



PROCEEDINGS 2

THE TENTH CONFERENCE OF
THE ASIAN-PACIFIC WEED SCIENCE SOCIETY

NOVEMBER 24-30 1985
CHIANGMAI, THAILAND

DEPARTMENT OF AGRICULTURE
THAI PESTICIDES ASSOCIATION



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THE ASIAN-PACIFIC WEED SCIENCE SOCIETY**

ASU Altazar

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ASIAN-PACIFIC WEED SCIENCE SOCIETY
CONFERENCE
1985**

**DEPARTMENT OF AGRICULTURE
THAI PESTICIDES ASSOCIATION**

ASIAN-PACIFIC WEED SCIENCE SOCIETY

1983 - 1985

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Foreword

It is now many months since the 10th Conference of the APWSS successfully ended. At that time, we thought the remaining papers that were not included in Proceedings 1 could be published in Proceedings 2 and sent out to participants by June 1986.

As it turned out, the matter at hand was not as simple as first thought. The number of papers to be included now total 58 much larger than expected. This is because many participants hand carried their papers for presentation but could not do so at the Conference due to a shortage of time. As a compensation we agree to publish them in Proceedings 2.

For those statistically minded, some figures are given below.

Total number of participants	530	persons
Local	238	persons
Foreign	292	persons
Papers presented (at the Conference)	117	papers
Papers published (excluding symposium)	110	papers

We regret that some papers were presented at the Conference but are not printed in Proceedings 2. This is because the full text did not arrived in time for publication in spite of our regrets for them. Their titles are printed in the contents but have no page number assigned to them.

Finally, I must express my thanks to all members of the Proceedings Committee who have devoted much of their time and effort in producing these publications. My special thanks to the staff of the National Weed Science Research Institute who cheerfully took on the publication work of the Proceedings, in addition to their daily chores. These publications would not be what they are without them.

Virach Chantrasmi
Chairman, Proceedings Committee.

OPENING REMARKS

Chaiya Poonsiriwong

The Governor of Chiangmai City, Thailand

Mr. President, distinguished delegates and guests, ladies and gentlemen:

This is the first time that Thailand has been selected as the host-country for a conference of the Asian and Pacific Weed Science Society and it is indeed a great honour for the city of Chiang Mai to have been selected as the host-city for the 10th Conference of the Society. On behalf of myself and the people of Chiang Mai I would like to extend a very warm of welcome to both the overseas and Thai participants of the Conference.

Chiang Mai is the second largest city in Thailand and although it is perhaps better known overseas for its beauty, culture and traditions, the province is a region of farmers and agricultural production. The province is more fortunate than other parts of Thailand in having areas of irrigation and a climate suitable for the production of a range of crops that cannot be produced elsewhere. However, the areas under agricultural production are not without their problems. A major problem is that related to weed infestation and competition.

Successful weed control management is not only of importance to the farmers of this province but also to farmers generally, and the cities and towns that are based on an agricultural economy like the majority of those in Thailand.

Conferences such as the one you are attending are important forums for the exchange of ideas and the presentation of technical developments. I have no doubt that there will be direct benefits to Thailand as a result of the 10th Asian and Pacific Weed Science Society Conference. I also hope that the conference will prove beneficial to the overseas participants.

In declaring this 10th Conference of the Asian and Pacific Weed Science Society open, I would also like to once again extend a warm welcome to Chiang Mai to both the overseas and Thai participants.

WELCOME ADDRESS

Tanongchit Wongsiri
President APWSS

Mr. Chairman, the Governor of Chiang Mai, distinguished delegates and guests, ladies and gentlemen;

Historically the Asian and Pacific Weed Science Society began as an Asian and Pacific Interchange at the East-West Center in Honolulu in 1967 under the general theme of 'Weed Control Basic to Agricultural Development'. Since that first gathering, meetings have been held successively every two years in different host-country venues including Philippines, Malaysia, New Zealand, Japan, Indonesia, Australia and India. Thailand in acting as the host for the first time agreed to host this, the 10th Conference of the Asian and Pacific Weed Science Society, in our beautiful city of Chiang Mai.

Because of Thailand's importance as both a food crop producer and food crop exporter, it has always been very conscious of the role that weeds can and do play in limiting food production. The weeds found today in Thailand are a combination of native species and introduced species, but many of the more significant weeds have been introduced with other agricultural objectives in mind. The troublesome weeds *Mimosa pigra* and water hyacinth were probably introduced to Southeast Asia from America by the early visits of Portuguese and Spanish traders. The weeds found in Thailand are also often common to the other countries of Southeast Asia and the Pacific.

The problem of weed infestation is not a problem only of agricultural lands but it is more widely recognised in this context because of its direct effect on food production. The significance of weed infestation in agricultural production varies with the type of crop, the type of weed, the type of soil, and many cultural aspects of production. Locally, it has been estimated that the effects of weed infestation and subsequent competition are responsible for a yield loss of between 20-30 percent annually in areas of rice production in Chiang Mai province. Almost 50,000 hectares of non-agricultural land in the four northern provinces of Chiang Rai, Chiang Mai, Lampoon and Lampang are currently infested by the troublesome weed *Mimosa pigra*; this weed is now rapidly spreading along both waterways and highways to the southern provinces of Thailand.

In formulating programmes of weed control management, the exchange of research findings and information is essential to prevent the repetition of research and accelerate the rate at which control programmes can be implemented. The 10th Asian and Pacific Weed Science Society Conference, like previous conferences of the Society, aims at providing such a forum of information exchange.

On behalf of the organising committee of this Conference I would like to call on the Chairman and Governor of Chiang Mai, Mr. Chaiya Poonsiriwong, to officially open the Conference.

KEYNOTE ADDRESS

Keith Moody

President IWSS

The Representative of the Governor of Chiangmai City, The President of the Asian-Pacific Weed Science Society, the Chairman of the Opening Session of the 10th Asian-Pacific Weed Science Society Conference, Distinguished Guests, Weed science colleagues, ladies and gentlemen.

I spent a long time deliberating as to what I should talk about today. I even checked with some of my friends and they suggested such things as "Give them some words of wisdom about weed science", "Discuss new technologies in weed control", "Talk about something related to the theme of the conference", and "Make it short".

Some of these ideas had appeal to me particularly the one about "making it short" so I will endeavour to follow this suggestion. However, when I was looking through the program I observed that some of the topics which were suggested would be covered during the conference in papers such as "Trends in future herbicide developments", "Weed control technology: needs, development and constraints", and "Systems analysis and simulation modelling" and I felt that there was no need for me to deal with these subjects as I am sure that they will be dealt with in a much better way than I could even hope to achieve.

As you all know, the first Asian-Pacific Weed Interchange was convened on 12 June 1967 at the University of Hawaii in Honolulu and terminated on the island of Kauai on 22 June. According to the summary of the program committee which was comprised of H.F. Clay, D.L. Plucknett, and R.R. Romanowski the interchange established the pressing need for weed science in the Asian-Pacific area and at the workshop meetings on Kauai, an organization, the "Asian-Pacific Weed Science Society" was formed to facilitate the interchange of current weed control information and to promote research in weed science.

Today, a little over 18 years later, is the start of the 10th biennial conference. Much has happened in weed science over the past 18 years. As examples, we have new herbicide chemistry, herbicide safeners, different methods of application of herbicides, herbicide resistance in weeds, greater concern about the effect of herbicides on the environment, the concern about herbicide safety to humans, bioherbicides, and genetic engineering. I am sure that we will learn more about these subjects and other important topics at this conference. However, there does not seem to have been much advancement in simple tools for weeding. We also have new weed science societies in the region, some of which are extremely active. Those of Thailand and Korea are examples.

There are more people in the region that have been trained in weed science and we have an increasing awareness of many people, even the decision makers, about the

importance of weeds and their control. In the past year, I have read reports that weeds are the major constraint to rice production in Latin America and Africa and that much more emphasis needs to be placed on weeds and their control throughout the world. Incidentally, these reports were not written by weed scientists.

Last year at the International Rice Research Institute, we held a 10-week rice weed control training course. We had only seven participants from six nations (five in the Asian-Pacific region) but 5 years ago when we tried to hold a similar course no one was interested. We have already had requests to repeat the course in 1986 and we have even had the suggestion that we should also develop a 2- or 3- week course.

What role has the Asian-Pacific Weed Science Society played during the time that it has been in existence and while these changes have been going on? Obviously by the fact that there are so many people here today from so many parts of the world, the Asian-Pacific Weed Science Society biennial meeting is an important forum for the exchange of weed science information and the society has, therefore, lived up to one of the reasons why it was formed. I think that all of you would agree that this biennial meeting ranks among the most important weed science conferences in the world.

But I wonder if we are doing all that we can. Has the information that has been generated and discussed at previous APWSS meetings been adequately disseminated? What about that which will be discussed at this meeting? Out of curiosity, how many of you in the audience today attended the 9th APWSS meeting in Manila? Can I have a show of hands please? Thank you. Out of the rest of the people in this room how many of you have seen copies of the three publications that were published as a result of the 9th conference and have read articles in those publications? Can we have a show of hands again please? Thank you.

I think that I have illustrated my point and answered my question. How do we ensure that the information that is published at this conference is made available to and read by more people? If the society had more funds then it could send copies free of charge or at greatly reduced prices to all its members who have paid their dues but who did not attend the meeting in question - a practice which is not done now. Or it could send copies to selected libraries throughout the region - a list of these libraries would have to be provided to the secretariat. However, that is still no guarantee that the publications would be read.

I remember once I asked a person involved with weed control research from a country in this region how many weed science books were in the library at his research institute. He said none. Out of curiosity, I went to the library and found about 2 dozen books pertaining to weed science, many of them gathering dust. They had probably not been opened from the day they were placed on the shelf. I hope that this was an isolated instance because I have no solutions as to how we can guarantee that a book will be read once it is in a library. But at least if it is there, I think, the chances are great that it will be read by interested people.

My earlier comments about the society reminds me of a saying that I heard when I was in Vietnam recently. When translated into English it is as follows: "Labor for transplanting is labor waste, labor for weeding is labor gain"! I wonder if the Asian-Pacific Weed Science Society and its members, of which I am one, have, if I may use

the analogy, been using their labor correctly and efficiently. I believe that we have been spending most of our labor on transplanting. We have done very little weeding.

Have we done enough to promote research in weed science in the region? What about our means of communication with each other and with the people that our research is ultimately aimed at the farmers. The newsletter, for example. Does it serve the purpose for which it was originally intended? I don't think so. How many of you have contributed to it since its inception. I believe it was Phil Motooka who, at the meeting in Manila, made the suggestion that it should no longer be published as very few people ever contributed to it. Should we take such a drastic step or should we take steps to improve it? Don't forget that one of the important means of communication for weed scientists throughout the world, the Infoletter published by the International Plant Protection Center, will not be published again in the format that many of us have become used to. Let us hope that this valuable publication is not lost forever.

What about training? If I remember correctly one of the recommendations of the first Asian-Pacific Conference was the need to train people from the South Pacific in weed science. However, I do not think that we should limit ourselves only to this area. What about the region as a whole? Have we lived up to our obligations? Do we have the capability to offer different levels of training to people of different educational backgrounds? Where can people go to obtain the training that they need? Are there in every country in the Asian-Pacific region sufficient people trained in weed science so that they can carry out meaningful research programs? I will let you provide your own answers.

What courses are offered in weed science at the undergraduate and postgraduate levels? What can we do to strengthen these, if needed? I was glad to note that there is a paper to be presented at this conference on "Education in weed science in the Pacific and Australian areas". Perhaps this will provide the answers.

I think that this society has an obligation to do more than it is doing today. I do not have concrete proposals as to what should be done. The above thoughts probably reflect the fact that I have lived 16 years in developing countries of the world and am, therefore, probably biased. However, I think that ideas can be generated as to what we can do as a society as we have discussions both during the scientific sessions and at social gatherings throughout this week. Once we have a set of proposals then it is necessary to work out a plan of action so that they come to fruition. Everyone in this room should be prepared to make a commitment to the society and to the advancement of weed science within the region. I realize that there may be difficulties because the members of this society come from many countries that span a large section of the globe and it is difficult to get together to plan things but surely there is some way that this problem can be overcome. I hope so.

Let us not waste the labor and talents of not only all of us who are gathered here today but also those of the many weed scientists in the region who for some reason or other could not be with us today. Let us put them to good use.

I would like to congratulate the members of the organizing committee for all the effort that they have expended in making this conference a reality. I look forward as

Permanent Logo Award

I am sure many of you do also, to seeing old friends, renewing acquaintances, and making new friendships.

I also look forward to hearing many of the interesting papers that are to be given during the coming week. My only regret is that the concurrent sessions prevent me from hearing as many papers as I would like to hear.

I hope that it is a most successful meeting.

Before I finish I want to leave you with one final thought. Let us make certain that we gain from the labor that we use not waste it. Let us all make the decision that we will all go out and weed in addition to transplanting so that in 2 years when we gather again in Taiwan we will have something in addition to the biennial meeting of the society to show for our efforts.

Thank you.

The APWSS, in spite of the many years of existence, do not have a permanent logo. Thus it was decided that one should be selected during the 10th Conference and designs were solicited for voting by attendees at this Conference.

CIBA - GEIGY generously donated the prize money of US.\$ 500 to make the winning design a worthwhile exercise.

As it turned out the highest number of votes 25.8% went to the design submitted by Dr. A.N. Rao of IRRI who was subsequently awarded the prize money. However two designs submitted were the existing APWSS "Globe" logo, with and without the wording around the globe. These received 12.4 % and 16.9% of the votes each, totalling 29.3% higher than the top single design. It was felt that the two are actually one and the same and the percentage should be added together.

This being the case, the existing "Globe" logo was adopted as the permanent one of the APWSS and should be used as on the cover of this proceedings 2

The Organizing Committee of the 10th Conference of the APWSS is most grateful to CIBA - GEIGY for donating the prize money, to the many contributors of designs as well as those who voted in the adoption of the permanent logo.

INTRODUCTION TO THAILAND'S AGRICULTURE

Y. Sarikaphuti

Department of Agriculture, Ministry of
Agriculture and Cooperatives, Bangkok, Thailand

Thailand is located on the Indochinese and Malayan Peninsula in the mid-portion of the Southeast Asian mainland between 6° and 20° north latitude and 97.5° and 105.5° east longitude. It is bound on the north and northeast by Laos, on the east by Kampuchea, on the west and the north by Burma and on the south by Malaysia. It extends down the Malay Peninsula between the Andaman Sea and the Gulf of Thailand.

The total area of Thailand is 51.3 million hectares which is generally divided into four regions : Northern, Northeastern, Central and Southern. Each region consists of a group of provinces (changwats). The core of the country is the central plain with flat fertile alluvial land watered by a network of canals and irrigation projects.

The Central Region includes the Chao Phraya River delta and the lower Central Plain. The Central Plain is a triangular shaped delta largely composed of lowland and swamps where water is impounded for rice cultivation for 4-5 months of the year. In the east and west of the Central Region, the terrain is varied with mountain ranges, rolling hills, and lowland, and most of the agricultural land is suitable only for upland crops. In these areas, a substantial proportion of the farm households grow no rice but rely entirely on cash crops such as maize, cassava, sugar and rubber. The Central Region accounts for about 20% of the nation's agricultural households.

The Northern Region includes the upper Central Plain. The Northern is the largest of the four regions in terms of area, but around two-thirds of the land is mountainous and unsuitable for agriculture. Major crops in the region are : rice in the valleys and flood plains during the rainy season ; upland rice, groundnuts, soybeans, mung beans, sesame and vegetables on the terraces. In the southern area of the region, maize and cotton are also grown. In the dry season, rice, soybeans, mung beans, groundnuts, sesame, tobacco and cool-season vegetables are grown in irrigated lands. About one quarter of the nation's agricultural households are in the Northern Region.

The Northeastern Region comprises almost one-third plateau sloping gradually to the north and east towards the Mekong River. Low soil fertility and poor moisture-holding capacity of the soils limit agricultural production during the period of low rainfall. The rainy season lasts from April to October, and average rainfall for the region as a whole is 1,280 mm. Rainfed rice is the major crop. Other crops include kenaf, cassava, maize, sorghum, sugarcane, bean, banana, pineapple and improved pasture.

The Southern Region extends from Chumphon province to the Malaysian border. The width of the peninsula is less than 20 km in some areas. The region is mountainous with narrow valleys cut by turbulent streams to the coast. Rubber is the main crop

but rice, coconut, and tropical fruits are also grown. Some 40% of the land area is unsuitable for agriculture with 30% and 70% of the remaining land area devoted to paddy and upland crops, mainly rubber, respectively.

The country is generally hot with high humidity. Temperature varies only slightly with the seasons. For most of the country, mean temperatures in January range from 22°C to 26°C and 28°C to 32°C in April. Mean monthly temperatures remain between 26°C and 30°C in Southern Thailand. Thailand has a tropical climate and most of the country has definite wet and dry seasons. Elevation range from sea level to about 2,600 m., but most of the area is less than 200 m. in elevation.

The weather conditions vary during the country's three seasons : the hot season, from March-May, when the temperature often approaches 38°C and the humidity remains high ; the wet season from June-October, when the temperature is rather low owing to the cloud cover, and the country gets most of its rain, making conditions quite sticky ; the cool season from November-February when it is hardly cool, but the temperature is at least more moderate. The northern mountains do become very cool at this time of the year, while on the Khorat Plateau of the northeast the day temperatures stay moderate, while the night becomes quite cool.

The greatest portion of the country receives from 1,000 to 1,500 mm. of annual rainfall. However, an area of the southeast and sections of peninsular Thailand receive more than 3,000 mm. per year.

In the far south this weather pattern is different, and the conditions alter according to the onset of the northeast and the southwest monsoons.

The characteristics of general soil groupings in Thailand are summarized in Table 1.

The total area of Thailand is 51.3 million ha (320,696,883 rai) which composed of forest land 15,660,000 ha. (97,875,000 rai), housing area 412,646 ha. (2,579,037 rai), paddy land 11,715,552 ha. (73,222,199 rai), field crop area 4,685,587 ha. (29,284,920 rai), fruit tree and tree crop 1,899,709 ha. (11,873,182 rai), vegetable and flower area 54,641 ha. (341,504 rai), grass land 122,610 ha. (766,312 rai) and other lands about 16,760,744 ha. (104,754,649 rai). The forest land decreased from 19,841,700 ha. (124,010,625 rai) in 1976 to 15,660,000 ha. (97,875,000 rai) in 1982. Over that time, the agricultural land (paddy land, field crop area, fruit tree and tree crop, vegetable and flower area, grass land) increased from 16,597,704 ha. (103,735,652 rai) in 1976 to 18,478,099 ha. (115,488,117 rai) in 1982 (Table 2).

The population of Thailand in 1985 is estimated at 51 million about 70 percent of the populations are farmers.

Agricultural products comprise about 70 percent of the total exports. The major export crops are rice, maize, cassava, and sugar, which are more than 60 percent of the total agricultural exports.

The agricultural production of economic crops of Thailand are shown in Table 3. Rice is the predominant economic crop in Thailand followed by maize, cassava, rubber, sugarcane, soybean, cotton, kenaf and mungbean. The planted area of rice, maize, cassava, rubber, sugarcane, soybean, cotton, kenaf, mungbean in 1983/84 were 62,033,000 rai (9,925,280 ha) ; 10,552,000 rai (1,688,320 ha) ; 8,779,000 rai

(1,404,640 *ha*) ; 10,143,000 *rai* (1,622,880 *ha*) ; 3,606,000 *rai* (576,960 *ha*) ; 990,000 *rai* (158,400 *ha*) ; 638,000 *rai* (102,080 *ha*) ; 1,261,000 *rai* (201,760 *ha*) ; and 3,069,000 *rai* (491,040 *ha*) ; respectively. While the yield per unit area of these crops were 302, 337, 2300, 67, 6000, 174, 187, 177 and 98 *kg./rai*, respectively. The planted area increased slightly between 1974/75 - 1983/84 which cause a crop production increase, except for kenaf and soybean. The yield per unit area considering the data during 1974/75 to 1983/84 indicate that : the yield of most crops is inconsistent and yield of some crops increased or decreased slightly. This is because of reduced soil fertility after the crops are planted for several years, soil erosion, wrong cultivations methods, the farmers' lack technical knowledge about soil and water management, cultural practices, land preparation, and high yielding varieties which could be transfered to the farmers.

The agricultural domestic consumption during 1974-1983 is shown in Table 4. The main economic crops consumed in the country were rice, cassava, coconut, maize, sugarcane with 12,544 ; 4,009 ; 1,093 ; 997, and 643 thousand metric tons respectively. The domestic agricultural consumption increase related to a population increase from 40.4 million to 50.9 million persons from 1974-1983.

The export of important agricultural products in 1980-1983, both quantity and value, are shown in Table 5. In 1983, the main agricultural exports were cassava, rice, maize, sugar and rubber products with 5,196 ; 3,534 ; 2,646, 1,526 and 552 thousands metric tons valued at 15,370 ; 20,100 ; 8,386 ; 6,325 and 11,739 million baht respectively.

The ratios below are of some crops for domestic consumption and export using 1983 figures from Tables 4 and 5, in 1,000 *tons*

Crop	Consumption : Export	Consumption : Export
Rice	12,544 : 3,534	1 : 0.3
Maize	997 : 2,646	1 : 2.6
Cassava	4,009 : 5,196	1 : 1.3
Sugarcane	643 : 1,526	1 : 2.4
Rubber	34 : 552	1 : 16

The tropical fruits in Thailand were of relatively minor economic importance in comparison to the enormous rice and field crops industry, it did contribute significant income and good living to many farmers and city homes. Nowadays, fruits become more and more important to the country as an export commodity.

Due to the difference of topography, fruit cultivation is characterized into two main types : ridge cultivation and arable land (or non ridge cultivation). The ridge cultivation is practiced mostly in the provinces situated near the 4 river mouths of the Central plain. Due to the high water table and poor drainage, all planting is done on ridges 4-5 meters wide, surrounded by polders for flood protection. Very intensive farming prevails in such cultivation. The life span of fruit trees on ridge cultivation type is relatively short in comparison to arable or non ridge cultivation. The non ridge cultivation, which is a common practice else where, constitutes the main fruit production of Thailand. An enormous quantity of fruits is produced yearly. Most of the production is consumed locally. Fresh and processed fruits have been exported in rather small quantity as compared to rice and field crops, which are the major export commodity of the country. However the volume and value of fruit exports keep increasing year

by year. (Table 6)

The current major importing countries of Thai fresh fruits are Malaysia, Singapore and Hong Kong, while for canned fruit, the importing countries are U.S.A., Canada and Europe. The export potential of fresh fruit is very promising. This potential can be exploited provided that correct orchard management, and proper post-harvest operations are carried out.

Forestry is also the main natural resource to control environmental balance. It is the habitat of our remaining wild animals, a recreation area and a raw material sources for industry. The forestry area is rapidly decreasing, from 175,224 *sq.km.* (17,522,400 *ha*) in 1978 to 156,600 *sq.km.* (15,660,000 *ha*) in 1982 (Table 2) because of the pressures of domestic consumption, agricultural areas and others. The government has realized the importance of forestry, and our forest management policy has been emphasized under the First five year plan as follows :-

1. Reforestation by the Royal Forestry Department.
2. Reforestation by the concession.
3. Reforestation by the private sector.

Forest plantations by government and private sectors in 1983 were 3572 *sq.km.* (357,200 *ha*) and 948 *sq.km.* (94,800 *ha*), respectively (Forestry Statistics of Thailand, 1983).

The population of Thailand increased from 45 million in 1978 to 51 million in 1985. It is expected that the population in the year 2000 will be about 76 million. The increased population will directly effect domestic wood consumption in terms of sawn lumber and wood products for house construction and furniture.

Domestic wood consumption is classified into 3 main categories as sawn lumber, wood pulp and fire - wood.

Imports and exports of forest products in 1983 were valued at 6,646,409,000 and 6,955,196,000 baht, respectively. Exports were reduced, which could be related to the population increase and the higher domestic consumption involved.

From the data of the office of Agricultural Economics, 1982, it is summarized that the proportion of the total workforce employed in the agricultural sector decreased from 68 percent in 1974 to 51 percent in 1983. Over the same period the non-agricultural workforce increased from 32 percent to 39 percent.

In the ten years from 1974, Thailand's Gross Domestic Product increased from 271,368 million B to 928,548 million B. The contribution of agriculture to G.D.P. has fallen steadily from 31.2 percent in 1974 to 21.8 percent in 1983.

In terms of productivity, defined as G.D.P. per worker, per year, the agricultural sector increased from 5,688 B in 1974 to 11,236 B in 1983. However, productivity in the non-agricultural sector increased from 26,352 baht to 66,525 baht over the same period. From these data it seems that the productivity of the non-agricultural sector is increasing much faster than in the agricultural sector.

Thailand now has the Fifth National Economic and Social Development Plan (1982-1986) which defines productivity improvement targets as follows :-

I. Policy directions

- (1) Restructure the agricultural production process by shifting from "extensive agriculture" to "intensive agriculture" i.e., placing a heavier emphasis on yield improvement.
- (2) Enable farmers to sell their products at fair prices. The government is to promote investment in basic marketing facilities in order to increase farmers' bargaining power.
- (3) Speed up the distribution of land ownership through land reform and the provision of land titles for agricultural purposes in order to create employment security for farmers and eradicate social inequality.
- (4) Provide monetary incentives to encourage government's financial institutions and commercial banks to extensively expand credit to farmers and agricultural institutions, including reduction in quality disparity of agricultural credit facilities given by various institutions.
- (5) Promote the merger of various rural organizations. Cooperatives, farmers groupings and various professional groupings are to merge into one organization in order to give mutual assistance in improving production, marketing, improvement of rural income, knowledge enhancement, training, and business management.

II. Development measures.

2.1 Improvement of natural resources utilization efficiency.

a. Water resource.

The water resources improvement and development eg. existing irrigated areas, river basins, dispersion of small scale water resources to non-irrigated areas are emphasized for the speed up for development. Explore and develop a scheme to draw water from the Mekhong river into Chao Phya river plain and the Northeast for long term irrigation purposes. Collect water charges in irrigated areas in order to create water utilization efficiency and introduce cost recovery principle for further expansion in these areas.

b. Land and forest.

- (1) Speed up land use surveys for the formulation of a land use policy in order to prohibit the expansion of urban areas into those agricultural areas where the government has already invested in irrigation systems or areas which have high soil fertility capable of producing high output, and to promote the appropriate cropping pattern.
- (2) Speed up land reform by emphasizing the eradication of land tenure problems in the Central and Lower Northern regions which have severe problems of landless and tenant farmers.
- (3) Survey forest land to separate out deteriorated forest areas suitable for agriculture in order to allocate this land for farmers in the form of forestry villages. Those deteriorated forest areas which are not suitable for agriculture will be reforested.
- (4) Revise and strictly enforce the Farm Rent Control Act in order to create justice for tenants and landlords.

(5) Prohibit self help land settlements in opening up new scheme, but improve the existing land settlements according to plans, and transfer the responsibility to the provinces.

(6) Improve land with low soil fertility and productivity, namely acid sulphate soil in the Central region, saline soil in the Northeast, soil erosion in the North, and deteriorated mining areas in the South.

