wet season and the duration of this wet period. As stated by Saouma (1975): "Man has been able to develop skills to deal with his environment, but he has not been able to master climate

and has remained under the threat of drought. With limited water and with the increase in population and the need for more and better food production, water has become the most precious natural resource in most regions of the world". Although Indonesia is located in the humid tropics, the annual precipitation varies from 530 mm (Palu, Sulawesi) to 6830 mm (Krangan, Java). Not only the total annual amounts show great differences, but even more characteristic for the rainfall in Indonesia is its seasonal distribution. While in some locations the dry season is insignificant and every month of the year receives more than 200 mm, other areas may have only one or two months of the year rainfall of more than 200 mm. Among the different factors, by which rainfall is determined, the following are mentioned by Braak (1929):

- Condensation in the tropical rainbelt
- The monsoons, caused by the influence of the continents of Asia and Australia
- Phenomena during the monsoon changes
- Local influences

According to Calder (1974) Christophorus Columbus did not discover the America's, but he discovered the trade winds who carried him there. As early as 1735 George Hadley was able to explain the occurrence of the trade winds. The monsoon winds are directly related to the trade winds. In this section the general air circulation will be discussed first in order to understand the various rainfall patterns occurring in Indonesia. The general air circulation however is often disturbed by local phenomena, among which mountain formations are the most significant. This will be the second topic. As a conclusion the most frequent occurring rainfall patterns and their distribution will be discussed.

The monsoons. In order to understand the occurrence of the monsoon seasons in Indonesia one has to keep in mind the particular geographic location of the Indonesian islands (Figure 1).

Near the equator a belt of low air pressure is located, varying in width from 200 - 1000 km. Due to evaporation of water from the oceans, rivers and jungles, the ascending air has a high moisture content. While ascending, the air cools off, forming heavy clouds. When the saturation point is reached, heavy precipitation and thunderstorms result. Energy is released and the air will ascend to great altitudes (15 à 20 km) where it moves in north and south direction over a distance of 3000 km.

At a latitude of ± 30°N and 30°S it meets the so-called jet stream and the air is forced to descend. While descending the air is warmed up and sucks up moisture like a sponge, but this never leads to precipitation. (The region of the deserts is located at this latitude). Near the surface, this air is picked up by the trade winds, which are directed towards the equator, but due to the earth rotation they blow as NE trades north of the equator and as SE trades south of the equator. This is the general air circulation, that exists over the vast oceans.

The equatorial low pressure belt follows the solar path, but is lagging in time. It is situated over the equator about one month after the sun passes through the zenith (April and October). The solar path is graphically shown in Figure 2.

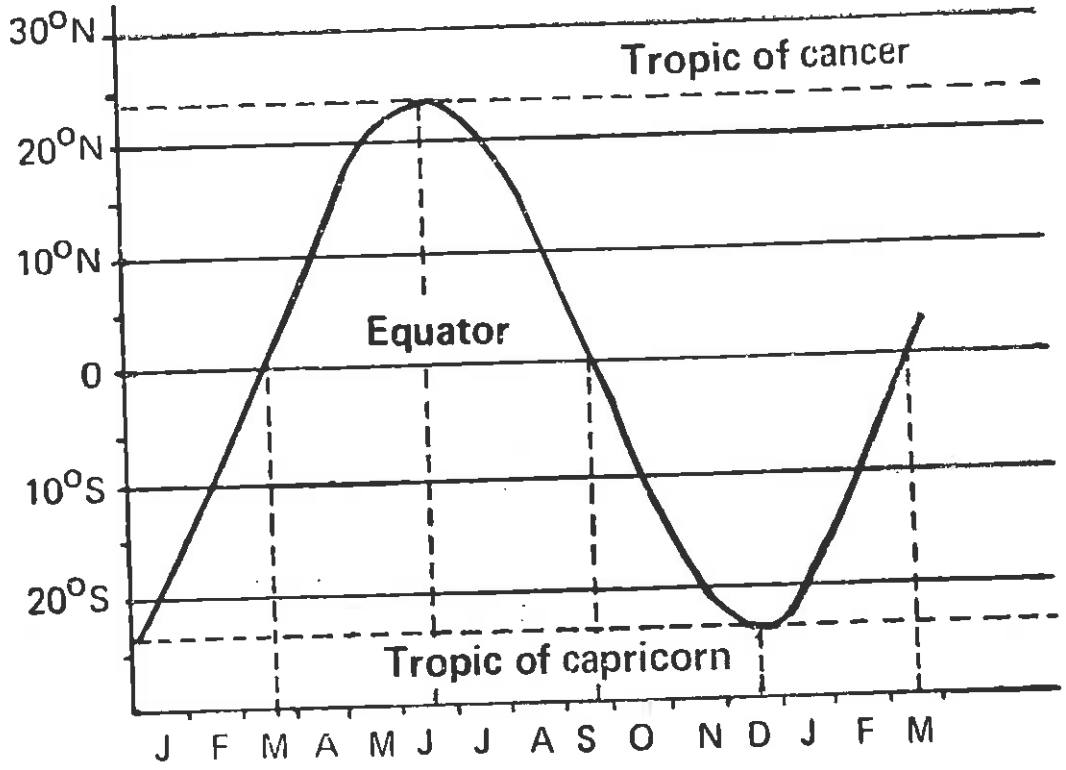

Figure 2: The Solar path (The declination of the sun)

During the northern summer the Eurasian continent is heated much more intensely than the tropical oceans. The heated air will therefore ascend to much greater height than the air in the tropical belt and will cross the equator and descend in the cold southern oceans. It is blown back towards the equator and will pick up moisture and will reach the Indian continent as the so-called SW monsoon. As soon as this SW

monsoon is over land and pushed against mountains or when it reaches the low pressure belt (at this time of the year located north of the equator) it generates precipitation. At the same time the Australian continent is cold. Dry air descending there will be blown back to the equator as SE trade winds and reaches Indonesia. Since the low pressure belt is north of the equator rainfall will be low or absent during this time. This dry period lasts from May to September.

After September the Eurasian continent cools off rapidly and the low pressure belt moves south. Air descending at 30°N will be blown back towards the equator. On the Asian continent, where the air cannot pick up moisture, the onset of the dry season is sharply marked: generally in October, November. However air descending over the South China sea will be blown back in northeast direction picking up moisture. When this air reaches the low pressure belt, located just south of the equator or when it is pushed against mountains it will generate precipitation. The onset of the rainy season in Indonesia, caused by the NW monsoon is generally around October and last until the low pressure belt moves away from the equator - around April.

In summary the alternating dry and wet seasons are caused by the cooling and heating of the continents, the equatorial low pressure belt and its slow movement lagging in time with the solar path and the trade winds, that blow the air back towards the equator.

Local effects. The aforementioned monsoon pattern is often disturbed by local influences, the most important being the mountains and the land-sea differences in temperature. While the temperature of the sea water remains almost constant during day and night, the temperatures overland are lower at night and higher during day-time compared to the surrounding seas. As a consequence, cool air at night is blown from the inland towards the sea. During day-time the reverse takes place and around mid-morning the wind direction changes 180° and air from the oceans is blown inland. If this air has a high moisture content it will condense when it is pushed up against the mountains. A ring of clouds is formed around single mountain peaks and the cloudiness increases rapidly when more humid air is pushed against the mountain ranges. If the saturation point is reached, heavy precipitation may occur in the afternoons. This orographic rainfall can take place during the wet and the dry seasons, but is more striking during the change of the monsoons, when the air circulation of the monsoons is minimal. In this period heavy afternoon precipitation may be expected on mountain slopes

parallel to the coastline. During the NW monsoon mountain slopes on the west side may endure exceptionally heavy downpours while mountain slopes on the leeward side may hardly receive any precipitation. During the SE trade winds particularly in the early period east-facing slopes may attract heavy rainfall due to the orographic lifting of humid air.

Rainfall patterns in Indonesia. As a consequence of the shifting position of the low pressure belt, the occurrence of the NW monsoon bringing humid air from the South China Sea towards Indonesia, the occurrence of the SE trade winds bringing cool and relatively dry air to Indonesia, and the mountaineous topography on most of the islands of Indonesia, many different rainfall patterns can be expected.

In general however the rainy season will start around September, October in areas exposed to the northwest monsoon winds and located in the western part of Indonesia. The belt of low pressure gradually moves southward and its presence invokes the rainy season. In southeast Indonesia the rainy season generally starts around December. Since this low pressure belt moves in northern direction again around February the rainy season will end first in southern parts of Indonesia (March) but will last longer in the northern parts. While regions near the equator have often continuous wet seasons throughout the year, the more south and east one comes the more pronounced will be the dry season. On Java we generally observe long dry seasons in the eastern regions and long wet seasons in the western part of the island. In Sulawesi the southern part is characterized by a long dry season, while the length of the dry season shortens going north.

Extremely heavy rainfall during the wet season is experienced on the western slopes of South Sulawesi. Here a combined monsoon and orographic lifting effect can be observed. On the leeward slopes of this same mountain range rainfall is very light during the same period. These leeward slopes however will receive heavy rainfall when the NW monsoon retreats and the southeast winds prevail. Valleys that are sheltered from the west and from the east (N-S direction) often experience dry weather throughout the year. Mountain slopes more or less parallel to the coastline such as those in West Java will receive rainfall throughout the year because of the sea-breeze that brings humid air inland.

While during the peak of the rainy season cloudy skies may prevail throughout the day, generally speaking rainfall is concentrated in the

afternoon due to the diurnal change of winds from inland winds during day-time to sea-bound winds at night. This patterns is more pronounced during the transition period (April, May and September, October).

In summary monthly precipitation values are given in Table 1 for characteristic locations.

Table 1. Some characteristic monthly rainfall records in Indonesia.

Location [1]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pontianak	218	181	205	235	221	184	126	135	247	308	339	236
Pakan Baru	261	187	276	257	195	123	117	178	225	292	310	287
Rangkas Bitung	282	246	214	215	216	156	123	128	140	207	212	240
Salatiga	403	349	395	280	199	122	75	50	68	135	259	354
Denpasar	335	243	205	91	82	72	57	52	35	111	158	296
Kupang	386	347	234	65	30	10	5	2	2	17	83	232
Jakarta	300	299	210	147	113	96	63	42	66	111	142	204
Parung	247	284	286	295	264	162	117	136	167	242	266	246
Bogor	409	381	299	436	377	280	276	268	326	401	407	370
Ujung Pandang	719	531	425	166	92	68	34	10	13	40	174	590
Takalala	141	141	128	173	233	179	127	58	41	66	116	126
Kajang	156	152	192	300	472	410	218	70	35	64	89	147

[1] The locations Pontianak — Kupang are a representative cross-section from locations near the equator to locations in S.E. Indonesia.
The locations Jakarta — Bogor represent a cross-section from the sea towards the mountains in N - S direction.
The locations Ujung Pandang — Kajang represent a cross-section from the sea towards the mountains in E - W direction.

TEMPERATURE

The air temperature is also influenced by the solar position and the topography. Since Indonesia is located between 5°N and 10°S of the equator the effect of the solar position is relatively small and therefore seasonal variations are not pronounced. The major factor causing temperature differences is the elevation above sea level. Data from Boerema (1946) are summarized in Table 2 and clearly illustrate that the air temperature decreases with increase in elevation. The temperature gradient for the maximum temperature is 0.62C per 100 m and for the minimum temperature 0.53C per 100 m (see Figure 3). The regression equations are as follows:

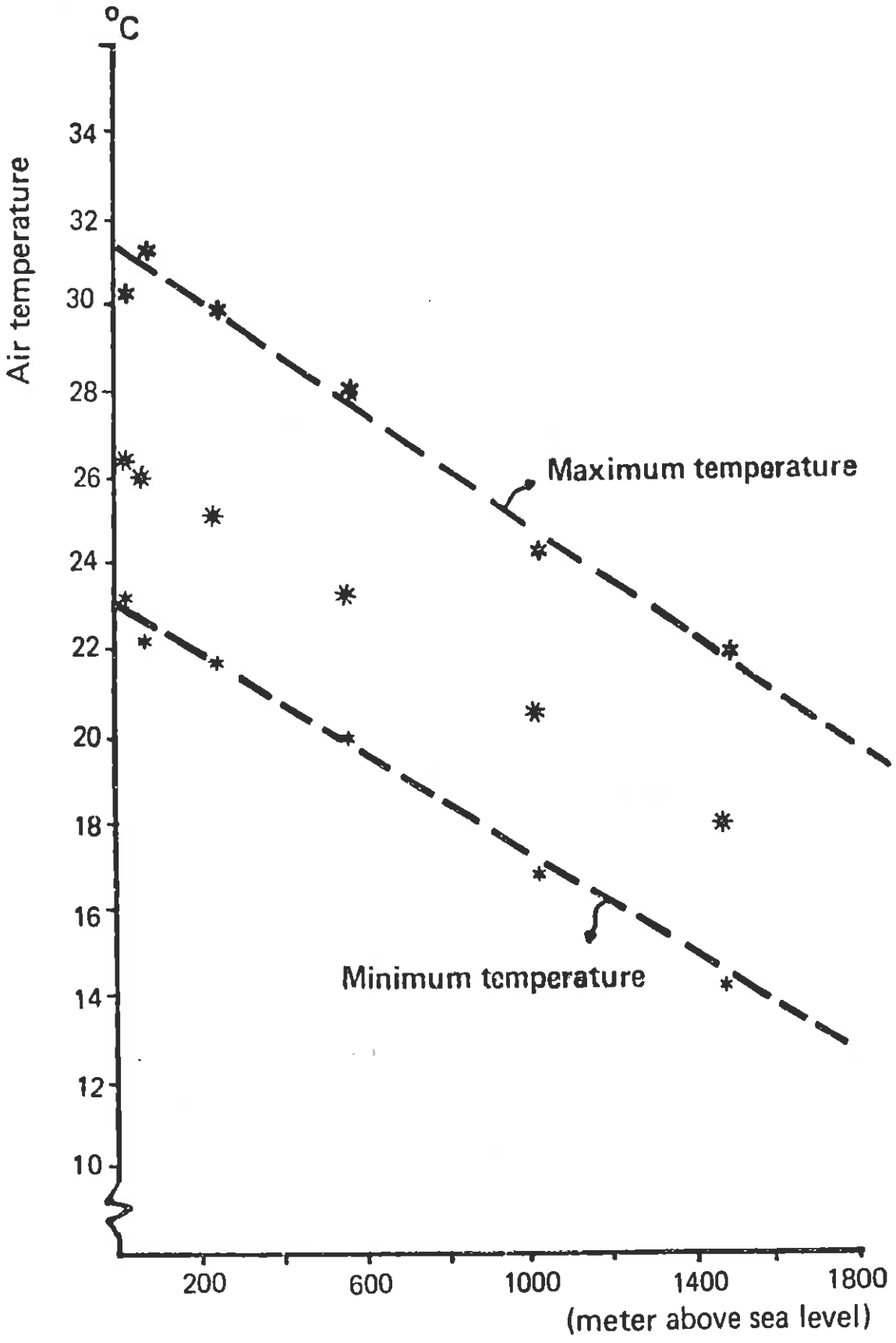

Figure 3: Effect of elevation on the Annual mean maximum and minimum air temperature

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$$y_{max} = 31.3 - 0.0062\,X \qquad (r > 0.9)$$
$$y_{min} = 22.8 - 0.0053\,X \qquad (r > 0.9)$$

(y is expressed in C and X in metres above sea level)

This relationship can be used as a rough approximation of the mean annual maximum and minimum air temperature at any given altitude. Some considerations should however be kept in mind (see figures 4A and 4B).

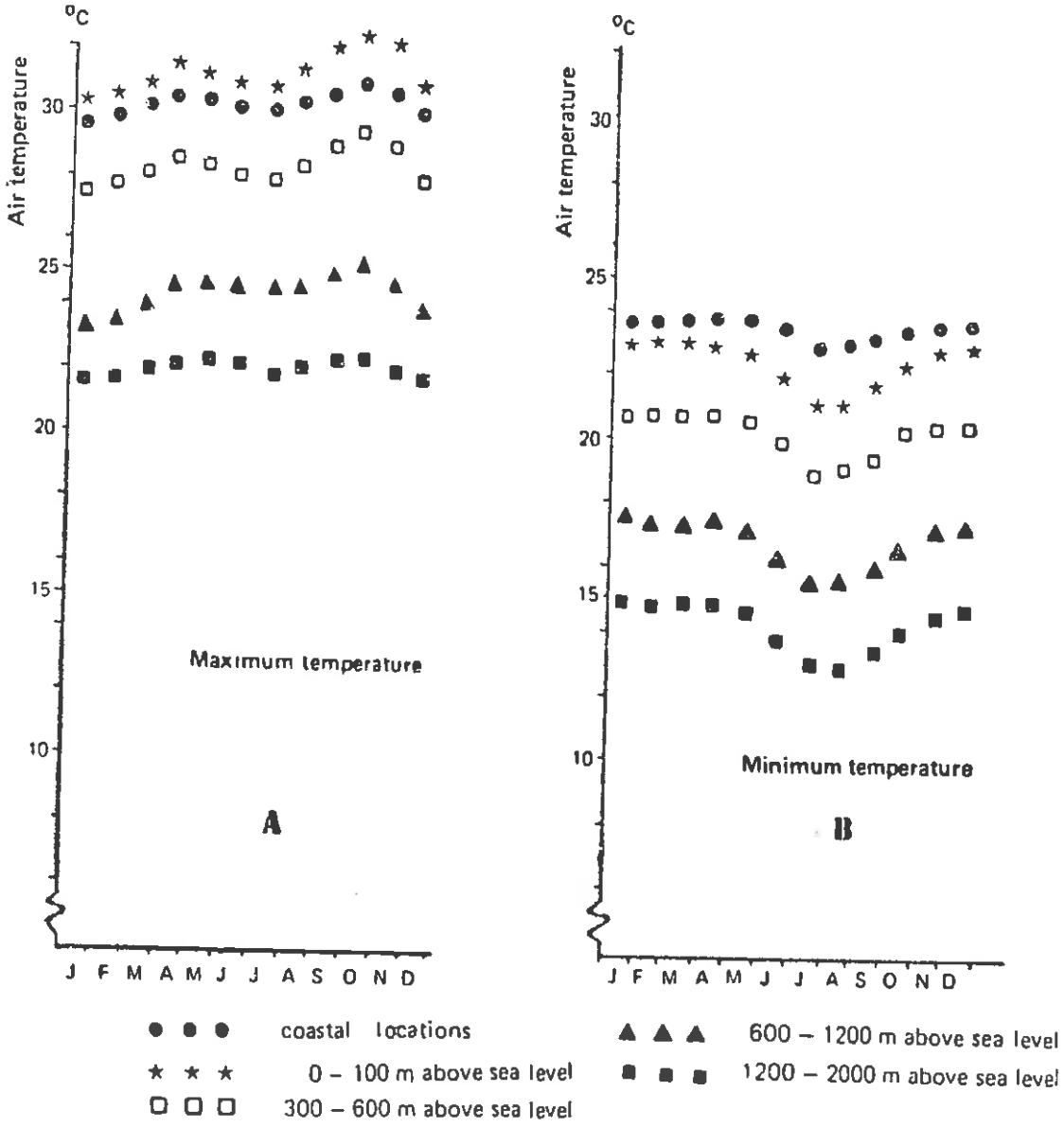


Figure 4 : Monthly fluctuation of the maximum (A) and minimum (B) air temperature for five elevation classes

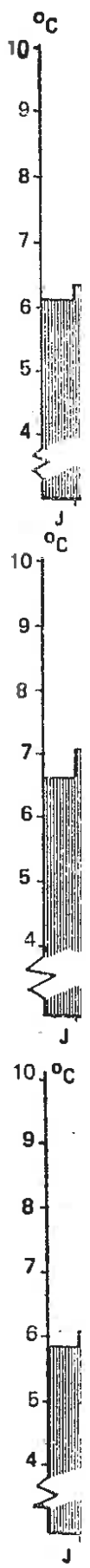
Table 2. The monthly maximum and minimum temperature for a number of representative locations in Indonesia. (Data from Boerema 1946).

Location	Elevation (m)	Maximum temperature in C												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Padang	(5)	30.3	30.7	30.7	30.7	30.9	30.9	30.6	30.5	30.2	29.8	29.8	29.8	30.4
Pasuruan	(5)	31.0	30.9	30.9	31.1	30.9	30.7	30.5	30.8	31.4	32.1	32.2	31.3	31.2
Nganjuk	(60)	30.3	30.0	30.8	31.7	31.6	31.3	31.2	31.8	32.7	33.2	32.8	31.2	31.6
Bogor	(250)	28.8	28.8	29.3	30.3	30.4	30.0	30.2	30.7	31.1	30.8	30.3	29.4	30.0
Salatiga	(580)	26.0	26.3	26.8	26.9	27.6	27.8	28.1	28.7	29.4	29.8	28.2	26.9	27.7
Bandung	(730)	27.1	26.9	27.4	27.5	27.8	27.6	27.4	28.4	28.9	28.7	28.0	27.3	27.8
Bukittinggi	(920)	25.2	25.8	26.3	26.6	26.8	26.5	26.2	26.1	25.9	25.7	25.4	25.2	26.0
Lembang	(1300)	23.2	22.9	23.2	23.2	23.1	23.0	23.1	23.7	24.5	23.8	23.6	23.2	23.2
Tosari	(1735)	19.3	19.2	19.1	19.0	19.0	18.5	18.0	18.2	18.9	19.4	19.1	19.0	18.9
Pangrango	(3023)	11.9	12.2	12.3	13.5	13.9	13.9	13.8	14.0	14.0	13.4	13.0	12.1	13.2

Location	Elevation (m)	Minimum temperature in C												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Padang	(5)	23.4	23.4	23.5	23.7	23.8	23.5	23.3	23.3	23.3	23.4	23.3	23.4	23.4
Pasuruan	(5)	23.6	23.6	23.3	23.1	22.5	21.8	20.9	21.0	21.6	22.8	23.7	23.6	22.6
Nganjuk	(60)	22.6	22.6	22.8	22.4	21.8	21.2	20.3	20.8	21.8	22.3	22.6	22.9	22.0
Bogor	(250)	21.8	21.8	21.8	22.0	22.1	21.6	21.1	21.2	21.6	21.9	22.0	22.0	21.7
Salatiga	(580)	20.0	20.0	20.0	20.0	19.7	18.8	17.6	17.6	18.2	19.2	19.7	19.7	19.2
Bandung	(730)	19.3	19.3	19.2	19.2	18.9	18.0	17.1	17.1	17.9	18.3	18.7	18.9	18.5
Bukittingi	(920)	18.3	18.1	18.4	18.8	18.6	17.8	17.6	17.6	18.0	18.3	18.6	18.5	18.2
Lembang	(1300)	16.2	16.3	16.5	16.5	16.4	15.5	14.5	14.7	15.1	15.8	16.0	16.2	15.8
Tosari	(1735)	14.9	14.9	15.0	14.8	14.6	13.9	13.0	12.9	13.4	14.3	14.8	14.9	14.3
Pangrango	(3023)	6.6	6.9	6.8	7.3	7.4	6.7	6.1	6.0	5.9	6.1	6.4	6.4	6.6

Due to the tempering effect of the more or less constant temperature of the surrounding seas, coastal regions have a smaller diurnal temperature variation than areas more inland. The mean annual maximum temperature in coastal areas is about 1C lower, the mean annual minimum temperature is around 1C higher than areas more inland. This difference is more pronounced in the dry season (± 2C) than in the wet season (± 0.5C).

In the more humid regions the seasonal variation is much smaller than in the regions with pronounced dry seasons. Near the equator the maximum temperatures as well as the minimum temperatures fluctuate less than 1C throughout the year, while in Southeast Indonesia the maximum temperature varies between 30.0C and 33.2C and the minimum temperature varies between 20.8C and 23.6C at sea level.



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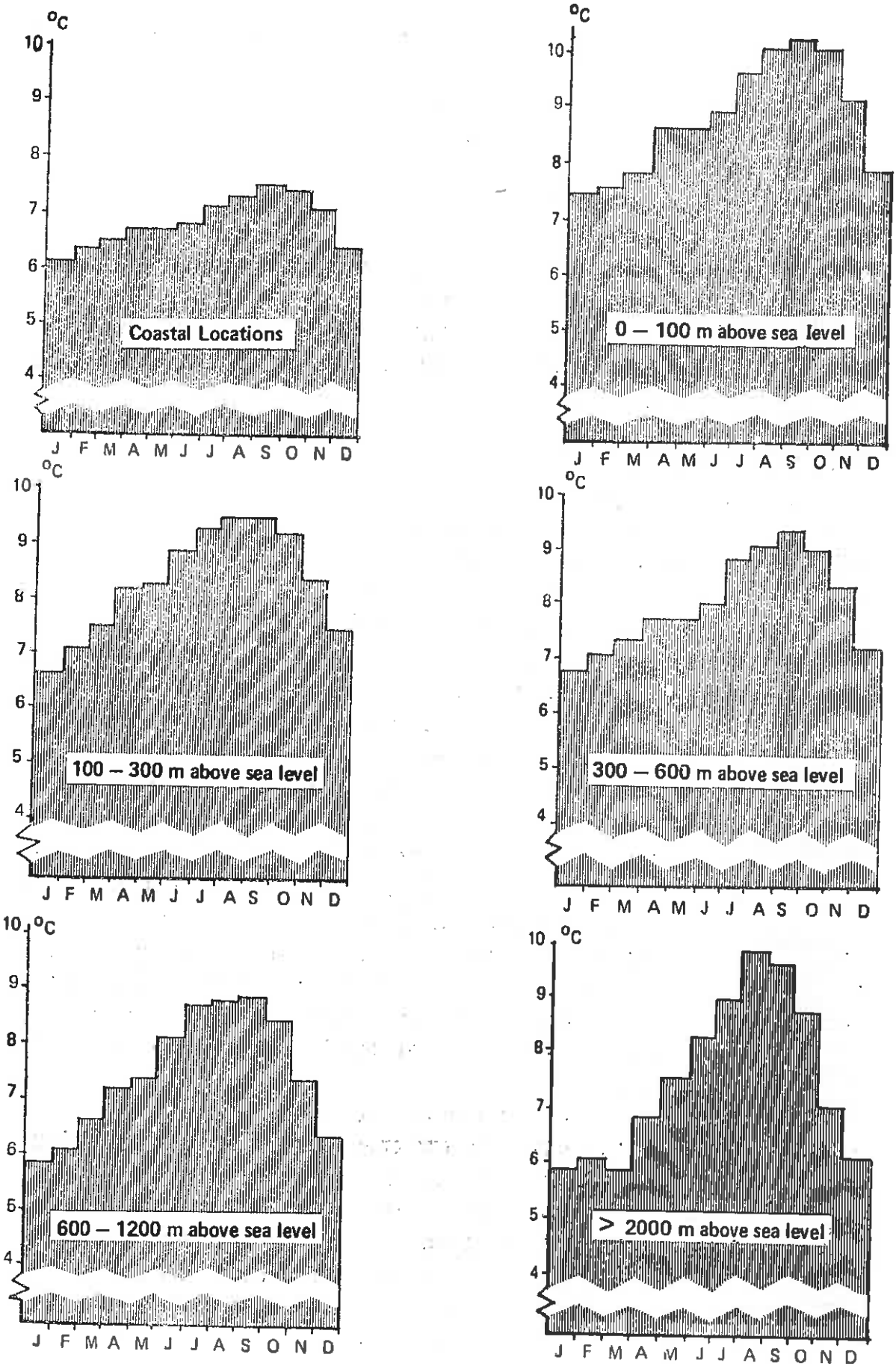

Figure 5 : The diurnal variation of air temperature for six elevation classes for each month

The annual variations as well as the diurnal fluctuations are less pronounced at higher elevation although above 2000 m the diurnal differences increase again, because of strong irradiation at night.

In general the minimum temperature is gradually increasing from August through December; from December to April the minimum temperature is more or less constant, but after April the nights become cooler. The lowest night temperatures are generally observed around July.

In general the maximum temperature shows two peaks during the year. The first minor peak is around April when the sun has moved through the zenith. Since this period coincides with the end of the dry season temperature during day-time may reach values of 35C at low elevations. After the onset of the rainy season temperatures drop and reach their lowest day time values around January (middle of the rainy season). Between January and April the temperature increases and between April and June a slight decrease is observed mainly due to the northerly position of the sun. After June the day temperatures gradually increase till the peak of October is reached.

The diurnal difference shows a gradual increase from January through April, May, followed by a sharper increase from June - August. The highest diurnal difference is between August and September, followed by a sharp decrease from October through December (Figure 5).

The seasonal fluctuations coincide with the wet and dry seasons although the changes are small. Generally speaking, the dry season is characterized by high maxima and low minima. The more pronounced the dry season, the more pronounced are the maximum and minimum temperatures. Particularly in Southeast Indonesia in those regions directly exposed to the southeast trade winds from Australia, the temperatures at night are cool even at sea level during July and August. During the rainy season day temperatures are low, while the night temperature is above the annual mean. Irradiation at night is small because of the cloud cover and the high humidity.

Since the above conditions are average conditions, a few remarks should be made with respect to extreme temperatures. The highest monthly means recorded is 33.8C in Asembagus during October, the highest recorded air temperature is 38C in Sawahan (Braak 1929). The lowest monthly-means are found on the top of the Pangrango in September (5.7C) while the lowest recorded air temperature also on the Pangrango was 0.5C. This however does not mean that frost does not occur in Indonesia. The isotherm of 0C above Indonesia lies at an average

height of 4500 m. With the exception of the snow covered summits of a couple of mountains in West Irian, all mountains in Indonesia lie below the level of zero temperature. However, in high elevated valleys and high enclosed plateaus cooled air stagnates in the lowest parts and loses more and more heat by irradiation. This effect is increased by the dryness of the air. As a consequence, temperatures on the ground may reach values below zero. Night frost is frequent at Kertasari, a tea estate situated on the plateau of the Pengalengan at an elevation of 1550 m. Also on the Dieng plateau (2100 m) night frost occurs.

OTHER CLIMATIC PARAMETERS

Without underestimating the importance of the other climatic variables such as relative humidity, radiation, evaporation and wind speed, their patterns are closely correlated with the occurrence of wet and dry seasons and they never reach values detrimental to plant growth. Their mean values will therefore be summarized only, based particularly on 5-year records from the agroclimatic stations of the Central Research Institute for Agriculture at Bogor (CRIA). For a more detailed discussion reference is made to the quarterly climatic reports of CRIA and a 5-year summary by Oldeman and Sjarifudin (1977, in press).

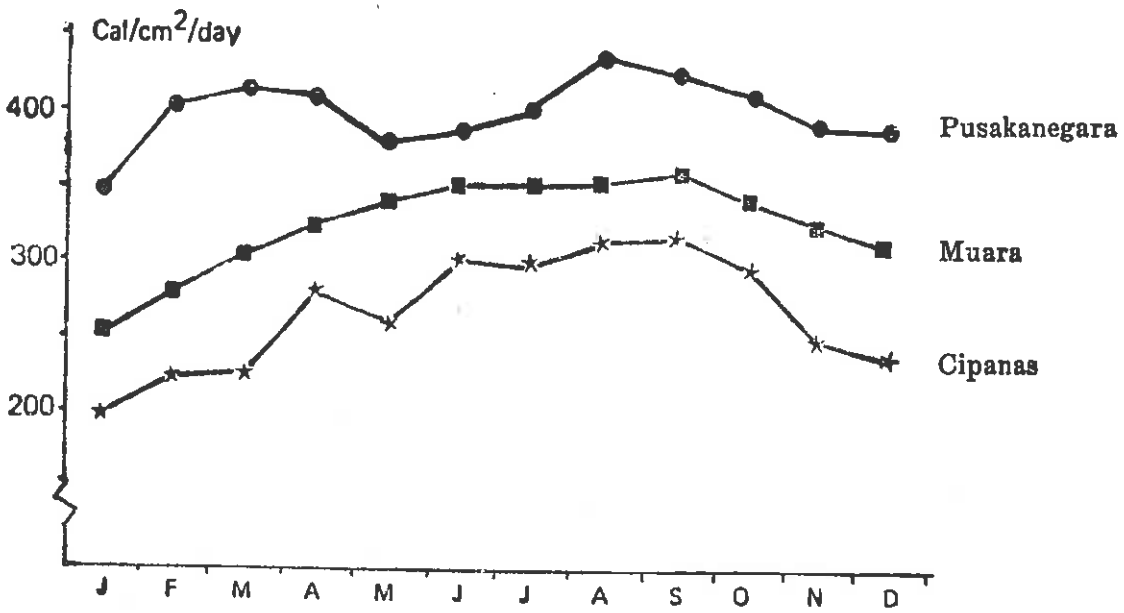

Figure 6A: Monthly radiation at three Locations

Radiation. The global radiation is a direct function of the amount of cloud cover and the thickness of the cloud layers. During the wet season the global radiation is considerably lower than during the dry season, but it is also lower at higher elevations mainly because of the condensation effect of humid air pushed against mountains as discussed before. At lower elevations where the dry season is more pronounced the effect of the solar position can be seen. High values are recorded in March and again in September when the sun moves through the zenith. During May and June the solar radiation is somewhat lower.

Evaporation. Evaporation is strongly influenced by radiation and air temperature. In the wet season evaporation values range from 75 mm per month at high elevations to 115 mm per month at sea level. From

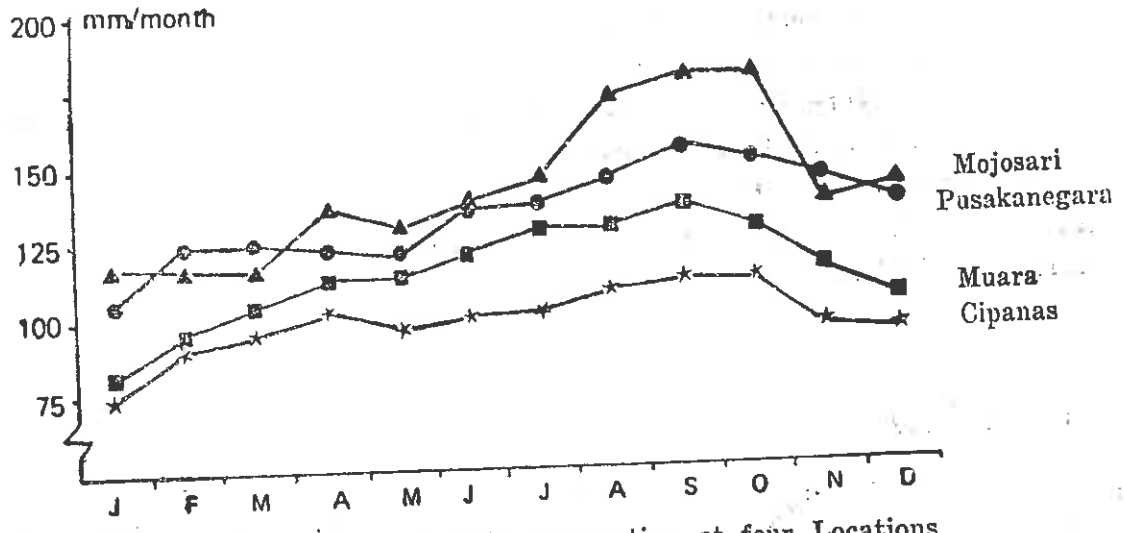

Figure 6B: Monthly evaporation at four Locations

January on the increase is slow, but when the dry season sets in, evaporation increases. In August, September evaporation reach monthly values from 110 mm at high altitude to 150 mm at sea level, but more inland evaporation is often as high as 180 mm per month. After October all values drop rather sharply to the wet season values.

Relative humidity. Seasonal as well as local variations in relative humidity are even smaller than of those climatic variables discussed above. While the maximum relative humidity at night never reaches values below 90% even in the dry season, during day-time the fluctuations follow more or less the same path as the radiation and evaporation.

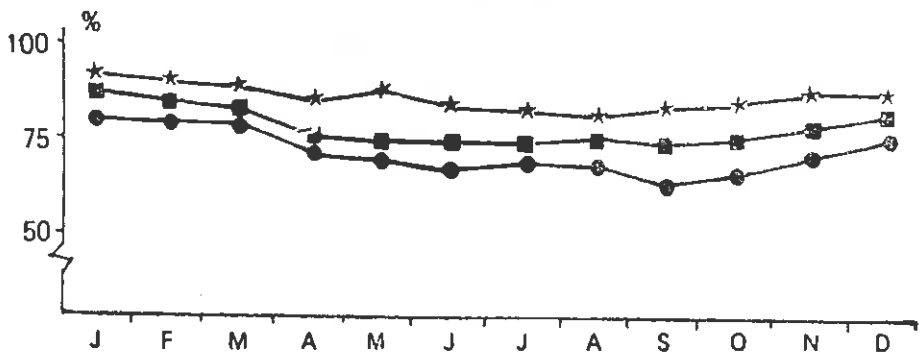

Figure 6C : Monthly mean relative humidity at three Locations

Pusakanegara (5 m, coastal plain, W. Java)
Muara (250 m, mountain foot, W. Java)
Cipanas (1100 m, mountain slope, W. Java)
Mojosari (30 m, inland plain, E. Java)

During the wet season the minimum monthly values are between 75% at low elevation to 86% at high elevation. The lowest values are recorded at the end of the dry season. In September the relative humidity is below 60% at low elevations and around 75% at high elevations. There is an exception that should be mentioned. The coastal regions are more humid in the dry season compared to inland regions at low elevation. The values for Muara and Pusakanegara are more or less similar. This may explain the difference in evaporation between Pusakanegara and Mojosari in the dry season.

Wind speed. The wind velocity seldom reaches values that cause severe damage to crops. Only the most southern part of Indonesia may occasionally feel the force of cyclones during the change of the monsoons in April, when they occur in the southern hemisphere, while the most northern part of Indonesia (Manado) may be affected by cyclones, that generate during the change of the monsoons in October. But cyclones generally occur only outside a seven-degree belt north or south of the equator. The wind velocity is generally very low at night and increases in strength during day-time. In Jakarta the maximum wind velocity, based on hourly periods, occurs around 2.00 p.m. and varies from 2.8 meter per second (mps) in the wet season to 3.4 mps in the dry season. In Pasuruan (East Java) these values are 3.1 and 4.5 respectively. The average 24-hour wind speed varies between 1.5 and 2.5 mps.

However, showers are occasionally accompanied by violent wind gusts, that can be destructive. The highest velocity recorded at the Batavia Observatory was 16 mps. During such squalls trees may be uprooted. (The damage in the Botanical Garden in Bogor in January 1971 is well known). These whirlwinds are very local and of rare occurrence at any fixed place.

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Weed Management and Weed Science Development in Indonesia

M. SOERJANI [1]

ABSTRACT

Weeds have been scientifically recognized in Indonesia since 1898 when the study of weeds was suggested and initiated. There have been several publication available describing the botany, ecology and control of weeds. The ten most important weed species in Indonesia are *Imperata cylindrica, Eichhornia crassipes, Cyperus rotundus, Salvinia molesta, Monochoria vaginalis, Mikania micrantha, Hydrilla verticillata, Echinochloa crus-galli, Cynodon dactylon* and *Panicum repens*. Weed management has been an integral part of agricultural activities for some time. There is a promising development of preventive measures due to the increase in public awareness of the importance of weed problems and the need for weed management. Mechanical control is still an important part of the effort to manage weed population. On an average, mechanical control is more expensive than chemical control. In plantations mechanical control cost is 125 - 175% higher than herbicidal control. In certain cases, however, mechanical control may be combined with the benefical utilization of weed mass as soil additives, cattle feed, and material for home industry. Biological control of weeds is still under investigation, but the present effort is primarily to control aquatic weeds using insects, fungi and fish. Chemical control use is increasing, particularly in plantations. Herbicides represent approximately 30% of the total pesticide consumption in Indonesia. The average annual consumption is over 2,000 tons (1969 - 1974). Weed research, weed science development and weed science training courses are briefly discussed.

INTRODUCTION

Numerous articles have been previously prepared and published on weed science in Indonesia (Soerjani and Tirtarahardja 1971, Soerjani and Azis 1973, Soerjani *et al* 1976). However, for the purpose of introducing Indonesia to the participants of the Sixth APWSS Conference held in this country, I will try again to summarize weed problems, weed management, weed research and weed science development in Indonesia.

WEED PROBLEMS

Weeds have interfered with human affairs since the beginning. Adam, the first prophet, was warned by Allah "to stay away from this bad tree, since he will be amongst the bad characters" (Qur'an 4 : 35).

[1] Weed Science Society of Indonesia, P.O. Box 17, Bogor, Indonesia.

The first known description of plant species considered as an aquatic weed: *Nelumbo nucifera* is found in the walls of Borobudur temple in Central Java (9th Century) describing the story of Buddha Gautama. It may be true, however, that people did not consciously recognize plant species of this kind as weeds nor did they intentionally practice weed control.

Weed problems have been scientifically recognized in Indonesia since 1898 when Dr. S.H. Koorders suggested the importance of studying weeds in Indonesian agriculture after he came across an American publication by Hitchcock and Clothier: "Vegetative propagation of perennial weeds" (Koorders 1898). The first response came from Blekkink (1902) who wrote an article on weeds in sugarcane plantations in Java. Mohr (1912) prepared a pocket book of "Weeds commonly found in Indonesia", followed by Boldingh (1932) who prepared a "Pocket flora of the agricultural areas in Java".

The more complete monumental works had been initiated by Backer and van Slooten (1924) with their "Illustrated handbook of tea weeds in Java" and Backer (1928 - 1934) with his "Weed flora of sugarcane soils in Java". In 1927 a thesis on the "Sociological and ecological studies on the tropical weed-vegetation of Pasuruan (the island of Java)" was submitted by W.J.C. Kooper to the Leiden University, the Netherlands. In 1932 Jochems wrote "Weeds in gardens" in a journal "de Tropische Natuur". The "Deutschen Limnologischen Sunda Expedition" listed 80 aquatic weed species in open water in Java, Bali and Sumatra (van Steenis and Ruttner 1933). Other publications in which weed flora have been referred to are the pocket books of de Voogd (1950) and van Steenis (1951). The most complete one is the 3 volumes of Backer and Backhuizen van den Brink (1963, 1965, 1968) "Flora of Java".

A recent review of weed problems illustrated the presence of 80 weed species in Indonesian plantations (rubber, tea, oilpalm and sugarcane), rice crops and lakes (Soerjani and Tirtarahardja 1971). In 1974 Tjitrosoepomo *et al*[2] listed 153 aquatic weed species commonly found in Indonesian open water, while Soerjani *et al* (1976) listed 21 important weed species in plantations and discussed their control. Table 1 summarized the list of the top ten weed species in Indonesia.

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[2] Tjitrosoepomo, G., S. Wirjahardja and M. Soerjani 1974. Aquatic weeds in Indonesia. Country report submitted to the Southeast Asian Workshop on Aquatic Weeds, Malang, Indonesia.

Table 1. Ten important weed species in Indonesia.

No.	Weed species	Vernacular name	Problems
1.	*Imperata cylindrica*	alang-alang	rubber; oilpalm, coconut; cinchona.
2.	*Eichhornia crassipes*	eceng gondok	open water.
3.	*Cyperus rotundus*	teki	sugarcane; upland crops: rice; maize.
4.	*Salvinia molesta*	kayambang	rice fields; open waters.
5.	*Monochoria vaginalis*	wewehan	rice fields.
6.	*Mikania micrantha*	sembung rambat	rubber; oilpalm; coconut; pines.
7.	*Hydrilla verticillata*	ganggang	open waters.
8.	*Echinochloa crus-galli*	jajagoan	rice fields; maize.
9.	*Cynodon dactylon*	grinting	sugar cane.
10.	*Panicum repens*	lempuyangan	tea; lakes.

WEED MANAGEMENT

It is obvious that weed management has been an integral part of agricultural systems in Indonesia since the beginning of agriculture as we know it and has continued to be so as man developed the use of a plow, which was intended primarily to pulverize the soil, introduce rotations, interrow cropping and rice irrigation systems. The elements of weed management can be classified as preventive measures such as cultural, mechanical, biological and chemical control methods.

Preventive measures. There has been an intensive introduction of new weed species (mainly from South America) such as waterhyacinth (*E. crassipes*) (in 1894), *Mikania* spp., *Chromolaena odorata* and *Mimosa invisa* as ground covers, *Brachiaria* spp., as cattle feed and *S. molesta* as a botanical curiousity (in 1951). It is expected that this can be prevented in the future by the effectiveness of the plant quarantine regulations within the framework of the Plant Protection Convention for Southeast Asia and Pacific Region sponsored by FAO since 1953. Indonesia ratified the convention in 1967. Broader prospects of preventive measures have been successfully demonstrated when the dam builders

(e.g. Brantas River, Solo River, Cisedane — Jakarta — Cibeet River, Rawa Pening, Jatiluhur lake authorities) initiated cooperation with research institutes and universities in monitoring aquatic weed problems and introduced preventive and control measures of aquatic weeds. The most successful achievement is that of the Brantas River authority, in which the newly built dams (Selorejo, Karangkates, Wlingi and Lahor) are free from aquatic weed infestation through a direct control campaign as well as indirect efforts to increase public awareness through leaders of the villages and school teachers. Posters, booklets and discussions are used successfully. Potential weed problems have to be effectively prevented, so that efforts can be concentrated on overcoming other actual, serious weed problems. Unfortunately, calculating the monetary turn-over of this effort is almost impossible, so that it is difficult to get administrative justification.

Cultural methods. The most important cultural method that contributes to the control of weed seed germination and growth, especially of grasses and sedges, is the continuous inundation of ricefields. The total area of ricefields is 4,84 million ha, which is approximately 50% of the total upland area. Other important cultural practices that may effectively contribute to the proper management of weeds are: rotation, multiple cropping, inter-row cropping and management of ground covers in plantation crops. In Java there are approximately 110,000 ha of ricefields converted periodically into sugarcane plantations. This reduces the presence of certain weed species, such as *Marsilea, Fimbristylis, Limnocharis flava,* and *Monochoria vaginalis.* The use of ground cover crops such as *Centrosema plumieri, Psophocarpus palustris* and others in rubber, oilpalm and coconut plantations is still commonly practised to suppress the growth of noxious perennial grasses. In young rubber, pine and teak forest plantations the cash cropping system using cassava, maize, peanut, sweet potatoes and others is a common practice to overcome weed problems.

Mechanical control. The most important type of mechanical weed control is manual weeding, particularly in annual crops and in small farms. This is because of the relatively high level of manpower employed in agriculture (5.41 man/ha by Soerjani and Azis 1973). Almost all activities in the small rice growing areas are done manually, including 1 - 2 weedings, through the social system "gotong-royong". In most plantation crops, manual weeding is still partly practised, although the cost in most cases is 125 - 175% higher than chemical control (Soerjani *et al* 1976). The

mechanical removal of waterhyacinth from Rawa Pening lake requires approximately 500% of what chemical weeding would cost. In general, mechanical methods of weed control can be combined or followed with some form of weed utilization. Not less than 59 species (75%) out of the 80 weed species in Indonesian agriculture (Soerjani and Tirtarahardja 1971) are found among the 6,145 plant species in the book of Heyne (1950) "The useful plants in Indonesia". This illustrates that most of the weed species may have one or another beneficial use for man, and this has received considerable attention recently. There are quite a number of reports available recently concerning the possible use of alang-alang, waterhyacinth and *S. molesta* for soil additives, cattle, pig and chicken feed, home industry, mushroom cultivation and others (Soewardi *et al* 1974).

Biological control. Biological control of weeds in Indonesia was initiated in 1935 when *Dactylopius tomentosus* was introduced to Sulawesi from Australia to control *Opuntia elatior*. The results were seen in 1939 when the cacti begun to succumb and fields were being re-tilled and pastured (DeBach 1964, Mangoendihardjo 1975). A lace bug (*Teleonemia scrupulosa*) feeding on *Lantana camara* was studied under quarantine conditions at Bogor, but escaped, and in ten years it spread all over Java and effectively controls *L. camara* (only) in dry season (Simmonds in Mangoendihardjo 1975). More recent efforts were started in 1970 when the biology of a gallmidge (*Orseoliella javanica*) on alang-alang was studied (Soerjani 1970). Mangoendihardjo (1975) reported another gallmidge (*Pachydiplosis* sp.) attacking *Paspalum scrobiculatum*. After the recommendation of the Southeast Asian Workshop on Aquatic Weeds in Malang in 1974 (Soerjani *et al* 1976a) more effort was made in finding suitable biological control methods to manage weed populations. Studies on the damage potentials, bionomics and host specificity have been initiated by BIOTROP (also in cooperation with the Commonwealth Institute of Biological Control) on natural enemies of important aquatic weeds such as *Nymphula responsalis* feeding on *S. molesta* and water lettuce (*Pistia stratiotes*). *Neochetina eichhorniae* was introduced from Florida in 1975 to study its possible use in the control of waterhyacinth. Grasscarp (*Ctenopharyngodon idella*) was introduced in 1949, 1964 and 1969 from Thailand, Japan and Thailand respectively, for fisheries and for aquatic weed control. It was known that the potential side effect of carp in damaging rice happens only when the ricefield is continuously inundated. The minimum water depth for grass carp growth is 30 cm. This is unlikely to occur in

ricefields and the degree of damage can be reduced by the presence of *H. verticillata*. On June 20, 1977 BIOTROP conducted a meeting attended by biologist, fisheries experts, weed scientists, agriculturists, dam engineers and planners to discuss the possible release of the fish in open water, both for fish production and aquatic weed control. Some fungi (*Rhizoctonia* sp., *Myrothecium roridum* and others) have been isolated from waterhyacinth and studies have been made to obtain data on the possible use of these fungi as biological control agents of waterhyacinth.

Chemical control. Inorganic herbicides were used prior to 1940's, e.g. (sodium chlorate and sodium arsenite) for alang-alang control. They were intensively used again during the period 1950 - 1960 and have been practically banned since 1970. The use of the more selective herbicides have been discussed since 1950, among others for rice (van de Goor 1950), for sugarcane (Duyverman 1957, Kuntohartono 1966), tea (Huysman and Gonggrijp 1951), rubber (Linde van Sprankhuizen and Sadjiarto 1957) and aquatic areas (Vaas 1951, Little 1969). The periods of herbicide study and use are as shown in Table 2.

Table 2. Periods of herbicide study and use in Indonesia

Herbicides for	First period	Second period		Third period
	1940	1950	1960	1970
Inorganic — plantations	———	====		———
Organic — plantations	.....	———	====	
— food crops		.....	———	
— aquatic areas		.....	———	

..... = under study
——— = limited use
==== = widely use

First Period = Inorganic herbicides.
Second Period = Limited use of selective herbicides.
Third Period = Wider use of selective herbicides.

Compared with some other countries (USA, Malaysia and Japan), the average herbicide use per hectare in Indonesia is low (Table 3). Although it is understood that the available manpower in agriculture per ha may influence the weed control methods, there are, however, other factors that

influence the quantitative use of herbicides. As shown in Tabel 3 the order of manpower availability for agriculture does not correspond with the average annual herbicide use per ha. In Malaysia the high rate of herbicide use is due to the intensive use of herbicide for plantations, while Japan consumes the greatest amount of herbicides per ha for rice. The reasons are that the manpower use per ha in Japan (3.35) is low due to the advanced development of the agricultural industry. Furthermore, the climate and conditions in Japan are such that there is a need to spray herbicides in most ricefields twice in any cropping season at rates that are sometimes over 2 times higher than in the USA and Africa (Nakayama 1976).

Table 3. The use of herbicide in various countries with different manpower availability for agriculture.

Country	Total agricultural land (million ha)	Manpower per ha agricultural land	Average annual herbicide use (ton) *	Average herbicide use per ha (kg/ha)
USA	436.3	0.02	139,998	0.3209
Malaysia	4.0	1.22	5,905	1.4762
Philippines	9.0	2.06	435	0.0483
Japan	7.0	3.35	23,691	3.3844
Indonesia	16.3	5.41	2,170	0.1331

* figures of 1964 - 1968 from FAO 23rd Production Yearbook 1969 except the Philippines (1963 - 1972) and Indonesia (1969 - 1974) from status reports submitted to the Southeast Asian Workshop on Pesticide Management Bangkok, April 1977.

The annual herbicide consumption has increased from 6.0% of the total pesticide use in 1969 to 29.0% in 1974 (Figure 1). Compared with Malaysia [3] and West Germany, it is interesting to note that in both countries there is a tendency for an increase in the percentage of herbicide used from 14% in 1972 to 74% in 1975 in Malaysia and from 9% in 1952 to 55% in 1971 in West Germany (Koch 1975).

[3] Status report of Malaysia submitted to the Southeast Asian Workshop on Pesticide Management, Bangkok, April 1977.

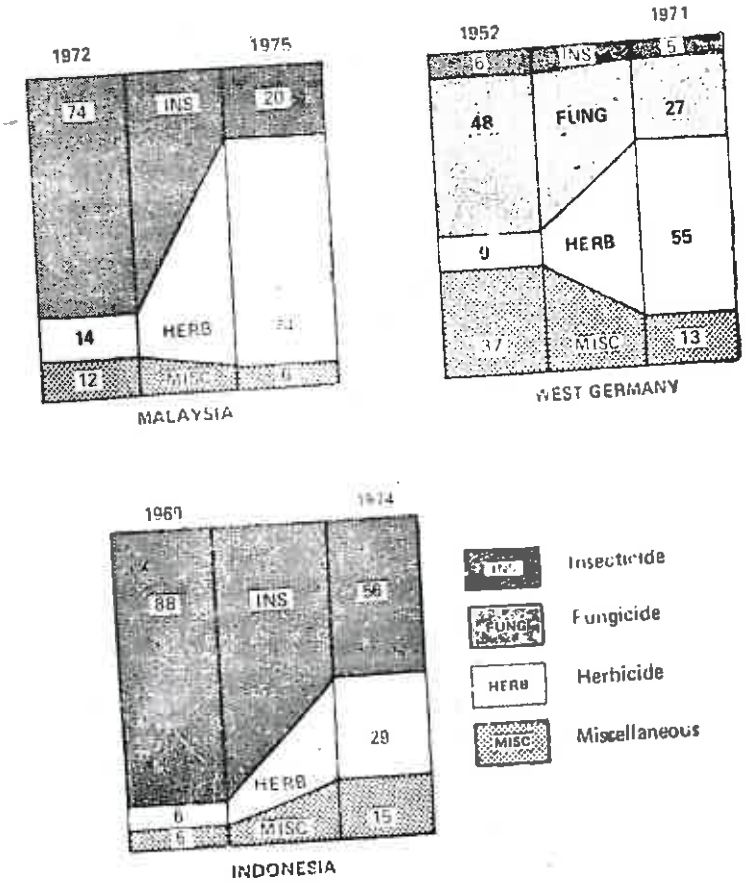

Figure 1. The percentage of herbicide use compared with other pesticides in Malaysia, West Germany and Indonesia.

It is estimated that in the future the herbicide usage will be 30% of the total pesticide consumption. The estimated figure for 1976 is 5,000 tons of herbicides with a value of Rp 10 billion (i.e. US $ 25 million). Figures from one of the tea plantations in Indonesia show that the total pesticide cost in tea production varies from 9.6% in 1972 to 3.9% in 1975, of which the percentage of herbicide used was 75.7% in 1972 and 59.2% in 1975 based on the total pesticide cost. It is likely that for most plantations in Indonesia, the herbicide consumption is about 50% (or over) of the total pesticide cost.

The Minister of Agriculture has issued annual decrees stipulating pesticide registration, distribution and use in Indonesia since 1973. Up till now there are 20 herbicides registered in Indonesia (Table 4) (based on ai).

Table 4. List of herbicide registered in Indonesia.

Active ingredient	Registered in				Recommended for use in
	1974	1975	1976	1977	
1. Ametryn	x		x		sugar cane.
2. Amitrol			x		rubber.
3. Atrazin	x		x		maize.
4. Benthiocarb				x	rice.
5. Cyanatryn		x	x		rubber.
6. 2,4-D			x	x	rubber, tea, rice, sugar cane, aquatic areas.
7. Dalapon	x		x		rubber, tea.
8. Diuron	x		x		rubber, tea, oilpalm, cotton.
9. Glyphosate				x	rubber, tea, oilpalm.
10. Linuron				x	rubber, tea, oilpalm, sugar cane.
11. MCPA	x		x	x	rubber, tea, rice.
12. MSMA	x		x		rubber.
13. Napropamid		x			rubber, tea.
14. Nitrofen	x		x		rice.
15. Paraquat	x		x		rubber, tea, oilpalm, cotton. rosella, aquatic areas.
16. Picloram				x	woody weeds.
17. Piperophos		x			rice.
18. Propanil	x		x		rice.
19. 2,4,5-T	x				woody weeds.
20. TCA		x			rubber, coffee, sugar cane.

There are some formulating manufacturers in Indonesia that produce 2,4-D, dalapon, diuron, MCPA and paraquat.

WEED RESEARCH AND WEED SCIENCE DEVELOPMENT

Weed research is one of the most recent academic developments, so weed science is one of the youngest sciences in Indonesia, although weed control is an old culture. Drs. Koorders and Backer are the two scientists among the very few who advocated the development of weed research

in Indonesia back at the end of the 19th Century and in 1920 - 1930 s. At present there are approximately 50 research and teaching staff at universities, institutes and agrochemical companies in Indonesia devoted to weed research and weed science and there are approximately 250 persons interested in the development of weed science in Indonesia. They are members of the Weed Science Society of Indonesia.

Weed science is officially taught at universities in Medan, Bogor, Bandung, Yogyakarta, Malang and Ujung Pandang. Training courses in weed science have been conducted by research institute such as the Central Research Institute for Agriculture and BIOTROP (for Southeast Asian participants) also by the Weed Science Society of Indonesia in 1975. As a forum to discuss weed problems and evaluate progress made in weed science the Weed Science Society of Indonesia has conducted biennial conferences since 1971. Some research units have conducted meetings with similar objectives. The Society also publishes a quarterly newsletter "Weeds in Indonesia".

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Physiological Studies on Seed Dormancy of Barnyardgrass (Echinochloa crus-galli Beauv. var. oryzicola Ohwi) [1]

Y. YAMASUE, K. SUDO and K. UEKI [2]

ABSTRACT

Primary dormancy of barnyardgrass (*Echinochloa crus-galli* Beauv. var. *oryzicola* Ohwi) seeds was surveyed for its type of seed dormancy. The fresh seeds, collected in 1975 and 1976 at our experiment field, did not germinate even under favorable conditions of sufficient moisture and temperatures at 25 to 30 C and were under a primary dormancy. The seeds were not light-sensitive. Germination of the seeds was markedly enhanced by physical scarification and H_2SO_4 or NaOH treatment. When imbibed under a low O_2 tension the seeds were allowed to germinate, whereas little germination was shown under high O_2 tension. When the water uptake of scarified and intact dormant seeds was examined over 48 hr imbibition at 27 C, the former absorbed 6.1 mg of water per seed and showed a lag about the ninth hours and the latter 4.6 mg with no apparent time lag phase. Immaturity and endogenous dormancy of the embryos themselves were determined by isolating them from the dormant seeds and placing them on an agar medium. The growth of the embryos was found to take place rapidly but was impeded by the presence of the pericarp. The true seeds also readily started their embryo growth when the pericarps and glumes were removed from the caryopses, and this suggested that the state of primary seed dormancy of this species may be maintained by the indehiscent pericarp, which encloses the true seed firmly and could give rise to a specific physiological state in the seed during the dormancy. No self-germination inhibitors have been found so far in the aqueous leachates or in eluates from a paper chromatogram of the ethanol extract of the dormant seeds.

INTRODUCTION

Barnyardgrass is a summer annual of the Gramineae and one of the most common weeds in rice fields. Seeds of this weed, locating principally on the soil surface after being shed from parent plants in fall, lie ungerminated in the soil for extended winter periods, but eventually germinate over a long period from spring to early summer. Those fresh seeds lying ungerminated in the soil are known to be under a primary dormancy and do not germinate even under favorable conditions of

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moisture and temperatures ranging from 25 to 30 C (Andersen 1968, Arai and Miyahara 1960; 1962, Bruns and Rasmussen 1958, Miyahara 1972).

Extensive studies on the seed dormancy of this species, including secondary dormancy, were carried out from the point of view for its control in rice paddies by Arai and Miyahara (1960; 1962) and Miyahara (1972). When the caryopsis was scarified, germination of the seed was enhanced but not when only the glumes were removed. It was suggested that the primary dormancy was little related to the glumes but it might be attributed to the pericarp and seed coats. They also reported that the dormant seed was able to absorb enough water for germination and the dormancy was broken by imbibition in pure nitrogen (Miyahara 1972). The importance of ascorbate, polyphenol and cytochrome oxydases for respiratory regulation during the dormancy and awakening stages was pointed out by Ueki and Shimizu (1968), Shimizu and Ueki (1972; 1972a), when they surveyed respiratory mechanisms of the seeds by soaking them in a number of chemicals and anti-metabolites. Endogenous substances which inhibit the germination of rice seeds have been found in ethanol extracts of barnyardgrass seeds (Fujii 1973).

In spite of experiments on the dormancy of barnyardgrass seed, it is not possible to understand fully the physiology of the seed dormany. However, seed dormancy is an important character of weeds, by which they maintain longevity in soil and frequently escape cultivation and herbicide sprays. Prior to a detailed study on the dormancy it is often advantageous to survey the type of dormancy as Crocker (1916) described. He proposed a classification of the types of primary dormancy based on immaturity or a metabolic block of the embryo; low permeability of the seed covers to water or gases; mechanical resistance of the seed covers to the embryonic growth and a combination of the above. The objective of this study was to determine the type of primary dormancy of barnyardgrass seed and to provide a guide for further experiments on the physiology of dormant seed. In this study the term "primary dormancy" has been reserved to describe the state of a mature seed, freshly collected, air-dried and stored at room temperature for a short period, which was unable to germinate after imbibition for a week under adequate moisture conditions and temperatures of 25 to 30 C. "Seed" has been used as a

convenient term to describe the dispersal unit of barnyardgrass propagule, which is a caryopsis within the glumes. In the caryopsis, layers of the indehiscent pericarp firmly encloses the true seed.

MATERIALS AND METHODS

Seeds used for the experiments were collected from a local population of barnyardgrass at our experimental rice paddy field in Kyoto Prefecture. Seeds were cleaned with tap water, air-dried and stored under room conditions. They were used for experiments within three months of collection unless otherwise noted. Preliminary tests indicated that the seeds collected varied in maturity and this was indicated by their size and the color of the pericarp and glumes. The degree of dormancy increased as the maturity increased. Only large, uniform and brown-colored seeds, which appeared to fully mature, were used in experiments. In a series of experiments, the seeds were subjected to germination tests in a growth chamber with fluorescent lighting and temperatures of 25 to 30 C. There was no significant difference in germination between continuous darkness and lighting during imbibition. Most experiments consisted of three replications of 20 seeds each, and were fully randomized in the growth chamber. Each experiment was repeated at least twice. Germination counts were made by using the protrusion of the radicle or coleoptile as the criterion for germination.

Immaturity and a metabolic block of the embryos were determined by culturing embryos isolated from the dormant seeds. Prior to the isolation, the seeds were soaked in distilled water for 12 hr and sterilized with 0.5% sodium hypochloride for 30 min. The isolated embryos, with sticking endosperm residues, were directly transfered onto an autoclaved culture medium consisting of 1.5% D-glucose, 1.5% D-sucrose and pH 5.50. Ten embryos were prepared, one per 24 × 300 mm test tube. True seeds and caryopses as well as intact dormant seeds were also prepared in a similar manner for references. Growth of the coleoptile and radicle was determined 10 days after imbibition on the culture medium.

Permeability of the seed covers to 0_2 uptake was investigated by soaking the intact dormant seeds under atmospheres of various 0_2 concentrations. Seeds were placed in a 25-ml glass bottle with an air-tight rubber stopper and pipetted with 0.5 ml of deaerated water. Scarified and true seeds were also similarly prepared for references. The scarification was performed by pricking the seeds through the outer covers

into true seeds. Seed cover impermeability was also determined by treating the dormant seeds with 2 N H_2SO_4 and 2 N NaOH. The seeds were soaked either in the acid or base aliquot for 0, 15, 30 and 60 min, washed with tap water and then the acid and base treated seeds were reversely treated with the base and acid for one min, respectively, to neutralize the chemical residues on the surfaces, and placed in 4-cm petridish on two sheets of Toyo No. 2 filter paper moistened with one ml of distilled water. After incubation in the growth chamber germination counts were made on 3, 4, 5, 7 and 10 days.

Permeability of the seed covers to water was studied by determining the amount of water absorbed by intact dormant seeds during imbibition. The seeds as well as scarified seeds, caryopses and true seeds were placed on the filter papers in 4-cm petridish and soaked in two ml of distilled water. True seeds used in this experiment were those stored at 10 to 20 C for a month after the two months storage room temperatures. Fresh weight of each replicated 20 seeds was precisely measured at 0, 2, 5, 9, 24 and 48 hr after the beginning of imbibition. Upon each measurement, the seeds were removed from the dish, placed on dry filter papers to wipe adhering water off and air-dried for one minute before weighing to obtain the amount of water taken up by the seed. Growth and germination inhibiting substances were also surveyed for their presences in leachates and ethanol extract of 100 g of dormant seeds by the methods of Fujii (1973) and Takahashi (1962) were used for barnyardgrass and rice seeds, respectively.

RESULTS AND DISCUSSION

Isolated embryos of dormant barnyardgrass seeds readily germinated and showed 70.0% germination 3 days after the beginning of imbibition (Figure 1). This indicates that embryos of the dormant seeds were neither immature nor metabolically blocked by themselves, provided that the excising practices used had not influenced their dormant state. True seeds also germinated and reached up to 60.0% germination on the third day, but both the caryopses and intact seeds did not show any germination for 10-days and appeared to remain dormant. This result suggests that the primary dormancy of this weed is imposed by the presence of pericarp as Arai and Miyahara (1960) and Miyahara (1972) have pointed out previously. Growth of the coleoptile and radicle was examined on the 10th day and it was found that there were significant differences in growth

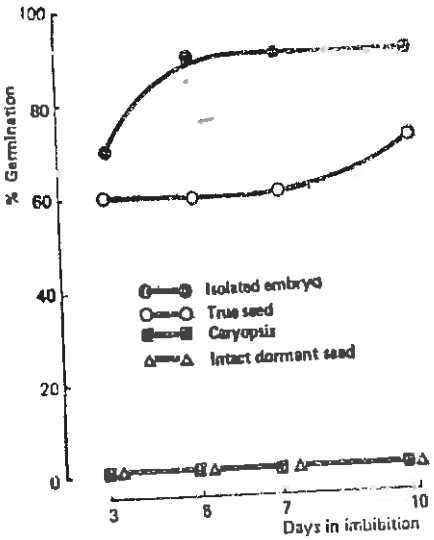

Figure 1. Germination of the isolated embryos of dormant barnyardgrass seeds imbibed on an agar medium

between the isolated embryos and true seeds (Figure 2). The differences may have been caused by the amount of available food reserves. The true seed retained enough reserves for the embryonic growth in the uninjured endosperm, whereas the isolated embryo only had a small amount of attached endosperm residue apart from those reserves within the embryo itself and the sugars in the culture medium.

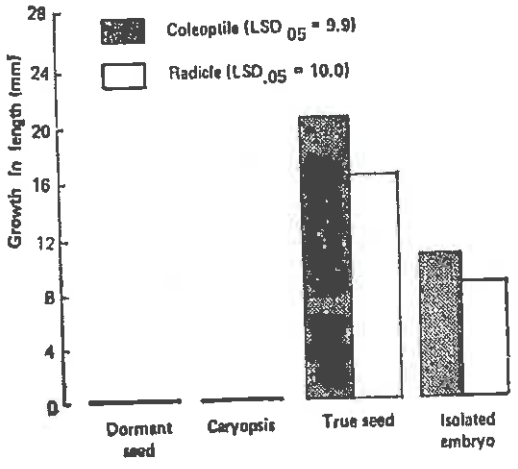

Figure 2. Growth of coleoptile and radicle of the embryo isolated from dormant barnyardgrass seed during 10- days imbibition.

Intact dormant seeds, true and scarified seeds were imbibed under He gases containing 0_2 at different concentrations. The intact seeds showed 88.3% germination at 0.0% 0_2, but 6.7% at 100.0% 0_2, and with increasing 0_2 concentrations, the percent germination decreased (Figure 3).

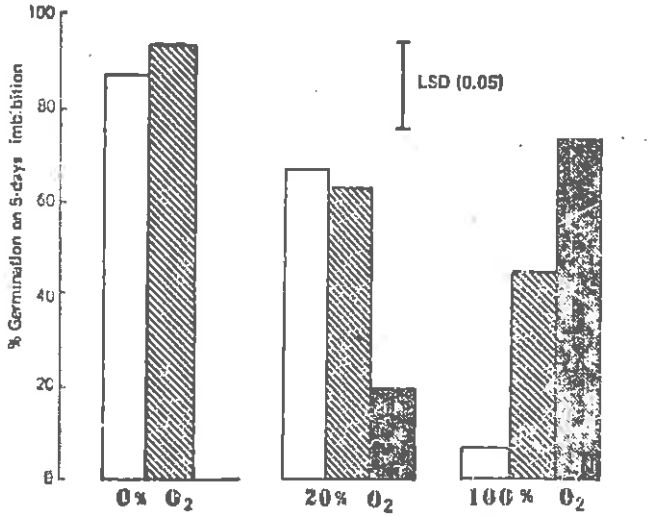

Figure 3. Effects of the atmospheric O_2 concentrations on the germination of intact dormant seeds. ☐, true seeds ▨ and scarified seeds ▩

A similar, but gradual trend was observed for the true seeds and they germinated 98.3, 53.3 and 45.0% at 0.0, 20.0 and 100.0% 0_2, respectively. However, all the coleoptiles both in the intact and true seeds imbibed under 0.0% 0_2 condition showed chlorosis. The reverse was the case for the scarified seeds and germination increased with increasing 0_2 concentrations. At 0.0% 0_2 there was no germination in the scarified seeds. Nakajima (1966) reported that seed germination of several aquatic plants including *Sagittaria trifolia* L. var. *typica*, *Monochoria vaginalis* Presl var. *plantaginea* was enhanced at a low 0_2 tension and produced an alcohol in deaerated water. Anaerobic respiration was suggested to be a form of adaptation frequently observable in seeds and other organs having outer covers with a low 0_2 permeability (Nakayama 1966). It is thus possible that the look of germination under anaerobic conditions and the high percent germination under aerobic conditions found in the scarified seeds might be a result of scarification-induced changes from the anaerobic to aerobic respiration in the seeds.

Germination of many seeds, particularly with hard seed covers, is well known to be stimulated by an acid treatment like concentrated sulfuric acid. The action of the treatment is often attributed to a decrease of seed cover impermeability to water and/or 0_2 uptake (Fujii 1975 and Nakayama 1966). When treated with 2 N H_2SO_4 for 15 min, the dormant seeds of barnyardgrass were observed to germinate readily to an extent of 71.7% and the germination decreased with increasing periods of the acid treatment (Figure 4). While an increase in the percentage germination was observed with increasing periods of the base treatment.

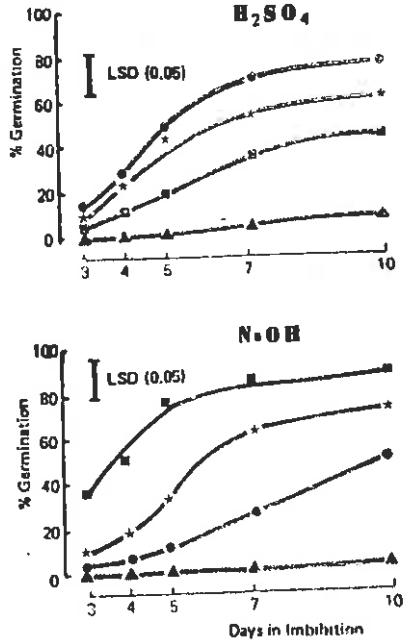

Figure 4. Effects of acid and base treatments on germination of intact dormant seeds of barnyardgrass. Treatments were made for the periods of 0(▲), 15 (●), 30 (★) and 60 (■) mins before imbibition.

Permeability of the seed covers to water was studied by determining the amount of water absorbed by intact dormant, scarified seeds, caryopses and true seeds. Under the conditions of this experiment, water uptake of scarified seeds was very rapid immediately after the begining of imbibition. It appeared to cease about the ninth hour and then resumed (Figure 5) as described for other seeds by Ching (1972) and Mayer and Polijakoff-Mayber (1963). The germination percent obtained for the scarified seed was 43.3 in 48 hr imbibition, whereas 0.0 for the intact

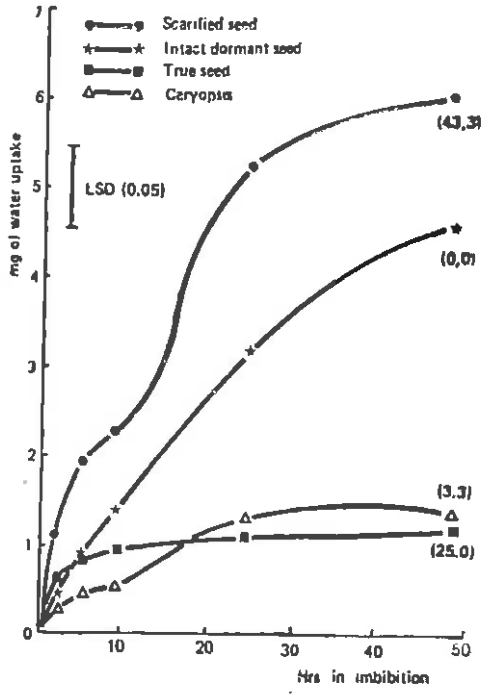

Figure 5. Amounts of the water absorbed by an intact dormant seed and scarified seed of barnyardgrass in a time course of imbibition. Values in the parentheses indicate the germination percentages observed at 48 hrs in imbibition.

dormant seeds which showed no apparent time lag in water uptake over 48 hr. The scarified and intact seeds absorbed 6.1 and 4.6 mg of water per seed during this 48 hr imbibition. It was not clear if most of the water absorbed by the intact dormant seed was a result of uptake by its glumes and pericarp, although our other preliminary trial suggested that more than 60% of the water absorbed by germinating seeds was taken up by the outer covers, including spaces between them, which enclosed the true seeds. True seeds absorbed water more rapidly than the caryopses during the initial stages of the 48 hr imbibition, but there was no siginificant difference in the rate of water uptake.

A number of observations indicated that endogenous growth and germination inhibitors may play an important role in the control of seed dormancy. In this experiment, endogenous inhibitors were surveyed by extracting the soaking water and homogenates of 100 g of dormant seeds with ethanol. Although there appeared to be fractions that inhibited the elongation of the hypocotyl and radicle of lettuce seed (*Lactuca sativa* L.), no fractions inhibitory to the germination of non dormant barnyard-

grass seeds have been found, so far under the conditions of this trial, in the leachates or eluates from paper chromatograms of the ethanol extract of the dormant seeds.

Those data reported herein suggested that the state of primary dormancy of the barnyardgrass seeds used could be maintained by the indehiscent pericarp, which encloses the true seed firmly and appears to be able to limit water and 0_2 supplies to a certain extent. In such a seed the embryo would be placed under a specific physiological state as, for instance, Vegis (1964) speculated that products of anaerobic respiration were converted in another direction other than those characteristic of growing plants. He further speculated that this alternate path is not coupled with processes of growth but instead with those which increase the resistance to unfavorable external environmental factors. However, detailed studies will be required on the physicochemical structures of the layers surrounding the caryopsis as well as on the physiological state within the embryo from the onset to the breaking of the seed dormancy of barnyardgrass.

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Preliminary Ecophysiological Studies on the Occurrence of Some Parasitic Weeds in Cibodas, Indonesia [1]

S. SOEROHALDOKO [2]

ABSTRACT

In Indonesia some species of the *Loranthaceae* occur as parasitic weeds on plants. These weeds can decrease the quality of the timber, the fruit production and the growth of some ornamental plants. Preliminary ecophysiological studies were made on the occurrence of the parasitic weeds *Scurrula fusca* G. Don, *Korthalsella japonica* (Thunb.) Engl., *Dendrophtoe magna* Dans. and *Viscum articulatum* Burm.f. in Cibodas (± 1400 m above sea level) Indonesia, where they grow naturally. A description is presented of some climatic factors in Cibodas and other ecophysiological factors in relation to the occurrence of these plants. In Cibodas these weeds occur generally in situations with a high light intensity. Control of the weeds is practised in Indonesia by physical removal from the host plants. These ecophysiological studies might be useful for enhancing weed control methods, especially where light plays an important role in the transport of certain "hormone like" selective herbicides.