(7) Amend the Ministry of Agriculture's laws and regulations to enable the government to preserve high fertility agricultural land or areas where the government has invested significant financial resources as future agricultural land.

(8) Implement reforestation of 300,000 rai per year by emphasizing private sector participation. The government will supervise the work according to correct technological methods in deteriorated forest areas, including the improvement and reforestation of swamps which have potential for coastal marine fishing.

(9) Promote the growing of fast growing trees to be used as fire wood and prevention of land erosion in the Northeast and North.

(10) Improve and decentralize the government's forestry manpower allocation structure in order to achieve better control and prevention of forest destruction.

c. Research and extension.

Productivity increase through water resources development and efficiency improvement of the utilization of land, water and forest, has a limited scope. It is essential to simultaneously develop in other supplementary factors of production, particularly the research and extension. Thus, it is necessary to speed up research and extension using modern technology with the following measures :-

(1) Speed up the formulation of the national agricultural research plan to be used in the coordination of research projects of various institutions both domestic and foreign, the priority ranking of research work, and in the management of research work to provide consistency with major issues which are consistent in each locality. Emphasis should be placed on yield improvement in rainfed areas by concentrating on major crops ; for example, paddy capable of with standing drought and saline soil ; high yield cash crops ; and perennial crops (by speeding up the production of high quality shoots or branches). This should be consistent with the variety of crops which will promote further agricultural diversification.

(2) Improve the agricultural extension system by constantly dispersing officials to small farms in order to train farmers about seed-water-fertilizer technology and pesticides, build up a group of modern farmers, and construct small experimental plots.

(3) Promote crop rotation systems like castor beans, beans, cotton, sesame and wheat in irrigated areas in the Central and Northern regions in order to increase land utilization efficiency. And promote the cultivation of those which use minimum water, such as beans, oil plants, cotton and perennial crops simultaneously with livestock rearing and inland fishery in the Northeast.

(4) Speed up the substitution of low yield paddy seeds, rubber trees, and fruit trees by high quality varieties.

(5) Promote inland fishery in natural water resources or reservoirs.

(6) Provide fertilizers for farmers more extensively and a larger quantity to reach a target of 30 percent of total demand for each year. Emphasis will be placed on rice farmers in rainfed areas and the quality of fertilizer will be strictly controlled.

(7) Encourage farmers to produce organic fertilizers.

(8) Produce and sell 5,000 tons of paddy seeds, 4,000 tons of various bean seeds per year, and encourage 4,000 farmers to produce high-yield paddy seeds.

d. Credit

In order to encourage the majority of farmers to use new technologies, including fertilizer and seed, improve production, and make more efficient use of land and water resources, it is necessary to provide credit extension with the Bank of Thailand who is to formulate policies and directions for the allocation of agricultural credit by coordination with appropriate agencies and institutions.

2.2 Agricultural diversification

a. Economic crops.

Promote the diversification of economic crops to minimize farmers' risks from fluctuating prices, and increase returns from land utilization by taking into consideration the potential of each area and market trend. Major economic crops consist of rice, rubber, cassava, maize, fruits, sugar-cane, vegetables, tobacco, groundnuts, and soybeans. The following measures will be implemented :-

(1) Expand double cropping of paddy in irrigated areas by promoting the use of fertilizers and the deep water broadcasting method. The government will improve the production of "rainfed" paddy by exchanging seeds and promoting the use of the new early variety, and by training farmers to use an appropriate amount of fertilizer.

(2) The government will promote the cultivation of other crops, such as temperate climate fruits, tea, coffee, wheat in the North ; coffee, cocoa, coconut and oil palm in the South ; kenaf, perennial crops, lac and silkworm in the Northeast, etc. To achieve this, it is necessary to speed up the production and distribution of high quality seeds to farmers, and teach them to control pests, as well as to formulate consistent programmes and operational plans for both production and marketing.

(3) Formulate and demarcate agricultural economic zones for crops and livestock by taking into consideration soil quality, market trends, farmer's capability and farmer's income.

(4) Introduce the technique of high level tapping and the use of latex stimulants for rubber plantations in the South and speed up the rubber replanting scheme.

(5) Speed up the substitution of cassava by rubber in the Eastern region in order to reduce cassava production down to the demand level.

2.3 Marketing and pricing policy

a. Overall measures.

(1) Formulate annual operational plans for specified commodities with production

and marketing targets and clear direction and measures.

(2) Review government intervention policies at the export and domestic marketing levels.

b. Wholesale and retail trade.

(1) Study and formulate plans to extensively provide basic marketing infrastructural facilities, such as rural roads, godwons, warehouses, silos, and communication systems, for remote areas.

(2) Improve and extend agricultural marketing and pricing information especially for remote areas in order to allow farmers to have equal understandings and opportunities as middlemen and promote a fair competition among them.

(4) Promote the private sector's role in providing weight and measure services with the government's supervision and guarantee.

c. Farm level trade

(1) Encourage farmers to form cooperatives.

(2) There must be a clear operational plan and the government should use market mechanism, in particular, the promotion of the private sector's purchasing power.

(3) Study the contract trading system in order to formulate guidelines and measures to create fair contracts between cooperatives and factories.

(4) Encourage both government financial institutions and commercial banks to provide extensive credit to farmers in order to improve production efficiency.

2.4 Improvement of farmers' institutions.

(1) Merge various farmers' institutions into agricultural cooperatives responsible for assisting members in all business matters.

(2) Improve the administrative mechanism of various government departments connected with farmers' institutions to encourage the merging of farmers' groups into agricultural cooperatives.

2.5 Agricultural credit

(1) Formulate agricultural credit plans for both the short and long-term in order to make credit extension consistent with agriculture and rural development in each locality.

(2) Increase BAAC's capital during the Fifth Plan period according to the BAAC Act.

(3) Increase the BAAC's capital and have commercial banks extend agricultural credit consistent with the importance of the agriculture sector.

2.6 Role of the private sector.

a. Provision of productive inputs.

(1) Encourage the private sector to play a greater role in the production of high yield seeds,

(2) To set up a chemical fertilizer plant,

(3) To produce marl,

(4) Encourage commercial banks and private financial institutions to extend more credit to small farmers.

(5) Encourage commercial banks to extend credit in areas which have high development potential.

b. Investment and joint management in the production process.

(1) Encourage the private sector to ; invest in land consolidation in irrigated areas with ditches and dikes ; provide productive inputs ; and manage the sale of outputs

(2) Encourage the private sector to undertake concessional arrangements in the management of water allocation, maintenance of the irrigation system and the collection of water charges in specified irrigated areas.

(3) Encourage and provide incentives to the private sector to set up agro industries near production locations in order to reduce marketing and pricing problems of major crops, such as maize and fruites.

2.7 Conservation of natural resources and the environment.

a. Soil

(1) Restore soil quality in areas previously used for mining activity in the South which caused environmental deterioration.

(2) Prevent soil erosion in highland areas by introducing soil conservation techniques to farmers.

(3) Formulate measures to prevent the expansion of urban areas on good agricultural land or areas in which the government has already invested funds or effort in developing an irrigation system.

b. Water resources.

(1) Study and formulate remedial measures for the environmental effect caused by the construction of dams or large reservoirs.

(2) Systematically formulate a water allocation plan for main river basins such as Chao Phya and MaeKlong river basins.

(3) Conserve and preserve the quality of water resources in order to avoid pollution which will cause damages to agricultural production and endanger marine life.

c. Forestry

(1) Conserve and seriously restore 40 million rai of watershed areas in the North and Northeast by planting fast growing trees.

(2) Conserve the 15 million rai of the 17 existing national parks.

(3) Expand the 21 existing wildlife conservation areas from 11.5 million rai to 12.8 million rai.

Future trends in agricultural development

The government plays a major role in agricultural development. The important role plays in agriculture is in the main infrastructure development e.g. communication systems, irrigation systems, new crop production research and agricultural extension. Most of the research projects will be involved with new crop varieties and varietal improvement, integrated pest control management, soil and water management and fertilizer use. Cost of production studies will concentrate more on the use of minimum inputs to gain high output for the benefit of farmers' income.

Although production technology developed through research is relatively complete for most economic crops, farmers, are far more interested in better and high yielding varieties. Costly inputs such as fertilizers and pesticides are adopted only for high value crops such as fruits and vegetables, sugarcane, tobacco, rubber, etc. Operations such as improved cultural practices are adopted only when market prices are high. Adoption of new production technology by farmers in Thailand, (like farmers elsewhere) depends largely on economic incentives rather than on yield incentives alone. The level of basic knowledge and the economic status of farmers are major constraints to the acceptance of technology and its application.

Future trends in agricultural development will emphasize agricultural production related to market demands, increase in farmers' agricultural income per farm household, increase in the value and growth rate of products and also increased crop diversification. New technologies and research efforts are required to serve the market's demand.

The backward rural areas, rainfed areas and irrigated areas are agricultural development regions which the government will emphasize as the area developments in the National Economic and Social Development Plan.

Each region needs suitable crop varieties and the adoption of new technologies for high production with minimum input.

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THAILAND STRATEGY FOR FERTILIZER DEVELOPMENT. OCTOBER 1979.

Table 1. Characteristics of General Soil Grouping in Thailand

Mapping Unit Groups	Great Soil Groups	Drainage	Texture	Fertility Status	Common Groups	Region
II	Alluvial	Poor	Fine	Moderate to High	Rice Irrigated Upland	Central, Northeastern eastern side of region
IV	Low-Humic Gley	Poor to Good	Medium	Low to Moderate	Rice Irrigated Upland	Central and Northeastern Region
V	Grumusols Rendzinas Brown Forest Noncalic Brown Red Brown	Good	Medium to Fine	High	Maize, cotton, Sugarcane, Soybean	Central Region
VI	Gray Podzolic	Excessive	Medium to coarse	Low	Cassava, Kenaf, Cotton, Sugarcane, Rubber	Widely spread through four regions
VII h four	Red-Yellow Podzolic	Good	Medium to Fine	Low	Cassava, Kenaf,	Scattered Sugarcane, Rubber regions
VIII	Reddish-Brown Latenitic Reddish-Brown Latosol Red-Yellow Latosol	Good	Medium to Fine	Low	Maize, Cotton, Soybean, Sugarcane, Pineapple, Cassava, Kenaf, Rubber	South to north of the western Part and Northeastern Region

Source : Thailand Strategy for Fertilizer Development, October 1979.

Table 2. Land holding for agriculture 1976-1982

Table 2. Land holding for agriculture 1976-1982										Unit : rai
Year	Farm holding land									Vegetable & flower area
	Total land	Forest land	Total	Farm Size	Number of Farm	Housing area	Paddy land	Field crop area	Fruit tree & tree crop	
1976	320,696,883	124,010,625	113,112,010	27.02	4,186,709	2,719,082	71,316,930	21,361,170	10,289,662	357,267
1977	320,696,883	116,574,025	113,796,436	26.38	4,313,291	2,691,846	71,497,303	23,324,732	10,074,959	333,068
1978	320,696,883	109,515,000	116,441,234	26.60	4,377,613	2,610,022	73,270,474	23,759,115	10,424,655	347,755
1979	320,696,883	106,392,982	117,602	875	26.69	4,405	919	25,257,139	11,043,778	313,931
1980	320,696,883	103,418,735	118,998,940	26.64	4,467,547	2,520,845	73,562,985	25,757,758	11,142,386	314,476
1981	320,696,883	100,582,425	121,293,839	26.76	4,532,351	2,490,538	73,523,312	27,384,932	11,411,612	300,045
1982*	320,696,883	97,875,000	123,586,793	26.38	4,685,455	2,579,037	73,222,199	29,284,920	11,873,182	341,504

Grass land	Idle land	Others land	Unclassified ^{2/}
410,623	4,101,990	2,555,290	83,574,248
323,978	3,102,332	2,448,218	90,326,422
349,027	2,948,179	2,732,007	94,740,649
517,363	3,023,325	2,096,896	96,701,026
523,014	3,064,494	2,112,982	98,279,208
761,284	3,372,258	2,049,858	98,820,619
766,312	3,881,080	1,638,479	99,235,090

Source : Center for Agriculture Statistics, Office of Agricultural Economics, 1984

Remarks : 1/ Forest land from LANDSAT-2, Forest Management Division, Royal Forest Department
2/ Unclassified is the land area of urban, rivers, highway, railroads, airport, shifting cultivation, old clearing and etc.

* Primary data

Table 3 Production transition of rice and important crops (planted area and production by items) in 1974/75 - 1983/84

Crop Year	Rice			Maize			Cassava			Rubber			Sugarcane		
	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield tons/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield tons/rai	Production 1,000 tons
1974/75	49,889	268	13,386	7,749	323	2,500	3,078	2.2	6,763	8,786	61.1	382.1	1,935	7.5	14,592
1975/76	55,602	275	15,300	8,200	349	2,863	4,327	2.4	10,230	8,786	56.2	348.7	2,444	8.1	9,910
1976/77	53,595	282	15,060	8,029	333	2,675	5,293	2.6	11,840	9,126	57.4	393.0	3,119	8.4	26,094
1977/78	56,444	247	13,921	7,534	223	1,677	7,282	2.2	16,358	9,275	63.0	431.0	3,541	5.3	18,941
1978/79	62,667	279	17,470	8,661	322	2,791	5,286	2.1	11,101	9,426	69.0	467.0	3,190	6.4	20,561
1979/80	58,971	267	15,757	9,529	300	2,863	7,250	2.3	16,540	9,576**	60.3	534.3	2,730	4.7	12,827
1980/81	60,110	289	17,368	8,960	335	2,998	7,940	2.2	17,744	9,615**	60.0**	465.2**	2,927	6.8	19,854
1981/82	59,970	296	17,775	9,769	352	3,449	7,726	2.3	17,788	9,867**	64.0**	507.7**	3,857	7.8	30,200
1982/83	60,134	281	16,078	10,494	286	3,002	8,551	2.2	18,988	10,001**	65.0**	576.0**	3,645	6.7	24,407
1983/84	62,033	302	18,730	10,552	337	3,552	8,779	2.3	19,985	10,143**	67.0**	593.9**	3,606	6.0	21,568

Remarks : *Primary data
**Estimated

Table 3 Cont. Production Transition of rice and important crops (planted area and production by items) in 1974/75 - 1983/84

Crop Year	Soy bean			Cotton			Kenaf			Mung Bean			Total		
	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield Kg/rai	Production 1,000 tons	Planted Area 1,000 rai	Yield tons/rai	Production 1,000 tons
1974/75	823	134	110.4	323	175	56.4	5,524	152	384.1	1,293	143	187.9	79,400	38,361.9	
1975/76	738	154	113.9	188	153	28.7	2,039	151	307.6	1,022	118	120.6	83,346	39,225.5	
1976/77	635	179	113.6	154	175	26.8	1,023	182	185.9	1,392	90	124.8	82,365	56,513.1	
1977/78	958	94	96.3	528	172	90.7	1,603	153	245.8	2,720	76	206.9	89,885	51,967.7	
1978/79	1,010	150	158.9	429	174	74.4	2,003	169	337.8	2,638	98	259.0	95,128	53,220.1	
1979/80	679	150	102.1	750	190	142.7	1,418	156	221.8	2,652	94	250.7	93,555	49,238.6	
1980/81	788	113	100.0	949	203	192.6	1,068	198	211.3	2,796	93	261.0	95,153	59,194.1	
1981/82	797	165	131.5	967	206	176.0	1,166	166	194.0	3,040	94	283.7	97,186	70,504.9	
1982/83	778	146	113.4	715	171	122.0	1,357	147	200.0	3,034	93	281.3	98,709	64,567.7	
1983/84	990	174	172.1	638	187	119.2	1,261	177	222.4	3,069	98	299.7	101,071	65,242.3	

Source : Ministry of Agriculture and CO-operatives
Agricultural Statistics of Thailand

Table 4 Agricultural domestic consumption, 1974-1983

Unit : 1,000 tons

Crop	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	Growth rate %
Rice	11,521	12,036	12,491	12,302	12,072	12,994	12,500	12,655	12,679	12,544	0.80
Maize	341	450	538	562	706	776	854	940	968	997	12.31
Sugar cane 1/	382	400	509	513	594	597	588	523	610	643	5.09
Cassava	334	873	503	1,594	217	978	3,066	1,444	500	4,009	17.93
Rubber	14	15	19	23	26	29	28	30	31	34	10.22
Mung bean	119	105	33	17	46	82	78	100	85	91	0.09
Soy bean	97	88	107	106	99	149	114	98	178	150	5.63
Kenaf 2/	149	143	135	158	147	200	211	209	206	191	4.96
Cotton	69	94	90	98	96	113	112	130	91	130	4.89
Coconut	650	840	909	935	875	986	810	936	1,130	1,093	4.07

Source : Division of Agricultural Economic Research, Office of Agricultural Economics

Remarks : 1/ Consumption and stock

2/ Conversion rate = 1 gunny bag = 1.134 kgs

3/ Excluded the native variety

Table 5 Export of important agricultural products in 1980 - 1983

Quantity : 1,000 tons
Value : million baht

Crop	1980		1981		1982		1983	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Rice	2,799.7	19,507.6	3,031.8	26,366.4	3,784.1	22,509.6	3,534.3	20,100.0
Rubber Products	453.6	12,323.3	473.1	10,831.8	433.6	7,576.0	552.4	11,739.0
Maize	2,175.3	7,200.8	2,547.4	8,235.8	2,801.2	8,230.8	2,646.4	8,386.0
Sugar	452.9	2,993.2	1,119.6	9,588.5	2,207.5	12,955.6	1,525.9	6,325.2
Cassava Products	5,216.7	14,880.7	6,263.2	16,432.1	7,812.7	19,734.1	5,195.7	15,369.6
Kenaf and Jute	20.8	127.4	6.2	30.0	7.6	36.3	6.7	27.9
Mung bean	65.8	612.0	109.5	1,135.1	130.6	1,314.9	84.6	869.9
Soy bean	3.4	27.9	2.5	22.6	1.3	11.4	1.0	9.3

Source : Office of Agricultural Economics, 1984

Table 6 Fresh and Processed Fruit Exported

	1978		1979		1980		1981		1982	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Fruits										
Durian	2,478	23.4	3,096	31.2	3,514	37.5	4,361	83.4	2,347	58.4
Banana	19,170	30.1	19,201	31.9	12,679	28.9	12,680	33.9	18,338	51.1
Mango	3,171	13.8	3,266	19.3	3,087	18.7	3,061	21.1	4,118	32.5
Pummeio	2,130	12.7	1,996	13.7	2,229	18.4	1,966	16.6	2,763	27
Grape	1,911	20.1	2,089	23.9	1,561	18	1,172	24.4	1,989	37.7
Papaya	4,510	10.6	6,038	15.4	4,735	14.3	-	-	12,428	68.5
Tangerine	4,495	16.3	1,431	8.3	1,506	11.9	948	7.6	4,367	38
Anona	1,120	6	785	4.5	726	5.5	-	-	1,705	12.6
Orange	75	0.5	58	0.4	276	2.6	-	-	-	-
Rambutan	304	1.8	233	1.8	105	1.1	412	3.7	523	3.9
Longan	-	-	3,285	55.7	3,684	92.2	5,517	154.3	10,315	296.5
Pineapple	93	0.4	6	0.06	36	0.2	-	-	-	-
Total of fresh fruit	39,457	135.7	41,481	206.16	34,138	249.3	30,117	345	58,893	626.2
Pineapple (canned)	-	-	129,721	1,384.5	148,247	1,678.1	172,650	2,198.5	155,639	2,083.9
Total	-	-	171,202	1,590.66	182,385	1,936.4	202,767	2,543.5	214,532	2,710.1

Source : Ministry of Agriculture and Co-operatives
 Agricultural Statistics of Thailand
 1 ha = 6.25 rai
 1 ton = 1,000 kg.

PARASITIC WEEDS OF SOUTHEAST ASIA^{1/}

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Musselman (1982) in his review of parasitic weeds of arable land distinguished three general groups of parasites based on

- (1) degree of dependence upon the host, facultative or obligate;
- (2) portion of the host plant that is attacked, stem or root; and
- (3) the presence or absence of chlorophyll, semi- or holoparasitic.

These fascinating or often damaging parasites are represented in Southeast Asia by some species of the families Cuscutaceae, Cassythaceae, Lorantheae, Balanophoraceae, Orobanchaceae, Scrophulariaceae, and Rafflesiaceae. The first three are stem parasites, others are root parasites.

The known extent of parasitism in these families including their hosts and distribution are presented in Table 1.

Many representatives of the Lorantheae can decrease the quality of timber (Pika, 1972), fruit production and growth of ornamental plants (Koernicke, 1910). Van Steenis (1972) reported the occurrence of several species of the Lorantheae on *Altingia excelsa* Noronha, a timber producing species. Koernicke (*op. cit.*) mentioned the occurrence of some species of the Lorantheae on industrial crops such as *Theobroma cacao* L. and *Myristica fragrans* Houtt.; on fruit trees like *Diospyros kaki* Thunb., *Citrus* species, *Mangifera indica* L. and other economic plants like *Tectona grandis*

L.f. and *Codiaeum variegatum* (L.) Bl.

The family Orobanchaceae is represented by the genera *Aeginetia* and *Christisonia* while Scrophulariaceae by the genus *Striga* in Southeast Asia. In a resume of 11 years of study on *Aeginetia* in the Philippines, Espino (1947) reported as much as 60 percent loss of sucrose in sugarcane under severe condition. Ling (1955) reported a considerable loss in yield of sugarcane in Taiwan when parasitized by *Aeginetia*.

Christisonia is represented in Thailand, Malay Archipelago, and the Philippines with one species each. This is parasitic on sugarcane and is believed to reduce the yield greatly, but no comprehensive studies have been made as yet.

Striga lutea Lour. (= *S. asiatica* (L.) O.K.) is the most widespread in the world and is the cause of the greatest economic loss in agriculture. Other species of *Striga* may be devastating on a local level but none compare with *S. lutea* as problem for

^{1/}The area is here defined to include the following countries: Indonesia, Thailand, South Vietnam, Khmer Republic, Laos, Malaysia, Singapore, and the Philippines.

and corn (in SEA), oats, teosinte, wheat, rye, sorghum, millets, and sugarcane in other parts of the world. Although nothing has been reported on the actual reduction in yield in Southeast Asia, in the United States an infestation in corn reduced yields by 20, 60, and 100 percent, in the 1st, 2nd, and 3rd years, respectively (Holm, *et al.* 1977). In southern India upland rice culture has been stopped because of 80 to 90 percent crop loss from *Striga*.

Members of the Balanophoraceae and Rafflesiaceae are confined mostly in forest trees, the former on *Ficus* spp. while the latter on vitaceous species.

The remaining parasitic flowering plants are placed in two genera (*Cuscuta* and *Cassytha*) of otherwise autotrophic families - Cuscutaceae and Cassythaceae respectively. While *Cuscuta* spp. are reported to seriously reduce yields, value of hay and seeds in Lucerne in Australia. Their effects on agricultural crops in Southeast Asia have not been reported. *Cuscuta* is rather similar in habit to *Cassytha*, but is easily distinguishable by its 3-merous flowers and globular berries.

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Table 1. Host and distribution of some parasitic weeds in Southeast Asia.

Family/Species	Host	Distribution
I. Balanophoraceae		
1. <i>Balanophora abbreviata</i> Bl.	<i>Ficus</i> spp.	Africa (Congo), Comores, Madagascar, S.W. China, Hainan, Indian and Indo-Chinese subcontinents, Andamans, Malaysia and the Pacific (Tahiti, Marquesas).
2. <i>B. fungosa</i> J.R. & G. Forst.	Bamboo rhizomes and various tree roots.	Upper Burma, Ryu Kyu Is., Micronesia (Marianas), Thailand, Malaysia: Philippines (Luzon, Palawan), E. Java, Celebes, E. New Guinea; Solomon Is., N. Queensland (Cape York, Peninsula), New Caledonia, New Hebrides, Fiji.
II. Cuscutaceae		
3. <i>Cuscuta australis</i> R. Br.	Many herbaceous species such as <i>Polygonum</i> , <i>Artemisia</i> , <i>Genista</i> , <i>Glycine</i> , <i>Lespedeza</i> , <i>Pelargonium</i> , <i>Piper</i> , <i>Xanthium</i> , <i>Codiaeum</i> , <i>Croton</i> , <i>Hygrophilla</i> , <i>Nothopanax</i> , <i>Ocimum</i> , <i>Pluchea</i> , <i>Polyscias</i> , <i>Tecoma</i> , <i>Polygonum</i> , etc.	C., S. and E. Asia to Australia, in Malaysia: Sumatra, Malay Peninsula, Java, and New Guinea.
4. <i>C. campestris</i> Yunker	<i>Medicago</i> , <i>Trifolium</i> , <i>Satureja</i> , <i>Ambrosia</i> , <i>Artemisia</i> , <i>Aster</i> , <i>Beta</i> , <i>Bidens</i> , <i>Callistephus</i> , <i>Capsicum</i> , <i>Cirsium</i> , <i>Dianthera</i> , <i>Ipomoea</i> , <i>Pelargonium</i> , <i>Sonchus</i> , <i>Xanthium</i> , <i>Cinchona</i> , <i>Cosmos</i> , <i>Crotalaria</i> , <i>Gynura</i> , etc.	Native of N. America, now cosmopolitan in Malaysia: W. and M. Java.
5. <i>Cuscuta chinensis</i> Lam.	On a great variety of herbaceous hosts; <i>Panicum repens</i> L., <i>Solanum torosum</i> Sw., <i>Wedelia biflora</i> DC., <i>W. triloba</i> Hitchc.	Abyssinia, Sokotra and Afghanistan eastward to Sri Lanka, Australia, and China, where it is most abundant.
6. <i>C. timoriensis</i> Decne. ex Engelm.	<i>Ficus glomerata</i>	Central Africa and Malaysia: E. Java and Lesser Sunda Islands (Wetear, Timor).

Family/Species	Host	Distribution
II. Cuscutaceae		
7. <i>C. reflexa</i> Roxb.	<i>Achyranthes</i> , <i>Adhatoda</i> , <i>Apluda</i> , <i>Calotropis</i> , <i>Carissa</i> , <i>Citrus</i> , <i>Clerodendrum</i> , <i>Cocculus</i> , <i>Coffea</i> , <i>Duranta</i> , <i>Fragaria</i> , <i>Melia</i> , <i>Nerium</i> , <i>Thevetia</i> , <i>Zizyphus</i> , <i>Artemisia</i> , <i>Boehmeria</i> , <i>Casuarina</i> , <i>Cestrum</i> , <i>Engelhardia</i> , <i>Euphorbia</i> , <i>Fuchsia</i> , <i>Justicia</i> , <i>Polygonum</i> , <i>Rubus</i> , <i>Stachytarpheta</i> , etc.; sometimes in dense masses, covering whole tree-crowns, or covering lower vegetation like a net.	Afghanistan and Baluchistan throughout N. India to Yunnan, China, Thailand, Sri Lanka and Malaysia, Java.
III. Cassythaceae		
8. <i>Cassytha capillaris</i> Meissn.	Gramineae, Cyperaceae	Thailand, Sri Lanka, Borneo.
9. <i>C. filiformis</i> L.	Gramineae, <i>Chromolaena odorata</i> (L.) King & Robinson, <i>Hibiscus tiliaceus</i> L., <i>Parinari ananense</i> Hance, <i>Pisonia grandis</i> R. Br., <i>Acalypha wilkesiana</i> Muell.-Arg.	Tropical areas in both the Old and New World.
IV. Loranthaceae		
10. <i>Dendrophthoe falcata</i> (L.) Etingsh	<i>Shorea siamensis</i> Miq.	Malaysia; Thailand; Australia; India.
11. <i>Dendrophthoe lanosa</i> (Korth.) Dans.	<i>Dipterocarpus</i> spp.	Thailand; Sumatra.
12. <i>D. magna</i> Dans.	<i>Alnus japonica</i> (Thunb.) Steud., <i>Brachychiton acerifolium</i> F.v. Muell., <i>Camelia japonica</i> L., <i>Diospyros kaki</i> Thunb., <i>Eucalyptus umbellata</i> Dum. Cours., <i>Melaleuca bracteata</i> F.v. Muell., <i>Magnolia grandiflora</i> L., <i>Prunus cerasoides</i> D. Don	Java.

Family/Species	Host	Distribution
IV. Loranthaceae		
13. <i>D. pentandra</i> (L.) Miq.	<i>Bombax ceiba</i> L., <i>Croton cuningii</i> Muell.-Arg., <i>Diospyros mollis</i> Griff., <i>Eugenia siamensis</i> Craib, <i>Excoecaria agallocha</i> L., <i>Ixora</i> sp., <i>Lepisanthes rubiginosa</i> Leenh., <i>Mangifera indica</i> L., <i>Muntingia calabura</i> L., <i>Pithecellobium dulce</i> Benth., <i>Pterocarpus indicus</i> Willd., <i>Sesbania grandiflora</i> (L.) Poir., <i>Shorea siamensis</i> Miq., <i>Sireblus asper</i> Lour.	Tropical southeastern Asia; western part of the Malay Archipelago.
14. <i>Elythranthe albida</i> Bl.	<i>Linociera</i> sp., <i>Litsea</i> sp., <i>Annona reticulata</i> L., <i>Schinia wallichii</i> (DC.) Korth.	Burma; Malaysia.
15. <i>Ginalloa siamica</i> Craib	<i>Shorea</i> sp.	Thailand.
16. <i>Helixanthera cylindrica</i> (Jack) Dans.	<i>Dalbergia</i> sp., <i>Saraca</i> sp.	Sumatra; Thailand.
17. <i>Helixanthera ligustrina</i> (Wall.) Dans.	<i>Aporosa</i> sp.	Thailand to the Himalayan regions.
18. <i>H. parasifica</i> Lour.	<i>Casuarina equisetifolia</i> J.R. & G. Forst., <i>Cinnamomum iners</i> Reinw. ex Bl., <i>Quercus</i> sp., <i>Schinia wallichii</i> (DC.) Korth.	India to Southern China southward to Borneo, Java, Sumatra; throughout the Philippines.
19. <i>H. pulchra</i> (DC.) Dans.	<i>Xanthophyllum virens</i> Roxb.	Thailand to the Malay Peninsula.
20. <i>Korthasella opuntia</i> (Thunb.) Merr.	Various trees.	Southeastern Asia from the Himalayas to Japan, the Philippines, the Malay Peninsula and Java; also in Australia and the Archipelagos east of it, the islands of the Indian Ocean, Abyssinia, and S. Africa.

Family/Species	Host	Distribution
IV. Loranthaceae		
21. <i>K. japonica</i> (Thunb.) Engl.	<i>Altingia excelsa</i> Noronha	Honshu (Kanto Dist. and westw.), Shikoku, Kyushu; Taiwan; China; India; Malaysia, and Australia.
22. <i>K. dacrydii</i> (Ridl.) Dans.	<i>Dacrycarpus cumingii</i> (Pari.) de Laub., <i>Dacrydium</i> sp.	Malay Peninsular
23. <i>Macrosolen brandisianus</i> van Tiegh.	On trees.	Thailand; Burma.
24. <i>Macrosolen cochinchinensis</i> (Lour.) van Tiegh.	<i>Anacardium occidentale</i> L., <i>Aporosa</i> sp., <i>Artocarpus heterophyllus</i> Lamk., <i>Calycopteris floribunda</i> Lamk., <i>Croton</i> sp., <i>Mangifera indica</i> L., <i>Parinari ananense</i> Hance., <i>Manilkara sapota</i> (L.) van Royen, <i>Chrysophyllum cainito</i> L., <i>Neonauclea media</i> (Havil.) Merr.	India to Indochina and Malaysia, throughout the Philippines.
25. <i>M. platyphylla</i> (King) Dans.	<i>Dillenia</i> sp., <i>Hevea brasiliensis</i> Muell.-Arg., <i>Parkia</i> sp.	Thailand; Perak.
26. <i>Scurrula atropurpurea</i> (Bl.) Dans.	<i>Camelia sinensis</i> Ktze., <i>Combretum quadrangulare</i> Kurz., <i>Mangifera indica</i> L., <i>Citrus grandis</i> (L.) Osbeck	Thailand; Java.
27. <i>S. ferruginea</i> (Jack) Dans.	<i>Croton</i> sp., <i>Mangifera indica</i> L.	India; Malaysia.
28. <i>S. fusca</i> G. Don	<i>Acosia decurrens</i> (Wendl.) Willd., <i>A. myrsifolia</i> Willd., <i>Bridelia minitiflora</i> Hook f., <i>Cupressus forbesii</i> Jepson, <i>Camelia japonica</i> L., <i>Cordia myxa</i> L., <i>Melaleuca bracteata</i> F.v. Muell., <i>Magnolia grandiflora</i> L., <i>Neonauclea lanceolata</i> (Bl.) Merr., <i>Prunus cerasoides</i> D. Don, <i>Saurauia blumiana</i> Benn.	Tropical Asia.

Family/Species	Host	Distribution
IV. Loranthaceae		
29. <i>S. gracilifolia</i> (Schult.) Dans.	<i>Olax scandens</i> Roxb.	India to Malaysia.
30. <i>Scurrula philippensis</i> (Cham. & Schlecht.) G. Don.	<i>Gmelina philippensis</i> Cham., <i>Lansium domesticum</i> Corr., <i>Sandoricum Koet jape</i> (Burm. f.) Merr., <i>Coffea arabica</i> L., <i>Cordia dichotoma</i> Forst. f., <i>Lagerstroemia speciosa</i> (L.) Pers.	Malaysia, Java, Philippines, Thailand.
31. <i>S. pulverulenta</i> Wall ex G. Don	<i>Butea monosperma</i> Ktze., <i>Shorea siamensis</i> Miq.	India; Burma.
32. <i>Taxillus chinensis</i> (DC.) Dans.	On trees.	Thailand; China.
33. <i>T. estipitatus</i> (Stapf) Dans.	<i>Persia americana</i> Mill., <i>Lansium domesticum</i> Corr., <i>Diospyros blancoi</i> A. DC., <i>Annona reticulata</i> L., <i>Ficus ampelas</i> Burm. f., <i>F. cumingii</i> Miq., <i>Ceiba pentandra</i> (L.) Gaertn., <i>Casuarina equisetifolia</i> Forst.	Southern China, Malay Peninsula, Borneo and the Philippines.
34. <i>Viscum articulatum</i> Burm. f.	<i>Eugenia</i> sp., <i>Henslowia</i> sp., <i>Nauclea</i> sp., <i>Ficus variegata</i> Bl., <i>Eucalyptus umbellata</i> Dum. Cours., <i>Neonauclea lanceolata</i> (Bl.) Merr., Hyperparasite on <i>Dendrophthoe pentandra</i> (L.) Miq. on <i>Bombax ceiba</i> L., Hyperparasite on <i>Dendrophthoe pentandra</i> (L.) Miq. on <i>Mangifera indica</i> L., Hyperparasite on <i>Dendrophthoe</i> sp. on <i>Shorea siamensis</i> Miq., Hyperparasite on <i>Dendrophthoe pentandra</i> (L.) Miq. on <i>Sireblus asper</i> Lour., Hyperparasite on <i>Helixanthera</i> sp., <i>Casuarina</i> , <i>Evodia</i> , <i>Calotropis</i> , <i>Flueggea</i> .	Southeastern tropical Asia, Malay Archipelago and North Australia.

Family/Species	Host	Distribution
IV. Loranthaceae		
35. <i>Viscum indostense</i> Dans.	On trees.	Thailand; Indo-China (Anam.).
36. <i>V. loranthi</i> Elm.	Hyperparasite on <i>Taxillus stipitatus</i> (Stapf) Dans.	Central Sumatra and the Philippines.
37. <i>V. orientale</i> Willd. (= <i>V. monolicum</i> Presl non DC.)	<i>Crypteronia</i> sp.	Tropical Southeastern Asia, Malay Archipelago, North Australia.
38. <i>V. ovalifolium</i> DC.	<i>Croton robustus</i> Kurz., <i>Cynometra</i> sp., <i>Diospyros malabarica</i> Kost., <i>Excoecaria agallocha</i> L., <i>Ficus benjamina</i> L., <i>Spondias pinnata</i> Kurz., <i>Terminalia corticosa</i> Pierre ex Laness., <i>Zizyphus</i> sp.	Burma; China; Malaysia.
V. Orobanchaceae		
39. <i>Aeginetia indica</i> Roxb.	On rhizomes and roots of bamboos, Gramineae, Zingiberaceae.	Indo-Malaysia.
40. <i>A. pedunculata</i> Wall.	Gramineae	Tropical Asia.
41. <i>Christisonia siamensis</i> Craib	Gramineae	Thailand (endemic).
42. <i>C. wightii</i> Elm.	Sugarcane, Zingiberaceae.	Philippines (endemic).
VI. Rafflesiaceae		
43. <i>Rafflesia arnoldii</i> Brown	Forest trees.	Indonesia (Sumatra).

Family/Species	Host	Distribution
VI. Rafflesiaceae		
44. <i>Rafflesia manillana</i> Teschm.	Forest trees.	Philippines, Malaysia.
45. <i>Sapria himalayana</i> Griff.	On roots of various woody climbers (mostly Vitaceae) and forest trees.	Thailand; Assam.
VII. Scrophulariaceae		
46. <i>Striga lutea</i> Lour. [= <i>s. asiatica</i> (L.) O.K.]	Gramineae (corn, sugarcane, oats, barley, teosinte, rye, rice).	Old and New World tropics.
47. <i>S. masuria</i> Benth.	Gramineae	Africa; Australia; Thailand.

SYSTEMS ANALYSIS AND SIMULATION FOR ESTABLISHING RESEARCH PRIORITIES AND INTEGRATING METHODS FOR WEED CONTROL

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ABSTRACT

Weeds and methods for their control form complex ecological systems. Two systems are described to illustrate the complexities of systems and an analytical approach that assisted in identifying major components of the system and their inter-relationships. The relationships recognised the importance of feedback controls in ecological systems and described them mathematically so that the dynamic behaviour of the systems could be simulated with the aid of a computer. The systems described were the seed cycle of pigweed (*Portulaca oleracea*) and the movement of a herbicide in the soil + plant system.

INTRODUCTION

This conference has as its theme the ecology of tropical weeds. The theme is highly relevant because a knowledge of the ecology of a weed is an essential base for designing a weed control program, particularly if the program attempts to integrate several methods of control each critical in their timing. Unfortunately, however, the ecology of many of our weeds is complex and poorly understood so farmers, advisers and researchers are all making tentative decisions because of insufficient information. The interaction of a weed with its environment is further complicated by our agricultural activities aimed at weed control.

Given the complexity of weeds and their environments and limited resources for weeds research (Blacklow, Pearce and Humphries 1984) are there techniques to assist us in the analysis of ecological systems so we may identify priorities for research and make sound management decisions? In this paper we describe an approach we have found helpful in identifying and pursuing research priorities. We will illustrate the method by describing two current research projects, one concerned with the changes in the nature and populations of seeds of pigweed, or common purslane (*Portulaca oleracea*), and the other with the movement of the herbicide chlorsulfuron in the soil-weed-crop system. As well as illustrating the research method the paper presents some results of our current research on these two projects.

The seed system of pigweed (*Portulaca oleracea*).

Pigweed is a weed in parts of the world with summer rainfall. Although pigweed does not grow during the cool, wet winters of southern Australia it is a weed of summer irrigated crops in that region. Because pigweed is a precocious annual that produces seed over a protracted time, if conditions are favourable, an analysis of the

seed system is important to an understanding of the ecology of the weed.

We visualised that the seed population of pigweed consists of several components (Fig. 1). Seed produced during the summer months may be germinable (non-dormant), innately dormant or dead, and there may be a flow of seed between these categories, e.g. innately dormant seed may become germinable. Additionally, seed shed onto the surface of the soil may be buried by cultivation and induced to be dormant by darkness. A variable proportion of the seed on the surface of the soil also may be inductively dormant if temperatures are below 34°C. The seed cycle is completed through germination, establishment, maturation and seed production.

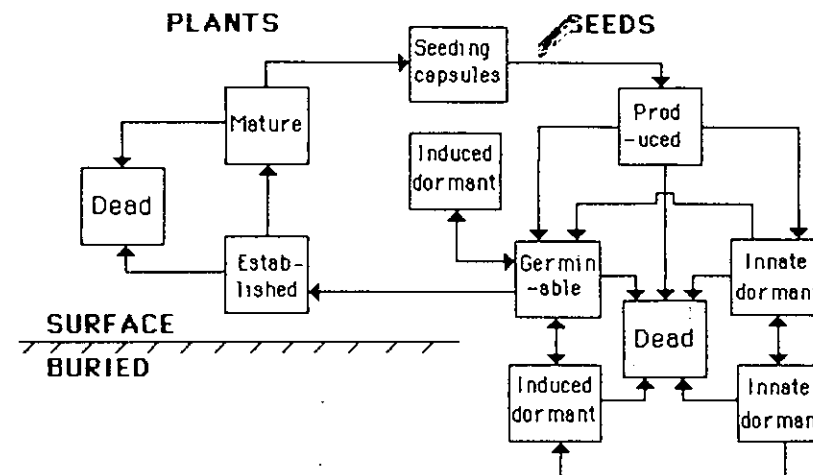


Fig. 1. The seed cycle of pigweed (*Portulaca oleracea*), only major pathways are shown.

An advantage of representing the system as boxes and flows was the clarity of communicating the major components of the system and their inter-relationships as perceived by the researchers; it was easier to discuss and make refinements to the analysis when it was represented diagrammatically, as in Fig. 1, than to rely on verbal communications about a complex system. The seed cycle for pigweed (Fig. 1) relied on general knowledge about annual plants and was refined as the literature on pigweed was reviewed. However, the analysis did not follow a thorough review of the literature, rather, as it will be emphasised later, a review of the literature was directed by the state and stage of thinking on the analysis of the system. After agreement was reached on the major components of the system the focus of the researchers switched to the processes that control the rates of flows between the components; some examples can be given.

Priorities in investigating rates of processes.

The rate of germination, attenuated by mortality of germinated seeds (Fig. 1) was hypothesised as controlled by feedback with the rate dependent on seed density (Fig.

2a); the rate constant, slope of Fig 2 (a), was hypothesised as a function of temperature. This phase of analysing the system illustrates some important principles.

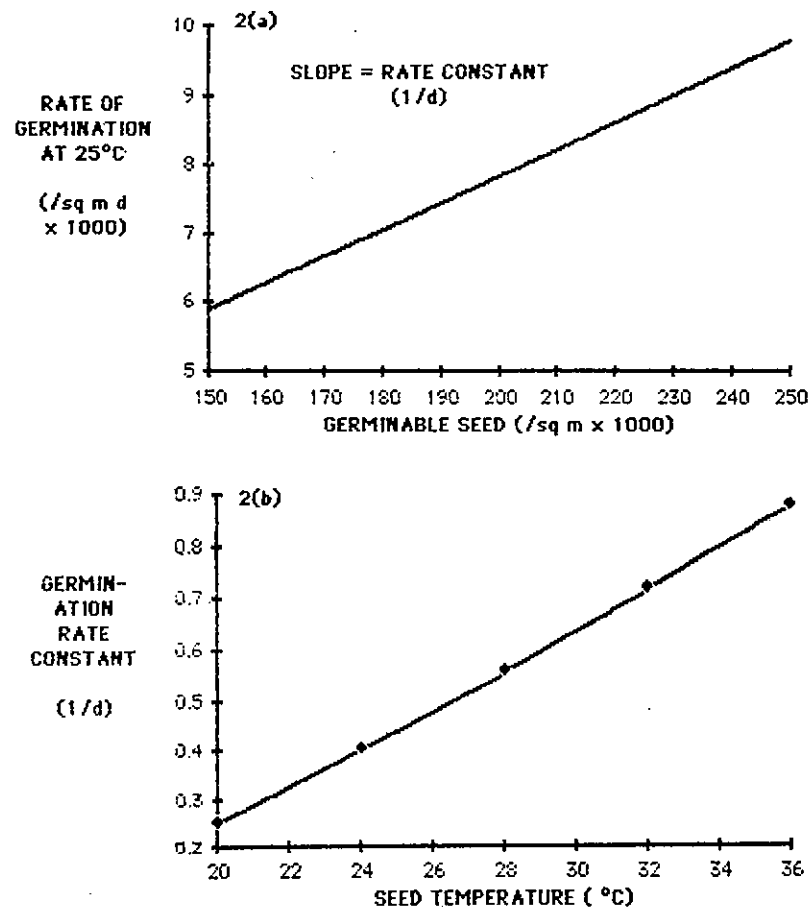


Fig. 2. The control by temperature of the rate of germination of pigweed (*P. oleracea*). (a) The feedback control of the rate by the density of seeds. (b) The rate constant of (a) as a function of temperature. (Poungprakhon and Blacklow, unpublished data.)

Stable ecological systems owe their survival to the evolution of feedback controls on the rates of component processes. Thus, the rate of germination in Fig. 2(a) is shown as a function of seed density and not, as abounds in the literature, as a function of time. Next, we chose our units of Fig. 2(a) so that we would be dealing with rate constants that have dimensions of the reciprocal of time. The inverse of a 1/time rate constant is the 1/e time constant or the time taken for 63 % of the final state, or goal, to be reached should the system be disturbed, eg. a change in density of germinable seed. It is relatively easy to visualise, intuitively, the time required for

63 % of a pool of germinable seed to germinate and how that time may change with, say, temperature. The reciprocals of the time constants were plotted as a function of temperature and are shown as the hypothesised relationship of Fig 2(b). The literature was searched for support of the hypothesis of Fig 2(b), and although there were helpful references, the hypothesis was tested by experiments with our Perth source of pigweed, these data are plotted in Fig. 2(b).

We would claim that in our studies of the rate of germination we have proceeded in a manner that shows sensitivity to the principles that govern the behaviour of ecological systems that we have been scientific in our approach through the formulation and testing of hypotheses; and that we have used the literature as an aid to our analysis rather than be dominated by a large volume of literature that all appears to be relevant. As a consequence our research priorities have been directed by us rather than by what others have written.

The scientific approach to the investigation of germination was repeated as a modular approach to our studies of the other processes connecting the boxes in Fig. 1. As another example we show the hypothesised controls of the rate of plant maturity (Fig. 3). Again, the rate was hypothesised as a function of the population, in this case the seedling densities. This relationship again established the slope as a parameter with a physiological as well as mathematical identity, i.e. the reciprocal or the time of flowering (Fig. 3a). The literature was helpful at this stage because Gutterman (1973) had published his work on the control of time to flowering by daylength (Fig. 3b).

A further example of our approach to researching the ecology of pigweed shows a relationship that proved to be important in explaining the seasonal dynamics of pigweed densities. A proportion of seed produced during the summer is innately, of physiologically, dormant (Fig. 1); the proportion is a function of temperature (Poungprakhon and Blacklow, unpublished data). We established by experiment that the rate constant of the release of seed from innate dormancy was also a function of temperature (Fig. 4b). The control of the imposition and release from innate dormancy by summer temperatures could be an adaptation of the species that prevents a loss of seed if unfavourable conditions were to follow the first rains of summer. It would also help to explain the sustained production of seedlings from seed reserves in the soil during the summer.

In the analysis of the pigweed system we hypothesised that buried seed may decay and die, particularly because published work had shown that buried seed would be prevented from germination due to the induced dormancy by darkness (Singh 1973). Surprisingly, the loss of germinability was very slow, irrespective of the storage conditions, and seed stored in wet or dry soil maintained 98 % germinability after 24 months (Fig. 5).

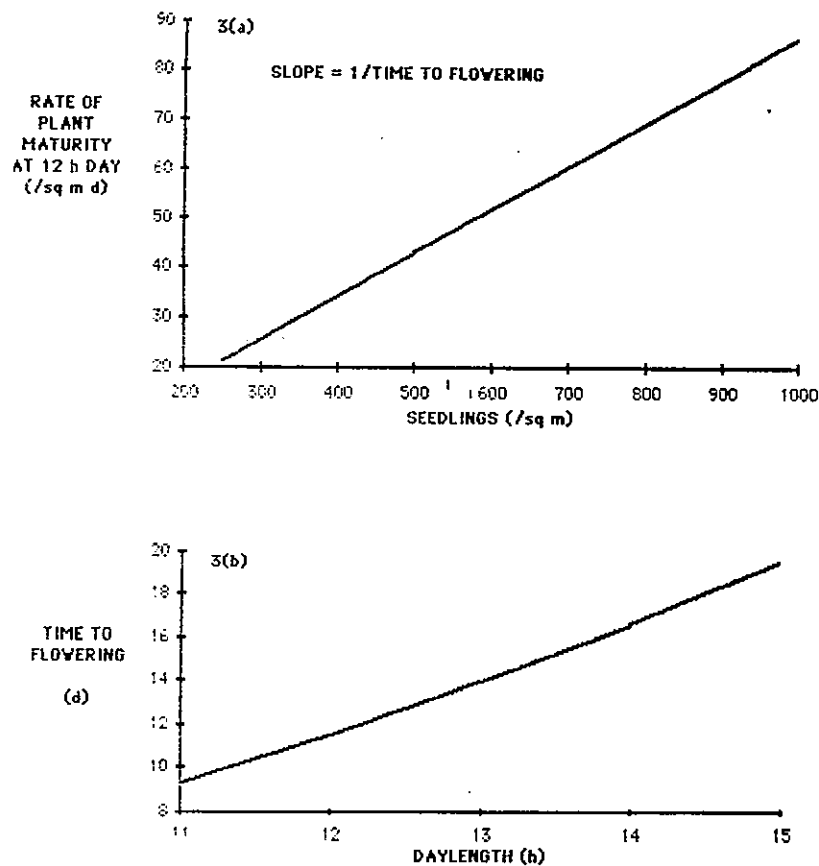


Fig. 3 The control by daylength of the rate of plant maturity of pigweed (*P. oleracea*). (a) Feedback control of the rate by the density of seedlings. (b) Time to flowering as a function of daylength. (Function (b) after Gutterman 1973)

The approaches described to establish the controls of the rates of changes of the components of the seed cycle were completed for all components shown in Fig. 1. Although some gaps in our knowledge remain we have included the best information we have into a simulation model that enables us to study the dynamic behaviour of the system under a variety of natural and imposed conditions. Before presenting the results of some simulations, a brief explanation of the method of simulation is given.

Simulation of options of weed control.

Simulation of the daily changes in the levels of densities of each of the components of the system shown in Fig. 1 was calculated as follows. The rate of a process was

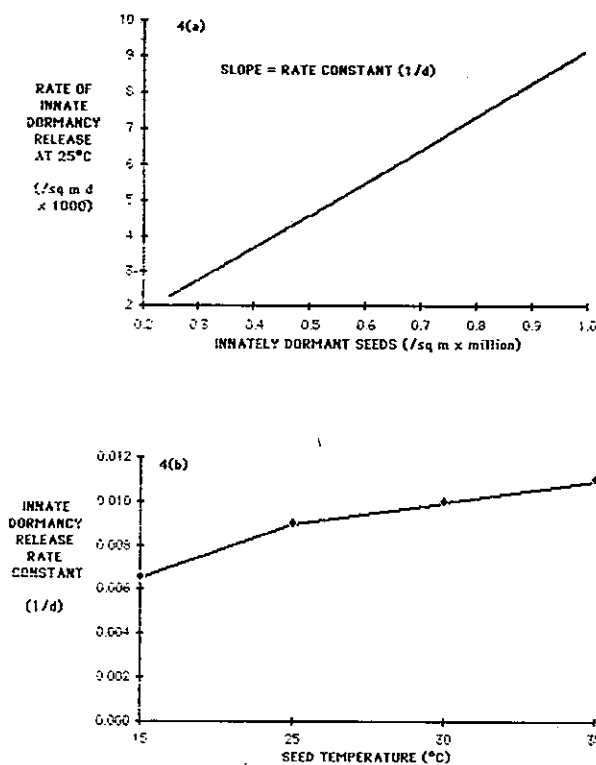


Fig. 4. The control by temperature of the rate of release of seed of pigweed (*P. oleracea*) from innate dormancy. (a) Feedback control of the rate. (b) The rate constant as a function of temperature. (Poungprakhon and Blacklow, unpublished data.)

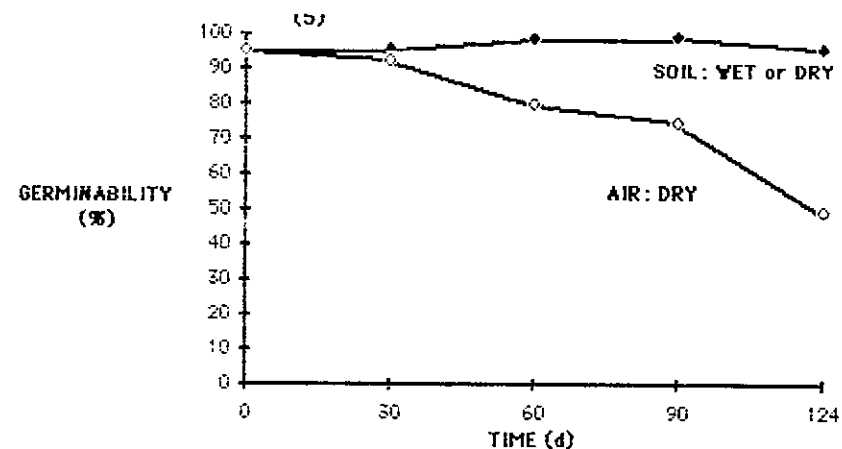


Fig. 5. Loss of germinability of pigweed (*P. oleracea*) stored at five temperatures, air-dry or in wet or dry soil, between 15 and 37°C. Seed was stored dry at 20°C for 20 months prior to this experiment. (Poungprakhon and Blacklow, unpublished data.)

multiplied by a small increment of time, eg. one day, and the result was an increment of change in the level. The increment was added to the component in the direction of flow and subtracted from the component that the flow was directed away from.

For the rate of germination (RG):

$$RG = RCG \times DGS$$

where RCG is the rate constant and DGS the density of germinable seed. Then,

$$DGS = RG \times \Delta T$$

where DGS is the change (decrease) in DGS over the interval of time ΔT . Finally,

$$DGS(T + \Delta T) = DGS(T) - \Delta DGS$$

Simulation of the dynamic, daily behaviour of the seed cycle for pigweed over three years required about 15 thousand calculations and was made feasible by the use of a computer. The results of a simulation are shown in Fig. 6. Although the model requires rigorous validation by checking the results with field data the dynamics as simulated give sensible results that agree with field experiences and some data in the literature (Miyanishi and Cavers 1981; Schweizer and Zimdahl 1984). The simulation model enabled us also to check the sensitivity of the system's behaviour to the hypothetical relationships of some of our rate equations.