INTRODUCTION

Some species of the *Loranthaceae* occur in Indonesia as parasitic weeds on economic plants. These weeds can decrease the quality of the timber (Pika 1972), the fruit production (Koernicke 1910) and the growth of ornamental plants (Koernicke 1910). It has been reported that several species of the *Loranthaceae* occur on *Altingia excelsa* Noronha (Van Steenis 1972). This tree produces good timber for building and bridge construction (Pika 1972).

Koernicke (1910) mentioned the occurrence of some species of the *Loranthaceae* on industrial crops like *Theobroma cacao* L. and *Myristica fragrans* Houtt., on fruit trees like *Diospyros kaki* Thunb., *Citrus* species and *Mangifera indica* L. and on other economic plants like *Tectona grandis* L.f. and *Codiaeum variegatum* (L.) Bl.

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1 The data was mainly collected during a Biotrop training course at Cibodas, Indonesia.

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Koorders (1923) mentioned 4 species of the *Loranthaceae* growing at Cibodas, Indonesia and belonging to the genera *Loranthus* and *Elytranthe*. Taxonomic studies were carried out by Danser (1931) on *Loranthaceae* of the Netherlands Indies.

According to Reynvaan (1926) the distribution of *Loranthus* seeds can take place quickly by the bird Burung Cabe (*Dicaeum flammeum* Sparrm.). After passing through the bird's body the seeds can germinate quickly. Light stimulates seed germination of the tropical *Loranthaceae* (Koernicke 1910).

Mechanical control of the *Loranthaceae* is practised in Indonesia by physical removal from the host plants.

The main aim of the observations in Cibodas was to collect data on ecophysiological factors of the parasitic weeds *Scurrula fusca* G. Don, *Korthalsella japonica* (Thunb.) Engl., *Dendrophthoe magna* Dans. and *Viscum articulatum* Burm.f. The area of research included a part of the nature reserve at Cibodas and the adjacent botanical garden (± 1300 — 1500 m above sea level). In this region these weeds grow naturally on trees. The data were mainly collected during a Biotrop training course at Cibodas, Indonesia.

MATERIALS AND METHODS

Special attention was paid to the parasitic weeds *S. fusca, K. japonica, D. magna* and *V. articulatum* during the expeditions at Cibodas where they grew naturally on the trees. The trees were then recorded as host plants.

The following notes were made on the occurrence of the parasitic weeds *S. fusca, K. japonica, D. magna* and *V. articulatum* on the trees:

1 = Name of the host on which the parasitic weed grew.
2 = Name of the parasitic weed.
3 = The height of plant where the parasitic weed grew.
4 = The distance from the soil to the point of attachment of the parasitic weed.
5 = The place where the parasitic weed occurred on the plant (stem, branch etc).
6 = Density of attack by the parasitic weed presented by the number 1 — 3; 1 = light, 2 = moderate, 3 = heavy.

7 = Sunlight intensity at the level of the parasitic weed. The full sunlight intensity is considered as 100%, total darkness as 0%. The estimation of the light intensity was done by a simple subjective judgement.

8 = Elevation from the level. The elevation was determined with an altimeter.

For the climatic factors in Cibodas, Braak (1929) gives the following data. The annual average relative humidity is 87% with a maximum of 100% and a minimum of 29%. The annual average duration of sunshine is 43%. The average duration of sunshine in January - February is 25%, in July - September is 57% and in March - April - October and November is 40%. The annual average temperature is 17.7 C, the absolute minimum is 10.1 C (August) and the absolute maximum is 26.8 C (October). The annual average rainfall is 3405 mm, with the highest precipitation in February (420 mm) and the lowest in July (116 mm). During a period of 6 years (1919 — 1924) there were 267 days with strong west winds, many were in February, fewer in May and none in September.

RESULTS AND DISCUSSION

The results of the observations are presented in Table 1. *S. fusca* grew on places with 75 - 90% sunlight intensity on the following plants:

Acacia decurrens (Wendl.) Willd.
Acacia myrtifolia Willd.
Bridelia minutiflora Hook.f.
Camellia japonica L.
Cordia myxa L.
Cupressus forbesii Jepson
Magnolia grandiflora L.
Melaleuca bracteata F. v. Muell.
Neonauclea lanceolata (Bl.) Merr.
Prunus cerasoides D. Don
Saurauia blumiana Benn.

D. magna grew on places with 80 - 100% sunlight intensity on the following plants:

Alnus japonica (Thunb.) Steud.
Brachychiton acerifolium F. v. Muell.

Table 1. The occurrence of some parasitic weeds at Cibodas, Indonesia.

1 Host plant	2 Parasitic weed	3	4	5	6	7 Light (%)	8 Elevation (m)
A. decurrens	*S. fusca*	10 m	6 m	branch	1	75	1300
A. excelsa	*K. japonica*	20 m	8 m	„	1	90	1400
A. japonica	*D. magna*	15 m	10 m	„	2	80	1300
A. myrtifolia	*S. fusca*	10 m	6 m	„	2	90	1300
B. acerifolium	*D. magna*	15 m	10 m	„	1	90	1400
B. minutiflora	*S. fusca*	15 m	6 m	„	2	75	1350
B. rupestris	*D. magna*	20 m	15 m	„	2	80	1400
C. fobersii	*S. fusca*	15 m	6 m	„	1	80	1300
C. japonica	*S. fusca*	6 m	5 m	„	1	90	1350
C. myxa	*S. fusca*	15 m	10 m	„	2	75	1400
D. kaki	*D. magna*	8 m	6 m	„	3	100	1450
E. umbellata	*V. articulatum* *D. magna*	20 m	8 m 10 m	„ „	1 1	90 100	1450
F. variegata	*V. articulatum*	30 m	10 m	„	3	75	1400
M. bracteata	*S. fusca* *D. magna*	12 m	5 m 6 m	„ „	1 2	75 80	1300
M. grandiflora	*S. fusca* *D. magna*	10 m	6 m 8 m	„ „	1 1	90 100	1450
N. lanceolata	*V. articulatum* *S. fusca*	20 m	10 m 11 m	„ „	2 1	80 75	1350
P. cerasoides	*S. fusca* *D. magna*	10 m	7 m 6 m	„ „	2 1	90 80	1350
S. blumiana	*S. fusca*	8 m	6 m	„	1	90	1400

Explanations:

3 = height of host plant; 4 = distance from the soil to the parasitic weed; 5 = occurrence of the parasitic weed on stem, branch etc.; 6 = denstiy of attack presented by the number 1 - 3. For further explanations 1 - 8 see also methods in text.

Partoatmodjo, former Directors of the Biotrop, Bogor, Indonesia, for the

Brachychiton rupestris K. Schum.
Diospyros kaki Thunb.
Eucalyptus umbellata Dum. Cours.
Magnolia grandiflora L.
Melaleuca bracteata F. v. Muell.
Prunus cerasoides D. Don

K. japonica grew on places with 90% sunlight intensity on
Altingia excelsa Noronha

V. articulatum was found on places with 75 - 90% sunlight intensity on the following plants:

Eucalyptus umbellata Dum. Cours
Ficus variegata Bl.
Neonauclea lanceolata (Bl.) Merr.

The seriousness of attack was considered heavy on *F. variegata* by *V. articulatum* and on *D. kaki* by *D. magna*. For more details see Table 1.

Vaas (1951) mentioned that the transport of growth substances in the plant, including certain "hormone-like" herbicides is stimulated by the same external factors (like temperature and light) that stimulate photosynthesis. According to his experiment in Rawa Pening, Indonesia, the effect of spraying 2,4 D on waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) is less when there is not much sunlight, as for instance when the sky is cloudy in the rainy season. There is a possibility that these parasitic weeds which occur in nature on places with high light intensity have also a high light compensation point. In this respect the transport of the growth substances will be increased in the dry season when there is more sunlight than in the rainy season. These ecophysiological studies might be useful for weed control, especially where the light factor can play an important role in the transport of certain "hormone - like" selective herbicides.

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On Mistletoe Parasitism

G. G. HAMBALI [1]

ABSTRACT

The origin of parasitism in mistletoe (Viscaceae, Loranthaceae, Santalaceae, Myzodendraceae) and the role of flower peckers (Dicaeidae) in establishing the host-mistletoe association is discussed briefly. The occurence of scolytid and cerambycid beetles in controlling *Dendropnthoe* spp. is reported and several suggestions concerning mistletoe control are also given.

INTRODUCTION

"A tree laden with mistletoe is one of the most beautiful sights of the Malayan rain forest". This quotation from Richards (1952) does contain a germ of truth since many loranthaceous mistletoe have colourful young foliage and flowers, hence accentuating the scenic value of many otherwise dull green tropical rain forests. However, one might have a different opinion since some of them, particularly those having the weed characteristics, are quite shaggy and in fact become a menace to numerous plantations which consequently makes a control measure desirable.

The term mistletoe refers here to aerial parasites which belong to the families Viscaceae, Loranthaceae, Santalaceae, and the unigeneric Myzodendraceae (Good 1974). The last-named family is endemic to South America and its dispersal, which seems to be carried out by wind, is very little known. Members of this family usually grow on *Nothofagus* (Fagaceae). A few genera of Santalaceae such as *Cladomyza, Dendromyza,* and *Hylomyza,* of necessity, are also covered by this term since they consist of members that usually parasitize the aerial parts of many trees. All species of *Phacellaria,* another santalaceous genus, are even known only as parasites on other mistletoes.

The bulk of mistletoes which become a menace to plantation belong to Viscaceae and Loranthaceae. At least three genera of the former family i.e. *Arceuthobium, Phoradendron,* and *Viscum* and a few of the latter such as *Amyema, Dendrophthoe, Macrosolen, Scurrula,* and *Tapinanthus* are quite notorious in some parts of the world. Although we may

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assume that a few of the remainder cannot be regarded as potentially menacing, very little knowledge on this part is available, hence necessitating their further study.

THE ORIGIN OF MISTLETOE PARASITISM

The thesis that the mistletoes have evolved from root parasitic plants, as already proposed by Kuijt (1969), which provides the only reasonable explanation of the early evolution in this group is accepted in this treatment. The basic drive of root parasitism is assumed here as the antithesis of allelopathy. Certain chemical stimulants which triggered root parasitism in the early autotrophic population are also assumed here to be of general occurence in many plant families, hence giving a possible explanation to the polyphagous nature of some root and aerial parasites. A few references concerning the role of these chemical stimulants in some root parasites could be traced in Kuijt (1969). The profound role of the flower peckers or mistletoe birds in the evolution of loranthaceous and santalaceaous mistletoes can no longer be questioned. Frequent deposition of the sticky seeds of the mistletoes by these birds on the branches of the potential host trees is considered here as the main factor that contribute to the development of branch parasitism from root parasitism.

The development of root parasitism from a superficial contact to a penetrating one as exemplified by *Dendrotrophe varians* (Bl.) Miq. (Santal.) which parasitizes roots of numerous terrestrial plants living nearby is an important evidence towards the explanation of the development of haustoria in the related *D. umbellata* (Bl.) Miq. that lives as an epiphytic root parasite. I saw the former species grow terrestrially on soil high in organic matter in South Borneo. A similar type of substrate, on which many epiphytes can thrive well, could be found on big horizontal branches of many old trees in the mountain forests in Java. The epiphytic shrubs such as *Vaccinium lucidum* (Bl.) Miq., *V. korthalsii* Miq. and *Rhododendron javanicum* (Bl.) Benn. often occupy this habitat. In the early stage of growth the roots of the epiphytic *D. umbellata* parasitize the roots of these epiphytes but in the mature stage thick roots of this parasite may also be found parasitizing the big branch of the tree on which it first grows epiphytically without doing any harm to the tree. The latter development occurs if the tree belongs to one of the potential hosts of this particular santalaceous mistletoe. *Altingia excelsa* Noroña and *Quercus lineata* Bl. are two representatives of these hosts. The roots

of two young individuals of this epiphytic *D. umbellata* growing on *Podocarpus imbricatus* Bl. in Cibodas (West Java) do not form any parasitic connection with this latter tree, hence suggesting that it does not belong to the potential host trees of this mistletoe. However, more field observations are still needed to reach a final conclusion. Although this example might serve as a link towards the development of perfect branch parasitism from root parasitism, this particular mistletoe has found its own *cul-de-sac* in its evolution since the grooved seeds of this mistletoe lack the long hairs typical of the seeds of other santalaceous mistletoe, which are beneficial in attaching the seeds to the host branches. Hence, the seeds of these particular mistletoes always need other established epiphyte associations — on which the mistletoe birds can perch, feed on the epiphyte fruits, and deposit the mistletoe seeds — before they can be intercepted effectively by the substrate, germinate, and grow parasitically into mature plants.

The presence of glutinous substance on the seeds of the early populations of loranthaceous and viscaceous root parasites or hairs in the case of santalaceous root parasites is certainly one of the factors which are responsible for the subsequent evolution of these three groups from terrestrial parasites into aerial parasites. In this particular case the first two groups are more adjusted towards the mode of dispersal by their associated birds than the third one since the hairy seeds of the latter do not stick on the branches of the host as readily as the seeds of the former two. However, there is one interesting thing about the dispersal of these groups. I once found a mixture of seeds of *Hylomyza sphaerocarpa* Dans., *Viscum articulatum* Burm.f. and *Macrosolen cochinchinensis* (Lour.) Tiegh. in a chain-like excretion of flower pecker (*Dicaeum*). The excretion stuck on a branch of *Syzygium gracile* (Korth.) Amsh., growing in Cibarengkok (West Java), on which also grew *Dendromyza reinwardtiana* (Bl. ex Korth.) Dans. This finding suggests that the seeds of loranthaceous and viscaceous mistletoe might provide a sort of natural glue to the hairy but non-glutinous seeds of santalaceous mistletoes and also to the seeds of many epiphytes which produce small berries or drupes. In England I found on branches of apple trees bird excretions that contained seeds of holly (*Ilex aquifolium* L.) and rose (*Rosa* sp.) glued together by the seeds of European mistletoe (*Viscum album* L.). In several field observations in Bogor Botanic Garden and in Ciletuh (West Java) I and Miss Camilla Huxley, an ardent student of myrmecophytes from

England, found that young individuals of *Hydnophytum formicarum* Jack, the most common rubiaceous epiphytic ant plant in West Java, frequently growing in association with mistletoes. In the Botanic Garden they are often seen growing close to each other on the branches of the host tree. In Ciletuh we found seedlings of this ant plant growing on the branches of *Scurrula atropurpurea* (Bl.) Dans. which parasitized *Citrus grandis* (L.) Osbeck. Some older individuals of this ant plant could also be found growing side by side with this mistletoe on the same branches of this host tree. Still in the same area we found a few more individuals on *Helixanthera parasitica* Lour. (Loranth.) which parasitized a fagaceous tree and in fact on the tree we found a mature ant plant with a germinating seed of this mistletoe. Our finding indicates strongly that the dispersal of this ant plant is also dependent on the mistletoe bird. This is particularly fascinating since the non-sticky seeds of *Hydnophytum formicarum* might be glued to tree branches along with the sticky mistletoe seeds when the birds happen to eat the fruit of these two plants which as already indicated often grow together and deposit seeds of both plants on the same branches.

Hyperparasitism in *Phacellaria* also seems to have developed through the simultaneous dispersal of its hairy seeds along with the glutinous loranthaceous mistletoe seeds. Hence the hairy seeds of these santalaceous mistletoes could stick more strongly on the branches of loranthaceous mistletoes on which they frequently grow as hyperparasites. However more field observations are necessary to confirm if this simultaneous dispersal is of general occurrence. This type of hyperparasitism and in fact many types of hyperparasitism in mistletoe are made possible by the frequent visits of the mistletoe birds to numerous species of mistletoes. These frequent visits are due to the mistletoe bird preference towards a diet consisting mainly of mistletoe berries or small berries including also small drupes produced by the upper storey communities. I wonder if human activities which result in the decrease of the number of small berry producing trees are responsible for the development of this preference.

The absence of the glutinous substance and hairs on the seeds of many present day root parasites such as *Nuytsia floribunda* R.Br., *Santalum* and Olacaceae is one important feature that can explain the retarded state of evolution into branch parasites in all these groups.

THE ESTABLISHMENT OF HOST-MISTLETOE ASSOCIATION

The establishment of host-mistletoe association in viscaceous, loranthaceous, and santalaceous mistletoes cannot be viewed without the flowerpeckers (Dicaeidae) as the dispersing agents of their seeds. The typical efficient evacuation mode of these birds by depositing the seeds along the branches on which they perch was first reported by van Heurn and this important finding was later reviewed by Docters van Leeuwen (1954) in his interesting article. This mode of evacuation is very efficient since the number of hits is greater than in the usual mode of evacuation of many birds.

The establishment of host specifity in many organisms is already generally assumed as a further step in the development of an original polyphagous population into an oligophagous one. Prolonged association of one mistletoe species with one particular host species or group of host species which could make the mistletoes highly adjusted to only one or a few nutrient systems of their potential hosts is considered here as the basic drive to host specifity. This latter condition could be enhanced by the occurrence of natural or artificial pure stands of any potential hosts that makes a prolonged host-mistletoe association possible. It could also be enhanced by the self-explosive mechanism favouring short-distance dispersal such as that found in the fruits of *Arceuthobium* and *Korthalsella* which enables longterm association with the same individual host. One factor that could stabilize host specifity is the development of foraging pattern of the mistletoe birds. This factor seems to have developed from the familiarity of each mistletoe bird with some particular mistletoes and their associated host or group of hosts in the restricted foraging area of each individual bird. Hence the birds will make more frequent visits to potential host trees that have similar features to the mistletoe-bearing trees which they have recognized previously than to other trees lacking these features. These patterned visits concentrate seed deposition on the already associated potential hosts of the mistletoes and as already suggested by Room (1973), the perching specifity of the mistletoe birds is important to ensure a survival level of successful seed dispersal. It follows that there must be certain properties of the already established host-mistletoe association that make the bird prefer to visit only some particular hosts. Mimicry appears to be the main particular property which characterizes this association. This important phenomenon is particularly striking in many host-mistletoe association in Australia in which the mistletoes mostly belong to the genus *Amyema* (Loranth.)

Although in the long run this mimicry might develop and accentuate host specifity in the mistletoes, any recently established association of this particular kind does not exclude the possibility of the mimicking mistletoe to grow on their potential hosts that do not possess characters that match those of the mistletoe. This is exemplified by a few species of Australian narrow-leaved *Amyema*, which I observed in Rijksherbarium in Leiden, which occasionally grow on their potential hosts that have broad leaves instead on their usual narrow-leaved hosts. This type of mimicry is much more common in Australia than in the tropical rainforest in Java where more subtle types of mimicry occur. The adverse environmental condition of Australia acts as a selection pressure that converge the evolution of characters of many plants living in this region, particularly characters that affect transpiration. Once a particular chance association occurs between a mistletoe and one or a few of its potential host species which possess the convergent leaf characters this association could be absorbed in the development of foraging pattern of the mistletoe birds. It will lead further to an established mimicry association. The adaptive value of the mimicking characters is clear since subsequent physiological adaptation that occurs later in the mistletoe could make the mistletoe seeds germinate and grow better on the same host species or group of host species to which the host tree of the mother mistletoe belongs than on its other potential host species. The seeds of the mistletoe individuals which possess the mimicking characters could have a greater chance to be deposited on the former host group. In this case high host specifity is not a prelude to mimicry phenomenon but a further development that could be resulted by the latter.

In the tropical rain forests only few examples of mimicry can be mentioned. The most striking one is shown by *Korthalsella dacrydii* (Ridl.) Dans. which in Java grows strictly on *Podocarpus imbricatus* and in Malaya on *Dacrydium* spp. This mistletoe resembles the slender branches of *P. imbricatus*. This type of association appears to be a very old one. The dispersal of this tiny mistletoe seems to be connected with small birds, such as *Psaltria exilis* (Paridae), that frequently visit the foliage of many trees in their search for small insects. Another example of a subtle form of mimicry is found in mistletoes growing in some mountain regions. Due to high light intensity, many individuals of *Dendrophthoe pentandra* (L.) Miq. in Cibodas Nature Reserve have reddish young foliage matching that of *Schima wallichii* (DC.) Korth., one of the principal hosts that also possesses leaf form that matches superficially that of the

mistletoe. However, despite the lack of mimicking properties, any prolonged associations between a particular mistletoe with its particular host or group of hosts also seem to enable the birds to recognize these associations such as exemplified by *Dendrophthoe magna* Dans. and also *Viscum stipitatum* Lecomte that grow only on fagaceous trees.

The great number of tree species that occur in the tropical rain forest and in our garden is certainly one factor that inhibits the development of host specifity in many mistletoes. In this case the importance of the polyphagous character of these mistletoes for maintaining survival in the tropical forests was already realized by Room (1973). However, the exact number of potential hosts of any of those mistletoes will probably never be known even though a large scale investigation is conducted since they often can grow on many unlikely hosts. Seeds of the polyphagous *Dendrophthoe pentandra* (L.) Miq. in fact could germinate and develop into young plants on *Ageratum conyzoides* L., *Glycine soja* (L.) Sieb. & Zucc., *Sida rhombifolia* L., *Cereus* sp., and *Euphorbia plumerioides* Teysm. ex Hassk. In *A. conyzoides* and *G. soja* regular elimination of the flower buds could prolong the growth of these two hosts, hence enabling the mistletoe seedlings to grow into young plants. This preliminary experiment which I conducted shows that the range of potential host of this mistletoe is wider than we might suppose.

It is interesting to note that the establishment of physiological races in *Viscum album* L. might be accelerated by the seemingly apomictic habit of this mistletoe. In a small village between Worcester and Hereford (England) I found many female plants of this dioecious mistletoe set abundant fruit despite the almost complete absence of male individuals. The seeds of this mistletoe could contain one to four embryos although those with two embryos are the most prevalent. The elimination of unsaleable berriless male individuals by the mistletoe owner probably increases the gene frequency of the apomicts which could enhance further formation of physiological races since once a particular apomict is adjusted to the nutrient system of a particular host species the subsequent mistletoe generation could be entirely dependent on this single host species.

NATURAL CONTROL OF MISTLETOES

Delias caterpillars (Pieridae) are frequently seen defoliating many loranthaceous mistletoes particularly *Dendrophthoe* spp., a phenomenon also observed by Docters van Leeuwen (1954). These caterpillars are

beneficial in retarding the profuse growth of the mistletoes, hence reducing the actual fruit production. However, they are often parasitized in turn by the larvae of *Apanteles* (Braconidae, Hymenoptera) and preyed by leaf-stitching ants (*Oecophylla smaragdina*).

My further field observations show that scolytid beetles are the most important insect in controlling the spread of many species of *Dendrophthoe* and *Scurrula* since they destroy many of their seeds which are deposited by the birds on the twigs they perch. These beetles are found in two localities in West Java and at least in two more localities in South Borneo. Cerambycid beetles are also found boring the stems of many mistletoes particularly those of *Dendrophthoe*. It is very probable that the many dead mistletoes observed by Docters van Leeuwen (1954) were not due to old age but to these beetles which escaped his attention. The role of the scolytid and cerambycid beetles are so important that without these two major insects more serious infestation of *Dendrophthoe* and *Scurrula* could occur. Despite their minor role in controlling mistletoe population, many beneficial organisms including fungi could be found in Docters van Leeuwen's report.

SUGGESTION

Considering the complexity of mistletoe biology, a careful approach should be taken in our effort to control mistletoe populations. The chemical spray as employed by Singh (1962) to control mistletoe population in India undoubtedly could not be recommended in Indonesia since it could kill the two principal beetles which are beneficial in keeping the mistletoe population low. I doubt very much if this method could replace the present role of these two wide-spread beetles.

Any efforts to control the mistletoe birds population cannot also be justified since our present knowledge on the biology of these birds is too limited to warrant any such measures. Their important role in the epiphyte ecosystem, in the pollination ecology of many forest flowers, and in keeping some insect populations low are too valuable to be sacrificed to only satisfy our lack of appreciation for these birds.

The conservative but effective method of regular pruning seems at the moment to be the best solution since in dealing with trees with heavy infestations the application of chemical spray alone is not sufficient. Any experimental attempts to combine this method with a small scale planting of ornamental trees or hedge plants that produce small

sweet berries such as *Muntinga calabura* L., *Carmona retusa* (Vahl.) Masamune and *Bridelia monoica* (Lour.) Merr., which are definitely known providing alternative food for the mistletoe birds, are very worthy of consideration since the possibility to make the mistletoe birds less dependent on mistletoe berries is still open.

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The Germination of Striga Species by Crop Root Exudates: Techniques for Selecting Resistant Crop Cultivars

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ABSTRACT

The parasitic *Striga* spp cause serious losses of cereal crops in Africa and Asia and cannot be controlled by any simple chemical or cultural measures. A number of varieties of sorghum and millet (*Pennisetum*) are known to be resistant or nearly so but a breeding programme is needed to transfer this resistance to more agronomically suitable varieties. A method of screening was therefore required which would help firstly in identifying those varieties in the world collection which were resistant and secondly those individual segregants which retained the resistant character in the course of a breeding programme. One form of resistance results from a lack of production by the roots of the substance which is necessary to trigger *Striga* germination. The technique is described whereby batches of 15 sorghum seedlings are grown in sand culture for one week and their root exudates assayed on one or more *Striga* spp. A further development is a technique for growing a single sorghum seedling in a Pasteur pipette. Some early results from the use of these techniques are described.

INTRODUCTION

The genus *Striga* (Scrophulariaceae) includes the most economically important of the parasitic higher plants. The two main species, *S. hermonthica* (Del.) Benth. in Africa and *S. asiatica* (L.) Kuntze (= *S. lutea* Lour) in Africa and Asia, affect millions of hectares of cereal crops — mainly sorghum (*Sorghum bicolor* (L.) Moench) and millet (*Pennisetum typhoides* (Stapf and Hubb.) but also maize (*Zea mays* L.), rice (*Oryza sativa* L.) and sugar cane (*Saccharum officinarum* L.). It is characteristic of both species that they cause the greatest damage under conditions of erratic rainfall and low soil fertility. Hence control measures involving any costly input such as herbicide are not generally applicable and even nitrogen fertilizer may not give an economic return. For these reasons the main approach to *Striga*-control, at least in sorghum and millet, is based on the selection and breeding of resistant varieties.

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It has been known for many years that some varieties of sorghum are quite highly resistant. It has been shown that Framida is resistant because its roots exude little or none of the stimulant which normally triggers germination of any seeds of *Striga* within a few mm of the growing root (Williams 1959). Other varieties such as those selected by Saunders (1933) produce plenty of stimulant but resist penetration of the parasite haustorium by some mechanical or physiological barrier in the root.

Either type of resistance will be of value but that based on lack of stimulant exudation is a great deal easier to detect and the following techniques were developed with the objective of providing a means of screening large numbers of varieties or lines for this type of resistance. Techniques were developed initially by the ODM Tropical Weeds Group at the Weed Research Organization and later modified and put into routine use at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

MATERIALS AND METHODS

The test plants used have included seeds of *S. hermonthica* originating from Nigeria and Sudan, *S. asiatica* from South Africa and India and *S. densiflora* Benth. from India. Sorghum varieties were obtained initially from the Institute of Agricultural Research, Samaru, Zaria, Nigeria but the routine screening is now being conducted on the world collection as held at ICRISAT. A few varieties of millet have been included, some direct from Nigeria and Sudan and others from the ICRISAT collection.

1. **Production of root exudate from sorghum variety or line.** Sorghum seeds are first sterilized by soaking in sodium hypochlorite solution (1% as available chlorine) for 25 minutes. They are then washed thoroughly to remove all traces of chlorine and are placed on filter paper in petridishes (about 200 seeds per 9 cm dish) to germinate at 25 C for about 24 hours.

The pre-germinated seeds are then transfered to small pots or cartons which have been partially filled with washed quartz (silver) sand. When a 6 cm diameter container is used the perforated base is covered with a filter paper and 150 g of sand added before sowing 15 pre-germinated seeds. These are then covered by a further 100 g of sand. The container is then placed in a second identical one without perforation and 25 ml distilled water added. The pots are then kept in the laboratory or glass-

house at 25 - 35 C. Neither temperature nor light is critical. Each day 15 ml distilled water is added and surplus allowed to drain for a few minutes. After 7 days the root solution is removed from each container with the aid of a suction pump. This solution can then be tested for its ability to stimulate *Striga* germination.

2. **Preparation of Striga seeds.** Striga seeds are sterilized before use by soaking in sodium hypochlorite solution (1% as available chlorine) for five minutes. The seeds are sprinkled onto the solution so avoiding their coagulation into lumps. After 5 minutes they are transferred onto filter paper in a Buchner funnel and washed thoroughly with distilled water. They are then allowed to dry and can be stored indefinitely before use.

Before *Striga* seeds will respond to any stimulant they must be imbibed ("pre-treated") for at least one week. For this pre-treatment process two layers of glass fibre filter paper are placed in the lid of a petridish and well wetted with distilled water. Discs of glass fibre filter paper are then cut by stainless steel cork-borer, 8 mm in diameter, and arranged on the moist filter paper (up to 50 per 9 cm petridish). Dry seeds of *Striga* are then carefully sprinkled so that there are approximately 25 on each 8 mm disc. More distilled water may need to be added carefully so that the discs are thoroughly wet, to the point that seeds are almost tending to float off. Glass fibre filter paper (Whatman GF/A) is important in helping to reduce fungal problems. Even in the absence of pathogenic organisms, cellulose filter paper can support fungi which produce highly toxic metabolites and interfere with germination. The 8 mm diameter of the individual discs is designed to fall within the field of the microscope used eventually for counting germination. The base of the petridish is then placed on top and the complete dish or dishes enclosed in polyethylene bag before being put in the dark in an incubator at 23 - 33 C. The temperature for pre-treatment does not appear to be critical. At the higher temperature 7 days is probably adequate; at 23 C 10-14 days may be needed.

3. **Germination test.** Rings of filter paper 0.5-1 cm wide are cut from 9 cm diameter, Whatman No. 1 papers. These are placed two per dish in the inside of petridish lids and wetted with distilled water to provide a partial seal and to prevent drying out.

Discs of pre-treated *Striga* seed are taken from the pre-treatment dishes and dabbed on dry filter paper to remove surplus moisture before being placed within the moist ring of filter paper. For each exudate to

be tested 4 replicate discs of each *Striga* type are used. These replicate discs are preferably taken one each from 4 different pre-treatment dishes. The petridish is normally marked into 4 or 5 segments so that different exudates can be tested in a single dish. There are normally two replicate pots per variety and the exudates from the two replicates are tested in separate petridishes.

Each disc is moistened with 20ul of root exudate, using a Micrometer syringe and disposable plastic tips which can be changed after each exudate. The petridishes are then covered, enclosed in polyethylene bags and left in an incubator (dark) at 33 C for 24 hours.

The radicles of germinated seeds are not readily seen when there is surplus water on the discs, so each disc is dabbed on dry filter paper prior to examination under a low power (× 20) stereoscopic microscope. Total seeds are counted while simultaneously each one germinated is recorded on a hand tally counter. Numbers germinated can then be calculated as a percentage of the total, for each individual disc.

4. **Producing exudate from single sorghum seedlings.** In studies on the genetics of the resistance mechanism and for selection of individual segregates from a breeding programme it is necessary to test individual crop seedlings. For this purpose, sorghum seeds are sterilised and pregerminated as above and then mounted on the surface of a sand-filled petridish, held in a vertical position so that the radicles grow straight down. After a further 24-48 hours during which some exposure to light is desirable the seedlings are transfered individually to Pasteur pipettes which have had their tips sealed in a flame, and been nearly filled with distilled water. A ring of filter paper or silicone rubber tubing is inserted into the neck of the pipette to hold the seed just above the water level.

The pipettes are then mounted in a rack and enclosed in an air-filled polyethylene bag and placed in the dark at 25-33 C. After 3 or 4 more days the root solution (about 2 ml per tube) can be assayed for *Striga* stimulant properties as above. Exposure to light at the earlier stage will help to suppress mesocotyl elongation and keep the seedlings in a better condition for growing on after the assay if they are found to be worth retaining.

RESULTS AND DISCUSSION

In earlier work at WRO, the double pot technique was used mainly as a source of "standard" root exudate for comparison with synthetic

stimulants (*e.g.* Chancellor *et al* 1971, Johnson *et al* 1976) or as a means of stimulating germination of *Striga* seeds in the presence of herbicide (Kasasian and Parker 1971). The level of germination achieved has varied somewhat but the conditions under which the pots are kept has not appeared to be critical. They are usually kept in the glasshouse at 23-30 C, and with supplementary light in winter but stimulant can be obtained from plants grown in complete darkness. An experiment with different day lengths of 9, 12 and 15 hours showed only a small difference in favour of the longest day.

When exudate is taken from the pot by suction it can be replaced by distilled water and there will be potent activity again in the new root solution within a further 24 hours.

Dilute nutrient solution does not interfere with stimulant exudation but high concentrations of nitrogen tend to decrease potency. This and other effects of nitrogen in reducing *Striga* will be reported elsewhere.

Exudates do not always lose potency when stored at 5 C but microbial contamination can result in variable storage life and solutions have normally been used on the day of collection.

Exudates from normally stimulant-producing sorghum varieties can be diluted to one tenth without complete loss of activity and in some cases this degree of dilution causes little reduction in potency.

Typical results from a series of routine screening tests at ICRISAT are shown in Table 1. Data have not been analysed statistically, but the results from two replicate pots of each variety are shown to indicate the degree of uniformity normally obtained. As the table includes results from several different tests the actual percentage germination is expressed as a percentage of that of the standard susceptible variety Swarna, which is included in every test and for which the actual germination varies from 20-86% with a mean value of 63% (standard deviation ± 12.9).

The selection of varieties in the table is by no means random. It includes a large proportion of the varieties in which resistance of one sort or another has been identified by various workers, including in particular Dr S. B. King working at Institute of Agricultural Research, Samaru, Nigeria. Several, however, have been identified for the first time by the ICRISAT screening. In the systematic screening process (i.e. random so far as *Striga* resistance is concerned) the proportion of non-stimulant lines found is less than 1%.

Table 1. Germination of *Striga asiatica* in response to root exudates from a range of sorghum lines grown in sand culture (expressed as % of the germination caused by the standard susceptible variety, Swarna).

Variety/line	Striga seed germination %		Mean %	Comments
	Rep I	Rep II		
SRN 4841	0	0	0	RSH
IS 8315 × WABC 4072	0	0	0	
555	0	0	0	
Framida (IS 8785)	0	0	0	
IS 7415	0	0	0	
IS 2643 (BH-4-1-4)	0	0	0	
IS 2404	0	0	0	
IS 1260	0	0	0	
IS 7306	0	0	0	
SRN 4310A	12	3	7	RSH
IS 2203	160	111	135	OMR
N-13	91	110	101	OMR
IS 1464	167	158	163	OMR
IS 8264	114	96	105	OMR
23-4	90	88	89	OMR
SRN 6788A	92	78	85	OMR/RSH
SRN 6838B	55	86	71	OMR/RSH
Serena	78	109	93	OMR
SRN 5790	93	99	95	OMR/RSH
2219B	102	96	99	S
3691B	98	119	108	S
IS 1124	105	120	112	S
IS 2162	187	169	178	S
IS 1436	167	154	160	S
Swarna			100	Standard

RSH — Known to be resistant to *S. hermonthica* too
OMR — Has other mechanism of resistance to *S. asiatica*
S — Susceptible to *S. asiatica*.

It is interesting to note that several of the varieties failing to stimulate *S. asiatica* had previously been selected for resistance to *S. hermonthica*, suggesting some correlation in resistance to the two *Striga* species. This has been the subject of more detailed study at WRO, where the single-seedling test has usually been employed in order to economise on the use of the seed of the sorghum lines.

The single-seedling test has not given completely consistent and reliable results and could no doubt be improved but various factors affecting its performance have already been explored. Varying degrees of light and darkness have suggested that the optimum is that amount of light which will suppress mesocotyl growth. This is desirable in any case to produce a healthy normal seedling which can be grown on if required. Complete darkness and continuous light each tend to reduce the potency of the exudate but not to destroy it altogether.

Complete sterility has been found to be neither essential nor unfavourable for normal stimulant activity. Completely sterile root solutions (checked by careful microbiological techniques) of a susceptible variety produced ample germination of *Striga*, whilst sterile solutions from Framida produced characteristically negligible germination.

Aeration of the distilled water before it is added to the pipette has sometimes improved sorghum root growth, and *Striga* germination but results have not been consistent.

Combined results from a number of such experiments are shown in Table 2, the germination in this case being expressed as a percentage of the standard YE90L pot exudate in each case.

Table 2 suggests good correlation between the germination responses of *S. hermonthica* and *S. asiatica* and indicates that resistance of this type to one species may be valid for the other, but more work is planned to confirm this with a larger range of sorghum varieties and strains of *Striga*. *S. densiflora* shows little or no correlation with the other species and presumably responds to a different range of substances in the sorghum root exudate.

Further work is in progress with both techniques, the pot test being used for screening of sorghum varieties and lines while the single seedling test will be of value where the number of seeds is very limited, or where plant to plant variation is to be studied, as in plant breeding work.

Table 2. Germination of three *Striga* spp. in response to exudates from individual sorghum seedlings. Mean from five seedlings (% germination as % of that from "standard" YE90L exudate in sand culture).

Variety	*S. hermonthica*		*S. asiatica*		*S. densiflora*	
	full	$^1/_{10}$	full	$^1/_{10}$	full	$^1/_{10}$
187	0	0	0	0	39	15
IS 7091	0	0	3	3	60	19
IS 7329	6	0	0	0	88	29
Framida	15	0	0	0	91	53
IS 7088	20	1	15	0	77	70
IS 7749	28	3	31	8	89	66
R 74	39	3	72	10	58	0
BC 9	50	8	82	29	100	24
CK 60	55	11	27	5	79	7
RCS (B)	59	5	90	21	62	0
Dholio	60	12	91	53	98	38
AICSIP 148	62	23	82	43	100	29
Serena	66	16	103	88	86	33
Dobbs	99	65	123	115	100	91
YE90L	99	67	108	54	98	55
Pot exudate YE90L	100	(31-76)	100	(26-64)	100	(27-80)
Distilled water	0		(0-9)		(0-2)	

full = undiluted root exudate
$^1/_{10}$ = root exudate diluted to $^1/_{10}$ with distilled water

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Germination Pattern and Growth of Phalaris minor L. Seeded at Different Depths.

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ABSTRACT

In 1975-1976, an experiment on the germination pattern and growth of wild canary grass (*Phalaris minor*) from different soil depths was laid down at Research Farm, Haryana Agricultural University, Hissar, India. Germination was found to be spread over 9 weeks and appeared to be initiated by availability of soil moisture at various depths. In general, the earliest germinating weeds were from 3 and 4 cm soil depth and these tended to have more tillers and produced seeds with high test weight. However, the greatest proportion of the weeds (60%) arose from seeds in the top 2 cm of soil after the first irrigation. Implications of the results are discussed in relation to the use of soil applied -herbicides such as nitrofen (2,4-dichlorophenyl *p*-nitrophenyl ether), methabenzthiazuron (1-benzthiazol-zyl-1,3-dimethyl urea) and terbutryn[2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine].

INTRODUCTION

Infestation of *Phalaris minor* (wild canary grass in English, kanki or mandusi in Hindi) is increasing at a fast rate in dwarf wheats grown in Haryana, Punjab and Uttar Pradesh states of northern India where wheat follows rice (*Oryza sativa* L.). There have been reports that this weed emerges along with the wheat crop [2] (Gautam *et al* 1973, Gill and Brar 1975) and recommending the preemergence application of nitrofen for its control. The pattern of weed emergence determines the success of a soil applied herbicide which has short persistence (Holroyd 1964). No work on these aspects of wild canary grass has been carried out. Therefore, a field experiment was conducted to study the germination pattern and growth of wild canary grass in relation to the depth of the seeds in the soil.

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[1] Associate Professor and Assistant Professor respectively, Department of Agronomy, Haryana Agricultural University, Hissar, India.

[2] Hooda, I.S. and V. Kumar 1973. Effect of different herbicides and their combinations on weed control and growth and yield of dwarf wheat, S-308. M.Sc. Thesis, submitted at Haryana Agricultural University, Hissar, India.

MATERIALS AND METHODS

These investigations were carried out at the Research Farm of the Department of Agronomy, Haryana Agricultural University (HAU), Hissar, India. The soil was sandy loam with 63.8% sand, 17.4% silt and 18.8% clay. The monthly average temperature and rainfall are given in Table 1.

Table 1. Average temperature and rainfall during the crop season.

	1975		1976			
	Nov.	Dec.	Jan.	Feb.	March	April
Max. Temp. (C)	27.6	23.8	21.2	22.6	27.8	30.9
Min. Temp. (C)	6.2	4.2	5.9	8.6	10.5	12.4
Rainfall (mm)	0	0	18.1	18.8	3.6	0.4

The 200 healthy seeds of wild canary grass were sown in one square meter area of plot size in each of the 5 depths, i.e. 1 cm, 2 cm, 3 cm, 4 cm and 5 cm on November 14, 1975. In 6th plot, 200 seeds of wheat, variety S-308, were also sown at the same time at normal depth of sowing (5 cm). The crop was fertilized @ 120 kg N, 20 kg P and 40 kg K per hectare. Six post planting irrigations, one each at crown root, tillering, jointing, heading, milk and dough stages were applied.

In each plot only 0.5 m^2 area was marked for recording all the observations. The date of plant emergence in each treatment was noted and seedlings were counted at weekly intervals. Each plot was finally assessed for average tillers/plant, number of seeds per ear and test weight.

RESULTS AND DISCUSSION

The data relating to emergence of *P. minor* and wheat are given in Table 2. The depth of seeding of *P. minor* has a pronounced effect on the emergence of the weed. It took 25 days for the weeds to emerge when planted at 1 cm and 2 cm depths while the emergence was much earlier when the seeds were planted at 3 and 4 cm depths. The reason for the delayed germination may be that the top 2 cm soil of the field was relatively dry and the emergence from this layer was only observed after the first irrigation given on December 4.

Table 2. Germination pattern of *Phalaris minor* seeded at different depths.

Table 2. Germination pattern of *Phalaris minor* seeded at different depths.

Treatment (depth of seeds) cm	Date of Germination	Number of plants emerged out of 100 seeds										% of final stand.
		Nov. 28	Dec. 4	Dec. 12	Dec. 19	Dec. 26	Jan. 2	Jan. 9	Jan. 16	Jan. 23	Jan. 30	Feb. 15	
Phalaris minor												
1	Dec. 9	0	0	52	73	76	77	77	89	90	88	88	29.8
2	Dec. 9	0	0	61	79	80	82	82	90	90	90	90	30.5
3	Nov. 25	32	46	54	55	57	60	62	72	75	71	71	24.1
4	Nov. 28	22	34	35	35	36	33	35	40	45	41	41	13.9
5	Dec. 28	0	0	0	4	6	6	6	5	5	5	5	1.7
Total		54	80	202	246	255	258	262	296	305	295	295	100.0
Wheat (5)	Nov. 23	80	81	84	84	84	84	84	84	84	84	84	

Irrigations: 1st = Dec. 4
2nd = Jan. 9
3rd = Feb. 10
4th = March 12

It was observed that about 80% of the weeds from the first 2 cm emerged only after the first irrigation and about 10% after the 2nd irrigation. The emergence from 3 cm was about 46% before the first irrigation, about 16% after the first irrigation and 9% subsequently. Emergence of weeds from 4 cm depth was 34% before the first irrigation and only 7% afterwards. The weed emergence was only 3% from 5 cm depth. In contrast an 80% emergence of wheat was completed within 15 days of seeding.

Taking the final stand of weeds as 100% infestation, the percentage of emergence of weeds from all depths before the first irrigation was 27.1 and before the second irrigation was 89.5. Similarly the infestation from the top 2 cm of soil was 60.3% and from 3 and 4 cm was 24.1% and 13.9%, respectively.

The data have clearly brought out that emergence of wild canary grass in sandy loam soil starts along with the wheat crop but the major infestation starts after the first irrigation and is due to a favourable level of soil moisture. Keeping in view, the germination pattern of wild canary grass the control of this weed requires the use of a persistent herbicide which remains active in the soil for at least 60 days. Hooda *et al* (1974) reported about 75% control of wild canary grass with nitrofen. About 25% of the weeds may escape as the surface layer of nitrofen may be destroyed before or after the first irrigation.

Table 3. Growth of *Phalaris minor* and wheat seeded at different depths

Treatment (depth of seeds) cm	Average Tillers/ Plant	No. of seeds per ear	Wt. of seeds per ear (g)	1000 grain wt. (g)
Phalaris minor				
1	3.17	408	0.736	1.80
2	3.33	415	0.741	1.78
3	4.42	350	0.791	2.26
4	4.50	313	0.603	1.92
5	0.80	315	0.636	2.01
Wheat (5)	2.87	30	1.350	45.00

Table data (Table 3) pertaining to growth characters of wild canary grass and wheat show that the weed plants which emerged from a depth of upto 4 cm have a higher average number of tillers/plant than the wheat. In general, the number of tillers/plant was highest in the earliest germinating *P. minor* from 3 - 4 cm and declined with time. Weed which emerged from 5 cm depth did not bear effective tillers. Similarly, early germinating plants from 3 and 4 cm depths produced seeds with high 1000 grain weight. Similar results were reported by Chancellor and Peters (1972) working on biology of *Avena fatua.*

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The Role of Allelopathy in Early Stages of Secondary Succession

M. NUMATA [1]

ABSTRACT

Weeds in arable lands are ecologically similar to pioneers in secondary succession, ruderal plants on footpaths between arable lands and aliens. One of noticeable characteristics common to such weedy species is allelopathy. Many facts have been known on the allelopathic action of weeds against crops, particularly concerning the crop rotation and soil sickness. We studied and identified allelopathic substances of weedy species in early stages of secondary succession, and considered their role in succession. Those species excrete, in common, allelopathic substances which contribute to maintain their temporary predominance in pioneer communities and postpone the progression of succession.

INTRODUCTION

Weeds found growing on arable lands are ecologically similar to pioneers in secondary succession, ruderal plants on footpaths between arable fields and aliens. One of the characteristics common to weedy species is allelopathy. This term was originated by Molisch (1937), followed by Knapp (1954), Grümmer (1955) and Rice (1964). Muller *et al* (1964) defined it as "chemical plant competition" or "chemical inhibition", however it means chemical plant cooperation as well as competition as Molisch already pointed out. In other words, allelopathy is "chemical plant coaction".

Regarding agricultural problems on crop rotation and soil sickness, allelopathic substances have been noticed since the time of de Candolle (1832) and J. von Liebig (1852). Allelopathy can be classified into autotoxic and antibiotic types. Related to ecological roles of allelopathy, it was found that extracts from the soil of Rosmalino-Ericion in the shrubby heath in the Mediterranean region had inhibited early growth after germination. Extracts from the roots of the characteristic species of the heath showed similar action. The stronger such an inhibitory action of component plants is, the higher the fidelity of plants to the alliance is. If a characteristic composition of species is established due to such a mechanism, allelopathy will be a strong basis for phytosociological phenomena.

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Knapp (1954) tried to extend the idea of allelopathy to the total range of plant community ecology. The excretion of salts by guttation of halophytes and the cuticular excretion of Ca, K, Mg, and P compounds are washed away by rain water and change the floristic composition of vegetation. Root exudates, for example amino acids, seem to change the floristic composition of vegetation through the enrichment of microflora of the rhizosphere. Autotoxic substances excreted from seeds during germination in relation to seeding density and substances inhibitory or promotive to the germination of seeds of different species are known. *Trifolium repens* seeded later on the seed-bed of grasses have a much higher percentage of under-developed seedlings than in simultaneous seeding. This is an effect of the age of the population. Roots of arable weeds often cause harmful effects to the germination of crops. For example, the germination of rape and oat is inhibited by *Agropyron repens*, and the germination and early growth of wheat are inhibited by *Cirsium arvense* and *Convolvulus arvensis*.

Grasslands of *Stipa pulchra, S. lepida, Poa scabrella*, etc in California degenerate into annual grasslands of exotic plants, *Bromus mollis* and *Avena fatua* where aromatic shrubs as *Salvia leucophylla* and *Artemisia californica* invade killing grasses with excreted terpens (Muller *et al* 1964, Muller 1966). This is a striking example of allelopathy affecting succession. More general examples were described by Keever (1950), Bard (1952), Rice (1964), etc. Keever explained the motive force of secondary succession on the basis of allelopathy as well as of ecological characteristics of seeds and seedlings.

THE ROLE OF ALLELOPATHY IN SUCCESSION

At the beginning of our study, *cis*-dehydromatricaria ester (*cis*-DME) was separated from rhizomes and roots of *Solidago altissima* which inhibits the growth of rice seedlings. Allelopathic substances of pioneer species of secondary succession such as *Ambrosia artemisiaefolia* var. *elatior* and *Erigeron annuus* were also identified. Biologically active allelopathic substances were extracted from the underground of the above-mentioned pioneer species and were tested by their effects on the germination and growth of rice seedlings. As a result of these tests, the crude extract exhibited inhibitory action on growth. In the case of *S. altissima, cis* DME was the sole growth inhibiting substance, however *E. annuus* was found to have three compounds chemically resembling

cis-DME, namely *cis*-matricaria ester (*cis*-ME), lachnophyllum ester (LE) and *trans*-matricaria ester (*trans*-ME) among which *cis*-ME and LE have strong inhibitory effects. Without exception they are methyl esters of polyacetylenic α, ß unsaturated C_{10}-carboxylic acids. The presence of these esters and their derivative in various species of Compositae was first discovered by Sørensen *et al* (1953) and has been exhaustively investigated by Bohlmann *et al* (1964). *Cis*-DME has a strong inhibitory effect on rice seedlings (Kawazu *et al* 1969).

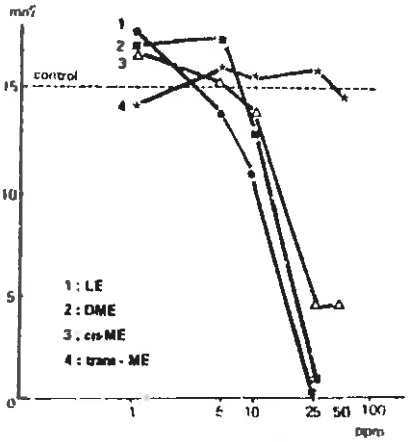

Figure 1. Inhibitory effects on the growth of rice seedlings.

In our experiment (Numata *et al* 1973), seeds of *Oryza sativa*, *Miscanthus sinensis*, etc were placed on a 0.4% agar plate containing 0.1—50 ppm of allelopathic substances (Figures 1 and 2). The inhibitory effect appears at between 5—10 ppm for other species. *Cis*-DME has an autotoxic effect on the germination of *S. altissima* itself between 10—20 ppm.

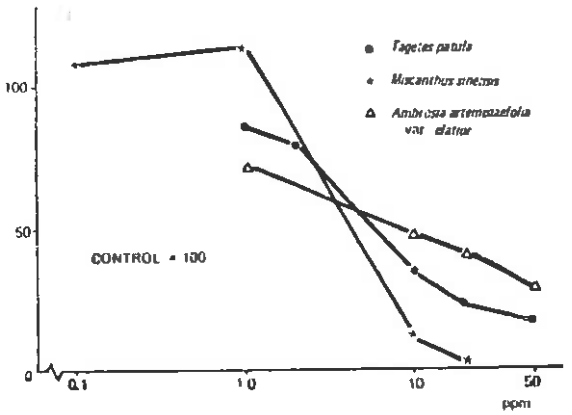

Figure 2. Effects of cis – DME for germination.

The antibiotic and autotoxic effects of *cis*-DME are very significant in maintaining the territory by vegetative propagation, inhibiting the invasion of native grasses, *M. sinensis*, and colonization in a new habitat not contaminated with *Cis*-DME.

These allelopathic substances must have moved from the plants to the soil in order to have come into contact with other competitive plants presumably at their germinating stage. In our experiment, the growth inhibitory action of *cis*-DME, etc was verified in the laboratory, however there was a question as to whether or not the root exudate might be decomposed by soil microorganisms. Concerning this question, the soil was collected from a *S. altissima* growing area, and 18 mg of *cis*-DME was extracted and identified from 3.2 kg of air-dried soil. This is equivalent to 5 ppm of *cis*-DME the concentration of which is enough to regulate the germination or growth of competitive plant seedlings. The succession of weedy pioneer species on disturbed soils has been observed and analysed (Numata and Yamai 1955, Numata 1956, Numata and Suzuki 1968, Hayashi and Numata 1967, Numata 1969), and it was concluded that *A. artemisiaefolia* var. *elatior* is a first year pioneer plant and *Erigeron* spp. and *S. altissima* follow it. They are then replaced by *M. sinensis* in several years. The replacement of dominants is mainly caused by their own species characteristics, particularly of their seeds and seedlings (Hayashi and Numata 1967; 1968), but there is another factor that controls the progression of succession caused by allelopathic substances excreted by those pioneer plants. These substances have no plant hormonal activities and they act merely as substances to other species or their own species. The communities of *E. floribundus* flourished in the second year after fallowing, however they rapidly lost vigor in the third year (Nishida and Kasahara 1975). This fact may be caused by autotoxic allelopathy. The allelopathic substances of *E. philadelphicus, E. floribundus, E. canadensis* as *E. annuus* were separated and identified (Numata *et al* 1975). The result showed that the above and underground parts of *E. floribundus* contained the largest amount of *cis*-LE having the largest inhibitory effect (Figure 3).

These toxic substances might have an effect on soil bacteria and might change the soil properties. To monitor such possibilities several typical soil bacteria (*Arthrobacter simplex, Bacillus magaterium, Corynebacterium* sp. and *Pseudomonas* sp.) were grown on a beef extract agar medium, and the growth inihibitory action was determined by the paper disk method. However, no inhibitory zone could be observed with a concentration up to 1,000 ppm when DME, LE and ME dissolved in alcohol were applied.

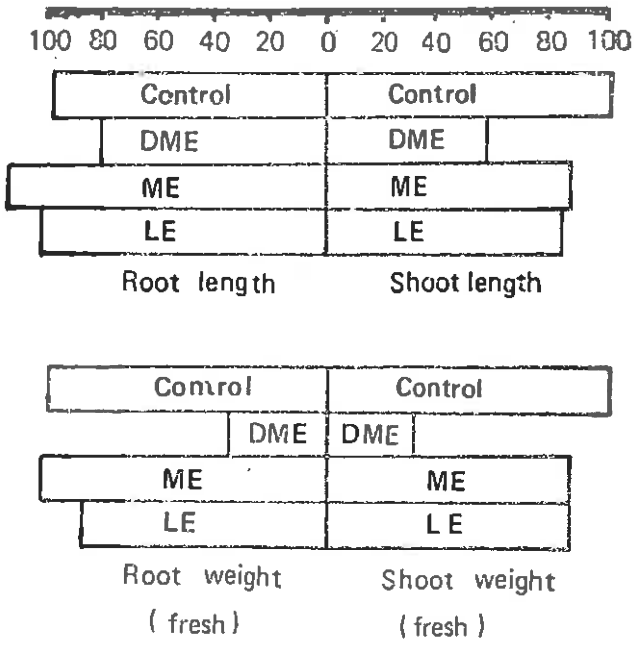

Figure 3. Effects of DME, LE and ME on the growth of hogweed (*Ambrosia artemisiaefolia* var. *elatior*)

The above-mentioned weedy pioneer species are all aliens, naturalized in Japan, which seem to keep their predominance by the process of allelopathy. On the other hand, some native plants dominating in the plagioseral stage might have a similar situation. *Artemisia princeps* is a forb contained in the *M. sinensis* stage (the perennial grass stage) as a differential species, however it becomes a dominant resulting in a plagioseral stage. The water extracted from the underground part of *A. princeps* strongly inhibits the germination of *Digitaria adscendens*. In our study, caffeic acid was separated and identified and the inhibitory effect was obvious at 60 - 70% of the growth suppression of rice seedlings. The effective concentration was around 250 ppm (ca. 1.5×10^{-4} M).

Caffeic acid is one of the most popular polyphenol compounds among plant products (Marby and Difeo 1973). However, this work first clarified that it is accumulated in the underground part of *A. princeps* in a high concentration (200 to 250 mg of caffeic acid per 1 kg dry weight of rhizomes and roots) which effectively inhibits the growth of a plant. This substance is easily extracted by water, and it means that the growth inhibitor in rhizomes and roots easily escapes to the surrounding with the distinct possibility of working as an allelopathic substance.

DISCUSSION

Allelopathy is considered from the standpoint of the cause of species combination in a community, weapon of plant competition, cause of soil sickness, and the motive force of secondary succession. In this paper the last point was discussed. There are some cases where a community invades another and promotes plant succession as in the case pointed out by Muller (1966). However, in our study on pioneer weedy species such as *Erigeron* spp. and *S. altissima* in secondary succession and a plagioseral species such as *A. princeps*, the role of allelopathic substances excreted from those plants has a kind of negative role suppressing the progression of succession. The progression of succession is mainly caused by the competition of dominants based on the ecological characteristics of those species, particularly of seeds and seedlings (Hayashi and Numata 1967, 1968).

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Some Weedy Species of Amaranthus (Amaranths) and Conyza/Erigeron (Fleabanes) Naturalized in the Asian-Pacific Region

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ABSTRACT

An account is given of the taxonomy (with keys to identification), distribution, history, ecology and physiology of two groups of weeds of American origin, namely, four closely related species of *Amaranthus* — *A. hybridus* L., *A. powellii* S. Wats., *A. quitensis* H.B.K. and *A. retroflexus* L. — weeds of summer crops and five species of *Conyza* (or *Erigeron*) — *C. albida* Willd. ex Spreng. [*C.* (*E.*) *floribunda* (*-us*) and *C.* (*E.*) *sumatrensis* of various authors], *C. bilbaoana* Remy, *C. bonariensis* (L.) Cronq. (syn. *E. linifolius* Willd.), *C. canadensis* (L.) Cronq. var. *canadensis* and *C. parva* Cronq. (= *E. pusillus* Nutt.) — weeds of uncultivated or resting land.

INTRODUCTION

A sensible approach to the study of weeds in the Asian-Pacific region begins with the weeds in one's own country. I have followed this approach with the two groups of closely related weeds of American origin, which are the subjects of this paper. To begin with, I confined my attention to New South Wales and adjacent parts of southeastern Australia.

The first group, the amaranths, are important weeds of summer crops and sometimes grow prolifically in waste places where fertility is high. The second group, the fleabanes are abundant in uncultivated situations, especially on roadsides and in waste places and are a prominent feature in plant succession in resting or abandoned cropping areas.

The common names of the plants in both groups are rather confused and I prefer, in this paper to use only botanical names for the individual species.

This paper is divided into two parts, the first dealing with the amaranths and the second with the fleabanes.

AMARANTHUS

Taxonomy. Misidentification of the four amaranths in this group has been quite common in various parts of the world, and it is only because

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of the excellent work of Sauer (1950; 1967) that I have been able to recognize the species, *A. hybridus*, *A. powellii* and *A. quitensis*. *A. retroflexus*, which has very distinctive perianth parts has been much better understood.

All species are monoecious and the following key, adapted from Sauer (1967) is based on characters of the whole inflorescence and the male and female flowers.

Key. A. Branches of inflorescence short and thick; perianth parts all rounded or obtuse at the apex, often with a shallow notch — *A. retroflexus* L.

A* Branches of inflorescence long and/or slender; outer perianth parts acute or acuminate.

B. Inflorescence stiff, usually with few branches, bract subtending the individual flowers with a heavy midrib, style branches thick at base, perianth parts and stamens 3 - 5 — *A. powellii* S. Wats.

B* Inflorescence lax, usually with many branches, bract with a moderately heavy midrib, style branches slender at base, perianth parts and stamens 5.

C. Perianth parts straight,the inner oblong, acute — *A. hybridus* L.

C* Perianth parts recurved, the inner spathulate, obtuse — *A. quitensis* H.B.K.

Important synonyms include *A. chlorostachys* Willd. and *A. patulus* Bertol. for *A. hybridus* and *A. chlorostachys* Willd. var. *pseudoretroflexus* Thell. for *A. powellii.*

The most useful aids to the identification of these species are the diagrams presented by Sauer (1950). Good illustration of *A. retroflexus* and *A. hybridus*, under the name *A. hybridus* var. *patulus* are to be found in Osada (1972), *A. powellii*, under the name *A. chlorostachys* var. *pseudoretroflexus* in Hayward and Druce (1919) and *A. quitensis* in Parodi (1964). The seeds of *A. powellii* are significantly bigger than the seeds of the other three species.

In all four species, the bract subtending each female flower exceeds the style branches. *A. hybridus*, *A. powellii* and *A. quitensis* are the progenitors of the domesticated species *A. cruentus* (syn. *A. paniculatus*), *A. hypochondriacus* and *A. caudatus* (syn. *A. edulis*) respectively, all

grown as food crops and/or ornamentals in various parts of the world. In these domesticated species the bract subtending each female flower does not exceed the style branches.

Distribution. Sauer (1967) records the native habitats of the four weedy species. They are all pioneers, occurring alorg riverbanks or in other open areas. *A. retroflexus* originates from central and eastern U.S.A. and adjacent regions in southeastern Canada and northeastern Mexico, *A. powellii* from the western Cordilleran system of North and South America, *A. hybridus* from mild and moist regions extending from eastern North America through Mexico and Central America to northernmost South America and *A. quitensis* from the mountains of northwestern South America to lower elevations in the temperate southern parts and the Galapagos Islands.

A. retroflexus, A. powellii and *A. hybridus* are now well-known weeds of cropping in North America, while *A. quitensis* is the most important weed of this group in South America. *A. quitensis* is abundant along the lower Hunter River in New South Wales (lat. 33°S) and is likely to occur in some of the Pacific Islands. *A. powellii* is abundant in the drier southern coastal region of New South Wales, the colder tablelands and in other parts of southern Australia. It is common in New Zealand and is naturalized in Japan[2]. *A. retroflexus* is a significant weed of cropping in parts of New South Wales and other southern states of Australia, but is quite insignificant in New Zealand. It occurs also in Japan. *A. hybridus* is abundant along the eastern coastal regions of Australia north of about lat. 35°S, extending into subtropical regions. It is also present in Japan and throughout the warmer Pacific islands. It does not appear to occur in New Zealand, nor does it occur in New Guinea where its place is taken by other species of *Amaranthus* including *A. dubius* which has sometimes been confused with it.

A thorough examination of herbarium material from the Asian-Pacific region and additional collections are necessary before a thorough understanding of the distribution of the four species can be gained.

History. I am able to make only limited observations on the history of these plants in the Asian-Pacific region. The earliest Australian and New Zealand records indicate that *A. powellii* may well have been the first to become naturalized perhaps by the middle of last century.

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[2] Numata, M. personal communication.

A. retroflexus is believed to have appeared in Japan soon after the beginning of the Meiji era, 1867.

Ecology and physiology. The factors which determine the distribution of the four species throughout the region are at this stage little understood. Germination characteristics are undoubtedly important and studies are at present being conducted at the University of Sydney. Because of doubts about the identification of species, published work which is, in any case, quite limited has to be treated with great caution.

Observations in the Sydney area indicate that flowering time of *A. powellii, A. hybridus* and *A. quitensis* differs appreciably and occurs in the same order as I have listed the species. It appears likely that *A. powellii* may be sensitive to day-length, while *A. hybridus* and *A. quitensis* may be short-day plants, but proper testing is required.

In pot experiments on the effects of trifluralin (α, α, α -trifluoro - 2,6 - dinitro - *N,N* - dipropyl - *p* - toluidine) on *A. hybridus* and *A. powellii*, Mein [3] showed that *A. powellii* was less sensitive than *A. hybridus*, thus adding weight to circumstantial evidence in the field where it had been noted that after continued use of trifluralin the relative abundance of these two species had changed from a similar frequency of both to a much lower frequency of *A. hybridus*. The difference in sensitivity was attributed to the greater seed size and more rapid seedling growth in *A. powellii*, with consequent dilution of effects of trifluralin, but there may be other factors involved and these are currently under investigation.

Such differences show the importance of accurate knowledge of the identity of our common weeds, for until the basic taxonomic work was done, both these species had been lumped together in New South Wales under the one name, *A. hybridus* **sens. lat.**

CONYZA (ERIGERON)

Taxonomy. It is indeed unfortunate that there is some confusion in what generic name should be used for the fleabanes. In this paper I am following Cronquist (1943; 1950) and a number of recent floras including Flora Europaea ed. T.G. Tutin *et al* and Flora of Turkey ed. P.H. Davis, in using the name *Conyza*, but, providing the proper adjusments are made in nomenclature I have no objection to the use of *Erigeron* in, for example, Ohwi (1965) and Okuyama (1974).

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[3] Mein, S. H. 1975. Master of Agric. Thesis. Univ. of Sydney.

Again, as with *Amaranthus*, there has, through the years, been much difficulty in the identification of the five species treated here. Unfortunately there has been no single work like Sauer's in *Amaranthus* to lean upon. After a study of the most helpful literature (Cabrera 1941; 1963, Burtt 1948, Tuyama and Asai 1967, Burbidge and Gray 1970, Marshall 1973, Guédès and Jovet 1975, Danin 1976) and much herbarium material from Australia and elsewhere, I am able to produce the following key.

Key. A. Involucral bracts glabrous or almost so, heads up to about 4 mm long.

B. Involucre cylindrical, outer florets with short but prominent white ligules, involucral bracts narrow, oblong.

C. Stems very hairy, leaf margins ciliate, involucral bracts with a few hairs and without purplish spot at apex — *C. canadensis* (L.) Cronq. var. *canadensis*.

C* Stems not noticeably hairy, leaf margins with a few scattered cilia only at base, involucral bracts glabrous, usually with purplish spot at apex — C. *parva* Cronq.

B* Involucre subglobular, outer florets filiform with an inconspicuous oblique limb, involucral bracts glabrous, narrowly triangular — *C. bilbaoana* Remy.

A* Involucral bracts hairy, heads from about 4 mm to 6 mm long.

D. Heads 5 - 6 mm long. Lateral branches of inflorescence often overtopping main axis; involucral bracts at least with a few long hairs at apex and when reflexed at maturity whitish on inside; pappus white or pinkish; receptacle smooth-pitted — *C. bonariensis* (L.) Cronq.

D* Heads 4 - 5 mm long. Inflorescence pyramidal with lateral branches not overtopping main axis. Involucral bracts without long hairs at apex; pappus straw-coloured; receptacle usually rough-pitted — *C. albida* Willd. ex Spreng.

If the generic name, *Erigeron*, is preferred the names for *C. canadensis*, *C. parva*, *C. bonariensis* and *C. albida* should be given as *E. canadensis* L., *E. pusillus* Nutt., *E. bonariensis* L. and *E. albidus* Willd. ex Spreng. A. Gray respectively. *C. bilbaoana* may possibly be referrable to *E. sordidus* Gill. ex Hook. et Arn.

Good illustrations of *C. canadensis* and *C. bonariensis*, both under *Erigeron* and *C. albida*, under the name *E. sumatrensis* are to be found in Kasahara (1968), Numata and Asano (1969), Osada (1972) and Numata and Yoshizawa (1975). *C. parva*, under the name *E. pusillus* is also pictured in Osada (1972).

Important synonyms include *C. ambigua* DC, *E. linifolius* Willd. and *E. crispus* Pourr. for *C. bonariensis*. Names often used for *C. albida* are *C.* (*E.*) *floribunda* (*-us*) and *C.* (*E.*) *sumatrensis* but both of these are, I believe, unacceptable. *C. floribunda* H.B.K. appears to be another species, with almost glabrous stems, leaves and involucral bracts and corymbose inflorescence. *E. sumatrensis* Retz., which was revived by Ridley (1918) for plants in Malaya and neighbouring countries, is based on a description of a plant collected in the 18th century in eastern Sumatra, but unfortunately the type specimen has not been found and the description is not precise enough to establish its identity for certain. It could be fitted to *C. albida* but just as well to *C. bonariensis* or to what appears to be another species which has been collected on Mt. Wilhelm in New Guinea and on Mt. Pangrango in Western Java. This latter plant, contrasted with *C. albida*, has leaves with much longer hairs and more robust filiform corollas. It is true that *C. albida* is now widespread throughout southeastern Asia, Indonesia and the Philippines, but Bentham (1861) recorded that both *C. albida* (under the name *E. bonariense*) and *C. bonariensis* (under the name *E. linifolius*) occured in the tropics. For the time being it seems best to use the name *C. albida*, following Guédès and Jovet (1975) and Danin (1976). True synonyms of *C. albida* include *C. altissima* Naudin and Debeaux and *E. musashiensis* Makino. In South America, Cabrera (1963) prefers to consider *C. albida* as a variety of *C. bonariensis* [*C. bonariensis* var *microcephala* (Cabr.) Cabr.].

Distribution. *C. canadensis* is native to the U.S.A. and Canada, *C. parva* to eastern U.S.A. *C. bilbaoana* was first described from Valdivia (lat.40°S.) in Chile and I have seen specimens from Chile, Argentina, Uruguay and southern Brazil. *C. bonariensis* was first described from the Argentine and is probably native to the more temperate parts of South America. *C. albida* first described from Brazil is probably native to subtropical South America, but it extends into tropical areas in Central America and the West Indies and into Florida.

In the Asian-Pacific region *C. canadensis* occurs widely in Japan and less commonly in southeastern Australia and probably occasionally in New Zealand. *C. bilbaoana* appears to be confined to the colder parts

of southeastern Australia and is abundant in parts of the South Island of New Zealand. *C. parva* occurs in Japan, Taiwan, Hong Kong, Hawaii, New Guinea and other Pacific island, eastern Australia and New Zealand (Tuyama 1970). *C. bonariensis* occurs throughout Australia extending into quite dry parts, New Zealand, Japan and at least some of the Pacific islands. Little is known of its present distribution between latitudes 20°N and 20°S. *C. albida* extends throughout most of the region being more abundant in the subtropical areas but extending into tropical and more temperate regions.

History. The introduction of *C. canadensis* into Europe in the 17th century and its spread throughout Europe have been well documented by Wein (1932). Wein also records that *C. bonariensis* was grown in gardens in Europe in the first half of the 18th century. These species could have been introduced to eastern and southeast Asia and to Australia and New Zealand from both Europe and America. I have seen a number of specimens of *C. bonariensis* collected in Australia in the 1840s. It was recorded for Hong Kong by Bentham (1861) and was collected by Maximowicz in Nagasaki in Japan in 1863, where it occurred as a ruderal plant. We may assume that both *C. canadensis* and *C. bonariensis* were well established in parts of the Asian-Pacific region by the latter half of last century. Early collections of *C. albida* were made, along with *C. bonariensis* in Queensland in the 1850s and 1860s but it could well have reached the Philippines long before this. Merrill (1918; 1923) who named it both *E. linifolius* and *E. sumatrensis*, considers that it was described by Blanco (1837) from Cebu, under the name *Baccharis ivaefolia*. *C. bilbaoana* certainly appeared in Australia by the latter half of last century. The introduction of *C. parva* into the region may have been more recent, though perhaps it has been like *C. bilbaoana* unrecognized for longer than the other species.

There have been some interesting shifts in the relative abundance of the various species. For example, Japanese reports (Osada 1972; 1975) indicate that both *C. canadensis* and *C. bonariensis* have given way in recent years to a greater abundance of *C. albida*. In Australia, observations indicate that *C. albida* is moving into more southern areas colonized previously essentially by *C. bonariensis*. *C. bilbaoana* appears to have occurred first in warmer coastal areas, presumably a reflection of where it was first introduced, but now it is scarcely to be found in such areas. It is now common only in parts of the colder tablelands.

Ecology and physiology. The changes mentioned above open up the question as to what ecological factors are effecting them. Only with a good knowledge of germination and growth characteristics of these species can this question be answered. The plants as a group are indicators of various stages of succession (Numata and Asano 1969, Numata and Yoshizawa 1975). One or other species has been shown by Keever (1950) and Nishida and Kasahara (1975) to exert some self-regulating allelopathic properties. The latter authors reported that phytotoxic substances from the roots of *C. albida* (as *E. sumatrensis*) induced negative geotropism of radicles in both *C. albida* and *C. bonariensis* (as *E. linifolius*). Numata (1975) suggest that these substances may have similar properties to the polyacetylinic compounds produced by other composites, in which case they could be expected to affect growth of other species also. Parks and Rice (1969) have shown inhibitory effects of extracts of *C. canadensis* on growth of blue-green algae. Nishida and Kasahara have also shown great effects in growth responses under illuminations of 6% or less, where seedlings did not develop into rosettes. Work in progress at the University of Sydney indicates that germination of all species is almost certainly greatly enhanced by light. Of the five species, *C. bonariensis* is the earliest to flower followed by *C. albida* and *C. canadensis*, along with *C. parva* and probably *C. bilbaoana*.

As with *Amaranthus*, it is planned to study the characteristics of these species in detail, in order to provide the essential information required to unravel the problems of occurrence and distribution.

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Abnormal Climate and Weed Control

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ABSTRACT

Abnormal climatic conditions that have recently occured everywhere in the world have provided great crop disasters, such as damage due to coldness, high temperature drought, and flood, all of which have resulted in the reduction of crop yield. In order to increase or maintain the crop production under such abnormal climate conditions, much of the cultural technology that has been developed so far, for example, varieties, soil preparation, crop rotation, fertilizer application, water management and irrigation systems, pest management etc, must be amended and improved. Weed control as part of pest management is influenced by such abnormal climate conditions. In this paper, three aspects of weed control technology as influenced by abnormal climate are discussed. They are the effects of temperature conditions on weed emergence patterns, the relationship between herbicidal activity and lower temperatures, and that between herbicidal activity and higher temperatures. Temperature conditions influence the term of emergence, the velocity of emergence, and the diversity of growing stages of the weed population, which govern weed control systems. In general, Tohoku under lower temperature conditions demands a sequential adoption of weed control measures. Herbicidal activity is affected directly by temperature, differing in the aspect of its response depending on the kinds of herbicides. Phenoxy-type herbicides such 2,4-D [(2,4-dichlorophenoxy)acetic acid] and MCPA ([(4-chloro-*o*-tolyl)oxy]acetic acid) have a potential for giving phytotoxic effects on rice plants because of having a high response to lower temperatures. An assumption on the relationship among herbicidal activity, weed control technology and rice growing as influenced by lower temperatures can be presented. Some herbicides such as *s*-triazine type herbicides and MCPA and MCPCA (2-methyl-4-chlorophenoxyaceto-*o*-chloroanalide) have a high response to high temperatures and are phytotoxic to rice if air temperature rises rapidly after application. Selected rice herbicides may be classified by responses to temperature conditions.

INTRODUCTION

Abnormal climate conditions have recently occurred everywhere in the world and caused great disasters, such as damage due to coldness, high temperature, drought and flood, all of which have resulted in the reduction of crop yield. The frequent occurrences of such disasters on the earth during 1972 to 1974 have been listed.[2] Further, in 1976

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2 Asakura 1975. Personal communication.

unusually high temperatures and less precipitation occurred in the spring in the European countries. On the other hand, low temperatures which occurred in the summer in the northern parts of Japan gave severe cold damage to rice and other upland crops and is also an example of the effect of abnormal climates.

Meteorologists say that frequent occurrences of such abnormal climates must be caused by lowering of the air temperature at the pole of the earth, and means the advent of a change from a warm age to a cold age. During the term of the transition of the earthly climate, opposite weathers such as high and low temperature conditions, and flood and drought are likely to happen adjacently in the middle altitude areas of the earth (Nemoto 1976).

According to Tsuboi (1976), these abnormal climates pose a great threat to the world's food production, coupled with explosively increasing population in developing countries.

Recently, Stansel (1976) has said that a decrease of two degrees C in the average world temperature plus a 15% decrease in average world precipitation could reduce world rice production by 19%, and drop in temperature of one-half degree C and a 10% decrease in precipitation could result in a 6 to 10% drop in rice production.

In order to maintain and/or increase food production even when such abnormal climatic conditions happen continuously in the future, various cultivation techniques that have been developed so far should be re-examined. That is to say, crop varieties, soil preparation, crop rotation, fertilizer application, water management and irrigation systems, pest control for plant diseases, pest insects, and weeds must be examined and improved.

Weed control, one of the pest management practices is expected to be affected by abnormal climatic conditions. Both temperature and rainfall have a close bearing on weed control technology in crop lands. The mutual relationship between ecological aspects of weeds and temperature conditions or rainfall may be considered.

In this paper, three aspects of weed control technology as influenced by abnormal climates, particularly by temperature conditions are discussed. They are the effects of air temperatures on weed emergence patterns and its significance, the relationship between herbicidal activity and lower temperatures, and that between herbicidal activity and higher temperatures.

TEMPERATURE AND WEED EMERGENCE PATTERN

As Japan stretches a long way from the north to the south, rice and other crops are grown in different crop seasons with different climatic conditions, especially different air temperature conditions. For instance, Tohoku in the north has a rice season from May to October while Kyushu in the south has one from June to December. There is a distinct difference in temperature gradients between the two areas. Comparing the mean air temperature for every 10 days during the 30 days period after transplanting, a difference of about 8 C exists between areas, and it governs the emergence pattern of the weed population after transplanting in paddy fields. Therefore, different weed control systems have to be employed in Tohoku and Kyushu.

In general, weed species require different temperatures for germination and emergence. According to Susuki and Sudo (1975), the lowest

Table 1. Emergence temperatures of principal annual weeds in paddy in Japan (Susuki and Sudo 1975).

Group	Weed Species	Air temperature (C)	Water temperature (C)
I	*Callitriche verna* *Alisma canaliculatum* *Aneilema japonica*	8	13
II	*Echinochloa oryzicola* *Juncus leschenaultii* *Eleocharis acicularis* var. *longiseta* *Rotala indica* *Limnophila sessiliflora* *Ludwigia prostrata*	9 — 10	14 — 15
III	*Eriocaulon robustus* *Elatine triandra* *Lindernia procumbens* *Sagittaria trifolia*	11 — 12	16 — 17
IV	*Cyperus difformis* *Deinostema violacea*	13 — 14	18
V	*Monochoria vaginalis* *Vandellia angustifolia*	15 — 16	19

temperatures which enable main annual weeds to emergence vary from 8 C to 16 C air temperature and from 13 C to 19 C water temperature (Table 1). These temperatures for weeds to emerge are roughly corresponding to the air and/or water temperatures during the period from transplanting to about the 30th day after it in Tohoku region. Consequently, in Tohoku, it is understood that paddy weeds emerge one after another extending over a comparatively long time as the air temperature rises i.e. they show a longer term emergence pattern. This fact, as a result, provides a richer diversity of weeds at the later stages of growth.

On the other hand, since air temperatures at transplanting time in Kyushu are generally already beyond the emergence temperatures for the weed species, the weeds' emergence occurs almost simultaneously within a shorter period of time after soil puddling or transplanting and less diversity is provided afterwards.

Further, temperature conditions are very important during the days until emergence. There are experimental results on the emergence pattern of the principal six weed species, that were obtained under early and normal rice season conditions which had lower and higher air temperatures (Noda and Eguchi 1965). The number of days necessary to obtain 10% and 80% emergence of all weed seeds present was greater under lower temperatures than under a higher temperatures in the case of almost all weed species. The difference between the conditions varies according to the weed species and can be classified into three groups. *Monochoria vaginalis* and *Rotala indica* were the slowest, *Fimbristylis littoralis* and *Cyperus microiria* were the quickest, and *Dopatrium junceum* and *Echinochloa crus-galli* were intermediate.

In addition, the growth patterns of these weeds after emergence differ with temperature and vary from area to area. For instance, there are differences in leaf number of barnyardgrass growing at Tohoku and that growing at Kyushu.

In conclusion, a longer term emergence of the weed population induced by lower temperature conditions, coupled with retarded emergence as well as a richer diversity of growing stages of the weed makes weed control difficult with a single herbicide application. Therefore, under the low temperature conditions, successive weed control measures, chemical and others, commonly required. This may be seen in the Tohoku region or in early season rice fields. In contrast, a shorter term emergence induced by a higher temperature, coupled with rapid emergence and less diversity

of growing stages of the weed population, provides conditions under which any control measure may be used if it is applied properly. However, when it is delayed or applied wrongly, success becomes extremely difficult to achieve because weed plants grow very rapidly under high temperatures and reach a stage at which they tolerate any control operation including herbicides. Based on this knowledge, sequentional weed control measures have been recommended in practice in Tohoku. But sequential application has not always good results in Kyushu.

On the other hand, temperature conditions may influence the depth of weed emergence, the total number of weed plants present, the composition of weed flora and so on, in addition to the change of emergence patterns already described. These problems, however, should be discussed in the future because there are no adequate experimental data at present.

LOW TEMPERATURE AND HERBICIDAL ACTIVITY

It has been known since the time when phenoxytype herbicides such as 2,4-D and MCPA were first introduced after World War II that they had a potential toxicity to rice at average air temperatures of less than 16 to 17 C. In northern Japan where such unusual low temperatures often happen during the first half of the rice growing season, concern has been particularly great. However, many technical improvements, such as optimum rate of application, correct timing of application, development of new milder phenoxytype herbicides, and cultural methods to avoid injurious effects on rice, have been achieved and have made the used these herbicides in rice possible. In 1976, phenoxytype herbicides were applied either a single formulations or in combinations with other chemicals to about one million hectare of rice in Japan.

The phytotoxic properties of phenoxytype herbicides in relation to temperature conditions have been to some extent revealed already. Response to lower temperatures decrease in the order of 2,4-D, MCPA, and MCPB (4-[(4-choro-otolyl)oxy]butyric acid). It also seems to differ according to the salt and type. It was experimentally indicated to be in the order of Na = Ca, ethyl ester, allyl ester, of MCPA and MCPB. The phytotoxic injury is often enhanced in sandy soil where there is much water loss or in the soils containing less organic matter. Further, unsound rice seedlings and excessive nitrogen application tend to enhance rice injury under the low temperature conditions.

Recently in Japan, machine-transplanted rice which requires younger seedlings less tolerant to unfavourable environmental conditions in rapidly

increasing. For such rice, herbicides have to be applied at the earlier stage of growth as well as under lower temperature conditions. This trend re-emphasize the concern about the application of phenoxytype herbicides and their mixtures to rice, coupled with the prediction of the lowering of air temperature due to abnormal climates on the earth. Abe (1976) recently said that MCPA and some of its combinations have given injurious effects on rice when the average air temperature was lowered by 2 C, though they recovered when exposed subsequently to normal temperatures. It has been, however, discussed that such effects remain until the harvest and possibly result in a reduction in rice yield if unusual low temperatures last for an extended period of time.

Further, besides phenoxytype herbicides, Nishikawa *et al* (1973) have shown that some main soil-applied herbicides may also have a detrimental influence on young rice seedlings under a low air temperature of 15 C in daytime and 8 C at night. This is 2 C lower than that of a usual year. Among three herbicides tested, butachlor [*N*-(butoxymethyl)-2-chloro-2′,6′-diethylacetanilide] gave the severest toxicity, followed by oxadiazon, [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)$\Delta^2$1,3,4-oxadiazolin], and CNP (4-nitrophenyl 2,4,6-trichlorophenyl ether).

In Tohoku and other cooler regions lowering the average air temperature by about 2 C may cause not only cold damage but also phytotoxic effects from herbicides when it occurs at a certain time in the first half of the rice growing season. For the past fifty years at Akita, Japan, the frequency of air temperatures dropping by 2 C for 10 days in a month during the period from May to September is estimated to be 10 to 20%.

Finally, an assumption on the relationships between herbicidal activity, rice growth, and weed control technology as influenced by the lowering of the air temperatures in the northern Japan, Tohoku, is illustrated and discussed in Figure 1.

HIGH TEMPERATURE AND HERBICIDAL ACTIVITY

The phytotoxicity of herbicides on rice plants as influenced by high temperature should be another main topic. In 1963 severe rice injury that seemed to be caused by prometryn [2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine] applied at temperatures 30 C or more was observed in paddy fields in the southern Japan, especially in Kyushu. Based on this information, some experiments were conducted to confirm it, using several main herbicides. The greatest increase of rice injury and weeding effec-

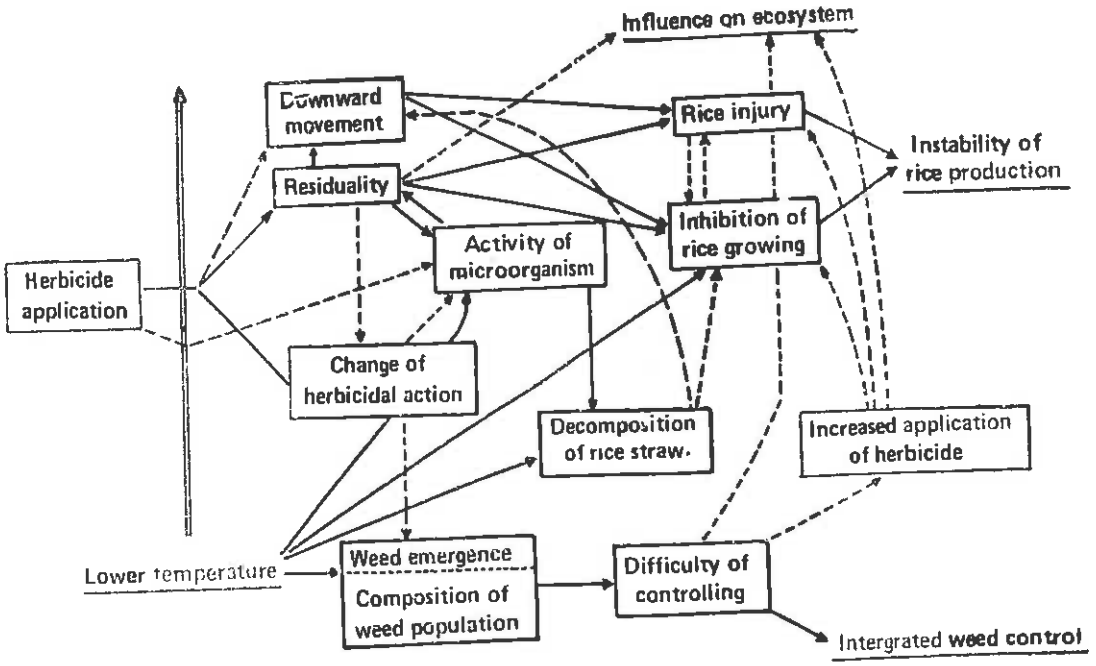

Figure 1. An assumption on the relationship among herbicidal activity, weed control technology, and rice growing as influenced by lowering of air temperature.

tiveness due to the rice of air temperature, from 18 C to 25 C and 32 C, were found with prometryn, followed by MCPA and PCP (pentachlorphenol). But the increase by a high temperature was hardly seen in nitrofen (2,4-dichlorophenyl-*p*-nitrophenyl ether), CNP and dichlobenil (2,6-dichlorobenzonitrile). Dichlobenil, on the contrary, gave severer damage under lower temperatures.

Further experiments were conducted using nine *s*-triazine type herbicides. The greatest injury due to a high temperature was seen in a group of chloro derivatives at R_5 position of the triazine ring, followed by methylmercapto compounds, and the least in methoxy group. On the other hand, compounds having isopropyl radical at R_3 and R_4 seemed to give severer injury than those having a methyl radical.

This rice injury is found in sandy soils, with of excessive nitrogen fertilizer application, and/or when using unsound rice seedlings. The mechanism of rice injury with triazine herbicides was assumed by Noda and Ibaraki (1969). Faster and greater absorption of chemicals into rice plants induced by such high temperatures as 30 C or more would be a main reason.

Besides *s*-triazine herbicides, MCPCA and MCPA herbicides also give toxicity on rice at high temperatures. In 1963, rice injury caused by MCPCA granules was found in Kyushu where unusually high temperatures occured just after herbicide application. The symptoms were characterized by the death of external leaves, the stunting of plants, abnormal malformation of roots, and disordering of tillers. MCPA also has a high response to high temperature, but the degree is different according to the salts or types of formulation.

The foregoing has so far presented a barrier to the safe use of herbicides in paddy rice in the south Japan. Consequently, higher temperatures as influenced by the abnormal climate in the future must be considered more in order to establish proper herbicide application techniques. Table 2 indicates selected rice herbicides classified by responses to temperature conditions.

Table 2. Selected rice herbicides in Japan classified by response to temperature conditions.

Class	Herbicide
High response to high temperature	Prometryn, Simetryn, Benthiocarb/Simetryn, Simetryn/MCPB, Molinate/Simetryn, Prometryn/MCPB, Benthiocarb/Simetryn/MCPB, Dimetametryn Piperophos, MCPA
High response to low temperature	2,4 D, MCPA, MCPB, Swep/MCPA, Simetryn/MCPB, Trifluralin/MCPA, Molinate/Simetryn/MCPB, Benthiocarb/Simetryn/MCPB, Dichlobenil
No or less response to temperature conditions	CNP, Nitrofen. Benthiocarb, Molinate, Oxadiazon, Chlometoxynil, Trifluralin, Benthiocarb/CNP

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Some of the Current Problems of the Noxious Weeds of California

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ABSTRACT

Eradication and containment programs are conducted on a state-wide basis on 34 species of noxious weeds. Eradication and control programs are carried on in parts of California for an additional 77 species of proclaimed noxious weeds. Weed infestations are described by net area/gross area. The net area is obtained by estimating the area that the weed infestation would occupy as a single heavy infestation. This aggregate or net area is expressed down to 0.01 hectare. The gross area is the area surrounded by the perimeter of the infestation. The net area gives an indication of the amount of weeds to be treated, an indication of the amount of chemicals needed. The gross area gives the extent of the area to be worked on, an estimate of the labor to be used in treating that infestation. Camelthorn (*Alhagi pseudalhagi*) has been the longest and most expensive eradication program. For more than 50 years state and county personnel have been involved in eradication of this deeply rooted perennial pest. Eradication techniques have progressed with the development of newer herbicides from the use of carbon bisulphide and the jar method of sodium arsenite to the present use of basal sprays of picloram (4-amino-3,5,6-trichloropicolinic acid). The cost of this program is impossible to estimate. Hydrilla (*Hydrilla verticillata*) is the most recent noxious weed to be found in California. A single infestation is known in a lake in the lower Sacramento Valley where it poses a serious threat to the rice industry and the many reservoirs of the State. Eradication of hydrilla by pumping out the lake and the subsoil will require rebuilding of this lake. The total cost of the program is now estimated at 3.2 million dollars. Additional eradication programs on skeletonweed (*Chondrilla juncea*), Scotch thistle (*Onopordum acanthium*), Dalmatian toadflax (*Linaria dalmatica*), and leafy spurge(*Euphorbia esula*) are also described.

INTRODUCTION

Eradication and containment programs are conducted on a state wide basis on 34 species of noxious weeds. Wherever these species occur the populations are subject to eradication measures. There are 77 other species of proclaimed noxious weeds that are under eradication or containment in parts of California. Those weed species under a state-wide program are eligible for state money to be used in the program. In larger

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infestations the costs of the treatment are shared equally by the state, county and the property owner. The property owner often may contribute his 1/3 share by furnishing labor or equipment.

Weed pest detection is an important function of the California Department of Food and Agriculture. With cooperation of the biologists of the county departments of agriculture approximately 300 new infestations of noxious weeds are discovered each year. These are beyond what would be considered the spread of a known infestation. Each year one or two species of weeds are found that are new to California or even new to North America. Evaluations are made as to the potential of a new weed species to be of serious economic importance to the agricultural industry. If the new weed species seems to be detrimental, eradication efforts are undertaken immediately.

Weed infestations are described on the basis of a net area over a gross area. The net area is obtained by estimating the area that the weed infestation would occupy if all the plants were aggregated into a single heavy infestation. This net area is expressed down to 0.01 hectare, or an area 10 m by 10 m. Any net infestation below this size is carried as 0.01 ha. The gross area is the total area surrounded by the perimeter of the infestation. The net area gives an indication of the numbers of plants to be treated, an rough estimate of the chemicals to be used. The gross area shows that total area to be covered, an indication of the amount of labor required to treat that infestation. Thus an infestation of 0.01 ha/10 ha is readily compared with an infestation of 0.01 ha/100 ha. If both infestations are to be treated, these figures may be added together; 0.02 ha of weeds are to be treated over an area of 110 ha.

CURRENT ERADICATION AND CONTAINMENT PROGRAMS

Camelthorn has been the longest and most expensive weed eradication program in California. For more than 50 years there has been a concerted effort made to eradicate this species from California agriculture. State and county personnel have used every method possible starting with carbon bisulphide and the jar method of sodium arsenite to basal sprays with various herbicides to picloram which has proven the most successful where it can be used. The long dormancy of the seeds and the deeply penetrating rhizomes have caused the most trouble with eradicating this weed. Several times in recent years camelthorn has been reduced to a total of less than 200 plants state-wide. Pest detection crews have found

previously unknown populations. Also, returning land to irrigation has brought out new growth of long dormant rhizomes. At this present time there are fewer than 100 plants of camelthorn in California except for an area of newly planted citrus along the Colorado River where there is a new infestation of 2 ha/81 ha. Being in a new citrus orchard makes the eradication program most difficult.

Hydrilla was first determined to be in California in 1976 when weed control efforts on what was thought to be elodea did not respond to the treatments. The plants persist by means of dormant tubers formed in the upper layers of the hydrosoil. The weed spreads rapidly by pieces of the plant and by turions, bud-like tips of stems that break off and float with the currents.

Flowers have not been seen on this material, but it is assumed that the plants are female as in Florida. At the present time this weed is restricted to a single artificial lake in the town of Marysville in the lower Sacramento River. All the drainage water of the town is collected here and pumped through the levee into the river. So far hydrilla has not been found in this very muddy water outside the lake. The eradication of hydrilla will require pumping out the lake and 2 meters depth of the hydrosoil. This work will damage the cemented banks of the lake. The total cost of the eradication effort against the weed and rebuilding the lake is now estimated at 3.2 million dollars.

Skeletonweed is a serious weed of grainlands often reducing production by 50%. This weed is now known from the four western states of Idaho, Washington, Oregon and California. Widespread infestations are known only from two adjacent counties of the Sierra Nevada foothills; the infestations are not yet found in the grainlands of the lower slopes and the valley bottomland. Small spot infestations of skeletonweed have been eradicated from 10 additional counties of California. Many of these spots have been railroad infestations. The main populations of this weed in Placer and El Dorado Counties have been contained by picloram sprayings where possible, preventing the spread into the valley grainlands. The eastern edges of the infestations go into the woodlands where detection is most difficult. Biological control is being integrated into the management of this pest; the agents being a species of a midge, a species of a mite and a rust fungus. We have profited greatly from the success of these biological control agents in Australia.

Leafy spurge is a serious weed of rangeland and cultivated ground. The plants form adventitious buds on the widely spreading lateral roots.

The weed spreads rapidly under cultivation and from the exploding seed capsules. This species has been under eradication in the three northeastern counties of California since it was first found in 1936. Proper timing and retreatments of the infestations have seemed to be as important in the control of leafy spurge as the particular chemicals used. This weed is regarded now as eradicated from California although one small population may still exist on the edge of a forest in north central California. By contrast, North Dakota reports over ½ million acres infested by leafy spurge.

Scotch thistle is a rangeland weed that can become sufficiently abundant as to exclude cattle from the area. The flowering plants of this biennial species may grow to 3 or 4 m tall and 3 m across. The plants are easily detected because of their size, but their occurrence in forested grazing lands makes the detection a difficult task. The flowering plants are used as an indication of the presence of dormant seed in the soil. The plants are killed and soil treated with picloram to give several years control. Repeated surveillance is necessary to continue the eradication efforts. Scotch thistle was first found in North America before 1900 in Utah. The rapid spread of this weed has occurred only recently. The first report in California was in 1958 but that infestation was there before 1942. Since 1958, Scotch thistle has been found in 18 counties of California, widely scattered over the state. Continued detection is necessary for this abundant weed of the western parts of the United States. California also has under eradication small infestations of taurian thistle and Illyrian thistle.

Dalmatian toadflax [*Linaria dalmatica* (L.) Mill.)] or [*Linaria genistifolia* subsp. *dalmatica* (L.) Maire & Petitm.] is an abundant unpalatable weed of rangelands of the western states. In California the ideal ecological conditions for this weed seem to be at the lower elevations of the yellow pine forest and perhaps extending into the rabbitbrush-sagebrush areas. This species spreads rapidly by seeds; many of the spot infestations are the first plants to grow on the sterilized areas of railroads and roadside edges. The seedlings rapidly produce rhizomes which complete the establishment and spread of the plants. Continued spread of this abundant weed has resulted in it being found in 31 of the 58 counties of California. California populations have been eradicated except for a very difficult occurrence for about 48 km along the Trinity River, a very remote and inaccessible area. A small population as an escaped ornamental plant also exists in the mountains in San Diego County.

Observations on the Ecology of Noxious Weeds on Ganga River Banks at Varanasi, India

R. S. AMBASHT [1]

ABSTRACT

Ganga river bank at Varanasi (old name Banaras — 25°1'N Lat., 83°1'E Long.) consisting of sandy fresh alluvium (55% to 80% of fine sand and the rest clay + silt almost equally) is subjected to natural stresses of flooding, silting and erosion in the rainy season (July to October), agricultural practices in winter (November to February) and dry hot scorching sun in summer (March to June). Of the twenty five plant species mostly annual weeds and a few perennial herbs recorded from the area the more characteristic ones have been ecologically studied for the mechanism of their perennation and propagation under such an unstable and stressed habitat and their effectiveness in binding the soil against erosive forces. *Alhagi camelorum* Fisch. a small leguminous weed survives through a network of very deep subterranean stems and roots full of vegetative buds from which new leafy shoots emerge, more so, when exposed and/or injured due to ploughing or mechanical eradication. In summer, when soil is very dry and loose and no crop cultivation is possible, its dense cover (exploiting moisture from deeper soil layers) protects the soil surface from strong winds. During the rains its aerial portion completely dies and grasses like *Saccharum benghalense* and *Cynodon dactylon*, sedges like *Cyperus rotundus*, and dicotyledons like *Xanthium strumarium* survive prolonged inundation through the formation of new roots full of air spaces as the old ones succumb to submergence and poor aeration. The first named species effectively binds the soil against erosion and experiments show their conservation values to exceed 90%.

INTRODUCTION

Ganga river bank at Varanasi, the site of this ecological study, is a specialised habitat of sloping topography experiencing floods, silting, erosion in rainy season, cultivation of crops in winter and extreme dryness in hot summer. Varanasi (old name Banaras, 25°1'N Lat., 83°1'E long.), one of the oldest cities of the world with a continuous record of human habitation (Ambasht 1975) has a chain of brick or stone buildings and bathing ghats along the river front on the eastern border of the city for over 5 miles. In the south of the township is the Banaras Hindu University

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and the river bank in the east of the University is devoid of buildings and is called University Ghat. The river bank is inundated with flood water during the rainy season (July to October), and the herbaceous vegetation succumbs to this stress. Rapid water runoff from catchment areas causes gully erosion at many places. Due to the cutting force of the swift currents of flood water on the embankments, riparian erosion leads to soil blocks from the bank falling into the mainstream. The flood water is turbid with silt and fine sand which is deposited at some places. The edaphic environment is under constant flux of erosion, waterlogging and silting during the rainy season, followed by intensive agricultural activities in winter (November to March) and extreme dryness and heat in summer (April to June). A number of weeds come up on the slopes and uplands (flood plains) as soon as the first few showers of the monsoon are received at the end of June and the beginning of July. But soon after that the sloping banks are covered by flood water. The uplands, in some years on a very extensive scale, are inundated due to high floods. The weeds succumb to this stress, but soon after the recession of the floods in October the exposed land is ploughed for cultivation of crops especially wheat. Weeds reappear either from perennating underground parts or through the germination of seeds. This paper is concerned with field and culture studies of some of the more characteristic weeds of this region in relation to bioedaphic conditions and their role in stabilizing the soil against water erosion.

MATERIALS AND METHODS

The soil profile has been studied in a trench over 3 m deep. Mechanical composition of four horizons *viz.* surface, 100 cm, 200 cm and 300 cm have been analysed by the International Pipette method. Other soil properties were measured at the surface, 40 cm and 80 cm depths only. Moisture content has been calculated as a percentage of water on oven dry weight basis. PH has been measured using electrical pH meter. $CaCO_3$ has been analyzed using a Collin's calcimeter. Nitrate nitrogen has been estimated colourimetrically by the method described by Snell and Snell (1949).

Floristic composition i.e. enumeration of weeds, their qualitative characteristics with respect to numbers, coverage, (abundance and dominance) and distribution pattern (frequency) have been estimated visually at regular intervals throughout the course of one year. The results are indicated by certain notations.

Out of the twenty five weed species (i.e. non crop plants coming up by themselves on cultivated croplands) six of the more important ones have been selected for closer observations for their ecological life cycle and adaptive mechanisms against erosion, silting and inundations. Culture experiments in large cement pots supplied with varying water regimes including partial submergence to simulate inundation, were carried out and plant reactions have been observed and measured. Sloping plots made of alluvial soils were planted with selected plant species and the erosion potential was estimated by spraying the plots with water and collecting the eroded soil in reservoirs, ovendrying it and weighing it. The conservation value (CV) of the plants has been conceived as the percentage of potential soil erosion which is checked by the plants. A formula $CV = 100 - (\frac{SWP}{SWO} \times 100)$ has been developed (Ambasht 1970) to obtain the conservation value (CV) from the dry weights of soil washed from the vegetated plot (SWP) and from a bare plot (SWO). Root studies have been done by tracing them along a trench (McLean and Cook 1946) and by digging a monolith and washing it in a pot of water (Weaver and Darland's method 1948). All biomass estimations are on an oven dry-weight basis.

RESULTS AND DISCUSSION

The edaphic conditions. The soil is without any characteristic profile development as it is continuously disturbed; in some years at certain places through erosion and in others through deposition of fresh layers of soil. In different years depositions may differ in colour and texture but there is no specific sequence in the proportion of different sized particles in them (Table 1). However, fine sand (0.2 mm to 0.02 mm size) is the major component ranging between 58% to 90% in different layers. Clay (smaller than 0.002 mm) is usually less than 15% and course sand (2 mm to 0.2 mm) is less than 2%. The rest is silt (0.02 to 0.002 mm). Moisture is highly variable in the three seasons specially on the surface. The pH ranges narrowly between 7 and 8. The nitrate content is low but calcium carbonate is rich ranging from 3.5% to 5.7%.

Weed flora. In summer most of the land is barren and the top soil becomes dry and loose. In isolated patches *A. camelorum* and *Chrozophora rottleri* are commonly found. With the onset of showers in early July

Table 1. Edaphic conditions of studied site at Ganga River bank at Varanasi (University Ghat).

	Moisture content (%)	pH	$CaCO_3$ (%)	NO_3 mg/100 g
SUMMER SEASON				
Surface	Nil	7.0	5.47	1.45
40 cm	4.5	7.5	3.55	1.45
80 cm	12.0	7.8	3.55	1.2
RAINY SEASON				
Surface	18.8	7.2	5.57	2.25
40 cm	22.0	7.5	5.1	1.45
80 cm	24.1	7.8	4.0	1.2
WINTER SEASON				
Surface	1.5	7.2	5.73	1.97
40 cm	7.5	7.2	4.1	1.7
80 cm	14.5	8.1	4.5	1.47

	Mechanical Composition			
	Course sand (%)	Fine sand (%)	Silt (%)	Clay (%)
Surface	0.25	58.4	24.4	14.45
100 cm	1.25	75.25	3.2	15.0
200 cm	1.25	64.4	16.2	14.2
300 cm	1.75	90.0	3.75	2.5

the aerial parts of *A. camelorum* and the entire plant of *C. rottleri* die and a new flush of weeds appears. *C. dactylon, Cyperus rotundus* sprout from underground rhizomes and tubers respectively and many other dicotyledonous weeds like *Euphorbia hirta, Euphorbia thymifolia,* germinate. In some perennials like *S. benghalense* on the uplands, new green shoots are formed. Young plants of these species are submerged by the rising waters of the river from the middle of July to September. All herbaceous plants die except for the underground parts of some species like *C. dactylon, S. benghalense* and *A. camelorum* which become dormant and send out new aerial shoots on the recession of floods in early October. Another flush of weeds appears after the land is ploughed for the cultivation of winter season crops like wheat, barley, gram and mustard.

This is the season of maximum weed activity. About 20 weed species appear and many of them are in fairly large numbers (Table 2). *A. camelorum, C. rottleri, X. strumarium,* assume dominance in patches. *Ranunculus scleratus, Gnaphalium luteo-album, Lippia nodiflora, Mollugo hirta* and *Rumex dentatus* appear rather on the lower slopes where moisture conditions are better.

Table 2. Weed flora of Ganga River bank at Varanasi in different seasons.

Name of species	Summer	Rainy	Winter
Alhagi camelorum	a,d	—	a
Alternanthera sessilis	—	r	r
Argemone mexicana	—	—	o
Celsia coromandelina	—	—	o
Chrozophora rottleri	d	—	d
Commelina benghalensis	—	o	—
Cyanotis axillaris	—	r	—
Cynodon dactylon	o	f	f
Cyperus rotundus	r	f	f
Datura sp.	r	r	r
Euphorbia hirta	r	vf	f
Euphorbia thymifolia	r	f	f
Gnaphalium luteo-album	—	—	la
Kyllinga triceps	—	o	—
Lippia nodiflora	o	—	r
Mollugo hirta	—	—	o
Potentilla supina	—	—	o
Ranunculus scleratus	—	—	la
Rumex dentatus	—	—	f
Saccharum benghalense	o	r	o
Solanum nigrum	—	—	f
Solanum xanthocarpum	—	o	f
Vandellia crustacea	—	o	—
Xanthium strumarium	—	f	a

Notations: — = absent; r = rare; o = occasional; f = frequent; a = abundant; d = dominant; v = very; l = locally.

Adaptive features and soil conservation values of some selected species.

A. camelorum or camel thorn is a leguminous weed of sandy deserts. It is reported to occur in deserts of India, Egypt and southern Russia. Here it is confined to sandy banks of the Ganga only and its moisture requirement during dry summer is met through a very deep subterranean

network of rhizomes and roots. An aerial shoot only 20 to 30 cm tall may have roots reaching below 3 m where the moisture content is about 12%. Another adaptive feature is the development of numerous vegetative buds on rhizomes and to a certain extent on roots too. From these new shoots keep developing especially when the aerial parts are injured or killed during cultivation. The plant defies all control measures and thrives well because the perennating rhizomes are too deep to dig out and form a network over wide areas. All efforts to excavate fully an entire root system have failed despite digging to 3 m depth over an of 4 m^2 area. Its soil conservation value reaches a maximum of 35% but during the rains the aerial shoots die naturally. The conservation value of roots is only 12%. However, during summer when the wind is strong during the day, its colonies prevent soil loss by forming a dense cover on isolated patches.

C. rotundus. This small sedge perennates through the dry season by means of small black tubers formed a few centimeters apart on the rhizomes. In the wet season, complete submergence leads to the death of aboveground parts but after the floods, new aerial shoots sprout from the tubers in large numbers. However, it can withstand partial submergence under cultural conditions well even for 6 to 8 months of continuous free water of 5 to 10 cm depth. The rhizomes and roots develop air filled tissues through which they receive the necessary supply of oxygen. Continuity of gaseous content has been tested and when one part of a rhizome is immersed in a glycerine-salt mixture (GSM) air bubbles come out from the other end. When grown on slopes subjected to erosion more tubers are formed per unit area of ground. A dense cover of this species has a conservation value of 80 to 90% and when the shoots are clipped the subterranean parts have a CV of 66% only.

C. dactylon. This grass also perennates by underground rhizomes during the very dry summers and when submerged during high floods. Partial submergence of 5-10 cm is withstood easily. Under these conditions the existing fibrous roots gradually die and new fibrous roots form in small clumps. These new roots have about one third of the cross section occupied by aerenchymatous tissues. This species is well adapted to sloping topography also and withstands heavy grazing. It binds the soil against erosion very effectively with a CV up to 90 - 97% and even when the shoot is clipped, the CV of the underground parts is 77%. Control is by mechanical means but the process is laborious because the rhizomes are quite deep.

E. hirta. A small weed adapted to grow under a wide range of biotic pressures fails to withstand inundation and silting. It has several germination flushes throughout the year. However on a slope its root morphology changes into a pronounced unilateral growth with more on the side opposite to slope exposure. It is a very poor soil binder with the conservation value as low as 6 to 12%. It is easily controlled by mechanical means.

S. benghalense is a tall tussock forming grass. It is manually removed from cultivated lands but on account of a very effective binding of soil against erosion, it is encouraged on marginal lands and steep slopes. The species survives partial submergence of 10 to 15 cm for 6 to 8 months and forms new fibrous roots heavily filled with aerenchymatous tissues. The roots easily reach 60 cm depth and bind the soil very effectively. It withstands heavy grazing pressure also, as its older leaves and stems become very rough and are avoided by cattle. Conservation value is between 92 to 96% even under frequent grazing (simulated by clipping).

X. strumarium is a noxious weed appearing throughout the river bank in the latter half of the rainy season and all through the winter season (September to March). Kaul [2] has shown photoperiodic ecotypic differentiation of populations adjusted for different short day photoperiods for flowering. This dicotyledonous weed withstands partial submergence of 6 to 8 weeks by formating adventitious roots that arise from the submerged portion of the stem. These roots float in water and have access to the atmosphere for oxygen. Very often these floating roots get infested with an epiphytic growth of green alga *Oedogonium* which is found to produce fine bubbles of oxygen in day time through photosynthesis. Thus the problem of poor aeration is solved.

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Weed Flora in Rice Paddy Fields in Taiwan[1]

LIANG-CHI HORNG and LII-SIN LEU[2]

ABSTRACT

Sixty-five species of weeds were found from 1425 sampling sites covering the island of Taiwan which had weeds in the first and the second crop seasons in 1976. The occurrence of weeds varied in different districts. The quantity and species of weeds in this study are much less than those surveyed by Wang (1968) 10 years ago. Due to the continuous application of herbicides during the last several years many species of annual weeds were not found. Monochoria (*Monochoria vaginalis* Presl.) remained the most abundant species. Knotgrass (*Paspalum distichum* L.), arrow head (*Sagittaria trifolia* L.), and bulrush (*Scirpus* spp.) have become important in several districts since they tolerate most of preemergent herbicides currently used.

INTRODUCTION

Herbicide chemicals have played a more important role in weed control in Taiwan in recent years due to the shortage of labor and to the improvement of herbicide safety and effectiveness. The herbicides used in the rice paddy fields of Taiwan include (in the order of quantity used) butachlor [2-chloro-2′,6′-diethyl-*N*-(butoxymethyl)acetanilide]; benthiocarb [*S*-(4-chlorobenzyl)*N*,*N*-diethylthiolcarbamate]; chlomethoxynil (2,4-dichlorophenyl-3-methoxy-4-nitrophenyl ether); CNP (2,4,6-trichlorophenyl-4-nitrophenyl ether) + MCPA (2-methyl-4-chlorophenoxy acetic acid); nitrofen (2,4-dichlorophenyl-4*p*-nitrophenyl ether); benthiocarb + CNP; benthiocarb + nitrofen; molinate (*S*-ethyl hexahydro-1*H*-azepine-1-carbothioate) + CNP; molinate + nitrofen; Oxidazon (5-*tert*-butyl-3-(2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazoline-2-one) and others.

The residual effect of these chemicals under field conditions lasts 1 to 3 months. No report has been published of any ill effect of these compounds on rice yield after several years of application. Thus, the use of herbicides for weed control has been widely accepted by farmers.

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According to a brief survey [3] approximately 75% of farmers in Central Taiwan use herbicides for weed control in paddy fields and this percentage keeps increasing. The herbicides used are mainly the preemergent type. They must be applied 1 to 3 days prior to or 1 to 7 days after transplantation of rice seedlings for the control of annual weed seedlings. But they are ineffective against those which sprout from tubers, rhizomes or runners of perennial weeds.

The survey was to monitor the changes in weed flora in rice paddy fields after mass application of herbicides since 1970. It also tried to find solutions for the major problems in weed control in paddy field for the future practice.

MATERIALS AND METHODS

The survey was conducted 30 to 40 days after the transplantation of rice seedlings in the first and the second crop seasons in 1976 except Tainan district was 20 DAT in the second rice crop. The numbers of districts, towns and sampling sites for this survey are listed below:

Districts	No. of towns	No. of sampling sites
Kaohsiung	26	233
Tainan	21	255
Taichung	32	282
Hsinchu	24	360
Taipei	17	170
Hwalien & Taitung	14	125
Total	134	1425

Using 50 cm by 50 cm wooden frame, four spots were selected randomly within a sampling site where weeds were observed. Weeds in each spot were removed, identified in the field or brought back to the laboratory (Hsu 1971; 1975 and Makino 1954), counted and the fresh weight taken.

[3] Horng, L.C. 1975. The survey of weed control methods by farmers in Central Taiwan District. (Unpublished data).

RESULTS AND DISCUSSION

Sixty-five species of weeds were found in rice paddy fields in Taiwan. The 33 major species whose occurrent frequencies were $> 5\%$ in one or more districts are listed in Tabel 1. Bulrush (*Scirpus juncoides* Roxb. and *S. wallichi* Nees), were considered as one species because it was difficult to discriminate between them at early stage. The same was true for Vandellia (*Vandellia anagallis* var. *verbenaefolia* Yam. and *V. angustifolia* Benth.). The other 32 species were of minor and each had occurrent frequency $< 5\%$ (see the supplementary list).

The occurrence of weeds varied in different districts. Arrow head was most abundant in Hsinchu and Taipei districts, but very scarce in Tainan district. However, bulrush was more frequent in Kaohsiung, Tainan, and Hsinchu districts. Knotgrass was more in Kaohsiung, Taichung, and Tainan districts. Blyxa (*Blyxa echinosperma* (Clark) Hooker) was found only in Taipei and part of Hsinchu districts.

When each species of weeds was expressed as a percentage of number of total plants in each district, the descending order of the 12 major weeds is as following: monochoria, smallflower umbrella plant (*Cyperus difformis* L.), arrow head, rotala (*Rotala indica* L.), false pimpernel (*Lindernia pyxidaria* All.), bulrush, barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.), knotgrass, star-sky alternanthera (*Alternanthera sessilis* R. Br.), vandellia, marsilea (*Marsilea quadrifolia* L.), and blyxa. Weeds such as spikerush (*Eleocharis acicularis* R. & S.), and waterwort (*Elatine triandra* Schk.) were not counted due to their tiny size.

Evidently, the quantity of annual weeds is much less now than it was a decade ago, espesially in the case of barnyardgrass. But monochoria and smallflower umbrella plant are still the most and the next abundant species, respectively. This might be due to the fact that they were the predominant species over the all in the past.

Arrow head, bulrush, and knotgrass have became more common now in comparison with the results obtained by Wang (Wang 1968), because they are resistant to most of preemergent herbicides used. Now, arrow head and bulrush can be effectively controlled by bentazon (3-isopropyl-2,1,3,-benzothiadiazin-4-one 2,2-dioxide) (Anon 1976). Although marsilea and spikerush are perennial, the quantity of them is a little less than that of 10 yr ago, because they are sensitive to several kinds of herbicides (Lin 1974). Star-sky alternanthera is a perennial broad leaf weed. It, like knotgrass can resist preemergent herbicides, therefore, most farmers remove them by hand about 10 to 14 days after the application of preemergent herbicides.

Table 1. Weed flora in rice paddy fields of Taiwan.

Table 1. Weed flora in rice paddy fields of Taiwan.

Weed species	Items	Districts and percentage of weeds in the first and the second rice crop seasons											
		Kaohsiung		Tainan		Taichung		Hsinchu		Taipei		Hwalien & Taitung	
		1	2	1	2	1	2	1	2	1	2	1	2
Monochoria vaginalis Presl	OF[1]	70	94	69	81	54	85	76	89	65	80	61	50
	NP[2]	28.5	28.5	26.3	34.1	31.8	34.6	47.6	48.1	24.7	40.6	16.4	17.8
Cyperus difformis Linn.	OF	29	74	52	67	40	73	12	58	30	52	51	80
	NP	7.4	32.3	13.8	23.9	19.0	17.5	2	9.9	8.9	16.2	31.8	39.8
Echinochloa crus-galli Beauv.	OF	42	56	20	15	67	47	28	18	64	34	42	48
	NP	2.4	2.9	0.7	1.1	11.6	3.1	2.5	1.7	5.4	2.4	2.2	3.3
Sagittaria trifolia Linn.	OF	28	25	3	0	11	21	60	44	77	56	49	33
	NP	10.6	4.6	0.5	0	2.6	4.3	26.6	8.6	34.9	11.5	14.8	9.5
Scirpus juncoides Roxb. & *S. wallichi* Nees	OF	56	31	53	28	21	10	24	26	12	15	12	9
	NP	14.9	2.9	9.4	14	4	1.4	7.6	7.9	1.2	0.8	1.2	0.3
Paspalum distichum Linn.	OF	45	40	32	40	59	26	22	22	19	14	8	11
	NP	4.3	2.2	1	4.4	4.4	1	0.9	1.4	0.6	0.4	0.1	0.5
Rotala indica Linn.	OF	17	42	19	16	17	51	10	32	20	48	14	17
	NP	10.9	8.7	4.7	3.6	2.2	17.1	2.1	5.4	3.4	8.4	3.3	4.7
Lindernia pyxidaria All.	OF	27	21	55	14	23	23	7	17	16	13	17	12
	NP	6.9	4.6	32.4	1.4	13.6	2.2	0.4	1.8	1.1	2.7	6.6	0.7
Alternanthera sessilis R. Br.	OF	28	25	21	21	31	28	14	18	11	9	17	11
	NP	1.7	1.4	0.7	1.1	1.9	1.6	0.4	1.5	0.3	0.2	0.7	0.5
Marsilea quadrifolia Linn.	OF	7	4	8	15	13	18	20	17	9	2	14	14
	NP	0.3	0.5	0.4	3.4	0.6	2	0.9	1.6	0.3	0.1	0.7	1
Vandellia anagallis Yam. & *V. angustifolia* Benth.	OF	11	21	9	16	11	26	1	9	1	5	8	11
	NP	0.8	3.9	1.7	4.4	0.4	2.2	0.02	0.8	0.02	0.1	0.6	3.1

Table 1. (*continued*).

Eleocharis acicularis R. & S.	OF	20	15	22	11	33	18	13	11	28	17	22	9
	NP	*	*	*	*	*	*	*	*	*	*	*	*
Elatine triandra Schk.	OF	10	8	18	12	3	3	9	7	14	8	10	3
	NP	*	*	*	*	*	*	*	*	*	*	*	*
Elyxa echinosperma (Clark) Hook.	OF	0	0	0	0	0	1	10	9	24	22	0	0
	NP	0	0	0	0	0	0.01	3.9	4.4	15.1	13.6	0	0
Ammania baccifera Linn.	OF	11	18	5	2	0	11	0	4	0	0	5	11
	NP	3.3	2.3	0.73	0.03	0	5.2	0	0.13	0	0	0.74	14.2
Sagittaria pygmea Miq.	OF	0	0	0	0	0	3	3	4	0	0	3	0
	NP	0	0	0	0	0	3.1	3.2	1.2	0	0	1.54	0
Ludwigia peploides subsp	OF	0	0	9	7	12	7	0	1	5.4	4.2	1.7	0
stipulacea (Ohwi) Raven.	NP	0	0	0.18	0.52	1	0.3	0	0.04	0.49	0.02	0.02	0
Eclipta prostrata (Linn.) Linn.	OF	9	8	10	4.4	9	8	0.6	4.3	1.4	0	10	6
	NP	0.63	0.26	0.57	0.76	0.5	0.7	0.01	0.4	0.02	0	0.72	0.34
Alternanthera nodifolia R. Br.	OF	6	4	9	6	17	3	1.7	0.5	1.4	0	7	2
	NP	0.53	0.19	0.34	0.64	1.4	0.7	0.07	0.03	0.08	0	0.72	0.07
Ludwigia octovalvis (Jacq.) Reaven	OF	6	5	3	4	6	7	1.7	7	2.7	1	3.4	0
	NP	0.85	0.23	0.08	0.18	0.3	0.4	0.04	0.2	0.13	0.06	0.11	0
Fimbristylis miliacea (Linn.) Vahl.	OF	0	4	0	4	0	5	0	5	0	20.8	0.	14
	NP	0	0.31	0	0.21	0	0.6	0	0.59	0	2.33	0	0.54
Polygonum lapathifolium Linn.	OF	3	0	3	0	10	4.5	3	7	1.4	0	7	3
	NP	0.09	0	0.22	0	0.7	0.34	0.4	0.3	0.02	0	1.42	0.84
Lobelia chinensis Lour.	OF	4	1	0	0	11	5.2	4	1.1	1	1	7	3
	NP	0.13	0.03	0	0	0.4	0.1	0.11	0.05	0.5	0.02	0.86	0.2
Ceratophyllum demersum Linn.	OF	0	3.8	4.2	6	0	0	9.1	8.2	0	12.5	5.1	3
	NP	*	*	*	*	*	*	*	*	*	*	*	*
Sphenoclea zeylanica Gaertn.	OF	2	4	3	12	0	0	1	1.6	0	0	0	3
	NP	0.09	1.11	0.12	2.56	0	0	0.05	0.23	0	0	0	0.23
Echinochloa colonum (Linn.) Link	OF	1	2	0	8.9	0	0	0	0.5	0	0	0	0
	NP	0.03	0.05	0	0.52	0	0	0	0.01	0	0	0	0
Lindernia cordifolia Merr.	OF	1	0	0.8	0	0	0	2.3	0.5	8.1	1.0	1.7	0
	NP	0.03	0	0.02	0	0	0	0.08	0.03	0.21	0.02	0.02	0
Leptochloa chinensis Nees.	OF	1	5	0	3	0	3.6	0	2.2	0	0	0	0
	NP	1.26	0.17	0	0.09	0	0.1	0	0.05	0	0	0	0
Leersia hexandra Sw.	OF	2	0	0.8	0	0	0	0.6	4.3	8.1	0	0	0
	NP	0.06	0	0.02	0	0	0	0.27	0.17	0.46	0	0	0
Centipeda minima (Linn.)	OF	3	0	0	0	1	1	0.6	1	0	0	8.5	0
A. Br. et Ascher	NP	0.09	0	0	0	0.3	0.2	0.06	0.04	0	0	1.4	0

Lindernia cordifolia Merr.	OF	1	0	0.8	0	0	0	2.3	0.5	8.1	1.0	1.7	0
	NP	0.03	0	0.02	0	0	0	0.08	0.03	0.21	0.02	0.02	0
Leptochloa chinensis Nees.	OF	1	5	0	3	0	3.6	0	2.2	0	0	0	0
	NP	1.26	0.17	0	0.09	0	0.1	0	0.05	0	0	0	0
Leersia hexandra Sw.	OF	2	0	0.8	0	0	0	0.6	4.3	8.1	0	0	0
	NP	0.06	0	0.02	0	0	0	0.27	0.17	0.46	0	0	0
Centipeda minima (Linn.) A. Br. et Ascher	OF	3	0	0	0	1	1	0.6	1	0	0	8.5	0
	NP	0.09	0	0	0	0.3	0.2	0.06	0.04	0	0	1.4	0
Commelina diffusa Burman f.	OF	0	0	0	0	0	0	0.6	1	0	0	5.1	1.5
	NP	0	0	0	0	0	0	0.02	0.05	0	0	0.14	0.01
Total sample sites		102	131	120	135	90	192	176	184	74	96	59	66
Total of NP %		95.55	97.21	94.4	96.91	96.70	98.87	98.82	98.92	97.83	99.42	89.95	97.63

1 OF: Occurrent frequency of each species as the percentage of total sample fields in each district.
2 NP: Number of plants of each species as the percentage of total number of weed plants in each district.
3 (1) and (2): Weeds found in the first and the second rice crop.
4 Numbers after district indicate the occurrent frequency of weeds.
5 Abbreviation of district of Kaohsiung (KH), Tainan (TN), Taichung (TC), Hsinchu (HC), Taipei (TP), Hwalien & Taitung (HT).
* It is difficult to count the number of weeds.

Supplementary list:

The occurrent frequency of each species less than 5% are briefly indicated as below: *Alopecurus aequalis Sobol.* var. *amurensis* (Komar.) Ohwi (1)[3] TC[4] 2.2,[5] HC 1.7; *Amaranthus viridis* Linn. (1) KH 1, (2) TC 2, HC 4; *Ammania multiflora* Roxb. (1) KH 1, TN 2.5, HT 3.4, (2)KH 1, TC 1, HC 4.3; *Cynodon dactylon* Pers. (1) TC 1, HC 1, (2) KH 1, TN 1, TC 1, HC 1; *Cyperus iria* Linn. (1) HT 2, (2) KH 3, HC 1, HT 5; *C. pilosus* Vahl. (1) TC 2; *C. rotundus* Linn. (1) HC 0.6, HT 1.7, (2) TN 1.5, TC 1, HT 3; *C. serotinus* Rottb. (1) TC 1; *Digitaria adscendens* (HBK) Henr. (2) KH 0.8, HC 1; *D. benryi* Rendle. (2) HC 0.5; *Drymaria cordata* (Linn.) Willd. (2) HC 1; *Dopatrium junceum* Hamilt. (1) TN 1.7, HC 1.1, TP 1.7, (2) KH 1, TN 1.5, HC 1.1, TP 1; *Eleusine indica* Gaertn. (2) TN 0.7, HT 1.5; *Eriocaulon formosanum* Hay. (1) HC 0.6, (2) HC 1.1; *Juncus prismatocarpus* R. Br. (1) HC 1, TP 1.4; *Kyllinga brevifolia* Rottb. (1) KH 1, TN 0.8, HT 1.7, (2) TC 0.5, HC 0.5; *Lindernia ciliata* (1) TP 1.4, (2) TP 4.2; *L. crustacea* (Linn.) F. Muell. (1) TC 1, TP 1, (2) TP 1; *Mariscus cyperinus* Vahl. (1) TN 1.7, HC 1.1; *Mazus japonicus* (Thumb.) O. Kuntz (1) TN 1.7, TP 1.4, HT 1.7; *Molluqo pentaphylla* Linn. (2) TC 1; *Panicum repens* Linn. (1) TC 1, (2) TC 1, HC 0.5; *Paspalum conjugatum* Berg. (1) KH 2, TN 2.5, TC 2.3, TP 1, (2) TN 1, TC 1, HC 3.8, TP 1; *Polygonum plebeium* R. Br. (1) TN 1.7, HT 1.7; *Ranunculus cantoniensis* DC. (1) HC 0.6; *Rorippa atrovirens* (Horem.) Ohwi et Hara (1) KH 4, TN 2,5, TC 1, HT 1.7; *R. cantoniensis* (1) TC 2; *Rotala rotundifolia* Koehne. (1) TN 3.3, HC 0.6, TP 1.4, (2) TN 2, HC 1.6; *R. leptopetala* Koehne. var. *littorea* Koehne. (1) KH 2, TN 3, HC 2.5, HT 1.7, (2) KH 3, TN 1, TC 1, HC 2, TP 0.5; *Scirpus lineolatus* Fr. et Sav. (1) KH 1, HT 3; *Sesuvium portulacastrum* (2) TC 4; *Soliva anthemifolia* R. Br. (1) KH 1, TN 0.8, HC 0.6, TP 1.4, (2) KH 2, TN 3, HC 0.5, TP 1.

According to Wang (1968), there were 145 species of weeds in paddy fields 10 years ago in Taiwan. But in this study only 65 species were found. Weeds such as *Dopatrium junceum* Hamilt., *Fimbristylis miliacea* (L.) Vahl., *Lindernia cordifolia* Merr., *Lobelia affinis* Wall., *L. radican* Thunb., *Eclipta prostrata* (L.) L., *Kyllinga brevifolia* Rottb., and *Alternanthera nodiflora* R. Br. were very abundant in the past. Now, they are much less due to their sensitivity to the herbicides used. The change of weed flora in paddy fields could be related to continuous application of herbicides during the last several years.

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Ecotypic Variations of Wild Common Oats (Avena fatua L.) in East Asia.

H. YAMAGUCHI [1]

ABSTRACT

One hundred and fifteen strains of wild common oats (*Avena fatua* L.) from Japan, Korea, Australia, Canada, Mexico and West Germany were raised in the experimental fields of University of Osaka Prefecture. The dates of inflorescence emergence and 15 morphological characters were studied. Geographical clines in plant height, periods of inflorescence emergence and the basal cover per panicle (CA) were observed. Wild common oats from higher latitudes showed late growing habits and a high plant stature with large CA, while oats from lower latitudes showed early growing habits and a low plant stature with small CA. Those from waste places in East Asia showed a high plant stature with large CA, while those from arable lands, especially winter cereal fields, showed a low plant stature with small CA. The agronomical ecotypes in East Asia, namely, dwarf races and compact panicle races showed a small CA. To clarify the relationships among weed oat populations, a principal component analysis (PCA) of their morphology was carried out. The cumulative proportion of total variation in first four principal component was 82%. Variations in the plant types of weed oats were well explained in the scatter diagram of component 1 and 2. Component 1 showed the size of the plant. Component 2 showed the shape of plant, stumpy vs slender. Weed oats from waste places of East Asia were slender but those from arable lands were stumpy. Hand weeding of East Asia might have produced the stumpy ecotypes of wild common oats.

INTRODUCTION

In general, widely dispersed plant species have some ecotypes. Ecotypic differentiations in weedy species are very common. Canada thistle and Johnson grass have some climatic ecotypes showing some different photoperiodic and thermoperiodic responses (Hunter and Smith 1978, Mc Whorther 1972). The edaphic ecotypes of barnyard grass showing different copper tolerances were reported in Japan (Morishima and Oka 1975). Foxtail grass (*Alopecurus aequalis* Sobol.) and wheat grass (*Agropyron tsukushiense* Ohwi) in Japan have agronomical ecotypes adapted to the field conditions, paddy vs upland (Matsumura 1967, Sakamoto 1961). More notable is the rice mimic of barnyard grass whose plant type resembles the cultivated rice very well (Yabuno 1966).

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Weed oats in Japan and Korea include three species and 11 subspecies. However, three subspecies of wild common oat with many taxonomical varieties are recognized as the harmful oats to crops. (Yamaguchi 1976). Their habitats are wheat, barley, oats and rape fields, river banks, roadsides, urban waste places and sand hills near the sea coast. Some racial differentiations of wild common oat were reported earlier (Yamaguchi 1976, Yamaguchi and Nakao 1975). Ecotypic relationships among wild common oat populations are reported in this paper.

MATERIALS AND METHODS

Wild common oat from Japan, Korea, Australia, Canada, Mexico and West Germany were raised in experimental fields. In 1974, seeds were sown on the sterile soil on 11 November, and the 2 to 3 leaved seedlings were then transplanted in early December, into fields with 15 by 15 cm spacing between and within the row.

In the spring of 1975, ecological and morphological characters were observed. 16 traits are the dates of inflorescence emergence after 1 April (variable *X14*), plant height (*X1*), panicle length (*X2*), number of spikelets per panicle (*X3*), lengths of first (flag) and second leaf blades (*X4*, *X7*), lengths of first and second internode (*X5*, *X8*), length of first and second leaf sheath (*X6*, *X9*), widths of first and second leaf blades (*X15*, *X16*), length and width of lower glume (*X10*, *X11*), number of panicles (*X12*) and the basal cover per panicle (*X13*). In principal component analysis, averages of strains were calculated using 8 random samples. According to the computor manual of TOSBAC-5600, principal component analysis was carried out using FILE/ST03D. To make a normal distribution, *X13* was transformed into logarithm function.

Habitats of the four strains from Hokkaido of Japan are cultivated oat fields. Those of the 26 strains from Honshu, the 4 from Shikoku, the 11 from Kyushu of Japan and the 3 from Korea Peninsula are waste places, i.e. roadsides, river banks, sand hills etc. Habitats of 6 strains from Honshu, 2 from Shikoku, 14 from Kyushu, 21 from Korea Peninsula and 2 from Cheju Island are winter cereal fields. Habitats of the 6 from Cheju are rape fields. Those of the three strains from Australia, the one from Mexico, the two from Canada, and the one from West Germany are upland wheat and barley fields. One strain of common oat (*A. fatua* L. subsp. *nodipilosa* Malz.) from Kyushu was raised for the contrast.

RESULTS AND DISCUSSION

Variations in the dates of inflorescence emergence (E.P.), plant height, panicle length, number of spikelets per panicle, number of panicles, and basal cover per panicle (CA) are shown in Table 1. Geographical clines in plant height, E.P. and CA were observed. Wild common oats from higher latitudes (i.e. Hokkaido, Canada and Germany) showed the late growing habits and the high plant stature with large CA. However, oats from lower latitudes (i.e. Kyushu, Mexico and Australia) showed the early growing habits and the low plant stature with small CA.

Using mean values of the 16 traits of the strains, correlation coefficients among characters were calculated. The correlation matrix is shown in Table 2. Starting from the correlation matrix, eigen values, eigen vectors and contributions of principal component were obtained as shown in Table 3. The cumulative proportion of total variance in the first four principal components were approximately 82%. The first principal component indicated the size factor of plant, because eigen vectors of plant height, lengths of leaf blades, leaf sheath and internode were large plus. Eigen vectors of the number of spikelets per panicle, E.P. and CA were large plus, too, because these traits were closely related to the size of plant (Table 2). The second principal component explained the shape of plant, slender vs stumpy, because eigen vectors of widths and lengths of leaf blades were large plus and those of plant height and length of internode were large minus. The main contributors of the third principal component were length and width of glume and the number of panicles. The main contributors of the fourth component were width of leaf blades, width of glume and the number of panicles. Therefore, the variation in plant types of wild common oats is well explained with components 1 and 2.

To clarify the relationships among weed oats populations, the component scores were calculated. Scatter diagram of the first (Z_1) and second (Z_2) component scores is shown in Figure 1. Ecotypic differences among strains are well projected in this diagram. One strain of ssp. *fatua* from Hokkaido showed the same plant style as Canadian and German strains, as shown in broken line (9). Three strains of ssp. *cultiformis* from Hokkaido showed high plant stature with large CA and wide leaf blades, however they were very stumpy as shown in broken line (8). Australian and Mexican strains were slender so their second component scores were large minus.

Table 1. Ecological and morphological variations in wild common oat.

Ecotypes, origin and habitats	No. of strains	No. of plants	E.P.*	Plant height (cm)	Panicle length (cm)	No. of spikelets per panicle	No. of panicles	C.A.**
Agro-ecotypes								
C- form	1	16	23.3	58.06	7.24	36.6	4.31	1.18
D- form	17	289	20.6	60.55	19.26	39.5	8.61	1.18
U- form	3	47	30.5	68.56	20.35	40.1	5.99	1.95
Common form	64	1123	31.8	110.83	24.52	54.7	7.92	4.92
Japan	4	73	49.6	133.04	34.49	80.6	4.02	5.70
Hokkaido	31	538	34.5	116.41	25.64	59.9	7.73	6.24
Honshu	26	474	35.8	119.72	26.41	63.8	7.20	6.80
waste	5	64	27.4	99.18	21.65	39.8	10.44	3.35
arable	4	59	33.3	115.10	24.03	56.8	9.32	7.19
Shikoku	25	453	25.4	99.67	21.62	43.8	8.57	2.80
Kyushu	11	202	26.7	100.67	21.38	44.4	9.01	3.26
waste	14	251	24.4	98.89	21.80	43.4	8.23	2.44
arable	22	394	30.0	98.89	22.50	43.9	5.56	2.76
Korea	18	315	30.5	95.11	21.69	39.8	5.48	2.26
Peninsula	3	47	30.8	84.15	20.39	32.8	5.13	1.84
waste	15	268	30.4	97.30	21.95	41.2	5.55	2.35
arable	4	79	27.9	115.92	26.14	62.4	5.92	5.01
Cheju	3	50	54.4	150.39	42.82	98.3	4.27	4.75
Canada & Germany	4	71	24.9	105.64	23.20	28.9	5.59	3.95
Mexico & Australia	1	24	25.6	114.50	25.51	44.7	5.50	3.69
Cultivated oat								

* E.P.: Dates of inflorescence emergence from 1 April.

** C.A.: Basal cover per panicle (cm^2).

** C.A.: Basal cover per panicle (cm^2).

Table 2. Correlation matrix of 16 characters in weed oats.

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
X1	1.00															
X2	.79	1.00														
X3	.72	.82	1.00													
X4	.42	.61	.66	1.00												
X5	.81	.48	.36	.20	1.00											
X6	.87	.75	.68	.37	.62	1.00										
X7	.64	.77	.85	.86	.27	.62	1 00									
X8	.81	.37	.33	.08	.83	.70	.24	1.00								
X9	.85	.79	.81	.56	.50	.93	.80	.58	1.00							
X10	-.12	-.11	-.22	.04	.06	-.06	-.13	.01	-.11	1.00						
X11	-.35	-.25	-.32	-.07	-.19	-.23	-.25	-.20	-.27	.45	1.00					
X12	-.22	-.31	-.26	.03	-.17	-.24	-.14	-.10	-.16	.31	.15	1.00				
X13	.83	.64	.70	.45	.64	.76	.64	.65	.77	-.18	-.31	-.21	1.00			
X14	.68	.70	.76	.41	.39	.70	.64	.38	.72	-.43	-.28	-.54	.72	1.00		
X15	-.04	.16	.16	.52	-.17	-.09	.36	-.16	.10	-.01	.23	.06	-.07	-.05	1.00	
X16	.04	.21	.22	.41	-.15	.07	.40	-.08	.23	-.06	.15	-.12	-.01	.04	.88	1.00

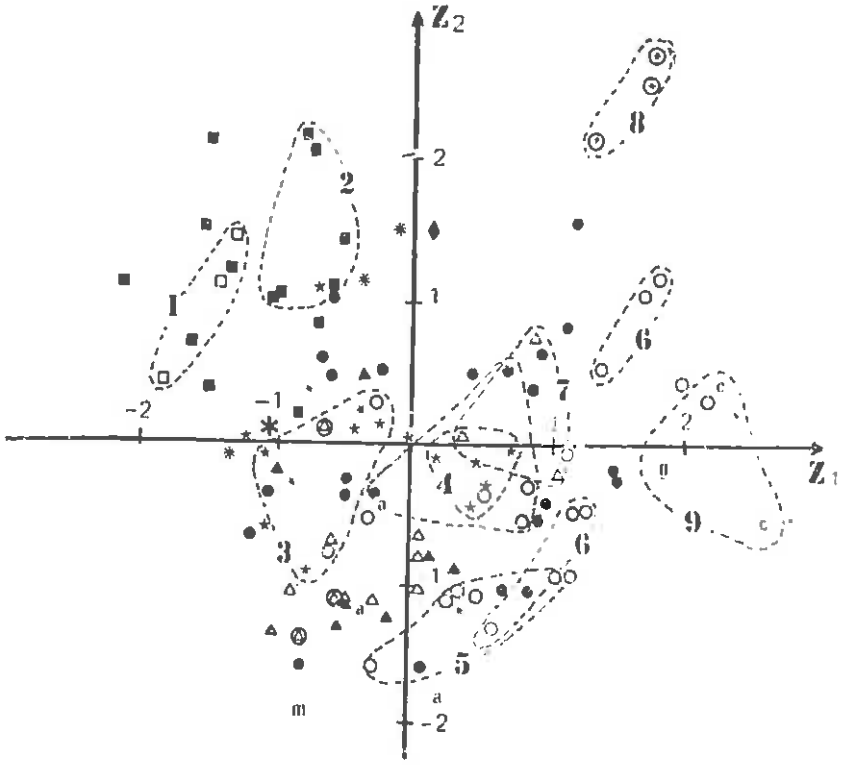
X1: Plant height, *X2:* Panicle length, *X3:* Number of spikelet per panicle, *X4:* Length of first leaf blade, *X5:* Length of first internode, *X6:* Length of first leaf sheath, *X7:* Length of second leaf blade, *X8:* Length of second internode, *X9:* Length of second leaf sheath, *X10:* Length of glume, *X11:* Width of glume, *X12:* Number of panicles, *X13:* Basal cover per panicle, *X14:* Date of inflorescence emergence, *X15:* Width of first leaf blade, *X16:* Width of second leaf blade.
(Correlation coefficient >0.182: significant at 5%, >0.235: significant at 1%).

Table 3. Eigen values, eigen vectors, contributions of the first four principal components.

Characters	(Mean)	First P.C. Vector 1	Second P.C. Vector 2	Third P.C. Vector 3	Fourth P.C. Vector 4
X1	(100.05)	0.338	-.141	.121	.066
X2	(23.54)	.314	.086	-.014	-.032
X3	(50.01)	.316	.124	-.109	-.186
X4	(16.34)	.223	.362	.109	-.285
X5	(41.37)	.234	-.274	.276	.222
X6	(24.06)	.321	-.114	.111	.067
X7	(25.12)	.299	.266	-.022	-.239
X8	(19.12)	.230	-.286	.283	.260
X9	(13.88)	.335	.034	.077	-.071
X10	(24.64)	-.074	.016	.615	-.060
X11	(6.84)	-.128	.164	.381	.357
X12	(7.33)	-.113	.053	.413	-.591
X13	(0.463*)	.313	-.114	.033	-.043
X14	(30.03)	.296	-.038	-.287	.090
X15	(8.97)	.034	.539	.094	.237
X16	(11.58)	.067	.499	.026	.386
Eigen value		7.663	2.705	1.714	1.059
Proportion of total variance %		47.90	16.91	10.72	6.62
Cumulative proportion of total variance %		47.90	64.80	75.52	82.14

* *X13* were transformed into $\log_{10}X$.

Plant statures of the common forms from Japan and Korea resemble each other. Common forms from waste places of Japan showed the late growing habits and a high and slender plant stature with large CA as shown in the examples surrounded with broken lines (5) and (6). However, the common form from the arable land of southern Japan showed the low and middle plant stature with small CA as shown in examples enclosed with broken lines (3) and (4). The common forms from Korea were more slender than those from Japan. The common forms from the Korea Peninsula showed a low plant stature and a slender plant type



● : ssp *septentrionalis* from wastes of Japan
★ : ssp. *septentrionalis* from arables of Japan
○ : ssp. *fatua* from wastes of Japan
• : ssp. *fatua* from arables of Japan
⊙ : ssp. *cultiformis* from arables of Japan
▲ : ssp. *septentrionalis* from arables of Korea
△ : ssp. *fatua* from arables of Korea
◍ : ssp. *septentrionalis* and ssp *fatua* from wastes of Korea
■ : D – form from Japan
□ : D – form from Korea
✱ : C – form from Korea
* : U – form from Korea
a : ssp *fatua* from Australia
m : ssp. *fatua* from Mexico
c : ssp. *fatua* from Canada
g : ssp. *fatua* from Germany
♦ : ssp. *nodipilosa* from Japan

1 : From rape fields of Cheju Island
2 : From wheat fields of Kitsuki, Kyushu, Japan
3 : From barley fields of Sasebo, Kyushu, Japan
4 : From wheat fields of Kitsuki
5 : From river banks of Sakai, Kinki, Japan
6 : From roadsides of Hashimoto, Kinki, Japan
7 : From rape fields of Cheju Island
8 : From oat fields of Hokkaido
9 : Spring wild oats from Hokkaido, Canada and Germany.

Figure 1. Scatter diagram of Z_1 and Z_2 component scores of PCA.

with a small CA, so their component scores were minus both in Z_1 and Z_2. The common forms from rape fields of Cheju showed a high plant stature with a large CA as shown in broken line (7).

As reported by Yamaguchi and Nakao (1975), dwarf races (D-form) showed a low plant stature and stumpy style with a small CA, because their second internodes were very much shortened. They could thus be distinguished from the other ecotypes very easily for their component scores were large minus in Z_1 and large plus in Z_2. The compact panicle race (C-form) showed a low plant stature with a small CA because their panicles were very short (Table 1). The shape of plant of C- forms resembled those of the common forms except for panicle morphology. The ecotypes could be distinguished from common form because their first internodes with panicle bases which stuck into the leaf sheat (U-form) were very much shortened. Plant types of the U-form also resembled to those of the common form. So, C-form and U-form exist near to the common form in Z_1 and Z_2 plane.

In Figure 1, ecotypic differentiations in the wild common oat as weeds in East Asia are well explained. Wild common oat from high latitudes exist in the first quadrant of Z_1-Z_2 plane, those from low latitudes exist in the third quadrant. However, most of the weed oats from urban wastes exist in the fourth quadrant and those from arable lands in the third and second quadrants. Therefore, the plant types of weed oats are low and stumpy in arable lands but high and slender in waste places.

It was assumed that the directions of ecotypic differentiations in wild common oat were determined by climatic and biotic factors. In biotic differentiation, adaptations to arable lands and ruderal sites were obvious in weed oats in East Asia. The author assumed that hand weedings in winter cereal fields might have produced the low and stumpy agro-ecotypes of weed oats in East Asia. Numata (1962) suggested that ecological adaptations to arable lands in weedy species might be progressed without phylogenetical diversities of given species. It can be said that the ecotypic differentiations of wild common oats are not in parallel with the phylogenic ones, and their adaptations to arable lands resulted in the lower and stumpy plant types.

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Plant Growth Inhibitors in Garden Pea Plants (Pisum sativum L.)

K. MUNAKATA and K. KAWASHIMA [1]

ABSTRACT

Plant growth inhibiting substances contained in garden pea plants (*Pisum sativum* L.) were studied in the course of the research about plant growth inhibitors in plants from the standpoint of identification of mother chemical structures for newer herbicides and the elucidation of the homogeneous allelopathy by the garden pea plants. After the extraction and separation experiments monitored by the plant growth inhibition tests using seedlings of garden pea, rice plant (*Oryza sativa* L.) and Chinese cabbage (*Brassica pekinensis* Ruprecht), three kinds of crystal materials were isolated and identified to be (+)-abscisic acid, p-coumaric acid and azelaic acid.

INTRODUCTION

The production of phytotoxic allelopathic substances produced by many plants has been well reviewed and discussed (Bonner 1950, Tuckey 1969, Rice 1974). In Japan, it has been known that garden pea plants exhibits allelopathy on itself with continuous cultivation on the same field (Takishima and Hayashi 1959). From the roots of garden pea plants two compounds of p-coumaric acid and vanillic acid were extracted and identified as substances toxic to raddish (Hatsuka daikon) and rice seedlings (Hatsuda *et al* 1963). The plant growth inhibiting substance of fresh immature garden peas was identified to be (+)-abscisic acid by rice seedling test (Isogai *et al* 1967).

During the course of the research on plant growth regulating substances, the authors have been interested in plant growth inhibiting substances contained in garden pea plants. The crude extracts of adult garden pea plants were found to show considerable inhibitory action on the growth of seedlings of garden pea, rice and chinese cabbage. Then, isolation of the plant growth inhibitory principles-contained in the extracts of garden pea plants was undertaken, and the authors identified three kinds of substances as plant growth inhibitors.

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MATERIALS AND METHODS

Instruments. IR spectra were obtained by JASCO IR-G spectrophotometer and UV spectra in Hitachi EPS-3T spectrophotometers. NMR spectra were recorded on JEOL MH-100 and FX-100 spectrometers with tetramethylsilane as internal standard.

Seedling growth inhibition test. Throughout the isolation and identification experiments, the plant growth inhibitors were monitored by the usual seedling growth test. Seeds of rice, Chinese cabbage and garden pea were dip and pregerminated in distilled water, incubated at 25 C for 24 hours for garden pea and Chinese cabbage, and three days for rice. Twenty five seeds, ten seeds in the case of garden pea of preemergence, with uniform shape and size were chosen and transferred into 9 cm petridishes, in which a sheet of filter paper treated with 3 ml of test sample solution was prepared beforehand. The dishes were incubated for three (Chinese cabbage) and seven (rice and garden pea) days under white fluorescent light (ca. 3000 lux.) at 25 C. The stem and root lengths of seedlings were measured and compared with the control seedlings.

Garden pea plants. Garden pea plants of variety Atsumishirobana were harvested at Atsumi, Aichi, Japan in the fall stage of the plant, and dried in the shade. The hole plant were pulverized and used for the extraction.

RESULTS AND DISCUSSION

Twenty seven kilograms of powdered leaves and stems of garden pea plants was extracted with three 50 L-portion of methanol. The combined extracts were evaporated at 60 C under reduced pressure to give a viscous extract which was extracted with ethyl acetate. The ethyl acetate soluble materials were separated into strong acidic, weak acidic, neutral and basic fractions by the treatment as shown in Figure 1. These fractions were assayed by the seedling test, and inhibitory activity was observed mainly in the strong acid fraction as shown in Table 1.

The strong acidic fraction which showed stronger growth inhibition was separated as shown in Figure 2. In the first place silica gel column chromatography was performed. The eluate with 1% MeOH in chloroform was further purified by repeated silica gel chromatography and P-1 substance was isolated and identified to be (+)-abscisic acid as the most active substance and P-4 substance which was identified to be indolecarbo-

Table 1. Relative effect of crude fractions of pea plants on the growth of rice and Chinese cabbage seedlings.

Crude fraction of pea plant (ppm)	Rice		Chinese cabbage	
	shoot	root	shoot	root
	%			
control	100	100	100	100
SA - 500	49.9	35.3	14.9	5.5
WA - 500	91.3	107.1	99.4	60.2
N - 500	86.1	86.6	111.2	104.8
B - 500	77.6	7.5	76.4	31.9

SA: strong acidic fraction.
WA: weak acidic fr.
N: neutral fr.
B: basic fr.

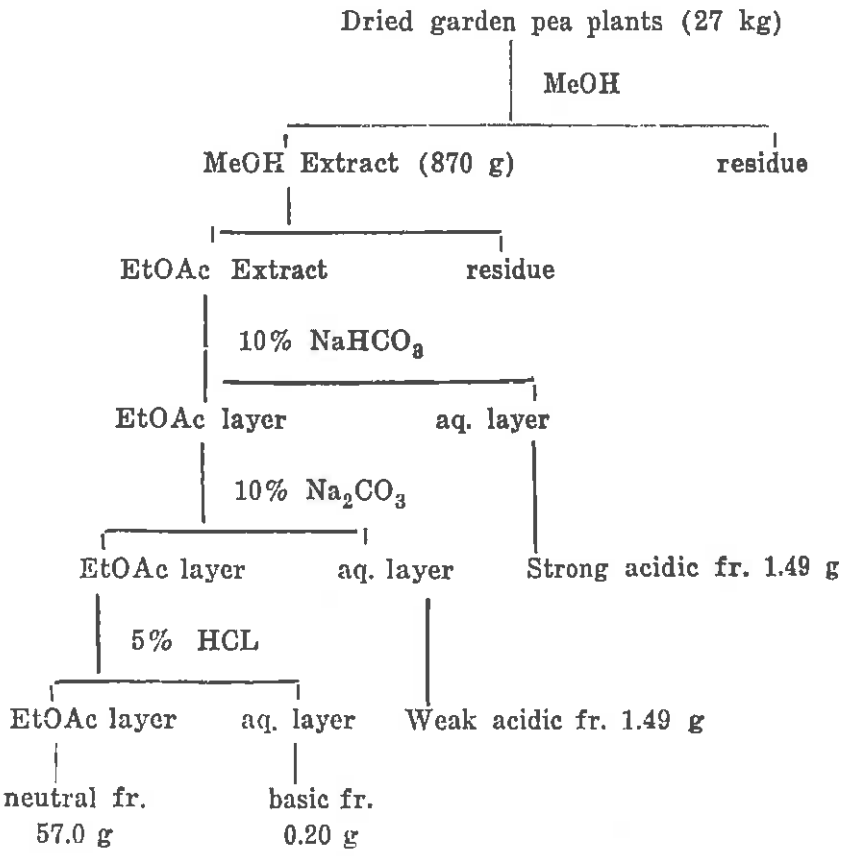


Figure 1. Extraction of plant growth inhibitors in garden pea plants.

xylic acid as an inactive substance. The eluate with 2% MeOH in chloroform was also further purified chromatographically as in Figure 2 to yield P-2 (p-coumaric acid) and P-3 (azeraic acid) and P-1 [(+) abscisic acid]. P-1, P-2, P-3 and P-4 substances were respectively identified with the authentic samples of (+)-abscisic acid, p-coumaric acid, azeraic acid and indolecarboxylic acids. The plant growth inhibiting activities of (+)-abscisic acid, (P-1), p-coumaric acid (P-2) and azeraic acid (P-3) were tested as in Table 2.