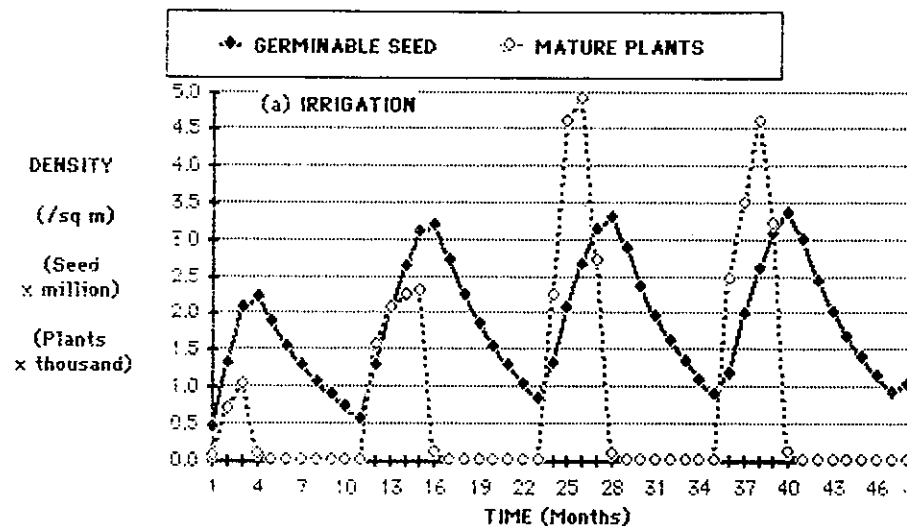


Fig. 6. Simulation of the densities of seeds of pigweed (*P. oleracea*) grown at Perth, western Australia. (a) Surface seed when winter rainfall was followed by summer irrigation.

In the simulated situation of summer irrigation a pure stand of pigweed produced summer peaks of 3.4 million germinable seeds and 5 thousand mature plants per square metre. Frosts destroyed the mature plants during the winter and the pool of germinable seed showed a winter decline also with the imposition of innate dormancy by the low temperatures. (Fig. 6a) We used the model to study the decay

of the density of surface seed by with-holding summer irrigation in effect a summer fallow imposed by drought. The pool of innately dormant seed decayed exponentially and was at a low level twelve months later, i.e. the next summer-cropping season (Fig. 6b). No appreciable densities of mature plants were produced following the with-holding of summer irrigation during the first summer but each summer a summer peak of germinable seed remained due to seed longevity and their release from induced dormancy by the winter temperatures (Fig. 6b).

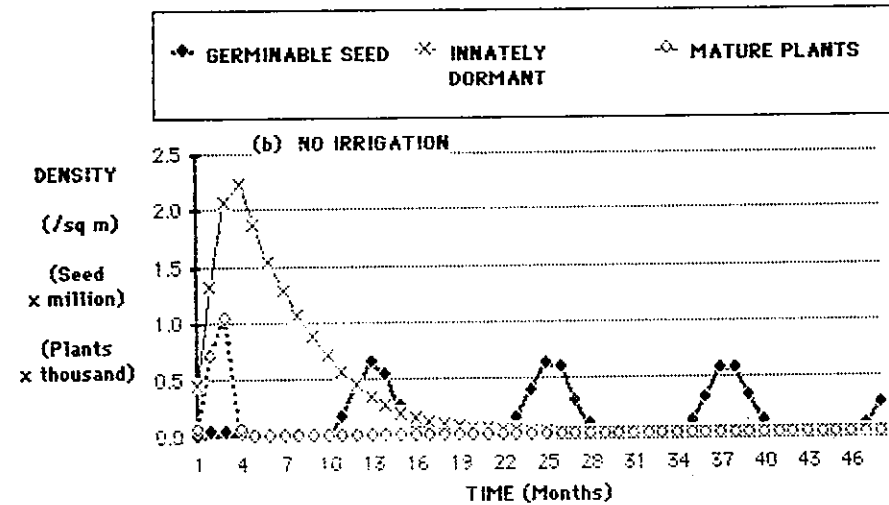


Fig. 6. Simulation of densities of seeds of pigweed (*P. oleracea*) grown at Perth, Western Australia. (b) As for (a) but without summer irrigation.

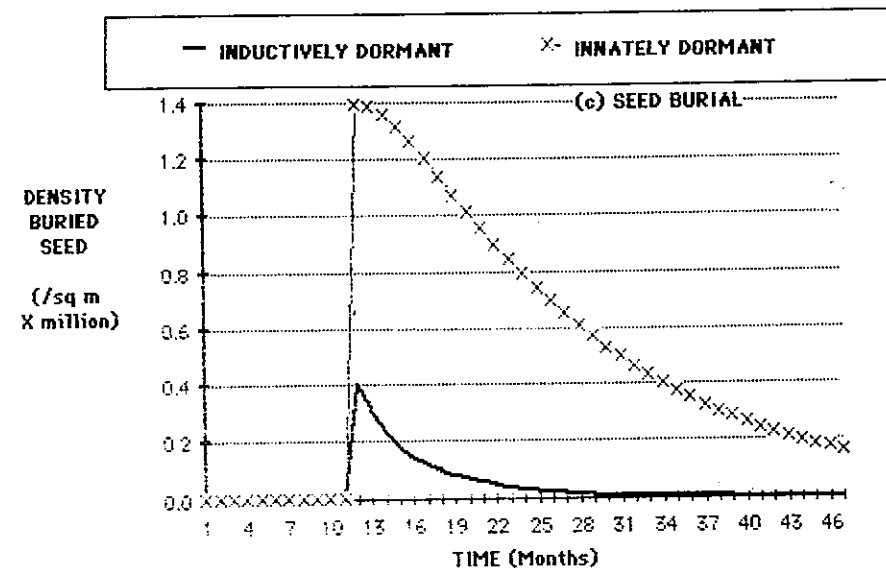


Fig. 6. Simulation of the densities of seeds of pigweed (*P. oleracea*) grown at Perth, Western Australia. (c) As for (a) but with cultivation in November to bury surface seed prior to direct drilling a summer crop.

Simulation enabled us to check the effectiveness of another option for weed control, the option to bury the surface seed with cultivation at the end of summer. All buried seed is dormant and if it decayed during the winter months the flow-diagram suggested the seed cycle could be broken and there would be no established plants in the summer crops, even if they were exhumed by cultivation associated with subsequent cropping. Our data showed (Fig 5) that the rate of decay was slow and this is reflected in the seed dynamics shown in Fig. 6(c). Consequently, spring cultivation that exhumed buried seed would restore a pool of innately dormant seed that would rapidly regenerate a pool of germinable seed stimulated by the warmer summer temperatures.

Research with the relationships and performance of the model of pigweed is continuing. Concurrent with this model of an ecological system is work on the analysis of another system, that of the movement of a herbicide in the soil-plant system.

Herbicides in the soil-weed-crop system.

We became interested in analysing the herbicide system as we attempted to research the reasons for differences in cultivar sensitivities of wheat to chlorsulfuron. The problem observed in the field in 1982 was that the herbicide chlorsulfuron caused damage to some cultivars of wheat during a cold, wet start to the growing season. There was much speculation about the cause of this damage. We took the problem into controlled environments and quickly established the interaction between cultivar-sensitivity and temperature (Fig.7). We visualised the concentration of herbicide in the root zone would be the residue left after leaching, degradation and plant uptake (Fig.8). Again, another complex system with many components and feedback loops between them. Investigation of components of the system will require a systematic identification of research priorities and an early attempt to place the results back into the context of the operating system so that the interactions are allowed to operate, as they do in the real world. Simulation may be the only realistic way of putting the components of the system together.

In controlled environment studies we showed (Bowran and Blacklow 1984) that differences in cultivar sensitivities only appeared if the soil temperature was below 13°C (Fig.7). Temperature could affect all rates of the processes of the system including the sensitivity of the site(s) of action of the herbicide in the plant (meristems; enzyme systems).

Although an encouraging amount of research findings have been published on this recently released herbicide we are at an early stage of quantifying the system. Our preliminary data show no differences in the net accumulation (uptake + metabolized of Fig.8) of the ^{14}C label of chlorsulfuron by sensitive and tolerant cultivars when the temperature was lowered from 25°C to 15°C (Table 1). However, there may be important differences in rates of metabolism between cultivars that would not be established by our total uptake data, we would need to know the partition of total uptake between unaltered and metabolised chlorsulfuron (Fig. 8). Metabolism has been suggested as the major reason for differences between species in their sensitivities to chlorsulfuron (Hapeman and Behrens 1984).

The major effect of temperature in our experiment was the higher proportion of radioactivity not accounted for. We presume this 'loss' was due to a faster rate of degradation in the warmer soil. Walker and Brown (1983) showed that degradation in soil followed first order reaction kinetics and that the half-lives were a function of temperature. Degradation and leaching (Fig. 8) will be important determinants of the persistence of chlorsulfuron in the root zone. Differences in root distributions and densities would further modify the exposure of a cultivar to a herbicide, hence the informational feedback loops, shown as broken lines, in Fig 8.

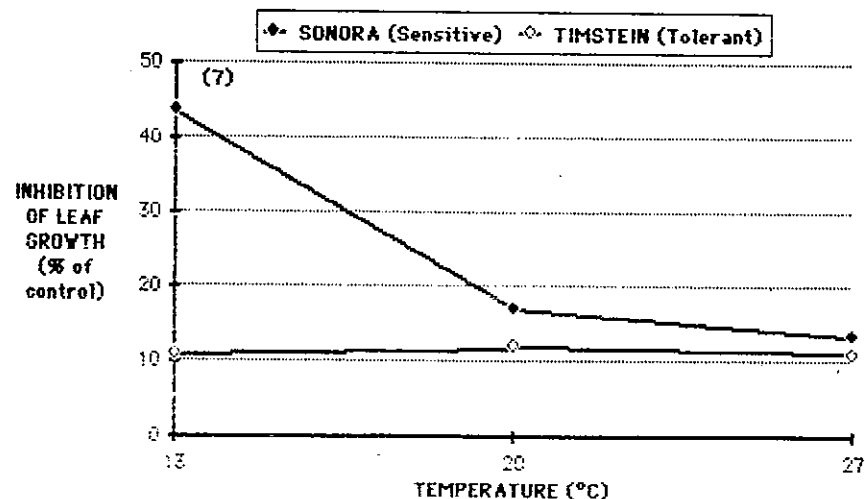


Fig. 7. The effect of soil temperature on the inhibition by chlorsulfuron of the growth rate of the third leaf of seedlings of a sensitive (Sonora) and tolerant (Timstein) cultivar of wheat. Seedlings were grown in soil containing 40 $\mu\text{g/kg}$ of the herbicide. (Bowran and Blacklow 1984.)

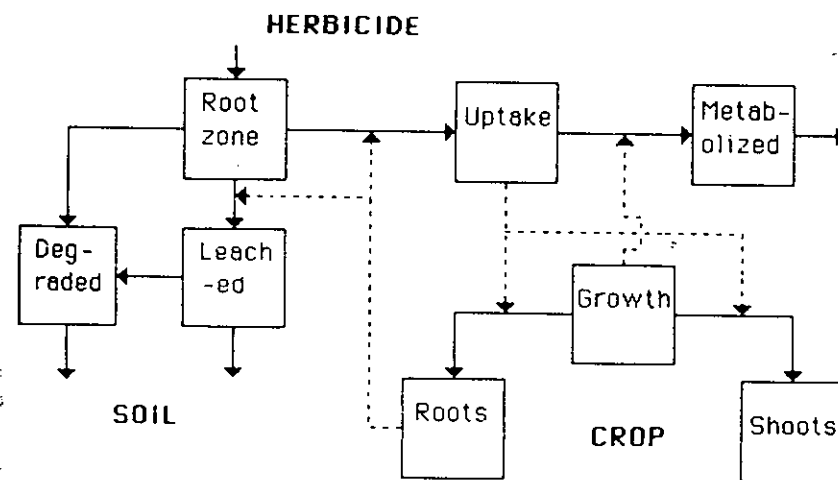


Fig. 8. Herbicide in the soil + crop system

Table 1. Effect of soil temperature on the uptake and distribution of chlorsulfuron by seedlings of wheat cultivars.

Temperature	Cultivar	Radioactivity (% Applied)			Distribution in Plants (% Uptake)	
		Soil	Plant	Unaccounted	Roots	Shoots
15°C/15°C (Day/Night)	Halberd	40	2.6	57	27	73
	Sonora	36	2.1	62	26	74
	Timstein	33	2.4	65	24	76
20°C/15°C	Halberd	23	2.9	74	38	62
	Sonora	19	2.5	79	43	57
	Timstein	23	2.7	74	41	59

2300 Bq per pot of 300 g soil and seedlings were harvested 25 days after emergence when four leaves had expanded.

We are at an early stage of a quantifying the herbicide system. When environmental factors affect several processes of a complex system quantification of the individual rates and testing their combined effects with a simulation model will be a strong approach to investigation of the response of the whole system to field conditions where several environmental variables may be changing at the same time. Our research priorities are now focused by our analysis of the system and our preliminary investigations of it.

ACKNOWLEDGEMENTS

Perhaps P Pheloung and R Papalia should have been included as co-authors. The research of K Pongprakhon was supported by a fellowship from the Australian Development Assistance Bureau. Research on the herbicide system was supported by the Wheat Industry Research Committee of Western Australia and the Soil Fertility Research Trust Fund of Western Australia.

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THE FAO PANEL ON IMPROVED WEED MANAGEMENT AND A SURVEY OF WEED SCIENCE EDUCATION IN PARTS OF THE ASIAN-PACIFIC REGION

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Most of you will be aware that there are several divisions within the Food and Agriculture Organisation of the United Nations, and that the Plant Production and Protection Division has a Plant Protection Service. The function of the Plant Protection Service is to assist developing countries with their weed, insect and plant disease problems, and it contains a person who is important to us all here today, the weed specialist. This post was held for short periods by Dr. L. Holm and Dr. C. Little before being developed as a permanent position by L.J. Mathews since 1977.

The FAO weed specialist is supported in the wider weed science community of the world by an advisory body, the panel of experts on Improved Weed Management, of which I am privileged to be a member. The panel was set up following the FAO/International Weed Science Society Expert Consultation on Improving Weed Management in developing countries which was held in Rome in September 1982. The consultation developed a total of 78 recommendations which were aimed at FAO itself, at governments and administrators, at research and educational institutions and weed science societies such as ourselves, at aid donor organisations, and at the international agrochemical industry. Copies of these recommendations are readily available and have been widely distributed, and we hope that they will form the basis for improving weed science and weed control in developing countries throughout the decade.

One of the important recommendations of the consultation was the setting up of the panel of experts on improved weed management, and this was done in 1983. The functions of the panel are to advise the Director-General of FAO and member governments with regard to the development and application of improved weed management in agriculture, fishery and forestry and to review principles and standardise procedures and techniques. The panel also serves as an advisory body for the implementation of FAO field programs. It has a four year life which ends in November 1987.

The panel is made up of twelve members, each of whom has been chosen to represent an area of experience and where appropriate a geographical area. The members of the panel are as follows:

Dr. I.O. Akobundu, Nigeria (Chairman)
Dr. A. Alves, Brazil

Dr. J.D. Fryer, UK
Dr. W. Koch, Germany
Dr. B.L. Mercado, Philippines
Dr. R.W. Michieka, Kenya
Dr. I.G. Rojas, Chile
Dr. A.R. Saghir, Lebanon
Dr. J.T. Swarbrick, Australia
Dr. Y-C. Li, China
Dr. R.L. Zimdahl, USA.

The panel met for the first time in Nairobi, Kenya in April 1984. It was unfortunate that only six members could be funded by FAO to attend the meeting, since we have not all met each other yet. The next meeting of the panel will be in South America early in 1986, but again only some of the panellists will be able to attend.

The main function of the meeting in Nairobi in 1984 was to develop action programs to reduce the drudgery of small farm weed control in the tropics. The panel report lists 25 recommendations addressed to a number of bodies. One of the main outcomes of this meeting was the setting up of six working groups whose responsibilities are to tackle various problems associated with improving weed management in the tropics. The working groups and their membership are as follows:

Weed Science Training (Undergraduate and Postgraduate)

Dr. J.T. Swarbrick (Co-ordinator)
Dr. B.L. Mercado
Dr. A.R. Saghir

Weed Science Short Courses and Training Aids

Dr. R.L. Zimdahl (Co-ordinator)
Dr. I.G. Rojas

Information and Publications

Dr. W. Koch (Co-ordinator)
Dr. Y-C. Li

Rice Weed Control in West Africa

Dr. I.O. Akobundu (Co-ordinator)
Dr. A. Alves

Striga and its Control

Dr. J.D. Fryer (Co-ordinator)
Dr. V.M. Bhan

Action Program for Developing Weed Control in Kenya

Dr. R.W. Michieka (Co-ordinator)

The working groups were largely left to develop their own programs and are to report to the panel at regular intervals.

The working group on weed science training at undergraduate and postgraduate levels decided to develop an outline syllabus for teaching weed science and control at undergraduate level, to develop a textbook based upon that syllabus supported by a range of teaching aids, and to survey existing weed science and weed control courses

throughout the tropics. If we can achieve these aims within the four year life of the panel we feel that we shall have laid a good foundation for similar working groups on the same subject in future panels.

The development of an outline syllabus for weed science and weed control at undergraduate level was fairly easy, since we had a number of successful models to work from. Like all syllabi, however, the result is a personal and subjective arrangement of the material necessary to give adequate training in the subject, and we were not able to develop it in great detail without more knowledge of the number of hours of lectures and practical work available to teach the subject in most colleges and universities. The detail to which any subject can be taught obviously depends on the time allocated to it by the educational administration of the institution. Any syllabus has to be modified to reflect the needs, priorities and constraints of both the teacher and the students. Dr. Mercado and I quickly discovered that the outline syllabus had to be modified to produce an acceptable textbook.

To support the syllabus and writing of a text we developed a partial list of books on weed science and weed control. This was put together over a year ago, and is of course already out of date due to the subsequent publication or notice of several important books in the area including those of Merrill and Lembi, of Radesovich and Holt, and of Fletcher.

The second activity of the panel was the writing of a textbook on weed science and weed control aimed at and affordable by undergraduate students in agriculture in developing countries. For some time it seemed as though a book being written by two eminent authors in this field was going to be suitable and we would not need to write a book of our own, but when it appeared that it might not be suitable we were encouraged by Dr. Matthews to start writing. Dr. Mercado and I are currently working very hard to have the book completed to the final author's draft stage by March 1986, after which it will be read and checked by all members of the panel before, we hope, FAO publishes it at a subsidised price for students in developing countries. The book is aimed specifically at undergraduate students doing agriculture courses in Southeast Asia, but will, we hope, be suitable for use in many other areas of the tropics.

The third activity of the panel has been a survey of existing weed science and control courses at colleges and universities throughout the tropics. Drs. Saghir, Mercado and myself have divided the tropics into three zones, as follows:

Dr. Mercado: India, Eastern and Southeastern Asia and the Philippines
Dr. Saghir: Africa, the Middle East and Asia as Far East as Pakistan
Dr. Swarbrick: the Caribbean, Central and South America, the Pacific Islands, Indonesia and Papua New Guinea.

The aims of the survey were fourfold - to contact people teaching weed science in the tropics, to let them know that FAO is actively interested in the area and preparing to help them, to find out what is currently being taught at what levels and where, and to ask if FAO's help with the provision of teaching material would be useful to them.

We started by developing an extensive list of the names and addresses of colleges and universities in the tropics which teach agriculture and related topics, and also

developed a survey form. Both of these were sent to Dr. Matthews at FAO in Rome for mailing, and he added a number of contacts of his own. We decided to send the survey form out in English only, and this inevitably led to some problems of understanding and translation. As well as the language problem, I am sure that we failed to reach a number of colleges and universities, and know that many to which the survey form was sent failed to reply. By sending out the forms fairly widely we also contacted and had replies from a number of institutions teaching weed science and weed control at high school and farmer level. I think that we were successful in reaching most appropriate colleges and universities, and hope that any which we over looked will let us know.

My own section of the survey covered the Caribbean, Central and South America, the islands of the Pacific Ocean, Papua New Guinea and Indonesia. I extended the survey to cover Australia and New Zealand because these countries are an integral part of weed science training in the Asian-Pacific region.

Another member of the panel, Dr Rojas of Chile, had already conducted a survey of universities teaching agriculture in eight countries in South America. His objectives were to find out the levels of training of the staff engaged in weed science education, research and extension and how many of the universities taught weed science and control. Dr. Rojas has very kindly sent me a copy of the unpublished summary of his survey. He surveyed 105 faculties of agriculture throughout the eight countries, and found that only 30.5% offered courses specifically in weed science and control. I expect from the findings of our survey that many of the rest would have included elements of weed science and control in subjects such as agronomy and crop protection. Dr. Rojas reports in his summary that there were 63 professionals employed in weed science and control teaching, research and extension in the 105 faculties, of which eight had Ph.D. degrees, eleven had M.Sc. degrees and 44 had first degrees in agriculture. Dr. Rojas draws attention in his summary to the low percentage of weed science and control teachers in the faculties of agriculture of South American universities who have higher degrees and to the large number of the universities teaching agriculture and related subjects which did not include specific weed science and control subjects in the curriculum. He stresses the need for further postgraduate training in weed science for lecturers and an increased percentage of universities to teach weed science and control as subjects in their own right. Dr. Rojas' summary and conclusions are interesting and I recommend them to you.

Weed Science Training in the Pacific Islands, Papua New Guinea, Indonesia, Australia and New Zealand

Survey forms were received back from thirteen nations within the region:

- Australia (9)
- Guam (1)
- Fiji (2)
- Hawaii, USA (2)
- Indonesia (9)
- Micronesia (1)
- New Zealand (2)
- Niue (1)

- Papua New Guinea (5)
- Samoa (2)
- Solomon Islands (1)
- Tonga (1)
- Western Samoa (1)

I shall discuss weed science training at tertiary level in the Pacific, Papua New Guinea and Indonesia first and then in Australia and New Zealand, before comparing the training courses available in the two groups of countries.

Weed science and weed control is taught at various levels in all countries of the Pacific, Papua New Guinea and Indonesia covered except in Guam, where no suitable teacher is available at the college of agriculture and life sciences. Help with material for presenting courses would be welcome by nearly all tertiary institutions throughout the region.

Postgraduate training in weed science is available at the university of Hawaii and at BIOTROP in Indonesia. The former offers a Masterate of Agricultural Science by course work and research; the level and structure of the course at BIOTROP was not stated.

Bachelor degree courses in agriculture are available at universities throughout the region, all of those which responded to the survey include elements of weed science within their courses. They include the university of Hawaii, the universities of Bogor, Hasamuddin, Mularwarman and San Ratulangi in Indonesia, the Papua New Guinea university of Technology and the university of the South Pacific in Western Samoa. The courses range in length from three to four years and the weed science component is taught as specific weed science subjects rather than as part of broader subjects such as Crop Protection or Agronomy. It generally occupies 20-40 hours of lectures and an equivalent or greater period of laboratory and field practical time.

Diploma level courses in agriculture and related subjects are widely available throughout the region; all those surveyed include weed science and control in their syllabi. Seven such courses were identified, one each in Fiji, Indonesia, Samoa, Tonga and Western Samoa and two in Papua New Guinea. They were offered at colleges of agriculture and of forestry, at a university and at an agricultural training institution as two or three year Diploma courses. Weed science and control is offered as a subject in its own right at two institutions, as part of crop protection in two colleges, as an aspect of agronomy in two other colleges, and as part of pesticides in forestry practice. The courses run for from 24 to 56 hours of combined lectures and practical classes.

Courses at high school level for future farmers and plantation managers and short courses for farmers, plantation managers, extension workers and other semiprofessional staff are frequent throughout the region. Most of them have a practical basis. The survey did not identify many of these courses since it set out to examine courses at undergraduate and postgraduate level. The working group on short courses and teaching aids has produced an internal interim report dated October 1984 listing many short courses in weed science and control throughout the tropics, and FAO published a directory of short courses on plant protection in December 1984.

Survey forms were received back from nine universities and colleges in Australia and two in New Zealand. Weed science and control is taught as part of courses in agriculture, horticulture and forestry in all eleven institutions. Seven of them were interested in receiving any material that FAO might develop to improve weed science education, and two (including my own) are interested in assisting with this work.

Postgraduate training in weed science and control is available at seven universities and colleges at Ph.D., M.Sc. and graduate Diploma levels. The universities of Western Australia, Adelaide, Tasmania and Massey all offer Ph.D. degrees mainly by research and thesis over 3 to 4 years; weed science is available as an option in all. M.Sc. degrees are available at Massey University and at Lincoln College in New Zealand, and graduate Diplomas in plant or crop protection at the Queensland Agricultural College, the Victorian College of Agriculture and Horticulture and (from 1987) at the Riverina-Murray Institute of higher education. The university of Tasmania offers a postgraduate Diploma in agricultural science.

M.Sc. degrees are normally by both course work and research and take two years to complete, except at the University of Tasmania where it is a three year research degree. Graduate and postgraduate Diplomas are one year courses, the graduate Diplomas mostly by course work but the postgraduate Diploma in Tasmania 50% by research. Neither the M.Sc. nor the graduate Diplomas offer weed science as a major study, although it is a significant element in the graduate Diplomas in plant protection. 50% of the postgraduate Diploma in agricultural science at the University of Tasmania can be devoted to research in weed science.

Bachelor degree courses in agriculture, agricultural science, agricultural business, horticulture and forestry are available at most Australian and New Zealand universities and colleges. They range in length from three to four years. Weed science is included in the second and third years of these courses as Weed Ecology and Control, as a significant part of Crop or Plant Protection, or submerged into more general subjects such as Agronomy, Crop or Pasture Production or Management or Crop Physiology. A number of these institutions introduce weed science in basic subjects such as Agronomy and develop it in more applied ones including Crop Protection. The Victorian college of Agriculture and Horticulture has a single subject Land Use and Unwanted Plants which covers vegetation management in public lands. The fourth year of the degree courses in agriculture and horticulture at the Queensland Agricultural College offers a fourth year major in plant protection which includes a significant amount of weed science and control.

It is difficult to extract a clear picture of the number of teaching hours allocated to weed science and control in the various degree courses in Australia and New Zealand, but it appears to vary between 20 and 120 hours.

Diploma and Associate Diploma courses in agriculture, horticulture and related areas are available at five of the Australian and New Zealand colleges which responded to the survey. These are applied courses which take either one or two years to complete and which generally include weed science and control as part of Agronomy, Crop Production or Crop or Pasture Management. Only in two cases is Plant Protection offered as a subject. The hours available for teaching weed science in these courses vary between 10 and 34.

I have no doubt that weed control is taught as part of agriculture in most of those Australian high schools which include agriculture as a formal classroom subject, but I expect that the amount of time devoted to it is very small. Very little emphasis is placed on agriculture in Australian high schools, most of which are in urban centres.

A number of occasional and more regular short courses are available in plant protection, pesticide application technology or weed control throughout Australia, but this survey did not ask about short courses or those at high school level.

When comparing the weed science and control training available at university and college level in the Pacific Islands, Papua New Guinea and Indonesia with that available in Australia and New Zealand, I am struck by the fact that the majority of the institutions teaching agriculture throughout the Pacific, Papua New Guinea and Indonesia teach weed science as a subject in its own right, whilst the majority of those in Australia and New Zealand submerge it in either agronomy or plant protection. Like most trends this probably has a historical basis, in that weed science is a relative newcomer as a subject in agricultural courses. Weed science has traditionally been included in Australian and New Zealand Universities and Colleges as a minor element in courses such as agronomy and plant protection. Whilst many of these institutions are well staffed with entomologists and plant pathologists, few appear to have staff with any specific training in weed science per se. Considering the relative importance of weeds as opposed to arthropods and pathogens as causes of loss in agricultural production systems, this traditional blindness by Australian tertiary educators is remarkable.

Many of the universities and colleges in the Pacific Islands, Papua New Guinea and Indonesia have developed their agriculture courses more recently than those of Australia and New Zealand, and have perhaps a clearer appreciation of the factors which are important in limiting overall agricultural production. A younger and more recently educated body of educational administrators and teaching staff with less traditional attitudes may also be partly responsible for the greater emphasis given to weed science in these countries.

The data given by this survey and summarised here could be taken as representative of the weed science and control teaching in undergraduate and postgraduate courses throughout the regions discussed. The survey was not comprehensive and all the institutions addressed did not reply, so other courses are no doubt available in a number of universities, colleges and training centres throughout the Pacific Islands, Papua New Guinea, Indonesia, Australia and New Zealand. I would like to hear from any institutions in my area that were overlooked in the survey, which failed to reply, or which have developed courses since the survey was conducted in April to September 1985.

If I might now summarise and comment on the findings of the survey, the situation is that weed science and control are taught in most Diploma and Degree courses in agriculture and related sciences throughout the region. M.Sc. and Ph.D. courses are also available at a few centres, but none of the ones which I surveyed have a chair of weed science.

As weed scientists we must ensure that all of our developing agriculturists obtain a sound understanding of both the principles and practice of weed science and weed

control during their undergraduate courses. We should also see to it that increasing number of our ablemost students are encouraged into M.Sc. and Ph.D. courses in weed science at those universities which offer this facility. The number of universities offering such courses must increase in the future.

We should also, both as a society and as a group of professionals in weed science, work towards the establishment of a chair of weed science at an appropriate university, perhaps in Indonesia, to provide a long term focus for academic research into the problems caused by weeds in tropical countries throughout the region and into their control by technologies which are appropriate to our cultures.

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WEED CONTROL TECHNOLOGY : NEEDS, DEVELOPMENT, CONSTRAINTS

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ABSTRACT

The development and successful introduction of new weed control technology, herbicides in particular, is a capital intensive business risk. Currently, for every 20,000 compounds synthesized and screened, one successful agricultural chemical is identified. Before any new product is released to the agricultural community \$40 million and 8 to 10 years in development and regulatory research is required. Weed control technology in the future will be more specific in regard to needs (problem - specific chemicals), application techniques and mixtures. Setting such direction requires greater emphasis on existing weed control problems and the specifics of technology delivery and acceptance.

INTRODUCTION

Weed control technology, what is it? We know weeds have been defined as plants which are growing where they are not desired, or plants out of place. Therefore the development of new and better systems to control weeds must be considered technology. But why does weed control technology advance? What is the driving force behind new technology? Is it science, concern for mankind, profit, environmental pressure or food production? I think we would all agree that these factors and many others are involved. However, a major, but often ignored, factor is farmer need. Weed control is as old as food crop production, and farmers will always want to control weeds faster, longer, safer and cheaper than ever before.

From total weed control by hand labor to Jethro Tull and Horse-Hoeing Husbandry to the current technology we continue to look for a better way to control weeds. We, scientists of government, the private sector and universities must be aware of the needs and problems of the grower. We cannot just forge ahead, we need prioritized objectives. Answers to specific questions are required.

- What does the producer (farmer) need?
- Can the farmer become more profitable or efficient?
- Would a solution to the problem make a significant contribution, i.e. does everyone benefit?
- Does an opportunity exist?
- Does the opportunity justify the effort?

- Who has the capability of solving the problem?
- Will resources limit technological development?
- Does a company have property rights protection in order to generate profit from its investment?
- Is the new technology environmentally safe?
- Does the registration process encourage new technology?
- Will the farmer accept and use the new technology?

As a general premise the primary constraints of industry or other institutions developing new technology are financial and human resources.

No one has unlimited resources to address all potential opportunities and subsequently projects are prioritized based on market size, potential and return on investment. Therefore, until the needs are identified and prioritized little is accomplished.

Needs

Weeds are plants that are neither all bad nor all good, depending upon your viewpoint. Weeds provide employment for local and transient labor hired to remove them. They provide physicians and veterinarians patients who are afflicted with allergies, skin disorders and poisoning due to exposure to pollen or poisonous chemicals the weeds produce. However, weeds can provide ground cover to prevent or reduce wind and water erosion or they can cover scars on the landscape created by man and nature. At other times weeds can be forage for livestock or flowers for the weary traveller. Therefore, it is important to identify specific needs or problems, prior to our decision to proceed toward a solution to a non-existent problem.

Each of us is cognizant of the impact of weeds on world food production. By their presence weeds compete for light, water, plant nutrients and space. The average estimated annual crop loss in the United States due to weeds is more than \$5 billion. Worldwide the losses could be more than double this figure. Yield and quality losses of rice have been estimated at 15% in the U.S. and 10% for the world. Annual crop losses due to weeds are estimated at 12% of the production value in Asia and almost 10% worldwide. Without question the opportunities for new weed control technology in Asia are significant as annual production currently involves more than 200 million hectares.

Once farmer needs are established, the size of the market alone does not justify a decision to invest in developing new herbicides and new technology, especially when the costs of development and introduction are considered.

The nature of the problem of the farmer must be clearly defined. If the chemist, laboratory scientist or agronomist does not have a clear understanding of target weeds, soils, cropping practices and climate, valuable time and resources can be allocated to non-productive efforts.

The economic situation of the world markets must be evaluated to assess farmer

profitability if a new product is used. In addition, the impact of a new product on the immediate community is also critical. If the introduction of a new product diminishes or abolishes the need for the existing labor in a country where agriculture is the only way of life, the negative impact on society may offset the technological advantage.

Regulations within each country must be scrutinized in order to proceed quickly and smoothly through the registration process to prevent delay of potential sales. Property rights or patent laws must also be reviewed to determine whether new technology will be protected. Without protection, investment of new technology by large companies is questionable.

Evaluation of the human resources available to address the needs is also critical. Without the scientific expertise and directional commitment the endeavor will fail. Our efforts, yours and mine, must address the needs of our people and our countries. If the current technology is acceptable or the market prevents investment in a product, we must be willing to accept the fact and address other important issues.

Development

New weed control opportunities are very often difficult to define, and many times discovery of a solution is even more difficult. It has been estimated that of the 20-30,000 chemical compounds synthesized each year, only one will have the possibility of being a commercial success. A compound is not identified as successful until it reaches the market and is utilized by the farmer. In order to become a market reality, an initial investment cost of nearly \$30 million is involved excluding the cost of a manufacturing facility. These costs include initial screening, product development and registration costs. The manufacturing facility may add anywhere from \$20-40 million to that initial cost. Using these factors, it is easy to understand why the agricultural chemical industry is a high technology, high risk business.

Weed control problems and weed control solutions continue to be more difficult to solve. In fact, addressing producer needs is becoming a more exact science as our technology becomes more advanced. As an example, consider the rate requirements of some of the new products. Rather than measuring ingredients in *kg/ha*, we are now required to use *g/ha*. Rather than using graduated cylinders and 1 litre or 5 litre containers, we are using pipettes and 250 *ml* bottles for transfer and also storage. Not only is rate more critical, but so is application technique. Spray overlap or double spraying of an area can create adverse biological response on desired vegetation.

Why have the investment costs increased so dramatically? Research and development requires financial and human resources. Consider the research facilities which exist in the private sector and within your own institutions.

The funding and maintenance of the laboratories to develop new chemistry becomes increasingly more expensive as are the scientists who conduct the experiments. At the same time, additional governmental regulations may be responsible for some of

the additional costs in introducing new compounds and may in part be responsible for some of the decline in new product introductions. However, the decline should not be construed to be negative. If the regulations provide safer products the farmer at an affordable price, everyone benefits.

Less money is being invested and devoted to synthesis, screening and field development of new products, while more and more money is being spent for registration, administration, environmental testing and residue analysis. The shift in monetary allocations has been attributed to a combination of increased public awareness, increased public concern, and increasingly stringent regulatory requirements. These new requirements have not only increased the capital expenditures, but have also lengthened the overall development and registration process. However, in areas where patents do not exist or where registration requirements are minimal, companies are allowed to sell quasi look-alike products without the investment cost of discovery, screening and development. These manufacturers are allowed to reap the rewards of research without establishing safety, toxicology and efficacy data required of the original registrant. When this type of activity prevails in the marketplace, large companies, those willing to initially invest in the development of new products, become more and more skeptical, and less willing to invest in the future growth and development of this world countries. The end result of these activities is that the farmer, the end user, is the one who is screened from obtaining the new technology so much required to meet his growing needs for greater productivity and greater monetary returns on his investment to meet some of his own personal goals.

Let me re-emphasize, the development of new agricultural chemical technology, new agricultural herbicides, is a time-consuming capital intensive process. In order for new technology to expand to new countries, particularly the developing countries, protective legislation of some type is required. The most common protection would come through patent laws, whereby a government permits the inventor exclusive rights to the invention for a fixed period of time in order to recover investment costs and to secure a profit. There is little incentive to invest in new weed control technology without patent protection because investment capital could be channeled into other areas. Another means of protection is through more stringent regulatory requirements within the developing countries. Strong regulatory guidelines that honor confidentiality and the exclusive use of the data submitted by the originator of that data can be nearly as strong as patent laws. Costly and time-consuming procedures, mandatory toxicology, metabolism and residue data will encourage the spread of technology in the best interest of the citizens of the receiving countries. Regulatory agencies should be concerned with the company that says "our product is just like product 'X'". The registration officials have no means of knowing the chemical properties of a compound unless data is submitted to support the claims. The officials have no knowledge of the toxicology or the toxicological properties of these look-alike products and most certainly have no guarantees of the safety of the product. In addition the registration officials may have little knowledge of the product efficacy as opposed to the original registrant who has invested a great deal of time and effort establishing the technical fit of the product which maintains the product name in many areas. Without product awareness, look-alike products would not exist.

Constraints

What will limit the development of new agricultural chemicals? One possibility could be investment cost. In the next few years, a greater proportion of the development burden will be carried by a limited number of companies. Unless investment incentives are established, the influx of new technology will decrease. These incentives could be patent protection/establishment or uniform registration requirements.

A second constraint could be the delivery of technology to the end user. The delivery will involve registration, product protection and an effective infrastructure for adoption. Once established, who conveys the message to the farmers? Can the industry do it alone? I doubt it, only a concerted effort by the agricultural community expands technology. Scientists are required to develop the technical fit, an extension system must spread the information to the farmer and rural credit must be available. Coupled with delivery is the acceptance of the new technology. What benefit is the technology to the farmer? In some cases, the benefit may be indirect. New products may replace old ones because of new environmental or regulatory standards. The farmer must be made aware of these requirements while meeting his specific needs. New registration requirements could become a challenge to some companies, but regardless of our affiliation, we have certain environmental responsibilities. As part of the respective communities, we must provide products and information to the people to relieve their fear of pesticides in the environment, if we expect herbicide use and development to expand.

I think the future holds some very unique opportunities for all of us. New and better herbicides will be developed to meet farmer need and expectations. To address the ever increasing weed pressures and weed spectrum shifts, mixtures will become more prevalent. In some situations, old products will have new life as a result of these mixtures.

Large untapped market opportunities may not be as easy to identify, giving rise to numerous products developed to be problem specific.

Genetic engineering will establish new parameters for crop production. New herbicide tolerant varieties will invade the marketplace bringing new meaning to herbicide selectivity. Imagine engineered tolerance to glyphosate or other non-selective products.

Safeners, herbicide antidotes and extenders will expand from grain sorghum and rice to other major annual crops throughout the world.

The herbicide application techniques will continue to develop. Backpack sprayers will ultimately be replaced by tractor drawn sprayers, and airplanes. In some speciality markets, small motorized spot sprayers and selective equipment will become standard equipment.

The limitation in the development of new compounds or technology will arise from the constraints of our own creativity and imagination. New ideas and identification of opportunities rest with us. The development and expansion of weed control technology provides us great opportunity and also a great deal of responsibility.

Each of us must continually strive for the safe and practical use of pesticides. If we entertain the idea of limiting use or limiting products we minimize the producer's ability to meet his needs. Our endeavors should search for means of making the farmer's task less tedious while increasing his productivity. Finally, when we talk about weed control technology in terms of needs, development and constraints, I think all of us need to be more aware that weed control technology is us. It is you and me striving to make agricultural production more efficient, more effective and more profitable to the producers in Asia-Pacific.

WEEDS PROBLEM IN THAILAND

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INTRODUCTION

Thailand is a Southeast Asian country in the tropical part of the world. It is located between latitude 6 and 20 degree north, and longitude 98 and 106 degree east. The land area is 51.4 million hectares, of which 19.4 million hectares are for farm use. It can be approximately divided as follows: paddy land 60.60 %, field crops 22.60 %, fruit crops & tree crops 9.40 %, grassland 0.63 %, horticultural crops 0.24 %, and the rest is unclassified.

With quite a good distribution of high rainfall over the long period in a year, weed is considered to be serious throughout the country, especially in the rainy season. Crop losses due to weeds in Thailand was reported by Suwanketnikom and Suwanmek. For example the yields of peanuts, sugarcane (3) cassava and pineapple (2) in weedy plantings were reduced more than 60 %, whereas kenaf, cotton, tobacco (4) corn and sorghum had yield reduced 50 %, or more.

Infestation area

The weed infestation area can be divided into three general categories, weeds in cropped area, non-cropped area and aquatic area.

Problems of weeds in crops

Weed problem in crops is considered very serious. The main problem caused by weed is the reduction of yield.

Lists of weed species in crops

Rice is the major crop that cover 60.6%, of agricultural area. Weed species are varied with the methods of planting and also location. The principle weeds encountered in dry seeded rice and water seeded rice are shown in Table I

In upland rice, weed species are more or less the same as in uplands crops in those region (see table 2)

Table 1. Weeds mostly found in direct seeded rice (Wongsaroj, p. 1985 personal communication)

Weed species	Dry seeded rice	Pre-germinating rice	Transplanted rice
<i>Ischaemum rugosum</i> Salisb	X X		
<i>I. barbatum</i> Retz	X X		
<i>Echinochloa colonum</i> (L.) Link	X		
<i>Oryza ridleyi</i> Hook.p	X		
<i>Pentapetes phrenicea</i> Linn	X		
<i>Echinochloa crus-galli</i> (L.) Beux		X	
<i>Sphenoclea zeylanica</i> Gaertn		X	X
<i>Cyperus difformis</i> Linn		X	
<i>Monochoria vaginalis</i> (Burm. f) Presl			X
<i>Chara zeylanica</i> Kl. en Willd.			X
<i>Fimbristylis miliacea</i> Vahl			X
<i>Marsilea crenata</i> Presl.			X

Table 2. Weed species in crops¹ other than rice mostly found in each region and regional location of Thailand(1)

Weed species	Central					
	Upper	East	West and Lower	North-east	North	South ²
<i>Ageratum conyzoides</i> Linn.		X		X	X	X
<i>Alternanthera sessilis</i> (L.) DC.	X				X	
<i>Alysicarpus vaginalis</i> (L.) DC.		X		X		
<i>Amaranthus viridis</i> Linn.	X	X	X	X	X	X
<i>A. spinosus</i> Linn.	X	X	X	X		X
<i>Aniscia martinicensis</i> (Jacq.) Choisy		X		X		
<i>Axonopus compressus</i> (Sw.) P. Beauv.						X
<i>Boerhavia erecta</i> Linn.	X	X		X		
<i>Borreria latifolia</i> (Lam.) Griseb						X
<i>Brachiaria milliformis</i> (Presl) A. Chase (vide Bov)						X
<i>B. paspaloides</i> (Presl) C.E. Hubb.						X
<i>B. reptans</i> (L.) Gard. et Hubb	X	X	X	X		X
<i>Cenchrus echinatus</i> Linn.		X	X	X		
<i>Chloris barbata</i> Sw.	X		X	X		X
<i>Commelina benghalensis</i> Linn.	X			X		X
<i>C. diffusa</i> Burn. f.	X	X		X		
<i>Corchorus aestuans</i> Linn.		X		X		
<i>C. iria</i> Linn.		X			X	
<i>C. rotundus</i> Linn.	X	X	X	X	X	X
<i>Cynodon dactylon</i> (L.) Pers.				X	X	
<i>Dactyloctenium aegyptium</i> (L.) P. Beauv.	X	X	X	X	X	X
<i>Digitaria adscendens</i> (HBK) Henr.	X	X	X	X	X	X
<i>Echinochloa colonum</i> (L.) Link	X	X	X	X	X	X
<i>Eclipta prostrata</i> Linn.				X	X	
<i>Eleusine indica</i> (L.) Gaertn.	X	X	X	X	X	X
<i>Eupatorium odoratum</i> Linn.		X		X	X	X
<i>Euphorbia geniculata</i> Orteg.	X	X	X	X	X	X

Table 2. Weed species in crops other than rice mostly found in each region and regional location of Thailand (continued).

Weed species	Central					
	Upper	East	West and Lower	North-east	North	South ²
<i>E. hirta</i> Linn.	X	X		X	X	X
<i>Gomphrena celosioides</i> Mant.	X			X		
<i>Gynandropsis gynandra</i> (L.) Brig.		X		X		X
<i>Hyptis suaveolens</i> Poit		X		X		
<i>Heliotropium indicum</i> Linn.	X	X		X	X	
<i>Imperata cylindrica</i> (L.) Beauv.						X
<i>Ipomoea gracilis</i> R. Br.	X	X		X	X	
<i>Lagascea mollis</i> Cav.	X	X				
<i>Leptochloa chinensis</i> (L.) Nees.	X	X		X	X	
<i>Mikania cordata</i> (Burm.f.) B.L. Robinson						X
<i>Mimosa pudica</i> Linn.						X
<i>Mollugo pentaphylla</i> Linn.	X	X		X		
<i>Ottolochloa nodosa</i> (Kunth) Dandy						X
<i>Oxalis corniculata</i> Linn.					X	
<i>Paederia</i> spp. Linn.	X	X		X	X	
<i>Paspalum commersonii</i> Lank.						X
<i>Paspalum conjugatum</i> Berg.						X
<i>Passiflora foetida</i> Linn.			X	X		X
<i>Pennisetum pedicellatum</i> Trin.	X	X	X	X		X
<i>P. polystachyon</i> Schult.	X	X	X	X		X
<i>P. setosum</i> (Swartg.) L.C. Rich		X	X			X
<i>Physalis minima</i> Linn.	X	X		X	X	
<i>Portulaca oleracea</i> Linn.	X	X	X	X	X	
<i>Richardia brasiliensis</i> Gomez.		X		X		
<i>Rottboellia exaltata</i> Linn.f.		X		X		
<i>Scoparia dulcis</i> Linn.	X	X				X
<i>Sida acuta</i> Burm f.	X			X		X
<i>Trianthema portulacastrum</i> Linn.	X	X	X	X		
<i>Triclaoum rosea</i> Nees. (<i>Rhynchelytrum repens</i>)			X			X
<i>Tridax procumbens</i> Linn.	X	X	X	X		
<i>Tribulus terrestris</i> Linn. (also <i>T. celosioides</i>)			X			
<i>Vernonia cineria</i> Less.	X		X	X		
<i>Xanthium</i> sp. Linn.					X	

1/ Crops chiefly grown in each location will be as follows :

Upper Central - corn, sorghum, soybeans, mungbeans, peanuts, cotton, and sugarcane.

East Central - cassava, sugarcane, and pineapple.

West and Lower Central

Central - sugarcane, pineapple, and coconut

Northeast - kenaf, jute, cassava, corn, cotton, and sugarcane.

North - soybeans, tobacco, oranges, semi-tropical fruits (longans, lychees), vegetables shallots, garlics, cole crops)

East and South - rubber, coconut, oranges, and hot-and-humid zone fruits (durian, rambutans etc.). Actually, rubber and coconut is much more in the South than in the East, but conversely with fruits.

2/ Climatic conditions in the East are more or less similar to these in the South.

Upland Crops: Weed species in upland crops are not much different in each crop. They are slightly varied with the locations. Some weeds mostly found in locations are shown in table 2

Problems of weeds in non-cropped areas

Many non-cropped areas can be grasslands, eg roadsides, area under powerlines, telephone lines and other wastelands. Even though lots of them have turned into natural pasture, still many are heavily infested with weed, which are not useful to livestock, directly or indirectly. Their attributes could be interfering with animal grazing activities such as plants with thick and sharp spines, having low nutrient value, and affecting the quality of animal products. However, probably all of the weeds are competitive to the useful plants more or less.

The general weeds in this area are perennial broadleaf weeds, such as *Mimosa pigra*, *M. pudica*. The annual broadleaves mostly found are *M. invisa*, *Cassia tora*, *C. occidentalis*, *Sida acuta*, *Achyranthes aspera* and *Euphorbia geniculata*. Perennial grasses consist of *Heteropogon contortus*, *Saccharum spontaneum*, *Imperata cylindrica*, *Pennisetum setosum* and bamboo plants. Annual grasses considered noxious in noncropped areas are *Pennisetum polystachyon*, *P. pedicellatum* and *Rotboellia exaltata*.

Problems of weeds in aquatic area (5)

Thailand and Southeast Asia in general have been subjected to introduction of several aquatic and terrestrial weed species which have become noxious pests, as *Eichhornia crassipes*, (water hyacinth) and *Mimosa pigra*, (giant mimosa). The explosive growth of aquatic weeds especially introduced weeds, has significant impact on agriculture, irrigation, fisheries, hydroelectric power, wildlife conservation, public health, recreation, flood control, drainage and inland navigation. Aquatic weeds are well established in all types of water system. The major aquatic weeds are *Eichhornia crassipes*, *M. pigra*, *Hydrilla verticillata*, *Potamogeton* spp., *Coix aquatica*. In addition, several potential weed species are present, including *Salvinia cucullata*, *Najas graminea*, *Eleocharis dulcis*, *Pistia stratiotes*, *Colocasia esculentum* and *Nymphaea lotus*. A list of aquatic plants present in Thailand is in table 3

Table 3 Some aquatic plants present in Thailand

Scientific Name	Common Name	Community
<i>Blyxa japonica</i> (Miq) Maxim		Submerged
<i>B. echinosperma</i> (Clarke) Hook		Submerged
<i>Ceratophyllum demersum</i> Linn.	coontail	Submerged
<i>Chara zeylanica</i> Kl ex Willd.		Submerged
<i>Hydrilla verticillata</i> (Lin.f.) Royle	Florida elodea	Submerged
<i>Limnophila heterophylla</i> (Roxb.) Benth		Submerged
<i>Myriophyllum brasiliense</i> Camb.	parrot feature	Submerged
<i>Najas graminea</i> Dilile	grassy naiad	Submerged
<i>Ottelia alismoides</i> (Lin.) Pers	ottelia	Submerged
<i>Potamogeton malayanus</i> Miquel	pondweed	Submerged
<i>Salvinia cucullata</i> Roxb.		Floating

Scientific Name	Common Name	Community
<i>Azolla pinnata</i> R. Br.	water velvet	Floating
<i>Eichhornia crassipes</i> (Mart.) Solms	water hyacinth	Floating
<i>Lusitana repens</i> Linn.		Floating
<i>Lemna minor</i> L.	duckweed	Floating
<i>Pistia stratiotes</i> L.	water lettuce	Floating
<i>Salvinia cucullata</i> Roxb. ex. Bory	floating waterfern	Floating
<i>Trapa bispinosa</i> Roxb.	water chestnut	Floating
<i>Alternanthera philoxeroides</i> (Mart.) Griseb	alligator weed	Emerged
<i>Coix aquatica</i> L.	coix	Emerged
<i>Colocasia esculentum</i> (L.) Schott	elephant ear	Emerged
<i>Cyperus corymbosus</i> L.	Sedge	Emerged
<i>C. difformis</i> L.	Sedge	Emerged
<i>C. digitatus</i> Roxb.	Sedge	Emerged
<i>C. iria</i> L.	Sedge	Emerged
<i>C. papyrus</i> L.	papyrus plant	Emerged
<i>C. procerus</i> Rottb	Sedge	Emerged
<i>C. pulcherinus</i> Willd. ex Kunth	Sedge	Emerged
<i>C. rotundus</i> L.	purple nutsedge	Emerged
<i>Eleocharis dulcis</i> (Burm f.) Hensched	spikerush	Emerged
<i>Fimbristylis miliacea</i> (L.) Vahl	Fimbristylis	Emerged
<i>Ipomoea aquatica</i> Forsh	aquatic morning glory	Emerged
<i>Limnocharis flava</i> (L.) Bucher		Emerged
<i>Monochoria hastata</i> (L.) Solms	monochoria	Emerged
<i>M. vaginalis</i> (Burm.f.) Presl		Emerged
<i>Nelumbo nucifera</i> Gaertn	water lotus	Emerged
<i>Nymphaea lotus</i> Linn.		Emerged
<i>Polygonum tomentosum</i> Willd.	water smartweed	Emerged
<i>Scirpus articulatus</i> Linn.		Emerged
<i>S. grossus</i> Lin. f.	bulrush	Emerged
<i>Brachiaria mutica</i> (Forsk) Stapf	paragrass	Marginal
<i>Echinochloa colonum</i> (L.) Link	jungerice	Marginal
<i>E. crusgalli</i> (L.) Link	barnyardgrass	Marginal
<i>Leersia hexandra</i> Sw.	cutgrass	Marginal
<i>Mimosa pigra</i> L.	giant sensitive plant	Marginal
<i>Panicum repens</i> Linn.	torpedograss	Marginal
<i>Pseudoraphis spinescens</i> (R.Br.) Vicherey		Marginal
<i>Salix tetrasperma</i> L.		Marginal
<i>Typha angustifolia</i> Linn.		Marginal

The most recent serious weed outbreak in Thailand is *M. pigra*, an herbaceous leguminous plant introduced into the country around 1960. Two *Mimosa* species were introduced by the Thai farmers in Chiangmai for the primary purpose of erosion control. The dominant species, *M. pigra*, has experienced a marked increased in distribution and density since 1977.