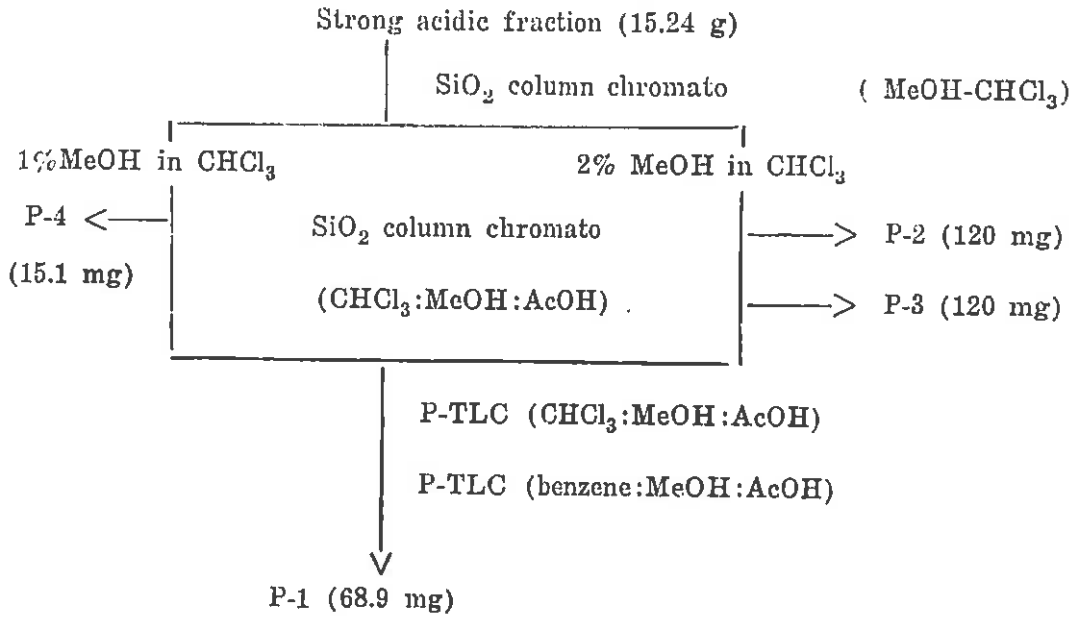
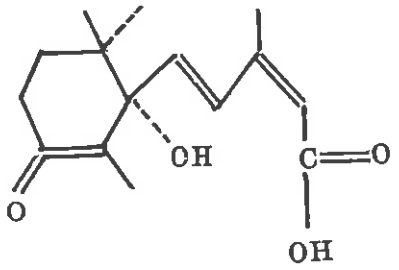
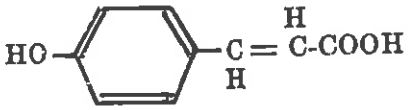


Figure 2. Separation of strong acidic fraction.

These three substances isolated from garden pea plants showed inhibitory activities to rice, Chinese cabbage and garden pea seedlings, in the concentration range of 50 ppm to 500 ppm, and (+)-abscisic acid is the strongest inhibitor. The minimum content of the acid is at least 1.3 mg/kg of dry matter and this is higher than one part in ten million, fresh weight of the normal plants. (Cornforth *et al* 1966). The large quantity of abscisic acid in garden pea plant is expected to explain partly the cause of soil sickness following continuous cultivation of the plant. It is supposed that these three active compounds might accumulate in the garden pea field and act synergistically against the pea plant and

Table 2. Plant growth inhibitors in garden pea plant (inhibitory effect and content).

Compound		Inhibitory effect Control = 100%		Content mg/kg dry
 (+)-Abscisic acid (P-1)	Rice	shoot	10 (50 ppm)	
		root	10 (50 ppm)	
	Chinese Cabbage	shoot	5 (50 ppm)	1.3
		root	4 (50 ppm)	
	Pea	shoot	50 (50 ppm)	
		root	50 (50 ppm)	
 p-Coumaric acid (P-2)	Rice	shoot	50 (500 ppm)	
		root	0 (500 ppm)	
	Chinese Cabbage	shoot	100 (500 ppm)	9.1
		root	40 (500 ppm)	
	Pea	shoot	100 (500 ppm)	
		root	40 (500 ppm)	
	Rice	shoot	95 (200 ppm)	
		root	25 (200 ppm)	
$HOOC(CH_2)_7COOH$	Chinese Cabbage	shoot	117 (200 ppm)	9.1
		root	55 (200 ppm)	
	Pea	shoot	114 (200 ppm)	
Azelaic acid (P-3)		root	76 (200 ppm)	

the other plants as plant growth inhibitors. To reveal this assumption, the isolation and identification to these inhibiting substances from the farm soil where garden pea plant has been grown and the phenomena of soil sickness has been observed has to be attempted. Chemically these three compounds are known compounds, but the chemical structures of inhibitory activity suggest some new related compounds which would provide a clue to possible newer plant growth regulators as herbicides.

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Isolation of Growth Inhibiting Substances from Alang-alang (Imperata cylindrica (L.) Beauv. var. major)

J. H. H. EUSSEN [1]

ABSTRACT

Aqueous extracts of leaves, rhizomes and roots of alang-alang *(Imperata cylindrica* (L.) Beauv. var. *major)* inhibit shoot elongation of *Lycopersicum esculentum* seedlings. Shoot elongation is stimulated at low and inhibited at higher concentration of the extract. The total germination percentage is not affected, germination, however, is delayed. The aqueous extracts are fractionated using liquid-liquid extraction and paper chromatography. In this way the biological activity of the extracts could be separated into several distinct fractions.

INTRODUCTION

Alang-alang present in a plant community competes strongly with most of the other members of that community, often resulting in an almost pure stand of this grass (Hubbard *et al* 1944, Eussen and Wirjahardja 1973). It was found that part of this strong competitive ability has to be related to an allelopathic type of interaction (Eussen and Wirjahardja 1973, Eussen *et al* 1976). Such an interaction is characterized by the release of subtances from the plant which affect the growth performances of other plants (Molisch 1937). These interactions have been frequently reported (Molisch 1937, Grümmer 1955; 1961, Bonner 1950, Börner 1960, Muller 1966; 1970, Winter 1961, Tukey 1969, Rice 1971; 1974, Whittaker 1970). The chemical substances involved are called kolines (Grümmer 1955) or allelochemics (Whittaker 1970). They may reach the environment of the plant by volatilization, leaching, exudation or as a result of decay of certain plant parts (Muller 1970, Rice 1974, Whittaker 1970). A number of these compounds, which generally belong to the group of secondary plant substances have been characterized (Rice 1974, Muller 1970, Whittaker 1970).

In the work described here an attempt is made to isolate substances from alang-alang which show growth regulating activity and may therefore play a role in its allelopathic activity.

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MATERIALS AND METHODS

Alang-alang plants were collected in an alang-alang vegetation 5 km south of Bogor. Leaves and rhizomes could easily be obtained in sufficient amounts. The collection of roots presented some difficulties due to their extensively branched nature. Sufficient quantities of roots, however, could be obtained from pots planted with alang-alang and dug in the field for a period of 6 months. The collected plant material was washed, dried at 80 C for 48 hr and ground (60 mesh). Aqueous extracts were made by percolating this ground material with distilled water, 400 ml for every 10 g. The extracts were concentrated by evaporation of the solvent under reduced pressure and 40 C. The concentration of the extract was given in percentage, expressing the equivalent amount of original plant material present in the extract (e.g. 10% : 100 ml extract contains the water soluble fraction of 10 g dried plant material).

The biological activity of the extract was tested on seed germination and seedling growth of *Lycopersicum esculentum* var. "Money maker". For this purpose seeds or seedlings were placed in petridishes (8 cm diameter) lined with filter paper to which 2 ml of the extract or, as control, distilled water was added. The highest concentration at which the extracts were tested was 20% for leaf and root extract and 10% for rhizome extract. At this concentration the osmotic value of the extracts is equal to approximately 50 mM mannitol (Eussen and Soerjani 1976). Besides on filter paper the biological activity of the extracts was also tested on soil. For this purpose 5 g sun-dried soil are placed in petridishes and 3.5 ml of the extract or distilled water was added.

For germination tests 30 seeds per dish were used. Germination was recorded daily until no germination occurred anymore. The total germination percentage reached values of 85 - 95% in the control dishes after 7 days. Germination delay was calculated as G_{50}, the percentage of germination at 50% germination in the control. For seedling growth tests seeds of *L. esculentum* were germinated in large petridishes. Seedlings with 0.5 cm root length were selected and placed in the dishes containing the extract or distilled water, 6 seedlings per dish. Root and shoot lengths were measured after 5 days, at which time they reached respectively 6-9 cm and 3-4 cm length in the control dishes. The original extract was subsequently exhaustively extracted with *n*-butanol at successively pH 7, pH 3 and pH 9, the butanol evaporated and the residue dissolved in distilled water. The fractions obtained in this way are referred to as

the neutral fraction (NF), acid fraction (AcF) and alkaline fraction (AlkF). The alkaline water extract that remained after the final extraction with butanol was neutralized, concentrated to a small volume and 4 N HCl was added till a final concentration of 2 N. This solution was heated for 330 min at 90 C and, after cooling, extrated with butanol as described above. The remaining alkaline extract was concentrated again and 4 N NaOH was added till a final concentration of 2 N. This solution was left at room temperature for 10 hr, after which it was evaporated under reduced pressure at 40 C and the residue dissolved in distilled water.

All fractions were diluted to the same volume as that of the original extract. The degree of biological activity of the fractions and of the original extract then can be compared using the concentration values of the original extract. The NF, AcF and AlkF of the original water extract and of the acid and alkaline hydrolysates were tested on their biological activity at a concentration of 10% for rhizome and 20% for leaf and root extract. Fractions showing biological activity were concentrated again and applied as bands to Whatman No. 3 paper. The paper was developed using 15% acetic acid (AcAc) as descending solvent. After drying the chromatograms were viewed under UV light (360 mμ) and cut into strips according to the observed UV pattern. The substances on these strips were eluated with distilled water and the eluates tested on their biological activity at a concentration of 10% for rhizome and 20% for root and leaf extract. Eluates exhibiting biological activity were concentrated again, applied as bands to Whatman No. 3 paper and the paper was developed with isopropanol: ammonia: water 8 : 1 : 1 (IAW) in a descending solvent system. The chromatograms were treated in the same way as described above and the eluates tested on their biological activity at a concentration of 20% for rhizome and 40% for leaf and root extract. In tests on the biological activity of eluates of chromatograms, eluates of the same zone of chromatograms treated in the same way without extract were used as control.

RESULTS AND DISCUSSION

Aqueous extracts of leaves, roots and rhizomes did not affect the total germination percentage of *L. esculentum* at the concentrations tested. Germination, however, was delayed. This delay, expressed in G_{50} was

Plant material, dried, ground.
extracted with distilled water.
↓ concentrated
extract (Figure 2)
↓
pH7 → ButOH extr. → NF (Table 1) → paper chrom. solv.: AcAc → eluates (Figure 3) → paper chrom. solv.: IAW → eluates (Figure 6).
↓
pH3 → " " → AcF (") → " " → (") → " " → (").
↓
pH9 → " " → AlkF (")
↓
acid hydrolysis
↓
pH7 → ButOH extr. → NF (Table 1) → paper chrom. solv.: AcAc → eluates (Figure 4) → paper chrom. solv.: IAW → eluates (Figure 7).
↓
pH3 → " " → AcF (") → " " → (") → " " → (").
↓
pH9 → " " → AlkF (")
↓
Alkaline hydrolysis
↓
pH7 → ButOH extr. → NF (Table 1) → paper chrom. solv.: AcAc → eluates (Figure 5) → paper chrom. solv.: IAW → eluates (Figure 8).
↓
pH3 → " " → AcF (") → " " → (") → " " → (").
↓
pH9 → " " → AlkF (")

Figure 1. Schematic presentation of the isolation procedure.

stronger as the concentration of the extract increased, rhizome extract being most effective in this respect (Figure 2). The effect of the extract on root and shoot elongation tested on filter paper was different nature. Root elongation was inhibited by the extract, shoot elongation stimulated at low extract concentrations and inhibited at higher concentrations. Here also rhizome extract appeared to exhibit the strongest inhibiting activity.

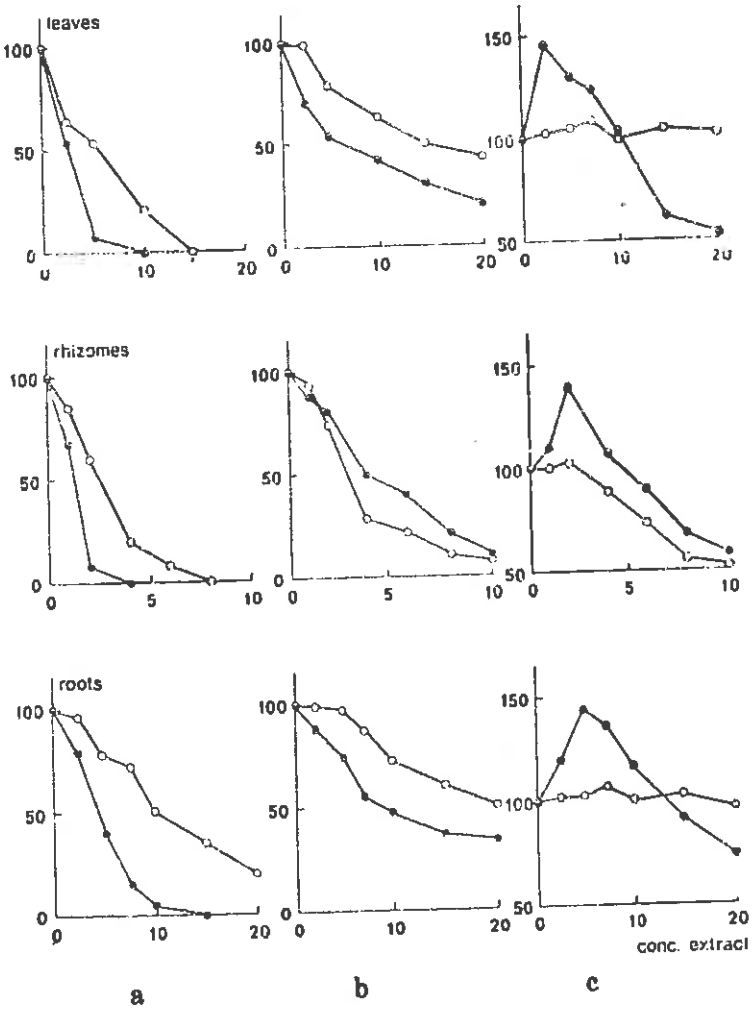

Figure 2. Biological activity of aqueous extracts of alang-alang leaves, rhizomes and roots a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum* (●) on filter paper, (o) on soil. Values in percentage of the control. Significant differences 5% level: 10%.

The biological activity of the extract tested on soil differed from that tested on filter paper (Figure 2). The most striking difference was the complete disappearence of the stimulation of shoot elongation. The inhibiting effect on shoot elongation of the leaf and root extract also disappeared. With root and leaf extract, root elongation and G_{50} were less affected on soil than on filter paper. With rhizome extract, however,

the inhibition of root elongation and shoot elongation was slightly stronger on soil.

Separation of the original water extract into NF, AcF and AlkF and testing these fractions on their biological activity, revealed that the inhibiting activity on G_{50}, root and shoot elongation was present in the NF and AcF, while the AlkF mainly showed stimulating activity on shoot elongation (Table 1). Among the fractions of the leaf, rhizome and root extracts the same distribution of the activity was found, except for the AlkF of the leaf extract in which no activity could be detected.

The distribution of the activity among the fractions of the acid hydrolysates differed from that of the original extract (Table 1). The NF and the AcF still contained inhibiting activity on G_{50} and root elongation. The NF, AcF and AlkF stimulated shoot elongation, except the NF and AcF of the rhizome hydrolysate which still contained considerable inhibiting activity on shoot elongation. Of the fractions of the alkaline hydrolysate, only the NF and the AcF of the hydrolysates of rhizome extract appeared to exhibit inhibiting activity on G_{50} and root elongation, while the AcF inhibited also shoot elongation. The AlkF again stimulated shoot elongation.

Considering the elimination on soil of the stimulating activity of the extracts on shoot elongation, which activity therefore will have no sig-

Table 1. Biological activity of the fractions of the original leaf, rhizome and root extracts and of the acid and alkaline hydrolysates.

	Leaves			Rhizomes			Roots		
	G_{50}	seedling root	length shoot	G_{50}	seedling root	length shoot	G_{50}	seedling root	length shoot
Water extract									
NF	7	25	52	2	55	80	5	5	82
AcF	10	41	70	48	8	18	26	26	52
AlkF	98	100	99	104	110	141	118	85	151
Acid hydrolysates									
NF	33	55	122	30	25	42	30	55	131
AcF	64	68	135	42	14	42	42	64	154
AlkF	104	112	156	85	81	125	88	100	157
Alkaline hydrolysates									
NF	107	94	152	55	52	105	95	101	124
AcF	87	83	150	28	10	34	85	96	141
AlkF	89	89	142	95	87	143	102	89	134

Values in percentage of the control. Significant difference 5% level: 20%.

nificance in the interaction of alang-alang with other plant species, only the fractions exhibiting inhibiting activity will be treated further.

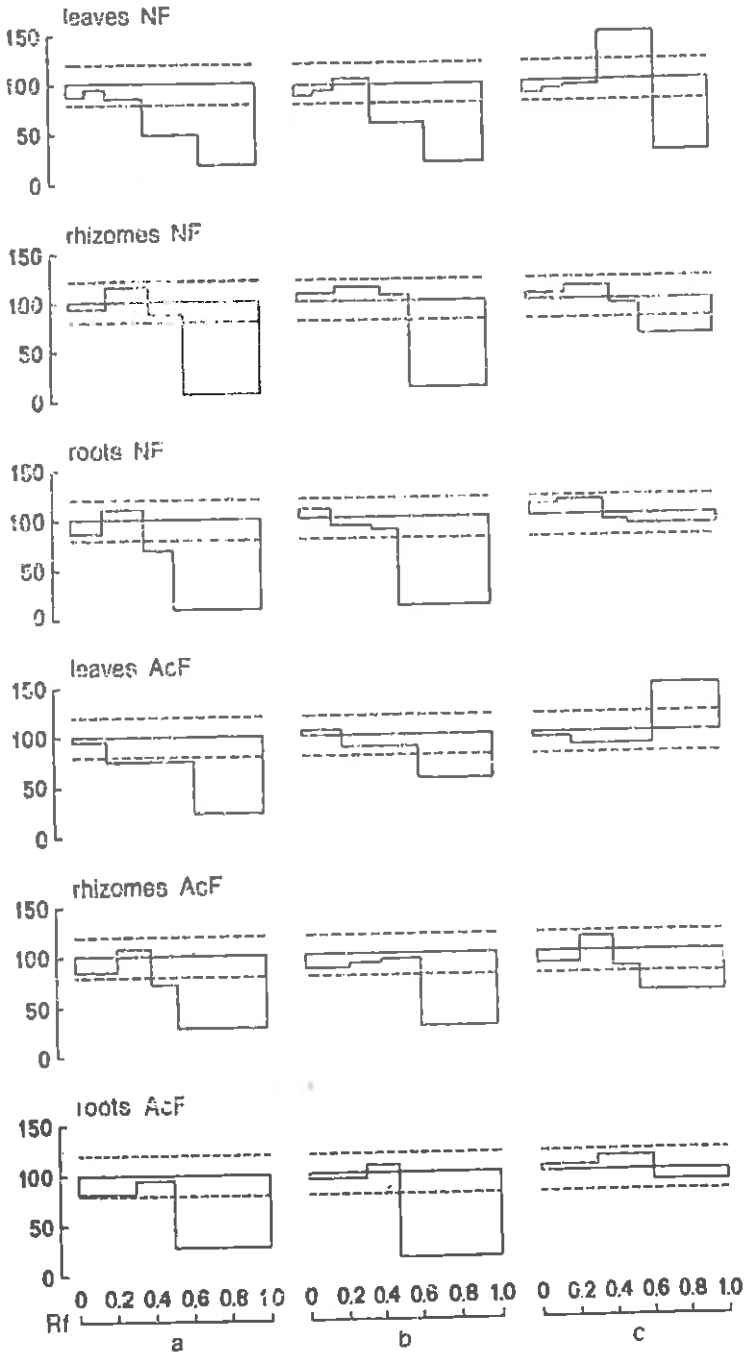

Figure 3. Biological activity of eluates of chromatograms (solvent AcAc) of the NF and AcF of leaf, rhizome and root extract. a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum*. Values in percentage of the control. Dotted lines: significant difference 5% level.

Separation of the substances in these fractions by paper chromatography with AcAc as solvent showed that substances with biological activity in general could be recovered in eluates from zone Rf 0.50 - 1.00

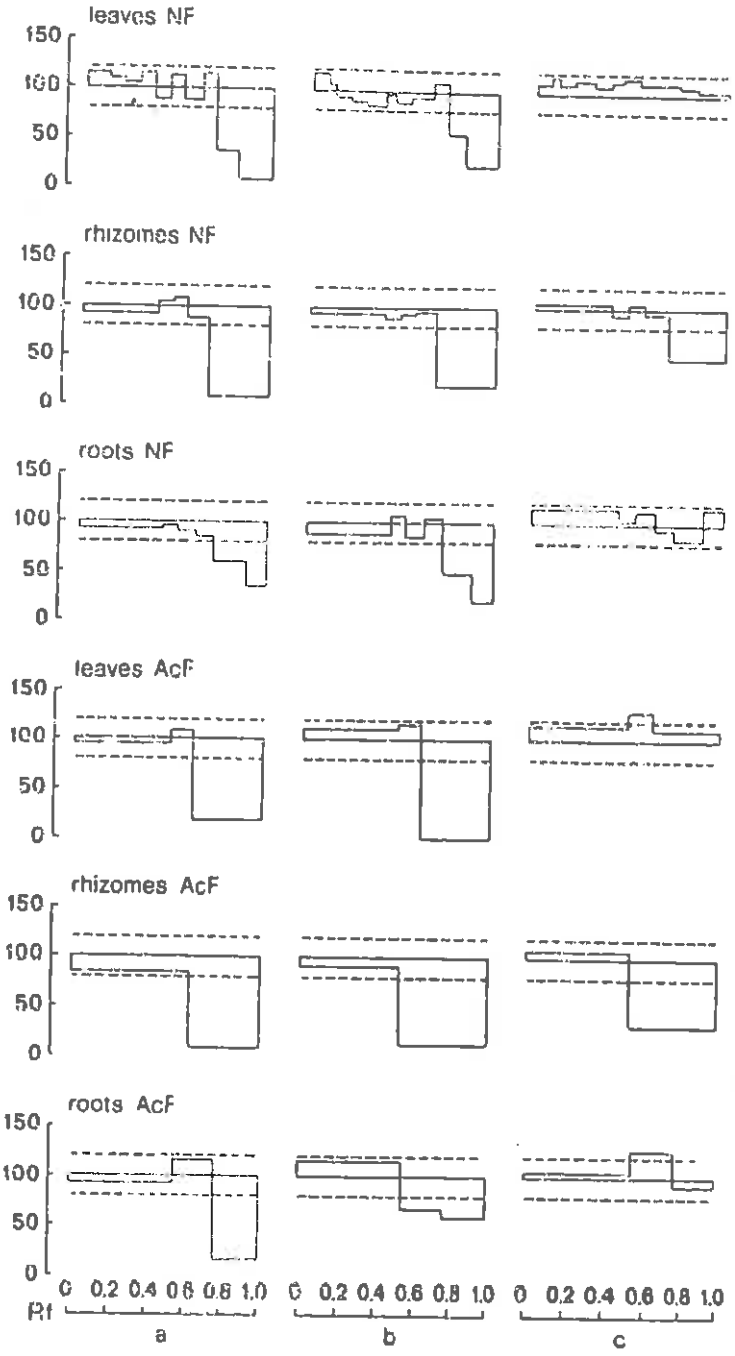

Figure 4. Biological activity of eluates of chromatograms (solvent AcAc), of the NF and AcF of the acid hydrolysates of leaf, rhizome and root extract. a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum*. Values in percentage of the control. Dotted lines: significant difference 5% level.

(Figure 3). In the NF of the leaves the inhibiting activity on shoot elongation was split up into a stimulating and inhibiting activity. The small inhibiting activity of the AcF on shoot elongation could not be recovered anymore. Instead a stimulating activity appeared to be present in the eluates of zone Rf 0.64 - 1.00. Inhibiting activity on G_{50} and root elongation was present at Rf 0.40 - 1.00 for the NF and Rf 0.62 - 1.00 for the AcF.

Shoot inhibiting activity of the NF and AcF of the root extract also could not be recovered, while the activity on G_{50} and root elongation was present in eluates of zone Rf 0.50 - 1.00. The biological activity of the NF and AcF of the rhizome extract could be recovered at Rf 0.60 - 1.00. Almost the same distribution of the biological activity on the chromatograms observed with the fractions of the original extract was observed with the fractions of the acid hydrolysates (Figure 4).

Also the distribution of the biological activity on the chromatograms of the fractions of the alkaline hydrolysates resembles that of the acid hydrolysates and the original water extract (Figure 5).

Here again the inhibiting activity on shoot elongation of the NF could not be recovered anymore. The inhibiting activity on shoot elongation of the AcF was separated into a stimulating and inhibiting activity.

Shoot inhibiting activity observed with the original fractions could be recovered from chromatograms of only a few of these fractions. With some fractions, eluates of the chromatograms even showed stimulating

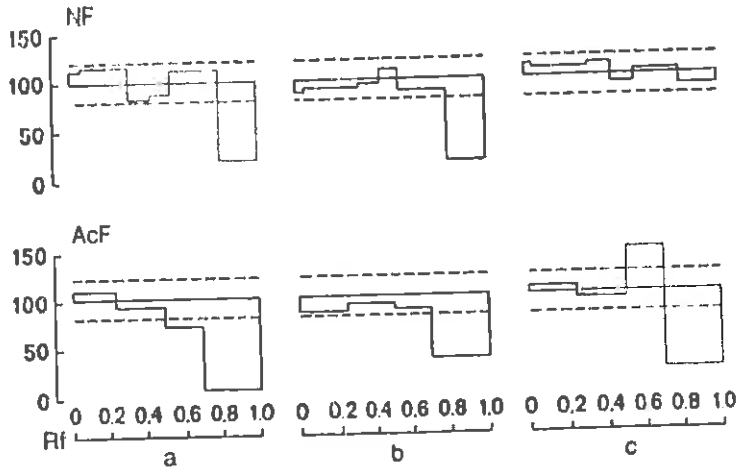

Figure 5. Biological activity of eluates chromatograms (solvent AcAc), of the NF and AcF of alkaline hydrolysates of rhizome extract. a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum*. Values in percentage of the control. Dotted lines: significant difference 5% level.

activity, when the original fraction inhibited shoot elongation. This change in type of the activity probably is caused by a decrease in concentration of the active substances due to the separation procedures. A concentration dependency of the kind of activity on shoot elongation was

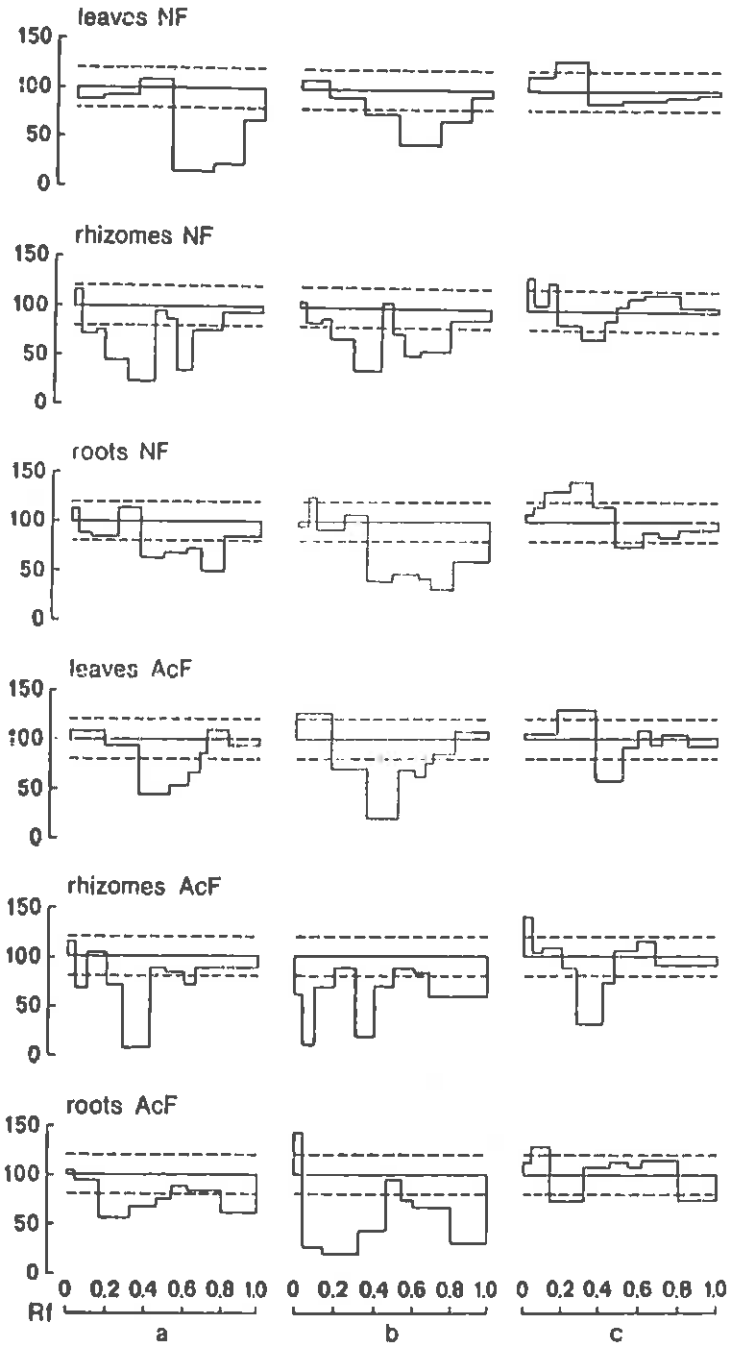

Figure 6. Biological activity of eluates of chromatograms (solvent IAW), of the NF and AcF of leaf, rhizome and root extract. a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum*. Values in percentage of the control. Dotted lines: significant difference 5% level.

found with the original water extracts (Figure 2) and could also be established with the AcF of leaf extract (Eussen and Soerjani 1976). Interactions between the active substances in the original extract may also contribute to this change in activity. In the interaction of alang-alang with other plant species shoot stimulating activity of the fractions or eluates however will have no significance as it disappears when the extract is in contact with soil (Figure 2).

Chromatograms of eluates with biological activity, developed with IAW showed more distinct zones under UV light. The biological activity was more distributed on the chromatogram with peaks of activity at certain Rf values (Figure 6, 7 and 8). In the NF of leaf extract the inhibiting activity on shoot elongation could not be recovered. A small stimulating activity appeared to be present in eluates from Rf 0.14 - 0.34. Inhibiting activity on G_{50} and root elongation was detected in the eluates from Rf 0.50 - 1.00. The AcF of leaf extract showed a stimulating and inhibiting activity on shoot elongation at respectively 0.18 - 0.37 and Rf 0.37 - 0.52. A strong inhibiting activity on root elongation was present in eluates of zone Rf 0.37 - 0.52, and smaller activities at Rf 0.16 - 0.37 and 0.52 - 0.71. The activity on G_{50} was recovered at about the same Rf values.

The distribution of the biological activity of the NF of root extract on the chromatogram resembles that of the NF of the leaf extract in that the shoot stimulating activity was recovered in eluates of zone Rf 0.08 - 0.36 and the inhibiting activity on G_{50} and root elongation was present in eluates of zone Rf 0.36 - 1.00. The AcF of roots showed two peaks of activity on G_{50} and root elongation, i.e. at Rf 0.05 - 0.46 and at Rf 0.60 - 1.00. Shoot elongation was slightly inhibited by the eluates of these zones.

Chromatograms of the NF of rhizome extract appeared to have two zones of activity on G_{50} and root elongation i.e. at Rf 0.05 - 0.42 and 0.50 - 0.78. Only a slight shoot inhibiting activity could be recovered in eluates from zone Rf 0.29 - 0.42, while the eluates from zone Rf 0.00 - 0.25 showed a slight shoot stimulating effect. On the chromatograms of the AcF three zones of activity on G_{50} and root elongation could be distinguished, i.e. at Rf 0.02 - 0.10, 0.20 - 0.42 and at 0.68 - 1.00 for root elongation and 0.50 - 0.56 for G_{50}. A strong shoot inhibiting activity was recovered at Rf 0.30 - 0.43, while eluates from zone Rf 0.00 - 0.05 showed shoot stimulating activity.

The distribution of the biological activity of the chromatograms of the acid hydrolysates is given in Figure 7. In the chromatograms of the NF of the hydrolysates of leaf extract G_{50} and root elongation were inhibited

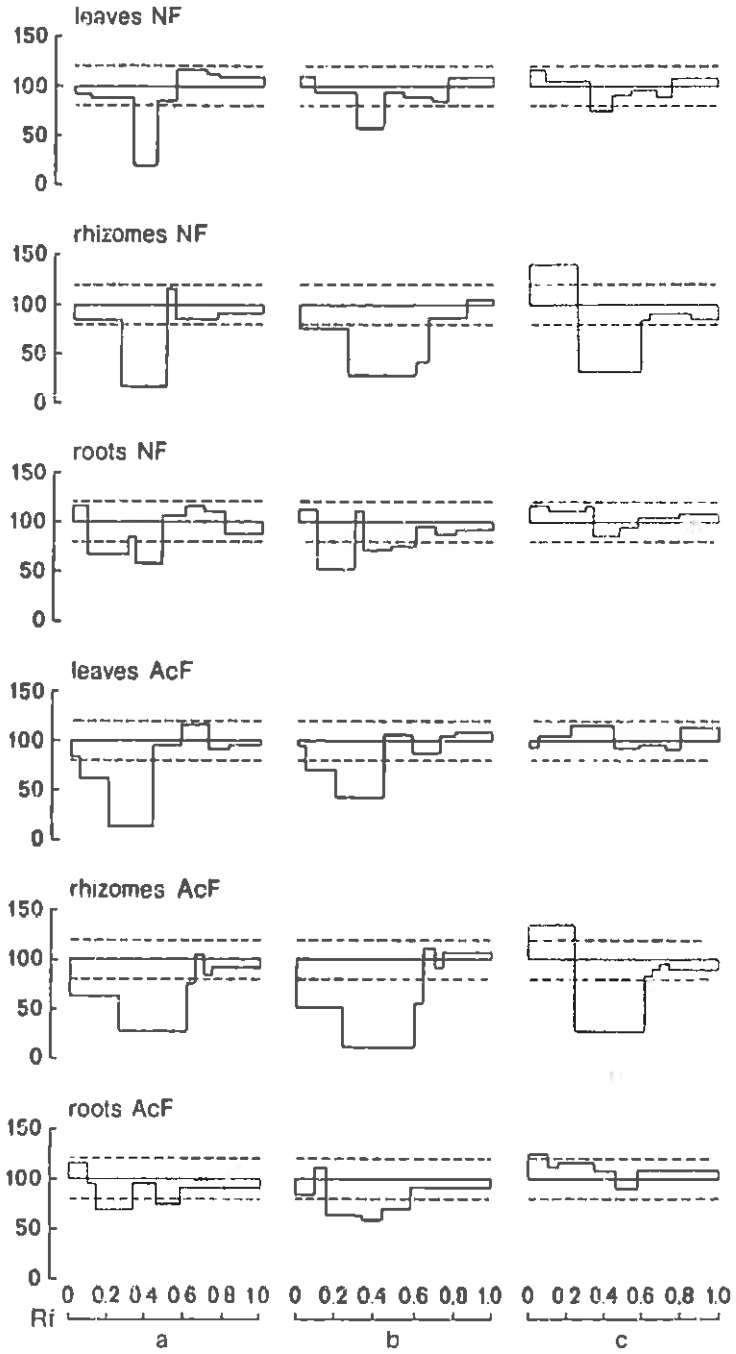

Figure 7. Biological activity of eluates of chromatograms (solvent IAW) of the NF and AcF of the acid hydrolysates of leaf, rhizome and root extract. a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum*. Values in percentage of the control. Dotted lines: significant difference 5% level.

by eluates of zone Rf 0.30 - 0.44. In the AcF this activity was recovered at Rf 0.04 - 0.46. The shoot inhibiting activity of the NF and AcF of the hydrolysate of rhizome extract was recovered in eluates of zone Rf 0.24 - 0.60 and stimulating activity appeared to be present at Rf 0.00 - 0.26. The eluates of zone Rf 0.00 - 0.62 exhibited inhibiting activity on G_{50} and root elongation. The activity on G_{50} and root elongation of the NF of hydrolysates of root extract was recovered at Rf 0.10 - 0.60. About the same areas i.e. Rf 0.16 - 0.58 of chromatograms of the AcF showed inhibiting activity on G_{50} and root elongation. Eluates of zone Rf 0.00 - 0.34 of chromatograms of the AcF stimulated shoot elongation.

Figure 8 gives the distribution of the biological activity on the chromatograms of the alkaline hydrolysates of rhizome extract. The AcF revealed two peaks of activity on G_{50}, i.e. at Rf 0.05 - 0.20 and 0.26 - 0.42, while root elongation was inhibited by eluates of Rf 0.05 - 0.42. A slight shoot inhibiting activity was recovered at Rf 0.24 - 0.42. Eluates of chromatograms of the NF of zone Rf 0.05 - 0.24 and Rf 0.34 - 0.46 inhibited G_{50} and root elongation.

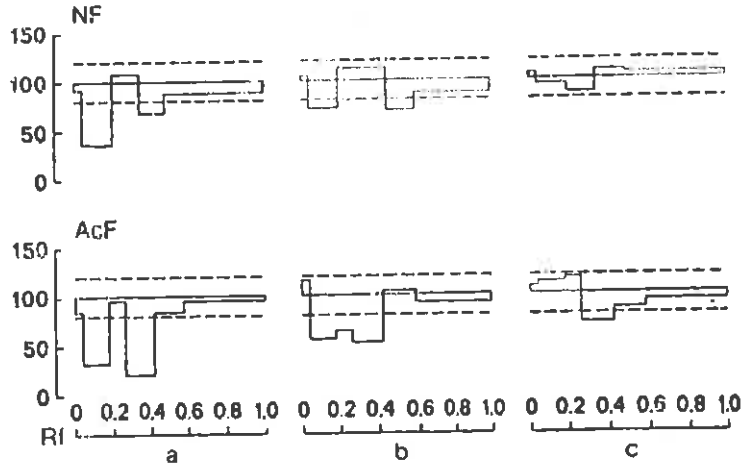

Figure 8. Biological activity of eluates of chromatograms (solvent IAW), of the NF and AcF of the alkaline hydrolysates of rhizome extract. a: G_{50}; b: root elongation; c: shoot elongation of *L. esculentum*. Values in percentage of the control. Dotted lines, significant difference 5% level.

Substances causing the biological activity of the NF and the AcF of the plant extracts behave the same when they are subjected to paper chromatography with AcAc as solvent, in this respect that they are recovered from the second half of the chromatogram. With IAW as solvent, however, the substances are more distributed on the chromatogram. Often eluates from the same area of the chromatograms of the

NF and AcF of leaf, root and rhizome extract and hydrolysates show biological activity, which may indicate that the same substances are responsible for this activity. There are, however, also differences in these substances as shown by the differences in biological activity of eluates of the same zone of chromatograms of different fractions. In the separation procedure of the substances in the extracts with paper chromatography, the displayed fluoresence pattern of the chromatograms is used as a criterion of distinction between different substances. Although in the last chromatographic separation the substances on the chromatograms may be relatively pure, the substances causing the biological activity are not necessarily characterized by this fluoresence colour. Further chemical analyses are necessary for characterization and identification of these substances.

Several biologically active distinct fractions thus could be isolated from alang-alang plant material. The active substances in these fractions may contribute to the allelopathic activity of alang-alang when they are released into the environment.

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Ecological Studies of Chrozophora rottleri A. Juss.[1]

R. S. AMBASHT[2] and BECHU LAL[3]

ABSTRACT

Chrozophora rottleri A. Juss. (Euphorbiaceae) is an annual weed of low lying areas and river banks in the Gangetic plains of northern India. The plants grow luxuriantly even in very dry summer, when most other herbaceous plants die. It is a weed of winter crops like wheat, barley, etc which are extensively cultivated on the river banks after the recession of flood water. This weed species interferes the growth of the winter crops cultivated on the river banks. Germination studies reveal that its seed requires a low temperature (10 to 20 C range) and prolonged continuous soaking in water for about 35 days for its germination. These conditions are available towards the end of the rainy season on low lying areas and river banks only. Alternating temperatures of 10 C to 20 C and 20 C to 30 C however, reduce essential soaking period to 22 days only. Percentage germination falls progressively with depth at which the seeds lie in the soil. Seed output and reproductive capacity are high. Productivity increases with the advancement of the age of the plant and the peak is found just before the fruit maturation stage although the biomass still continues to increase. Biomass attains its peak at the time fruit maturation. Seeds are heavier and are dispersed by explosion of fruits up to a few metres distance around the plant. Seeds are oily and rich in energy. Energy content (Kcal/g dry weight of the plant material) of leaf, stem and root increases up to the flowering stage and then decreases. This species dies in the month of June/July after a few showers of rain when the areas are inundated.

INTRODUCTION

C. rottleri A. Juss, is an annual weed of low lying areas and river banks in the Gangetic plains of northern India. It is distributed throughout the drier parts of India, westward to Spain and North Africa (Cooke 1908). The plant is robust and has a bushy appearance. At Varanasi (India) the plant grows mostly in the drying margins of low lying areas such as temporary ponds and on the river banks exposed after the recession of flood waters. The river banks are inundated in the rainy

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season from July to early September. By the end of September they are again exposes as the water recedes . The temperature of the soil as well as of the atmosphere begins to decrease as winter sets in after the rains. The seeds start germinating in October. Exposed banks are ploughed for raising winter crops of wheat, barley, gram etc. *C. rottleri* is a prominent weed both in cultivated and uncultivated lands on the river banks. Due to its robust and spreading habit and large leaves it shades crop plants as well as competes for soil nutrients. The crops are harvested manually and *C. rottleri* is left in the field. It continues to grow and assumes complete vegetal dominance in the summer season (March to June).

In view of the dominant nature of the weed, it was selected for detailed autecological studies. Its phenology, growth, dry matter production, nitrogen accumulation and energy content in different parts of the plants, etc have been worked out at monthly intervals from the young seedling to the fully mature stage.

MATERIALS AND METHODS

Seeds were collected from mature plants growing on the banks of river Ganga (Rajghat site) and Baruna (near Varanasi district court) in the month of May/June, 1973. For the study of germination behaviour the seeds were kept between two sheets of moistened blotting paper over a wet cotton pad in petridishes. Different temperature treatments were given by placing the petridishes in temperature controlled incubators and refrigerators. Seeds were also placed at different depths in soil to study the effect of depth on seed germination.

To study biomass and productivity of *C. rottleri* in its natural habitat, the plants were sampled at the monthly intervals from the seedling (30 days age of the plant) to the declining phase of the plant. In order to ensure correct sampling from the field with respect to their age, a large number of plants were marked at each site at the seedling stage. The dry weights of plant parts as well as of complete plants were determined. The harvested material was oven dried at 80 C for about 48 hours. The productivity (g/plant/day) was calculated from the gain in the dry weights at monthly intervals.

Energy content (Kcal/g dry weight of the plant material) was determined by Parr Oxygen bomb calorimeter using the following formula:

$$C = \frac{(W_1 \times \Delta t) + (W_2 \times \Delta t)}{W} \text{ Cal/g of oven dry weight}$$

Where C = energy content of plant material
W = weight of pellet
W_1 = water equivalent of bomb vessel (532 in present case)
W_2 = volume of water taken (1350 ml in present case)
Δt = rise in temperature

Total nitrogen of the plant was determined by using Winkler's modified method (Piper 1944) and the percent total nitrogen was calculated by using the following formula:

$$\% \text{ Nitrogen} = \frac{(T\text{-}B) \times N \times 1.4}{S}$$

Where T = volume of hydrochloric acid used in actual titration
B = volume of hydrochloric acid used in blank titration
N = normality of hydrochloric acid
S = weight of material taken (in g)

RESULTS AND DISCUSSION

(a) **Seed germination.** Seeds are dispersed from the parent plant by an explosive mechanism up to a maximum distance of three metres in May/June.[4] The seeds in nature, do not germinate immediately and remain on the ground to the end of September. However, when placed under different temperatures in continuously moist conditions, it was found that there is no dormancy and the seeds germinate after about 35 days at certain temperatures. Neither mechanical scarification nor washing in running water had any effect on germination. Three sets of 50 seeds were placed at 0 C, 10 C, 20 C, 30 C and 45 C. Sets kept at 10 C showed about 70% germination and at 20 C about 60% germination whereas in the other sets there was no germination. In another experiment seeds were kept at alternating temperature sets of 0 and 10 C, 10 and 20 C, 20 and 30 C and 30 and 45 C. In each set the lower temperature lasted 16 hours and the higher temperature 8 hours in a 24 hours daily cycle. Only in the temperature sets of 10 and 20 C and 20 and 30 C did the seeds germinate (62% and 60% respectively). In the other sets there was no germination even up to 2 months period of observation. Although the precentage germination is somewhat less than at constant tem-

[4] Lal, B. 1976. Ecology of two medicinal plants *Scoparia dulcis*. Linn. and *Chrozophora rottleri* A. Juss. Ph.D. Thesis, Banaras Hindu University, India.

peratures, it took place in a shorter period of 18 to 21 days after setting up the experiment. Dry seeds kept at low temperature for 30 to 40 days did not germinate, unless subjected to wetting at 10 to 20 C for a period of 30 to 35 days. Thus the seed germination in *C. rottleri* is regulated jointly by low temperatures and continuous abundant moisture for a few weeks. In nature, at Varanasi such conditions are obtained on

Table 1. Seed germination of *C. rottleri* at different constant and alternating temperatures.
Age of seed: fresh seeds Locality: Baruna river bank.

Temperature treatment	Days required to start germination	Germination %
(A) Constant temperatures		
C		
0	Nil	Nil
10	35	70±4.25
20	30	60±4.00
30	Nil	Nil
45	Nil	Nil
(B) Alternating temperatures		
C		
0 & 10	Nil	Nil
10 & 20	21	62±3.46
20 & 30	18	60±2.00
30 & 45	Nil	Nil

floodable lands like Ganga and Baruna river banks and lowlying areas. Since such conditions do not exist at the time of seed dispersal (May/June) at Varanasi the germination is delayed till they occur in the month of October (at river banks). Thus the low temperature requirement and soaking period needed cause an enforced dormancy in nature. This part of study explains the mechanism of the plants successful appearance on only those areas experiencing inundation for at least a few weeks.

Another feature of floodable land is silting at some places which buries seeds. Seeds of *C. rottleri* were placed at the soil surface, 5 cm, 10 cm, 15 cm depths in garden pots, and watered regularly. Germination took place in all cases but the percentage decreased from 72% at the surface to only 50% at 15 cm depth (Table 2).

Table 2. Seed germination of *C. rottleri* at different soil depths.
Age of seed: six months Locality: Ganga river bank.

Depth of sowing (cm)	Days required to start germination	Germination %
Surface	35	71.6±5.68
5	38	68.3±2.88
10	40	62.0±6.24
15	45	50.0±4.58

(b) **Biomass and productivity.** The plant biomass increases continuously up to 210 days and then declines to some extent in May and June. The plants succumb to rain and flooding in July.

Biomass increments have been estimated separately for plant parts such as leaf, stem, fruit and root. Initially the biomass of leaf was greater than that of stem and root but later the stem biomass superseded the leaf biomass. After attaining the maximum biomass the plant entered a declining phase. The maximum shoot biomass obtained for individual plants are 367.93 g at Rajghat and 293.87 g at Baruna river bank in 210 days. The biomass of the root increased for 210 days and then decreased. The maximum values of root biomass at corresponding sites obtained are 28.86 and 21.87 g/plant. Thus it is evident from Table 3 that the biomass of the root is much less than that of the shoot.

From Table 3 it is clear that total biomass at the early stages at both sites was almost equal but with the aging of the plant, the effect of environmental stresses became evident and clear variations in the biomass of the plants at the two sites developed. The decline in the biomass after the peak was mainly on account of shedding of fruits, litter fall and consumption by herbivores. Some tiny insects were also found on the lower surface of the leaves before the fruit maturation stage. These insects eat away the leaf lamina resulting in holes of various sizes and shapes.

The productivity of *C. rottleri* was at its maximum just before fruit maturation. The period just preceding the peak biomass was found to be most efficient in productivity. After attaining the peak value there is a decrease in the rate of production (Table 4) although the biomass of the plant continues to increase up to the fruit maturity stage. At the

Table 3. Monthly variations in dry biomass (g/plant) of *C. rottleri* at different sites.

Site	Plant parts	Age of sampled plants (days)								
		30	60	90	120	150	180	210	240	270
Ganga river bank	Leaf	0.470	3.767	11.200	30.620	68.400	94.100	117.830	110.450	92.500
	Stem	0.127	1.338	6.140	26.150	70.490	134.899	172.200	173.100	165.580
	Fruit	—	—	—	0.590	4.900	28.100	77.900	68.950	49.920
	Root	0.103	0.866	2.788	8.344	70.163	23.880	28.865	27.900	27.800
	Total shoot	0.599	5.105	17.340	57.360	143.790	257.099	367.930	352.500	308.000
	Total shoot +root	0.700	5.971	20.128	65.704	160.953	280.979	396.795	380.400	335.800
Baruna river bank	Leaf	0.490	3.280	9.000	23.420	52.260	82.690	100.725	89.500	63.240
	Stem	0.120	1.240	5.860	18.750	50.200	95.800	130.900	132.200	120.100
	Fruit	—	—	—	0.334	3.500	18.470	62.250	57.100	40.560
	Root	0.110	0.852	2.288	6.800	13.695	17.825	21.874	21.519	21.500
	Total shoot	0.610	4.520	14.860	42.504	106.060	196.960	293.875	278.800	223.900
	Total shoot +root	0.720	5.372	17.148	49.304	119.755	214.785	315.749	300.319	245.400

Each datum is average of three readings.

Table 4. Monthly variations in productivity (g/plant/day) of *C. rottleri* at different sites.

Sites	Plant parts	Age of plants (days)								
		30	60	90	120	150	180	210	240	270
Ganga river bank	Shoot	0.019	0.150	0.407	1.334	2.881	3.776	3.694	0.514	1.483
	Root	0.003	0.025	0.064	0.185	0.327	0.223	0.166	0.032	0.003
	Total shoot + root	0.022	0.175	0.471	1.519	3.208	3.999	3.860	0.546	1.486
Baruna river bank	Shoot	0.020	0.130	0.344	0.921	2.118	3.030	3.230	0.502	1.830
	Root	0.003	0.024	0.047	0.150	0.229	0.137	0.134	0.011	—
	Total shoot + root	0.023	0.154	0.391	1.071	2.347	3.167	3.364	0.513	1.830

Table 5. Monthly variations in energy content (Kcal/g dry weight) of plant part of *C. rottleri* at different sites.

Site	Plant parts	Age of plants (days)								
		30	60	90	120	150	180	210	240	270
Ganga river bank	Leaf	3.882	3.974	4.101	4.335	3.774	3.697	3.650	3.580	3.435
	Stem	3.760	3.885	3.919	4.135	3.840	3.758	3.690	3.625	3.405
	Fruit	—	—	—	—	4.363	4.450	4.510	4.600	4.658
	Root	3.760	3.810	3.925	3.980	4.063	4.020	3.936	3.930	3.856
Baruna river bank	Leaf	3.657	3.720	4.000	4.200	3.625	3.380	3.526	3.475	3.442
	Stem	3.500	3.680	3.750	4.010	3.436	3.380	3.310	3.266	3.248
	Fruit	—	—	—	—	4.238	4.400	4.552	4.580	4.635
	Root	3.458	3.580	3.789	3.820	3.890	3.863	3.814	3.750	3.796

mature stage the rate of production also declines due to a reduced rate of photosynthesis since chlorophyll and water contents decrease at this age. Woledge and Jewiss (1969) observed the decrease in the rate of photosynthesis with increase in age of *Festuca arundinacea*.

(c) **Energy content.** The energy content per gram dry weight of the leaf and fruit of *C. rottleri* is greater than that of the stem and root. Energy values of plant parts ranged between 3.248 to 4.658 Kcal/g plant material. The energy content of the leaf and stem increased for 210 days (early flowering) and of root for 150 days only (Table 5).

Table 6. Monthly variations in percentage nitrogen content in plant parts of *C. rottleri* at different sites.

Plant	parts Sites	Age of plant (days) 30	60	90	120	150	180	210	240	270
Ganga river bank	Leaf	2.56	2.70	2.84	3.10	3.06	3.00	2.86	2.75	2.20
	Stem	0.90	0.97	1.10	1.16	1.25	1.05	0.94	0.80	0.72
	Fruit	—	—	—	—	1.80	1.86	1.95	2.00	2.00
	Root	0.63	0.66	0.75	0.78	0.80	0.75	0.68	0.62	0.59
Baruna river bank	Leaf	2.50	2.62	2.80	2.95	2.98	2.85	2.70	2.56	2.31
	Stem	0.85	0.95	0.99	1.18	1.30	1.26	1.16	1.05	0.82
	Fruit	—	—	—	—	1.60	1.75	1.81	1.85	1.96
	Root	0.50	0.56	0.65	0.66	0.68	0.61	0.58	0.52	0.48

The energy content of plant material depends upon the quality and quantity of organic compounds it contains. Energy is chiefly stored in the form of carbohydrates, proteins, and fats in the plant body. Seeds of *C. rottleri* are rich in oil and hence richer in energy than other plant parts. The energy content of this species is correlated with the age of the plant and the change in environmental temperature (during the life period of the plant). Low temperatures favours the synthesis of fat following decrease in carbohydrate (McNair 1945) and this may be the reason for the higher energy values of leaf, stem and root of *C. rottleri* up to flowering stage (up to middle of February) as there is a fall in climatic temperature during the first 150 days of the plant life on river bank. Golley (1960) has also observed that plants growing at low temperatures have higher caloric value on per gram basis.

The decrease in energy content per gram of leaf and stem of *C. rottleri* after 120 days also indicates that from these plant parts there is a translocation of energy rich material to the newly formed flowers and fruits resulting in the storage of maximum quantity of energy in seeds.

(d) **Nitrogen content.** Nitrogen content (%) in *C. rottleri* varied in plant components at different sites and age of the plant. In the early stage there was an increase in nitrogen content (up to about 150 days) but after that there was a decrease (Table 6). Leaves and fruits contained greater percentages of nitrogen than stems and roots. The decrease in the percentage nitrogen content in plant parts after the flowering stage is due to the translocation of nitrogen from older leaves and stem tissues to newly formed flowers and fruits. Midorikawa (1959), and Davy and Taylor (1975) have also observed an increase in percentage of nitrogen in younger and newly formed tissues of plants. The highest accumulation of nitrogen in leaves is due to its active metabolic state. Nitrogen content is less in stem and least in root. Nitrogen is an important mineral element for the growth of the plant, specially of the leaves. It is an essential constituent of proteins, chlorophyll and protoplasm. Since this weed species grows along with agricultural crops in winter it also deprives the crop of the quantity of the nutrient available in the soil. On the basis of data on the plant density and quantity of nitrogen in each adult plant, it is estimated that *C. rottleri* takes up about 0.2 tons/ha of nitrogen at Ganga River Bank and 0.27 tons/ha of nitrogen at Baruna River Bank.

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Competitive Ability of Echinochloa colonum L. Against Direct-Seeded Lowland Rice

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ABSTRACT

The average natural density of *Echinochloa colonum* L. in most rainfed direct-seeded rice areas of Central Luzon in the Philippines in 280/m² or 2.8 million plants per hectare. Drill-seeded rice suffered considerable reduction in yield when the weed was present at a density of at least 80/m² during the first 40 days after seeding. With the rice variety used competition appears keen for light as the weed grows taller than the crops. Maximum tillering capacity occurred during the first 40 days of cropping. It produced more tillers than rice and yielded about 42,000 seeds/plant. The seeds which were shed successively, beginning at the seventh week, remained dormant for some time.

INTRODUCTION

To increase rice production in the country, the Philippine government has pushed the direct-seeded rice program in rainfed areas. The system intends to take full advantage of the rainfall in the area. In either drill-seeded rice or broadcast-seeded fields, weeds become a very serious problem. Whereas a farmer can easily ignore the weeds in irrigated transplanted rice, it is quite impossible to do so in a direct-seeded rice field. The absence of flooding and the simultaneous germination of rice and weed seeds makes direct weed control measures imperative to obtain optimum yield in this type of rice culture.

In most of the direct-seeded rice areas in the Philippines, *E. colonum* is either the predominant weed or the only weed species present. *E. colonum* is an annual grass, closely resembling the rice plant at the seedling stage. Known in English as jungle rice it is distinguished by a red or purple coloration at the base of the shoot. Holm and Herberger (1969) consider it as number 4 in his list of the world's worst weeds. Highly adaptive, it can thrive both in flooded and non-flooded or upland conditions. The natural density of *E. colonum* in the experimental area in Bulacan,

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a province in the central part of the Luzon island, averages 280/m² or 2.8 million plants per hectare. Just how competitive this weed is, is the subject of the present paper.

MATERIALS AND METHODS

Rice seeds, cv-22, were drill-seeded at the rate of 80 kg/ha in a rainfed farmer's field in the Bulacan province during the wet seasons of 1975, and 1976. Different densities of *E. colonum* were allowed to grow with the rice. The densities were maintained by weekly hand weeding up to 40 days after seeding. Recommended fertilization rate and control measures for insect pest control were followed. Each density was replicated three times in a randomized complete block design.

To follow the growth behavior of *E. colonum*, seedlings at the two-leaf stage (1 week old) were transplanted to four no. 16 earthen pots, 1 plant/pot, in saturated lowland soil. The pots were kept outdoors. Height and tiller number were taken weekly, together with the total number of seeds produced at maturity.

For the seed population in the soil, soil samples, 10 cm deep were taken and placed in half kerosene cans. The number of *E. colonum* seedlings that emerged were counted for 10 weeks.

RESULTS AND DISCUSSION

Table 1 shows how *E. colonum* when present in the different densities, affected the yield of rice, during the first 40 days of the crop. The first 40 days is considered as the critical period of competition for this

Table 1. Yield of rice when grown with different densities of *Echinochloa colonum* L.

Density/m²	Yield	
	Kg/ha	Percent reduction
0	4158.1	
10	4080.0	1.8
20	3942.6	4.9
40	3858.2	7.2
80	3006.4	25.2
120	2556.9	39.0
160	1521.0	63.4
280 (natural vegetation)	996.8	75.9

crop (Arai 1967). Compared with *E. crus-galli* in transplanted rice, *E. colonum* appear less competitive. Lubigan and Vega (1971) reported the critical threshold of *E. crus-galli* to be below 20/m². In the studies conducted, significant reduction in yield due to *E. colonum* is apparent only at a density of the least 80/m². Such a figure may be quite consoling but when one looks at the natural vegetation there were 280/m², more than 3 times that which can be allowed to grow with rice.

Judging from the similarities in morphology between rice and *E. colonum* keen competition for nutrients, water and light can be expected. Just how much the natural vegetation of *E. colonum* reduced some of the agronomic characters of rice during the first 40 days, including nitrogen uptake, leading to reduced yield is shown in Table 2. Tiller number and

Table 2. Tiller number, height, leaf number and nitrogen percentage in rice as afected by the natural vegetation (280/m²) of *E. colonum* 40 days after seeding.

	Tiller number	Height	Leaf number	Percent nitrogen
Rice alone	8.8	65.6	34	1.54
Rice + *E. colonum*	8.3	62.8	27	1.29

height were not affected by weeds but leaf number was reduced by 18.4%. Although the percent nitrogen was only slightly reduced, the total nitrogen, if based per plant or per entire shoot, would show a more considerable reduction. Rice height was only slightly affected but weed height was more than 70 cm, a good 7 to 8 cm above the crop. Hence, competition for light may be very keen between the crop and the weed. This is further aggravated by the greater number of leaves produced by the weed.

When planted alone in pots *E. colonum* produced more tillers but did not grow as high as when grown in competition with rice under field conditions (Table 3). At 6 weeks, 10 tillers were produced per plant but height was only 32 cm as compared to 6 tillers and height of 70 cm under field conditions. The maximum tillering capacity of the weed took place within four to six weeks which coincided with the critical period of competition for rice.

Table 3. Height and tiller number of *Echinochloa colonum* at different stages of development.

Age (weeks)	Height (cm)*	Tiller number
2	15.2	1
3	14.5	1
4	20.2	2
5	24.5	7
6	31.3	10
7	35.8	12
8	41.7	16
9	47.0	15
10	48.0	17
11	48.2	18
12	47.8	22
13	47.8	25
14	47.0	24
15	46.3	24

* Average of 4 replications.

The high density of *E. colonum* in the field during the cropping season can be attributed to two possible causes; one the tremendous number of seeds produced per plant, the production starting as early as 7 weeks after seeding; second, the dormancy of the newly shed seeds.

Counts made on seed production revealed an average of 42,758 seeds produced per plant within 16 weeks. Newly mature seeds did not germinate readily either on filter paper or on soil. Although the dormancy period was not determined, it may possibly follow a similar pattern as that of *E. crus-galli* which requires at least 4 months dormancy period (Brod 1968).

The relatively high density of *E. colonum* without reduction in yield indicated the relatively greater competitive power of rice against *E. colonum* than other weeds such as *E. crus-galli* and *Scirpus maritimus*. Such power can be further increased if the rice variety grown would be taller than the weed (Lubigan and Mercado 1974).

Measures that can effect approximately 70% control of the present natural *E. colonum* vegetation would be satisfactory on a temporary basis. However, because of its high reproductive potential, the density to be allowed per growing season should be much lower than what appears to be the critical threshold level in order to gradually reduce its abundance in a particular field.

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The Effect of Genotype and Phenotype on the Competition between Wheat and Annual Ryegrass (Lolium rigidum Gaud.)

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ABSTRACT

Visually, annual ryegrass (*Lolium rigidum* Gaud.) and other weeds appear to have more damaging effects in the newly introduced wheat cultivars of semi-dwarf parentage, than in the taller 'traditional' cultivars. If this is the case, the superior grain yields of semi-dwarf cultivars exhibited under the weed-free conditions of breeders plots, could well be nullified in weedy environments. In this experiment the competitive abilities of 29 wheat cultivars were measured in the presence of annual ryegrass. There were significant ($P < 0.05$) differences between cultivars; yield reductions at a ryegrass density of 1500 plants/m^2 ranged from 23.1% to 47.8%. These differences in competitive ability could not however be attributed to any measured parameters, namely, cultivar height, tiller number, dry matter production, spikelet number or grain yield level. There was little evidence to suggest that cultivars of semi-dwarf parentage and/or type were more affected by ryegrass than were the 'traditional' cultivars.

INTRODUCTION

Theoretically weeds could be more damaging in shorter crops due to increased light competition. As Australian wheat breeders have been selecting for short straw for many years, some new wheat cultivars are semi-dwarf, that is around two-thirds the height of the older cultivars (Fisher and Martin 1974). Visually, weeds particularly annual ryegrass appear to have more damaging effects on these shorter cultivars than on taller cultivars. If this is the case, the superior yields of semi-dwarf cultivars exhibited under weed free conditions could well be nullified in weedy environments.

A preliminary experiment (Reeves 1976) indicated that there were no differences in ability to compete with ryegrass, amongst four Australian wheat varieties. It was considered however that this result may have been due to inherent similarities in the varieties used. Consequently a further experiment was conducted involving the screening of a large number of wheat genotypes under a range of ryegrass densities. This paper reports the results of that experiment.

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MATERIALS AND METHODS

The experiment was conducted in 1975 at the Rutherglen Research Station situated in N.E. Victoria, Australia. Soil type at the site was Rutherglen loam (Poutsma and Skene 1961), Dr. 3.13 (Northcote 1965). This soil is typical of the wheatgrowing soils in northern Victoria.

Total rainfall for the growing season (May-November) at Rutherglen in 1975 was 491 mm.

Twenty-nine cultivars seeded at 85 kg/ha with 15 kg/ha of phosphorus were sown with a drill. These cultivars (see table 2) consisted of 10 with a maturity height of less than 80 cm, 10 with a maturity height of 80 to 100 cm, and 9 greater than 100 cm.

The six ryegrass densities used (D0 to D5) are shown in Table 1.

Table 1. Ryegrass densities obtained under the wheat cultivars *

Treatment	Ryegrass density plants/m²
D0	0
D1	82
D2	117
D3	925
D4	1087
D5	1737

* Main effects only shown as there were no cultivar x density interactions.

These were obtained by drill broadcasting quantities of seed immediately after the wheat was sown and lightly harrowing it into the soil. The experimental design was a randomized block, split plot, with cultivars as the main plots and ryegrass densities as the subplots. There were four replicates.

The plot size was 2 m by 2 m, but to avoid possible edge effects only 1.8 m by 1.2 m were used for measurements. Ryegrass was counted in 3 quadrats (of 0.9 m²) per subplot, additionally wheat and ryegrass were sampled at maturity, 1 m drill row × 0.18 m per plot. These samples were used to determine wheat and ryegrass dry matter production, wheat fertile tiller production and wheat spikelet number per ear. Individual replicate data for the grain yield of each cultivar was fitted to a regression equation of the form:

$$Y = a + bD + cD^2$$

where Y was grain yield reduction expressed as a percentage of the weedfree control, and D was the ryegrass density (plants/m^2).

These relationships were used to derive percentage wheat yield reduction at 3 selected ryegrass densities — 100 plants/m^2, 1000 plants/m^2 and 1500 plants/m^2. Preliminary analyses indicated that similar trends in results were obtained at each of these densities, but as there was less variability about the data at the highest density — 1500 plants/m^2, these values were selected as a measure of competitive ability. Accordingly the values obtained were then subjected to analysis of variance, 29 treatments $\times$ 4 replicates and Duncan's Multiple Range test was used to rank the differences between cultivars.

Additionally, in an attempt to determine the reasons for any differences obtained, percentage wheat grain yield reduction was regressed against cultivar height (at maturity), grain yield, wheat dry matter production, fertile tiller number and spikelet number (all at D0).

RESULTS AND DISCUSSION

There were significant differences ($P<0.05$) between the wheat cultivars examined in their ability to compete with annual ryegrass. Grain yield reductions obtained at a ryegrass density of 1500 plants/m^2 ranged from 23.1% to 47.8% (Table 2). The effect of ryegrass on the grain yield of cultivar S3 (yield reduction 47.8%) was significantly greater than its effects on the cultivars M9, M5, T3, T10, T8, T5, T4 and T7 (yield reductions 23.1% to 28.8%); there were no differences between the other cultivars.

No significant correlations were obtained between yield reduction and the other variables measured, namely, cultivar height, dry matter production, fertile tiller production, spikelet number, or grain yield although there was a trend for yield reduction to increase as level of yield increased (CD 36.1%). Mean yield reductions of the 15 cultivars with semi-dwarf parentage did not differ greatly from the other cultivars — 35% and 30% respectively. It is interesting however to consider the differences between cv S3 and the eight 'significantly different' cultivars which could possibly have contributed to their relative competitive abilities. Table 3 summaries the measured parameters of cv S3 and mean values for the 'different' cultivars.

Table 2. Yield reduction, pedigree, height and grain yield of the wheat cultivars.

Cultivar		Pedigree *	Height cm	Grain † yield t/ha	% Yield reductions at 1500 RG/m²
S3	—	T × SD	60	3.22	47.8a
S2	—	SD × SD	56	2.58	41.7ab
M7	MX-27	SD × SD	96	3.07	41.6ab
M4	DX3-51	SD × SD	96	3.80	41.0ab
M1	TEAL	T × T	96	3.98	40.2ab
S8	—	SD × SD	62	2.32	39.8ab
S1	—	SD × SD	58	2.33	37.5ab
S9	—	SD × SD	60	2.21	37.4ab
M3	HL21	T × T	112	2.89	35.9ab
T2	ZENITH	T × T	100	2.09	35.5ab
M10	GL55	T × T	110	3.12	35.4ab
S7	—	SD × SD	70	2.62	35.4ab
M2	EAGLE	T × T	112	2.74	35.3ab
M6	DX6-97	SD × SD	88	2.78	32.6ab
S6	—	SD × SD	66	2.06	32.0ab
T6	W5892 YJ151	T × T	106	2.69	31.0ab
T9	W5801XH119	T × T	116	2.45	30.4ab
M8	OLYMPIC	T × T	108	2.70	30.4ab
S5	—	SD × SD	60	2.17	30.3ab
S4	—	SD × SD	58	2.02	29.5ab
S10	—	SD × SD	76	1.62	29.4ab
T7	W5918ZK279	T × SD	112	2.05	28.8b
T4	SUMMIT	T × T	100	1.83	27.2b
T5	W5924ZK15	T × SD	98	2.19	26.4b
T8	TARSA	T × T	120	1.77	25.5b
T10	W5892 YJ184	T × T	100	2.80	24.4b
T3	W5681XH23.5	T × T	98	2.20	23.8b
M5	SHERPA	T × T	104	3.11	23.1b
M9	GAMBEE	T × T	100	2.27	23.1b

— Computer number only

* T = 'Traditional' variety SD = semi dwarf

† Yield of DO treatment

Values in the one column with the same postscript letters do not differ ($p > 0.05$).

Table 3. Agronomic characteristics of cv S3 and 'significantly different' cultivars.

Cultivar	Height** cnr	Fert. Tillers† /M.D.S.	DM† Prod^N Kg/ha	Spikelets/ ear†	Grain Yield† t/ha
S3	60a	52.8a	5854a	14.3a	3.22a
* 'Different'	104b	44.9b	6684a	13.7a	2.02b

* Mean values of. cvs M5, 9, T3, 4, 5, 8 and 10
** At maturity
† At D0

Values in the one column with the same postscript letter do not differ ($P > 0.05$)

As both Smith and Levick (1974) and Reeves (1976) found that the damaging effects of ryegrass on wheat were mainly restricted to the pre-tillering period, it would be surprising if the differences in mature hight of these cultivars contributed greatly to their different competitive abilities, as there were no height differences at tillering, (visual observation).

The other significantly different features were fertile tiller production and grain yield ($P < 0.05$). It can be seen that cv S3 was a freely tillering, high yielding line compared to the 'different' cultivars. As neither of these parameters were highly correlated with yield reduction (CD's 0.04% and 36.1% respectively), it must be assumed that some other unmeasured parameter contributed to the differing yield reductions. It is possible that differences in root development and production were involved, as Smith and Levick (1974) found that competition between ryegrass and wheat was mainly for soil nitrogen. Further experimentation is investigating this aspect of root growth.

The experiment set out to investigate whether wheat cultivars differed in their ability to compete with annual ryegrass. Differences were successfully demonstrated, but the causes for these differences have yet to be ascertained. There is however little evidence to support the theory that cultivars of semidwarf growth habit are more affected by ryegrass than the 'traditional' cultivars.

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Critical Period for Weed Competition for Potatoes in Java

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ABSTRACT

A brief description is given of the cultivation of potatoes in Java, Indonesia. A field trial on the control of weeds in this crop showed that losses due to weeds can amount to around 20%. When the potatoes were kept weed free for the first four weeks after planting, there was no significant reduction in yield.

INTRODUCTION

The potato (*Solanum tuberosum* L.) is successfully cultivated at altitudes greater than 1000 metres above sea level in various regions of Java. According to the available data (Anon 1975) potato production in 1974 reached about 136 thousand tonnes, harvested on around 13,000 hectares. This accounted for about 20% of the total highland vegetable production. Potatoes, after cabbage, are the second most important highland vegetable crop on Java and are a very profitable crop, with profits ranging from 25 to 50% of the total production costs.

After planting, the potato generally takes about 10 days to emerge. Earthing up and ridging is usually done 25 to 30 days after planting or when the plants are 10 to 15 cm high. In the rainy season, earthing up is sometimes repeated 45 to 55 days after planting. After 80 to 90 days the foliage dies and harvesting takes place 90 to 100 days after planting. All weeding is done by hand, usually at the same time as earhing up. Recent surveys showed that this weeding takes 20 to 30% of the farmer's time, but accounts for only 2 to 6% of the total production cost. This is due to predominantly low wages in the rural areas and comparatively high costs of fertilizers and pesticides.

Pests and diseases cause considerable losses and consequently substantial attention is being paid to them (Eveleens and Vermeulen 1976). Much less attention is being paid to weed control. However, losses due to weeds are worth considering. In India, Mani *et al* (1968) found that weeds can reduce potato yields by as much as 25 to 35%. In the same

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country, Moolani and Agarwal (1967) and Mehrota *et al* (1969) described promising results from using herbicides in potatoes. Also in other tropical parts of the world herbicides have given satisfactory results (Kasasian and Seeyave 1967, Ramirez and Mata 1974). In contrast to this, in Indonesia, Susilowirjono and Satsyati (1976) found no significant competitive effects of weeds on the growth and yield of potatoes. A post emergence application of metribuzin however, appeared to increase the yield.

The present experiment was conducted at the Horticultural Experimental Station Segunung, West Java, at an altitude of 1100 m on an andosol soil type. Two aspects of cultural practices regarding weeds were evaluated:

1. Before planting, the effect of the common practice of burying weeds in groves or holes before cultivation.
2. After planting, the effect of keeping the potatoes weed free for the first four weeks, when the crop is expected to be most vulnerable to competition.

MATERIALS AND METHODS

The potato variety Rapan 181 was used. Stable manure was applied at a rate of 25 t/ha and mineral fertilizers applied at the rate of 120 kg N, 120 kg P_2O_5 and 130 kg K_2O per hectare in the form of urea, "TSP" and "ZK" respectively. Dominant weeds in the trial were the grasses *Eleusine indica* and *Panicum repens* and the broad leaved weeds *Galinsoga parviflora* and *Polygonum nepalense*.

The experiment was set up in a split-plot design with four replications. The main treatments were:

A_1 Removal of weeds before cultivation.

A_2 Burying weeds before cultivation in 40 cm deep groves, 70 cm apart, at a rate of about 15 to 20 t/ha fresh weight.

The sub-treatments consisted of:

B_1 Weed-free during the life of the crop by handweeding every two weeks.

B_2 Weed-free until four weeks after planting by handweeding twice.

B_3 No weed control.

The plot size was 4.8×5.6 m.

For treatment A_2 the fresh weeds in the groves were covered with some soil and the manure and artificial fertilizer deposited on this. Then more soil was added until the surface was level and seed potatoes were

planted in a row on top and covered with about 10 cm of soil. The planting distance in the row (on the grove) was 30 cm. For treatment A_1 the planting was the same, except that weeds were removed. Every two weeks the height of the plants was measured and the percentage of soil cover noted. At harvest time, 0.21 m^2 weed samples were taken at random in every plot and their dry weight determined. Planting was in May 1976 and harvesting and grading was done 100 days later. Pesticides to control fungi and insects were routinely applied.

RESULTS AND DISCUSSION

The results presented in Table 1 indicate that the main treatments had no significant influence on the yield of potatoes or the growth of weeds. However, the yield from the plots where the weeds were buried tended to be lower.

Table 1. The Effects of weed removal (A_1) or burying weeds in groves before cultivation (A_2) on the yield of potatoes and growth of weeds.

Treatment	Mean yield of potatoes, kg/27 m^2	Dry weight weed sample at harvest time, g/0.21 m^2
A_1	47.3 a	38 b
A_2	43.1 a	60 b
	SSD = 7.8	SSD = 30

Figures followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

Table 2 shows that potatoes weeded through the whole growth cycle yielded 47.9 kg/plot, equivalent to 18 t/ha. With no weed control yield was reduced by 22%.