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Table 4. The most abundant aquatic plants present in Thailand

Plant Species	Part	Aquatic Systems
1. <i>Eichhornia crassipes</i>	C, NE, N, S	canals, rivers, lakes
2. <i>Mimosa pigra</i>	N, C	canals, lakes, rivers
3. <i>Hydrilla verticillata</i>	N, NE, S	lakes, canals
4. <i>Potamogeton malaianus</i>	NE, S, C	canals, lakes
5. <i>Coix aquatica</i>	C	canals, rivers
6. <i>Salvinia cucullata</i>	NE, C	lakes
7. <i>Najas graminea</i>	N, NE	canals, lakes
8. <i>Eleocharis dulcis</i>	NE	lakes
9. <i>Pistia stratiotes</i>	N, C	lakes
10. <i>Colocasia esculentum</i>	C, NE	rivers, lakes

N.B. C = Central Region N = North Region
 NE = Northeastern Region S = Southern Region

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A DRY SEASON LOWLAND RICE FIELD WEED SURVEY IN CENTRAL AND SOUTHERN LUZON, PHILIPPINES

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ABSTRACT

A survey of lowland rice (*Oryza sativa* L.) field weeds was carried out in nine provinces in central and southern Luzon, Philippines between January 22 and April 10, 1985. A total of 410 fields were assessed at the heading to flowering stages of rice. Thus, the data provide information on weeds which are surviving the weed control measures applied by the farmer. A total of 61 weed species were found with 17 species occurring in more than 20% of the fields surveyed. Sixteen species were found in all the provinces while 19 were found in only one province. The most commonly occurring species were *Monochoria vaginalis* (Burm. f.) Presl and *Echinochloa glabrescens* Munro ex Hook. f.

INTRODUCTION

Rice fields can be colonized by terrestrial, semi-aquatic, or aquatic plants depending on the type of rice culture and also on the season (Moody and Drost, 1983). In rainfed rice fields, all three communities occupy the same physical location at different times of the year. During cultivation lowland rice fields are subjected to flooding, plowing, and turning up of the substrate followed by a period of rice monoculture. This period is usually short because the field is rapidly invaded by weeds (Moody and Drost, 1983).

Recently disturbed habitats such as planted fields have a natural flora of plants adapted to survive in such conditions (Grime, 1979). All plant species are affected by climatic, edaphic, and biotic factors. Weeds are the product of their natural environment. Studies of existing weed communities are important for their management and control. A knowledge of community patterns and the effect of edaphic, climatic, and biotic factors on growth and reproduction, help to gain insight into the mechanism of specialization and distribution of the species (Moody, 1983).

A survey of lowland rice field weeds was carried out in nine provinces in central and southern Luzon, Philippines in the wet season in 1984 by Pablico and Moody (1985). A total of 56 weed species assigned to 40 genera and 22 families were found. The most commonly occurring weed species were *M. vaginalis*, *E. glabrescens*, and *Ludwigia octovalvis* (Jacq.) Raven.

The objective of this survey was to repeat the survey of lowland rice field weeds in the same areas during the dry season of 1985 to determine the seasonal effect on weed occurrence.

MATERIALS AND METHOD

This survey of lowland rice fields in the heading to flowering stages was carried out in central and southern Luzon, Philippines between January 22 and April 10, 1985. The survey was carried out in the same provinces (Fig. 1) as those surveyed in the wet season (Pablico and Moody, 1985). The same route and the same survey method were used as in the previous survey. Fields adjacent to the road were assessed.

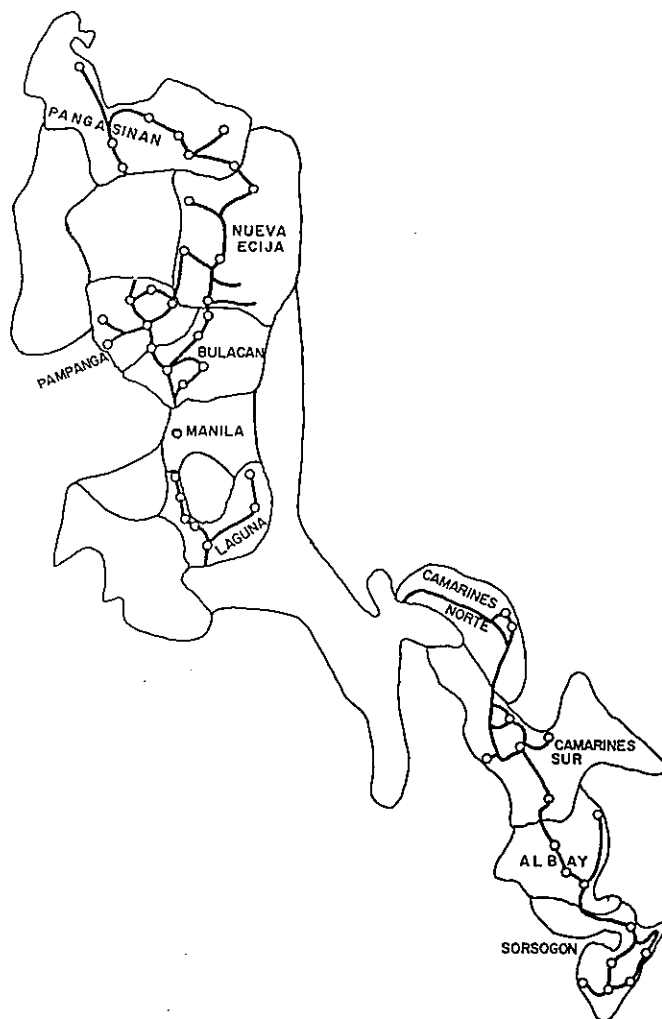


Fig. 1. Map of central and southern Luzon, Philippines indicating provinces surveyed and the major roads travelled.

Because the survey was conducted during heading and flowering of the rice crop, it does not include those weed species that were deliberately removed by the farmer. Only those species which are surviving the weed control measures applied were recorded. These represent the potential future weed control problems in lowland rice.

A total of 410 fields were assessed (Table 1); 303 were transplanted and the remainder were wet-seeded (pregerminated seed sown on puddled soil).

Table 1. Number of fields surveyed in nine provinces in central and southern Luzon, Philippines, 1985 dry season.

Province	Number of fields surveyed		
	Transplanted rice	Wet-seeded rice	Total
Pangasinan	60	3	63
Nueva Ecija	26	39	65
Pampanga	6	23	29
Bulacan	9	27	36
Laguna	44	0	44
Camarines Norte	30	0	30
Camarines Sur	39	14	53
Albay	41	0	41
Sorsogon	48	1	49
Total	303	107	410

In large scale rice growing areas, fields were assessed at approximately 1 km intervals and, wherever possible, on alternate sides of the road. When the rice growing areas were scattered, field assessment was done irrespective of the distance between the sites. However, every effort was taken to make certain that at least 1 km separated successive sampling sites.

Each field was surveyed by two people. The weeds growing above the rice canopy were scored for percentage cover by scanning the whole field; those occurring below the crop canopy were scored by carefully examining four locations, each approximately 1 m² in area, selected at random at each side of the field. The ratings were then averaged. The following rating scale was used: 0 = no weeds present; tr = a few scattered plants; 1 = 1-10% weed cover; 2 = 11-20% weed cover; 3 = 21-30% weed cover; 4 = 31-40% weed cover; 5 = 41-50% weed cover; 6 = 51-60% weed cover; 7 = 61-70% weed cover; 8 = 71-80% weed cover; 9 = 81-90% weed cover; and 10 = 91-100% weed cover.

RESULTS AND DISCUSSION

A total of 61 weed species assigned to 46 genera and 25 families were recorded in the survey area (Table 2). Of these 33 species were observed in less than 5% of the fields surveyed. Of the remaining 29 species, 4 were seen in 5 to 10% of the field's surveyed.

The number of weed species in the different provinces ranged from 27 (representing 14 families) in Bulacan and Laguna to 44 (representing 19 families) in Camarines Sur. The only families containing more than 10 species were the Poaceae (17) and the Cyperaceae (13) which together accounted for 49% of the weed species. Sixteen species were observed in all the provinces surveyed while 19 species were found in only one province. Seven weed species [*Corchorus olitorius* L., *Echinochloa stagnina* (Retz.) P. Beauv., *Fimbristylis dichotoma* (L.) Vahl, *Paspalum conjugatum* Berg., *Polygonum barbatum* L., *Rotala catholica* (Cham. & Schlecht.) B. van Leeuwen, and *Sesbania sesban* (L.) Merr.] which were found in the wet season (Pablico and Moody, 1985) were not observed in the dry season. However, 12 additional species which occurred in less than 5% of the fields surveyed were observed in the dry season (Table 2). Many of these reflecting the lack of water in the fields.

Table 2. Weeds occurring in lowland rice in nine provinces in central and southern Luzon, Philippines, 1985 dry season.

Family	Species	Province								
		Pangasinan	Pampanga	Nueva Ecija	Bulacan	Laguna	Camarines Norte	Camarines Sur	Albay	Sorsogon
Alismataceae	* <i>Sagittaria trifolia</i> L.	-	-	-	-	-	-	-	-	x
Amaranthaceae	<i>Alternanthera sessilis</i> (L.) DC.	x	-	x	x	x	x	x	x	-
Araceae	<i>Pistia stratiotes</i> L.	x	x	x	x	x	x	x	x	x
Asteraceae	*† <i>Ageratum conyzoides</i> L.	-	x	-	-	-	-	x	x	-
	<i>Eclipta alba</i> (L.) Hassk.	x	x	x	x	x	x	x	x	x
	<i>Sphaeranthus africanus</i> L.	x	x	x	x	x	x	x	-	x
Capparaceae	*† <i>Vernonia cinerea</i> (L.) Less.	-	-	-	-	-	-	x	-	-
	**† <i>Cleome rutidosperma</i> DC.	-	x	-	-	-	-	x	-	-
Commelinaceae	*† <i>Commelina benghalensis</i> L.	-	-	-	-	-	-	x	-	-
	<i>Commelina diffusa</i> Burm. f.	x	x	x	x	x	x	x	x	x
Convolvulaceae	<i>Ipomoea aquatica</i> Forssk.	x	x	x	x	x	x	-	-	x
	† <i>Ipomoea triloba</i> L.	-	-	-	-	-	-	x	x	-
Cyperaceae	* <i>Cyperus compactus</i> Retz.	-	-	-	-	-	-	-	x	-
	<i>Cyperus difformis</i> L.	x	x	x	x	x	x	x	x	x
Cyperaceae	<i>Cyperus distans</i> L.F.	-	x	-	-	-	-	-	-	x
	(continued) * <i>Cyperus imbricatus</i> Retz.	-	-	-	x	-	x	x	x	-
	<i>Cyperus iria</i> L.	x	x	x	x	x	x	x	x	x
	** <i>Cyperus pilosus</i> Vahl	-	-	-	-	-	-	x	-	-
	<i>Cyperus rotundus</i> L.	x	x	x	-	-	-	x	-	-
	<i>Fimbristylis acuminata</i> Vahl	-	-	-	-	-	-	-	x	-
	<i>Fimbristylis miliacea</i> (L.) Vahl	x	x	x	x	x	x	x	x	x
	<i>Fuirena ciliaris</i> (L.) Roxb.	x	x	x	x	-	x	x	x	x
	* <i>Scirpus grossus</i> L.f.	x	-	-	-	-	-	x	x	x
	<i>Scirpus maritimus</i> L.	x	x	x	-	x	x	x	-	x
	<i>Scirpus supinus</i> L.	x	x	x	x	x	x	x	x	x
Eriocaulaceae	* <i>Eriocaulon cinereum</i> R.Br.	-	-	-	-	-	-	-	-	x
Euphorbiaceae	† <i>Phyllanthus fraternus</i> Webster	x	-	-	-	-	-	-	-	-
Lamiaceae	<i>Hyptis capitata</i> Jacq.	-	x	-	-	-	-	-	-	-
Lythraceae	<i>Ammannia coccinea</i> Rottb.	x	x	x	x	x	x	x	x	x

Table 2. Continued.

Family	Species	Province								
		Pangasinan	Pampanga	Nueva Ecija	Bulacan	Laguna	Camarines Norte	Camarines Sur	Albay	Sorsogon
Malvaceae	† <i>Urena lobata</i> L.	-	-	-	-	-	-	x	-	-
Marsileaceae	<i>Marsilea minuta</i> L.	x	x	x	x	x	-	x	x	x
Mimosaceae	† <i>Mimosa pudica</i> L.	x	x	-	-	-	-	x	-	-
Onagraceae	<i>Ludwigia adscendens</i> (L.) Hara	-	x	x	x	x	x	x	x	x
	<i>Ludwigia octovalvis</i> (Jacq.) Raven	x	x	x	x	x	x	x	x	x
Papilionaceae	<i>Aeschynomene indica</i> L.	x	x	x	x	x	x	x	x	-
	**† <i>Calopogonium mucunoides</i> Desv.	-	-	-	-	-	-	x	-	-
	* <i>Macroptilium lathyroides</i> (L.) Urb.	-	-	-	x	-	x	x	x	-
	** <i>Ceratopteris thalictroides</i> (L.) Brogn.	-	-	-	-	-	-	x	-	x
Poaceae	<i>Brachiaria mutica</i> (Forsk.) Stapf	x	x	-	-	-	-	x	x	-
	<i>Cynodon dactylon</i> (L.) Pers.	-	x	-	x	x	-	-	-	-
	† <i>Dactyloctenium aegyptium</i> (L.) Willd.	x	-	-	-	-	-	-	-	-
	** <i>Digitaria ciliaris</i> (Retz.) Koel	-	x	-	-	-	-	-	-	-
	<i>Echinochloa colona</i> (L.) Link	x	x	x	x	x	x	x	x	x
	<i>Echinochloa crus-galli</i> (L.) Beauv. ssp. <i>hispidula</i> (Retz.) Honda	x	x	x	x	x	x	x	x	x
Poaceae (continued)	<i>Echinochloa glabrescens</i> Munro ex Hook.f.	x	x	x	x	x	x	x	x	x
	† <i>Eleusine indica</i> (L.) Gaertn.	-	x	-	-	-	-	-	-	-
	<i>Isachne globosa</i> (Thunb.) O.K.	-	-	-	-	-	-	x	x	x
	* <i>Ischaemum polystachyum</i> Presl.	-	-	-	-	-	-	-	-	x
	<i>Ischaemum rugosum</i> Salisb.	x	x	x	x	x	x	x	x	x
	<i>Leersia hexandra</i> Sw.	x	x	x	-	x	x	x	x	x
	<i>Leptochloa chinensis</i> (L.) Nees	x	-	x	-	x	x	x	x	x
	** <i>Panicum repens</i> L.	-	-	x	-	-	-	-	-	x
	<i>Paspalum paspalodes</i> (Michx.) Scribn.	x	x	x	x	x	x	x	x	x
	<i>Sporobolus diander</i> (Retz.) P. Beauv.	-	-	-	-	-	-	-	-	x
Pontederiaceae	<i>Monochoria vaginalis</i> (Burm.f.) Presl	x	x	x	x	x	x	x	x	x
Rubiaceae	* <i>Borreria ocymoides</i> (Burm.f.) DC.	x	-	-	-	-	-	-	-	-
	<i>Hedyotis corymbosa</i> (L.) Lam.	-	-	x	-	-	-	x	-	-
Scrophulariaceae	<i>Lindernia antipoda</i> (L.) Alston	x	x	x	x	x	x	x	x	x
Solanaceae	† <i>Physalis angulata</i> L.	-	x	-	-	-	-	-	-	-

Table 2. Continued.

Family	Species	Province								
		Pangasinan	Pampanga	Nueva Ecija	Bulacan	Laguna	Camarines Norte	Camarines Sur	Albay	Sorsogon
Sphenocleaceae	<i>Sphenoclea zeylanica</i> Gaertn.	x	x	x	x	x	x	x	x	-
Sterculiaceae	<i>Melochia concatenata</i> L.	-	x	-	-	-	-	-	-	-
Number of families		17	18	15	14	14	13	19	14	14
Number of species	61	33	37	30	27	27	28	44	32	34

*Not observed in wet-seeded rice.

**Not observed in transplanted rice.

†Not observed in wet season 1984.

Of the weed species listed in Table 2, 6 were not found in transplanted rice and 1 were not found in wet-seeded rice.

The ten most commonly occurring weed species in the different provinces are listed in Table 3. Of these species, *M. vaginalis*, *E. glabrescens*, *Fimbristylis miliacea* (L.) Vahl, and *L. octovalvis* were among the top ten in all provinces while *Paspalum paspalodes* (Michx.) Scribn. was among the top ten in eight provinces. In the dry season *Scirpus supinus* L. was among the top ten weed species in seven provinces in contrast to eight in the wet season (Pablico and Moody, 1985) while *Ischaemum rugosum* Salisb. was among the ten most commonly occurring weed species in only one province in contrast to eight in the dry season. *I. rugosum* was a much less important component of the weed flora in the dry season than the wet season. On average, it was the eight most commonly observed weed species in the wet season whereas in the dry season it ranked twentieth. Six species (see Table 3) were among the ten most commonly observed species in only one province.

Nine of the ten most commonly occurring weed species, averaged across all provinces, are annuals and one, *P. paspalodes* is a perennial. Of the 21 species listed in Table 3, 6 are grasses, 5 are sedges, and 3, *M. vaginalis*, *Pistia stratiotes* L., and *Commelina diffusa* Burm. f., are broadleaf monocotyledonous weeds. Of the top ten, four are grasses and three are sedges.

Except for *Cyperus distans* L.f. which occurred in less than 5% of the fields surveyed, all of the species listed in Table 3 were found in more than 10% of the fields. Additional weed species which occurred in more than 10% of the fields surveyed but were not ranked among the ten in any province were *Echinochloa colona* (L.) Link, *Fuirena ciliaris* (L.) Roxb., *Ipomoea aquatica* Forssk., and *Ludwigia adscendens* (L.) Hara.

Table 3. The ten most commonly occurring weed species in lowland rice in nine provinces in central and southern Luzon, Philippines, 1985 dry season.

Weed species	Province									
	Pangasinan	Pampanga	Nueva Ecija	Bulacan	Laguna	Camarines Norte	Camarines Sur	Albay	Sorsogon	Average
<i>Monochoria vaginalis</i>	3	2	2	3	2	2	3	1	1	1
<i>Echinochloa glabrescens</i>	2	1	1	2	5	3	2	8	10	2
<i>Paspalum paspalodes</i>	1	2	3	1	1	1	5	6	-	3
<i>Fimbristylis miliacea</i>	4	10	4	5	7	5	1	3	4	4
<i>Scirpus supinus</i>	5	6	8	-	-	6	6	4	7	5
<i>Ludwigia octovalvis</i>	8	8	5	6	10	6	10	7	3	6
<i>Echinochloa crus-galli</i> spp. <i>hispidula</i>	-	-	7	6	9	6	-	2	2	7
<i>Lindernia antipoda</i>	9	10	-	9	6	3	10	-	6	8
<i>Cyperus difformis</i>	6	4	-	-	4	-	8	-	-	9
<i>Leersia hexandra</i>	7	-	-	-	-	-	4	-	-	10
<i>Cyperus iria</i>	-	-	6	9	-	-	7	10	-	11
<i>Eclipta alba</i>	-	5	8	4	-	-	-	8	-	13
<i>Narsilea minuta</i>	-	5	8	4	-	-	-	8	-	13
<i>Ammania coccinea</i>	10	-	-	-	-	-	-	-	-	14
<i>Commelina diffusa</i>	-	-	-	-	-	9	-	-	-	15
<i>Pistia stratiotes</i>	-	-	-	-	7	-	-	-	9	16
<i>Sphenoclea zeylanica</i>	-	7	-	-	-	-	-	-	-	17
<i>Isachne globosa</i>	-	-	-	-	-	-	-	4	5	18
<i>Ischaemum rugosum</i>	-	-	-	-	-	9	-	-	-	20
<i>Sphaeranthus africanus</i>	-	-	-	-	-	-	8	-	-	24
<i>Cyperus distans</i>	-	-	-	-	-	-	-	-	-	29

C. distans was an important weed only in Sorsogon province. In the dry season, it was observed also in Pampanga province (Table 2) whereas in the wet season it was observed in five provinces in addition to Sorsogon.

The most commonly occurring weeds in transplanted rice and wet-seeded rice and their severity of infestation are given in Table 4. In transplanted rice, the most commonly found species was *M. vaginalis* while it was *E. glabrescens* in wet-seeded rice. *M. vaginalis* occurred in only 49% of the wet-seeded rice fields in contrast to 82% of the transplanted rice fields. Eight species were common to both types of rice culture but the order in which they were ranked varied.

Species occurring in the top ten in transplanted rice in the dry season which did not occur in the top ten in the wet season were *C. diffusa* and *Commelina difformis* L. while *I. rugosum* and *Cyperus iria* L. dropped out of the top ten. *C. diffusa* which occurred in 60% of the transplanted rice fields was observed in only 12% of the wet-seeded fields while *Lindernia antipoda* (L.) Alston was observed in only 24% of the wet-seeded fields compared to 42% of the transplanted fields. Weed species occurring in the top ten in wet-seeded rice that did not occur in

the top ten in transplanted rice were *C. iria* and *Marsilea minuta* L. *C. iria* was observed in 25% of the transplanted fields while *M. minuta* was found in only 17% of these fields.

Table 4. Severity of infestation of the ten most commonly occurring weed species in transplanted and wet-seeded rice in nine provinces in central and southern Luzon, Philippines, 1985 dry season.

Weed species	Percent cover ^a											Total
	tr	1	2	3	4	5	6	7	8	9	10	
<i>Transplanted rice</i>												
<i>Monochoria vaginalis</i>	218	7	12	6	2	2	1	-	-	-	-	248 (8)
<i>Echinochloa glabrescens</i>	173	5	7	5	7	1	1	-	-	-	-	190 (6)
<i>Fimbristylis miliacea</i>	168	9	4	4	4	2	-	-	-	-	-	191 (6)
<i>Commelina diffusa</i>	182	-	-	-	-	-	-	-	-	-	-	182 (6)
<i>Paspalum paspalodes</i>	177	3	-	-	-	-	1	-	-	-	-	181 (6)
<i>Scirpus supinus</i>	153	1	2	1	-	-	-	-	-	-	-	157 (5)
<i>Ludwigia octovalvis</i>	147	1	-	2	-	-	-	-	-	-	-	150 (5)
<i>Cyperus difformis</i>	137	-	1	-	-	-	-	-	-	-	-	138 (4)
<i>Echinochloa crus-galli</i> spp. <i>hispidula</i>	100	-	8	11	7	2	2	-	-	-	-	130 (4)
<i>Lindernia antipoda</i>	125	1	2	-	1	-	-	-	-	-	-	129 (4)
<i>Wet-seeded rice</i>												
<i>Echinochloa glabrescens</i>	45	12	7	4	6	4	8	3	3	2	6	100 (9)
<i>Fimbristylis miliacea</i>	54	2	-	1	3	1	1	1	-	-	-	63 (5)
<i>Paspalum paspalodes</i>	50	1	1	-	1	-	1	-	-	-	-	54 (5)
<i>Monochoria vaginalis</i>	50	2	-	-	-	-	-	-	-	-	-	52 (4)
<i>Ludwigia octovalvis</i>	45	-	1	2	1	1	-	-	-	-	-	50 (4)
<i>Ludwigia octovalvis</i>	45	-	1	2	1	1	-	-	-	-	-	50 (4)
<i>Cyperus iria</i>	44	1	1	1	1	-	-	-	-	-	-	48 (4)
<i>Scirpus supinus</i>	41	-	3	1	2	-	-	-	-	-	-	47 (4)
<i>Marsilea minuta</i>	43	2	-	-	-	-	-	-	-	-	-	45 (4)
<i>Cyperus difformis</i>	42	-	2	-	-	-	-	-	-	-	-	44 (4)
<i>Echinochloa crus-galli</i> spp. <i>hispidula</i>	34	-	-	1	1	-	-	-	-	-	-	36 (3)

^a tr = a few scattered plants, 1 = 1-10% weed cover, 2 = 11-20% weed cover, 3 = 21-30% weed cover, 4 = 31-40% weed cover, 5 = 41-50% weed cover, 6 = 51-60% weed cover, 7 = 61-70% weed cover, 8 = 71-80% weed cover, 9 = 81-90% weed cover, 10 = 91-100% weed cover.

^b Percentage of fields infested indicated in parentheses.

M. vaginalis and *E. glabrescens* were the most commonly observed species in the area occurring in 73% of the fields surveyed. The other species occurring in 50% or more of the fields surveyed were *F. miliacea* (62%), *P. paspalodes* (57%), and *S. supinus* (50%). The remainder of the weed species listed in Table 4 were found in more than 20% of the fields surveyed. Other weed species that also occurred in more than 20% of the fields were *Ammannia coccinea* Rottb., *Eclipta alba* (L.) Hassk., and *Leersia hexandra* Sw.

As in the wet season, severe infestations (5 or greater) of any of the most commonly occurring weed species were relatively rare in transplanted rice. In wet-seeded rice, *E. glabrescens* had scores of five or greater in 26% of the fields in which it occurred. In six fields, the weed infestation was so severe that the crop was hardly discernible.

Similar relationships were observed in the occurrence of *E. glabrescens* and *Echinochloa crus-galli* ssp. *hispidula* (Retz.) Honda in the dry season as in the wet season. In Pangasinan, Nueva Ecija, Pampanga, and Camarines Sur, over 50% of the fields were infested with *E. glabrescens* alone, 10% or less of the fields were infested with *E. crus-galli* ssp. *hispidula* and less than 10% were infested with a mixture of the two species (Table 5). The reverse relationship was observed in Albay and Sorsogon. The reasons for this are not known but further research is planned to determine why.

Table 5. Percentage of fields infested with *Echinochloa glabrescens* and *Echinochloa crus-galli* ssp. *hispidula* and their mixture in six provinces in central and southern Luzon, Philippines, 1985 dry season.

Province	<i>Echinochloa glabrescens</i>	<i>Echinochloa crus-galli</i> ssp. <i>hispidula</i>	A + B	No A, No B
	(A)	(B)		
Pangasinan	78	0	8	14
Nueva Ecija	63	0	37	0
Pampanga	66	0	34	0
Camarines Sur	55	9	17	19
Albay	10	45	31	14
Sorsogon	4	51	29	16

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ALLELOPATHIC EFFECTS OF THE ROOT EXUDATES FROM THE OBNOXIOUS WEED, *Parthenium hysterophorus* L.

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ABSTRACT

A novel system called "Continuous Root Exudate Trapping System" was employed to investigate the allelopathic potentials of the hazardous weed, *Parthenium hysterophorus*. The setup allowed the collection of root exudates alone from an undisturbed living plant. The exudates, thus collected were separated into three fractions and each of them were tested against the germination and seedling growth of pearl millet seeds.

The greatest inhibition was found in the neutral fraction. Germination was significantly inhibited by all the fractions at all concentrations. With the seedling growth, radicle length was inhibited more than the plumule growth. Following the results of thin layer chromatography, it was concluded that Parthenin or any other major sesquiterpene lactone was not a part of the exudates from the roots of *Parthenium hysterophorus*.

INTRODUCTION

Allelopathy has been defined as the chemical warfare between plants (Putnam, 1983). There has been a constant flow of literature over a number of plants that are having allelopathic impact on other plants and on themselves. Rice (1979) has reported more than 400 of such studies in a review on allelopathy.