The yield from the plots where weeds were buried tended to be lower, this might have been due to the production of toxic substances by the fresh decomposing plant material (Patrick *et al* 1963). This factor however, might also be negligible due to the possible rapid breakdown of these compounds (Patrick *et al* 1964). Further, in these plots there might have been a temporary inavailability of minerals due to microbial fixation. Microbial activity is known to increase following addition of

fresh plant material to the soil. In the plots where the weeds were buried, there likewise might have been an increased competition from weeds, following rapid regeneration of weed fragments. As indicated in Table 1, the dry weight of the weeds of these plots was considerably higher than in the plots where the weeds were removed before cultivation.

Table 2. The effects of weeding (B_1), weeding for the first four weeks (B_2) and no weed control (B_3) on the yield of potatoes and growth of weeds.

Treatment	Mean yield of potatoes, kg/27 m²	Dry weight weed sample at harvest time, g/0.21 m²
B_1	49.9 a	—
B_2	46.8 a	29 c
B_3	38.8 b	70 d
	SSD = 6.4	SSD = 23

Figures followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

The absence of significant difference in yield between treatments B_1 and B_2, coupled with a significantly lower yield in treatment B_3, suggests that the most critical period for weed competition for potatoes in Java is in the first month after planting.

The results of this experiment indicate that it is important for potatoes to be weeded in the first four weeks after planting. In general, a good potato crop will reach a soil coverage of 30 to 55% or more, in four to five weeks, depending on planting distance and cultivar. After six weeks this can be 70%. In this experiment it was around 50% at six weeks. Survey data has shown that the light under the canopy will then be reduced by 60 to 95%. So weeds emerging after the first four weeks will have less chance of competing. This implies that the sooner a dense and closed canopy is reached, the less severe competition from weeds is likely to be. In this respect, choosing the planting distance and variety in relation to early emergence and dense canopy are important factors (Yip *et al* 1974). In suboptimal conditions, however, the canopy might not always be dense and in India Chakraborty (1971) found that mulching of potatoes after earthing up was one of the best methods of controlling weeds and it improved the yield.

The use of herbicides in weed control in potatoes in Java has not yet been tried on a wide scale, and it is expected that at the moment their commercial use would be limited due to their high prices and the technical problems of application.

After this initial trial, more work remains to be done with regard to different time intervals for weeding, seasonal differences, different varieties and planting distances.

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Dealing with Damage from Herbicides in Horticulture

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ABSTRACT

Herbicides are useful agricultural tools, but the careless use of herbicides close to susceptible horticultural crops can easily be the cause of damage, due to inherent biological activity, persistence and lack of selectivity which are characteristic properties of many herbicides. Some of the symptoms of reaction to exposure to herbicides by sensitive plants may be confused with the responses to certain environmental factors or to inroads by pathological agencies such as diseases or insect infestations. It is therefore important to identify the cause of any abnormality and a checklist is provided for guidance when investigating allegations of damage suspected to have been caused by herbicides. Where herbicides are shown to have been responsible, the relatively few available remedies for minimising the effects of damage are discussed.

INTRODUCTION

The use of herbicides throughout the world is continuing to increase. As their useful properties are becoming more widely recognised and appreciated, herbicides are finding more widespread use, especially in the area of food production.

The attractive features of herbicides are succinctly covered by Crafts (1975) as high phytotoxicity, selectivity in many mixed plant communities, low cost, convenience of formulation and application, and low human toxicity. However some properties such as selectivity and persistence in the soil or plant tissue can be undesirable and embarrassingly expensive if herbicides are applied carelessly, particularly if used close to susceptible crops which have economic value. Furthermore herbicide sprays can drift downwind or their residues can be washed into areas where desirable crops might be growing. Symptoms of abnormal growth in sensitive plants may appear and be ultimately identified as "damage" if plant health suffers or the quantity or quality of crop yields is depressed.

Significant damage caused by herbicides in horticultural situations usually occurs unwittingly. Problems generally arise through the use of herbicides by unskilled hands, or from inadequate planning, or from carelessness. Closer settlement in many areas of intense (and diverse)

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cultivation naturally increases the risks associated with spray application when hydraulic or airblast equipment is used. Very small floating droplets are readily produced and when carried on air currents these droplets can be unintentionally responsible for reactions displayed by crop plants located downwind from spraying operations.

HOW DO PLANTS REACT?

The visible symptoms of herbicidal damage in sensitive plants usually are seen initially in the form of abnormalities such as wilting, yellowing or distortion of foliage. In cases of gross exposure of such plants to a herbicide, death may occur a few weeks later. However, damage may not necessarily be obvious in the form of visible symptoms. In cases of herbicidal spray drift at low concentrations, exposure may simply result in slower growth or be responsible for low yields or small fruit or premature senility at a later date.

With some plant species, especially woody plants and perennials, and notably with contact herbicides, damage may be of brief duration. It may be nothing more than an unsightly malformed appearance from which plants eventually recover as distorted leaves fall off. The cure is patience, which costs nothing. On the other hand, the residues of slow-acting systemic herbicides in herbaceous crops may cause long-term damage, taking the form of semipermanent stunting or depressed harvest or even death. In such an event it may well be advisable to replace all badly affected plants or even replant completely with another crop. The consequence of damage is expense in one form or another and someone has to pay — farmer, culprit, or possibly an insurance company. Intangible expenses can also be incurred — lost time, innumerable phone calls and plenty of discussion, as well as strained relationships between farmers, agents and contractors.

The normal symptoms of reaction to exposure to commercial herbicides in most common weeds and crop plants are well described and illustrated in weed control literature such as Crafts (1975), Kasasian (1971) and Fryer and Makepeace (1970). However, the degree of development and the interpretation of such symptoms can vary considerably. The main factors responsible for variation in appearance and extent of symptoms in an individual plant species are the particular chemicals used and the amount of herbicide taken up. The differences in sensitivity between varieties and the duration of exposure are also important. Of slightly less significance are the different stages of growth

and nutritional vigour of the crops exposed and the seasonal growth patterns of such crops at different times of the year.

SOME SYMPTOMS CAN BE CONFUSED

It is important to remember, as pointed out by Williams *et al* (1973) that there are several natural agencies — entomological, pathological, nutritional and genetic, that can cause abnormal symptoms which are similar at first glance to those induced by exposure to herbicides. These causal agents are few but their effects, as shown by the following examples, can be profound:

(a) **Malnutrition.** Various mineral deficiencies can cause mottling or chlorosis or vein-clearing. On the other hand, unthriftiness or wilting may be due merely to insufficient soil moisture.

(b) **Extremes of temperature.** Short periods of cold weather can cause premature flower shedding in strawberries, ribbed and spiralled juvenile leaves in bananas, or banded chlorotic areas in sugarcane foliage. Hot dry weather by contrast is usually responsible for general wilting and leaf margin necrosis.

(c) **Insect damage.** Attacks or infestations by insects, especially jassids, some wasps and aphids, can often cause spots, galls, rolled leaves and other leaf malformations; similarly thrips and mites often cause "silvering" or bronze colorations, as well as premature defoliation.

(d) **Pathological agencies.** Mosaic, witch's broom, wallaby-ear and fern-leaf viruses can be expressed in many plants as mottled or etiolated foliage, anastomosed veins, or as malformed or striped flowers. The more common leaf diseases described variously as tumours or distortions which are generally symptomatic of bacterial and fungal diseases are generally more distinctive and tend to occur in specific and sensitive cultivars.

Intimate knowledge of particular idiosyncrasies in specific plants will help reduce the risk of confusion in some problem areas. There is for example the physiological propensity for "fasciation" of vascular tissue in the flowering shoots of ornamental species of *Celosia,* and the genetic occurrence of sectional chimera tissue in fruit and leaves of some varieties of *Citrus*. How often have these natural phenomena been ascribed to "damage" from herbicides? To the untrained eye in many

of the above biological situations, there is an obvious risk of confusion with the symptoms of reaction to herbicidal exposure.

IS IT REALLY HERBICIDAL DAMAGE?

Visibly bad situations are understandably responsible for the worst initial impressions; nevertheless it is recommended that any investigator should go back to fundamental questions when confronted by an apparent disaster. It is therefore necessary to check every possible alternative when investigating allegations of herbicide damage. As guidelines in any field investigation, especially following suspicions of illegal or irregular herbicide use, here is a checklist that can be profitably followed:

1. Study closely leaves, growing points and both leaf and flower buds of the affected plants and examine for fasciation, galls, adventitious growth, vein clearing or other distortion. Compare frequently with similar parts from unaffected plants. Turn the leaves over and check with a lens for presence of any jassids, aphids or mites, or their eggs or cast skins indicating earlier infestations.
2. Carefully dig up some plants and examine the roots for any nematode galls that may be present, or identify roots that may be rotting from fungal infection.
3. Slice some stems and look for insect tunnels or brown discolourations (*Fusarium* may be clogging vessels and causing wilting, even under good growing conditions).
4. Check for any gradations in severity or other patterns of symptoms in the affected area, as well as in weeds, ornamentals or other crops in the vicinity of the affected crop plants. Compare again with similar plant parts from an unaffected area.
5. Ask when the symptoms were first noticed; check for any possible correlation with farm operations in the vicinity of the affected crop.
6. If a herbicide is known to have been used in the general area,

   (a) check for any errors or carelessness in application, for anything significant in the wind records, or in any aspects of the operator's techniques, especially if there was any likelihood of drift having occurred.

   (b) similarly ask questions through "the back door"; it is often remarkable what is known by and only revealed by asking questions of other people e.g. contractors, agents and workmen employed by the local authority.

(c) confirmation of uptake of a suspected herbicide could be important, and a residue analysis of plant tissue should give positive proof. As Eagle (1976) has pointed out, there is a large number of herbicides which can cause symptoms that are practically identical. Tissue analysis can usually be satisfactorily carried out by an adequately equipped analytical chemist, in most cases, provided that no more than a fortnight has elapsed since exposure of plants. For best chance of detection of residues, samples of plants should be taken without delay and kept in deep freeze until the chemist is ready to handle them.

(d) in some countries, e.g. most states of Australia, the use of herbicides by operators working on land they do not own e.g. public utilities or spraying contractors, is usually restricted by law. If it is strongly suspected that this type of operator is responsible for damage, an appropriate notification under the relevant Act should be lodged with the nearest office of the responsible Government Department without delay; officers of that Department will then take over the investigation and do any sampling they think necessary.

The guiding principle for any investigator is the need to keep an open mind and not jump to conclusions. The guiding principles for any person using herbicides in horticultural situations are care and common sense, implying consideration for the welfare of neighbours as well as an intimate knowledge of the crops of the district and the local weather patterns. Acceptance of the directions printed on herbicide labels, as well as proper respect for the biological properties of the chosen herbicides, naturally go hand in hand.

HOW CAN DAMAGE BE MINIMISED ?

In some situations where damage is likely and relatively valuable crops are at risk, protectants such as activated carbon may be used to detoxify soil-active herbicides. Application is best made in partially filled seed furrows, as was originally demonstrated by Ripper (1956). More recently, as reviewed by Gupta (1976), there has been a development of interest in specific chemical antidotes which cancel or reduce the phytotoxicity of certain herbicides towards particular crop plants. Looking ahead, as suggested by Busey (1976), there could well be practical developments in future commercial horticulture in the form of programmed genetic resistance towards some herbicides, arising from the use of herbicide tolerance tests in plant breeding.

In most current crop situations however, accidental contact by herbicides is best controlled by prevention i.e. the avoidance of exposure by exercising proper care from the very beginning. Care in the selection of an adequate buffer zone, a safe wind direction, and other optimal conditions for spraying should be self-evident. These precautions go hand in hand with the choice (if available) of low-volatile formulations, as discussed by Grover (1976), the addition to made up sprays of thixotropic polymers to maintain an acceptable range in droplet sizes, as recommended by Arvier (1975), the use of efficient equipment, including the concept of controlled droplet application, as advocated by Matthews (1976) and of course the choice of safe environmental situations. These considerations involve a close watch on the proximity of target to crop, the choice of a favourable weather forecast and the restriction of spraying activities to an uncomplicated open terrain.

If an accidental exposure or contact does occur, can the potential damage be offset or minimised?

There are two lines of action available, *viz*:

1. If conventional foliage-absorbed herbicides such as 2,4-D, 2,2-DPA or chlorates (but not diquat or paraquat) are involved, if exposure has been only slight such as would occur through drift, and if the farmer has become aware of this exposure almost immediately, prompt overhead irrigation may minimise uptake through leaves. A timely shower of rain within a half hour or so can be equally efficacious as spray irrigation in washing off small amounts of herbicide from the leaves of exposed plants.

2. If, by contrast and as is usually the case, an appreciable time has elapsed and exposure to leaf-absorbed materials is thought to have been significant, the farmer must decide if it is worth trying to salvage something from the crop. The same decision is faced if exposure to either paraquat or diquat has occurred, as these herbicides are absorbed extremely quickly — within minutes in fact, and no amount or intensity of washing will remove these herbicides from the foliage.

There are two alternatives when the question of salvage becomes significant:

(a) if the farmer decides that damage, actual or potential, is too severe for the crop to recover, he should ask himself if there is

time to plough out and replant with a replacement crop with similar growth requirements

(b) if he thinks that an attempt at resuscitation is justified, he should cultivate, irrigate, fertilize and apply normal pest and disease control measures to give the damaged crop the best possible chance of recovery.

Where only slight "damage" has occurred and the crop is encouraged to "grow on", it should be remembered that most affected crops may grow more slowly through the period of "recovery" and hence can be expected to mature a little later than would normally be the case. In any event in such rescue attempts, the farmer should be advised to take detailed notes of the crop history and performance, including rates, dates, weather, size and shape of fruit and other harvest data. All these records could be very useful for posterity as reliable information is scanty on this contentious subject of "salvage".

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Ecological Characteristics of Perennial Sedges, Eleocharis kuroguwai Ohwi and Cyperus serotinus Rottb.[1]

KIL UNG KIM and BYEUNG HOA KANG[2]

ABSTRACT

Ecological characteristics of *Eleocharis kuroguwai* Ohwi and *Cyperus serotinus* Rottb. were determined by sampling at 20-day intervals from 0 to 140 days after sowing (DAS). The maximum shoot number for *E. kuroguwai*, 62, and *C. serotinus*, 113, was obtained about 80 and 100 DAS, and afterwards the shoot number decreased with age. Throughout its life cycle, *C. serotinus* showed more vigorous growth and higher dry matter production than *E. kuroguwai* indicating that *C. serotinus* is a more competitive sedge. Tuber formation of both sedges started under decreasing day length i.e. *E. kuroguwai* in early September, about 80 DAS and *C. serotinus* in late August, 70 DAS. In 140 days one plant produced a maximum of 142 tubers for *E. kuroguwai* and 116 tubers for *C. serotinus* at harvesting time. Tuber initiation and production of both sedges were photoperiodically controlled. Nine hours of light initiated tuber formation within 5 days after treatment. Shading significantly reduced tuber production and under 20% of sunlight, a 97% and a 45% reduction were obtained with *E. kuroguwai* and *C. serotinus*, respectivity, showing *E. kuroguwai* to be more sensitive to shading.

INTRODUCTION

The continuous use of the same herbicide to control the common annual weeds results in the predominance of perennial sedges which are more competitive and difficult to control (Ahn *et al* 1975). Perennial weeds are more difficult to control since underground tubers and bulbs accumulate food reserves which support regrowth after the aerial shoot is killed. Ueki *et al* (1969) reported that *E. kuroguwai* posseses tuber dormancy and Matsubara and Nakamura (1969) found that the irregular sprouting of *E. kuroguwai* caused it to be most difficult to control. Kim and Choi (1976) suggested that irregular sprouting may be caused by irregular distribution of perennial weeds at various soil depths and by the dormancy of these weeds.

Perennial weeds which are currently infesting extensive areas of Korea are *E. kuroguwai, C. serotinus* and *Potamogeton distinctus* etc. These species propagate mainly from a network of underground organs. A further infestation increase of these perennial weeds is expected unless

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appropriate control measures are taken. In Korea, no cheap commercial herbicides are yet available for the control of these weeds. Thus, an understanding of the growth characteristics and environmental factors favoring their development may be worth while in formulating effective control systems.

This study was conducted to determine the growth characteristics and the effect of light intensity and photoperiodism on the growth and tuber production of *C. serotinus* and *S. kuroguwai.*

MATERIALS AND METHODS

All tubers used in this experiment were taken from paddy fields of the Crop Experiment Station, Suweon, Korea. A loam soil of 2.4% organic matter was used to fill two thirds of a 1/2000a Wagner pot. 1.25 g of N, P_2O_5, K_2O was incorporated into each pot just before sowing. The series of experiments were conducted during the summer of 1975 - 1976 at the Crop Experiment Station, Suweon, Korea. A tuber of each species was sowed in a pot for all experiments.

Growth characteristics of *E. kuroguwai* and *C. serotinus*. Tubers of each species were sown on June 17 in 40 Wagner pots. At every 20-day interval, 5 pots were sampled until final harvest, 140 days after sowing. The number of shoots and tubers, and dry weight of shoots and tubers were determined.

Effect of shading on the growth of *E. kuroguwai* and *C. serotinus*. Three light intensities, full sunlight (no shade), 50% of full sunlight (shaded with one layer of bamboo blind) and 20% of full sunlight (shaded with two layers of bamboo blind) were used. One-month-old plants grown in 1/2000a, Wagner pots were exposed to different light intensities beginning July 21 and lasting until October 19 (90 days of growth). Average plant height, number of shoots and tubers, and total dry weight were determined.

Photoperiodic response of *E. kuroguwai* and *C. serotinus*. One-month-old plants of *E. kuroguwai* and *C. serotinus* grown in 1/2000a Wagner pots were subjected to the following photoperiods for 90 days in the phytotron glasshouse: 12, 14 and 16 hours. Day length was automatically controlled and the temperature inside the glasshouse was maintained at 25/20 C in day and at night, respectively. A 30-klux fluorescent light was used. At the end of the experiment, the number of shoots and tubers, dry weight and plant height were determined.

In order to determine the effect of short photoperiod on the induction of tuber formation, 40-day-old plants of *E. kuroguwai* and *C. serotinus* grown under 14 hours day-length, were subjected to a 9-hour photoperiod per day for 1, 5, 15 and 25 days. Except for the 25-day treatment, immediately after exposure to the prescribed periods the plants were subjected to natural conditions, mostly a 14-hour photoperiod, for a total of 25 days after the start of treatment. Then the number of tubers formed were determined.

RESULTS AND DISCUSSION

Plant height. *C. serotinus* is a fast-growing sedge which increases in height at an average rate of 2.3 cm per day during the first 40 days of growth. It attained its maximum height at 60 DAS (Table 1). During the early stage the rapid growth makes this species very competitive against rice. Thus, the improved semi-dwarf rice varieties could be easily shaded by this weed during the rapid growth period.

E. kuroguwai is a slow-growing sedge which increase at about 1 cm in height per day until 80 DAS, and thereafter plant height decreases slightly. This characteristic makes *E. kuroguwai* less competitive than *C. serotinus*.

Shoots and tubers production. Maximum shoot numbers for *E. kuroguwai*, 62, and for *C. serotinus*, 113 were produced in 80 and 100 DAS, respecti-

Table 1. Growth characteristics of *Cyperus serotinus* and *Eleocharis kuroguwai*[1]

Days after sowing (DAS)	Plant height (cm)		Shoots (no./pot)		Tubers (no./pot)	
	CS	EK	CS	EK	CS	EK
20	44	23	4 d	2 d	0 c	0 d
40	93	41	34 c	17 c	0 c	0 d
60	130	72	79 b	45 b	0 c	0 d
80	134	81	101 ab	62 a	14 b	11 c
100	125	80	113 a	61 a	117 a	59 b
120	126	81	94 b	61 a	114 a	71 b
140	123	79	84 b	56 ab	116 a	142 a

[1] Tubers were sown on June 23 and sampled at every 20-day interval until November 4.

[2] CS: *Cyperus serotinus*, EK: *Eleocharis kuroguwai*.

[3] In each column, means followed by the same letter are not significantly different at 5% level using Duncan's multiple range test.

vely (Table 1). After this, the shoot number decreased due to the death of some shoots. Tuber production of both sedges started about 80 DAS, at the time when shoot numbers had almost reached their maximum. Tuber production of both sedges showed a linear increase from 70 to 140 DAS. In terms of shoot production, *C. serotinus* is much more productive than *E. kuroguwai*. The fact that the ratio of tubers over shoots is 1.4 indicates that one shoot produces more than one tuber. But in *E. kuroguwai* the ratio of tubers over shoots was more than 2.5, indicating *E. kuroguwai* is more productive in tuber production per shoot than *C. serotinus*.

Dry matter production. The growth curve of *E. kuroguwai* in terms of dry matter production has been divided into two phases (Figure 1). The

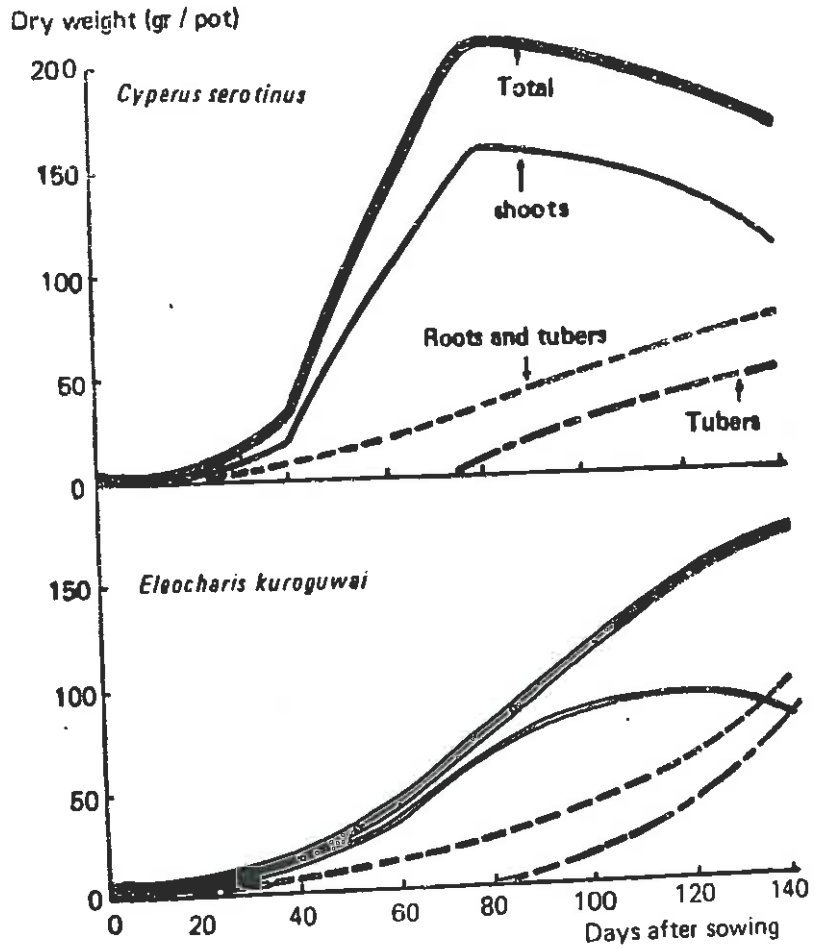

Figure 1. Increase in dry weight of the different plant parts of *Cyperus serotinus* and *Eleocharis kuroguwai* Ohwi.

first phase which is from sowing to 40 DAS is characterized by a relatively slow increase in dry weight. During this period, only green leaves and culms contributed significantly to the total dry weight. The second phase of the growth curve, from 40 DAS to 140 DAS, is characterized by a very rapid increase in dry weight which is mainly influenced by shoot production at the beginning and by tuber production later. Increases in tuber weight started about 100 DAS which belongs to the late part of the second growth stage while the contribution of shoots to total dry weight become less significant in this stage. This is understandable because the shoot is the photosynthetic site for the food reserves accumulated in the tuber. The increase in tuber weight, however, continued up to the end of this phase, contributing a large proportion to total dry weight.

The growth curve of *C. serotinus* is shown in three phases (Figure 1): the first is a slow increase phase from sowing to 40 DAS, the second is a rapid increase phase up to 80 DAS which was mainly influenced by number and weight of shoots (mainly green leaves and culms) and the last is a slightly decreasing phase from 80 DAS to 140 DAS. In this last stage tuber production plays an important role in shaping the growth curve. Productivity of dry matter per unit area was significantly greater in *C. serotinus* than that of *E. kuroguwai*.

Shading response. At 90 days after shading, total dry weight of *C. serotinus* was reduced by 18% and 99% when light intensities were reduced to 50% and 20% of sunlight, respectively (Table 2). However,

Table 2. Effect of shading on the growth and dry weight of *Cyperus serotinus* and *Eleocharis kuroguwai*.[1]

% of sun light	Plant height (cm)		Shoots[3] (no./pot)		Tubers[3] (no./pot)		Total[3] dry wt. (g/pot)	
	CS[2]	EK[2]	CS	EK	CS	EK	CS	EK
100	109	71	76 a	48 a	130 a	120 a	127 a	74 a
50	125	85	67 a	28 b	77 b	50 b	104 b	29 b
20	92	68	17 b	8 c	42 c	4 c	13 c	5 c

[1] Determined at 90 days after shading treatment.

[2] CS: *Cyperus serotinus*, EK: *Eleocharis kuroguwai*.

[3] In each column, means followed by the same letter are not significantly different at 5% level using Duncan's multiple range test.

E. kuroguwai's dry weight as reduced by 68% and 94% under 50% and 20% of sunlight, respectively, 90 days after shading. The greatest dry weight reduction in both sedges was due to fewer tubers followed by fewer shoots. These results indicate that at low light intensities or at lower photosynthetic rates underground parts are affected more than shoots. The response of both sedges to low light intensity was very similar to that found by Visperas [3] for *Scirpus maritimus* L. and by Sierra (1973) for *Cyperus rotundus* L., another noxious sedge. Increased infestations of both sedges in Korea might be to some extent attributed to the expanded area planted to the improved short-statured rice varieties, like Tongil (indica-japonica cross) which may be less competitive against sedges. Thus, for controlling these weeds the planting of the taller, more competitive varieties might be more advantageous than the continued use of short-statured rice variaties. The advantage of a taller variety against *S. maritimus*, another noxious paddy sedge, has been shown for IR 442-2-58, an intermediate statured rice line over IR 20, a semidwarf variety (IRRI 1974).

Photoperiodic response. It is well known that photoperiodism affects various aspects of plant growth and development. The plant heights of both sedges were not greatly affected by the photoperiods studied. Generally, the longer the photoperiod, the taller the plants but the differences were not significant. However, longer photoperiod (16-hour) did delay flowering. It also caused a production of a maximum of 201 shoots for *C. serotinus* and 50 shoots for *E. kuroguwai* as compared with only 33 shoots for *C. serotinus* and 10 shoots for *E. kuroguwai* under the 12-hour photoperiod (Table 3). Tuber number was inversely related to the photoperiod. In 90 days, 143 and 28 tubers for *C. serotinus* and *E. kuroguwai*, respectively, were produced under 12-hour illumination, but no tubers were found in the 14 and 16-hour photoperiods. These results suggest that the shorter photoperiods plays an important role in tuber production. Further, under a temperate climate in the northern hemisphere the fact that tuber formation starts in late August or early September under field conditions confirms that short day length initiates tuber formation.

[3] Visperas. R.M. 1975. Autecology of *Scirpus maritimus* L. MS. Thesis, University of the Philippines at Los Banos, 1-67.

Table 3. Average tuber number and dry weight of perennial sedges at various photoperiods for 90 days.

Photoperiod (hours)	Plant height (cm)		Shoots[2] (no./pot)		Tubers[2] (no./pot)		Total dry[2] wt. (g/pot)	
	CS[1]	EK[1]	CS	EK	CS	EK	CS	EK
12	129	80	33 c	10 c	143 a	28 a	61 b	5 b
14	135	83	97 b	24 b	0 b	0 b	47 b	9 b
16	135	84	201 a	50 a	0 b	0 b	151 a	29 a

[1] CS: *Cyperus serotinus*, EK: *Eleocharis kuroguwai*.

[2] In each column, means followed by the same letter are not significantly different at 5% level using Duncan's multiple range test.

Increased photoperiods significantly increased the total dry weight of both sedges due to the greater dry weight of shoots. Regardless of photoperiods used, *C. serotinus* was 5 to 10 times more productive than *E. kuroguwai*. Visperas [3] has shown with *S. maritimus* L. that 10-hour photoperiod produced significantly higher total number of tubers than did 16-hour, but there was a much higher shoot weight under the longer photoperiod. Berger and Day (1969), studying *C. rotundus* L. found that tuber formation is photoperiodically controlled. Garg *et al* (1967) and Jansen (1971) reported that rhizome differentiation in the related weedy species, *Cyperus esculentus*, is also influenced by the shorter photoperiod.

When both sedges grown under 14-hour photoperiod were exposed to 9-hour photoperiod for 5 days, tubers were initiated (Table 4). A continuous 9 hours photoperiod for 15 and 25 days markedly increased the number of tubers in both weeds though more so with *C. serotinus*. These results clearly indicate that tuber formation of both weeds is photoperiodically controlled.

Based on results obtained, several recommendations can be drawn. Firstly, the use of a taller rice variety which can more easily shade those sedges will provide better competition. Secondly, the use of a short duration variety which can be harvested in early September at time when day length is getting shorter, would considerably reduce the number of tubers, hence lower the weed population in succeeding crops. Thirdly,

dense plantings may allow the rice plants to establish a canopy sufficient to shade these weeds thus giving the rice crop an advantage.

Table 4. Effect of short photoperiod treatment on tuber formation of perennial sedges [1].

Short day[2] treatment (days)	Number of tubers formed	
	CS[3]	EK[3]
1	0	0
5	8	5
15	22	14
25	32	22

1 Tuber number counted 25 days after the start of treatment
2 Photoperiod applied : 9 hours per day.
3 CS: *Cyperus serotinus*, EK: *Eleocharis kuroguwai*.

Both sedges required a relatively long time to emerge in this pot experiment, but this may not be true under field conditions. In the field tubers are at various physiological stages and therefore they can be sprouted at any time. This means that under field conditions these sedges may quickly emerge and become established to compete with a rice crop.

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Germination, Growth and Control of Sida rhombifolia L.

L. W. SMITH [1]

ABSTRACT

Paddy's lucerne or common sida (*Sida rhombifolia* L.) is a summer growing weed of roadsides, waste areas and horse pastures in the higher rainfall coastal regions of eastern and northern Australia. Because it is relatively difficult to control, studies of the biology of this perennial plant were undertaken to ascertain points of weakness or growth periods when control measures may be more effective. Results to date indicate that the majority of the seed is dormant (hard seed coat) for 12 to 24 months after maturity. The seed has an optimum temperature range for germination of 25 to 32 C and plant growth is best at 25 to 30 C. Glasshouse studies have shown that the plant is moderately resistant to 2,4-D [(2,4-dichlorophenoxy) acetic acid] and related herbicides.

INTRODUCTION

Paddy's lucerne is an indigenous plant to the higher rainfall coastal regions of eastern and northern Australia. It is a perennial plant with fibrous stems and a tap root that penetrates deeply into soils of arable and pasture lands and particularly seems to be associated with pastures grazed by horses. It is also a common plant along roadsides, fencelines and in waste places (Maiden 1894).

It is a persistent and difficult plant to eradicate, the mature plants are avoided by stock because it is very fibrous and the ripe seeds are hard and prickly. The seeds have been known to be irritating to horses mouths and poultry have been affected with internal inflammation by feed containing the seed (Whittet 1958). The plant is mainly a summer growing weed and becomes dormant in the winter months.

Around the Sydney region it normally commences regrowth from buds on the stems in September-October of each year and becomes dormant in May with the onset of frosts. Seeds are produced over the summer and autumn period (December to April).

Paddy's lucerne appears to have increased recently at Hawkesbury Agricultural College during a period of wet summers. Very little infor-

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mation is available regarding the biology and control of paddy's lucerne and the work reported is aimed at extending our knowledge about this weed.

MATERIALS AND METHODS

Paddy's lucerne seed was collected at Hawkesbury Agricultural College in March 1974, June 1976 and February 1977, and stored in screw top jars. The seeds were germinated in incubators (dark) or in glasshouses (light) which were temperature controlled. Plants were grown in the temperature controlled glasshouses at 10-15 C, 15-20 C, 20-25 C and 25-30 C, night-day temperatures respectively. Normal daylight was used for plant growth studies and humidity was not controlled. All plants were grown in a sandy loam soil. The growth regulators and herbicides used were purchased from local chemical suppliers or were supplied free by several companies.

Germination tests were carried out in plastic petridishes in incubators at 5 C, 20 C, 25 C, 32 C and 35 C or in the temperature controlled glasshouses. Each treatment was replicated twice and fifty seeds were used per treatment. The treatments included the effects of various temperatures, germination in light and dark, the effects of growth regulators, sulphuric acid and abrasive treatments on the germination of the seed collected over the 3 year period. All figures have been expressed as percentage germination and no statistical analysis has been undertaken at this stage.

Plants grown in the glasshouses were germinated from seed sown in a sandy loam soil, when they were 1 - 2 cm high the seedlings were transplanted into 15 cm pots and established 2 weeks at 20-25 C before transferring to the various temperature treatments. Liquid fertilizer ("Aquasol", 1 g/4L) was applied every 2 weeks.

The plants were harvested at various time intervals by cutting off the top growth, measuring the leaf area on a planimeter and then weighing the dried shoot and roots of individual plants.

For the depth of germination study one hundred seeds (2 pots of 50) were planted at depths of 0, 2 mm, 1 cm, 3 cm, 6 cm and 10 cm in a sandy loam soil. Appearance of the plant above the soil surface was measured as successful establishment (germination).

For the herbicide screening trials, plants were established as described, but a soil mix consisting of 50% sandy loam soil plus 50% horse

manure was used to grow the plants in. These plants were grown in a glasshouse which was not environmentally controlled.

When the plants were 15-25 cm high and just beginning to flower they were treated with the herbicide treatments outlined in Table 1. A "Drake and Fletcher" knapsack sprayer was used for all treatments. Each treatment was replicated four times and the plants harvested 6 weeks after treatment by cutting off the top growth and measuring fresh and dry weights.

Table 1. List of herbicides tested in glasshouse trials for control of paddy's lucerne.

asulam — methyl sulfanilcarbamate
dicamba — 2,6-dichlorobenzonitrile
dicamba + MCPA
MCPA — [(4-chloro-o-tolyl)oxy] acetic acid
mecoprop — 2-[(4-chloro-o-tolyl)oxy] propionic acid
2,4-D — (2,4-dichlorophenoxy) acetic acid

RESULTS AND DISCUSSION

Freshly harvested paddy's lucerne seed will not germinate readily. Only 5 to 8% of freshly collected seed germinates in the first 6 months. However, two and one half years after collection, germination percentages of up to 70% can be obtained. The optimum temperature for germination is in the 30-32 C range with little germination at temperatures below 20 C (Table 2).

Table 2. Effect of temperature on the germination of paddy's lucerne seed collected over a 3-year period.

Temperature C	% germination *		
	1974	1976	1977
20	10	4	—
25	44	5	5
32	70	4	4
35	32	—	1

* Germination tests carried out in February, 1977.

Germination was not affected by light or growth regulators. However, the dormancy exhibited by freshly collected seed could be removed by abraiding the seed with sandpaper or treating with sulphuric acid (Table 3). This would indicate that the dormancy is due to a hard or impermeable seed coat. This type of dormancy has been shown to exist in other members of the family Malvaceae (La Croix and Staniforth 1964) of which paddy's lucerne is a member.

Table 3. Effect of temperature, light and dark, and treatment of seed with sulphuric acid on germination of freshly collected paddy's lucerne seed *

Temperature C	% germination	
	Untreated	H_2SO_4 treated **
25 dark	10	54
25 light	6	66
5 dark	0	0
35 dark	6	20

* Experiment carried out in 1974 on freshly collected seed.

** Seed was treated with concentrated H_2SO_4 for half a minute and then washed for 15 minutes in running water (Steinbauer and Grigsby 1959).

Paddy's lucerne seed will germinate from a depth of up to 6 cm in the soil with optimum emergence between 2 mm and 3 cm (Table 4).

Table 4. Effect of depth of planting on the number of paddy's lucerne seed emerging from soil.

Depth of planting seed (cm)	Number emerging from soil *
0	0
0.2	60
1	56
3	52
6	12
10	0

* Numbers represent seedlings emerging from 100 seeds planted. Experiment carried out in 1976 with seed collected in 1974. Glasshouse temperature 25 C night, 30 C day.

In the conditions tested, the growth of paddy's lucerne was best at a night temperature of 25 C and a day temperature of 30 C (Table 5). Growth was very poor at temperatures below 20 C. These temperature growth characteristics roughly match the field growth of the weed in Australian conditions.

Table 5. Effect of temperature on the growth of paddy's lucerne seedlings.

Temperature ranges (C)	Total leaf area (cm^2)	Dry weight (g)	
		Leaves	Roots
10 — 15*	9 (4)**	.04	.01
15 — 20	15 (2)	.04	.08
20 — 25	96 (4)	.62	.31
25 — 30	229 (3)	1.80	1.06

* Night-day temperatures of glasshouses.

** Numbers in brackets indicate the number of plants used, these were the only ones surviving from 5 placed in each glasshouse originally. Plants harvested 8 weeks after placing in glasshouses.

The plant appears to be relatively resistant to 2,4 - D and related compounds because under glasshouse tests little effects besides callous tissue development and some stunting were in evidence with treatments up to 1 kg/ha. Further tests are in progress.

ACKNOWLEDGEMENTS

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Weedy Species of Stachytarpheta in Hawaii [1]

D. L. PLUCKNETT and A. WHISTLER [2]

ABSTRACT

Four species of weedy shrubs belonging to the genus *Stachytarpheta* are found in Hawaii. These are *S. mutabilis, S. cayennensis, S. urticifola,* and *S. jamaicensis.* They are hard to distinguish and are often incorrectly named. *S. mutabilis* is not very important as a weed; however, the other three are common in disturbed areas, pastures, and particularly along roadsides. All three can be important pasture weeds, especially *S. urticifolia,* which often forms dense pure stands in wetland pastures and causes severe losses in forage production. All reproduce readily from seed and become established quickly in newly-established pastures and in fields planted to perennial tree crops.

In Hawaii there are four weedy species of the genus *Stachytarpheta,* which belongs to the family Verbenaceae. These weedy shrubs and near-shrubs, natives of tropical America, are now naturalized throughout the islands. Difficult to distinguish from one another, they are often incorrectly named.

Stachytarpheta spp. are important weed of pastures, cultivated land, waste areas and roadsides. They often form dense stands and take over large land areas. Heavy seed producers, they spread rapidly and compete with more desirable crop or pasture plants.

There is a need to attempt to differentiate between these species and to evaluate their importance as weeds throughout the State.

BOTANICAL DESCRIPTIONS

The genus *Stachytarpheta* consists of about 40 species. Many of these species have been spread accidentally or as ornamental plants throughout the tropics and subtropics. Seven species: *S. angustifolia, S. australis, S. cayennensis, S. indica, S. jamaicensis, S. mutabilis,* and *S. urticifolia* have been reported as weeds at one time or another in some parts of the world (Holm *et al* in press).

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The four weedy species in Hawaii can be differentiated best on the basis of degree of vestiture (hairiness); shape and size of the marginal teeth of leaves: size, hairiness and indentation of the rachis; and flower color. The characters are only useful to a certain extent, however, for the species do hybridize, giving rice to intergrading types.

A general description of the genus *Stachytarpheta* can be given as follows:

Erect shrubs or herbaceous undershrubs 0.3 to 3 m high; stems 4-angled usually when young; **leaves** opposite, ovate to elliptic, margins variously toothed; **flowers** in terminal spikes, few at a time, maturing from the base to the top of the spike; **corolla** salverform with a narrow, curved tube 5 to 10 mm long and a flat limb 5 to 10 mm across, red, pink, lavendar, blue, purple or white in color; fertile **stamens** 2, inside the corolla tube; ovary 2-celled, each cell with a single seed; **fruit** subtended by a pointed bract and often embedded within a thickened rachis.

THE WEEDY SPECIES IN HAWAII

In Hawaii, *Stachytarpheta* species are known collectively by the following names: oi, o'i, ówí, jo-ee, joee, and hau'oi. All of them are commonly called vervains.

Figure 1 illustrates details of leaf and bract shapes and sizes for the four species. These characters are useful in differentiating between them.

KEY TO THE SPECIES

1. Plant densely long-hairy; rachis of inflorescence more than 5 mm thick; bracts more than 8 mm long
   . . . . . *S. mutabilis*
1. Plant glabrous to short pubescent; rachis less than 4 mm thick; bracts less than 7 mm long
   2. Leaves short-hairy; bract awl-shaped, about 1 mm wide, mature fruit reflexed away from rachis
      . . . . . *S. cayennensis*
   2. Leaves nearly glabrous; bract lanceolate, about 2 mm wide; mature fruit embedded in rachis.
      3. Teeth of leaf margin nearly equal-sided; leaf tip acute; narrowly acute tip of bract nearly ½ bract length.
         . . . . . *S. urticifolia*

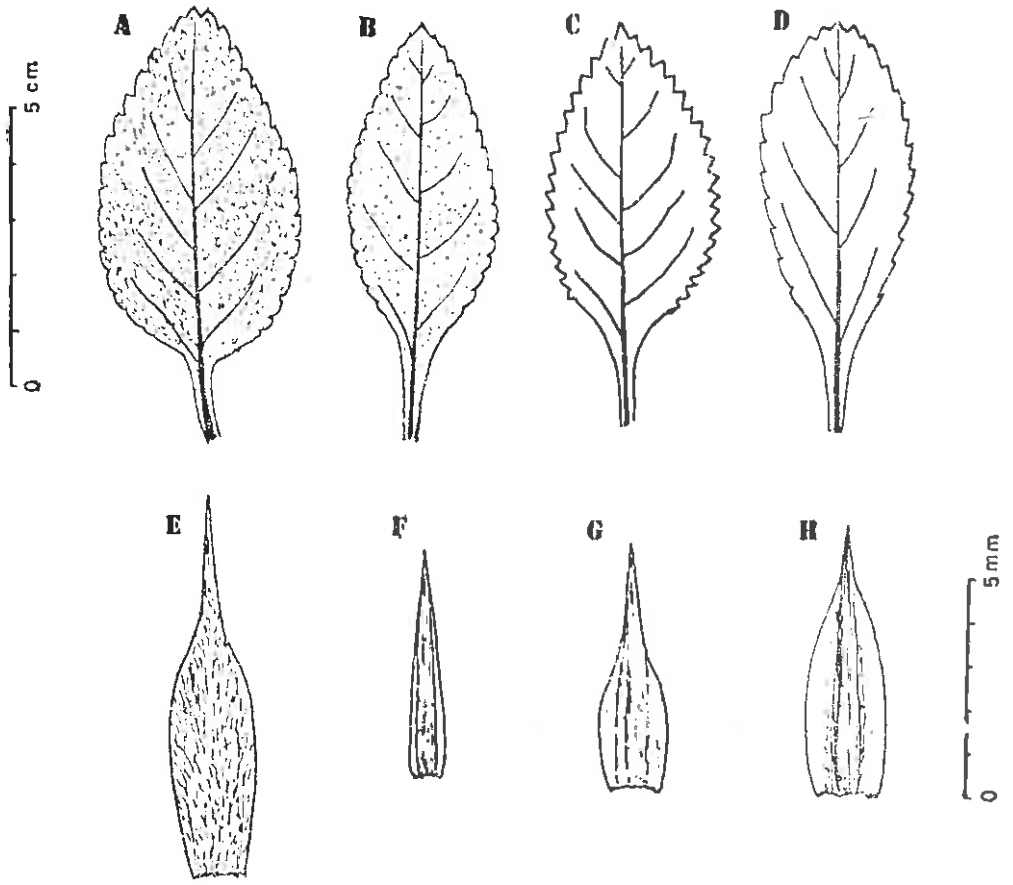

Figure 1. Distinguishing characteristics of leaves and bracts of *S. mutabilis* (A and E), *S. cayennensis* (B and F), *S. urticifolia* (C and G) and *S. jamaicensis* (D and H).

3. Teeth of leaf margin unequally sided (lower edge up to 3 times as long as upper edge) ; leaf tip rounded; narrowly acute tip of bract about ¼ of bract length.
. . . . . *S. jamaicensis*

Description and notes on the species are as follows:

1. *S. cayennensis* (L. C. Rich.) Vahl (*S. dichotoma* of St. John and Hosaka 1932) [Note: This species introduced to Hawaii is called by Moldenke *S. australis* which he named in 1940. The differences between this and *S. cayennensis* are not clear, and St. John lists both species as occurring in Hawaii. Since *S. cayennensis* is much more common in the literature, we have chosen to use this instead of the dubious *S. australis*.] Cayenne vervain, porter-weed.

A short-hairy shrub 0.5 to 1.6 m high; **leaves** with rounded teeth on the margins (crenate-serrate), **corolla** 7 mm across, lavender or light blue (rarely white); **bract** awl-shaped; **fruit** not embedded in the narrow rachis.

Habitat: A fairly common plant, which has been reported from most of the islands. It often occurs on wetter sides of the islands, but may occasionally be found in drier areas. It appears to thrive in areas with rainfall above 1500 mm and can be found from sea level to over 1200 m elevation.

Importance: *S. cayennensis* is a weed of pastures, rangelands, croplands, forests, and waste areas.

2. *S. jamaicensis* (L.) Vahl — (*S. dichotoma* of Pope 1929). Jamaica vervain. A smooth, glabrous, herbaceous or partly woody **perennial** shrub, usually 0.3 to 1 m, sometimes 2 m high; **leaves** opposite, serrate with marginal teeth unequally sided, tip somewhat blunt or rounded; **corolla** 10 mm across, usually lavender in color; **bract** with a short tip; **fruit** embedded in pits in the thickened rachis, rachis pits narrower than width of the axis of the rachis.

Habitat: Much the same as *S. cayennensis* (see above).

Importance: *S. jamaicensis* is a weed of pastures, rangelands, croplands, forests, and waste areas.

3. *S. urticifolia* Sims (*S. cayennensis* of Degener 1938; *S. indica* of St. John and Hosaka, 1932; *S. jamaicensis* of Backer, 1965). Blue rat's tail, blue vervain. A smooth, herbaceous to sub-woody **perennial** shrub (Figure 2); **leaves** nearly glabrous, acute, margins saw-toothed (dentate) with sides nearly equal; **corolla** 10 mm across, purple or deep blue (rarely white); **bract** with a long narrow tip; **fruit** embedded in the thickened rachis.

Habitat: A very common plant, which has been reported from all islands, *S. urticifolia* thrives in areas receiving 1000 mm or more of rainfall. However, it is frequently found in drier areas as well. It grows in areas from near sea level to over 1200 m.

Importance: The most important weed of the genus *Stachytarpheta* in Hawaii, *S. urticifolia* is a serious weed of pastures and rangelands, particularly in wetter areas. It is a weed of forests and forest margins, cropland, and of waste areas.

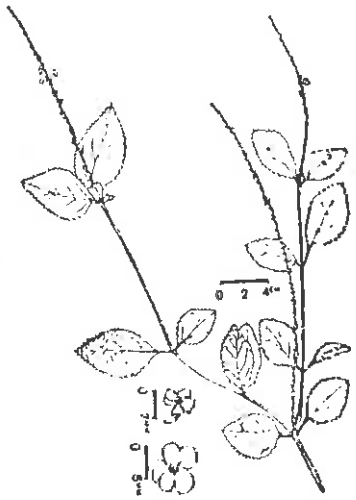

Figure 2. *S. urticifolia* – plant habit, flower.

4. *S. mutabilis* (Jacq.) Vahl. Changeable vervain. A. densely hairy herbaceous to near-woody **perennial** shrub (Figure 3), 1 to 3 m high; **leaves** broad, teeth of margins somewhat rounded; corolla 15 mm across, red or violet fading to pink; bract **hairy** with a long tip; fruit embedded in the thickened **rachis.**



Figure 3. *S. mutabilis* – plant habit, fruit, flower.

Habitat: Found only on Kauai, at Hanalei, in a wet (2000 mm or more of rainfall) zone at 100 - 150 m elevation. Found on roadsides and along the edges of pastures and in wastelands.

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Approaches in the Control and Management of Perennial Weeds in Rice [1]

S. K. De Datta [2]

ABSTRACT

Increased use of herbicides to control annual rice weeds in temperate East Asia has resulted in serious problems posed by perennial weeds. For tropical Asia, there is evidence that use of a single method of weed control, such as continuous use of the same or similar herbicides, perennial weeds could create a similar serious problem. Rice farmers must integrate all available and relevant technologies to reduce losses of grain yield and quality caused by all weeds. As direct methods of perennial weed control, hand weeding, use of a push-type rotary weeder, mechanical weeding, and herbicides are alternatives from which rice growers can choose. For indirect methods of perennial weed control, appropriate land, water, soil, and weed management practices should be developed. The use of a rice variety that competes better with perennial weeds, the transplant method of planting, suitable cropping systems could minimize further the buildup of difficult-to-control weeds — such as perennials. Various approaches should be followed to develop suitable management of perennial weeds in rice. An efficient perennial-weed management system for rice should integrate preventive measures, crop rotation, soil and water management practices, tillage practices, use of competitive varieties, and herbicides. Integrated weed control in the management of perennial weeds must be compatible with the management of annual weeds and other pests, such as insects and diseases, and with other practices that help in increasing rice production. Furthermore, in developing suitable controls for perennial weeds in rice, farmer's resource capabilities must be considered.

INTRODUCTION

Weeds are perhaps one of the oldest and most difficult production constraints in agriculture. In rice, weed problems are different under different systems of rice culture.

Weeds in transplanted rice cause from partial damage to nearly complete failure of the crop depending on water control, degree of land preparation, and fertilizer practices. Hand weeding or rotary weeding of transplanted rice is common in some countries in tropical Asia. Herbicides are most commonly used in areas of inadequate labor and high wages, particularly in Taiwan, Korea, and Japan.

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The weed problem in dry-seeded upland or rainfed lowland rice is serious and hand weeding is common but the labor requirement is high. As a result, one frequently sees poor upland or rainfed lowland rice crops on weed-infested fields. Nevertheless, technology is available that should do a fair job of controlling annual weeds in lowland and upland rice (De Datta and Barker 1977).

Perennial weeds pose a serious threat to both lowland and upland rice culture. Often, an increase in the perennial weed problem is associated with continuous use of the same or similar herbicides. Such is the case in the rice-growing areas of temperate East Asia. For example, about 22% of the total rice fields in Korea is infested with perennial weeds (Ryang *et al* 1976). The distribution of infestation by species is: *Cyperus serotinus* Rottb., 25.2% > *Spirodela polyrrhiza* (L.) Schleid, 17.7% > *Potamogeton franchetti* A. Benn et Baag., 15.2% > *Eleocharis acicularis* Roem. et Schutt., 10.6% > *Sagittaria pygmaea* Miq., 10.5% >. *E. kuroguwai* Ohwi., 4.5% > *S. hotarui* ohwi, 3.8%. Other perennial weeds compose about 12% of the total perennial weed population. The use of herbicides on rice in Korea was extended to about 49% of the total rice-growing area in 1974 (Ryang *et al* 1976). Although herbicides are able to control annual weeds, control of perennial weeds remain a difficult problem.

In Taiwan, *Marsilea minuta* L. (formerly *M. quadrifolia*) has been cited as an important perennial weed in flooded-rice fields (Chang and De Datta 1972). Several herbicides, such as EPTC/MCPA [*S*-ethyl *N,N*-dipropyl (thiocarbamate)/4-chloro-2-methylphenoxyacetic acid] and trifluralin/MCPA (2,6-dinitro-*N,N*-dipropyl-4 trifluoromethylaniline) do not control this weed. I observed a similar situation in the Mytho area of Vietnam.

In Japan, *E. kuroguwai* Ohwi a perennial sedge, is an important weed that causes a serious problem in rice fields (Ueki and Kobayashi 1976). Many herbicides that control annual weeds are not able to control *Eleocharis* spp. and other perennial weeds.

In tropical Asia, perennial weeds such as *Scirpus maritimus* L. pose serious weed problems in lowland rice. Ghosh *et al* (1973) observed heavy stands of *S. maritimus* in rice fields of the International Rice Research Institute (IRRI). *S. maritimus* has also been reported at the Central Experiment Station of the University of the Philippines at Los Baños (UPLB) (Paller *et al* 1972) and in Isabela, Nueva Vizcaya, and Samar provinces, Philippines (De Datta and Lacsina 1974).

S. maritimus has been reported from other tropical Asian countries (De Datta 1974, De Datta and Lacsina 1974). *S. maritimus* and *S. mucronatus* L. have also been reported in Europe and the Americas (Luib and Van de Weerd 1976). Chemical control of these weeds has developed in both tropical Asia (De Datta and Lacsina 1972, De Datta 1974, De Datta and Lacsina 1974) and in temperate Europe and the Americas (Luib and Van de Weerd 1976). In the Philippines, one of the perennial weeds that causes serious concern with reduced tillage or poorly prepared land is *Paspalum distichum* L. This perennial weed is not a serious problem with good tillage and water management.

In upland rice, perennial nutsedge, *Cyperus rotundus* L. is a serious weed for which suitable control measures should be developed. Okafor and De Datta (1974) indicate that nutsedge competes with upland rice for moisture and nitrogen. In addition, nutsedge competition reduces the light transmission ratio (LTR) in proportion to the increase in nutsedge population density (Okafor and De Datta 1976).

The upland rice area in southern parts of Sumatra and Kalimantan, Indonesia may increase if nutsedge and alang-alang (*Imperata cylindrica* (L.) Beauv.) can be effectively controlled (De Datta 1975).

This paper summarizes the approaches for the control and management of perennial weeds in rice.

CONTROL AND MANAGEMENT OF PERENNIAL WEEDS

Before I discuss the control of and management measures for perennial weeds, it is worthwhile to give examples of difficult weeds in lowland (Table 1) and upland rice (Table 2) and their mode of propagation.

Direct methods. Direct methods of control for annual weeds such as hand weeding, mechanical weeding (by rotary weeder in a paddy or by chemical or hand in upland), and chemical weed control are applicable at various degree even for perennial weeds. In most of temperate Asia, although hand weeding still complements other methods of weed control, chemical control is the most dominant control measure of weeds (De Datta and Barker 1977).

In Korea, chemicals have been identified that minimize perennial weed problems in rice fields. For example, for *C. serotinus* control, glyphosate [(*N*-(phosphonomethyl)glycine], perfluidone (1,1,1-trifluoro-*N*-[2-methyl-4(phenyl sulfonyl)phenyl] methanesulfonamide), and bentazon [3-isopropyl-1*H*-2,1-3-benzothiadiazin-4-(3*H*)-one 2,2-dioxide] were effective. Control of *P. franchetti*, *E. acicularis*, and *S. polyrrhiza* was

Table 1. Some difficult perennial weeds in lowland rice fields in Asia and their mode of propagation. (Adapted from De Datta 1974)

Difficult weeds in lowland rice	Mode of propagation
Broadleaf weeds :	
Marsilea minuta (Fern) (Taiwan, Korea)	Rhizome or spore
Marsilea crenata (Fern) (Taiwan, Philippines, Indonesia, Malaysia)	Rhizome or spore
Sagittaria aginashi (Korea)	Tuber
Potamogeton distinctus (Korea)	Tuber
Sagittaria pygmaea (Korea, Japan, Taiwan)	Tuber
Sedges :	
Eleocharis acicularis (Taiwan, Korea, Japan)	Rhizome and seed
Eleocharis kuroguwai (Korea)	Tuber
Scirpus maritimus and other species (Philippines, Thailand, Vietnam, India)	Tuber
Cyperus serotinus (Korea)	Tuber
Cyperus imbricatus (Philippines, prevalent on swampy areas grown to rice — Bicol, Bulacan)	Seed
Grass :	
Paspalum distichum (Philippines)	Rhizome and seed

Table 2. Some difficult perennial weeds in upland rice and their mode of propagation. (Adapted from De Datta 1974)

Difficult weeds in upland rice	Mode of propagation
Sedge :	
Cyperus rotundus	Rhizome and tuber
Broadleaf :	
Mimosa invisa	Seed
Grass :	
Imperata cylindrica	Rhizome

excellent with piperophos [*S*-(2-methyl-1,1-piperyl-carbonylmethyl)-*O,O*,-di-n-propyl-thiophosphate] + dimethametryn [2-methyl thio-4-ethylamino-6-(2,1-dimethylpropylamino)-*s*-triazine] and molinate (*S*-ethyl hexahydro-1*H*-azepine-1-carbothioate) + simetryn [2-methylthio-4,6-bis(ethylamino)-*s* triazine] and benthiocarb [*S*-(4-chlorobenzyl)-*N,N*-diethylthiolcarbamate] + simetryn (Ryang *et al* 1976).

Denize (1968) reported that in Japan, paraquat (1,1'-dimethyl-4,4'-bipyridylium dichloride) controlled the perennial sedge, *E. acicularis* in rice fields before planting.

In most of tropical Asia, labor is ample relative to land, and wage rates are low (less than US $ 1 per day). Hence, hand weeding is the dominant and perhaps the most effective method of controlling all weeds. In lowland rice, rotary weeding is a useful method to control perennial weeds. For example, in an experiment conducted during the 1972 wet season on farmers' fields at two sites in Isabela and Nueva Vizcaya provinces, Philippines, both hand weedings and rotary weedings gave yields comparable to chemical combination treatments (Table 3). The experimental sites were infested with perennial sedge, *S. maritimus* (De Datta and Lacsina 1974).

Table 3. Comparative control of *Scirpus maritimus* and other weeds with rotary weeder, hand weeding, and herbicide silvex in transplanted IR20 and IR24 rices. 1972 Wet season. (Adapted from De Datta and Lacsina 1974)

Treatment[1]	Application		Grain yield[3] (t/ha)	
	Rate (kg ai/ha)	Time[2] (DT)	Isabela IR24	Nueva Vizcaya IR20
Butachlor fb silvex	2.0 fb 1.0	3 fb 30	6.0 a	3.8 a
Butachlor fb silvex	1.5 fb 1.0	3 fb 30	5.2 a	3.8 a
2,4-D IPE fb silvex	0.8 fb 1.0	3 fb 30	5.4 a	3.8 a
Hand weeding	twice	20 fb 30	5.2 a	3.9 a
Rotary weeding	twice	20 fb 30	5.7 a	3.8 a
Untreated control	—	—	4.5 b	3.1 b

[1] fb = followed by; IPE = isopropyl ester.

[2] DT = days after transplanting.

[3] Avg. of three replications at 14% moisture. Any two treatment means followed by the same letter are not significantly different at the 5% level.

Several herbicides have been identified that look outstanding in controlling *S. maritimus*. For example, the selective herbicides bentazon and silvex [2-(2,4,5-trichlorophenoxy)propionic acid] gave excellent control of perennial sedge, *S. maritimus*, in both transplanted and direct-seeded flooded rice (Table 4). Results further indicate that with a mixed population of annual weeds and the perennial sedge, *S. maritimus*, no single chemical can control both groups of weeds (De Datta 1974, De Datta and Lacsina 1974).

For perennial nutsedge control in upland rice, K-223 (1-[α,α-dimethylbenzyl)-3-(*p*-tolyl) urea]) incorporated before seeding rice-gave excellent control with no visible crop damage and increased the grain yield (De Datta 1974, Okafor and De Datta 1976a). The herbicide K-223, however, does not control grassy weeds. Therefore, it has to be followed by a selective grass herbicide such as butachlor (Table 5). Perfluidone and silvex were also fairly successful in controlling nutsedge (Okafor and De Datta 1976a).

Besides K-223, a related compound, K-1441 [3-methyl-1-(α,α dimethyl)-3-phenyl urea] is reported to be effective against purple and yellow nutsedge weeds in Japan (Takematsu *et al* 1976).

For the perennial grass, alang-alang control, Eussen and Soerjani (1976) reviewed detailed control measures with chemicals.

One of the greatest obstacles in developing a good minimum or zero tillage technology is the presence of perennial weeds such as *Paspalum distichum* L. Contact herbicides such as paraquat can not control *P. distichum* effectively, making minimum and zero tillage unsuitable in many situations. Dalapon (2,2-dichloropropionic acid), a systemic chemical, kills most of the annual and perennial weeds, but at high rates it is toxic to crops and persists in the soil for a long time.

Recently, researchers discovered a new broad-spectrum herbicide, glyphosate, a chemical that is actively translocated from leaf and stem tissues to underground roots or rhizomes of perennial weeds. Moreover, the inactivation of glyphosate in the soil is rapid and complete. This lack of residual activity make the compound a potential candidate for use in zero or minimum tillage (Spurrier 1973).

In a study conducted at the International Rice Research Institute (IRRI) during the 1975 wet season, good weed control was obtained in plots sprayed with glyphosate at 2.0 kg/ha 7 days before transplanting IR30 rice, and with glyphosate at 2.0 kg/ha followed by one plowing

Table 4. Effect of post-emergence application of liquid herbicides on weed (*Scirpus maritimus*) control, crop tole-rance, and grain yield of broadcast and transplanted IR22 rice. 1973 Late dry season. (Adapted from De

Table 4. Effect of post-emergence application of liquid herbicides on weed (*Scirpus maritimus*) control, crop tolerance, and grain yield of broadcast and transplanted IR22 rice. 1973 Late dry season. (Adapted from De Datta 1974)

Treatment	Rate [1] (kg/ha)	Time of application (DT)	Transplant						Broadcast					
			Grain yield [2] (t/ha)	Control rating [3]		Toxicity rating [4]		Weed weight [5] (g/m²)	Grain yield [2] (t/ha)	Control rating [3]		Toxicity rating [4]		Weed weight [5] (g/m²)
				19 DH	Heading of rice	19 DH	Heading of rice			19 DH	Heading of rice	19 DH	Heading of rice	
Bentazon	1.5	25	5.5 a	4	9	0	0	5	5.2 ab	4	9	0	0	0
Silvex	0.75	25	5.2 a	3	9	0	0	1	5.6 a	4	9	0	0	3
Butachlor [6] fb	0.75 fb	6 fb	4.0 b	4	6	0	3	46	4.6 bc	5	6	0	2	30
silvex	0.75	25												
Weed-free control	—	20 fb 30	5.6 a	3	9	0	0	0	5.4 a	9	0	0	0	1
Untreated control	—	—	2.5 c	4	4	0	0	234	0.8 d	4	1	0	0	386

[1] Of active ingredient. [2] Avg. of four replications at 14% moisture; any two treatment means followed by the same letter are not significantly different at the 5% level. [3] Scale : 0 — 10; 0 = no control, 10 = complete control. [4] Scale : 0 — 10; 0 = no toxicity, 10 = complete kill. [5] Taken at 62 days after transplanting or seeding. [6] Granule. DT = days after transplanting. DH = days after heading.

Table 5. Effects of a substituted urea herbicide (K-223) on the control of perennial nutsedge under simulated upland conditions (rice variety : IR442-2-58). IRRI 1973 late dry season. (Adapted from De Datta 1974)

Herbicide treatment*	Rate (kg ai/ha)	Total weed weight (g/m^2)	Dry weight of nutsedge (g/m^2)	Grain yield (t/ha)
K-223 fb Butachlor fb Bentazon	10 fb 2 fb 2	98 ab	2 a	4.10 a
K-223 fb Butachlor fb Bentazon	8 fb 2 fb 2	92 ab	5 ab	4.05 ab
K-223 fb Butachlor	10 fb 2	77 ab	3 a	4.04 ab
K-223 fb Butachlor	8 fb 2	54 a	6 ab	3.81 bc
K-223 fb Butachlor fb Bentazon	6 fb 2 fb 2	79 ab	12 abc	3.52 cd
Butachlor fb Bentazon	2 fb 2	62 a	18 abcd	3.52 cd
K-223 fb Butachlor	6 fb 2	64 a	14 abcd	3.43 d
Hand weeding	twice	27 a	2 a	4.04 a
Untreated control	—	666 c	58 e	0.41 e

* K-223, applied pre-planting.
Butachlor, 3 days after seeding.
Bentazon, applied 7 days after crop emergence.

and by conventional tillage practices (one plowing and two harrowings). The study was conducted in plots continuously flooded to 5 cm water depth. There were higher weed weights in plots treated with glyphosate at 2.0 kg/ha 12 days before transplanting than in plots treated 7 days before transplanting (Table 6). Apparently, applying the chemical for a longer period before transplanting did not control weed seeds, which germinated and grew before transplanting time. It appears that glyphosate has no residual effect when in contact with the soil. Paraquat at 2.0 kg/ha followed by one plowing desiccated the *P. distichum* leaves better than glyphosate but new leaves and tillers developed faster from the basal parts in paraquat-treated weeds than that with glyphosate[3]. This resulted in a significantly lower grain yield with paraquat followed by one plowing than with glyphosate followed by one plowing (Table 6).

In the 1976 dry season spraying glyphosate alone at 2.0 kg/ha 7 days before transplanting eliminated perennial weed, *P. distichum*, but did not control the annual sedge, *Fimbristylis littoralis*. A mixture of glyphosate and paraquat applied at any rate 7 days before transplanting failed to

3 Lin, W.L. 1976. Weed control with minimum and zero tillage in flooded rice. Univ. Philippines at Los Baños. M.S. Thesis (Agronomy). Oct., 1976. 89 pp.

control *P. distichum*. On the other hand, application of glyphosate followed by paraquat showed a much broader spectrum of weed control and lower dry weight of weeds than an application made in a single dose of mixture (Table 7). These results indicate that the translocated herbicide, glyphosate, and the contact herbicide, paraquat, are not suitable as mixtures in controlling weeds.

Table 6. Effects of chemicals as substitute for land preparation on the dry weight of weeds and grain yield of transplanted IR30 rice[1]. IRRI 1975 wet season. (Adapted from Lin 1976)

Treatment [2]	Application		Dry weight of weeds [4] (g/sq m)				Grain yield (t/ha)
	Rate (kg/ha)	Time [3] (DBP)	Grasses	Sedges	Broad-leaves	*Paspalum distichum*	
Glyphosate	2.0	7 DBP	13 a	0 a	3 a	20 a	4.5 a
Glyphosate	2.0	12 DBP	103 b	0.4 a	17 a	58 b	2.5 b
Glyphosate fb 1 plowing	2.0	7 DBP	21 a	0.6 a	3 a	0 c	4.6 a
Glyphosate fb 1 plowing	2.0	12 DBP	4 a	1.0 a	12 a	28 a	4.3 a
Paraquat fb 1 plowing	2.0	7 DBP	8 a	0.5 a	0.1 a	121 e	3.5 b
1 Plowing and 2 harrowings	—	—	5 a	2.4 a	13 a	36 a	4.1 a
CV (%)			28.0	25.0	21.0	31	9.0

1 Avg. of four replications. Any two means followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test).

2 fb = followed by; plowing and harrowings were done two days before transplanting.

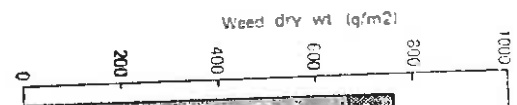
3 DBP = days before planting.

4 At heading stage of rice.

Among the combination of chemical treatments tried, good weed control was obtained with glyphosate at 1.5 kg/ha 7 days before transplanting. The most effective control of *P. distichum* was obtained in plots sprayed with glyphosate at 2.0 kg/ha 7 days before transplanting followed by one plowing 2 days before transplanting (Table 7). These results of Lin [3] demonstrate that the perennial grass, *P. distichum* could not be controlled by paraquat alone, but demonstrated that sequential application of glyphosate followed by paraquat was most effective in controlling *P. distichum* as well as other weeds. However, this trial was conducted with transplanted rice and an optimum water condition, which itself is known to suppress regrowth of weeds.

Table 7. Effects of tillage and chemical treatments on weed dry weight (at heading stage) and grain yield of transplanted IR26 rice[1]. IRRI 1976 dry season. (Adapted from Lin 1976)

Treatment/chemical[2]	Application		Dry weight of weeds[4] (g/sq m)				Grain yield (t/ha)
	Rate (kg/ha)	Time[3] (DBP)	Grasses	Sedges	Broad-leaves	*Paspalum distichum*	
Glyphosate + Paraquat	2.0 + 0.5	7	66	1037 b	1	295 cde	3.0 de
Glyphosate + Paraquat	1.5 + 1.0	7	149	198 c	0	684 a	3.6 cde
Glyphosate fb Paraquat	2.0 fb 0.5	7 fb 6	59	4443 c	1	63 cde	4.3 bcd
Glyphosate fb Paraquat	1.5 fb 1.0	7 fb 3	83	194 c	0	77 de	5.7 a
Glyphosate	2.0	7	106	2052 a	8	106 cde	2.6 e
Paraquat	2.0	7	78	56 c	0	444 ab	4.3 bcd
Glyphosate fb 1 plowing	2.0	7 fb 2	24	356 c	8	11 e	5.7 a
1 Plowing fb 2 harrowings	—	2	8	81 c	4	157 bcde	5.7 a
Untreated control	—	—	23	1872 a	9	469 abc	0.9 f
CV (%)			26.0	23.0	—	23.0	12.0



[1] Avg. of four replications; any two means followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test). [2] + = tank-mixed; fb = followed by. [3] DBP = days before planting. [4] At heading stage of rice.

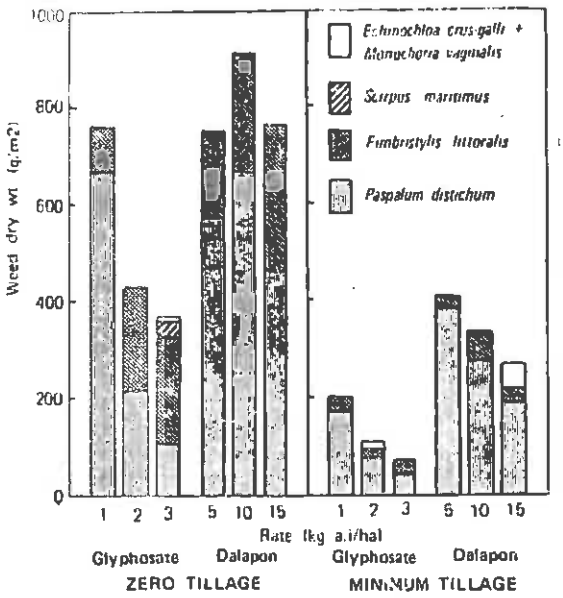


Figure 1. Weed dry weight at harvest, as indices of preplant weed control by glyphosate and dalapon, under minimum and zero tillage, IRRI 1976 wet season. (Adapted from Bolton and De Datta 1976).

In another trial with rainfed, direct-seeded rice in an area where the dominant weed species was *P. distichum* representing 67% of the total dry weight of weeds, *P. distichum* was the least effectively controlled weed species in both minimum and zero tillage plots (Figure 1). Despite this, the zero tillage plots that received 2.0 or 3.0 kg/ha glyphosate had significantly lower dry weight of this weed than other plots. Among minimum tillage plots, those treated with 3.0 kg/ha glyphosate had the lowest dry weight of *P. distichum*, but this was only significantly different from the weed weight in plots treated with 5.0 kg/ha dalapon[4]. None of the herbicide combinations gave satisfactory preplant control with zero tillage in rainfed rice.

It appears that a glyphosate treatment followed by a paraquat treatment may give sufficient sustained preplant weed control with optimum conditions of water management. Such was the case in an earlier expeperiment[3]. Where conditions are less than optimum, such as with rainfed dry-seeded rice even 3.0 kg/ha glyphosate followed by paraquat could not give adequate weed control[4]. With minimum tillage, however, it was possible to obtain satisfactory control with 2.0 kg/ha glyphosate, without subsequent paraquat application.

Dalapon was less effective than glyphosate in controlling *P. distichum*. With dalapon herbicide alone, it was not possible to achieve effective weed control, particularly of *P. distichum*. When the application was

[4] Bolton, F.R. 1976. Minimum and zero tillage in lowland rice. M.S. Thesis. University of Reading, England. 153 pp. (unpublished).

followed by tillage, however, effective weed control was achieved with 2.0 or 3.0 kg/ha glyphosate, but dalapon at 15 kg/ha was ineffective.

Indirect methods. It is becoming increasingly evident that continuous and increasing use of herbicides causes some population shift from easy-to-control weeds to difficult-to-control weeds. Most of the difficult-to-control weeds are perennials. Rapid industrialization in Korea, Japan and Taiwan resulted into higher wage rate of labor and more dependence on chemicals over that of other methods of weed control (De Datta and Barker 1977).

In Korea, herbicide consumption has steadily increased since 1967 and 49% of the total rice area was treated with herbicide in 1974 (Ryang *et al* 1976). The 1974 herbicide consumption for Korean rice was 20,000 t/yr (Ahn *et al* 1976). Repeated use of butachlor [*N*-butoxymethyl-2, chloro-2'-6' diethyl acetanilide], benthiocarb, simetryn, nitrofen (2,4-dichlorophenyl-*p*-nitrophenyl ether), that were normally recommended for annual weeds developed a predominance of the perennial sedges such as *E. kuroguwai* and *C. serotinus*. Within 4 years of the start of repeated application, the population of these perennial sedges rose from 45 to 69%. During the same period, the broadleaf weed population decreased from 45 to 10%. The population shift was attributed to successive elimination of the herbicide-sensitive species and their gradual replacement by the tolerant weed species (Ahn *et al* 1976). These shifts in weeds from annuals to perennials caused substantial yield reduction (Table 8).

Effects of tillage. Where perennial grasses such as *P. distichum* are present, continued poor land preparation, or continued zero-tillage treatment, would result in increased incidence of those weeds. In trials conducted in Malaysia, Seth *et al* (1971) observed that the incidence of weeds in the growing rice crop was generally less following the use of minimum tillage than in zero tillage.

In a recent study at IRRI, Bolton and De Datta (1976) reported that zero tillage involving preplant herbicides (H) alone (3.0 kg dalapon/ha followed by 0.6 kg paraquat/ha) failed to satisfactorily control *P. distichum* and *S. maritimus*, and the annual weed, *F. littoralis*. But when the preplant herbicide treatments (H) were followed by a tillage operation (T), control of those weeds improved as shown by a significantly lower weed weight in the HT treatment (Table 9).

Table 8. Rice yield with repeated annual application of herbicides in paddy fields in Korea. (Adapted from Ahn *et al* 1976)

Herbicide	Rate (kg ai/ha)	Yield [1]					
		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
Butachlor	1.5	4.9 bc	93	4.5 b	80	4.2 b	72
Benthiocarb/simetryn	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 DT [2]	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

[1] In each column, means followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[2] DT = days after transplanting.

In another experiment at IRRI, Bolton and De Datta[5] observed that after two crops with zero tillage, the perennial weeds, *P. distichum* and *S. maritimus* became dominant because of ineffective control by the pre-plant herbicides (dalapon followed by paraquat). At that stage, the zero tillage treatment had to be discontinued for one crop, because of the increased incidence of perennial weeds.

The absence of *P. distichum* from conventional and minimum-tillage plots suggested that tillage alone is probably the most practical method for controlling *P. distichum*. However, not all perennial weeds are entirely controlled by tillage operations. For example, in an experiment at IRRI, the perennial sedge *S. maritimus* was not entirely controlled by increased tillage operations although without chemical weed control, the weed population was lower and the grain yield was higher with good land preparation (one plowing and two harrowings) than with poor land preparation (one plowing and one harrowing) (Table 10). With both land preparation levels, bentazon significantly increased grain yield in the treated over untreated control but the grain yield difference was less with good land preparation (De Datta and Lacsina 1974).

[5] Bolton, F.R. and S.K. De Datta. Minimum and zero tillage in lowland rice. IRRI Saturday Seminar, Dec. 18, 1976 (Unpublished mimeo).