Allelochemicals or allelopathins are released by the donor plants from living leaves as volatiles or leachates or from roots through exudation or sloughing off of dead tissues or decaying plant litter or leaching from leaf litter on the soil surface (Putnam, 1983). It is important that one doing research in allelopathy should be able not only to differentiate between the regular competitive effects and allelopathic effect, but also to distinguish between the various sources of allelochemicals. It would be sensible to find the source and attribute the allelopathic effect, rather than getting extracts of leaves or stems or roots of donor plants and bio-assaying it. Chemicals identified and bio-assayed in the latter methods should not be claimed as directly responsible for the exhibited allelopathic activity.

It is also a big task to find a way to stimulate the natural release of allelochemicals. Tang and Young (1982) developed a novel system called Continuous Root Exudate Trapping System (CRETS) which allows a researcher to get more clear picture of the compounds that are released naturally, from an undisturbed living plant. This

system exclusively permits the study of root exudates.

The plant used in the study was *Parthenium hysterophorus* L., a well known obnoxious weed. White Top, as it is called, is a major agricultural and medicinal hazard (Towers *et al.*, 1977). Allelopathic impact of *Parthenium* spp. has been studied by a number of workers (Bonner and Galston, 1944., Went, 1970., Kanchan, 1976., Kanchan and Jeyachandra, 1976 and Dharmaraj and Mohammed Ali, 1985). Study of root exudates from *P. hysterophorus*, however, was not done earlier and therefore, an attempt was made to employ CRETS and study the root exudates of *Parthenium hysterophorus*, specifically.

MATERIALS AND METHODS:

The CRETS method developed by Tang and Young (1982) was followed with a few modifications. Seeds of *Parthenium hysterophorus* L. were sown in a wooden tray containing sand and allowed to get established. After 20 days, seedlings of 15 cm height were transplanted in the container. The containers used in this system were fabricated using 4 litre solvent bottles with their bottoms removed. The bottles were placed, neck down, on a wooden stand. Two containers were filled with a 2:1 (v/v) mixture of sand and rock. The containers were wrapped completely with aluminum foil and sterilized at a temperature of 100°C for 2 days. Four seedlings of *Parthenium hysterophorus* were planted in one container (after washing the roots) and the second container was maintained as control.

A hydrophobic resin, Amberlite XAD-4 (Mallinckrodt, Quebec, Canada), was cleaned well with running hot water, acetone, acetonitrile and diethyl ether (Junk *et al.*, 1974) and the resin was packed in glass tubes (custom made to fit the necks of the bottle) using methanol. The column, after packing, was washed well to remove any methanolic residue.

When both the plant and the control pots were fitted with the identically packed columns, they were connected to two separate fish tank pumps for air to be pumped into the system. This connection was established through a side arm of glass tubing and Teflon tubings. The bottom end of the side arm was inserted into the resin column and the top end was let to stand over the mouth of the container. There was on "Y" joint in the middle of the side arm (Slightly above height of the neck of the bottle) which was connected to the pump. This system ensured a steady and constant circulation of the flow from the containers through the resin, which would catch all the organics, while the inorganics would pass the resin column and get air lifted back to the container. All the ends and joints were sealed with Teflon (plumbing) tape to check any possible leak in the system. The column was wrapped with aluminum foil and all the glass tubes were wrapped with black (electrical) tape to curtail any moss growth. The soil surface of both the containers was covered with aluminum foil to make sure that there was no way of plant debris or leaf litter to enter the system. This system, thus ensured that root exudation was the only source of allelopathins to pass through the resin column. Both the pots were soaked with 0.1 strength nutrient solution (Hoagland's), until the water level was kept at constantly 5-6 cm above the 'Y' joint of the side arm.

The columns were changed once in 3 days and in each time a fresh and clean packing of resin was replaced. The detached column was washed with distilled water and then eluted with methanol. Eluates from 30 such columns were pooled. (As Parthenium was growing fast and started to lodge, a new set up was established with new containers and fresh plants after 15 collections). The pooled eluate was rotary evaporated to get rid of the methanol. A portion of the concentrate was retained, while most of it was diluted with distilled water (to pH 7) and dichloromethane was used to extract a fraction (NEUTRAL). In the same way, pH of the pooled concentrate was adjusted to 2 (with 1N HCl) and to 11 (with 1N NaOH) to obtain ACID and BASIC fractions. The fractions were not dried or rotary evaporated, but it was made sure that there was a final volume of 300-400 ml in each of the extracts.

Pearl Millet (*Pennisetum typhoides*) seeds were used to bioassay the allelopathic activity of the extracts. 10 seeds were spread on a filter paper and normal germination trays were used to house the seeds. 2 trays were used for each fraction and a control was maintained for each replication. Three such replications were maintained. 50% and 100% concentrations of each of the fractions were tried, while for the control tray, the eluate from the 'no plant' container of the CRETS was made use of. After 5 days, the germination counts, radicle and plumule lengths were recorded and analysed.

Treatments:

- T₁ = 50% Acidic fraction
- T₂ = 100% Acidic fraction
- T₃ = 50% Basic fraction
- T₄ = 100% Basic fraction
- T₅ = 50% Neutral fraction
- T₆ = 100% Neutral fraction
- T₇ = Control.

The retained portion of the concentrate (of the pooled eluate) was extracted with chloroform and thin layer chromatography, to check out the presence of Parthenin or any related sesquiterpene lactones, was done. (Rodriguez, 1975 and Pickman *et al.*, 1980).

RESULTS AND DISCUSSIONS

Of the 3 fractions tested, the neutral fraction contained most of the allelopathic activity. Basic fraction also showed a high degree of allelopathic impact, while the effect from the acidic fraction was minimal. But, all the 3 of them had significant inhibition of seed germination (Table I) and inhibition of growth (Table II and III).

Highest activity was found in the full concentration levels, in all the 3 fractions. Although, 50% concentration had lesser effect of inhibition, it too was significantly higher than the control.

Inhibition of germination:

100% concentration of the neutral fraction had an inhibitory effect of 77.67% over control followed by 50% concentration of the same fraction (68.14% over control).

The 100% concentrations of basic and acid fractions had an inhibitory effect of 36.01% and 10.91% respectively.

TABLE-I

Fraction	Treatment	Germination %			Total	Mean	% inhibition over control
		R I	R II	R III			
Acidic	1	79.6	76.9	75.3	231.8	77.37	10.913
	2	77.9	80.2	80.1	238.2	79.40	13.190
Basic	3	67.3	68.7	69.2	205.2	68.40	23.255
	4	54.3	56.7	60.1	171.1	57.03	36.012
Neutral	5	27.7	29.2	28.3	85.2	28.40	68.135
	6	19.3	20.3	20.1	59.7	19.90	77.672
Control	7	89.0	91.0	87.3	267.3	89.10	0
Total		415.1	423.0	420.4	1258.5	-	-

C.D. (P =0.05) =3.07

TABLE-II

Fraction	Treatment	Radicle length (mm)			Total	Mean	% inhibition over control
		RI	R II	R III			
Acidic	1	38.7	39.1	38.9	116.7	38.900	2.439
	2	30.1	31.3	30.8	92.2	30.733	22.922
Basic	3	15.3	15.9	16.3	47.5	15.833	60.291
	4	12.8	13.1	12.7	38.6	12.866	67.732
Neutral	5	10.6	11.1	10.3	32.0	10.666	73.250
	6	8.7	7.8	9.1	25.6	8.533	78.599
Control	7	40.1	39.8	39.7	119.6	39.866	0
Total		156.3	158.1	157.8	472.2	-	-

C.D. (P =0.05) =0.80

TABLE-III

Fraction	Treatment	Plumule length (mm)			Total	Mean % inhibition over control	
		RI	RII	RIII			
Acidic	1	21.3	20.9	21.7	63.9	21.30	0.103
	2	19.8	18.9	19.2	57.9	19.30	9.483
	3	16.3	17.1	12.9	46.3	15.43	27.633
Basic	4	13.9	12.2	14.1	40.2	13.40	37.154
	5	8.3	9.1	8.2	25.6	8.53	59.994
Neutral	6	5.7	4.2	4.1	14.0	4.66	78.145
Control	7	22.2	20.1	21.7	64.0	21.33	0
Total		107.5	102.5	101.9	311.9	-	-

C.D. (P =0.05) =1.97

Inhibition of seedling growth:

Radicle length was found to be more affected by all the extracts at all the concentrations although 100% concentration of the neutral fraction had almost the same inhibitory effect on both radicle and plumule growth (78.60% and 78.15% respectively).

The findings of the present study fall in line with earlier reports by Lakshmi Rajan (1973), Kanchan and Jeyachandra (1976), Khosla et al., (1980) and Khosla and Sobti (1981). A few of the reports are very specific and they attribute the allelopathic activity of *Parthenium hysterophorus* to the presence of sesquiterpene lactones especially Parthenin (Kanchan, 1975 and Kuldeep Singh et al., 1981). But, the TLC systems in the present study showed a clear absence of Parthenin or Coronopilin, the two major sesquiterpenoids of the plant. As this system (CRETS) perfectly simulates the natural environment to trap the root exudates specifically, it is concluded that the root exudates of *Parthenium hysterophorus* do not contain Parthenin and that the chemical enters the soil only through decomposing leaf litter. Further investigations will soon be taken up to identify the constituents of each of the fractions using GC-MS facilities.

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DIFFERENCES IN PHENOTYPIC CHARACTERS OF PURPLE NUTSEDGE COLLECTED FROM VARIOUS SOIL MOISTURE HABITATS IN THAILAND

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ABSTRACT

Forty-eight clones of purple nutsedge (*Cyperus rotundus* S.L.) collected from various locations in Thailand were grown in Kyoto, Japan, to clarify phenotypic variations. Most clones collected from dry and wet habitats were recognized as the O— and L—type, respectively, based on the composition of sesquiterpenes extracted from tubers. Main sesquiterpenes of the O—type are cyperene, cyperenol and cyperenone; those of the L—type are cyperene and cyperenol. The O—type clones have a smaller number of rachises/shoots, a greater number of inflorescences/rachises, smaller tubers, a greater number of leaves, shorter plant lengths, deeper scale colors, leafy-bract shorter than inflorescence, position of longest leaf far from flag leaf, less root and rhizome dry weight, more number of nodes on rhizome. Characters of the L—type are opposite to the O—type.

INTRODUCTION

Komai and Ueki (5) divided clones of purple nutsedge collected from Japan and Taiwan according to the major sesquiterpenes in tuber into three chemotypes, H—, M— and O—type. Distribution of these types were geographically restricted; the O—type was found in the Okinawa Islands and Taiwan, while the others were found at a higher latitude. Recently in Thailand the L—type, a new chemotype found in paddy areas, and the O—type, found in upland fields, were reported different in plant height and tuber sizes (6). There was taxonomical confusion among *C. rotundus* L., *C. retzii* Nees. and *C. tuberosus* Rottb.. Characteristic used for classification were the width of spikelet; color, tip and shape of scale; the persistence of scales on the rhizome (1). Although the first and third species were thought to be conspecific (9), the first and second species were classified into two subspecies (4). And there was difficulty in distinguishing the tall form of the first from the last two species (4). The last two species were also found in wet habitats (1, 10).

To clarify the variation of purple nutsedge (*C. rotundus* s.l.), morphological characters of clones collected in Thailand were compared by their chemotypes.

MATERIALS AND METHODS

Tubers of the eighty-five clones, collected from Thailand during the dry season from January 6 to February 2, 1984, were steam-distilled, extracted and analysed with gas-chromatography for sesquiterpenes according to the methods of Komai

et al. (5). Then forty-eight clones mostly without heading found during field collection and capable of being divided into O— and L—types were selected for comparative study. Each of the four or five young ramets produced from each clone was transplanted into a 10-cm diameter plastic pot and placed under field conditions at Kyoto University for 4 months beginning June 12, 1984.

During the growing period, heading time was determined every 2 or 3 days, and the following parameters were measured and observed at least on two heading shoots per pot: number of leaves; length of longest leaf, longest leafy bract (the lowest bract) and rachis (the term used by Wills and Briscoe (12)); branching of inflorescence ray; scale color; achene shape; length of achene and style-base. At the end of experiment above-ground shoot dry weight were measured. Number of shoots, rachises and inflorescences were counted per pot. For the underground parts, the following parameters were measured per pot: root dry weight; number of tubers; length, diameter and dry weight of ten mature tubers; number of nodes and dry weight of ten rhizomes. Voucher specimens, collected from the field and pot experiments, were also used to interpret the difference.

RESULTS

Sesquiterpene composition was varied among clones in the O— and L—types. In Table 1, 85 % of the O—type clones were from dry and rather dry habitats such as non-cropping areas, upland rice fields, vegetable fields, corn fields etc., whereas in the L—type 87 % of the clones were from wet and rather wet habitats such as ditch banks, river banks, lowland rice fields etc...

Table 1. Relation between chemotypes of clones and soil moisture levels of their habitats used in experiment.

Chemotypes**	Soil moisture level in clone habitat*				Total
	Dry	Rather dry	Rather wet	Wet	
O	5 (15.1)	23 (69.6)	5 (15.1)***		33
L		2 (13.3)	9 (60)	4 (26.6)	15

- * Dry : non-cropping area, soil moisture depended on precipitation.
Rather dry : upland crop field, irrigation available if soil moisture decreased.
Rather wet : lowland rice field, flooded area.
Wet : ditch bank, irrigation ditch.

- ** Main sesquiterpenes of O—type : Cyperene, cyperenol and cyperenone.
Main sesquiterpenes of L—type : Cyperene and cyperenol.

- ***Figures in parentheses show the percent of total in each type.

Forty-eight clones grown under the same condition, were found significantly different in most characteristics measured. as shown in Figure 1 1 and 1 2

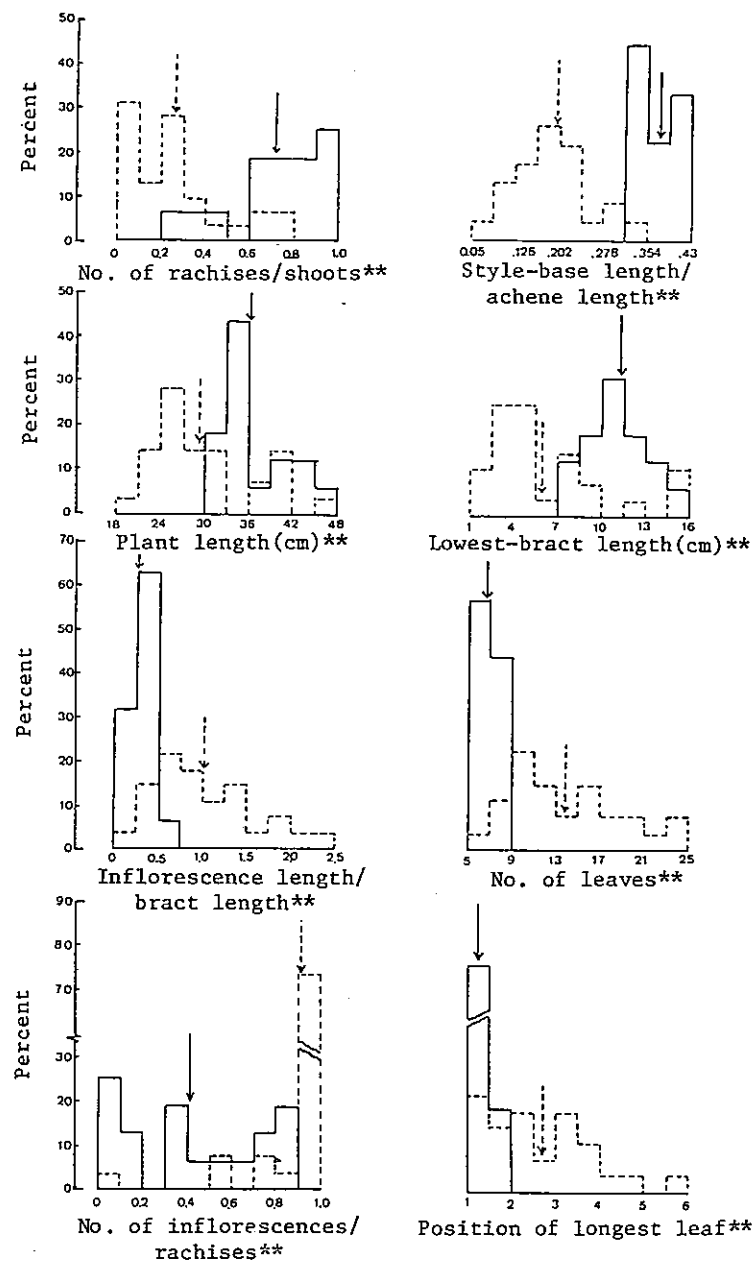


Figure 1.1 Percent frequency showing the differences of measured character in the O— (----) and L—type (—) clones when grown under the same condition. Arrow shows the mean position. Number of observation $N_O = 33$, $N_L = 15$.

** : significantly different at 1 % level.

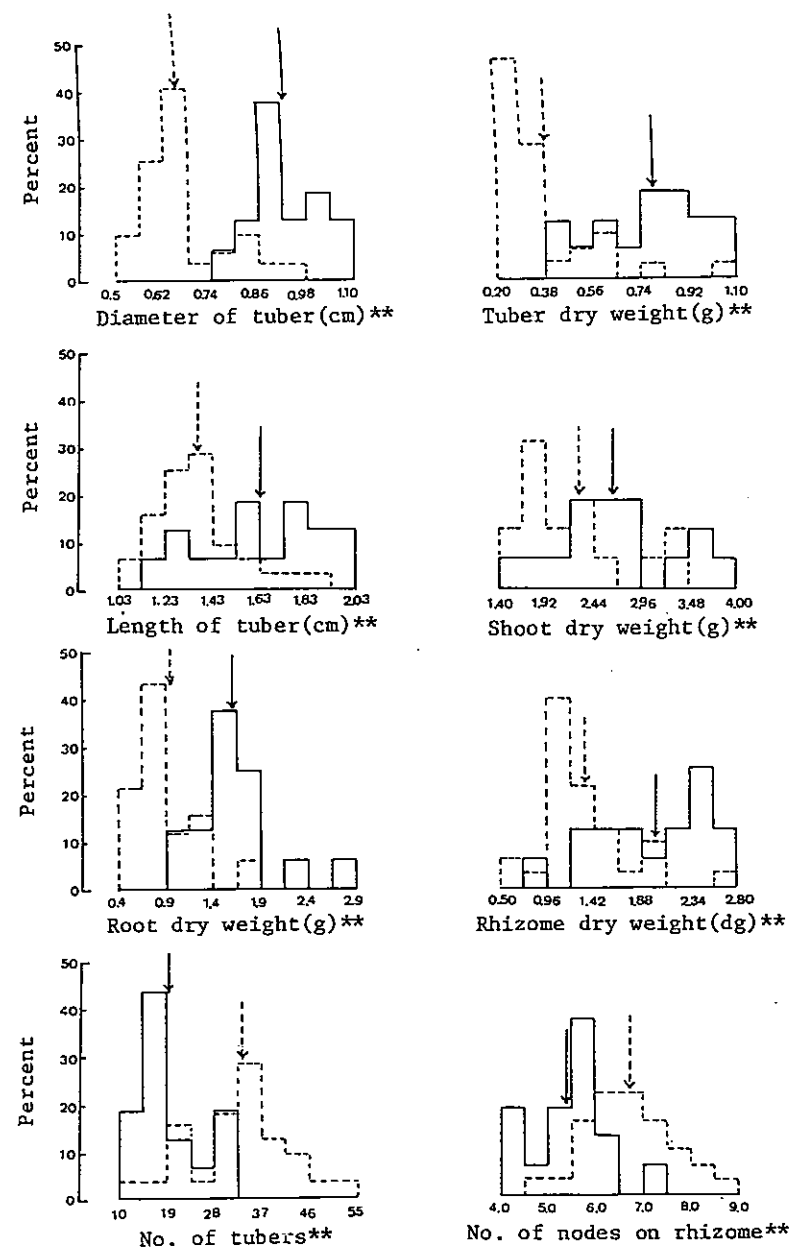


Figure 1.2 The same caption as in Figure 1.1.

Figure 2 shows the scatter diagram of all clones. Seeds in most clones regarded as L—type were abortive or had an oblong-obovate shape; most seeds of the O—type were mature and had an elliptic, oblong or oblong-elliptic shape. Secondary ray branching and no spikelet in some inflorescences were found in the L—type. Two clones in the L—type produced no spikelet at all. Abortive seeds were also found in some clones of the L—type. Fertile-mature achenes of the L—type had an oblong-ovate shape and those of the most O—type clones were varied from an elliptic, oblong-elliptic to oblong.

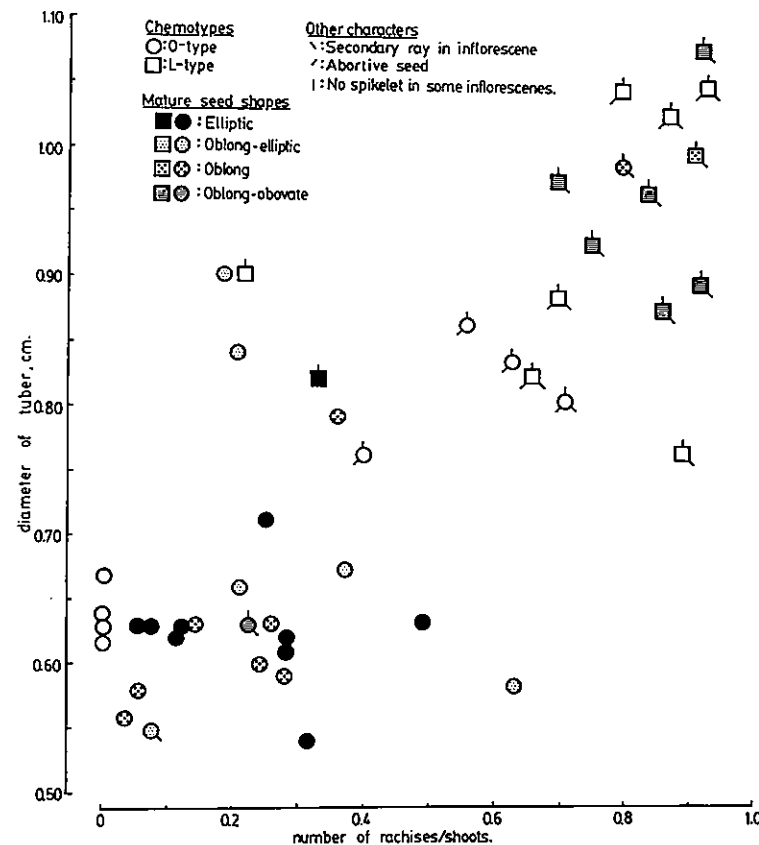


Figure 2. Scatter diagram of purple nutsedge 48 clones collected from various conditions in Thailand.

Scale color of the L—type was pale, varying from yellowish, yellowish-brown to brown among clones. Those from the O—type were purplish brown to reddish brown. At the ripening stage most scales, especially those of fertile achenes in the L—type clones disarticulate rather easily by a slight rubbing touch. Scales of those having abortive seeds were relatively thin.

DISCUSSION

Purple nutsedge in Thailand is distributed in cultivated and non-cultivated areas of various soil conditions. Most purple nutsedge clones regarded as L—type are from rather wet soil habitats and those regarded as O—type are from dry soil habitats. As for the chemotypes, the L—type clones had cyperene and cyperenol, so far the identifiable oxidized sesquiterpene; while the O—type clones had cyperene, cyperenol and cyperenone. The step of oxidization of cyperene is thought to be through cyperenol to cyperenone (7). This difference in the degree of oxidization is thought to be related to the moisture and consequent aeration levels of habitat soil.

Difference of characteristics measured in both types was very distinct in their extreme habitats. Characteristics which appropriate for distinguishing are tuber size, length of leafy bract comparing with inflorescence, pale color of scales, achene shape, secondary ray in inflorescence, and no spikelet produced in some inflorescence, although the last two characters seem to be plastic due to the variable soil factor. However, variation of clones in each type was also found. The O—type clones collected from rather wet habitats showed some characters similar to the L—type such as more root dry weight, large tubers, a small number of tubers, most tubers emerged with shoots, more rachises, longer plant length, leafy bract longer than inflorescence, no spikelet in some inflorescence, and abortive seeds. Clones of the L—type and the O—type clones collected from wet habitats are similar to *C. tuberosus* Rottb. and/or *C. retzii* Nees. in tuber production (2), achene shape (8) and the pale color of scales (11).

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ECOLOGY AND THE CONTROL OF *Sagittaria pygmaea* IN PADDY FIELD

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ABSTRACT

Recently, perennial weeds have come into problems in place of annual weeds in Japanese paddy field. Especially, *Sagittaria pygmaea* occupies 57 percentage in paddy field of Kyushu region.

Tubers collected from the paddy fields of three prefectures were transplanted in paddy field, respectively. Numbers of tuber were 3/m² at the start. Shift of numbers of tuber was investigated for five years. On the other hand, shift of panicle numbers of rice and shift of rice yield were investigated. In the paddy field that *S. pygmaea* reproduced at maximum, rice yield decreased 20-30 percent.

In the case that pyrazolate granule was treated in *S. pygmaea*-reproduced field, the herbicide was very effective at the treated year, but, numbers of tuber increased from the next year. Cultivation of three times in winter was effective to decrease numbers of tuber.

INTRODUCTION

The control of annual weeds in paddy field has become easy by development of many herbicides that show stable effectiveness to the weeds and safety to rice. But, perennial weeds have come into problems in place of annual weeds. Especially, *Sagittaria pygmaea* occupies 57 percentage in paddy field of Kyushu region. Moreover, the herbicides recognized as effective herbicides to *S. pygmaea* sometimes do not show stable effectiveness to *S. pygmaea*. So, it is requested to establish the control technics of *S. pygmaea*.

MATERIALS AND METHODS

The experiment was conducted from 1978 to 1982 for five years in early rice- transplanting field and ordinary rice- transplanting field. The fields were divided into two soil moisture plots from rice harvesting time to rice transplanting time, viz. irrigated plots and non-irrigated plots.

Tubers were collected from the paddy fields of Saga(S.), Nagasaki(N.) and Ooita(O.) prefecture, and, the tubers were transplanted in paddy field, respectively. Number of tuber was 3/m² at the start.

Number of tuber, panicle number of rice and rice yield were investigated for five years.

Pyrazolate treatment in early stage and cultivation in winter were investigated to control *S. pygmaea*.

RESULTS

The reproductive pattern :

Shift of number of tuber for five years was shown in Figure 1. At the irrigated plots in early rice-transplanting field, number of tuber increased remarkably from first year to second year, but, decreased slightly or was retarded since third year. Remarkable increase of tuber at the plots from first year to second year was depend on high temperature and irrigation from rice harvesting time to late in October. On the other hand at the non-irrigated plots in early rice-transplanting field, number of tuber increased slightly from first year to second year. Slight increase of tuber at the plots was depend on dry soil condition that top of *S. pygmaea* was withered.