Table 9. Weed dry weight at harvest as influenced by the treatment combinations of pre-plant herbicides (H), tillage (T) and flooding (F). IRRI 1976 dry season. (Adapted from Bolton 1976)

Treatments	Weed dry weight (g/m^2)					Total weed dry weight[3] (g/m^2)
	Annuals		Perennials			
	Broadleaved	Sedge	Grass	Sedge	Grass	
	Mv[1]	Fl	Ec	Sm	Pd	
H[2]	0	454	40	274	15	784 ef
T	7	0	21	233	7	267 abcd
F	8	1111	13	64	109	1305 f
HT	23	0	1	133	17	174 ab
HF	2	130	32	217	31	411 cde
TH	5	0	4	245	16	271 abcd
TF	5	0	8	206	21	239 abc
FH	0	349	5	272	8	635 def
FT	14	0	0	158	35	207 abc
HTF	3	0	24	97	14	138 a
HFT	4	0	0	162	3	169 a
THF	9	0	11	300	32	352 bcd
TFH	9	0	1	174	83	266 abcd
FHT	16	0	8	218	49	191 abcd
FTH	3	3	8	266	11	291 abcd
CT	5	0	0	228	35	268 abcd
CV (%)	79	88	106	12	83	7

1 Mv = *Monochoria vaginalis*; Fl = *Fimbristylis littoralis*; Ec = *Echinochloa crus-galli* (*E. crus-pavonis*); Sm = *Scirpus maritimus*; Pd = *Paspalum distichum*.
2 H = pre-plant herbicide; T = tillage; F = flooding; CT = conventional tillage.
3 Values followed by a common letter are not significantly different at the 5%.

Effects of water depth. Recent data at IRRI (Bolton and De Datta 1976) demonstrate that flooding alone does not control the perennial grass, *P. distichum*. However, tillage followed by flooding (TF) or flooding followed by tillage (FT) gave about the same control of weeds (primarily *P. distichum*) as shown by weed dry weight at harvest (Table 9). The grain yield, however, was somewhat higher with TF than with FT treatment (Figure 2). Other field observations suggest that the perennial sedge *S. maritimus* growth is generally unaffected by water depths. These results suggest that not all perennial weeds are adversely affected by flooding.

Table 10. Effect of bentazon herbicide on weed control and grain yield of broadcast-seeded IR22 rice under poor (1 plowing and 1 harrowing) and good (1 plowing and 2 harrowings) land preparation. IRRI, Dec. 1972-Mar. 1973. (Adapted from De Datta and Lacsina 1974)

Chemical	Application rate (kg ai/ha)		Weed control rating [3] 21 DS		Weed count (no./sq m) 60 DS		Grain yield [4] (t/ha)	
	PL[1]	GL[2]	PL	GL	PL	GL	PL	GL
Bentazon	1.5	1.5	6	4	80	0	5.5 a	6.6 a
Bentazon	3.0	3.0	6	4	45	2	5.8 a	6.9 a
Untreated control	—	—	0	3	300	215	1.9 b	4.2 b

1 PL = poor land preparation; herbicide was applied before seeding rice.
2 GL = good land preparation; herbicide was applied 26 days after seeding (DS).
3 Scale: 0—10; 0 = no control, 10 = complete control.
4 Avg. of three replications. Any two means followed by the same letters are not significantly different at the 5% level.

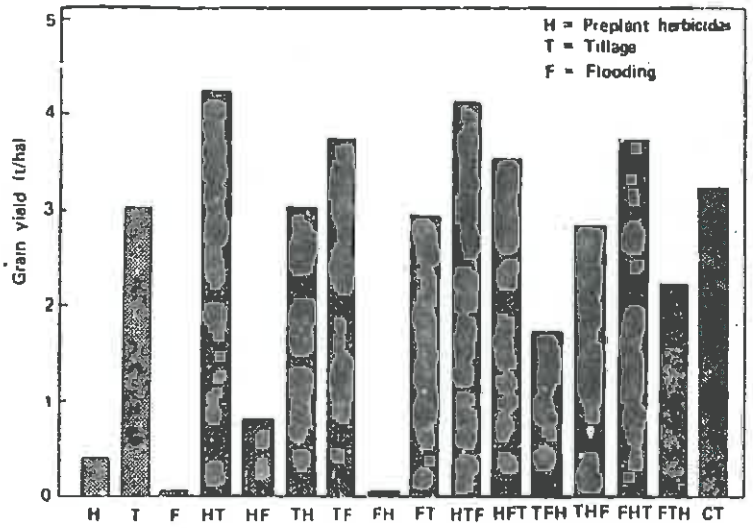


Figure 2. Grain yield of IR 30 as influenced by the land preparation treatments, IRRI 1976 dry season. (Adapted from Bolton 1976).

Effect of variety. Increased plant height and vigorous tillering appears to help minimize perennial weed growth. In an experiment at IRRI, for example, IR34 an intermediate-statured variety, and IR1632-93-2-2, a heavy-tillering semidwarf, were able to suppress perennial weeds, particularly *P. distichum,* more than a somewhat low tillering, semidwarf IR30[5] (Figure 3). The varietal differences in suppressing *P. distichum* and other weeds were not significant, however.

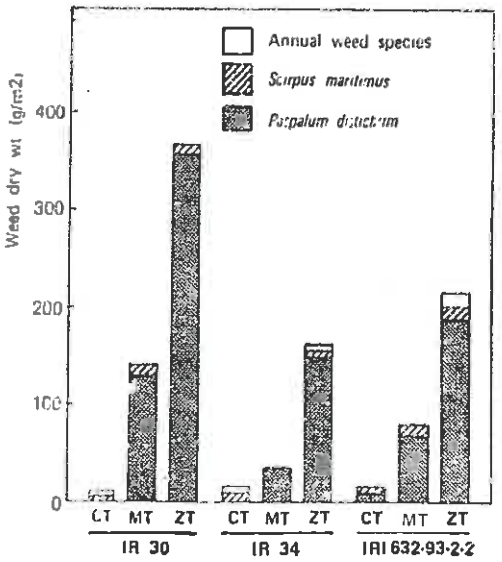


Figure 3. Varietal differences in suppressing perennial weeds (weed dry weight at harvest of the first crop) with conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT), IRRI 1975 dry season. (Adapted from Bolton and De Datta 1976)

In another IRRI study (De Datta 1974), it was found that an intermediate-statured rice like IR442-2-58 (130-cm plant height) could compete better with annual weeds or with a mixed population of annual and perennial (*S. maritimus*) weeds than could a semidwarf rice variety like IR20 (100 cm plant height) (Table 11). That and other studies [6] clearly demonstrate that where difficult-to-control weeds like *S. maritimus* are present, it is better to grow varities about 130-cm tall than it is to grow the semidwarf rice varieties.

Effects of planting method. Transplanting gives the rice plants the advantage of a good head start over the perennial weeds, as compared with direct seeding where rice and weeds germinate about the same time. In experiments at IRRI,[3] where *P. distichum* was the major weed, transplanting gave a lower number and a lower dry weight of *P. distichum* than broadcast seeding (Table 12). The grain yield was lower with broadcasting method than with transplanting method [3] (Table 12).

In another experiment at IRRI, without weed (primarily perennial weed *S. maritimus*) control, the weed weight was higher with broadcast seeding than with transplanting method. Without weed control, the grain yield of IR22 was 2.5 t/ha from transplanting compared with 0.8 t/ha from direct-seeding (De Datta 1974). With weed-free conditions (two handweedings), the IR22 yields were similar for both methods of plantings (Table 4).

[6] Visperas, R.M. 1973. *Scirpus maritimus* L., growth characteristics and response to light duration and intensity. IRRI Saturday Seminar, June 2, 1973. (Unpublished mimeo).

Table 11. Crop yield and growth (weed weight) of *Scirpus maritimus* and a mixed population of annual weeds and *S. maritimus* under semidwarf rice variety IR20 and intermediate-statured rice variety IR442-2-58. IRRI (Adapted from De Datta 1974).

Treatment	Grain yield [1] (t/ha)	Weed weight[2] (g/m²)			
		Scirpus maritimus	*Echinochloa crus-galli*	Sedges	Broad-leaves
			IR20		
Unweeded control					
Annual weeds only	4.5 b	0	247	55	7
S. maritimus only	3.0 cd	420	0	0	0
Annual weeds + *S. maritimus*	2.2 d	418	135	17	2
Hand weeding twice [3]	6.8 a	3	0	2	0
			IR442-2-58		
Unweeded control					
Annual weeds only	5.1 a	0	200	42	3
S. maritimus only	3.3 b	408	0	0	0
Annual weeds + *S. maritimus*	2.8 b	362	133	10	3
Hand weeding twice [3]	5.6 a	2	10	0	2

[1] Avg. of three replications at 14% moisture. Any two means followed by the same letter are not significantly different at the 5% level.
[2] Taken at 62 days after transplanting (DT).
[3] At 20 DT followed by 30 DT.

Those results suggest that when perennial weeds such as *P. distichum* and *S. maritimus* are present, transplanting will minimize weed competition as compared to direct-seeding.

Effects of cropping system and land and water management. Published research on crop rotation and herbicide application, particularly in the Asian tropics, is limited. The concept of combining crop rotation and herbicide application involves a total system for the entire cropping unit. Weeds such as *S. maritimus* that are difficult to control in lowland fields, might be controlled by a soil or land management system including an upland crop. Such weeds can probably be effectively controlled at their most vulnerable stage in the cropping system.

Table 12. Number of weeds, weed weight, and grain yield of IR30 rice under broadcast-seeding and transplanting methods of planting. IRRI 1975 wet season. (Adapted from Lin 1976)

Methods of planting [1]	No. of weeds [2] (no./m²)				Dry weight of weeds [2] (g/m²)				Grain yield [3] (t/ha)
	Grasses	Broad-leaves	Sedges	*Paspalum distichum*	Grasses	Broad-leaves	Sedges	*Paspalum distichum*	
Broadcast seeding	78	0	4	103	48	0	4	132	3.4
Transplanting	3	8	4	21	5	13	2	36	4.1

1 Land was prepared well with 1 plowing and 2 harrowings.

2 Measured at heading stage of rice.

3 Average of four replications.

Harwood and Bantilan (1974) demonstrated that various management treatments applied over time can eliminate troublesome grasses and sedges in an intensive cropping system and do it with a low level of cash inputs. Bantilan *et al* (1974) showed that a crop's competitive ability was enhanced as when corn was intercropped with mung bean, as the level of weed control was reduced; the relative advantage of intercropping increased to a point where its productivity was 75% greater than that of monoculture. Bantilan and Harwood [7] concluded that the concept of an integrated approach to weed control is not only much more feasible in Asia where mechanization is limited, but is also much more necessary because less production capital is available than in the developed countries. However, De Datta (1974) pointed out that chemical weed control is often necessary in integrated weed management systems even when the rate of herbicide application is decreased.

In a long-term IRRI experiment, three cropping systems were studied for the effects on the population density of *S. maritimus*.

Various crops and soil, water, and weed management practices shifted the weed population from species that are more difficult to control to those that are easier to control (Lacsina and De Datta, 1975). The perennial sedge *S. maritimus* persisted in continuous lowland rice, but not *C. rotundus*, a perennial sedge that grows primarily in upland culture (Table 13). Lowland rice rotated with upland crops with no weed control had fewer weeds than continuous lowland rice. But there were fewer perennial weeds, *S. maritimus*, under alternating dry and wet conditions. Although *S. maritimus* and *C.rotundus* were the only two perennial weeds studied in these experiments (Lacsina and De Datta 1975, De Datta and Jereza 1976), the results are expected to be similar with other perennial weeds. Further, these results demonstrate the advantage of rotating crops in a planned sequence as well as the benefit of reducing yield losses caused by weed competition to a minimum.

Total eradication. A total eradication approach to perennial weeds such as *S. maritimus* weed was tried at IRRI. The approach involve the use of benzyladenine for breaking bud dormancy and the subsequent destruction of top growth with selective herbicides like bentazon or silvex.

At 1.0 kg/ha benzyladenine (BA) bud dormany was significantly broken for *S. maritimus* tubers in both greenhouse and field experiments. In the field experiments, induced sprouts from dormant buds in BA-

[7] Bantilan, R.T. and R.R. Harwood, 1973. Weed management in intensive cropping systems. IRRI Saturday Seminar, July 28, 1973. (Unpublished mimeo).

Table 13. Shifting of annual and perennial weeds in rice and other crops in untreated controls under three cropping systems. IRRI 1974, 1975 and 1976 dry and wet seasons.

Crop no.	Season	Weed population (no./m²)		
		Annuals[1]	Perennials	
			S. maritimus	*C. rotundus*
			Continuous lowland rice	
1	1974 dry	415	289	0
2	1974 wet	0	310	0
3	1975 dry	725	406	0
4	1975 wet	340	325	0
5	1976 dry	990	205	0
6	1976 wet	1168	300	0
7	1977 dry	277	191	0
			Corn-mungbean fb lowland rice	
1	1974 dry	208	59	90
2	1974 wet	0	236	0
3	1975 dry	1008	36	32
4	1975 wet	364	167	0
5	1976 dry	1420	60	30
6	1976 wet	639	191	0
7	1977 dry	620	59	8
			Corn fb two crops of dry-seeded bunded lowland rice	
1	1974 dry	171	65	99
2	1974 wet	513	29	38
3	1974 wet	3328	0	0
4	1975 dry	2386	35	53
5	1975 wet	1463	20	33
6	1975 wet	1352	33	71
7	1976 dry	2825	15	75
8	1976 wet	1422	67	115
9	1977 dry	521	26	38

1 Grasses, broadleaved weeds, and sedges.

treated plots were effectively controlled by either bentazon or silvex applied 20 days after direct seeding or transplanting of rice (Kim and De Datta 1974).

This approach to minimize infestation and possible eradication of *S. maritimus* may have relevance in the control or eradication of other perennial weeds if a less-expensive chemical than benzyladenine is identified.

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Growth and Tuber Formation of Water Nutsedge (Cyperus serotinus Rottb.)

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ABSTRACT

Water nutsedge (*Cyperus serotinus* Rottb.), a perennial Cyperaceae, is a troublesome weed in the rice fields of Japan and Korea. It reproduces itself mainly by tubers. The buds of tubers began to sprout in early spring, then shoots increased rapidly in late spring and summer. The formation of new tubers began early in September. The depth of soil layer in which the tubers were formed was about 0-10 cm from the soil surface. The number of tubers formed in 5-10 cm layer was greater than that in 0-5 cm layer in the ordinary rice fields, but the former was smaller than the latter in fields with a thick growth of the plants. Shoot emergence from tubers fluctuated with soil moisture conditions. The sprouting of tubers was suppressed as the depth of the tubers and the moisture of the soil increased. In flooded soil most tubers did not sprout and many of them died. A close relationship was recognized between the depth of tubers (X), the length of the part of shoot in the soil (Y), and the length of ascending rhizomes, $Z/Y = 1.53 \log X + 0.45$. The number of shoots increased rapidly, but the rate fell off after the beginning of September.

INTRODUCTION

Water nutsedge is one of the most important perennials in Japan and Korea. A basic knowledge of its growth habits and its life cycle are important to improve control measures.

Ecological studies on water nutsedge have been carried out since 1965 (Nakagawa 1977; Nakagawa *et al* 1973). I report here the results of some experiments on the following problems (1) the form and the life cycle (2) tuber formation and their distribution in the soil (3) relationships between the depth of tubers in the soil, soil moisture content and emergence (4) the increase of shoots and the growth of subteranean organs.

FORM AND LIFE CYCLE

The buds of tubers began to sprout in late March and the emergence occurred after early April. The number of shoots increased rapidly in late spring and summer.

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Swelling of the base of shoots was not so noticeable, and the main reproductive organ of water nutsedge was the tuber. Rhizomes originating from the base of shoots differentiated into new shoots until the end of summer and thereafter into tubers. Sometimes, the apex of a rhizome originating from a new tuber differentiated into another tuber in the same season. We termed the former an intermediate tuber and the latter an apex tuber.

THE TUBER FORMATION AND ITS DISTRIBUTION IN THE SOIL

In any field most tubers were formed in the soil within 10 cm of the soil surface. But a detailed comparison between the ratio of number of tubers in the soil layer within a depth of 0 to 5 cm and that of 5 to 10 cm shows that the vertical distribution changed markedly in response to the field conditions (Table 1).

Table 1. Vertical distributions of water nutsedge tubers in various rice fields

Field condition (density of nutsedge and cultural method of rice)	Percentage of tuber numbers in each soil layer		
	0-5 cm	5-10 cm	10-15 cm
	%		
No rice plant: dense planted nutsedge	66	30	4
No rice plant: sparse planted nutsedge	45	43	11
Rice plant of normal season culture	45	48	6
Rice plant of early season culture (I)	34	66	0
Rice plant of early season culture (II)	28	63	9
Rice plant of direct sowing culture	38	59	2

Number of tubers in 0 to 5 cm deep was about twice as many as in 5 to 10 cm in the field with no rice plants and densely planted nutsedge, but numbers of tubers in each depth were equal in the fields with no rice plants and sparse planted nutsedges or with rice plants of normal season culture. On the other hand, the tubers in 5 to 10 cm deep were more than in 0 to 5 cm in the fields with rice plants of early season culture or direct sowing culture.

These may be important factors affecting the sprouting of tubers or the death of tubers during winter.

RELATIONSHIPS BETWEEN THE DEPTH OF TUBER IN THE SOIL, SOIL WATER AND THE EMERGENCE

The progress of emergence from tubers fluctuated with the soil moisture conditions (Table 2). Under drained soil conditions, the

Table 2. The emergence percentages of water nutsedge from tubers planted in various depths in drained or wet soils.

Soil moisture condition	Depth of tuber from soil surface	Date							
		April			May			June	
		10	20	30	10	20	30	10	20
	cm	%							
Drained	3	1	12	95					
	6		2	71	99				
	12			14	61	88			
	18			4	36	58	65		
Wet	3		5	93					
	6			10	26	43	65	83	94
	12					2	7	24	50
	18							6	24

shoots originating from tubers at a depth of 3 cm emerged after the beginning of April until the end of the month. The deeper the tubers were planted, the later was the time of emergence. However most of the emergence had occurred before the end of May. Under wet soil conditions, the emergence from tubers in deeper soil was much later and the last emergence from the 6 cm depth occurred at the end of June. Under flooded conditions, most tubers at the soil surface emerged readily but no shoot emerged from the tubers in the soil.

The viability of tubers after wintering was determined by germination tests (Table 3). Tubers were dug out on the 25th of January and 13th of April. All tubers on the soil surface under drained and wet soil conditions did not germinate, but under the flooded condition they did. Most of the tubers at 1 cm depth germinated. The germination of tubers in the soil deeper than 3 cm differed from that of tubers near the soil surface. Under drained soil conditions most tubers at depths greater

than 3 cm germinated, but under wet soil conditions germination was poorer at depths greater than 12 cm. Under flooded conditions few tubers in the soil deeper than 6 cm germinated.

Table 3. The germination of tubers dug up from soil with different moisture conditions.

Depth	Dry		Wet		Flooded	
	J*	A*	J	A	J	A
cm	%					
0	0	0	5	0	100	89
1	46	52	67	0	95	93
3	100	100	100	98	72	71
6	100	98	98	93	28	23
12	98	97	93	50	13	10
18	98	84	33	35	31	26

* The date of digging
J : 25 th of January
A : 13 th of April

THE LENGTH OF ASCENDING RHIZOMES DIFFERENTIATED FROM TUBERS AT VARIOUS DEPTH IN THE SOIL

The lengths of ascending rhizomes from tubers planted in deep soil attained several centimeters. In contrast, those from tubers near the soil surface were extremely short and it appeared that the base of the shoots originated from the tuber directly. It was found that both of the length of the part of shoots in the soil (Y) and the length of

Table 4. The relationships between the depth of tubers, the length of parts of shoots in the soil and the length of ascending rhizomes.

Depth of tubers (X)		cm	1	3	6	12	18
Length of parts of shoots in the soil	(Y)	cm	0.6	1.4	2.5	3.8	5.7
Length of ascending rhizome	(Z)	cm	0.3	1.7	4.0	8.6	13.2
Z/Y			0.5	1.2	1.6	2,3	2.3

ascending rhizomes from tubers (Z) related closely to the depth of tubers (X). A nearly linear relationship was obtained between the ratio of Z to Y and the logarithm of X as follows: $Z/Y = 1.53 \log X + 0.45$ (Table 4).

THE GROWTH OF SHOOTS AND THE TUBER FORMATION

Until late summer rhizomes differentiated into new shoots and the number of shoots increased rapidly. The relation between logarithm of shoot numbers (Y) and the days after planting (X) gave straight lines (Table 5). But the rate of increase fell after the beginning of September. It was presumed that rhizomes differentiated into tubers and not into shoots after that time.

Table 5. The progress of shoot increases (number of shoots per square meter).

Date of survey		Aug. 8	18	23	28	Sept. 1	2	7	12	21	Oct. 4
Days after planting		0	10	15	20	24	25	30	35	44	57
Number of seedlings planted in a plot	1	1.4	6	11	24	51	56	106	226	359	572
	4	5.6	10	21	53	118	133	274	447	701	856
	16	22.2	58	112	306	489	543	644	956	1090	1280

The weight of shoots and root of plants that emerged later were lighter than those that emerged earlier. But the weight of rhizomes and tubers while showing the same trend did not differ to the same extent as the shoots and roots.

Table 6. The dry weight of each organ per shoot classified according to the emergence time (mg).

Days after emergence / organs	42	37	32	27	22	15	13
	38	33	28	23	16	14	0
Leaves and stems	1757	1501	1029	644	457	260	139
Rhizomes	215	222	168	134	119	72	58
Tubers	218	286	243	252	258	128	116
Roots	235	172	84	77	63	48	23

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Effect of Cutting and Burying Bulbs on Sprouting and Early Development of Oxalis latifolia Kunth under Two Moisture Regimes

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ABSTRACT

Bulbs of *Oxalis latifolia* Kunth either cut or left intact were placed on the soil surface or buried 4 cm deep in pots 9 cm high. Bulbs in the pots in which with moisture supply was delayed did not sprout until water was added (watering was started 5½ weeks after planting). Under both immediate and delayed watering cumulative sprouting percentage was highest for the cut and buried bulbs at the earliest time of recording. This was followed by the intact bulbs while the cut and exposed bulbs had the least percentage. The same order occurred for the mean cumulative number of petioles sprouted per week. The mean cumulative number of petioles produced per week showed a typical growth curve under immediate moisture supply but only the logarithmic phase of the curve was depicted in the case of delayed moisture supply.

INTRODUCTION

O. latifolia is perhaps the most widespread species of the genus *Oxalis* (Chawdhry 1974). It occurs mainly in central and equatorial America, the West Indies, South Africa, Ceylon, New Zealand and the Mediterranean Region. In East Africa it occurs widely in the cultivated highlands, i.e. above 1000 m and therefore existing in most of the coffee producing areas (Ivens 1967). There appears to be no quantitative assess ment of the economic importance of the weed in East Africa. However, it is thought that *O. latifolia* and its related species *O. semiloba* do not compete with plantation crops (Stephens 1961) but they are troublesome weeds in coffee nurseries, pyrethrum fields and areas planted with annual crops where a complete cover may decrease the stand and yield of the crop (Green *et al* 1974). The life growth pattern of *O. latifolia* has been described by Chawdhry (1974). Control of the weed in East Africa (Stephens 1961, Wallis 1958) and elsewhere (Jackson 1961) by application of herbicides has met with little success. This has been attributed to the inability of the herbicides to reach the dormant or mature bulbs (Preest

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1964). Cultivation has had variable results depending on the type and intensity of the method, but in no case is *O. latifolia* reported to have been eliminated economically.

This study was conducted to examine the effect of simulated cultivation on sprouting and early development of *O. latifolia* in the greenhouse. It was hoped the results would enable us to understand better the effect of cultivating the weed under field conditions.

MATERIALS AND METHODS

Bulbs of *O. latifolia* all of which had developed brown outer leaf sheaths were collected from a banana/coffee plantation near Tropical Pesticides Research Institute (TPRI) where cultivation had been done 2 days earlier. They were selected for uniform size and they averaged 0.463 g each after drying at 80 C for 18 hours. In one set of three bulbs each bulb was left intact. The resultant three intact bulbs and six bulb pieces were either placed on the soil surface or buried 4 cm deep in pots of 9 cm high on 10th September 1976. The pot soil was of a sandy loam texture dug from a virgin area. The moisture of the unwatered soil at the time of planting expressed as percentage of soil dried at 70 C for 24 hours was 42.3%. Each of the sets of the pots was either watered immediately or delayed until 5.5 weeks after planting. This period was likened to a continuous dry period which can occur at the end of a wet season. Water was supplied overhead from a hose without a rose. The pots which were watered immediately were replicated 20 times while those which were watered later were replicated 20 times. Within each watering regime the pots were randomly placed over a wooden bench and the original position of the bulbs or bulb pieces were not disturbed. Thus the design was a factorial completely randomized block. The rate of sprouting (indicated by the emergence of the shoots from the bulb or bulb piece) was assessed by the cumulative number of pots with at least one sprouted bulb or bulb piece per week. The cumulative number of petioles sprouted per pot were also counted. These parameters were counted until 7 weeks from planting for the pots watered immediately and 8 weeks after the start of watering for the pots delayed in moisture supply. At the end of the two periods, plant were weighed but this is not reported in this paper.

RESULTS AND DISCUSSION

The effect of the treatments on sprouting rate, recorded as cumulative percentage of pots with at least one sprouted bulb or bulb piece per week is shown in Tables 1 (a) and (b). In the set of bulbs watered immediately first sprouting was noticed 2 weeks after planting. At this time while sprouting percentage was 55% for the cut and buried bulbs, less than 10% was recorded for the exposed bulbs both intact and cut. Sprouting thereafter occurred in the trends shown in Table 1 (a) and by week 7 maximum sprouting had taken place in all the treatments.

Table 1. Cumulative number of pots with at least one sprouted bulb or bulb piece as percentage of total number of pots planted.

(a) Immediate moisture supply

Treatments	Weeks after planting					
	2	3	4	5	6	7
Cut and buried	55	100	100	100	100	100
Cut and exposed	5	55	75	85	90	95
Intact and buried	40	78	90	95	95	95
Intact and exposed	10	35	60	90	90	100

(b) Delayed moisture supply

Treatments	Weeks since watering was started							
	1	2	3	4	5	6	7	8
Cut and buried	32	95	100	100	100	100	100	100
Cut and exposed	0	16	37	68	79	90	90	90
Intact and buried	26	95	100	100	100	100	100	100
Intact and exposed	5	58	79	90	90	90	90	90

Sprouting did not occur for the bulbs first subjected to moisture stress until 6 days after watering was started i.e. 6.5 weeks after planting. The percentages of initial sprouting were less than for the bulbs which had been watered immediately. Maximum sprouting was attained 6 weeks

from the start of watering. Other studies on the above lines on *O. latifolia* seem to be wanting but similar work has been done in other perennial weeds. Hammerton (1974) found that tubers of nutgrass (*Cyperus rotundus* L.) exposed on the soil surface without moisture underwent a very rapid desiccation with germination declining from 5% at 3 days after planting to 0% 7 days after planting. In the same period moisture content of the tubers decreased from 33% to 10%. The moisture content of the bulbs was not measured in our experiment but it is logical to suppose that a considerable amount of moisture was lost. Whereas there was some germination in Hammerton's experiment in ours there was apparently none while the bulbs were being desiccated. This cannot be said with certainly particularly for the buried bulbs because they may have germinated but shoots may have failed to reach the soil surface. Besides, the desiccated tubers in Hammerton's experiments were treated to a special germination.

In the bulbs which were watered immediately, sprouting was earlier in the intact and buried than in the intact and exposed bulbs. This can neither be attributed to differences in moisture loss since water was being added frequently nor to differences in carbohydrate reserves since both types of bulbs were intact and thus most likely to have the same quantities of carbohydrate reserves. Most likely this was due to merely being covered with the soil under which roots were established more easily. Therefore soil cover supplemented the carbohydrate reserves in establishment of the bulbs. The importance of carbohydrate reserves in plant establishments is well known, so that rhizomes of couch grass (*Agropyron repens* (L.) Beauv.) buried more than 7 cm led to less chances of survival. When it is taken into consideration that bulbs of *O. latifolia* can form up to a depth of 30 cm (Hunter and Over de Linden 1958), placing such bulbs at a depth of 4 cm can hardly be described as burying.

The earlier sprouting in the bulbs denied moisture initially indicates that some development must have taken place particularly in the buried bulbs during this initial dry period. Apparently there was a germination but shoots did not reach the soil surface. Shoots can sometimes fail to reach the soil surface especially if establishment is very poor. The first sprouting percentages were higher for the cut and buried bulbs than for intact bulbs under both moisture regimes. Cutting propagating organs as a stimulatory process in establishment is a widely used principle in

vegetative propagation of plants. This has been attributed to such factors as removal of dominance leading to transfer of growth substances to regions of root initiation.[2]

The developmental productivity of the weed was measured by the mean cumulative number of bulb or bulb pieces and petioles sprouted per pot. Both parameters were very well correlated but for the sake of clearity the discussion will mainly concentrate on petiole production shown in Figure 1 (a) and (b). The rate of petiole production was highest for

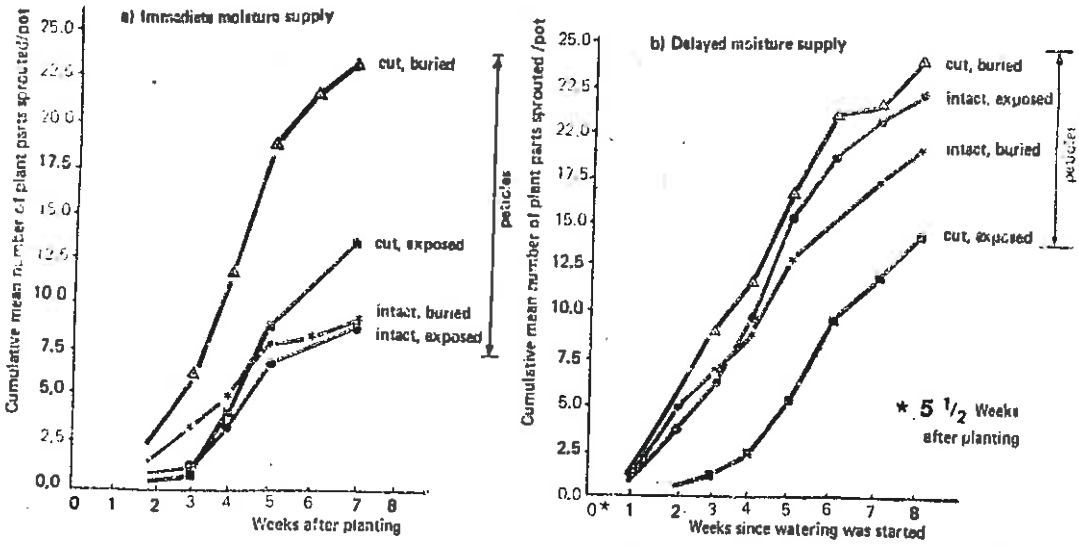

Figure 1. Mean cumulative number of petioles produced perpot perweek.

the cut and buried bulbs under both moisture regimes. There was not much difference in petiole production within the intact bulbs. These observations tally with the rate of sprouting noted earlier. Under immediate moisture supply, the cut and exposed bulbs which had sprouted more slowly than the intact and buried bulbs, eventually produced more petioles than the latter. This lack of correspondence between sprouting rate and petiole productivity indicates that apart from earliness of sprouting the number of propagules from which petioles emerge is a major factor in the perennation of the weed. That fragmenting propagating organs aids in the spread of perennial weeds is a universal principle of the biology of perennial weeds (Fryer and Evans 1968). Under

[2] Leakey, R.P.B. 1974. Factors affecting the growth of shoots from fragmented rhizomes of *Agropyron repens* (L.) Beauv. Ph.D. Thesis, University of Reading, England.

delayed moisture supply the rate of petiole production was lower for the intact and exposed bulbs than for the intact and buried bulbs in the first 3 weeks of watering (a situation similar to sprouting rate). After this period, petiole production of the latter surpassed that of the former. It is difficult to account for this but it appears that the function of conserving moisture and carbohydrate reserves which had been served by the buried and intact bulbs no longer became important as water was applied. Perhaps after the intact and exposed established bulbs were established, there was more surface exposed for petiole production than for the intact and buried bulbs. This role of orientation in establishment was not found to be important in the tubers of *C. rotundus* (Siera 1973) but this may only apply to tubers planted in the soil which the latter dealt with. In *O. latifolia* it may be very important because in a later study there appeared to be apical dominance within the scales of the bulbs which give rise to petioles.

Generally it can be seen that during the first 3 weeks of watering a higher petiole production was recorded for the bulbs which had been initially denied water than for those watered immediately. In fact the rate of petiole production of the latter bulbs followed a typical growth curve whereas the former bulbs seemed to have undergone the establishment or lag phase by the beginning of recording. Thus inspite of lack of water the bulbs were developing using the carbohydrate reserves in the parent bulb so that on adding water they accelerated to a logarithmic phase. It should be noted that when recording was started the bulbs watered immediately were 2 weeks while those denied moisture initially were 6.5 weeks from planting. The production of petioles from the cut and exposed bulbs however, followed a typical growth curve suggesting that establishment depended on the supply of new resources made available to the plants through moisture supply.

The following conclusions can be drawn from this study. Subjecting bulbs of *O. latifolia* especially if fragmented to a period of moisture stress checks the propagation of the weed but this can be completely nullified by any subsequent presence of moisture. Failure to get a sufficiently long continuous dry period makes the application of this principle alone for field weed control a formidable task. One possibility is to supplement desiccation for example by the application of herbicide after the weed has been cultivated in the dry season. The value of deep cultivation was not fully investigated in this experiment.

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Germination and Growth Inhibitors in Clerodendrum viscosum Vent., a Perennial Weed[1]

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ABSTRACT

Germination and growth responses of four different test species were employed to assess inhibitory activity extracts and leachates of various plant-parts of *Clerodendrum viscosum* Vent. However, the mustard bioassay was preferred as it was most reproducible and not as subject to microbial contamination. The leachates contained more inhibitors than the extracts. Increasing the amount of plant material increased the inhibition and all plant-parts were inhibitory. Leachates of dry tissues were less inhibitory than those of fresh tissues, and ash from dried material was devoid of any activity. Young roots and stems as well as old leaves seemed to possess higher concentrations of inhibitors. Although the inhibitory factors were stable when stored up to 224 days at room temperature, they could not resist breakdown when chilled at 8 C. Decreasing activity was evident on heating the leachates. Phytotoxicity of leaf leachate was greater in the light than in the dark, but root and stem leachates showed similar activity under the two conditions. Treatment of leachates with Norit removed all the inhibitors from the aqueous solutions. The repressing power of the leachates was neither lost by autoclaving nor after inoculation with a soil micro-organism. Soil samples collected in and around *C. viscosum* plants were found to be harmful to both weeds and crops.

INTRODUCTION

C. viscosum Vent., a robust undershrub that grows to a maximum height of 1.8 m, gives off a foetid smell. It is clothed with yellowish silky pubescence and sometimes covered with large raised lenticular warts. It is common throughout India, Burma and Ceylon (Wealth of India 1950), forming dense thickets (Kanjilal 1939). It prevails in moister districts along streams and shady places as well as along drier ones in the edges of glades (Haines 1961). It reproduces by means of suckers (Gamble 1957) and is reported to be useful in the reclamation of land (Duthie 1903).

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All parts of the plant possess a bitter pungent taste and various parts are employed medicinally (Wealth of India 1950, Gamble 1957). The roots are used for fermenting liquors in Garo Hills (Kanjilal 1939) and utilised externally for tumours and certain skin diseases (Wealth of India 1950). Fresh leaf-juice is considered to be vermifuge, being injected into the rectum for ascarids (Kanjilal 1939; Wealth of India 1950). The leaves also form a cheap substitute for chiretta (*Swertia chirata* L.) as a tonic and antiperiodic (Cooke 1958). The leaves, warmed with ghee, are applied to the head for catarrhal colds (Gamble 1957).

Information is lacking on the biochemical characteristics of the root, stem, leaf and inflorescence of *C. viscosum*. It is spreading fast to the exclusion of other species in diverse habitats in the vicinity of Calcutta (Datta and Majumder 1966). In its habitat, the population of other species is very thin and even those which emerge also exhibit poor growth. Anything which prevents a seed from germinating or discourages a plant from growing must have a strong influence on the makeup of the plant community of the region (Salisbury 1957). Following the outlines of the work on *Croton bonplandianum* (Datta and Sinha-Roy 1973), we initiated this study to demonstrate the presence of germination and growth inhibitors in *C. viscosum*.

MATERIALS AND METHODS

Vigorously thriving individuals of *C. viscosum* were collected from a particular site near Calcutta during the years 1974 - 1976 and were brought to the laboratory. The root, stem, leaf and inflorescence from each plant were detached. Aqueous leachate was prepared by soaking 100 g of each fresh plant-part in 200 ml of distilled water for 3 days. It was filtered through Whatman No. 1 filter paper and the filtrate made up to 250 ml with water; this constituted the standard or stock solution. Concentrations were expressed as 1:0, 1:1 and 1:3 to denote the amount of plant material diluted with 0, 1 and 3 times the volume of water from the stock solution.

We principally employed a mustard bioassay to estimate the inhibitory activity of the various leachates, although responses of germinating rice, pea and mustard were utilised at the initial phase of the investigation. The bioassay consisted of placing surface-sterilised (2% sodium hypochlorite for 10 min) seeds in a sterile petridish (11 cm in diam) and 10 ml of

test solution or water. The dishes were covered and held for 3 days (or 5 days for rice) at room temperature (26.0 ± 2.4 C). Data are presented as percentage of germination as well as average length of root and hypocotyl. The degree of inhibition was ascertained on the basis of seed germination and seedling growth of the control set.

RESULTS AND DISCUSSION

Preliminary experiments carried out under aseptic conditions revealed that autoclaving, i.e. sterilisation of the leachates caused no reduction in inhibitory action. No colony of bacteria or fungi was evident after 5 days in unopened dishes. At no time did the bioassays show any sign of bacterial or fungal contamination.

It was also established that the leachates contained more inhibitors than the extracts (which was obtained by crushing equal quantity of plant material with water in a Waring blendor). A concentration of 1:0 was strongly inhibiting, but the effect gradually became reduced upon dilution.

Root leachate was found to be more inhibitory to lettuce than to mustard, whereas pea and rice bioassays indicated no inhibition. However, stem and leaf leachates were more toxic to mustard than other test seeds. Though inflorescence leachate yielded poor germination of mustard and lettuce seeds, the germination of pea and rice was not adversely affected.

Comparison of aqueous leachates of dried tissues with those of fresh tissues indicated that the former resulted in loss of activity. No inhibition arose from adding the ash of dry material to the petridishes containing test seeds. The ash represented merely 2% of the original sample.

Bioassay of the leachates of young roots and stems as well as old leaves seemed to demonstrate that the inhibitory components increased in these plant-parts. This trend might point to the formation of inhibitors in the roots and their translocation to the leaves via the stem.

The inhibitory activity of leachates was influenced by light and dark conditions. The inhibition was more accentuated when the germinating dishes were exposed to light than when kept under darkness. However, this was not true for root and stem leachates both of which contributing equal activity in the presence and absence of light.

Heating the stock solution at 40-100 C caused a decline in inhibitory activity, as both germination and seedling growth were below the corresponding controls. When similar solutions and their dilutions were

subjected to chilling (8 C), there was diminished activity at the lower temperature. Diaz-Colon *et al* (1970) claimed some loss of activity upon chilling or freezing yaupon (*Ilex vomitoria*) fruit extract.

To judge if the phytotoxins from *C. viscosum* would be stable under field conditions, soil samples were collected at a depth of 10 cm from the areas infested by the species. Soils 1 m away from the plants served as controls. Soil collection were made in November (commencement of dry season). The soils of each area were transferred to dishes, covered with filter paper which was then suitably moistened and crop and weed seeds were put in the surface. The soil samples were noted to be detrimental not only to the germination and seedling growth of pea, mustard, rice and lettuce but also to those of weeds like *Amaranthus spinosus, Cassia sophera, Cassia tora* and *Tephrosia hamiltonii.*

Using the mustard bioassay, it was observed that the inoculation of *C. viscosum* leachates with micro-organisms like *Rhizopus nigricans* resulted in very little reduction in activity. It might be assumed that micro-organisms other than *Rhizopus* could be responsible for the loss of phytotoxicity in the soil. The loss of activity in the soil had been viewed

Table 1. Percent germination as well as root and hypocotyl lengths (cm) of mustard in presence of *C. viscosum* leachates treated with varying amounts of Norit

Type of leachate	Treatment with Norit (g)	Germination			
		0	1 : 0	1 : 1	1 : 3
Root leachate	0	88.0	19.0	22.0	39.0
	5	98.0	82.0	92.0	96.0
	10	91.0	79.0	83.0	86.0
	15	96.0	86.0	95.0	97.0
	20	94.0	78.0	88.0	94.0
Stem leachate	0	88.0	0	25.0	34.0
	5	98.0	94.0	96.0	96.0
	10	98.0	86.0	90.0	92.0
	15	95.0	86.0	89.0	92.0
	20	96.0	82.0	90.0	92.0
Leaf leachate	0	88.0	0	24.0	33.0
	5	98.0	76.0	82.0	84.0
	10	95.0	79.0	78.0	86.0
	15	96.0	76.0	88.0	92.0
	20	98.0	92.0	94.0	94.0

	Root length				Hypocotyl length			
	0	1 : 0	1 : 1	1 : 3	0	1 : 0	1 : 1	1 : 3
Root leachate	2.76	0.14	0.74	2.19	0.86	0.13	0.33	0.64
	1.50	0.52	0.73	1.14	0.52	0.43	0.49	0.49
	1.30	0.60	1.00	1.32	0.50	0.39	0.50	0.55
	1.82	0.85	1.33	1.39	1.78	1.13	1.58	1.61
	2.18	0.80	1.55	2.05	0.47	0.31	0.48	0.52
Stem leachate	2.17	0	0.63	0.85	0.84	0	0.31	0.37
	1.50	0.35	1.00	1.43	0.58	0.56	0.44	0.77
	1.50	0.40	0.66	0.73	0.44	0.39	0.56	0.58
	1.80	0.90	1.39	1.42	1.70	0.77	1.69	1.70
	2.01	0.68	1.35	2.03	1.28	0.68	0.93	1.25
Leaf leachate	0.97	0	0.24	0.43	0.49	0	0.15	0.33
	1.50	0.33	0.61	0.82	0.58	0.34	0.39	0.45
	1.91	0.55	0.56	1.17	0.94	0.44	0.50	0.66
	1.82	0.39	0.48	1.41	1.78	0.78	1.04	1.69
	2.98	0.56	0.88	1.58	1.25	0.83	0.87	1.90

as the inhibitors being subjected to microbial decomposition or being adsorbed by colloids (Le Tourneau and Heggeness 1957). On the other hand, Wilson and Rice (1968) theorised that the colloidal material of the soil might play a significant role in accumulating the phytotoxins to a toxic level. More information on this aspect is needed before arriving at a definite conclusion.

Treatment with Norit (activated carbon) removed all inhibitors from the aqueous leachates (Table 1). Five, 10, 15 and 20 g Norit were each added to 250 ml of each of the leachates and their dilutions, being stirred continuously for 20 min. At the end of this time, the carbon was filtered off and the filtrates examined. Assay of the filtrates from Norit-treated material proved that the inhibition of both germination and growth was almost erased. By adding increasing amounts of Norit to the leachates, it appeared that 5 g was sufficient to eliminate all activity.

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Studies on Chemical Control of Imperata cylindrica (L.) Beauv.[1]

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ABSTRACT

Imperata cylindrica (L.) Beauv. is a deep rooted grass which usually grows along the field channels. If left unchecked it invades crop land. Results of three sets of experiments have indicated that combinations of bromacil (5-bromo-3-*sec*-butyl-6-methyluracil) or terbacil (3-*tert*-butyl-5-chloro-6-methyluracil) or diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] at 4.0 kg/ha with dalapon (2,2-dichloropropionic acid) (5.0 kg/ha) or paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) (1.0 L/ha) as sequential spray are effective in controlling *I. cylindrica*.

INTRODUCTION

I. cylindrica, locally known as cotton grass or cogongrass is an erect, perennial grass with hard, creeping rhizomes spreading in the soil. Leaves in the aerial shoots are very close, errect acuminate and pale green in color (Tadulingam and Narayan 1955). The terminal, characteristic spikes are densely clothed with long, white silky hairs and this noxious weed belongs to the family Poaceae (Gramineae). This grass was introduced at the Agricultural Research Station, Siruguppa (Tungabhadra Project, Karnataka State, India) to strengthen the newly opened channels in the deep black clay soils. Within a few years, it not only strengthened bunds but also invaded the nearby cultivable area. The rhizomes were found even at a metre depth and it was difficult to control *I. cylindrica* with ordinary tools. Chemical control of this grass by herbicides has been reported by several workers (Dickens and Buchanan 1975, Bloomfield 1975, Ivens 1973, Lamb 1975 and Wang 1976). However, complete eradication economically by herbicides alone has not been possible. Studies were started to find out the effect of various herbicides and herbicide mixtures on the control of *I. cylindrica*.

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MATERIALS AND METHODS

In order to strengthen bunds in the newly irrigated fields in the deep black soils of the Agricultural Research Station, Siruguppa (Tungabhadra Project area) the earlier agronomists introduced *I. cylindrica* and *Panicum repens* (L.). During the course of 8 to 10 years both grasses have invaded the valuable cultivable area. As roots had gone deeper into the lower zones of the soil (nearly a metre), it was difficult to control this grass by hand digging along the field channels. There was a patch of about 200 m in length and 2 to 3 m wide along the main irrigation canal badly infested by *I. cylindrica*. This area was divided into small plots of 1.0 m by 1.0 m dimensions with a channel of 30 cm around each plot. Before spraying, the original volume (percentage ground area covered by grass multiplied by average height in cm) of the green grass was recorded. Spraying was done during the second week of November, 1975. Herbicide doses mentioned in this article are expressed as active ingredient or acid equivalent only. Before spraying, teepol, a surfactant was added to the spray-medium at the rate of 0.05%. The studies were made in three sets of experiments (Table 1, 2 and 3 respectively).

1. Diuron and its mixture with four other herbicides.
2. Bromacil and its mixture with seven other herbicides.
3. Paraquat (as a sequential spray) with seven other herbicides.

In each set of experiment, two checks, one of shoot cut at ground level and another an untreated check were included for comparison. Wherever paraquat was applied, it was given as a sequential spray, that is, eight days after the application of another herbicide. Each set of experiment was conducted in a randomised block design with three replications. Observations at 30 days interval were recorded for a period of 180 days after spraying.

The following herbicides have been used in these experiments: diuron, simazine [2-chloro-4,6-bis(ethylamino)-*s*-triazine], amitrole-T (3-amino-*s*-triazole plus ammonium thiocyanate), dalapon, bromacil, methazole [2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione], paraquat, terbacil and glyphosate [*N*-(phosphonomethyl)glycine].

RESULTS AND DISCUSSION

Observations on the effect of diuron and its compatible tank mixtures on *I. cylindrica* have been presented in Table 1. Based on the percentage

of volume of fresh green grass after 180 days, it can be said that the diuron (4.0 kg/ha) + dalapon (5.0 kg/ha) mixture was most effective and reduced the volume to 3.2% of the original volume. The second best combination was that of diuron (4.0 kg) and bromacil (4.0 kg) which reduced the original volume to 5.5%. Compared with the above treatments, the shoot cut at ground level reduced the volume to 70% of the original volume and when the grass was not cut, the volume increased to 150.3%.

The effect of bromacil and its mixtures with other herbicides on the growth of *I. cylindrica* is presented in Table 2. The four mixtures of bromacil (4.0 kg) with terbacil (4.0 kg); or with dalapon (5.0 kg) or with diuron (4.0 kg) or with sequential spray of paraquat (1.0 L) have brought down the original volume of this grass to 2.3%, 3.9%, 4.4% and 5.6% respectively. In this set of experiments, the cutting treatment increased the volume to 119.5% and no cutting to 110.5% over the original volume after 180 days.

In the third set of trials, application of paraquat (1.0 L/ha) followed eight days after spraying with other herbicides. Results (Table 3) indicated that three combinations reduced the original volume to less than 10.00%, 180 days after application. Paraquat (1.0 L) and bromacil (4.0 kg); paraquat and terbacil (4.0 kg) and paraquat and dalapon (5.0 kg) reduced the original volume of grass to 5.3%, 6.7% and 9.5% respectively.

From the above three sets of trials the following combinations were found to be most effective in controlling *I. cylindrica*.

1. Bromacil or terbacil (4.0 kg) with a sequential spray of paraquat (1.0 L).
2. Bromacil (4.0 kg) with a tank mixture of diuron (4.0 kg) or terbacil (4.0 kg).
3. Dalapon (5.0 kg) with a tank mixture of diuron (4.0 kg) or bromacil (4.0 kg) or with a sequential spray of paraquat (1.0 L).

Application of bromacil or terbacil or diuron causes slow and sure mortality by way of inhibiting photosystem II of the photosynthetic mechanism. Whereas, paraquat being a contact herbicide, causes rapid desiccation of foliage, and loss of integrity of the cell membrance. The mechanism of this herbicide involves the formation of the free radical by reduction of ion and subsequent auto-oxidation to yield the original ion. OH' radicals or H_2O_2 formed during auto-oxidation are the primary

Table 1. Effect of diuron and herbicide mixture on *Imperata cylindrica* (L.) Beauv.

Volume of grass in cm^2 (average of 3 replications)

Table 1. Effect of diuron and herbicide mixture on *Imperata cylindrica* (L.) Beauv.

Treatment	Volume of grass in cm² (average of 3 replications) Days after spraying						
	Original volume	30	60	90	120 *	180	Percent of the original volume
Diuron @ 4.0 kg/ha	1340.0	194.9	184.5	150.0	166.7	250.0	18.6
„ + simazine 4.0 kg/ha	1279.2	169.6	193.8	170.0	97.7	137.0	10.7
„ + amitrole-T 2.0 L/ha	1531.9	39.0	75.8	81.3	132.7	150.0	9.7
„ + dalapon 5.0 kg/ha	1120.6	95.8	40.7	22.2	19.3	35.0	3.2
„ + bromacil 4.0 kg/ha	1155.7	39.6	40.5	51.0	54.3	64.6	5.5
Shoot cut	2024.0	965.2	1035.0	1192.5	1240.0	1417.0	70.0
Check	1861.6	1996.7	2256.7	2351.7	2408.3	2797.0	150.3

* Observations on 150 days after spraying were not recorded.

Table 2. Effect of bromacil and herbicide mixtures on *Imperata cylindrica* (L.) Beauv.

Treatment	Volume of grass in cm^2 (average of 3 replications) Days after spraying						
	Original volume	30	60	90	120	180	Percent of the original volume
Bromacil @ 4.0 kg/ha	2237.5	192.4	119.2	96.5	81.0	267.8	11.9
„ + methazole 4.0 kg/ha	1610.4	35.0	40.0	78.0	164.5	270.4	16.8
„ + amitrole-T 2.0 L/ha	1934.8	175.9	59.5	77.0	92.5	323.5	16.7
„ + paraquat 1.0 L/ha	1886.5	11.7	29.2	36.6	48.3	106.8	5.6
„ + dalapon 5.0 kg/ha	2498.6	17.3	25.7	35.8	46.0	98.7	3.9
„ + diuron 4.0 „	1834.2	28.8	30.3	44.8	57.7	80.6	4.4
„ + terbacil 4.0 „	2250.0	167.2	125.3	89.5	66.0	51.0	2.3
„ + simazine 4.0 „	2096.5	112.4	151.5	167.6	185.7	337.5	16.1
Shoot cut	2024.4	965.2	1035.0	1192.5	1840.0	2417.5	119.5
Check	2326.0	2814.5	3133.3	3163.3	3002.0	3037.0	110.5

Table 3. Effect of paraquat as sequential spray after the application of some herbicides on *Imperata cylindrica* (L.)

Table 3. Effect of paraquat as sequential spray after the application of some herbicides on *Imperata cylindrica* (L.) Beauv.

Treatment	Volume of grass in cm² (average of 3 replications) Days after spraying						
	Original volume	30	60	90	120	180	Percent of the original volume
Paraquat @ 1.0 L/ha	1299.1	23.2	176.2	261.2	350.2	689.0	53.0
„ and diuron 4.0 kg/ha	1549.7	30.1	65.3	146.7	155.7	165.0	10.6
„ and dalapon 5.0 kg/ha	2039.7	3.6	2.4	1.3	10.0	19.5	9.5
„ and bromacil 4.0 „	1765.6	12.5	22.4	17.9	75.0	94.0	5.3
„ and terbacil 4.0 „	1881.5	26.7	21.7	12.5	26.6	127.0	6.7
„ and glyphosate 4.0 „	1446.2	17.8	149.2	220.8	430.0	494.0	34.1
„ and amitrol T 2.0 L/ha	1646.3	17.4	50.3	60.1	204.2	381.0	23.1
„ and simazine 4.0 kg/ha	1875.4	28.1	91.2	114.2	229.0	287.0	15.3
Shoot cut	1840.0	796.8	852.5	1139.3	1198.7	1667.0	96.0
Check	2079.6	2158.3	2309.4	2560.6	2827.5	2908.0	139.8

toxicants (Ashton and Crafts 1973). The sequential spray of paraquat following the application of other systemic herbicides like bromacil or diuron causes more effective mortality in *I. cylindrica*. Repeated application of either bromacil, terbacil, diuron or dalapon at 4.0 kg/ha three times at an interval of 150 to 180 days also found very effective. The first application itself kills 75 to 80% of *I. cylindrica* but the subsequent application at a six months interval causes 95 to 98% mortality. Later on, deep ploughing, collection and burning of rhizomes would bring back the land to cultivation.

It has been found that the application of dalapon with other herbicides like bromacil or diuron is more effective than using it alone. While the mode of action of dalapon is through the degradation of the cell membrance and protein structure and ultimately it acts as a growth inhibitor, the uracils, substituted ureas and triazines inhibit the Hill's reaction in the photosynthetic mechanism (Ashton and Crafts 1973).

Dickens and Buchanan (1975) reported that all soil sterilants provided acceptable control of cogongrass but single application of TCA (trichloroacetic acid) at 56.0 kg/ha or dalapon at 8.3 kg/ha controlled it to a great extent without prolonged soil sterility. Bloomfield (1975) found that application of 30 kg/ha of dalapon-sodium 85% was effective in controlling *I. cylindrica* in Saudi Arabia. Ivens (1973) found a high degree of control for 11 months with an application of dalapon at 15 to 20 kg/ha, asulam (methyl sulfanilycarbamate) at 8.0 kg/ha and glyphosate at 4.0 kg/ha and tetrapion (2,2,3,3,-tetrafluoropropionic acid) at 10.0 kg/ha.

It may be infered from these series of experiments that *I. cylindrica* can be controlled by application of mixtures of bromacil or terbacil or diuron with dalapon or with the sequential spray of paraquat for two to three times at an interval of four to six months.

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Notes on the Distribution of Waterhyacinth (Eichhornia crassipes (Mart) Solms.), Water Lettuce (Pistia stratiotes L.) and Salvinia (Salvinia herzogii de la Sota)

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ABSTRACT

The presence of noxious free floating species in New Zealand's adventive flora, provides the potential for this life form to succeed and extend weed problems, particularly in eutrophic waters. Waterhyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*) and salvinia (*Salvinia* spp.) have all displayed aggressive colonisation and the displacement of resident flora at localities where field populations have been identified. Waterhyacinth (seed) and salvinia (spores) reproduce both sexually and vegetatively; the seeding potential of water lettuce in New Zealand is yet to be described. The present distribution of these plants in the South Pacific and their potential significance to waterplant management is discussed.

INTRODUCTION

Water weed problems associated with introduced submerged species have been experienced for more than two decades in lakes on the central volcanic plateau of the North Island of New Zealand (Chapman 1970). Similarly, drainage and irrigation authorities throughout the country have been troubled with both submerged and emergent water plants [2].

The present submerged flora of New Zealand is capable of creating a nuisance in a wide range of water types. Most important are *Lagarosiphon major* (Ridl.) Moss in oligotrophic waters, and *Egeria densa* (Plench.) in eutrophic waters.

With the introduction of aggressive free-floating species, the potential for these life forms to succeed submerged species in the hydrosere, and extend weed problems particularly in enriched waters, is of concern.

Native free-floating species, which include *Azolla rubra* A. Br., *Lemna minor* L., *Spirodela punctata* (G.F.W. Meyer) Thompson, and *Wolffia australiana* (Benth.) den Hartog and van der Plas, are widespread in New Zealand, but their nuisance potential is limited to small water-bodies which

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2 Eady, F.C. 1972. Unpublished report on aquatic weeds in New Zealand drainage systems. Project SH-33. Ministry of Agriculture and Fisheries. Palmerston North.

are protected from exposure to wind. Waterhyacinth, water lettuce and salvinia have a greater nuisance potential and can colonise more extensive and exposed water-bodies. Hence a statement of their present distribution in the South Pacific is of interest.

Waterhyacinth. The species is a true indigene of South Amerika (Sculthorpe 1967) and the first record of its appearance in the South Pacific Region is 1894 at the Bogor Botanic Gardens in Java (Backer 1951). By 1902 it was common in continental Southeast Asia, and was introduced to Ceylon during 1905. Backer (1951) notes that from its original stations in Southeast Asia, it is now a frequent weed in Australia (Aston 1973), Kalimantan, the Philippines, Guam, Sumatra and Java.

The first record of waterhyacinth in New Zealand is 1914 (Mason 1970), in Fiji is 1905 (Parham 1972), and in New Caledonia in 1925 [3]. It is present but rare in the Cook Islands (Rarotonga) and is locally common on Norfolk Island [4]. Many of the Pacific Islands have little or no available waterplant habitats (Niue for example) hence although water hyacinth is present in western Samoa and is sometimes washed out to sea in floods, available habitat limits its nuisance potential. This is not the case in Fiji and New Zealand, and both have declared waterhyacinth a noxious plant.

There is some suggestion that the vigour of waterhyacinth is diminishing at localities such as Rarotonga as Sykes [4] notes that Wilder considered it a noxious weed which was "spreading fast" in the 1920's, whilst he recorded only a few plants in one small garden pool during 1976 - 77.

Waterhyacinth has been reported from Guadalcanal in the Solomon Islands [5] but not from Tonga [4].

Water Lettuce. The native range of water lettuce is not accurately known, neither has its biology been investigated in detail. Sculthorpe (1967) considered it is a pan tropical species with a continuous distribution except for tropical Australia, Micronesia and Polynesia. In fact Blake (1954) recorded it in the vicinity of Darwin in 1946, and it is now cultivated in garden pools in Queensland (Aston 1973). In 1967, it was reported to be covering the surface of a large dam at Brisbane (Aston 1973).

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[3] Morat, P.H. personal communication
[4] Sykes, W.R. personal communication
[5] Steel, R.J.H. personal communication.

Water lettuce has been reported as an aquarium collection in New Caledonia [3, 5] and Whitmore (1966) has drawn attention to a collection by Reichinger during 1905 in Bougainville or Buka. It has not been reported from Fiji, Samoa, Tonga, Rarotonga, or Norfolk Island.

The first record of water lettuce in New Zealand is an aquarium collection in Whangarei, 1974. It is now present as an aggressive field population at Welcome Bay, Tauranga, and is held in aquaria from Rotorua to Whangarei.

Salvinia. New Zealand material previously referred to *Salvinia auriculata* Aublet is now classified as *Salvinia herzogii* de la Sota. *Salvinia* identified as *S. auriculata* from warm temperate Argentina south to the Rio de la Plota is probably also *S. herzogii* (de la Sota 1962, as quoted by Sculthorpe 1967).

This plant was first recorded in New Zealand during 1963 at western Springs lake, Auckland, and has since been troublesome at that locality. It has spread to several localities north to Waipapakauri (Mason 1975) and is present in ornamental ponds on the Hauraki Plains.

Salvinia sp. is reported as present in New Caledonia [3] but not in the Solomons, Samoa, or Rarotonga. Australian material is referred to *S. auriculata* Aublet (Aston 1973) and was first recorded from Brisbane during 1953. Fiji material is similarly referred to *S. auriculata* and was first reported as present during 1970 (Parham 1972, Hughes [6]).

RESULTS AND DISCUSSION

New Zealand's free-floating native flora is not competitive relative to introduced species such as ferny azolla (*Azolla pinnata* R.Br.), Waterhyacinth, water lettuce and salvinia. At western Springs lake for example, salvinia is the eco-dominant when in competition with the native species. Similarly, waterhyacinth at 53 North Island localities, and water lettuce at Welcome Bay, Tauranga, have aggressively dominated the native species.

No quantitative data are to hand on the competitive ability of individual species in associations where combinations of the introduced species are included in a common community. Observational records from North-

6 Hughes, H.R. personal communication.

land sites where both waterhyacinth and salvinia are present do suggest however that waterhyacinth is the most successful competitor. Water lettuce has not been observed growing in association with either waterhyacinth or salvinia in New Zealand.

As assessment of the true nuisance potential of each of these species wou'd require;

1. a statement of the environmental requirements of each species in relation to New Zealand conditions.
2. an assessment of water-bodies which satisfy these growth requirements,
3. a statement of interspecific competition which might be expected within these environmental limits,
4. a statement of water use requirements at each of these localities.

Such an appraisal would not be possible without controlled introductions of these plants at selected localities.

It is suggested that the localised distribution of these species in the north of the North Island may reflect only the introduction and initial spread of these plants. Case histories for plants such as *Lagarosiphon major* have shown that the southern lakes are eminently suitable habitats for plants which had previously been restricted to the central North Island.

Aquatic weeds in New Zealand have the potential to interfere with farm production, recreation and the environment [7]. Changing management practices, improvements in weed control technology, and a decline in the vigour of submerged weeds at some localities (Lake Rotorua for example) are resolving many of the countries submerged weed problems. The advent of free-floating weed problems caused by introduced species should be avoided at all costs. The significance of new locality records for water plants must be accommodated in any weed control programme.

The Ministry of Agriculture and Fisheries in New Zealand initiated an eradication programme for waterhyacinth in 1955 and since that time vegetative plants at all known localities have been controlled before the onset of flowering. During 1970, 20 years after the presence of flowering adults, seedling establishment requires that the surveillance and control programme continues.

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[7] Noxious Weeds Administration 1973. Report on the Committee of Inquiry. Wellington, New Zealand.

Until the seeding potential of new introductions such as water lettuce are described, and it can be stated the plant is of low nuisance potential in New Zealand, any new locality records are of concern.

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Seasonal Changes of Growth of Aquatic Weeds and their Control

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ABSTRACT

Growth of aquatic weeds was seasonally investigated in creeks of the paddy area on the northern coast of Ariake Sea in Kyushu Island of Japan. Of the four problem weeds, waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) was found to change its coverage in creeks most during three years, because almost all the plants were killed by coldness in winter or early spring. The other three species, knotgrass (*Paspalum distichum* L.), its hairy sub-species and parrotfeather (*Myriophyllum brasiliense* Camb.), were found to change their coverages in creeks little; this was because their shoots remained alive in the water even when the surface of the water was frozen by low winter temperatures. Many newly germinated seedlings of waterhyacinth appeared in the summer and the fall, and they were found to play a big role in producing the overabundant growth of waterhyacinth in the area. To control waterhyacinth, attempts were made to pick up these seedlings and overwintering plants. Chemical control of the four species was also tried. Paraquat (1,1'-dimethyl-4,4'-bipyridinium ion), diquat [6,7-dihydrodipyrido(1,2-*a*:2',1'-*c*)pyrazinediium ion], 2,4-D [(2,4-dichlorophenoxy)acetic acid] and endothall [7-oxabicyclo(2,2,1)heptane-2,3-dicarboxylic acid] were effective against waterhyacinth; glyphosate [*N*-(phosphonomethyl)glycine], dalapon (2,2-dichloropropionic acid), MCPA ([4-chloro-o-tolyl)oxy] acetic acid), diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] and asulam (methyl sulfanilcarbamate) against *Paspalum* spp.; and 2,4-D against parrotfeather.

INTRODUCTION

In recent years, invasion of aquatic weeds into irrigation channels, rivers, ponds and lakes, and hydroelectric dams has become a very serious problem, especially in the southwestern part, as Kyushu Island, of Japan. The most troublesome weed is waterhyacinth, and Ueki *et al* (1976) studied its habitats in Japan. In Kyushu Island, Miyahara *et al* (1976) found that knotgrass, its hairy subspecies (*Paspalum* sp.) and parrotfeather were very important aquatic weeds in addition to waterhyacinth in creeks of the paddy area. On other islands of Japan, *Hydrilla verticillata* (L.f.) Royle. was important weed in irrigation channels of Aichi Prefecture [2]. *Phragmites communis* Trin., *Zizania latifolia* Turcz., Leersia spp., *Hydrocharis dubia* (Bl.) Backer, *Ottelia alismoides* (L.) Pers., *Najas* spp.,

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[1] Kyushu National Agricultural Experiment Station, Chikugo, Fukuoka, 833 Japan.

[2] Kusanagi, T. 1977. Personal communication.

Potamogeton spp., *Trapa* spp., *Limnophila sessiliflora* Bl., *Spirodela polyrrhyza* (L.) Schleid., *Lemna* spp., *Salvinia natans* All., *Azolla* spp., *Ricciocarpus natans* (L.) Corda., several green algae and others were distributed widely and were sometimes important (Miyahara *et al* 1976, Numata and Yoshizawa 1975).

Miyahara *et al* (1976) studied the distributions and coverages of aquatic weeds in the creeks of Kyushu Island. In this study, seasonal changes in their growth were investigated in all creeks of about 1000 ha paddy area in the "creek paddy region" of Kyushu Island. And also, control methods, mainly, with herbicides, for four important weeds in Kyushu Island, waterhyacinth, knotgrass, its hairy subspecies and parrotfeather, were investigated.

SEASONAL CHANGES OF GROWTH

Studies were conducted from 1974 to 1976 and coverages of main aquatic weeds were measured seasonally or yearly at 502 points of investigated creeks in Kyushu Island of Japan. Waterhyacinth, knotgrass, its hairy subspecies and parrotfeather were troublesome species in these creeks.

In the study of the growth of the weeds, waterhyacinth was found to grow most excessively there in late summer and fall every year, but its coverage over the water surface of creeks changed during the three years more than that of any of the other aquatic species investigated because almost all the plants were killed by the cold temperatures of winter or early spring. The mean coverage of waterhyacinth in investigated creeks were 23, 4, 30 and 16% of the water surface of the creeks in the fall of 1974, the early summer and the fall of 1975, and the fall of 1976, respectively. It seems that the growth of waterhyacinth was affected by temperature conditions of winter, spring and summer. Overwintering waterhyacinth plants were very few compared with the number in the preceding fall, which was more than 50 plants per square meter (half a million plants per ha) in thickly inhabited creeks. In the spring of 1976, overwintering plants were found in only 36% of those creeks where waterhyacinth grew in the preceding fall, and less than 100 plants per ha survived in half of these creeks. Overwintering waterhyacinth was rare in creeks where the growth of the weed was not abundant in the preceding fall. However, many newly germinated waterhyacinth seedlings appeared in the summer and fall in many creeks, and, in 1976, 39% of creeks con-

taining waterhyacinth seemed to be inhabited with only plants which had germinated in summer and fall of the year. Seedlings were found to play a big role in producing the over abundant growth of waterhyacinth in the area.

Coverages of knotgrass, its hairy subspecies, parrotfeather and others over the water surface changed little during three years. For instance, those of hairy subspecies of knotgrass were 11, 12, 12 and 14%, and those of parrotfeather were 11, 12, 11 and 12% of the water surface of creeks, in the fall of 1974, in the early summer and fall of 1975, and in the fall of 1976, respectively. This occurred because shoots of both weeds were alive in the water even when the surface of the water was frozen by low winter temperatures. Emerged shoots of knotgrass and its hairy subspecies seemed burned in winter, although some of them were still alive. The shoots of parrotfeather were completely killed in winter. However, submerged shoots of the three species, which were frequently found as floating mats in the upper layer of creek water, were usually freshly green all year, and, from those shoots, new buds grew abundantly to give similar coverages in summer and fall as in preceding years.

HAND-WEEDING OF WATERHYACINTH

For controlling waterhyacinth, attempts were made to pick-up seedlings and overwintering plants by hand twice in summer in about 0.1 ha experimental creek, because the number of these plants were remarkably less at this season than that in the fall. Compared with untreated creeks, it was found that removal of about one-tenth waterhyacinth plants was enough to keep the water surface clean. However, many seedlings appeared in the summer and fall, so it seemed very difficult to eliminate all waterhyacinth plants from the creeks of the area by hand or mechanically.

CHEMICAL CONTROL OF FOUR IMPORTANT WEEDS

Herbicide experiments were conducted outdoors or in the greenhouse with 1/5,000 and 1/2,000 are Wagner pots in 1976.

Waterhyacinth. Trial I: glyphosate (2.5 and 5.0 kg/ha), paraquat (0.3, 0.6 and 1.2 kg/ha), 2,4-D amine (2.0, 4.0 and 8.0 kg/ha) and paraquat + 2,4-D amine (0.6 + 2.0 and 0.6 + 4.0 kg/ha) were applied and 2,4-D amine and paraquat + 2,4-D amine were found very effective.

Trial II: 2,4-D amine, 2,4-D Na, MCPA Na (1.0 and 2.0 kg/ha each) and endothall (2.9 and 5.8 kg/ha) were applied and all of these were very effective. But, 2,4-D amine seemed better than 2,4-D Na and MCPA Na.

Trial III: paraquat, diquat (0.6 and 1.2 kg/ha each), paraquat + 2,4-D amine, dikuat + 2,4-D amine (0.6 + 1.0 and 0.6 + 2.0 kg/ha each) and 2,4-D amine (2.0 kg/ha) were applied and diquat or diquat + 2,4-D amine were more effective than paraquat or paraquat + 2,4-D amine. In conclusion, paraquat (in combination with 2,4-D amine), diquat, 2,4-D amine and endothall were very promising for controlling waterhyacinth, as reported by Widyanto (1976) and others.

Knotgrass and its hairy subspecies. Trial I: glyphosate (1.0 and 2.0 kg/ha), dalapon (10.0 kg/ha), asulam (7.5 and 15.0 kg/ha) and tetrapion (2,2,3,3-tetrafluoropropionic acid) (24.0 kg/ha); and

Trial II: glyphosate (1.0 and 2.0 kg/ha), dalapon (5.0, 10.0 and 20.0 kg/ha), asulam (3.8, 7.5 and 15.0 kg/ha), tetraipion (12.0 and 24.0 kg/ha) and dalapon + MCPA + diuron (2.5 + 0.8 + 0.8 and 5.0 + 1.7 + 1.7 kg/ha) were applied to both species. Glyphosate, asulam and dalapon + MCPA + diuron were very effective at killing shoots and also inhibiting regrowth of these weeds. In preliminary experiments, paraquat was applied to these species, but it was found to be ineffective in inhibiting their regrowth.

Parrotfeather. Trial I: glyphosate (2.0 and 4.0 kg/ha), 2,4-D amine (0.5 and 1.0 kg/ha) and 2,4-D ethyl ester (granule) (0.5 and 1.0 kg/ha); and

Trial II: 2,4-D amine, 2,4-D Naa, 2,4-D ethyl ester (wettable powder) and MCPA Na (0.25, 0.5 and 1.0 kg/ha each), and endothall (1.4 and 2.9 kg/ha) were applied to the weed. It seemed in this study that 2,4-D amine was the most effective of the phenoxys and other treatments.

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Longevity of Waterhyacinth (Eichhornia crassipes (Mart.) Solms) Seed in New Zealand [1]

L. J. MATTHEWS, B. E. MANSON and B. T. COFFEY [2]

ABSTRACT

Waterhyacinth has been recorded at 71 localities in the North Island of New Zealand. All known infestations were controlled with 2,4-D (2,4-dichlorophenoxy acetic acid ester) during the summer of 1955-1956. Since that time regrowths have been rigorously controlled before the onset of flowering. The presence of seedling plants and immature adults in some of these areas during the summer of 1971-1977 suggest that seed set by plants 14 to 20 years previously is viable, and will germinate under favourable conditions. Laboratory studies confirm that germination rates for fresh waterhyacinth seed are in excess of 90%.

INTRODUCTION

The potential of waterhyacinth to spread by vegetative propagation has received comment from numerous authors (Sculthorpe 1967). Stoloniferous vegetative growth is extremely rapid and Aston (1973) quotes that 3 plants may produce 3000 new plants in 50 days (this is a doubling time of 5 days!) whilst a single plant has been known to develop into a patch c.a. 600 square meters in extent in a single season.

The floral biology of waterhyacinth has been investigated by Agharkar and Banerji (1930), Penfold and Earle (1948), Haigh (1936) and Backer (1951). It is a heterostylic, entomophilous species, and Sculthorpe (1967) has summarised data on the distribution of its flower types. Curiously enough, flowers where the style exceeds the length of both stamen whorls are characteristic in Ceylon, whilst flower where the style stamen whorls are characteristic in intermediate in length between the two stamen whorls are characteristic in India, southern USA and Malaysia. Flowers in southern USA and India are apparently self pollinated but flowers in Malaysia are probably self incompatible as fruits are unknown.

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This distribution of flower types is not surprising where perhaps only one vegetative fragment may have bridged a dispersal barrier. It will however preclude successful cross pollination by insects, and the flowers must rely on self pollination.

New Zealand material has flowers where the style length is intermediate in length between the stamen whorls, and it is presumably self fertile as viable seeds are produced.

Reports from Southeast Asia and Ceylon that seed is never set or that cross pollination is rarely successful have inculcated the belief that reproduction by seed is of minor importance (Sculthorpe 1967). However the Commission for Technical Cooperation in Africa South of the Sahara/ Scientific Council for Africa South of the Sahara (1967) recognized the need for data on the fruiting, germination, and dissemination of both seeds and vegetative material.

Pettet (1964) for example has provided an excellent case history of the significance of seed in the dispersal of waterhyacinth in the White Nile region. Similarly, Matthews (1967) has commented on the seeding potential of New Zealand material.

Haigh (1936), Hitchcock *et al* (1949), Hitchcock *et al* (1950), Parija (1934), Pettet (1964), and Sculthorpe (1967) have investigated aspects of waterhyacinth's seedling establishment. Their experimental data suggest:

- neither drying of the seeds nor a prolonged dormant period is necessary for germination
- high temperatures and/or intense light are required for germination
- germination is most likely to occur in shallow water warmed by intense sunlight
- seeds can tolerate a long dry period and yet remain viable
- a stable diurnal temperature will enhance germination.

Having reached the seedling stage, the young plants require anchorage in a firm substratum, which remains wet, for about a month before floating off as adult plants.

Matthews (1967) has reported waterhyacinth seed germinating after 15 years in New Zealand. The data on which that report was based are presented and the period of viability is extended.

All data on seedling production, and control efficiency for adult plants, are based on observational records by officer of the Ministry of Agriculture and Fisheries, who have been involved in the eradication programme for waterhyacinth in New Zealand.

MATERIALS AND METHODS

Fresh seed was collected from plants (from Ruawai) which had been held in buckets of water in the glasshouse. Germination rate was determined by incubating 100 seeds in moist soil (in petridishes with glass covers) under bright sunlight in a glasshouse.

RESULTS AND DISCUSSION

Locality records, the date waterhyacinth plants were adequately controlled with 2,4-D, and the years during which seedlings were observed at these localities is presented in Table 1.

At 10 of these 34 localities, seedlings have been observed where no flowering adults had been recorded for 14 to 20 years, suggesting that seed has remained viable for this period. These localities include (New Zealand Map Series 1967): Mangamuka (N 10 048578, 15 years) Totara North (N 11 223792, 15 years) Tautora (N 15 346261, 14 years) Oakura Bay (N 16 848373, and N 16 848371, 14 years) Otaika (N 24 754875, 18 years) Onehunga (18 years) Lake Rotorua (15 years) and the Orini Canal, Rangitaiki (20 years).

The remaining 37 sites where waterhyacinth has been recorded in New Zealand required only one spraying to remove vegetative plants and no seedling establishment occurred.

Ninety-six percent of the fresh waterhyacinth seed which was incubated under glasshouse conditions germinated within one month. Seedlings collected from field localities developed in an identical manner to that described by Sculthorpe (1967). Observational data from New Zealand localities further confirms the conclusions reached by Sculthorpe in that seedlings were only observed in areas exposed to full sunlight during the warmest summer months (February to late March). However, no waterhyacinth seedlings have been observed in shallow water in New Zealand. All have been confined to moist, emersed hydro-soils which have been exposed during a water level draw-down.

It is clear that waterhyacinth seedlings have an obligate requirement for bright light or high temperatures, and a particular requirement for water level fluctuations. These conditions are not met every season, and seedlings have been observed in places where they have been stranded

Table 1. Locality records, date of first control and reinfestation of sites for water-hyacinth in New Zealand †

	Locality (N.Z. Map Series 1972)	Date of first control	Reinfestation by seedlings 19-
*	N 10 048578	1956	56, 57, 58, 59, 60, 61, 63, 71
	N 10 765532	1956	63
*	N 11 223792	1956	56, 57, 58, 59, 60, 61, 63, 71
	N 11 489691	1956	58
	N 14 895330	1957	58
	N 14 105242	1955	56, 57, 58, 59, 61, 63
	N 14 033336	1959	61
	N 15 478453	1956	56, 57, 59
	N 15 640458	1957	57
	N 15 382472	1955	56
	N 15 419471	1955	56
*	N 15 346261	1955	56, 57, 58, 59, 60, 61, 63, 69
	N 15 579246	1957	58
*	N 16 848373	1957	58, 59, 71
*	N 16 848371	1957	58, 59, 71
	N 19 378062	1957	57, 58, 59, 60, 61
	N 20 655049	1955	56, 57
	N 20 999109	1956	57
	Ruawai	1972	74
*	N 24 923836	1957	71
*	N 24 754875	1958	59, 60, 63, 76
	N 33 907293	1956	57, 58, 59, 63
	Batley	1957	58, 59
*	Onehunga	1955	56, 57, 73
	N 52 651910	1955	56, 57, 59, 60, 63
*	Lake Rotorua	1956	56, 57, 58, 59, 61, 68, 71
*	Orini canal, Rangitaiki	1957	57, late 60s, 71, 76, 77
	N 72 233458	1955	56, 57, 58, 59, 61
	N 78 704116	1955	56
	N 80 183308	1955	56, 58
	N 98 307350	1955	56, 59
	Te Reinga	1955	56, 58
	Wanganui (Castle Cliff)	1955	56, 58, 59
	Shannon	1955	56, 58, 59

† Data for 1960s are not complete.

* Sites at which seedlings have originated from seed after 14 to 20 years.

and irreversibly dessicated due to a prolonged drop of water levels. Further, it is of interest that the seed crop set by former populations has been sorted in such a manner that not all seed is committed to growth during a given season. As the seed does not appear to have an obligate dormancy period, it is probably the physical burial and re-exposure of the seed population in a particular habitat which is providing a continuous inoculum for seedling establishment.

Further work is required to assess residual seed populations in previously infested habitats, and constant surveillance will be required to effect the ultimate eradication of this noxious weed.

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The Effect of GA_3 on the Growth of Waterhyacinth (Eichhornia crassipes (Mart.) Solms)

L. S. WIDYANTO [1]

ABSTRACT

Gibberellins may control the growth of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) as an alternative to herbicides. Gibberellins (GA_3) up to 0.02 ppm might stimulate the growth of the plant 24% over the normal growth in terms of fresh weight. Increasing the concentration over 0.02 ppm may start to reduce the growth of the plant. The bulbous form of the petiole which is the floating character of the plant is changed to the more cylindrical and longer form as an indication that the plant loss its floating character. When treated in a 0.02 ppm GA_3 solution, the diameter of the original petioles of waterhyacinth was decreased up to 0.20 cm as compared to the normal one, while the length of the petiole was increased 25% over the normal petiole length. A water extract of roots showed a similar activity with GA_3 solution, comparable to approximately 1µg gibberellin-like substances per gram fresh roots.

INTRODUCTION

Much have been said about waterhyacinth, a plant originating from South America, particularly since this plant was introduced into new areas in the world, before and during the beginning of the 20th century. The new areas include North America, Asia and Africa. An important phenomenon is in its rapid multiplication. In Indonesia, the leaves double in 7 - 10 days (Widyanto 1976), and the plants can adapt to extreme water conditions, such as extremely low or extremely high nutrient concentration. It has been claimed that the rapid vegetative growth of waterhyacinth is affected by gibberellins (Brians *et al* in Sircar and Chakraverty 1962). GA_3 is one of the 23 derivatives of gibberellins. It is systematically named 3 : 10 : 13-trihydroxy-4-methyl-16-methylene-5, 9-gibb-1-ene-4-6-dicarboxylic acid 4-10 lactone, and trivially named gibberellic acid, which is one of the most potent gibberellins. Gibberellins were originally discovered through their effects on stem elongation. The most pronounced stem elongation effect of the gibberellins occurs with two types of plants, i.e. the rosette and the genetically dwarf plants (Paleg and

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West 1972). Waterhyacinth is a rosette plant. The effect of gibberellic acid on the waterhyacinth stem was reported by Pieterse *et al* (1976) who showed that 0.01 ppm gibberellic acid may start to inhibit waterhyacinth floating mechanism. Gibberellins are therefore a potential alternative to herbicides to control waterhyacinth growth. The study was conducted firstly to study the effect of gibberellins on waterhyacinth petiole (i.e. diameter and length), which facilitates its floating habit and secondly to measure the presence of gibberellin-like substances in the root extract of waterhyacinth.

MATERIALS AND METHODS

Waterhyacinth plants were selected for their similarity in leaf number, height and fresh weight of the plant. The selected plants were planted individually in 4 L of 1/5 strength Hoagland solution (Machlis and Torrey 1956) in 5 L-plastic pots. GA_3 used was a crystal form produced by Pfaltz and Bauer Inc. and dissolved in aquadest. The GA_3 solution was mixed with the Hoagland solution to make the following concentrations 0, 0.001, 0.005, 0.010, 0.020 and 0.030 ppm. The experiment was completely randomized with 3 replications. The experiment lasted for 4 weeks and every week the diameter and length of the original petioles were measured using a micrometer and a rule respectively. After 4 weeks the plants were harvested and the fresh as well as dry weights were determined.

A similar experiment was conducted with the following treatments: 0, 0.003, 0.030, 0.300 ppm GA_3 and water extract of fresh root waterhyacinth. Root extract was prepared by blending 100 g fresh root of waterhyacinth with 500 ml aquadest, and extracted 3 times with 500 ml aquadest each for 2, 1/2, 1/2 hr. then evaporated in a rotavapor at 35 C to reduce the volume down to 300 ml. All experiments were conducted in the BIOTROP glasshouse without special arrangements for light and humidity while the temperature ranged between 25 - 34 C.

RESULTS AND DISCUSSION

The result of the experiment in Table 1 shows that GA_3 at an increasing concentration up to 0.02 ppm may stimulate the growth of waterhyacinth in terms of the increase of fresh weight of the plant after

Table 1. The effect of GA_3 on the increase of fresh weight and dry weight of waterhyacinth after 4 weeks (% of control).

GA_3 concentration (ppm)	Increase of fresh weight after 4 weeks (% of the control)	Dry weight of the plant after 4 weeks (% of the control)
0.001	69.2	79.7
0.005	97.3	92.1
0.010	112.4	100.0
0.020	124.3	105.5
0.030	109.8	95.0

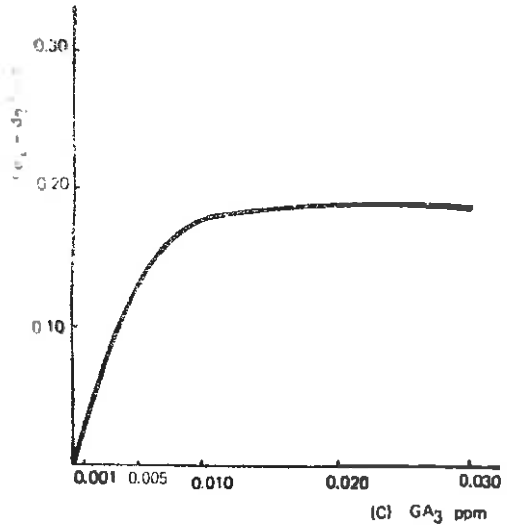

Figure 1. The effect of GA_3 on the decrease of petiole diameter 4 weeks after planting
d_1 = diameter petioles at planting date
d_2 = diameter of the same petioles 4 weeks after planting.

4 weeks. At 0.020 ppm GA_3 the increase of fresh weight is 24% over the increase of fresh weight of the plant grown in the same solution without GA_3. Increasing the concentration of GA_3 over 0.020 ppm showed the tendency of the decrease of the fresh weight increment of the plant.

Based on the measurement of the diameter of the original petiole, Figure 1 shows that an increasing concentration of GA_3 up to 0.020 ppm decreased the petiole diameter of the plant 4 weeks after planting. The petiole diameter of the plants grown under normal conditions was 2.27 cm, while that at 0.020 ppm GA_3 was 1.98 cm and the difference between the

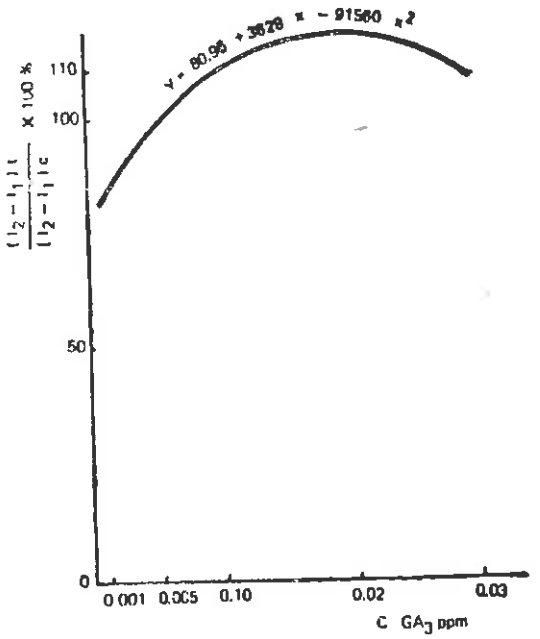

Figure 2. The effect of GA_3 on the increase of petiole length as compared to the increase of petiole length of the control (in %).
l_1 = length of petiole at planting date
l_2 = length of petiole 4 weeks after planting
t = treated
c = control

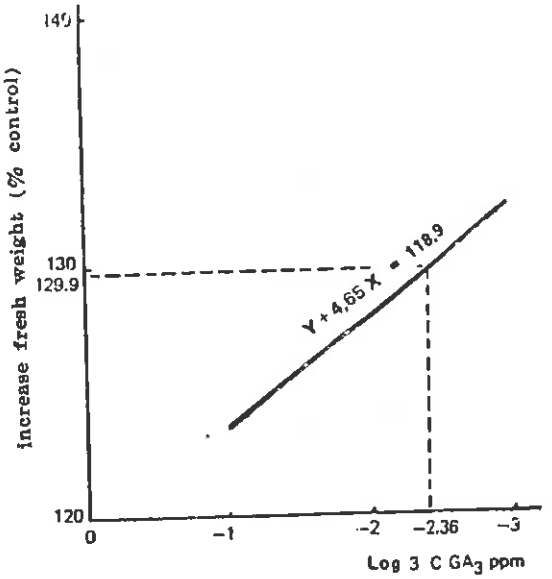

Figure 3. The effect of water extract of 100 gr of root of waterhyacinth compared to the effect of GA_3 solution at different concentration. The root contains 0.001 mg/g GA_3 like substance.

petiole diameter of GA_3 treated plants and control plants was highly significant. The petioles of newly formed leaves of the treated plants were more cylindrical and slender than those of control plants.

The decrease in petiole diameter was compensated for by the increase in the petiole length. Four weeks after planting the petioles of the plants grown in normal conditions increased by 1.4 cm in length, while those of the plants grown in 0.030 ppm GA_3 increased 25% more than control. The differences in the petiole length between GA_3 treated plants and the control were highly significant.

The increase in length and decrease in diameter of petioles, changed its bulbous form into cylindrical form, by which the plants had a tendency to lose its floating character.

A bioassay test to compare the effect of waterhyacinth root extract and the effect of GA_3 treatments on waterhyacinth showed that the root extract has a growth regulating activities similar to that of GA_3 in terms

of their effect on the fresh weight of the plant and elongation of petioles. The chemical analyses of the nutrient solution before transplanting and after harvest, showed that the increase of fresh weight and length of petiole of the root-extract-treated plant was not caused by additional nutrient released from the root extract of waterhyacinth. Based on its growth regulating activity on waterhyacinth it is calculated that the fresh roots of waterhyacinth may contain approximately 1 μg of gibberellin-like substances per gram.

Further studies are needed to investigate the effect of the change in floating character on the plant mass productivity by measuring the production of new stolons. Another investigation is now underway to find a better bioassay technique to identify and isolate the gibberellin-like substance from waterhyacinth roots.

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Herbicide Release from a Rubber-Based Formulation to Control Waterhyacinth (Eichhornia crassipes (Mart.) Solms)

Y. A. HUSIN [1], L. SUTANTO [2] and D. PERMADI [3]

ABSTRACT

Five different levels of sulphur in the rubber-based ametryn [2-(ethylamino)-4-(isopropylamino)-6-(methylthio)-s-triazine] formulation were studied. Water samples were taken during the course of experiment up to 39 days of exposure time. The rate of ametryn released from the formulations containing different sulphur contents were relatively high during the first 6 days of exposure, but were slower after 30 days of exposure. There was no significant difference of the amounts of ametryn released from the formulations containing 0.2, 0.5, 1.0, 1.5 and 2.5 phr (part per hundred rubber) sulphur. The highest percentage of ametryn released from each formulation within 21 - 30 days fell between 35.2% and 47.6%. Using rubber-based ametryn at the doses of 0.5, 0.8 and 1.0 kg ai/ha on waterhyacinth, the plants was completely damaged at 22 days after application, however, using ametryn 80 WP at the same doses caused waterhyacinth died at 12 days after application. There was no significant change of pH observed, but a gradual decrease of dissolved oxygen was occurred.

INTRODUCTION

To prevent our environment from any kind of pesticides pollution several attempts have been carried out. Recently, slow release or controlled release biocides have been tried to minimize undesirable effect of pesticides to non-target organisms.

In this study rubber-based slow release ametryn formulation have been tested to discover the rate of release and the recovery of ametryn and also its effectiveness to control waterhyacinth.

Using controlled release or slow release biocides for controlling aquatic weeds has several advantages, they (a) minimize herbicide residues available in aquatic systems, (b) maintain toxic concentration of herbicides in close proximity to the target organism, (c) increase the efficacy and longevity of the herbicide by protecting it from environmental degradation, and (d) decrease application costs because less frequent applications are required (Harris 1973).

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To determine ametryn released from the rubber-based formulations in this study, two analytical methods were used, i.e. spectrophotometric and bioassay methods. The results of these two methods were compared to obtain information, if simple biossay method to analyse ametryn in water is satisfactory.

According tc McKone *et al* (1972), ultra violet spectrophotometric method was adequate at 0.01 ppm level of ametryn from a water sample, but unreliable at lower levels. Using gas liquid chromatography with alkali flame ionization detector 0.001 ppm of ametryn in water could be reliably determined with recoveries close to 100%.

Until recently bioassay method for estimating the concentration of ametryn in water has not been reported. It is due to the fact that little attention has been given to the use of this herbicide for aquatic weed control. Results of analysis by instrumental methods were compared with bioassay methods by many researchers and they found that some of the instrumental methods were confirmed with bioassay methods.

MATERIALS AND METHODS

Rubber-based pellets used in this experiment were prepared by the Research Institute for Estate Crops, Bogor. Ametryn was impregnated with rubber and other ingredients using two different speed rollers and blended for 30 minutes, and then extruded and vulcanized at 140 C for 30 minutes. The pellet had a long cylindrical shape with 0.4 - 0.5 mm in diameter.

The ingredients of the rubber-based ametryn formulation used in this experiment contained: (1) ZnO 5.0 phr (part per hundred rubber), (2) ZDC (zinc diethyl dithiocarbamate) 0.2 phr, (3) sulphur each with 0.2; 0.5; 1.0; 1.5 and 2.5 phr, (4) MBT (mercapto benzothiazole) 0.5 phr, (5) dyestuff 0.3 phr, and (6) ametryn (ai) 10 phr.

Sulphur as a vulcanizer of the rubber was supposed to affect the release of ametryn from the formulations, 0.2 phr of sulphur in this formulation was the lowest amount, since lower than this the pellet was sticky; and 2.5 phr was the highest, higher than this amount the pellet was very hard. Based on this, the rubber-based pellet contained ametryn (ai) 8.5%.

Rates of ametryn release. Determination of the rates of herbicide release from floating rubber-based ametryn containing different sulphur content

was undertaken by placing weighed sample of the pellets into 25% Hoagland solution, taking a water sample after a given period of exposure and measuring the concentration of ametryn by spectrophotometric and bioassay methods using *Spirodela polyrrhiza* as test plants.

Four litres of 25% Hoagland solution were added to 5 L plastic pail lined with a polyethylene bag. The rubber-based ametryn to be tested 4.8 ± 0.1 mg equal to 1.0 µg/ml of ametryn was added to the container and after a specified number of days a 500-ml aliquot for spectrophotometric analysis was obtained after swirling the solution to ensure mixing, at the same time a sample was taken and analysed by bioassay method.

Each test was repeated twice, for the untreated control rubber-based pellet without containing ametryn was used. To know the rate of disappearence of ametryn in the media, solution of ametryn 80 WP was injected into the containers to achieve a concentration of 1.0 µg ai/ml ametryn.

The experiment was carried out under greenhouse conditions. Water lost by evaporation was replaced every day to maintain the volume of the water at 4 L. The experimental data were subjected to an analysis of variance for a split-plot design with sulphur content as the mainplot and the periods of exposure as the subplot.

The spectrophotometric method followed the Delley method (Knusli 1964) and the bioassay was a modification of the methods presented by Damanakis (1970) and Reisler and Tjitrosemito [4]. Standard curve for bioassay method was constructed from *S. polyrrhiza* grown in 25% Hoagland solution in 100-ml cups treated with a series of ametryn concentrations ranging from 0.002 to 0.020 ppm. The standard curve was obtained by plotting percentage increase weight of growth compared with untreated control against ametryn concentrations.

The effect of rubber-based ametryn on waterhyacinth. Pails were each filled with 4 L of 25% Hoagland solution and treated with rubber-based ametryn containing 0.2, 0.5, 1.0, and 1.5 phr sulphur to achieve the doses of 0.5, 0.8, and 1.0 kg ai/ha of ametryn respectively.

Waterhyacinth with the same SGR (Summed Growth Ratio) were planted in the pails. Each treatment was done with three replications, rubber-based pellet without containing ametryn was used for the untreated control.

The data were subjected to an analysis of variance for a completely randomized design. Damage of plants were observed visually using the

[4] Reisler, A. and S. Tjitrosemito 1975. Bioassay of herbicides residues in soil and water. Workshop on research methodology in weed science, Bandung, Indonesia.

rating system [5] of 1 to 9. Dissolved oxygen and pH of the water were determined every three days until the plants died.

RESULTS AND DISCUSSION

Rates of ametryn release. Comparative rates of release from the five floating rubber-based formulations of different sulphur contents are shown in Figure 1. The usual pattern was a rapid increase in the amount of ametryn recovered with each succeeding period of exposure up to 6 days, and then a very gradual increase in the amount of ametryn recovered up

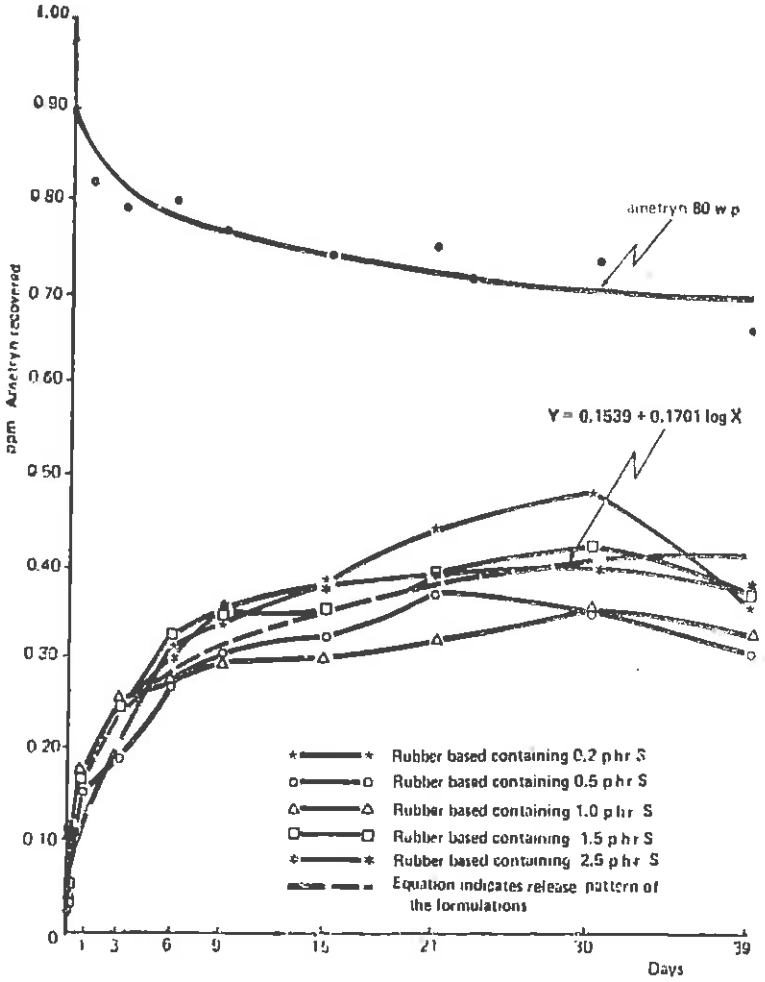

Figure 1 Recovery of ametryn from rubber-based formulations after different periods of exposure to Hoagland solution 25 % (using spectrophotometric method).

[5] Comber, J.B. and S. Slamet 1975. The measurement of plant responses. Workshop on research methodology in weed science, Bandung, Indonesia.

to 30 days. Ametryn in solution from all rubber-based formulations decreased after 39 days. It seems that after 30 days the rate of release was lower than the rate of degradation.

The difference in release rates may have been caused by the swelling of the formulations. Figure 2 shows that at 4 or 6 days the formulations had decreased in weight but thereafter the weight increased. Therefore initially components of the formulations were released at a faster rate than water was absorbed. It can also be seen that water uptake was greater with the formulations of higher sulphur content.

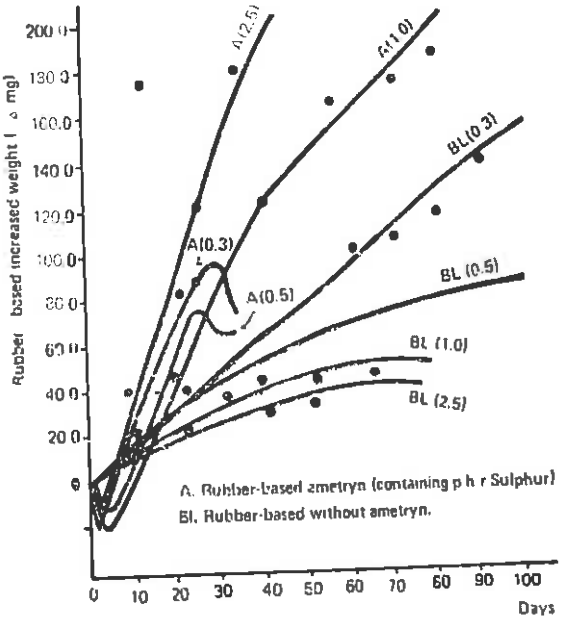

Figure 2. Weight changes of rubber-based ametryn after different periods of exposure to water

The highest concentration of ametryn was obtained at 30 days except for the rubber containing 0.5 phr sulphur when it was 21 days. About 29.6% ametryn was released from the five rubber-based formulations within 6 days and about 45.0% within 30 days. The ametryn which was not released from the rubber-based formulations might be fixed by the rubber or degraded during the blending or vulcanization of the rubber.

It was found that the release pattern did not indicate a control diffusion process, it did not give a straight line if concentration of ametryn plotted against $\sqrt{\text{time}}$. But it was found that the release of ametryn from those five rubber-based formulations was linear if concentration of ametryn plotted against logarithm of time in days.

Comparison of the release of the formulations up to 39 days showed no significant difference (P = 0.05) among rubber-based containing 0.2; 0.5; 1.0; 1.5 and 3.5 phr sulphur. The order of decreasing release rates were 0.2 phr sulphur > 2.5 phr sulphur > 1.5 phr sulphur > 1.0 phr sulphur > 0.5 phr sulphur. Thus with the higher sulphur content the rates of release were generally higher.

Figure 1 shows the disappearance of ametryn 80 WP in the 25% Hoagland solution, the disappearance was about 10.7% after the first 3 days as compared with the result of analysis at 2 hours after treatment. The disappearance was about 26.1% within 39 days. It was observed during the course of experiment that most of the experimental pots were attacked by algae.

An experiment to determine the release of 2,4-D amine [amine(2,4-dichlorophenoxy) acetate] from rubber based formulations in water was carried out by Biadul [6] (1975) and indicated that the highest concentration of 2,4-D amine was obtained from a formulation containing 0.3 phr sulphur occurred after 14 days, it represented about 0.53%. That of formulations containing 0.5 and 1.0 phr sulphur occurred after 21 days (0.29% and 0.90% respectively). Susilo [7] (1975) reported that the highest amount of paraquat (1,1-dimethyl-4,4'-bipyridinium ion) released from rubber-based formulation was about 3.30% after 36 days.

Comparing the results of 2,4-D amine and paraquat, rubber-based ametryn has a higher rate of release and higher percentages of herbicide are recovered. The use of ametryn or other triazines in such rubber-based formulation appears to be more promising than 2,4-D amine or paraquat.

Results of ametryn detection by spectrophotometric and biossay methods agreed closely with a correlation coefficient of + 0.997 (Figure 3). Similarly good concordance between instrumental and bioassay methods of determining triazines have been reported by Behrens (1970) and Eberle and Gerber (1975). From the result obtained in this study it seems that bioassay method using *S. polyrrhiza* as the test plant can be used to determine ametryn in water with the detection limit as low as 0.002 ppm.

Effect of rubber-based ametryn on waterhyacinth. At five days after treatment the color of waterhyacinth leaves treated with rubber-based ametryn at 0.8 and 1.0 kg ai/ha turned to brownish black.

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[6] Biadul, P. 1975. Studies on the different formulation of 2,4-D amine for waterhyacinth (unpublished). Biotrop, Bogor.

[7] Susilo, H. 1975. Chemical analysis of paraquat, diquat and 2,4-D residue in water (unpublished). Biotrop, Bogor.

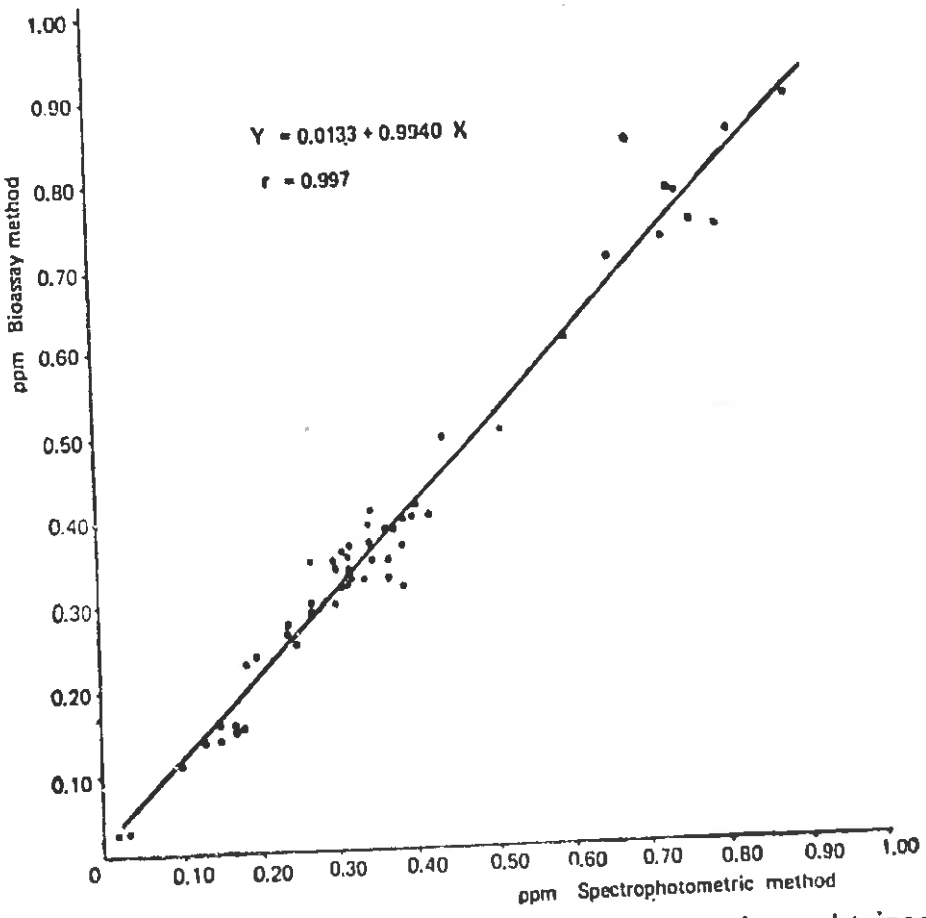

Figure 3. Correlation of the ametryn concentrations obtained by spectrophotometric and bioassay methods

There was a highly significant difference between the dry weight of untreated waterhyacinth and treated waterhyacinth at 20 days after application, but there was no signifficant difference among the sulphur content in the rubber-based formulation on the growth of waterhyacinth from those three doses of application. And also among the three doses of rubber-based ametryn (i.e. 0.5, 0.8 and 1.0 kg ai/ha ametryn) applied on waterhyacinth did not indicate a significant difference on the damage of waterhyacinth until 20 days after application (Figure 4).

As a comparison, a solution of ametryn 80 WP which was injected at the same doses as rubber-based ametryn treatment into the pails, caused waterhyacinth died within 12 days after application. However, that of rubber-based ametryn caused waterhyacinth died at 22 days after application.

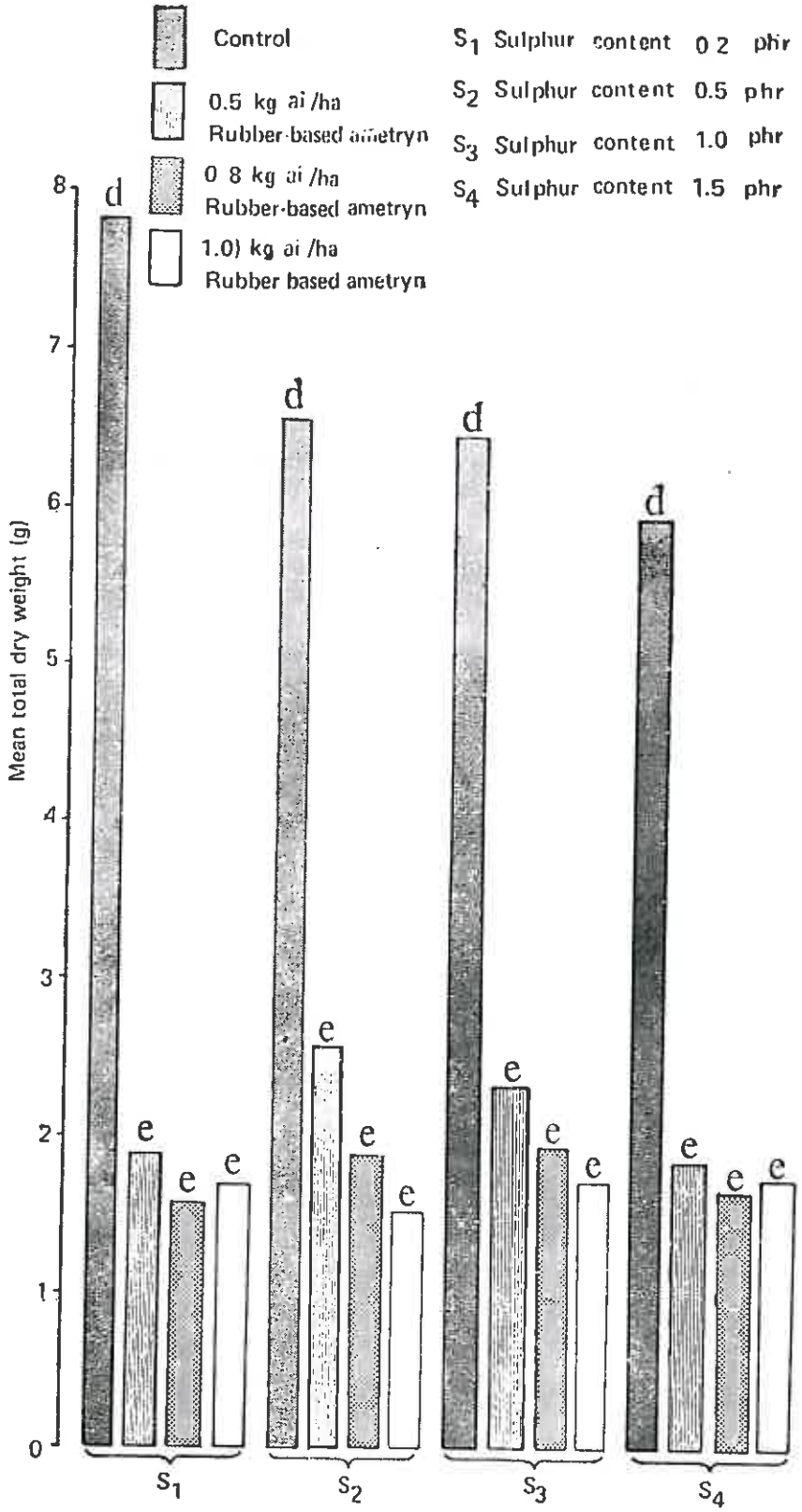

Figure 4. Dry weight of water hyacinth as affected by rubber-based ametryn at 20 days after application. Bars with the same letter do not differ significantly at $P \geq 0.05$.

During the course of the experiment only slight changes of pH was observed, the pH among the treated and untreated pails ranging from 5.8 to 6.5. A gradual decrease of dissolved oxygen was observed in the treated as well as untreated pails, the decrease of dissolved oxygen was from 1.9 to 1.6 ppm.

ACKNOWLEDGEMENTS

The authors are indebted to Dr. M. Soerjani, Program Manager of Tropical Pest Biology, SEAMEO-BIOTROP, Bogor, for his encouragement, guidance and suggestion during the experiment. Thanks are also due Ir. A.F.S. Budiman M.Sc., Research Institute for Estate Crop, Bogor, for his generous assistance in providing rubber-based ametryn in this study.

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Some Preliminary Observations on the Selective Toxicity of Ammonia Towards Salvinia molesta D. S. Mitchell

J. K. P. ARIYARATNE [1]

ABSTRACT

Salvinia (*Salvinia molesta* D.S. Mitchell) was found to be sensitive to bases. Ammonia was shown to be effective in killing salvinia selectively. Several other small molecules appear to be selectively toxic towards salvinia. Some plants with hairy leaves appear to be more susceptible to ammonia and certain other small molecules than those with a thick cuticle.

In Sri Lanka large areas of rice fields, marshes and waterways are infested with salvinia. Fields under salvinia are either manually cleared or treated with weedicides and then cultivated. However, in most cases the remaining salvinia rapidly grows eventually edging out the paddy plants. The objective of the present study was to investigate the feasibility of devising a convenient method which could be used to kill salvinia especially in rice fields.

A laboratory experiment on a small scale (35 by 23 by 12 cm tank) was carried out in an attempt to investigate the effect of the suppression of photosynthesis on rapidly propagating salvinia. It was intended to achieve this by a sprayable contact filter consisting of a dark green, appreciably alkaline, solution of low surface tension. It was hoped that the suppression of photosynthesis by such a solution would eventually kill the rapidly growing salvinia selectively. It was expected that the red and the blue spectral regions of solar energy would be cut off by the dark green solution and the alkaline nature of the solution would hinder the assimilation of carbon dioxide, at least temporarily. The green solution was prepared by the controlled oxidation of aniline with 5% potassium dichromate solution and dilute sulphuric acid, and the resulting solution was made alkaline with 20% sodium hydroxide solution. The detergent, "Teepol" was added to lower the surface tension. As this was only a preliminary experiment, arbitrary quantities (ml scale) of the reagents were used in preparing the green solution. Surprisingly, it was observed

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that this solution killed the salvinia plants within a few hours after spraying, indicating that the lethal effect of the solution was not due to suppression of photosynthesis, but to some other reason. A systematic study of the variables of the solution showed that this lethal effect was due to alkalinity. This was conclusively shown by spraying salvinia with 5% and 10% (w/v) sodium hydroxide. With 5% sodium hydroxide the salvinia leaves turned appreciably brown in about five minutes; 10% sodium hydroxide produced the same effect in about 2 minutes. The lethal effect of these alkaline solutions was also confirmed under field conditions. It was observed that the alkaline solutions killed the salvinia selectively leaving rice plants and some other weeds relatively unaffected.

These observations led us to consider the possibility of using a basic solution to kill salvinia selectively, especially in rice fields infested with the weed. Since the use of sodium hydroxide would entail the problem of increasing the salinity of the soil, the efficiency of ammonia as a selective killer for salvinia was investigated. In laboratory experiments, 5% and 10% (v/v) aqueous solutions of 0.88 ammonia with and without 0.1% (v/v) detergent was sprayed on salvinia. The salvinia leaves turned noticeably dark brown within about 15 - 30 minutes after spraying. The entire plant died within 2 - 3 days. The dead plants were dark brown and desintegrated readily on handling. When the detergent was used in conjunction with ammonia, the initial browning of the leaves occured more quickly. However, as far as the final result observed after 2 - 3 days was concerned, the addition of detergent did not appear to make any difference. When the plant was kept in a confined space (a covered, tall, one-litre beaker) with a piece of cotton wool soaked in 0.88 ammonia, so that only the ammonia gas came into contact with salvinia, the leaves turned brown within 5 minutes. In all cases the salvinia did not sprout again. The experiments with the ammonia solutions were repeated under field conditions on a small scale (4 by 4 m). The results generally agreed with those observed in the laboratory. Depending on the efficiency of contact coverage, 75% - 90% kill could be obtained in a single spraying. Very careful spraying ensuring complete contact of all the plants with the solution resulted in a 100% kill. Rice plants were slightly wilted initially, but within 2 - 3 days they grew quite vigorously. Most plants in local rice fields appeared to be relatively unaffected by the ammonia. There were no noticeable adverse effects on aquatic macro flora. The salvinia which survived a single treatment could be killed in a second mopping-up spraying.

During this study it was tentatively inferred that the selective toxicity of ammonia towards salvinia may perhaps be due to the ease of entry of the small molecule through the leaf which has a peculiar structure. Studies with small molecules such as methyl amine, ethyl amine, acetic acid, chloroacetic acid, chloroform, ethyl acetoacetate, acetyl acetone, etc are in progress. Some of these molecules appear to be quite toxic towards salvinia in low concentrations and some appear to be translocated within the plant when applied to the leaf. The translocation of chloroacetic acid is presently being studied using isotopically labelled compounds. Preliminary observations show that the plants with hairy leaves are generally very much more susceptible to ammonia and the molecules mentioned above, than those with a thick cuticle.

New Combinations of Herbicides to Control Waterhyacinth (Eichhornia crassipes (Mart.) Solms)

L. S. WIDYANTO, H. A. BURHAN, H. SUSILO and M. NUR [1]

ABSTRACT

Mixture of herbicides to control waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) may serve as alternative to a high dose of a single herbicide, especially when the mixed herbicides show a synergistic effect. Under laboratory conditions, a mixture of perfluidone (1,1,1-trifluoro-*N*-[2-methyl-4-(phenylsulfonyl)phenyl] methanesulfonamide) with 2,4-D [(2,4-dichlorophenoxy) acetic acid] at (0.5 + 2.0) kg/ha [2] increased the damage to waterhyacinth by almost 100%, while a single application of perfluidone up to 2.0 kg/ha did not show any damage to the plant. Glyphosate [*N*-(phosphonomethyl)glycine] mixed with 2,4-D clearly showed a synergistic damaging effect on waterhyacinth as indicated by the isobole of 50% damage. Under local conditions at Rawa Pening lake in Central Java, Indonesia, waterhyacinth was normally controlled with 2,4-D at 6.0 kg/ha. Reduction of 2,4-D to 2.0 kg/ha was possible by mixing it with the following herbicides: paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) at 0.5 kg/ha, diquat [6,7-dihydrodipyrido(1,2-α:2',1'-c)pyrazinediium ion] at 1.0 kg/ha, perfluidone at 1.0 kg/ha, glyphosate at 1.0 kg/ha, cyanatryn (2-[(4-ethylamino-6-methylthio-*s*-triazin-2-yl)amino]-2-methylpropionitrile) at 3.0 kg/ha and velpar [3-cyclohexyl-6-(dimethylamino)-1-methyl-*s*-triazine-2,4-(1*H*,3*H*)-dione] at 3.0 kg/ha. The damage to waterhyacinth caused by these treatments were 80, 90, 100, 100, 91.5 and 98.5% respectively. A single treatment of ametryn [2-(ethylamino)-4-(isopropylamino)-6-methylthio)-*s*-triazine] at 6.0 kg/ha caused 69% damage to waterhyacinth.

INTRODUCTION

Waterhyacinth became a problem in Rawa Pening, a semi-natural lake in Central Java, Indonesia, shortly after its establishment in 1916. Efforts to control it, were first initiated using mechanical method in 1932 and have been continued irregularly. Since 1951 chemical control method (using 2,4-D) was started. However, it is still a serious problem. This problem has been magnified by the formation of floating islands formed from the bottom of the lake (Little 1969, Soerjani 1975; 1976).

The Rawa Pening lake has an important role in the irrigation of 24,000 ha of ricefields in the coastal plain, of which 6,000 ha have a

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[2] In this paper all kg/ha mean kg ai/ha.

second crop every year. The water storage of the lake serves generators of a hydroelectric power plant which produces approximately 20 MV electricity (Soerjani 1975).

Better management of the lake is considered very important. The Department of Irrigation, of the Ministry of Public Works and Electric Power, which is the authority responsible for the lake, has initiated cooperative work with BIOTROP to conduct ecological studies to identify and assess the magnitude of the problem of aquatic weeds, to advise on the implementation of a crash program to control waterhyacinth, to remove the floating islands and to suggest the future weed management program for the lake. One of the projects in this cooperation is to find effective herbicides to control waterhyacinth.

The recommended rates of 2,4-D amine or its ester vary considerably, i.e. from 2.0 kg/ha or 4.0 kg/ha (Blackburn 1962 and Burkhalter *et al* 1974), to 6.0 kg/ha (Verma 1967) or 8.0 kg/ha (Hitchcock *et al* 1949). In the past the use of 2,4-D in Rawa Pening to control waterhyacinth required not less than 6.0 kg/ha (Little 1969). The use of 2,4-D in such a high dosage may cause damage to a number of crops through spray drift or by contaminating irrigation water, e.g. in cotton growing areas (Obeid 1975) and may cause the non-potability of the water immediately after treatment. Therefore, alternative to the use of 2,4-D have been evaluated (Obeid 1975 and Soerjani *et al* 1976). Other possible herbicides are ametryn, cyanatryn (Soerjani *et al* 1976), glyphosate (Pieterse *et al* 1976) or a combination of some herbicides, e.g. paraquat and 2,4-D (Soerjani *et al* 1976). Velpar is a herbicide with relatively low toxicity (LD_{50} for male rats is 1,690 mg/kg), so it is interesting to see its effectiveness to control waterhyacinth. Another new herbicide interesting to investigate is perfluidone; this is a promising selective preemergence herbicide primarily to control *Cyperus* spp. and for use in mixtures with other herbicides to improve possibilities for controlling broad-leaved weed (Richardson and Dean 1974).

The present study was aimed at finding alternative treatments for controlling waterhyacinth, in which the use of herbicides could be minimized by mixing them with 2,4-D.

MATERIALS AND METHODS

Pot experiments. Two pot experiments were conducted under greenhouse condition without special arrangement for light, temperature and humidity. The waterhyacinth plants were selected for their similarity in height

(12 to 20 cm), number of leaves (5 to 7 leaves) and fresh weight (25 to 27 g/plant). They were planted in plastic pots of 5 L filled with water [3] from a pond at the Bogor Botanic Garden for the first experiment and 25% Hoagland solution for the second experiment, 4 L each. The plants were treated one week after planting based on 1,000 L/ha. The design of the experiments was completely randomized, with 3 replicates, and observations were done weekly based on visual assessment of damage percentage of the plants.

The treatments were:

First experiment:	perfluidone	at 0.5; 1.0; and 2.0 kg/ha.
	2,4-D amine	at 1.0; 2.0; and 3.0 kg/ha.
	perfluidone + 2,4-D	at (0.5 + 2.0); (1.0 + 2.0) and (1.5 + 2.0) kg/ha.

In this experiment three methods of application were tested, i.e. foliar, root and foliar + root treatment.

Second experiment:	glyphosate	at 0.5; 1.0 and 2.0 kg/ha.
	2,4-D amine	at 0 5; 1.0 and 2.0 kg/ha.
	glyphosate + 2,4-D	at (0.5 + 0.5); (0.5 + 1.0); (0.5 + 2.0); (1.0 + 0.5); (1.0 + 1.0); (1.0 + 2.0); (2.0 + 0.5); (2.0 + 1.0); (2.0 + 2.0) kg/ha.

The solution was sprayed onto the leaves (and roots) with a knapsack sprayer. The 50% damage of the plants was calculated and graphed for possible representation of synergism of mixtures of glyphosate and 2,4-D (Tammes 1964).

Field experiments. Two other experiments were conducted at Rawa Pening lake in floating bamboo plots of 3 by 4 m with 4 to 5 m distance between plots. The plants used were 50 - 60 cm in height sprayed one week after transplanting in the plots. Completely randomized design with 3 replicates were used in each experiment. The result of the herbicide treatments was weekly recorded based on visual assessment of damage percentage of the plants.

[3] pH of water 6, Ca 6.83 ppm, NO_3 0.67 ppm, NH_4 0.30 ppm, PO_4 0.02 ppm.

The herbicides used were:

First experiment:
ametryn at 2.0 and 4.0 kg ai/ha.
cyanatryn at 2.0 and 3.0 kg ai/ha.
diquat + 2,4-D at (0.5 + 2.0) and (1.0 + 2.0) kg ai/ha.
glyphosate + 2,4-D at (0.5 + 2.0) and (1.0 + 2.0) kg ai/ha.
paraquat + 2,4-D at (0.5 + 2.0) and (1.0 + 2.0) kg ai/ha.
perfluidone + 2,4-D at (1.0 + 2.0) and (2.0 + 2.0) kg ai/ha.
velpar at 2.0 and 3.0 kg ai/ha.

Second experiment:
ametryn at 4.0 and 6.0 kg ai/ha.
cyanatryn at 3.0 and 5.0 kg ai/ha.
cyanatryn + 2,4-D at (3.0 + 2.0) kg ai/ha.
paraquat + 2,4-D at (1.0 + 2.0) kg ai/ha.
velpar at 4.0 and 5.0 kg ai/ha.
velpar + 2,4-D at (3.0 + 2.0) kg ai/ha.

RESULTS AND DISCUSSION

Perfluidone alone did not have any effect on waterhyacinth, even when observations were continued over one month after applications of the

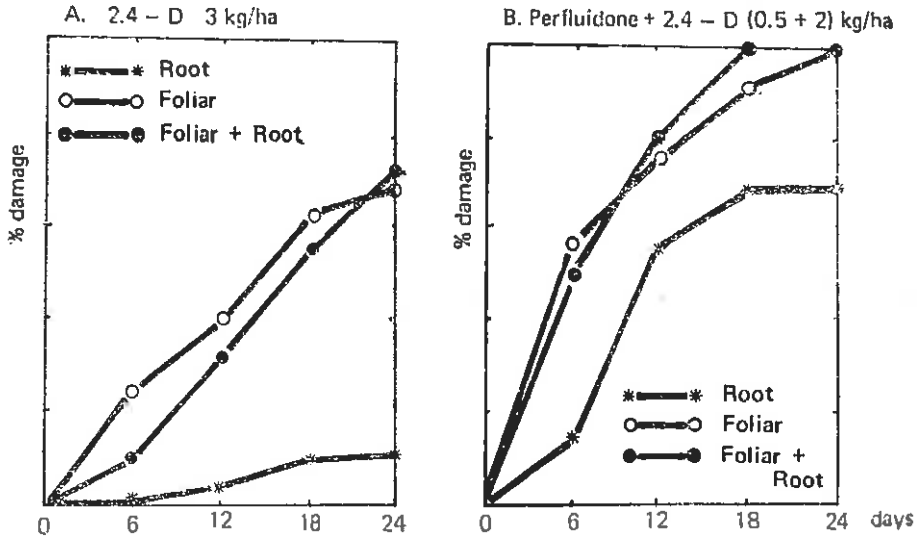


Figure 1 Effect of root, foliar and root + foliar applications of perfluidone and 2.4 – D and their combination on waterhyacinth

herbicides. Figure 1 shows that 2,4-D amine had a better effect on waterhyacinth, especially at 3.0 kg/ha when applied to the leaves or leaves and roots. The root applied 2,4-D treatment showed less effect on waterhyacinth. This may have been due to an unknown incompatibility factor(s) in the water, that influenced the polarity of the salt formulation of 2,4-D or translocation to the site of action may just be poorer via the roots versus more direct application to the foliage. There was no significant difference between dosages of the same herbicide but there was a highly significant difference between application of either 2,4-D or perfluidone and mixture of the two.

Table 1 shows the percent of damage of waterhyacinth following spraying with mixtures of glyphosate and 2,4-D 15 days after treatments. Glyphosate at 2.0 kg/ha gave sufficient control of waterhyacinth, so that additional mixtures with 2,4-D at different dosages (0.5 to 2.0 kg/ha) did not change the plant damage. The lowest dosage of glyphosate mixed with 2,4-D which caused reasonable damage to the plant was 1.0 kg/ha

kg/ha glyphosate \ kg/ha 2,4-D	0	0.5	1.0	2.0
2.0	90	87	93	98
1.0	48	75	82	(93)
0.5	20	47	50	80
0	0	15	42	72

◯ promising combination with reasonable % of damage

Table 1. The effect of combination of glyphosate and 2,4-D on waterhyacinth 15 days after treatment. (% damage of the plant)

mixed with 2.0 kg/ha 2,4-D that gave 93% of damage. Weed damage of 90% or over is considered as reasonably sufficient [4]. Glyphosate alone may give sufficient damage, but it requires higher dosage, i.e. 2.0 kg/ha.

[4] Comber, T.B. and S. Slamet 1975. The measurement of plant responses. Workshop on Research Methodology in Weed Science, Bandung, Indonesia.

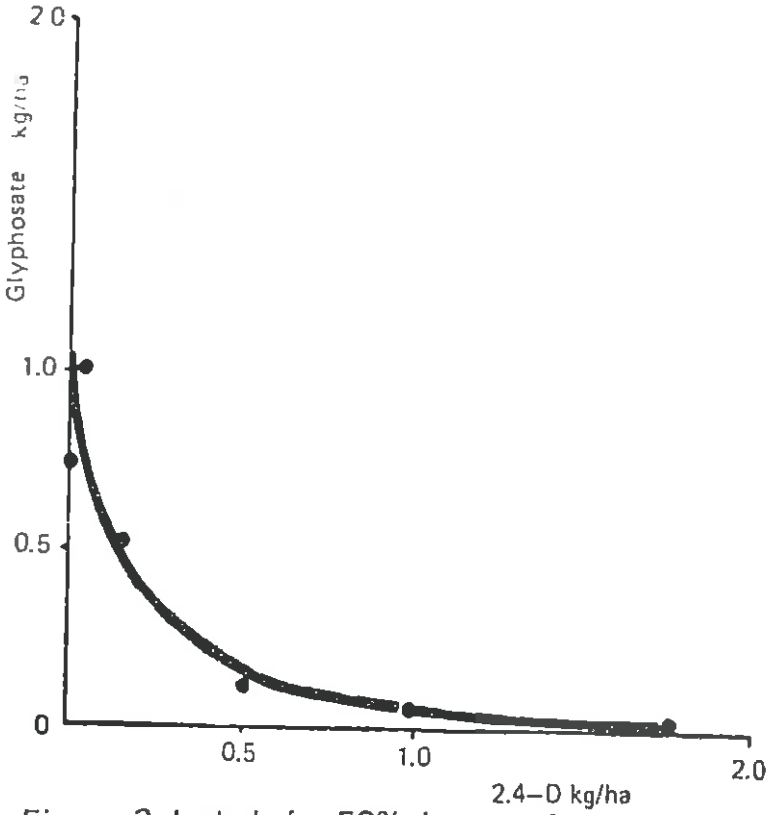
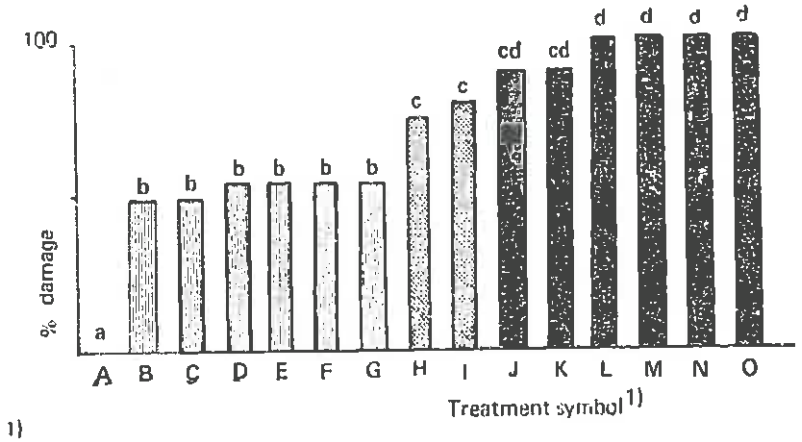


Figure 2. Isobole for 50% damage of waterhyacinth showing the synergism of glyphosate and 2.4–D mixtures (calculated after Tammes 1964 (2nd pot experiment).

Figure 2 shows the isobole for 50% damage of waterhyacinth as affected by the synergism of glyphosate and 2,4-D. This justifies the mixtures of the two herbicides to increase their effectiveness.

The result of the first herbicide trial at Rawa Pening lake is shown in Figure 3, from which it is clear that ametryn at 4.0 kg/ha, cyanatryn at 3.0 kg/ha and velpar at 3.0 kg/ha did not cause a sufficient percentage of damage to the plants. A sufficient percentage (over 90%) of damage was obtained, however, with mixtures of 2,4-D with paraquat (2.0 + 1.0) kg/ha; diquat (2.0 + 1.0) kg/ha; perfluidone (2.0 + 1.0) kg/ha and glyphosate 2.0 + 1.0 kg/ha that resulting in 90, 90, 100 and 100% damage respectively.



1)

A : control
B : cyanatryn 2 kg/ha
C : ametryn 2 kg/ha
D : cyanatryn 3 kg/ha
E : velpar 2 kg/ha
F : velpar 3 kg/ha
G : ametryn 4 kg/ha
H : diquat + 2,4–D (0.5 + 2.0) kg/ha
I : paraquat + 2,4–D (0.5 + 2.0) kg/ha
J : paraquat + 2,4–D (1.0 + 2.0) kg/ha
K : diquat + 2,4–D (1.0 + 2.0) kg/ha
L : perfluidone + 2,4–D (1.0 + 2.0) kg/ha
M : perfluidone + 2,4–D (2.0 + 2.0) kg/ha
N : glyphosate + 2,4–D (0.5 + 2.0) kg/ha
O : glyphosate + 2,4–D (1.0 + 2.0) kg/ha

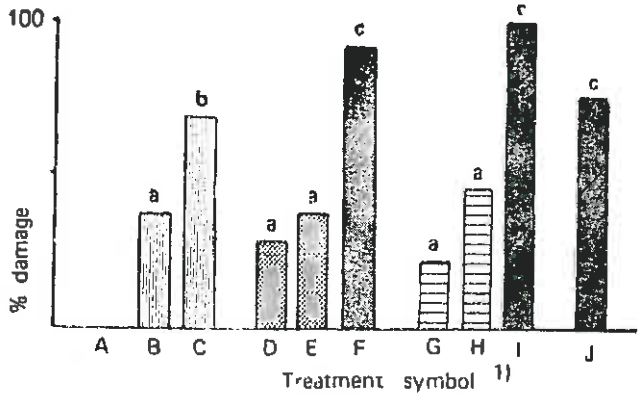
Bars with the same letter do not differ significantly at 5 % level (determined by HSD test)

Figure 3. Damage (%) of waterhyacinth 24 days after treatment (First field experiment)

A further experiment showed that increasing the dosage of cyanatryn up to 5 kg/ha still did not give satisfactory control of waterhyacinth, but a mixture of cyanatryn + 2,4-D at (3.0 + 2.0) kg/ha gave 91.5% damage of the plants. Velpar at 5.0 kg/ha gave only 44.5% damage, but a mixture with 2,4-D at (3.0 + 2.0) kg/ha caused 98.5% of damage. A single application of ametryn needs 6.0 kg/ha to cause 69% damage (Figure 4).

Based on the above results, the following treatment are considered to be most promising for waterhyacinth control.

ametryn higher than 6.0 kg/ha.
cyanatryn + 2.4-D at (3.0 + 2.0) kg/ha.
diquat + 2,4-D at (1.0 + 2.0) kg/ha.
glyphosate + 2,4-D at (1.0 + 2.0) kg/ha.
paraquat + 2,4-D at (1.0 + 2.0) kg/ha.
perfluidone + 2,4-D at (1.0 + 2.0) kg/ha.
velpar + 2,4-D at (3.0 + 2.0) kg/ha.



1)

A : Control
B : ametryn 4 kg/ha
C : ametryn 6 kg/ha
D : cyanatryn 3 kg/ha
E : cyanatryn 5 kg/ha
F : cyanatryn + 2.4–D (3.0 + 2.0) kg/ha
G : velpar 3 kg/ha
H : velpar 5 kg/ha
I : velpar + 2.4–D (3.0 + 2.0) kg/ha
J : paraquat+ 2.4–D (1.0 + 2.5) kg/ha

Bars with the same letter do not differ significantly at 5 % level (determined by HSD test)

Figure 4. Damage (%) of waterhyacinth 24 days treatment (Second field experiment).

ACKNOWLEDGEMENT

The authors indebted to Dr. M. Soerjani, Program Manager of Tropical Pest Biology Program for his continuous interest during the study and for correcting the manuscript. The officers of the Ministry of Public Works and Electric Power, in particular of the Directorate General of Irrigation, made this work possible through a cooperative work on Rawa Pening lake.

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Aquatic Weeds of Ponds in Assam, India [1]

S. RADHAKRISHNAN and B. R. BHUYAN [2]

ABSTRACT

Large number of water bodies, both natural and man-made, available in Assam are infested with aquatic macrophytes making them unfit for fish culture and other economic uses. Results of a survey of weed populations in 85 to 90 tanks in the Sibsagar district of Assam during different seasons indicated that the incidence of weeds was high, the range in the percentage of infestation being 86 to 92. About 27 species belonging to four categories *viz.*, submersed, emersed, free floating and marginal were frequently encountered, of which *Nymphoides* spp., *Trapa bispinosa*, *Eichhornia crassipes*, *Salvinia* spp., *Azolla pinnata*, *Colocasia antiquorum* and *Marsilea quadrifolia* were the most dominant. The seasonal abundance of some of these macrophytes, their association and the probable causes for their high incidence in Assam waters are briefly dealt with. The salient physico-chemical features of water in the weed-choked and weed-free ponds are compared.

INTRODUCTION

Assam which is a land-locked state and situated on the north-eastern region of India has a rich and varied aquatic flora consisting of submersed, emersed, free floating and marginal plants. The topography and climatic conditions of the region with its high rain fall offer ideal situations for the prolific growth of these macrophytes. Myriads of ponds, tanks, pools, bheels and canals that exist in the state are infested with aquatic weeds rendering them useless for intensive fish cultural purposes and other economic uses. Besides, vast areas of paddy fields and irrigated lands are also rendered unproductive by the dense growth of macro-vegetation. The infestation of aquatic weeds appears to be more acute in the plains of Assam than in the hilly regions of Garo, Khasi Jaintia and Mikir and north Cachar districts of the state. The cultivable water area in the state has been estimated at 20,000 hectares of which about 12,000 hectares are reported to be infested with aquatic weeds. Thick marginal growth of aquatic plants in several ancient temple tanks in Sibsagar has been observed by Bhuyan (1970). In spite of the wide-spread occurrence of aquatic weeds in Assam, very little information is

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1. The work was done in the Sibsagar district of Assam by the Staff of Pond Culture Unit of Central Inland Fisheries Research Institute, Joysagar, Assam.

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available on the type of aquatic and semi aquatic weeds and their extent of infestation in the cultivable waters of the state. Hence a detailed survey of weeds in different water bodies in and around Sibsagar, Assam was conducted during winter, summer and monsoon seasons of 1964 and the results are briefly reported in this communication.

MATERIALS AND METHODS

Eighty five water bodies varying from 0.04 to 3.6 hectares in area in Sibsagar were surveyed during January, June and September representing winter, monsoon and summer seasons respectively. In the monsoon season, however, an extra of five ponds were also surveyed. The important hydrological features of some weed-infested and weed-free ponds were recorded.

Random samples of weeds were collected from each water body with the help of a one square metre bamboo quadrat and their species composition and total weight were recorded. Water samples were analysed for pH, total alkalinity, free carbon dioxide, dissolved oxygen, nitrate, phosphate, free ammonia and chlorides using the standard methods (A.P.H.A. 1946).

RESULTS AND DISCUSSION

The survey showed that about 27 species of aquatic macrophytes were mainly responsible for the large-scale infestation of ponds in Sibsagar. About six species of free floating weeds were recorded, of which *E. crassipes*, *Salvinia* spp. and *A. pinnata* were the most common. *Nymphoides* spp. and *T. bispinosa* among the seven emergent weeds, *Ceratophyllum demersum*, *Hydrilla verticillata* and *Najas indica* among the eight submerged weeds and *C. antiquorum* and *M. quadrifolia* among the six marginal weeds were the most dominant forms encountered during the study. The survey also revealed that about 86 to 92% of ponds in Sibsagar were infested with various types of aquatic weeds. In 40 to 50% of these water bodies the entire surface was covered with weeds while the remaining ones had at least 25% weed cover. The infestation of weeds was generally more in the shallow water areas (1 to 2 m deep) than the deeper ones. It was also noticed that in shallow ponds, free floating and submersed weeds were usually more dominant while in deeper ones emersed weeds were the

most predominant. However, in larger and deeper bodies the growth of emersed weeds was usually restricted to the marginal zones up to a depth of about 3 to 4 m.

The various aquatic macrophytes encountered during the survey and their percentage occurrence in the total number of water bodies studied are shown in Table 1. Among the macrophytes, the maximum infestation of ponds was due to *Nymphoides* spp. (59.17%) and the minimum by *Spirodela polyrrhiza, Jussiaea repens* and *Euryale ferox* (1.15%). The floating weed *E. crassipes* came next in the order of abundance (49.19%)

Table 1. The percentage of incidence of aquatic weeds in the ponds surveyed during different seasons in 1964.

Name of plant	Percentage of infestation of weeds			Average of three seasons
	winter	monsoon	summer *	
Eichhornia crassipes	42.35	51.11	54.11	49.19
Pistia stratiotes	5.88	8.88	7.06	7.27
Spirodela polyrrhiza	1.18	1.11	1.18	1.15
Lemna minor	9.41	4.44	5.83	6.57
Salvinia spp.	23.53	24.44	22.35	23.44
Azolla pinnata	15.29	15.55	8.23	13.02
Nymphaea stellata	3.53	8.88	9.41	7.27
Nelumbo nucifera	5.88	3.33	2.35	3.85
Euryale ferox	1.18	1.11	1.18	1.15
Trapa bispinosa	28.23	38.88	42.35	36.48
Nymphoides spp.	45.89	62.21	69.40	59.17
Potamogeton nodosus	1.18	3.33	2.35	2.28
Utricularia stellaris	2.35	2.22	3.53	2.70
Najas indica	3.53	6.66	3.53	4.57
Ceratophylum demersum	5.88	10.00	4.71	6.86
Hydrilla verticillata	3.53	10.00	7.06	6.86
Nechamandra alternifolia	5.88	3.33	1.88	3.69
Vallisneria spiralis	3.53	2.22	4.71	3.49
Ottelia alismoides	2.35	2.22	1.18	1.91
Ipomoea aquatica	5.88	7.77	8.23	7.29
Limnophila heterophylla	4.71	4.44	2.35	3.83
Monochoria hastata	3.53	6.66	3.53	4.57
Colocasia antiquorum	34.12	45.55	54.11	44.59
Marsilea quadrifolia	21.17	27.77	29.41	26.11
Jussiaea repens	1.18	1.11	1.18	1.15

* winter (January), monsoon (June), Summer (September).

followed by *C. antiquorum* (44.59%), *T. bispinosa* (36.48%), *M. quadrifolia* (26.11%), *Salvinia* spp. (23.44%) and *A. pinnata* (13.02%). The infestation of submersed weeds ranged from 1.91% (*Ottelia alismoides*) to 6.86% (*H. verticillata* and *C. demersum*).

Several floating and emergent weeds especially *E. crassipes, T. bispinosa* and *Nymphoides* spp. predominated in many water bodies during post-monsoon summer months (Aug.—Sept.) while *Salvinia* spp., *Pistia stratiotes, A. pinnata, H. verticillata. C. demersum, N. indica* etc showed their peak growth in monsoon period (June—July). The smaller floating plants like *Lemna minor, S. polyrrhiza* etc were however maximum during winter (Nov.—Dec.) and minimum in monsoon months (June—July).

A number of free floating and submerged weeds like *E. crassipes, Salvinia* spp., *A. pinnata, L. minor, P. stratiotes, N. indica, Utricularia stellaris* etc often formed monotypic stands, choking the entire water body. The emersed weeds *T. bispinosa* and *Nymphoides* spp. also formed fairly huge mats individually or in association with other weeds like *Nelumbo nucifera, Nymphaea* sp. and rarely with *E. ferox*. It was interesting to note that in several water bodies *T. bispinosa* and *N. nucifera* were found to grow together without adversely affecting the growth of either, both the species showing the annual cycle by desintegrating in early winter (Oct.) and reappearing during late winter (Jan.—Feb.). The association of *L. minor* and *S. polyrrhiza, H. verticillata* and *N. indica, Nymphaea* sp. and *Nymphoides* spp. were also encountered in several ponds surveyed.

The salient hydrological characters of water in the weed-infested and weed-free ponds are presented in Table 2. It could be seen that the physico-chemical features of water in the ponds were significantly influenced by the excessive weed growth. The weed infested ponds generally showed lower turbidity, pH, water temperature and dissolved oxygen and higher free carbon dioxide, total alkalinity, nitrate, phosphate, free ammonia and chlorides than those without weeds.

Though a limited growth of aquatic plants is desirable in ponds (Alikunhi 1957, Phillipose 1968) excessive growth of plant populations besides depleting the nutrient status of water and soil often interferes with the utilisation of such water areas for fish culture (Pruginin 1968; Van der Lingen 1968). Philipose (1968) has reported that the eastern zone of India has the maximum weed incidence of 40 to 70% compared to 20 to 25% for the rest of India. However, the present study has revealed that about 86 to 92% of water bodies in Sibsagar were infested with

Table 2. The physico-chemical conditions of water in the weed-infested and weed free ponds.

Parameters	Ranges in the physico-chemical conditions	
	weed-infested ponds	weed-free pond
Water temperature (C)	19.00 — 32.50	19.50 — 35.00
Turbidity (mm)	110.00 — 240.00	130.00 — 550.00
pH	6.10 — 6.85	6.85 — 9.40
Dissolved oxygen (ppm)	0.80 — 9.40	3.00 — 11.40
Free carbon dioxide (ppm)	2.20 — 29.96	nil — 3.52
Total alkalinity (ppm)	22.00 — 102.00	23.00 — 40.00
Nitrate (ppm)	0.03 — 00.14	0.03 — 0.12
Phosphate (ppm)	0.02 — 00.60	0.02 — 0.31
Free ammonia (ppm)	nil — 00.60	nil — 0.28
Chloride (ppm)	nil — 20.00	nil — 3.60

different types of aquatic weeds. Among the 27 weed species recorded during the survey, *Nymphoides* spp., *E. crassipes*, *T. bispinosa*, *Salvinia* spp. and *A. pinnata* are the most noxious weeds causing considerable damage to fisheries due to their high abundance and fast growth. Though the occurrence of *C. antiquorum* (44.59%) and *M. quadrifolia* (26.11%) was also high, they may not pose much problem as they grow mainly in the marginal areas and on the banks of the ponds.

The macrophytes have been observed to lock up essential nutrients which adversely affect the phytoplankton production in cultivable waters (Kaul *et al* 1973). However, the higher phosphate level observed in the weed-infested ponds may probably be due to the release of immobilised phosphorus under weed cover (Ramachandran and Ramaprabhu 1968). The survey has indicated that the free floating and emersed macrophytes are mostly responsible for the excessive infestation of ponds in Sibsagar. The mat formation of these weeds besides causing adverse effects on the ecology of ponds, increases the loss of water through transpiration (Brij Gopal 1973).

The excessive rains and the frequent flooding and submerging of water areas causing wide dispersal of seeds and vegetative parts appear to be the primary factor for the high incidence of weeds in the area (Radhakrishnan and Bhuyan 1973). Other factors such as topography, depth, clarity and fertility of the water, improper maintenance etc. are also responsible for the wide-spread infestation of aquatic weeds in Assam waters.

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Managerial Practices to Control Wild Oats (Avena ludoviciana Dur. and A. fatua L.) in Queensland

B. J. WILSON, O. CARTLEDGE and F. B. WATKINS [1]

ABSTRACT

The repeated annual use of herbicides to control wild oats (*Avena ludoviciana* Dur. and *A. fatua* L.) was investigated. In the first trial the wild oat seed density in the soil after the wheat (*Triticum aestivum* L. 'Gamut') crop was less than the initial soil seed density only after the triallate [*S*-(2,3,3-trichloroallyl)diisopropylthiocarbamate] plus barban (4-chloro-2-butynyl *m*-chlorocarbanilate) treatment. Seed numbers in the soil had declined five months after the crop, so that the number in the triallate plots was also less than one year previously. In a four year trial, triallate and trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) produced levels of wild oat control which resulted in grain yield increases between 55% and 120% in three of the years. There were still five to twelve wild oat plants per m^2 in the maturing wheat crop in the third and fourth years of applying triallate and trifluralin. Barban was less effective on the wild oats than the other herbicides, resulting in smaller yield increases. The incidence of wild oats in relation to crop rotations was surveyed over four years on five farms covering 2000 ha. Winter crops following two or three summer crops had low wild oat populations (1.0 on a scale 0 to 10). The wild oat density was rated at 2.5 and 5.0 in second and third winter crops respectively.

INTRODUCTION

Some managerial practices developed in temperate regions for controlling wild oats are not applicable in Queensland due to differences in climatic and edaphic factors. Delayed seeding, one of the best methods of cultural control available in Canada (Banting 1974), cannot be applied in Queensland because of the uncertain incidence of autumn-winter planting rains in this region of predominently summer rainfall; when a suitable rain falls, farmers must plant since further rainfall may be too light or too late for planting (Thompson and Beckmann 1959, Waring *et al* 1958). The planting of wild oat infested areas to greenfeed crops and pastures, recommended elsewhere (Banting 1974 and Reeves [2]) is also impracticable in the area considered in this paper — the Condamine

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[2] Personal Communication.

Plains of the Darling Downs in Queensland — because for economic reasons the farms are adapted entirely to grain growing. Thus for winter crop monoculture in this area, farmers need to rely on herbicides.

The Darling Downs, however, is suitable for growing summer crops, an advantage the area has over most other parts of the world where wild oats are a problem. This allows farmers to rotate winter crops grown on summer fallow with summer crops grown on winter fallow. The success of this practice for controlling wild oats was reported by Philpotts (1975). She found that the wild oat density was reduced by 96.7% after one summer crop, and by 99.7% after two or three summer crops in northern New South Wales.

This paper reports on the effectiveness of repeated annual applications of herbicides, and of rotational cropping, as managerial practices for wild oat control.

MATERIALS AND METHODS

Winter crop monoculture trials. Trial 1. The trial was established in 1969 on the black earth plains at Bongeen, approximately 50 km west of Toowoomba, Australia. The initial population of wild oat seeds in the soil (0 to 7.5 cm) was 825 per m^2; 268 seeds per m^2 were sown on April 30, bringing the total soil seed population to 1093 per m^2. Wild oat seedlings which emerged presowing were counted on June 4 before they were killed with paraquat (1,1'-dimethyl-4,4'-bipyridinium ion). Plots 1.6 m by 30 m, replicated six times, were laid out in a randomized block design. Triallate at 0.85 kg ai/ha was applied on June 12 with a self-propelled plot sprayer and soil incorporated by the planting operation. Wheat 'Gamut' was sown at a rate of 45 kg/ha. Barban at 0.175 kg ai/ha in a volume of 112 L/ha was applied at the 1 to 2½ leaf stage of the wild oats. Results were obtained from three 0.42 m^2 quadrats per plot pulled on September 29; a whole plot grain harvest was not taken in 1969 because of severe frost damage. The number of wild oat seeds in the soil (0 to 7.5 cm) was measured again in April, 1970, before floods damaged the trial area.

Trial 2. In June, 1971, a new trial was established nearby. Trifluralin at 0.4 kg ai/ha was substituted for the triallate + barban treatment. Other treatments were applied as above for four years. One thousand wild oat seeds per m^2 were sown over the trial area on June 7, 1971. Wheat 'Gamut' was sown on July 25, and in subsequent years on June 1, July 15 and June 4.

Results were obtained from two 0.5 m² quadrats per plot pulled two to four weeks before crop maturity. Grain yield was obtained by header harvesting the whole plot.

Survey of wild oat density versus cropping practices. The density of wild oats was rated in 101 strips or paddocks on five farms in the Bongeen area (including the farm where the above trial was located). The total area of the farms was 2000 ha. Each strip or paddock was rated on a scale of 0 to 10 : 0 = no wild oats, 1 to 2 = scattered wild oats, 5 to 6 moderate infestation, 8 to 10 = dense wild oats. The ratings were made by one person or two people in consultation over the years 1973 to 1976. They were made just prior to harvest when wild oat panicles were clearly visible above the crop. Cropping histories for three to six years prior to 1973, were obtained from the farmers.

RESULTS AND DISCUSSION

Winter crop monoculture trials. Trial 1. Triallate used alone or together with barban was far more effective than barban alone in reducing the wild oat plant density and wild oat seed production in 1969 (Table 1).

Table 1. Effect of three herbicide treatments on wild oat seed production and the subsequent soil seed density (0 to 7.5 cm).

Treatment	1969				April, 1970
	Initial soil seed density (seeds/m²)	Wild oat density in crop (plants/m²)	Seed production (seeds/m²)	Post-harvest [1] soil seed density (seeds/m²)	Soil seed density (seeds/m²)
Control	1093	261 a[2]	3260 a	3721	1923 a
Triallate	1093	43 b	624 c	1085	739 b
Triallate + Barban	1093	29 b	346 c	807	387 b
Barban	1093	224 a	2240 b	2701	2023 a

[1] Calculated by: initial soil seed density minus number germinated presowing (371 per m²), minus number germinated in crop (261 per m²), added to number of seeds produced in crop.

[2] Means with the same letter are not significantly different at $P < 0.05$ (Duncan's multiple range test).

The postharvest seed density in the soil was calculated as described in Table 1. Triallate + barban was the only treatment in which the post-harvest seed density was less than the initial soil seed density. In this year there was no grain harvest, but normally the numbers of wild oat seeds shown in Table 1 would be reduced by removal with the wheat grain.

The number of wild oat seeds in the soil (0 to 7.5 cm) four and a half months later (Table 1) was less than the calculated values, but the same trends are shown. This reduction could be expected as the high temperatures and rainfall (Table 2) over summer would aid the decay of wild oat seeds (Quail and Carter 1968). The results in Table 1 thus show that triallate and triallate + barban should result in a decline in wild oat numbers whereas barban alone would be ineffective.

Table 2. Monthly rainfall (mm)

Year	Months												Annual total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1969	49	11	45	11	95	23	6	70	28	101	92	52	583
1970	112	38	36	23	17	15	2	3	72	37	64	270	689
1971	291	159	2	13	14	9	35	50	36	70	93	133	905
1972	113	23	27	16	37	27	0	17	37	205	153	69	724
1973	91	62	29	9	11	14	90	43	72	42	46	86	595
1974	116	3	8	13	38	23	0	41	32	85	168	98	625
Monthly Means	129	49	25	14	35	19	22	37	46	90	103	118	687

Trial 2. Triallate was as effective in 1971 as in 1969 (Figure 1). Wild oat plant density and dry weight were reduced by 86.3% and 80% respectively and the wheat yield was increased by 120%. Again in 1971, barban did not reduce the wild oat plant density. However the dry weight of wild oats was reduced sufficiently for a 36% increase in grain yield. Trifluralin was intermediate between triallate and barban in effectiveness.

Statistical analysis of the data in Figure 1 is restricted to within years. The error terms in these analyses were too heterogeneous for a between years analysis.

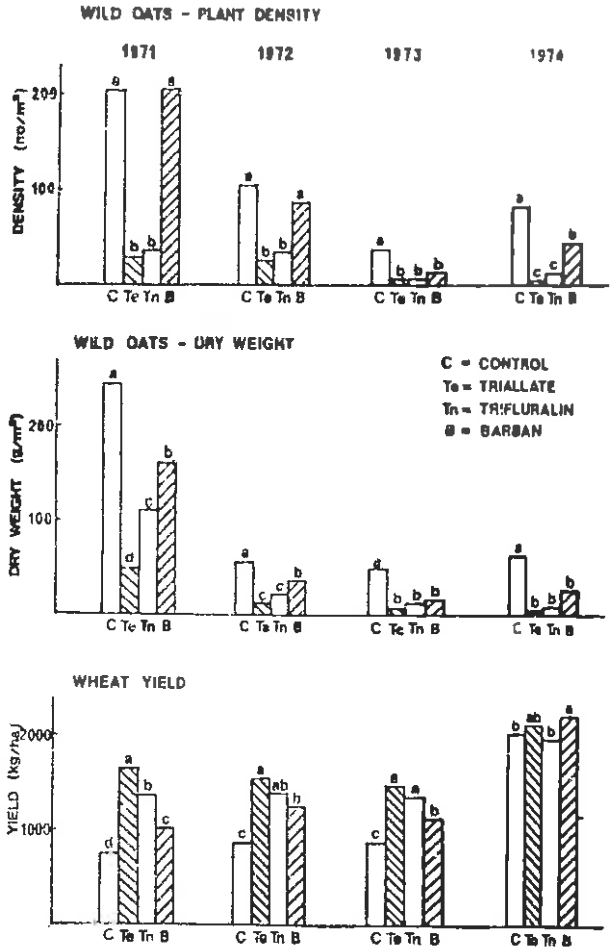


Figure 1. Effect of repeated application on triallate, trifluralin and barban on wheat grain yield and the density and dry weight of wild oats. Means with the same letter are significantly different within years (Duncans multiple range test).

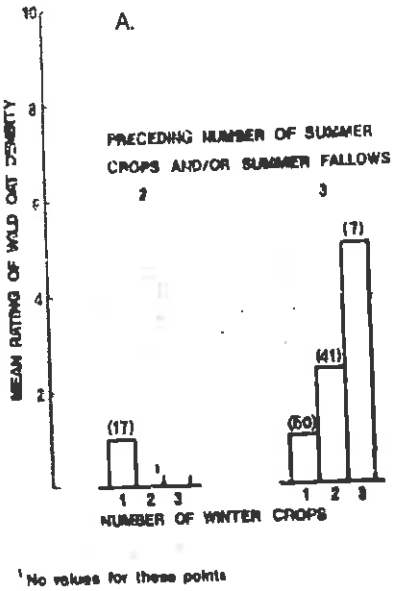
The density and dry weight of wild oat plants in the control declined particularly in 1972 (Figure 1). Although this decline in wild oats is not consistent with the findings in trial 1, the farm survey (see below), or the report of Wilson and Cussans (1975), it has occurred elsewhere (Hughes 1975, Philpotts 1975). This may be due to the removal of wild oat seed with harvested grain, the decay of seeds over summer, and the control by cultivation of wild oats which germinate presowing.

Triallate and trifluralin were equally effective in the years following 1971 (Figure 1). However, there were still five to twelve wild oat plants per m^2 in the maturing wheat crop in the third and fourth years of applying triallate or trifluralin. Barban generally remained less effective than the other herbicides; even in 1973 when its effect on wild

oats was not significantly different, grain yield remained lower than in the other treatments. Our results agree with Selman (1975) and Hughes (1975) in that the repeated use of triallate reduced but did not eradicate wild oats, and that triallate is superior to barban.

Yields were higher in 1974 than in previous years (Figure 1). This is at least partly attributable to a near optimum planting time (June 1) with good following rainfalls in late August to October (Table 2) (Doyle and Marcellos 1974). Inadequate rainfall delayed planting in 1971 and 1973 (Table 2) and this could be expected to result in lower yields. In 1972, drought followed by heavy late rainfalls adversely affected yields; the values presented are from the quadrat harvest.

The wheat was apparently able to tolerate a higher wild oat density under the conditions of 1974, compared with 1973. Yield was more than doubled in 1974 despite the increase in wild oat density.



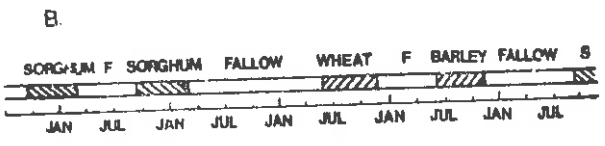


Figure 2A. Effect on wild oat plant density of successive winter crops planted after two or three summer crops and/or summer fallows. The number of ratings in each mean is shown in brackets.

2B. Example of the most common cropping sequence - two winter crops after three summer fallows and/or summer crops.

Survey of wild oat density versus cropping practices. The results of the survey are shown in Figure 2A. The density of wild oats in second and third winter crops was successively higher than in the first winter crop after three years of summer fallow and/or summer crops grown on winter fallow. Seed populations apparently build up with successive wheat crops as shown also by trial 1 and by Wilson and Cussans (1975). The wild oat densities in the first winter crops after two and three summer crops were similar, thus agreeing with the results of Philpotts (1975).

The number of values in each mean in Figure 2A show that two winter crops followed by three summer crops (or summer fallows) is the most common cropping sequence. A typical cropping sequence is illustrated in Figure 2B. Sunflowers (*Helianthus annuus*) may be substituted for the summer fallow or one of the sorghum (*Sorghum vulgare* Pers.) crops. Canary (*Phalaris canariensis* L.) may occasionally be substituted for the wheat or barley (*Hordeum distichum* L.).

A rating of 2 to 3 on our scale would equal no more than one or two wild oats per m^2. Provided these farmers do not go beyond two successive winter crops, they would not on average be incurring any yield losses due to wild oats (Philpotts 1975 and McNamara.[8])

It should be noted that the fluctuating density of wild oats shown in Figure 2A is occurring in an ongoing system of rotations. The result of introducing summer crops grown on winter fallow into an area heavily infested with wild oats may well produce more dramatic results than shown here.

The survey shows that the farmers in the Bongeen area have developed a rotational system which is providing good control of wild oats. Also, at current grain prices the system has proved to be economically sound. If a price differential developed in favour of winter crops, the length of the summer cropping phase could be reduced from three to two years; this would permit two winter crops in four instead of five years. If the price differential was still greater, the summer cropping phase could be reduced to one year, possibly without a serious increase in the incidence of wild oats (Philpotts 1975). The next step would be a winter crop monoculture. Our results show that this could be successfully conducted by relying on the repeated use of triallate; trifluralin is not registered for use in wheat and barley in Queensland.

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[8] Personal communication.

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Selective Weed Control in Wheat with HOE 23408

T. G. REEVES and H. D. BROOKE [1]

ABSTRACT

HOE 23408 [2-(4-(2',4'-dichlorophenoxy)phenoxy)-methyl propionate] a new herbicide being developed by Hoechst AG for wild oat control, has given excellent post-emergence control of annual ryegrass (*Lolium rigidum* Gaud.) in wheat. When applied to ryegrass infested wheat at the 3-leaf stage, mean percentage reduction in weed density at 0.36 kg ai/ha was 93% and mean wheat yield increase was 540 kg/ha (or 20%). Crop damage was not apparent in any experiment; when applied to weedfree wheat at up to 1.44 kg ai/ha. HOE 23408 did not reduce crop yield. The addition of wetting agent did not measurably affect activity on weed or crop. Similarly no significant losses in weed control were noted when HOE 23408 was mixed with bromoxynil (3,5-dibromo-4-hydroxy benzonitrile), terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine], methabenzthiazuron [*N*-(benzothiazol-2yl)-*N*,*N*'-dimethylurea] or dicamba (3,6-dichloro-2-methoxybenzoic acid). The potential advantages of having for the first time an effective post-emergence herbicide for ryegrass control in wheat are discussed.

INTRODUCTION

Annual ryegrass is one of the most commonly occurring and important weeds in field crops of southern Australia. Control measures for this weed have included pasture management, cultivation and selective chemical control with pre-emergence herbicides (Lumb and McPherson 1964, Reeves and Tuohey 1972). However, until recently there have been no herbicides that would give effective postemergence ryegrass control and still retain selectivity in cereal, oilseed and grain legume crops.

HOE 23408 a new product being developed by Hoechst AG, mainly for wild oat control has, however, given control of ryegrass in wheat and a number of other crops when applied after crop and weed emergence.

This paper reports results from experiments conducted from 1975-1976, which investigated the factors influencing post-emergence ryegrass control with HOE 23408.

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MATERIALS AND METHODS

The sample of HOE 23408 (dichlofop-methyl) used in our experiments was formulated as an emulsifiable concentrate containing 360 g/L of active ingredient. All applications of this material were made in 100 litres of water per hectare, using a hand held boom sprayer fitted with 73° fan nozzles. The following factors were investigated in 1975 and/or 1976: time by rate of application (2 experiments), effect of wetting agents (2 experiments), mixtures with other herbicides (1 experiment) and crop tolerance (1 experiment).

All experiments were randomized blocks with at least 3 replicates. Factorial treatment combinations were included in some of the investigations and plot size was 2 m by 20 m. Ryegrass was counted in late winter, in 3 dm by 3 dm quadrats, five per plot. All plots were harvested with a combine harvester for grain yield determinations. HOE 23408 is subsequently referred to in this paper as HOE.

Time by rate of application (see Table 1). In 1975 HOE was applied to ryegrass infested wheat at 3 times, whilst in 1976 two times of application were investigated. The rates of application and growth stages of the crop and weed are shown in Table 2.

All rates of HOE applied after crop and weed emergence significantly reduced ryegrass populations in both 1975 and 1976 ($P<0.05$). When applied pre-emergence however, significant reductions were only obtained at rates above 0.36 kg ai/ha.

These reductions in weed density resulted in significant grain yield increases and there were no significant differences between the effects of rates or times of application on grain yield.

Effect of wetting agents (see Table 2). During 1976, two experiments were conducted to investigate the effects of wetting agents on ryegrass control in wheat with HOE. In both experiments factorial combinations of HOE and Agral 60[2] wetting agent were applied to ryegrass infested wheat cv. Egret at the 3-leaf stage. The objectives were to measure the effect of added wetter on various rates of HOE and secondly to determine optimum rate of wetter.

In the first experiment, significant reductions in ryegrass density, and increases in grain yield were obtained with HOE, but addition of wetter at 0.5% v/v did not affect weed control or grain yield response.

2 Agral 60 is registered trademark of I.C.I.

Table 1. Effect of rate and time of application of HOE 23408 on ryegrass density and wheat yields 1975 - 1976. *

Treatment		1975		1976	
		Ryegrass Plants/ m^2	Wheat grain yield t/ha	Ryegrass Plants/ m^2	Wheat grain yield t/ha
Rate					
HOE 23408	0 kg ai/ha	281.0a	3.05	261.1a	2.41
	0.18	n.t.	n.t.	48.8b	2.94
	0.36	25.1b	3.80	11.0c	3.11
	0.72	3.2c	3.72	2.4c	3.27
	1.44	0	3.84	n.t.	n.t.
	LSD $P<0.05 =$		0.25		0.51
Crop and weed stage					
Postsowing pre-em		n.t.	n.t.	136.1a	2.75
1 - 2 leaves		83.8a	3.59	n.t.	n.t.
3 - 4 leaves		79.0a	3.62	93.2b	2.87
6 - 10 leaves		71.0a	3.60	n.t.	n.t.
	LSD $P<0.05 =$		n.s.		n.s.

* Main effects only shown as no interactions occurred
n.t. = not tested
n.s. = not significant
Postscript letters refer only to the comparison between rates of application or between times of application.
Values followed by the same letter do not differ ($P>0.05$).

Although rates of wetter in the second experiment varied from 0.25% v/v to 1.0% v/v, there were again no significant differences in the control of ryegrass or final grain yields.

Mixtures with other herbicides. (see Table 3). Previous experience with HOE had indicated no activity on broadleaved weeds. Consequently where populations of grassy and broadleaved weeds are present together,

Table 2. Effect of wetting agent on ryegrass densities and resultant wheat yields 1976.*

Treatment		Ryegrass plants/m²	Wheat grain yield t/ha
Without wetter		46.4a	3.09
Wetter 0.5% v/v.		34.4a	2.01
	LSD P<0.05		n.s.
HOE 23408	0 kg ai/ha	152.8a	2.72
	0.09	93.8ab	3.03
	0.18	70.2b	3.01
	0.36	26.0c	3.07
	0.72	3.9d	3.16
	1.44	0	3.33
	LSD P<0.05		0.19

* Main effects only shown as no interactions occurred. Postscript letters refer only to the comparison between wetter application or the comparison between rates of HOE application. Values followed by the same letter do not differ (P>0.05).

Table 3. Effect of mixing HOE 23408 with other herbicides, on control of ryegrass and grain yield response 1976.

Treatment kg ai/ha		Ryegrass plants/ m²	Wheat grain yield t/ha
HOE 23408	0	179.9a	2.98
	0.18	32.8b	3.22
	0.36	2.5de	3.34
	0.72	0	3.35
HOE 23408	0.36 + bromoxynil 0.28	2.0e	3.35
	0.36 + terbutryn 0.25	11.2c	3.48
	0.36 + methabenzthiazuron 0.6	3.7d	3.18
	0.36 + dicamba 0.14	13.2c	3.20
	LSD P<0.05 =		n.s.

Values followed by the same postscript letters do not differ (P>0.05).

mixtures of HOE with other herbicides are necessary for control. In this experiment HOE was mixed with four herbicides and applied to ryegrass infested Egret wheat at the 3-leaf stage to investigate possible antagonism. The chemicals used were: bromoxynil, terbutryn, methabenzthiazuron and dicamba.

All mixtures significantly reduced ryegrass populations compared to the unsprayed control treatment, although there was some visual evidence of antagonism between dicamba and HOE. Grain yields were not significantly different.

Tolerance of weedfree wheat to HOE (see Table 4). Three rates of HOE were applied to weedfree wheat, cv. Egret, at two growth stages in order to investigate crop tolerance to HOE. Additionally applications were made with or without wetting agent (0.5% v/v).

Applications of HOE at rates up to 1.44 kg ai/ha did not reduce wheat grain yield. There were no differences in crop tolerance whether applied at the 3-leaf stage or tillering nor did the addition of wetting agent affect grain yield.

Table 4. Effect of HOE 23408 on grain yield of weedfree wheat cv. Egret 1976 *

Treatment kg ai/ha		Wheat grain yield t/ha
Rate		
HOE 23408	0	2.69
	0.36	2.54
	0.72	2.62
	1.44	2.65
LSD	$P<0.05$	n.s.
Crop stage		
HOE 23408	3 leaves	2.67
	Tillering	2.58
LSD	$P<0.05$	n.s.
Effect of wetter		
Without wetter		2.61
Wetter 0.5% v/v		2.64
LSD	$P<0.05$	n.s.

* Main effects only shown as there were no interactions.

RESULTS AND DISCUSSION

The excellent post-emergence ryegrass control resulting from applications of HOE 23408, could revolutionize wheat-growing in much of southern Australia. Whilst diallate [*S*-2,3-dichloroallyl-*N*,*N*-di-isopropyl(thiocarbamate)] and trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) have both been widely used for control of ryegrass in wheat, they have the often recorded disadvantages of most pre-emergence herbicides, namely, application is necessary before the weed problem can be seen and secondly both chemicals require thorough incorporation into a level, well cultivated seedbed. The use of HOE should allow greater flexibility in deciding which areas to spray, and will also give in-crop ryegrass control under conditions where diallate and trifluralin cannot be used e.g. in zero-tillage systems.

In all experiments reported here where ryegrass was controlled, mean wheat yield increase were 540 kg/ha at 0.36 kg ai/ha and 0.72 kg ai/ha of HOE respectively. No crop damage was apparent in any experiment.

Application of wetting agent has increased the activity of HOE 23408 by up to 100% in wild oat control experiments under Canadian conditions[3]. Our results with ryegrass showed no response to wetter; future investigations will however, include evaluation of different wetters plus a repeat of these initial investigations.

The results of mixing HOE with broadleaf herbicides were most encouraging, as Friesen (1976) has reported severe reduction of herbicidal activity when HOE is mixed with some herbicides. Our results with ryegrass confirm his findings in wild oats that bromoxynil does not appreciably reduce weed control when used in a mixture with HOE.

With the advent of this selective post-emergence herbicide it is important to know the level of weed infestation which can be tolerated before it is economically desirable to spray. In these times of rising developmental costs it is unlikely that HOE will be a cheap herbicide. The relationships reported by Reeves (1976), between ryegrass density and wheat yield reduction, should greatly aid in the efficient use of herbicides such as HOE for post-emergence control of ryegrass in wheat. As HOE is also suitable for use in some other crops such as oilseed rape (*Brassica napus*) and lupins (*Lupinus angustifolius*), additional information is currently being obtained on the effects of ryegrass density on these species.

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Chemical Control of Wild and Red Rice [1]

S. WIRJAHARDJA [2] and C. PARKER [3]

ABSTRACT

Large-, medium- and small-seeded red rice from Swaziland, long awned, straw hulled and short awned, black hulled red rice from USA, *Oryza punctata* Kotschy ex Steud. and two cv i.e. Blue Bonnet from South Africa and IR 28 were tested against alachlor [2-chloro-2,6-diethyl-*N*-(methoxymethyl)acetanilide], benthiocarb [5-(4-chlorobenzyl)-*N*,*N*-diethylthiolcarbamate], metolachlor [2-chloro-*N*-ethylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] and molinate (*S*-ethylhexahydro-2*H*-azepine-1-carbothioate). The selectivity of alachlor against *O. punctata* was confirmed at 0.9 kg/ha when crop varieties were protected by NA (1,8-napthalic anhydride), but this compound appears unlikely to be selective against other red rice types. Results with metolachlor were inconclusive owing to excessive activity at the doses used. Severe crop damage occurred at the lowest dose of 0.4 kg/ha, even with protectant. Molinate incorporated pre-planting was the most selective chemical and could be selective against most red rice types in both rice cv protected by NA (1%) at 3 kg/ha. Benthiocarb incorporated pre-planting at 4 kg/ha was safe in IR 28 even without NA, but also could be selective against several red rice types in cv Blue Bonnet (+ NA). There were large differences in the susceptibility of different red rice types. In particular the Swaziland medium-seeded red rice and both US types were relatively sensitive to benthiocarb and molinate, though not quite susceptible as *O. punctata*. Swaziland large- and small-seeded were both relatively tolerant.

INTRODUCTION

The distribution of wild rice species, the problems they create and their control has been reviewed and reported (Backer 1946, Oka and Chang 1959; 1963, Tateoka 1962, Bidaux 1971, Purseglove 1972, Aubin *et al* 1975, Grist 1975, Katayama and Kuroda 1975, Nakayama 1975, Wirjahardja and Nurfilmarasa 1975). One species, *O. punctata* Kotschy ex Steud., has built up to serious proportions in Swaziland, and a series of experiments on the chemical control has been carried out at the Weed Research Organization in Britain (Parker and Dean 1976). The experiment reported here was part of that series of experiments. The object was to study the chemical control in rice of *O. punctata* and red rice

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2 BIOTROP, P.O. Box 17 Bogor, Indonesia.

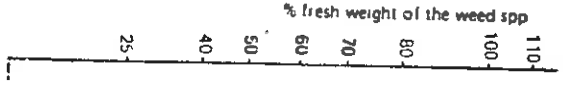
3 ARC-WRO, Begbroke Hill, Yarnton, Oxford, OX5 1PF, England.

Table 1. Fresh weight means (g) of the wild and red rice types, *O. punctata*, the rice cultivars and their control as affected by the herbicides, 2 weeks after treatments.

Treatment (kg/ha) \ Species		A	B	C	D	E	F	G	H	J	K
Alachlor	0.6	4.068^{e}	3.260^{d}	2.727^{f}	2.914^{e}	2.979^{h}	0.727^{e}	2.884^{efgh}	3.875^{d}	2.869^{g}	3.258^{f}
Alachlor	0.9	4.034^{e}	2.722^{e}	2.511^{f}	2.763^{e}	2.598^{g}	—	2.707^{efg}	3.800^{d}	2.361^{f}	2.795^{de}
Alachlor	1.35	2.595^{d}	0.806^{bc}	1.795^{e}	1.615^{d}	0.922^{f}	—	1.587^{bc}	2.786^{bcd}	1.429^{e}	1.914^{bc}
Metolachlor	0.4	1.195^{bc}	0.115^{a}	1.150^{d}	1.102^{c}	0.571^{e}	0.258^{b}	1.253^{abc}	1.246^{a}	0.707^{cd}	0.834^{a}
Metolachlor	0.6	0.806^{de}	0.007^{a}	0.629^{bc}	0.693^{b}	0.373^{d}	0.006^{a}	0.863^{a}	1.054^{ab}	0.544^{bc}	0.708^{a}
Metolachlor	0.9	0.123^{a}	—	0.108^{a}	0.506^{b}	0.009^{ab}	—	0.698^{a}	0.874^{a}	0.460^{b}	0.120^{g}
Benthiocarb	4.0	3.354^{de}	0.931^{c}	2.777^{fg}	1.369^{cd}	0.194^{c}	—	3.393^{hi}	3.773^{d}	1.552^{e}	2.055^{bc}
Benthiocarb	6.0	2.550^{d}	0.664^{bc}	1.995^{e}	0.409^{b}	0.203^{c}	—	2.602^{ef}	2.380^{abc}	0.785^{d}	1.695^{b}
Benthiocarb	9.0	1.964^{c}	0.086^{a}	2.006^{e}	0.050^{a}	0.006^{a}	—	1.911^{cd}	1.194^{ab}	0.026^{a}	1.893^{c}
Molinate	2.0	3.118^{de}	0.493^{b}	2.556^{f}	0.031^{a}	0.019^{b}	—	3.154^{ghi}	3.559^{d}	0.140^{a}	2.642^{d}
Molinate	3.0	0.592^{ab}	0.005^{a}	1.008^{cd}	—	—	—	2.483^{de}	3.402^{d}	—	2.912^{de}
Molinate	4.5	0.078^{a}	—	0.200^{ab}	—	—	—	1.710^{bc}	3.299^{d}	—	0.906^{a}
Untreated		5.386^{f}	3.673^{f}	3.204^{fg}	3.861^{f}	3.639^{i}	2.769^{d}	3.751^{i}	4.077^{e}	3.816^{h}	3.013^{ef}

Values with the same subscript are not significantly different ($P > 0.05$). — totally killed

A. Large-seeded Swaziland red rice.
B. Medium-seeded Swaziland red rice.
C. Small-seeded Swaziland red rice.
D. Long awned, straw hulled US red rice.
E. Short awned, black hulled US red rice.
F. *O. punctata*.
G. IR 28.
H. IR 28 + NA.
J. Blue Bonnet.
K. Blue Bonnet + NA.



both the weeds and the cultivars with or without treatment with NA. At 0.9 kg/ha alachlor was selective against *O. punctata* when crop varieties were protected with NA, but it appears unlikely to be effective against other red rice types at that dose.

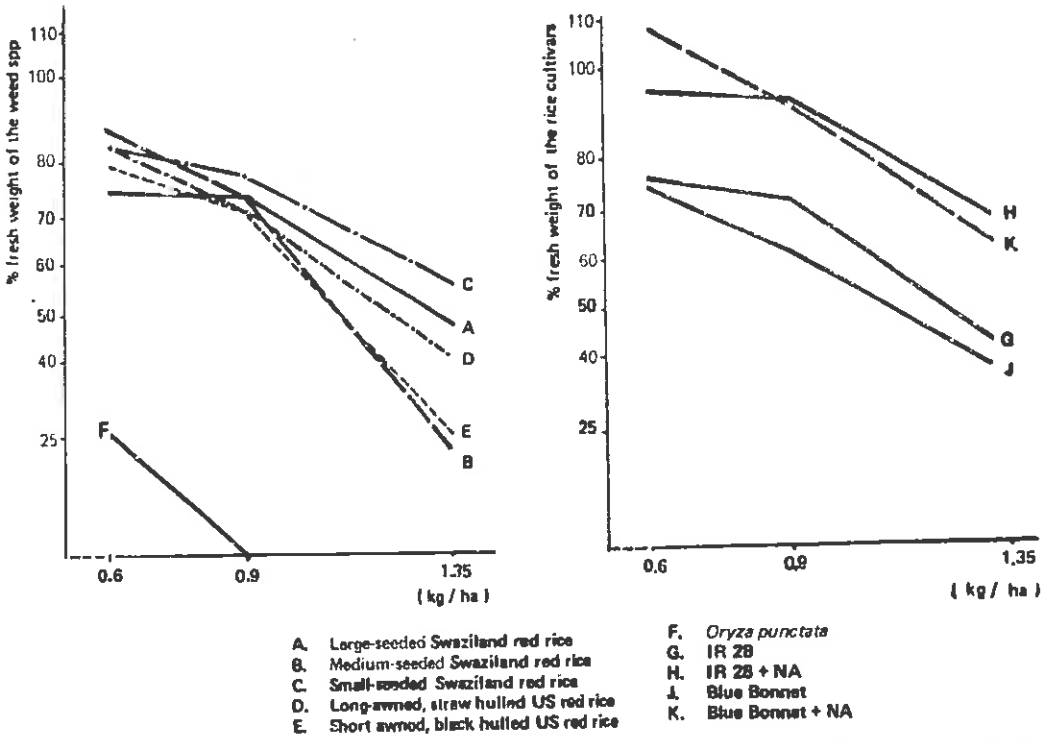


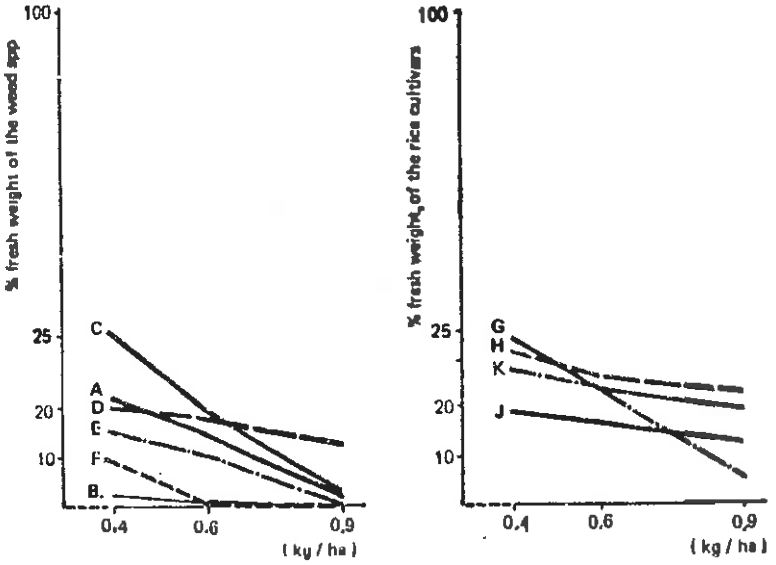
Figure 1. The effect of alachlor against red rice types, *Oryza punctata* and the rice cultivars unprotected and protected with NA.

Results with metolachlor were inconclusive (Figure 2) owing to excessive activity, of the doses used. Severe crop damage occurred at the lowest dose of 0.4 kg/ha, even with protectant.

Benthiocarb at 4 kg/ha (Figure 3) was safe in IR 28 even without NA, but also could be selective against several red rice types in the cultivar Blue Bonnet treated with NA.

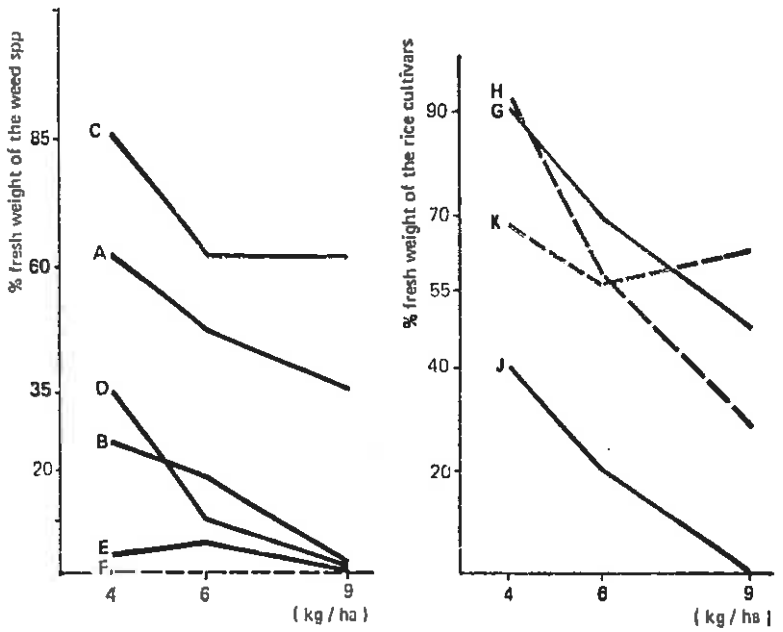
Molinate incorporated pre-planting (Figure 4) was the most selective chemical and could be selective against most red rice types at 3 kg/ha in both rice cultivars protected with NA.

Both benthiocarb and molinate were incorporated pre-planting, a technique not easily followed in the field. Alternative methods of applying these herbicides now need investigating.



A. Large-seeded Swaziland red rice
B. Medium-seeded Swaziland red rice
C. Small-seeded Swaziland red rice
D. Long awned, straw hulled US red rice
E. Short awned, black hulled US red rice
F. *Oryza punctata*
G. IR 28
H. IR 28 + NA
J. Blue Bonnet
K. Blue Bonnet + NA

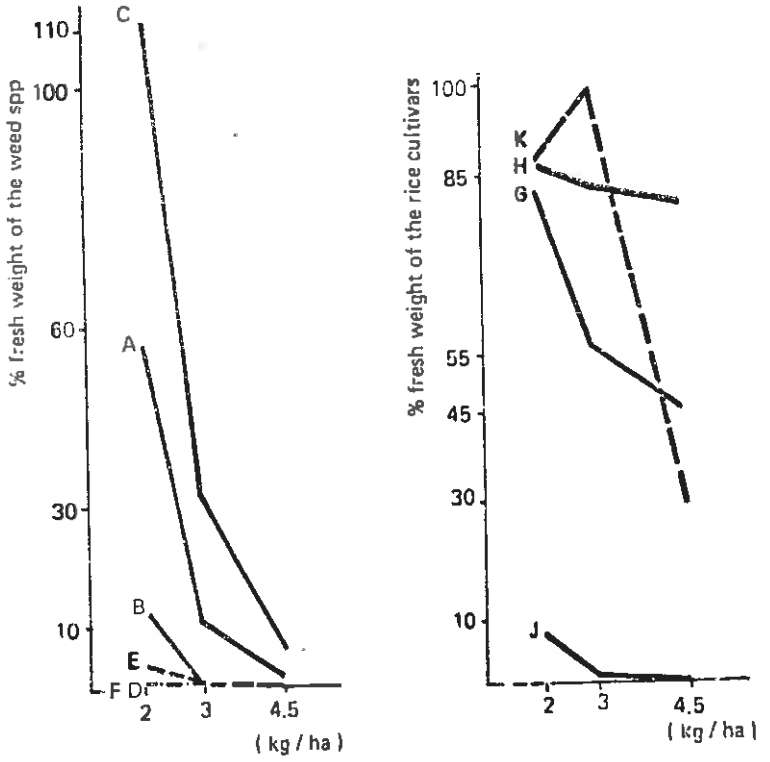
Figure 2. The effect of metolachlor against red rice types, *Oryza punctata* and the rice cultivars unprotected and protected with NA.



A. Large-seeded Swaziland red rice
B. Medium-seeded Swaziland red rice
C. Small-seeded Swaziland red rice
D. Long-awned, straw hulled US red rice
E. Short awned, black hulled US red rice
F. *Oryza punctata*
G. IR 28
H. IR 28 + NA
J. Blue Bonnet
K. Blue Bonnet + NA

Figure 3. The effect of benthiocarb against red rice types, *Oryza punctata* and the rice cultivars unprotected and protected with NA.

There were large differences in the susceptibility of different red rice types. In particular the Swaziland medium-seeded red rice and both US types were relatively sensitive to benthiocarb and molinate, though not quite as susceptible as *O. punctata*. Swaziland large- and small-seeded were both relatively tolerant.



A. Large-seeded Swaziland red rice
B. Medium-seeded Swaziland red rice
C. Small-seeded Swaziland red rice
D. Long-awned, straw hulled US red rice
E. Short awned, black hulled US red rice
F. *Oryza punctata*
G. IR 28
H. IR 28 + NA
J. Blue Bonnet
K. Blue Bonnet + NA

Figure 4. The effect of molinate against red rice types, *Oryza punctata* and the rice cultivars unprotected and protected with NA.

ACKNOWLEDGEMENT

The authors desire to acknowledge the indebtedness to the Director of the Weed Research Organization in Britain for providing the opportunity and facilities for conducting this study. Their gratitude is also due to all staff for their kind assistance.

Oxadiazon. Weed Control, Crop Tolerance and Yield Results of Field Trials Conducted in the Philippines on Some Rice Crops

Y. PERRET [1] and M. SIMMONDS [2]

ABSTRACT

The results of 18 experiments with oxadiazon [(2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-$\triangle^2$-1,3,4-oxadiazolin-5-one] are reported with particular relevance to biological activity and crop yields. Applications of oxadiazon at rates of 0.5 and 0.6 kg ai/ha made preemergence of weeds and either pre or post of crop transplanting, gave levels of weed control equivalent to local reference treatments with minimal adverse crop reaction. Weeds of importance, particularly broad-leaved species were controlled for 6 weeks or more. Yield increases were either equivalent or superior to those of the reference chemicals and the hand-weeded check.

INTRODUCTION

Since a review of initial results and practical applications of oxadiazon was reported by Burgaud *et al* (1969), the development of this herbicide for use in rice has been the subject of much technical evaluation. Cooke and Simmonds (1970) summarized some of the extensive Japanese work and Kawamura (1971) discussed a new, simple application method. Chevrel and Tyrrell (1973), collating work from Japan, USA, South America, Italy and France, recognised the difficulties associated with recommending application techniques across international boundaries and Hayashi (1973) provided data on residues in crop and soil. This information was extended by Ishizuka *et al* (1975) with Carbon-14 studies and Abrosi and Desmoras (1975) clarified crop and weed absorbtion mechanisms to the chemical, relating this to plant age and chemical residues.

More recently the widespread commercial acceptance of oxadiazon for Japanese (temperate Asia) rice has prompted a detailed series of work on the tropical Asian crop in the Philippines. This country grows rice across a sufficiently broad spectrum of conditions and methods so that the results obtained from the work can probably be transposed to other parts of tropical Asia with little need for radical technical modifications. These results are reported.

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MATERIALS AND METHODS

The literature cited earlier has detailed the chemistry, toxicological data and mode of activity of oxadiazon. Work in the Philippines on rice has been carried out with six oxadiazon formulations, but this report deals only with three:
(a) granular formulation containing 2% w/w oxadiazon, (b) emulsifiable concentrate containing 12% w/v oxadiazon and (c) emulsifiable concentrate containing 25% w/v oxadiazon.

The chemical reference products used were butachlor [*N*-(butoxymethyl)-2-chloro-2',6'-diethyl-acetanilide] applied at 1.25 kg ai/ha (or 2 kg ai/ha on direct seeded rainfed rice) and 2,4-D IPE, [2,4-(dichlorophenoxy)acetic acid, isopropyl ester] applied at 0.8 kg ai/ha. All trials included clean weeded and non-weeded controls.

All granular formulations were applied after transplanting the crop but before weed emergence. The 12% oxadiazon EC was applied before transplanting and immediately after leveling and the 25% EC was applied after sowing and before weed emergence. All trials were carried out under accepted statistical standards.

RESULTS AND DISCUSSION

Transplanted rice. The results in Table 1 (1976) and Table 3 (1977) indicate the provision of high levels of weed control as expressed in yield terms in the more difficult conditions of dry-season crops. Under 1976 conditions the effect of 0.6 kg ai/ha oxadiazon, applied either before or after transplanting, is shown to be equivalent to any chemical tested as well as the clean weeded check. As a result, the work in 1977 was concentrated on a dose of 0.5 kg ai/ha and again results were at the level of or superior to those of butachlor, 2,4-D IPE and the clean weeded check. Table 2, wet season results, shows the good yield response and reliability of oxadiazon treated plots with both pre and post transplanting applications.

Table 4 shows the greater variation of rice tolerance to oxadiazon when compared to the reference chemicals, although as the grading of 3 and up is regarded as unacceptable, the tolerance of normal doses of oxadiazon by rice gives no cause for concern. This table also shows the broad-spectrum weed control activity of oxadiazon and exhibits particularly its good, long term effect on broad leaved weeds.

Table 1. Effect of oxadiazon treatments, expressed as grain yield, on transplanted irrigated rice at six locations. Dry

Table 1. Effect of oxadiazon treatments, expressed as grain yield, on transplanted irrigated rice at six locations. Dry season 1976.

			Yield (t/ha)[1]							
Location			Laguna	Tarlac	Laguna	Panay	Panay	Negros		
Variety			IR 34	IR 32	IR 28	IR 30	IR 30	IR 26		
Seedbed preparation			Dapog[5]	Wetbed[6]	Dapog	Wetbed	Wetbed	Wetbed		
Product	Treatments Dose rate kg ai/ha	Time							Mean	% of untreated control
oxadiazon 12% EC	0.6	1 to 3 DBT[2]	6.9	5.0 a	2.9 a	2.7	3.1	3.6	4.03	126
oxadiazon 2% G	0.6	4 DAT[3]	6.6	5.8 a		2.7	2.9	3.9	4.38	137
butachlor 5% G	1.25	4 DAT	6.5	5.5 a	3.2 a	2.2	2.2	3.7	3.88	122
2,4-D IPE 3.2% G	0.8	4 DAT	6.4	4.9 a	2.1 ab	2.8	2.6	3.6	3.74	117
Hand weeded twice			6.9	5.3 a	0.6 bc	3.2	2.2	3.9	3.69	116
Untreated check			6.2	3.8 b	0.2 c	2.4	2.5	3.8	3.28	100
Coefficient of variation			9.9%	14.5%	46.2%	21.2%	17.3%	3.8%		
Significance[4]			NS	S	S	NS	NS	NS		
LSD 5%				1.0	1.7					

[1] Average of four replications. In each column any two means followed by the same letter are not significantly different at the 5% level.
[2] DBT = days before transplanting.
[3] DAT = days after transplanting.
[4] N.S. = non significant. S = significant at 5% level.
[5] Dapog = small seedling transplant.
[6] Wetbed = traditional transplant.

Table 2. Effect of oxadiazon treatments, expressed as grain yield on transplanted irrigated rice at five locations. Wet season 1976.

Location			Laguna	Laguna	Laguna	Bulacan	Tarlac		
Variety			IR 26	IR 32	IR 32	IR 12	IR 36		
Seedbed preparation			Dapog	Dapog	Dapog	Wetbed	Wetbed		
	Yield (t/ha)[1]								
Product	Treatments Dose rate kg ai/ha	Time						Mean	% of untreated control
oxadiazon 12% EC	0.5	3 to 1 DBT[2]	—	—	—	3.3 b	4.1	3.69	105
oxadiazon 12% EC	0.6	3 to 1 DBT	4.4 a	—	—	—	—	4.40	125
oxadiazon 2% G	0.5	3 to 1 DBT	—	—	—	3.6 a	4.3	3.96	113
oxadiazon 2% G	0.5	4 DAT[3]	4.5 a	4.5	5.9 a	3.3 b	3.9	4.42	126
butachlor 5% G	1.25	4 DAT	3.7 a	3.9	6.0 a	3.3 b	3.8	4.05	115
2,4-D IPE 3.2% G	0.8	4 DAT	4.0 a	4.2	5.6 a	3.4 ab	3.9	4.22	120
Hand weeded twice			4.3 a	4.6	5.9 a	3.4 ab	4.1	4.44	127
Untreated check			2.2 b	4.0	4.8 b	2.9 c	3.6	3.50	100
Coefficient of variation			17.9%	9.9%	7.2%	5.4%	8.2%		
Significance[4]			HS	NS	S	HS	NS		
LSD 5%			1.0		0.6	0.3			

1 Average of four replications. In each column any two means followed by the same letter are not significantly different at the 5% level.
2 DBT = days before transplanting.
3 DAT = days after transplanting.
4 N.S. = non significant. S = significant at 5% level. H.S. = high significant (1% level).

Table 3. Effect of oxadiazon treatments on total yield of transplanted irrigated rice at six locations. Dry season 1977.

Table 3. Effect of oxadiazon treatments on total yield of transplanted irrigated rice at six locations. Dry season 1977.

Location				Laguna	Bulacan	Bulacan	Laguna	Laguna	Laguna		
Variety				IR 15.14	IR 12	IR 12	C 4	IR 32	IR 32		
Seedbed preparation				Dapog	Wetbed	Wetbed	Dapog	Wetbed	Dapog		
	Treatments			Yield (t/ha)[1]							
Product	Dose rate kg ai/ha		Time							Mean	% of untreated control
oxadiazon	2% EC	0.5	2 DBT[2]	2.6	3.6 b	3.5 ab	3.9 a	4.9	4.2 a	3.80	132
oxadiazon	2% G	0.5	4 DAT[3]	2.6	3.8 ab	3.3 b	3.8 a	4.9	3.7 ab	3.67	128
butachlor	5% G	1.25	4 DAT	2.4	3.7 b	3.6 ab	3.9 a	4.9	3.6 ab	3.66	127
2,4-D IPE	3.2% G	0.8	4 DAT	2.5	3.5 b	3.2 bc	3.6 a	4.5	3.0 ab	3.41	118
Hand weeded twice				2.6	4.2 a	3.7 a	3.9 a	4.7	3.3 ab	3.76	130
Untreated check				2.1	2.8 c	2.8 c	3.0 b	4.1	2.5 b	2.87	100
Coefficient of variation				18.8%	9.2%	8.7%	9.2%	9.4%	12.6%		
Significance[4]				NS	HS	HS	HS	NS	HS		
LSD 5%					0.5	0.4	0.5		1.3		

[1] Average of four replications. In each column any two means followed by the same letter are not significantly different at the 5% level.

[2] DBT = days before transplanting.

[3] DAT = days after transplanting.

[4] N.S. = non significant. S = significant at 5% level. H.S. = high significant (1% level).

Table 4. Oxadiazon. Showing the tolerance of transplanted rice to and the weed control activity of pre and post-planting applications of this herbicide. Average of three seasons of experiments.

Treatment	kg ai/ha	Phytotoxicity[1]		Weed control[1]					
		15 DAT[2]	45 DAT	30 DAT			45 DAT		
				G[3]	S	B/L	G	S	B/L
Preplanting									
oxadiazon 12% EC	0.5	1.1	0.7	7.5	7.6	8.3	5.8	6.5	8.3
Post-planting									
oxadiazon 2% G	0.5	1.5	0.9	7.0	6.9	7.4	4.7	6.0	7.8
oxadiazon 2% G	0.6	1.6	1.6	7.0	8.2	8.5	4.5	7.8	8.2
butachlor 5% G	1.25	0.6	0.5	5.7	8.3	7.4	5.5	7.8	6.7
2,4-D IPE 3.2% G	0.8	0.6	0.3	4.6	4.9	4.6	3.9	4.0	3.4
untreated control[4]		0	0	9	130	96	5	94	87

	acceptable phytotoxicity								efficient weed control				
notation	[0]	1	2	2.5	[3]	4	5	6	[7]	7.5	8	9	[10]
corresponding % of destruction	0	2.5	5	10	15	30	50	70	85	90	95	97.5	100%

1 Scale : 0 to 10

2 DAT = days after transplanting.

3 G = grasses. S = sedges. B/L = broad-leaved weeds.

4 Figures show the average number of weeds present in 1 m² of the untreated control plots.

Direct seeded rice. Table 5 indicates the acceptability of normal oxadiazon doses applied as the 25% EC formulation in terms of weed control, crop tolerance and crop yield. However the reduction in both crop tolerance and yield with a twice-normal dose indicates lower margins of tolerance for this particular culture and formulation.

The experiments reported show that oxadiazon at normal herbicidal doses is tolerated by transplanted and direct seeded lowland rainfed rice to allow high yield response. Work carried out by the IRRI (1973, 1974

Table 5. Grain yield, phytotoxicity, weed control. For direct seeded rainfed rice BPI-RI-2 variety as affected by the different herbicide treatments. (Maligaya BPI station/Rhone-Poulenc coop. project 1976 wet season)

Herbicide treatment	Rate kg ai/ha	Time DAS[1]	Grain Yield[2] t/ha	Toxicity 20 DAS	Toxicity 40 DAS	Weed control rating 20 DAS G[3]	20 DAS S	20 DAS B/L	40 DAS G	40 DAS S	40 DAS B/L
oxadiazon 25% EC	0.5	4	2.1	0	0	9	9	9	9	9	9
oxadiazon 25% EC	0.75	4	2.0	0	0	9	9	9	9	9	9
oxadiazon 25% EC	1.00	4	0.9	0	0	9	9	9	9	9	9
butachlor 69% EC	2.0	4	1.5	6	4	9	9	9	9	9	9
hand weeding		20 + 40 DAS	2.3	0	0	9	9	9	9	9	9
untreated (control)			2.0	0	0	14.7	154.5	57.2	23.3	183.3	44.3[4]
LSD — .05			NS								
.01			NS								
CV %			3.0								

Scale of rating

Toxicity rating

0 — no toxicity
1 to 3 — slight toxicity
4 to 6 — moderate toxicity
7 to 9 — severe toxicity
10 — 100% toxic or complete kill

Weed control rating

0 — no control
1 to 3 — slight control
4 to 6 — moderate control
7 to 9 — excellent control
10 — 100% control or complete control

[1] DAS = days after seeding
[2] Grain yield at 14% moisture content
[3] G = grasses S = sedges B/L = broad-leaved weeds
[4] Figures show the average number of weeds present in 0.25m² of the untreated plots

and 1975) on upland rice alone and on upland rice plus associated cropping patterns also shows long term, broad spectrum weed control plus a high yield response even though, under upland conditions, higher doses are used. Possibly the most sensitive rice culture is pregerminated direct

seeded rice and IRRI (1974) showed a mixture of oxadiazon plus 2,4-D IPE (0.5 kg ai/ha plus 0.5 kg ai/ha) applied to this crop allowed normal yields albeit with marginal tolerance. Rice tolerance to oxadiazon is not a fully physiological effect but acceptable margins of safety exist and can be enhanced by management practices, i.e. reliable water management.

The weed control spectrum of oxadiazon at a dose of 0.5 kg ai/ha makes it particularly suited to conditions in the Philippines. The trials have shown efficient control of the grasses *Echinochloa crus-galli* (L) Beauv. and *E. crus-pavonis* (H.B.K.) Shult, sedges such as *Cyperus difformis* (L) and *Fimbristylis littoralis*, Gaudich. and particularly the broad-leaved weeds *Eclipta alba* (L.), *E. prostrata* (L), *Ludwigia octovalvis* (Jacq) Raven, *Marsilea crenata, Monochoria vaginalis* (Bern) Presl. and *Sphenochloa zeylanica* Gaertn. All these are sensitive to pre-emergence herbicidal treatment of oxadiazon and are abundantly found in Philippine rice crops. Their control by the various formulations of this chemical results in the increases in rice yields reported above.

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Results of Field Trials Conducted in France with Associations of Isoproturon and Dinoterb for Control of Weeds in Cereals

J. ROGNON and M. MOUTERDE [1]

ABSTRACT

A total of 150 field trials with postemergence treatments conducted in France between 1972 and 1976 on winter wheat and winter barley have indicated the presence of synergistic and complementary activity of isoproturon[*N*-(isopropyl-4-phenyl)-*N'*,*N'*-dimethylurea] associated with dinoterb (dinitro-2,4-tertiobutyl-6-phenol). The treatments, carried out during the tillering stage, have proved selective to both wheat and barley, and have shown good efficacy against blackgrass (*Alopecurus myosuroïdes* Huds.), ryegrass (*Lolium* sp.), windgrass (*Apera spicaventi* (L.) Beauv.), wild oats (*Avena fatua* L. and *Avena ludoviciana* L.) in particular, as well as against broad leaf weeds. The presence of dinoterb has the effect of increasing the speed of action of isoproturon and, by improving its foliar penetration, gives better control of grasses. It also contributes by reducing the effect of adverse climatic conditions on the performance of isoproturon. Yield increases recorded have been between 11% and 101% in the case of blackgrass infestation, between 48% and 87%, and between 6%and 210% in the presence of ryegrass and wild oats respectively. Associations of isoproturon and dinoterb are presently used in several West European countries.

INTRODUCTION

The first publications on isoproturon were presented to the Academie des Sciences, Paris (France) and at the Symposium on Crop Protection, Gent (Belgium). The herbicide has been introduced commercially in France since 1974 for control of weeds in winter wheat and winter barley. It is effective mainly as a grasskiller and its efficacy against broad-leaf weeds infesting winter cereals in Europe is considered insufficient, e.g. catchweed bedstraw (*Galium aparine* L.), speedwell (*Veronica* sp.) and wild radish (*Raphanus raphanistrum* L.), hence the necessity to associate it with a completementary herbicide.

Choice was made for an association with dinoterb in view of its consistent performance with early applications, during conditions of low temperature. In fact the majority of isoproturon treatments are made before the end of winter, when weather conditions are not very favourable for the performance of herbicides of the phenoxy acids group.

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Field trials have indicated that dinoterb also facilitates penetration of isoproturon into the foliage of gramineae. As a result it speeds up the process of intoxication and the killing of sensitive species, and markedly improves the final results. Furthermore, a synergistic effect is clearly evident with the simultaneous application of the two herbicides.

MATERIALS AND METHODS

The first trials were conducted in 1972 using a wettable powder containing 50% w/w isoproturon, and adding, immediately before application, a liquid formulation containing 250 g/L dinoterb. In 1973, the experiments were carried out with a wettable powder containing 30% and 30% w/w of the two active ingredients. Subsequently treatments have been carried out with a flowable concentrate containing 230 g/L isoproturon + 210 g/L dinoterb, the latter as the diethanolamine salt (Tolkan V). Since 1975 a second flowable concentrate containing 210 g/L isoproturon + 190 g/L dinoterb in the form dimethylamine salt (Tolkan S), has been comparatively tested.

The reference products used were: metoxuron [*N*-(chloro-3-methoxy-4-phenyl)-*N'*,*N'*-dimethylurea], chlortoluron [*N*-(chloro-3-methyl-4-phenyl)-*N*,*N*-dimethylurea] and a mixture of chortoluron and mecoprop (2-[(4-chloro-o-tolyl)oxy] propionic acid). Most treatments were carried out during the early tillering stage, when weeds were still young.

Weed control trials. These trials, with only two replicates and a plot size of 30 m², are conducted to evaluate visually the effect of the products both on the weeds and on the crop. Seventy-one trials of this type have been carried out on winter soft wheat and 14 on winter barley. The range of dosages tested has been decided, in each situation, according to the type of grasses present. Control of wild oats for example necessitates higher dosages than blackgrass. The trials have been conducted in several cereal growing districts of France, under widely different climatic and physical soil conditions.

Yield trials under weedfree conditions. These trials, carried out according to the Fisher block design with six replicates and plot size of 100 m², included analysis of variance of the yield. Moreover, in order to determine precisely the effect of the herbicide on the yield, independently from the beneficial effect of weed control, the trials were conducted under normally occuring weedfree conditions. Dosages tested included at least: the rate

most likely to be commonly used and twice that dose. Also included were reference herbicide products. Thirty trials of this type have been carried out on winter wheat and four on winter barley.

Yield trials under weedy conditions. This type of trial, for which the same statistical design is adopted, is conducted under normally occuring weedy conditions. Each product is used at the most effective dosage for the weed species present and the given soil type. These experiments had the objective to measure the increase in yield due to the herbicidal efficacy of the products and their effect on the crop, under practical field conditions. Eighteen yield trials were conducted in 1975 and thirteen in 1976.

RESULTS AND DISCUSSION

Climatic conditions. Weather conditions during winter and early spring from 1972 to 1975, have differed substantially in the various regions; in general, however, the conditions have been quite favourable for the uptake of herbicides.

Very wet conditions in some cases have caused delays of treatments, which were thus carried out on weeds in advanced stages of growth. In other cases, prevailing dry conditions were the cause of reduced efficacy of all products. In 1976 drought conditions were recorded during the spring period in France. Germination of weeds took place gradually after each short period of rain. As a consequence, treatments with herbicides were made on weeds at different stages of growth, under conditions which made soil penetration of herbicides rather inefficient.

Efficacy against grasses. Results obtained during the five years under review are summarized on tables 1 to 5.

Control of blackgrass is satisfactory at 1050 g/ha isoproturon + 960 g/ha dinoterb, and very good at 1495 g/ha + 1365 g/ha. Efficacy appears to depend little on the stage of growth of the weed. However, reduced efficacy has been recorded with treatments made toward the end of the tillering stage; particularly in concomitance with dry weather conditions. On the other hand, control of blackgrass during the shooting and heading stages is complete. Among the other grasses, windgrass, annual bluegrass (*Poa annua* L.) and rough stalked meadow grass (*P. trivialis* L.) present the same degree of sensitivity as blackgrass.

Table 1. Weed control trials on winter wheat in 1972 (herbicidal effect on weeds and crops expressed in % untreated control).

ai g/ha	Lolium	Wheat
Isoproturon + dinoterb		
2000 + 1700	100	0
3000 + 1700	100	2.5
4000 + 1700	100	5

Average of two trials.

Compared to blackgrass, efficacy against ryegrass, (*Lolium multiflorum* Lam. and *L. rigidum* L.), is more dependent on the stage of growth of the weed. In fact, control is best with treatments effected during the seedling stage, while it decreases with the appearance of the second tiller. Good control is obtained with 1495 g/ha isoproturon + 1365 g/ha dinoterb before tillering. During tillering, the weed stage during which treatments are more common, in view of its rapid development, dosages between 1720 and 1840 g/ha isoproturon are necessary for good control.

Wild oats are the most difficult species to control. At the start of tillering the products are effective at rates between 1720 + 1575 g/ha and 1840 + 1680 g/ha, but 2100 g/ha isoproturon + 1915 g/ha dinoterb are necessary during the second tiller stage. Past this stage, control of wild oats is generally poor. In the case of dry weather conditions after the treatments, weed control obtained with mixtures of isoproturon and dinoterb is better than with the reference products, particularly if ryegrass and wild oats are present.

Efficacy against broadleaf weeds. Table 1 to 5 also summarize results of isoproturon + dinoterb mixtures for control of broadleaf weeds like ivyleaf speedwell (*Veronica hederaefolia* L.) and catchweed bedstraw.

In France these two weeds are frequently associated with infestation of blackgrass and wild oats. Moreover, they are resistant to several herbicides currently used commercially. For these reasons, a product with a broad spectrum of activity should control effectively: grasses, speedwell and catchweed bedstraw.

Table 2. Weed control trials on winter wheat and winter barley in 1973 (herbicidal effect on weeds and crops expressed in % of untreated control).

ai g/ha	*Alopecurus*	*Lolium*	*Avena*	*Veronica*	*Galium*	Wheat	Barley
Isoproturon + dinoterb							
1050 + 960	93			69	71	0	
1500 + 1370	97	77		81	77	0.3	0
1800 + 1645	100	90	85	74	83	0.3	0
2100 + 1915			93	85	96	0	
2400 + 2190	99			97	97	4.9	
3600 + 3302	100	98		98	100	13.1	5
4200 + 3835			98	97	100	11.1	
Metoxuron							
3200	93			49	78	2	2.5
4000	97	65	71	50		3.3	
6400	98			68	95	19.4	7.5
8000	100	86	85	70		10.6	
Chlortoluron							
2000	67	74	50	44	48	4.8	0.8
2400			53	35	50	0.6	
4000	82	98		49	78	12.3	3.3
4800			79	50	85	9.4	
Chlortoluron + mecoprop							
2000 + 2000	100	87		67	51	3	7.5
2400 + 2400	100	94		83	95	15	15
4000 + 4000			70	75		3.5	
4800 + 4800			92	78		14	

Average of 27 trials on wheat and 3 on barley.

Table 3. Weed control trials on winter wheat and winter barley in 1974 (herbicidal effect on weeds and crops expressed in % of untreated control).

ai g/ha	*Alopecurus*	*Lolium*	*Avena*	*Veronica*	*Galium*	Wheat	Barley
Isoproturon + dinoterb							
1265 + 1155	90	99		86		0	
1495 + 1365	93	97	72	94	86	0	0.8
1840 + 1680	96	98	84	96	89	0.8	0.9
2185 + 1995	100	100	89	100	94	1.6	
2990 + 2730	97	100	97	100	96	4.4	3.8
3680 + 3360	100	100	95	100	96	8.6	9.9
Metoxuron							
3200	81	77		29	69	0.3	5.5
4000	90	72	75	45	67	0.6	
6400	96	97	95	67	91	9.6	20.4
8000	96	89	91	65	93	13.8	
Chlortoluron							
2000	82	97		11	22	0.3	1.6
2500	100	99	65	22	15	0.3	
4000	96	99	85	49	48	7.9	5.4
5000	100	100	89	56	50	17.9	
Chlortoluron + mecoprop							
2000 + 2000	83	100		88	89	2.6	1
2400 + 2400	99	99	62	86	79	5.8	
4000 + 4000	95	100	85	93	97	19.1	12.7
4800 + 4800	100	100	88	97	97	25	

Averages of 20 trials on wheat and 6 trials on barley.

Table 4. Weed control trials on winter wheat in 1975 (herbicidal effect on weeds and crops expressed in % of untreated control).

ai g/ha	*Alopecurus*	*Lolium*	*Avena*	*Veronica*	*Galium*	Wheat
Isoproturon + dinoterb						
TOLKAN V						
1265 + 1155	91	97		92	40	0
1495 + 1365	97	100		94	50	0
1720 + 1575	99	98	90	95	70	0
1840 + 1680		97	93			0
2990 + 2730	100	100		98	92	4
3680 + 3360		100	99			2.5
TOLKAN S						
1470 + 1330	95	97		94	67	0
1840 + 1660		97	96	94	80	1
2940 + 2660	100	100		96	86	12
3675 + 3325		99	100	98	97	4
Metoxuron						
3200	97	97		37	70	0
4000		57	73			0
6400	99	97		67	100	10
8000		82	82			2
Chlortoluron						
2000	90	97		17	30	0
2500		91	83			0
4000	96	100		28	75	5
5000		95	96			3
Chlortoluron + mecoprop						
2000 + 2000	95			91	85	1
2400 + 2400		64	83			1
4000 + 4000	100			93	97	3.5
4800 + 4800		96	96			12

Averages of seven trials on wheat.

Table 5. Weed control trials on winter wheat and winter barley in 1976 (herbicidal effect on weeds and crops expressed in % of untreated control).

ai g/ha	*Alopecurus*	*Lolium*	*Avena*	*Veronica*	*Galium*	Wheat	Barley
Isoproturon + dinoterb							
TOLKAN V							
1035 + 945	81			91	92	0	
1495 + 1365	86			91	92	0	0
1720 + 1575	100	87	81	95	92	0.5	
1840 + 1680	100	93	85	95	92	0.5	0
2070 + 1890	100	96	90	96	92	3.3	0
2990 + 2730	94			96	97	1.4	
3450 + 3150	100	97	94	98	92	10	7
TOLKAN S							
1260 + 1140	90			91	50	0	0
1470 + 1330	95	88	82	94	88	0	0
1680 + 1520	100	90	86	94	92	0	
1890 + 1710	100	94	90	94	92	2	
2520 + 2280	96			95	92	0.6	
2940 + 2660	99	96	95	98	95	7.3	4
3360 + 3040		98	95	98	97	11.8	
Metoxuron							
3200	59			71	97	0	0.7
4000	99	57	72	84	92	0.5	0
6400	86			90	97	1.3	2.5
8000	100	65	89	95	95	13.5	10
Chlortoluron							
2000	59			30	15	0	0
2500	96	90	66	64	92	2.5	0
4000	80			30	15	0.5	0.7
5000	97	98	91	78	92	12.5	0
Chlortoluron + mecoprop							
2000 + 2000	60			80	98	0	0.7
2400 + 2400	97	80	54	87	92	0.6	0
4000 + 4000	84			93	97	2.5	1.9
4800 + 4800	99	92	74	94	97	5.3	2.5

Averages of 15 trials on wheat and 5 on barley.

Most broadleaf weeds are controlled at 1050 g/ha isoproturon + 960 g/ha dinoterb. However, 1495 g/ha + 1365 g/ha are required to control: corn spurry, (*Spergula arvensis* L.), prostrate knotweed, (*Polygonum aviculare* L.), speedwell, and catchweed bedstraw. Control of ivyleaf speedwell in an advanced stage of growth, just prior to flowering, is obtained at 1800 g/ha + 1465 g/ha. This dosage is also required to control catchweed bedstraw when weed size exceeds 15 cm, moreover its sensitivity is greatly reduced under dry and/or cold weather conditions. Wild violet (*Viola tricolor* L.) and ladysthumb (*Polygonum persicaria* L.) are controlled only during the seedling stage.

While isoproturon has also good residual activity, dinoterb, on the other hand, displays only postemergence effect.

Crop selectivity. The associations of isoproturon and dinoterb are well tolerated by winter soft wheat and winter barley. Temporary setbacks in growth have been recorded in case of treatments followed by heavy rainfall, recovery of the affected cereals, however, is normally very quick. Early treatments, during the first part of the tillering stage, are advocated, since the crop would have sufficient time to recover from any initial phytotoxicity. Limited scorching due to dinoterb may also be observed, this, however ,is of no consequence for the further development of the affected plants. Two factors could be the reason for prolonged phytotoxicity: advanced stage of growth of the crop, and highly calcareous soils.

Results of yield trials conducted under weedfree conditions are summarized in Table 6. They show good selectivity of isoproturon + dinoterb mixtures, which, even at double the dosage used for commercial applications, have no detrimental effect on the yield.

Only the results of 1976 trials indicate a significant yield reduction. This is the consequence of results obtained in one single experiment conducted under exceptionally severe conditions. In any case, complete selectivity is obtained with standard dosages. It should be noted that hard wheat varieties display a lesser degree of tolerance, and that isoproturon + dinoterb mixtures are not recommended on these varieties.

Yield trials under weedy conditions. Table 7 summarizes results obtained in the presence of each dominant grass species, and it consequently reflects the effect of nature and the severity of weed infestations on the yield. Yield increases measured vary between 11% and 101% in the case of heavy

Table 6. Yield trials on winter wheat under weedfree conditions (annual averages) (yields expressed in % of untreated control).

	1973		1974	1975	1976
	1st series	2nd series			
Isoproturon + dinoterb					
TOLKAN V					
1200 + 1095		105		113.4	
1720 + 1575					
1800 + 1645		104.8			
1840 + 1680			100.6		
2100 + 1915	101				
2400 + 2190		100.8			
2760 + 2520			98.9		
3150 + 2890	99.4			109	98.7
3480 + 3180					
3680 + 3360			97.3		
4200 + 3835	94.2				
TOLKAN S					101.1
1680 + 1520					100.4
2520 + 2280					94.3
3360 + 3040					
Metoxuron				114.6	
3200			99.9		104.9
4000	101.2			110.6	
6400					100.7
8000	93.5				
Number of trials	8	6	7	4	5
N. S. trials	3	3	5	0	4
C. V.	6.78	4.34	3.46	9.38	3.36
F calculated	2.29	2.08	2.38	1.26	4.42
F at 0.05	2.48	3.29	2.53	3.26	2.51
F at 0.01	3.58	5.42	3.70	5.41	3.67
L.S.D. at 0.05	N.S.	N.S.	N.S.	N.S.	2.06
Average yield of untreated control in kg/ha	5180	4650	5020	4090	4690

Table 7. Yield trials on winter wheat under natural weedy conditions (annual averages) (yields expressed in % of untreated control).

	1975		1976	
	Number of trials	Yield	Number of trials	Yield
Alopecurus	7	138.1	7	107.7
Lolium rigidum	2	169	1	159.2
Lolium multiforum	2	162.7	0	
Avena	6	141.7	5	158.3
All weeds	18	144.6	13	131.4
Average yield of untreated control in kg/ha	18	3210	13	2990

infestations of blackgrass and broadleaf weeds, between 48% and 87% in case of ryegrass, between 6.5% and 210% in case of wild oat infestations.

The technical and practical suitability of dinoterb associations with isoproturon has been confirmed. However, in order to obtain better results, dosages should be adjusted according to: the weed species present, their stage of growth, the severity of the infestation and the soil type.

The efficacy range of isoproturon is situated between 1500 and 2000 g/ha. Control of wild oats requires higher dosages than that of blackgrass. Dosages should be increased if soil clay content exceeds 30%, whereas they should be decreased in the case of light permeable soils, and highly calcareous soils. On the other hand, dosages of dinoterb depend on the presence and stage of development of speedwell and catchweed bedstraw. It is within these limits that the best ratio of the two compounds should be selected to deal effectively with most field situations.

All results obtained have shown a preference for early treatments. This will ensure consistency of performance and will obviate the risks of reduced selectivity. Crops, in fact, show a higher degree of tolerance during the first half of the tillering stage.

A remarkable property of isoproturon, which is not affected by the presence of dinoterb, is its selectivity for all winter soft wheat and winter barley varieties. Spring varieties, on the other hand, have proved less tolerant, consequently it is not recommended to use the higher dosages,

like those necessary for the control of wild oats. In France, furthermore, climatic conditions in spring are less favourable than in winter for good herbicidal effects. Comparative studies with the two formulations under test (TOLKAN V and TOLKAN S), have also indicated that, at the same rate of active ingredient, the latter is more effective. This formulation, which contains dinoterb in the form of the dimethylamine salt, presents very good physical properties, which would permit a more effective release of the active ingredient, with the result of on improved herbicidal effect. This mixture has just been introduced commercially in France.

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Chemical Weed Control in Wheat

P. A. SARKAR and A. K. GHOSH [1]

ABSTRACT

In dwarf wheat (*Triticum aestivum* L. 'Mukta'), maximum grain yield, 2567 and 2560 kg/ha, was obtained from bromofenoxim (3,5-dibromo-2-hydroxybenzaldehyde 2,4-dinitrophenyloxime) and U 46 KV-T-Fluid (1.5 kg/ha) treatments respectively. Bromofenoxim treatment gave highest ear head density (63/m row length) and high 1000 grain weight (43.2 g). U 46 KV-T-Fluid gave best weed control throughout the growing season of the crop. MSMA (Monosodium methanearsonate) showed highest crop phytotoxicity among the herbicide treatments. Yield performance of bifenox [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate] at 1.5 kg/ha (2367 kg/ha), methabenzthiazuron (1-benzthiazol-2-yl-1,3-dimethylurea) (2420 kg/ha) and propanil (3',4'-dichloropropionanilide) (2353 kg/ha) was comparable to hand weeding (2327 kg/ha) treatment.

INTRODUCTION

The present cultural strategy of wheat for higher production involves growing high-yielding dwarf varieties under high levels of fertilizer and irrigation. These conditions stimulate crop as well as weed growth. If the weeds are not controlled, the strategy fails and there is yield reduction from 6 to 35% (Mani *et al* 1968). Weeds compete with the crop for plant nutrients (Asana 1951, Verma and Bandopadhyay [2]), soil moisture (Kaul 1950) and light. The degree of competition between the crop plants and weeds depends on numerous causes such as nature and intensity of weed infestation, agronomic practices and method of weed control adopted (Mani *et al* 1968).

The common weed control method followed in wheat culture by the majority of farmers in our country is hand weeding. The method is difficult, laborious, time taking, costly (Mukhopadhyay 1965) and not effective. Many weeds escape during the operation, regenerate after a short period and reduce the crop yield.

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[1] Agronomy Department, Allahabad Agricultural Institute, Allahabad - 211007, India.

[2] Verma, R.D. and N. Bandopadhyay 1960. Control of weeds in wheat by chemical and cultural methods. M. Sc. thesis, IARI, New Delhi.

High-yielding varieties of wheat pose interesting and challenging problems in respect to chemical weed control. Therefore, chemical methods of weed control need to be assessed by use of selective herbicides.

The proposed study was undertaken with a view to determine the effectiveness of eight selective herbicides in controlling weeds in wheat.

MATERIALS AND METHODS

The field trial was conducted during winter season of 1975 - 1976 at Allahabad Agricultural Institute. The soil in the experimental field was Gangestic alluvium and sandy loam in nature with 50% sand, 33% silt and 17% clay. The land was given a pre-sowing irrigation; prepared well by ploughing, harrowing and levelling, and fertilized with 100 kg nitrogen, 30 kg phosphorus and 30 kg potash per hectare. Half the total quantity of nitrogen and the whole amount of phosphorus and potash was applied as a basal dose. The remaining amount of nitrogen was used as a top-dressing in two equal splits. The crop, cv Mukta, was sown by seed drill with a row spacing of 20 cm and a seed-rate of 100 kg/ha. The crop was given five irrigations.

The experiment was laid out in a randomised block design with three replications and fourteen weed control treatments. Each plot was 15 m^2 (5 by 3 m) in size. The treatments, in all, included twelve herbicide treatments, one handweeding and an unweeded control. The herbicides used were, bentazon [3-isopropyl-(1H)-benzo-2,1,3-thiadiazin-4-one 2,2-dioxide], U 46 KV-T-Fluid, bifenox, MSMA, 2,4-D sodium salt [(2,4-dichlorophenoxy) sodium acetat], propanil, bromofenoxim and methabenzthiazuron. The herbicides were applied by a knapsack sprayer with fan-type nozzel 20 days after sowing (DAS).

Weed flora assessment was done thrice, 20 (before herbicide application) 30 and 60 days after sowing. Quadrats of 0.1 m^2 was used for weed assessment.

The predominant weed species present in the experimental plots were *Chenopodium album*, *Spergula arvensis*, *Launia asplanifolia*, *Cynodon dactylon*, *Cyperus rotundus*, *Vicia* spp., *Anagallis arvensis*.

Phytotoxicity rating on crop plants was done seven days after herbicide application (27 DAS).

RESULTS AND DISCUSSION

Initial assessment of the weed flora, as dry weight of weeds (20 DAS), showed marked variation between treatments, ranging from 1.4 to 4.2 g/m^2. The herbicide application was made 20 DAS and the handweeding 21 DAS. Observation on dry weight of weeds 30 DAS showed a difference in weed control due to treatments. Lowest dry weight (2 g/m^2) was obtained from plots treated with U 46 KV-T-Fluid at 1.5 kg/ha and the highest (19 g/m^2) from unweeded control. Other treatments like U 46 KV-T-Fluid (0.5 kg/ha), MSMA (16 kg/ha) and bromofenoxim gave weed dry weight of 5.5, 6.5 and 6.5 g/m^2 respectively.

Observation taken 60 DAS showed weed dry weight of 1.5 g/m^2 from U 46 KV-T-Fluid (1.5 kg/ha), followed by 6.5 g/m^2 from both U 46 KV-T-Fluid (0.5 kg/ha) and MSMA (6 kg/ha), and 8 g/m^2 from bromofenoxim treatment. Unweeded control gave highest weed weight (51 g/m^2) during this observation (Table 1).

Table 1. Influence of weed control treatments on dry weight of weeds and grain yield.

Treatments	Application rate (kg/ha)	Dry weight of weeds (g/m^2) 20 DAS	30 DAS	60 DAS	Grain yield (kg/ha)
Bentazon	0.5	1.5	10.5	22.5	2170
Bentazon	1.5	1.4	13.0	23.0	2160
U 46 KV-T-Fluid	0.5	2.5	5.5	6.5	2290
U 46 KV-T-Fluid	1.5	3.5	2.0	1.5	2560
Bifenox	0.5	2.1	10.5	22.5	2220
Bifenox	1.5	2.9	14.5	17.0	2367
MSMA	3.0	3.5	12.0	32.0	1677
MSMA	6.0	2.0	6.5	6.5	1190
2,4-D Na salt	0.5	3.9	7.5	15.5	2287
Propanil	1.0	3.6	11.5	28.0	2353
Bromophenoxim	1.5	2.0	6.5	8.0	2567
Methabenzthiazuron	1.5	3.2	8.5	17.0	2420
Hand weeding	1 × 21 DAS*	3.3	11.0	27.0	2327
Unweeded control	—	4.2	19.0	51.0	2063

* DAS = Days after sowing.

MSMA at both 3 and 6 kg/ha showed higher phytotoxicity in wheat. Bifenox, 2,4-D Na salt and propanil were also phytotoxic to the crop plants (Table 2).

Table 2. Influence of weed control treatments on crop phytotoxicity, ear head density and 1000 grain weight.

Treatments	Aplication rate (kg/ha)	Earhead density per 1 m row length	1000 grain weight (g)	Phytotoxicity*** 27 DAS
Beniazon	0.5	49	38.3	0
Bentazon	1.5	52	40.7	0
U 46 KV-T-Fluid*	0.5	50	42.0	0
U 46 KV-T-Fluid	1.5	57	44.3	0
Bifenox	0.5	51	40.9	1
Bifenox	1.5	54	40.6	3
MSMA	3.0	53	36.3	3
MSMA	6.0	48	32.4	4
2,4-D Na salt	0.5	51	44.5	1
Propanil	1.0	47	41.1	2
Bromophenoxim	1.5	63	43.2	0
Methabenzthiazuron	1.5	57	42.6	0
Hand weeding	1 × 21 DAS**	52	39.9	0
Untreated control	—	52	38.6	0

* Commercial material
** DAS = Days after sowing
*** Scale is 0 to 10 where 0 is no toxicity and 10 is plant completely killed

Weed control treatments had a marked effect on ear head density which ranged from 47 to 63/m row length. Highest density of 63 ear heads/m row length was obtained in bromofenoxim treatment (Table 2).

The grain yield data showed the maximum production under bromofenoxim (2567 kg/ha) and U 46 KV-T-Fluid (2560 kg/ha) at the higher rate. Bromofenoxim treatment gave the highest ear head density (63/m row length), high 1000 grain weight (43.2 g) and good weed control during the growing season (dry weed weight of 6.5 g/m^2 30 DAS and 8 g/m^2 60 DAS) of the crop. U 46 KV-T-Fluid at the higher rate showed best weed control throughout the growing season (dry weed weight of 2 g/m^2 at 30 DAS and 1.5 g/m^2 at 60 DAS) of the crop. Both the treatments did

not show any phytotoxicity. Yield performance due to bifenox at 1.5 kg/ha (2367 kg/ha), methabenzthiazuron (2420 kg/ha) and propanil (2353 kg/ha) treatments was comparable to hand weeding (2327 kg/ha) treatment. Unweeded control gave a lower grain yield of 2063 kg/ha.

It is interesting to note that though MSMA at 6 kg/ha gave good weed control, the grain yield was lowest (1190 kg/ha) because of the highest phytotoxicity (Table 1 and 2).

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