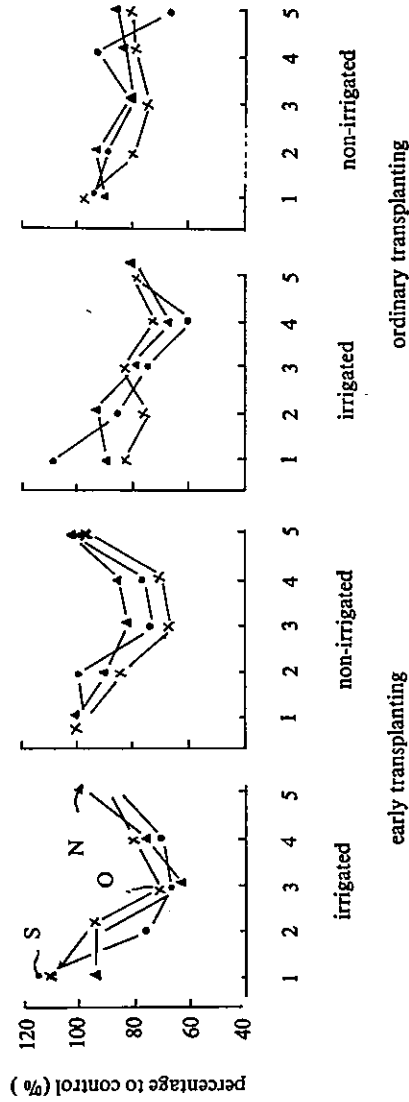


Figure 1 Shift of number of tuber

In ordinary rice-transplanting field, number of tuber increased until third year and was retarded since fourth year.

Number of tuber of S. was larger than that of N. or O. from first year to second year, but, the difference reduced since third year.

The damage to rice plant

Shift of panicle number of rice plant for five years was shown in Figure 2. According to yearly increase of tuber, panicle number of rice plant decreased in order. The decrease of panicle number was larger at the irrigated plots than at the non-irrigated plots.

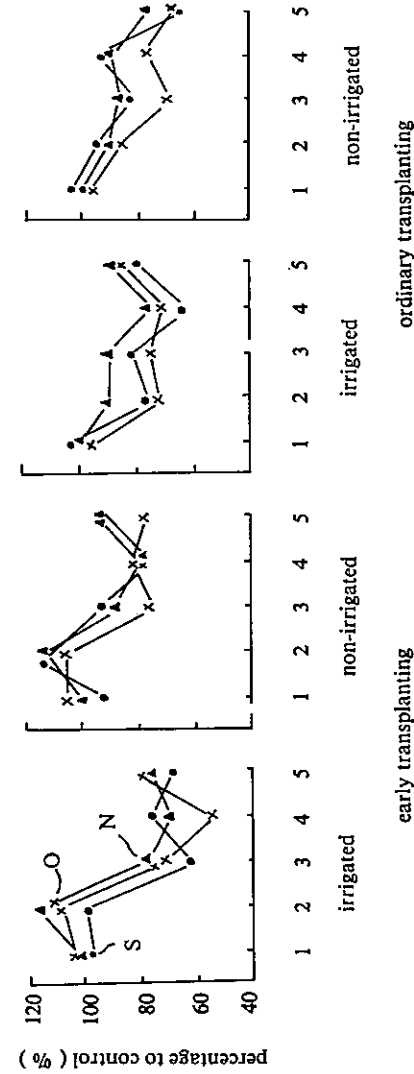


Figure 2 Shift of panicle number of rice plant

Shift of rice yield was shown in Figure 3. According to yearly increase of tuber, rice yield decreased from second year in ordinary rice-transplanting field and from third year in early rice-transplanting field. No decrease of rice yield at second year in early rice-transplanting field depend on decrease of control plots that rice plant was lodged by excessive nitrogen. In the paddy field that *S. pygmaea* reproduced at maximum rice yield decreased 20-30 percentage.

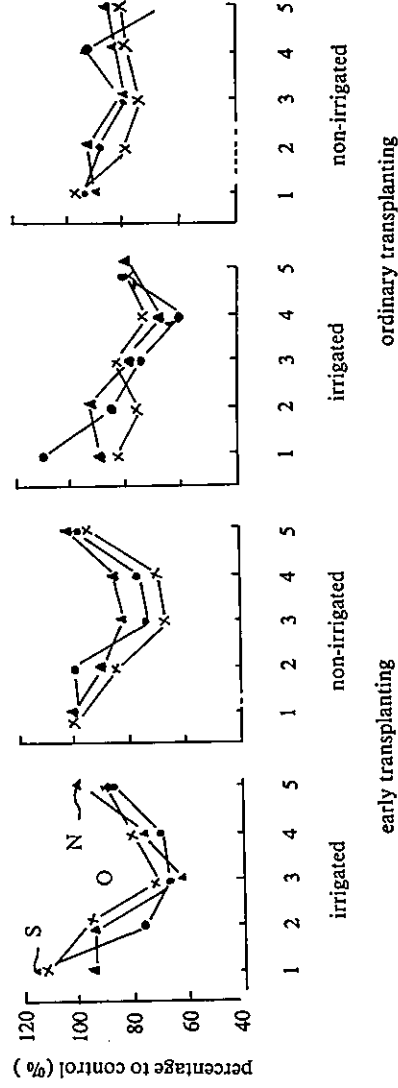


Figure 3 Shift of rice yield

The control :

At the plots that pyrazolate granule was treated at second year, number of tuber was investigated for four years (Figure 4). The herbicide was very effective to *S. pygmaea* at the treated year, but, number of tuber increased from the next year. It is considered that single application of pyrazolate is not sufficient to control *S. pygmaea* perfectly. Cultivation of three times in winter was effective to decrease number of tuber.

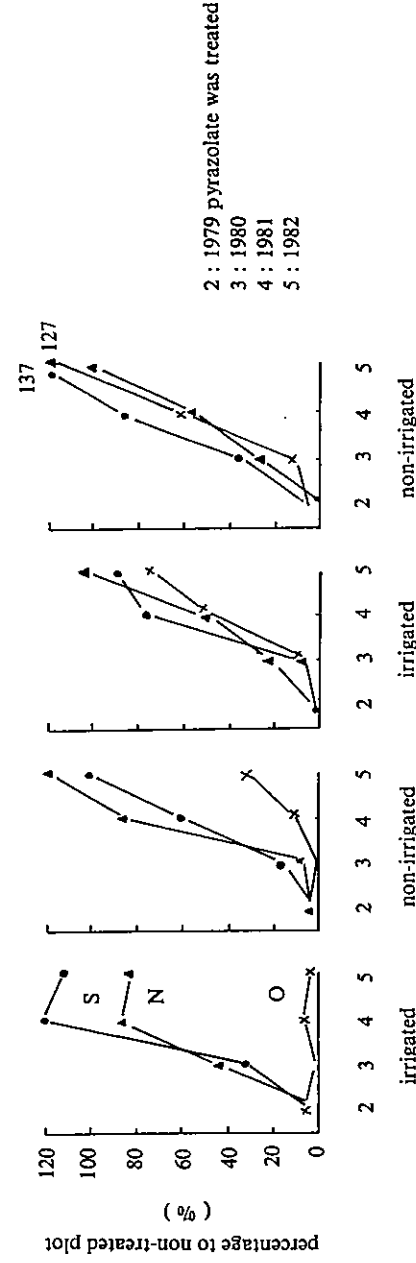


Figure 4 Shift of number of tuber at the herbicide treated plot

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EFFECT OF TEMPERATURE AND CHEMICALS ON BREAKING SEED DORMANCY IN WILD RICE (*Oryza perennis*).

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ABSTRACT

Wild rice (*Oryza perennis*) as weed is causing great concerns in the direct-seeding rice areas, especially in deepwater rice areas in Thailand. Seeds of wild rice shatter readily at maturity and possess seed dormancy, enabling survival for extended periods under unfavorable conditions. This study was conducted to determine proper conditions in the environment for breaking seed dormancy in wild rice of annual and perennial species by heating and chemical treatment. Percentage germination of both annual and perennial species of wild rice was higher under the treatment of dry condition than those of moist and submerged conditions, and there was an observable tendency to promote germination in higher temperature treatment. The effect of constant temperature treatments of 20 °C, 30 °C and 40 °C on dormancy breaking of freshly harvested wild rice seeds was generally low, and there were no significant differences among 5, 10 and 20 days in heat treatment. Longer exposure to heat treatment was required to promote germination.

Gibberellic acid at 10^{-3} M was found to be most effective for breaking seed dormancy of annual type wild rice, but not highly effective against perennial type. Methylene blue, 2-mercaptoethanol, L-dithiothreitol, kinetin and N-6-benzyladenine were less effective.

INTRODUCTION

Wild rice (*Oryza perennis*) as weed is causing great concern in the direct-seeding rice areas, especially in deepwater rice areas in Thailand (5). The infestations of "weedy types" wild rice reduce yield of cultivated rice and lower the grade of rice due to the presence of red grains (4). Another problem posed by wild rice populations is natural hybridization, through which wild rice absorbs more or less genes from cultivated rice (7) and disperses the seed for ensuring the continuity of the species (1). Seeds of wild rice shatter readily at maturity and possess seed dormancy, enabling survival for extended periods under unfavorable conditions.

Several studies have been reported on the nature of seed dormancy of wild rice (2,6,8,10,11) and effects of some chemicals on seed dormancy (3,9), primarily from ecological and physiological points. The present study was designed to determine basis for breaking dormancy in wild rice of annual and perennial annual intermediate types and to evaluate the effects of various classes of chemicals on germination to take control measures in the fields.

In this report, we followed the taxon designated by Morishima *et al.* (7), which

classify the Asian form of *O. perennis* into perennial, intermediate, annual, and weedy types which might have been derived from hybrids between the wild and cultivated plants.

MATERIALS AND METHODS

Seeds of wild rice (*O. perennis*) were collected from number of populations of wild rice in Saraburi (annual type) and Sing Buri (perennial-annual intermediate type) in Thailand in 1983 and 1984, and they were grown from July 1984 to May 1985 in a greenhouse at The Institute of Physical and Chemical Research. A day/night temperature of 31/26 °C and a 13-hr day length were maintained throughout growing period of wild rice. The plants showed vigorous growth, heading time ranging from early to late November 1984. After maturation, naturally shattered seeds were collected randomly and they were kept in a dessicator under room temperature. For temperature treatment of 50, 40, 30, and 20 °C, seeds samples were dried on glass petri dishes in the oven or incubators for designated periods. Test solutions of chemicals shown in Table 4 were freshly prepared for the effect on removal of dormancy, and 20 seeds were placed in 6-cm-diameter glass petri dishes containing one sheet of Whatman No. 3 filter paper and 2 ml of respective chemical solutions. The temperature during 10 day incubation was kept at 30 °C in darkness. After removal from the solution, the ungerminated seeds were dehulled individually by hand and were added with 5 ml of distilled water for further germination test. All the germination tests were routinely performed at 30 °C for 10 days in darkness with four replications of 20 seeds per petri dish.

RESULTS AND DISCUSSION

Germination in response to post-harvest maturation and dehulling. Freshly harvested seeds of both annual and perennial-annual intermediate types of *O. perennis* showed no germination immediately after harvest. At 130 days after harvest, unhulled seed of annual type germinated much higher, close to the same level with cultivated rice, whereas that of perennial-annual intermediate type remained low germination (Table 1). These results were contradictory to our report (5) and general understanding that seed of annual type wild rice has deeper dormancy than that of perennial one. This was partly caused by delayed maturity, accordingly by lack of after-ripening in perennial-annual intermediate type. When both types of wild rice seeds were dehulled, germination percentage was raised to higher degree especially in perennial-annual intermediate type, indicative of different nature of coat-imposed dormancy. These results suggested that 130 days of after-ripening for perennial-annual intermediate type was long enough to remove embryo dormancy. Percentage germination following heating. In the environment, seeds of wild rice shatter immediately after they reached maturity, and with the passage of time, seed dormancy would be broken under the various soil water regimes such as dry, moist or submerged and clement temperature regimes. Based on the assumption of tropical environment condition, germination

Table 1. Germination of wild rice seeds in response to post-harvest maturation and dehulling.

Species and types (Seed sources)	Germination (%)				
	1 day after harvest	130 days after storage at room temperature		1 day after harvest	
	(Jan. 10, 1985) UH	(May 20, 1985) UH	DH	(May 22, 1985) UH	DH
<i>O. perennis</i> annual type (Saraburi)	0	90.0	97.5	NT	NT
<i>O. perennis</i> perennial-annual intermediate type (Sing Buri)	0	18.8	87.5	3.9	69.5
<i>O. sativa</i> Lep Mue Nahng 111 (Cultivated rice)	0	100.0	96.5	NT	NT

UH : unhulled, DH : dehulled, NT : not tested.

Wild rice seeds of both annual and perennial-annual intermediate types germinated much greater under dry condition than under moist or submerged conditions (Table 2). Germination percentage of perennial-annual intermediate type of Sing Buri was 12–22 percent even under the submerged condition, whereas that of annual type of Saraburi did not germinate under moist and submerged conditions. These results suggested a differential adaptability of these two species of wild rice, whose habitats were entirely different from each other. The difference among temperature regimes was not clear, but there was a tendency that germination was raised at highest temperature regime of 50 °C. It was postulated from this

Table 2. Percentage germination following heating at various temperatures under dry, moist and submerged conditions for 20 days.

Species and types (Seed sources)	Conditions	Germination (%)			
		Temperature (°C)			
		20	30	40	50
<i>O. perennis</i> annual type (Saraburi)	Dry	85.0	90.3	89.8	95.5
	Moist	0	0	0	0
	Submerged	0	0	0	0
<i>O. perennis</i> perennial-annual intermediate type (Sing Buri)	Dry	67.0	80.5	75.9	88.8
	Moist	3.9	0	5.7	0
	Submerged	22.0	0	12.2	0

Dry : Seeds were kept in dry petri dishes.

Moist : Seeds were wrapped up with moist filter paper and were kept in petri dishes.

Submerged : Seeds were sunk to the bottom of beakers filled with distilled water, which was replaced every other day.

experiment that seeds of wild rice shatter after maturity and encounter the clement temperature higher than 30° C under dry soil water regime, and consequently they germinate much greater than the other conditions.

Effect of constant temperature. The dormancy of freshly harvested wild rice seeds was not easily broken with short days of temperature treatment, observing only 20 percent of germination at the highest temperature regime in annual type. No significant difference in germination percentage was observed among the treatment of 5, 10 and 20 days. However, 40 and 80 days treatment under 40° C showed much higher germination, and these results indicated the accumulations of higher temperature treatment were essential for breaking dormancy (Table 3), and it was also noted that the percentage of germinated grains became higher after 15 days in a germination test.

Table 3. Effect of constant temperature on dormancy breaking of freshly harvested wild rice seeds.

Species and types (Seed sources)	Temperature (°C)	Germination (%)				
		Period of treatment (day)				
		5	10	20	40	80
<i>O. perennis</i> annual type (Saraburi)	20	3.8	0	2.5	7.5	15.0
	30	5.0	5.0	3.8	35.0	75.0
	40	5.0	21.3	12.5	61.3	86.3
	Untreated	0	0	0	0	0
<i>O. perennis</i> perennial-annual intermediate type (Sing Buri)	20	0	0	0	1.3	0
	30	2.5	2.5	0	11.3	10.0
	40	3.8	1.3	8.8	8.8	20.0
	Untreated	0	0	0	0	0

Effect of constant temperature on dormancy breaking of perennial-annual intermediate type was not higher than that of annual type. This was partly due to the delayed heading and ripening period in the perennial-annual intermediate type, subsequently after-ripening was not complete. Effects of chemicals on removal of dormancy. The effects of 8 chemical substances on removal of dormancy were investigated (Table 4). In the Expt. 1, among the chemicals tested, gibberellic acid at 10⁻³ M greatly stimulated the seed germination of annual type wild rice, and slight stimulatory effects were shown at 10⁻⁴ M treatment. However, the effect of gibberellic acid in the perennial-annual intermediate type was lower at 10⁻³ M. These results were considered to be related to the degree of after-ripening in the seeds of perennial-annual intermediate type of wild rice. The other chemicals such as methylene blue, 2-mercaptoethanol, L-dithiothreitol, kinetin, and N-6-benzyladenine had no effect on removal of dormancy. In the Expt. 2, seeds of perennial-annual intermediate type with advanced degrees of after-ripening were used. Although germination of untreated seeds were 32.5%, gibberellic acid stimulated germination at 10⁻³ M, followed by newly tested 2-(2,4-dichloro-3-methylphenoxy) propionanilide. The stimulatory effect of gibberellic acid on germination was also reported in rice (*Oryza sativa* L. ssp. indica) seeds (9).

Table 4. Effect of chemicals on removal of dormancy in freshly harvested wild rice seeds.

Chemicals	Molar Concentration (M)	Germination (%)			
		Expt. 1		Expt. 2	
		<i>O. perennis</i> annual type (Saraburi)	<i>O. perennis</i> perennial-annual intermediate type, (Sing Buri)	<i>O. perennis</i> perennial-annual intermediate type (Sing Buri)	
		UH	UH	UH	DH*
Methylene blue	10 ⁻⁵	5.0	0	41.3	84.0
	10 ⁻⁴	10.0	0	41.3	85.5
	10 ⁻³	6.3	0	36.3	86.8
2-Mercaptoethanol	10 ⁻⁵	6.3	0	32.5	81.5
	10 ⁻⁴	6.3	0	33.8	72.5
	10 ⁻³	5.0	0	46.3	78.0
L-Dithiothreitol	10 ⁻⁵	10.0	0	35.0	83.0
	10 ⁻⁴	6.3	0	30.0	70.3
	10 ⁻³	3.8	0	50.0	84.0
Gibberellic acid	10 ⁻⁵	7.5	0	37.5	63.7
	10 ⁻⁴	15.0	1.3	53.8	93.0
	10 ⁻³	71.3	23.8	92.5	83.3
Kinetin	10 ⁻⁵	3.8	1.3	33.8	86.8
	10 ⁻⁴	8.8	1.3	32.5	--
	10 ⁻³	0	0	0	--
N-6-Benzyladenine	10 ⁻⁵	5.0	0	36.3	87.0
	10 ⁻⁴	10.0	0	41.3	--
	10 ⁻³	0	0	0	--
Dinitrophenol	10 ⁻⁵	NT	NT	55.0	72.0
	10 ⁻⁴	NT	NT	65.0	80.0
	10 ⁻³	NT	NT	0	--
2-(2,4-Dichloro-3-methylphenoxy) propionanilide	10 ⁻⁵	NT	NT	52.5	82.8
	10 ⁻⁴	NT	NT	63.8	84.0
	10 ⁻³	NT	NT	76.3	61.3
Untreated		6.3	0	32.5	98.3

UH : unhulled, NT : not tested. -- : moldy

DH* : Ungerminated seeds under the administration of chemicals were dehulled, and then transferred to distilled water for germination test.

When the ungerminated seeds under the administration of chemicals for 10 days were dehulled, the germination was extremely increased, showing a nature of coat-imposed dormancy. In this series of the experiments, the degree of imbibition was unaccountable because dry seeds were soaked in chemical solutions without vacuum infiltration. Among the chemicals tested, however, gibberellic acid was found to be the most effective chemical on removal in wild rice seeds.

To elucidate a mechanism of seed dormancy in wild rice, further investigation on physiological and biochemical state of embryo and endosperm must be conducted.

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EFFECTS OF WEED COMPETITION IN DRY SEASON IRRIGATED SOYBEAN IN NORTHERN THAILAND

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ABSTRACT

In the highland areas of Northern Thailand, irrigated soybean crops are often grown during the dry season following paddy rice. In many cases, weed control is either poor or non-existent, the most common practice being cutting and burning the rice straw immediately prior to direct seeding the soybean with zero tillage. This practice was compared with weeded and non-weeded treatments and resulted in a weed dry weight at harvest of 62 percent (1.1 t/ha) of the non-weeded treatment. Grain yields of soybean were 1.0, 1.3 and 1.7 t/ha for the non-weeded, stubble burnt and weed-free treatments respectively.

INTRODUCTION

In the highlands of Northern Thailand, irrigated soybean crops in paddy are often grown during the dry season following wet season rice. In most cases, weed control is poor or non-existent as farmers believe that competition from weeds is minimal unless the weeds overtop the soybean crop. Where weed control in any form is practised, the most common method is to cut and burn the stubble of the preceding rice crop. This destroys existing weeds, the soybean crop being planted as soon as possible thereafter and no further weed control takes place during crop growth. Neither the effect of weed competition on soybean nor the efficacy of the farmers' traditional weed control practice has been quantified for the highlands, and so an experiment was conducted in a farmer's field during the 1984/85 dry season.

MATERIALS AND METHODS

The experiment was conducted in a farmer's paddy field at Ban Thon Kam in the Mae Ta Man Valley at an altitude of approximately 450 metres. An RCB design with four replicates was used with replicated blocks being assigned to individual bays. The treatments were:

- i) stubble burning without further weed control
- ii) hand weeding twice, at 30 and 60 days after sowing
- iii) non weeded check

Plots measured 3 x 4 metres. In all plots, the stubble from the preceding rice crop was slashed. The straw was removed from both the check and hand weeded treatments with some of this being placed on the plots of the stubble burnt

treatment to ensure an adequate and uniform cover. After burning these plots, all bays were flush irrigated and, three days later, inoculated soybean seed (S.J. 5), was direct seeded without tillage using a dibbling stick at a spacing of 25 x 20 cms (3 seeds per hill). No weed control was practised after sowing in either the check or the stubble burnt plots. Weed counts were taken in all plots prior to the first weeding. At harvest, dry weight of weeds, total soybean crop dryweight and grain were recorded.

RESULTS

The burning of the stubble from the preceding rice crop resulted in a significant reduction in weed densities (80 percent overall) at 30 days after sowing (Table 1). At harvest, however, weed, soybean crop dryweights and grain yields did not differ significantly from the control (Table 2).

Two weedings, at 30 and 60 days after sowing reduced weed growth at harvest by 41 percent and resulted in increased soybean crop dryweight and grain yield when compared with the non-weeded check (Table 2).

Table 1. Mean densities of broadleaf and grass weeds growing in association with dry season irrigated soybeans at 30 days after sowing.

Treatment	Weed Densities (numbers per sq metre)		
	Broadleaf species	Grasses & Sedges	Total
Non-weeded check	318	383	701
Weeded 30 & 60 d.a.s. ^{a/}	300	332	632
Stubble Burnt	19	113	132
LSD _{0.01}	135	186	255

^{a/} d.a.s. = days after sowing

Table 2. Mean dryweights at harvest of soybeans and weeds growing in association in paddy fields in 1984/85 dry season.

Treatment	Weed Dry	Soybeans (t/ha)	
	Weight t/ha	Crop dry wt.	Grain Yield
Non-weeded check	1.79	2.01	0.96
Stubble Burnt	1.11	2.82	1.21
Weeded 30 & 60 d.a.s. ^{a/}	0.81	4.41	1.75
LSD _{0.01}	0.85	1.14	0.54

^{a/} d.a.s. = days after sowing.

It appears that the traditional practice of stubble burning is not an effective weed control method. It gave large reductions in weed densities up to 30 days after seeding and probably beyond. However, this did not give an increase in grain yield as weed dry weight at harvest was not significantly different from season long competition. Since a second weeding at 60 days after sowing resulted in a reduction of weed dry weights at harvest and an increase in grain yield, this indicates that weed growth and competition in this period was critical with respect to crop yields. As December and January were the coldest months, slow initial growth of both weeds and soybean may have accounted for the small effect of this weed free period on crop growth and yield. Higher temperatures between 30 and 60 days after seeding, with a subsequent increase in weed growth, may explain the significant increase in yield from the two weedings.

Stubble burning has been shown to effectively control weeds up to 30 days but not result in increased grain yield at harvest. This may simply reflect the large variation in weed populations in these fields and variation in weed control resulting from uneven burning. Great variation in the latter has been observed in farmers' fields too. Therefore, a combination of stubble burning followed by earlier plantings at higher temperatures, closer row spacings for early canopy closure, and one weeding at 60 days could be an effective and economic means of weed control for dry season soybeans after paddy.

Season long weed competition reduced yields by 0.79 t/ha when compared with the practice of two weedings at 30 and 60 days after sowing. At a farmgate price in this instance of US\$. 260.00 per tonne, this represents a monetary loss of US\$ 205 per hectare. A labour input of 55 days per hectare is required for two weedings giving a marginal return to labour of US\$ 3.74 per workerday. This is more than double the imputed day rate (US\$ 1.50) for casual labour commonly used in the Mae Ta Man Valley which indicates that even if a farmer cannot use his own labour, it is economic for him to hire others to weed his crop.

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GERMINATION ECOLOGY ON UNEVEN EMERGENCE OF ANNUAL PADDY WEEDS

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ABSTRACT

Arable land weeds, in general, show an emergence pattern extending over long period. This may be partially due to ununiformity of physiological states of soil buried seeds. Phenological changes in seed dormancy and intra and inter plant variations of seed dormancy were investigated using twelve annual paddy weeds.

The phenological patterns of seed dormancy were divided into four groups, i.e. *Echinochloa oryzicola*, *Monochoria vaginalis* and *Eclipta prostrata* showed deep primary dormancy and deep secondary dormancy, *Lindernia procumbens* and *Ludwigia prostrata* exhibited shallow primary dormancy and deep secondary dormancy, *Eriocaulon sieboldianum*, *Ammannia multiflora* and *A. coccinea* showed deep primary dormancy and shallow secondary dormancy, and *Cyperus difformis*, *Lindernia dubia* and *Rotala indica* did not indicate clear primary and secondary dormancy. Emergence uniformity, mean emergence time and total percentage emergence varied among species. *M. vaginalis*, *E. sieboldianum* and *L. prostrata* did not exhibit a marked peak of emergence, and then emergence uniformity of these species became relatively low. In *E. oryzicola*, *R. indica*, *L. procumbens*, *A. coccinea* and *L. prostrata* the main factor affecting uneven emergence was intra plant variation of seed dormancy, while in other species the main factor was inter plant variation. Germination strategies varied among species in a field.

INTRODUCTION

Arable weeds, in general, show an emergence pattern extending over a long period because of uneven seed germination. This phenomenon causes knotty problems on weed control practices. Hand weeding used to be done more than three times during a period of rice culture to eliminate weed seedlings emerging successively in Japan. Additionally some seeds remain in soils as seed bank to be a cause of infestation in the next year.

Uneven seed germination is an adaptive mechanism for the weed population to escape from extinction by severe disturbance (Baker 1965, and Jain 1979), and may partly result from intra-plant and inter-plants variations in seed dormancy. Palmblad (1969) have indicated populational variation in seed germination. Cavers and Harper (1966) have demonstrated that differences were found in germination behaviour between seeds within a plant and from different plants in the same site. In addition, changes in dormancy of soil buried seeds, reported by such workers as Taylerson (1969), Roberts (1978), and Baskin and Baskin (1978), may also affect the field emergence pattern.

In the present study, germination strategies of annual paddy weeds growing in the same habitat were tried to classify by comparing emergence patterns and seasonal

changes in dormancy among these species.

MATERIALS AND METHODS

Plant materials. For each of eleven weed species, twenty plants were collected from a paddy rice field in Kyoto Prefecture on 15 July 1983. Mature seeds were collected from these plants, transplanted at our experimental field during October and November, and were stored dry at laboratory temperature and humidity.

Field emergence patterns. Weed seeds collected from each plant were placed on a steam-sterilized soil surface filled in 1/10,000 a pots on 10 February 1984, and were covered about 2 mm with sieved soil. There were two replicates of a hundred seeds for each treatment. The pots were sunk in the field so that the inside soil level was the same as outside the pot. At weekly intervals, the seedlings were counted and removed, then percentage, rate and uniformity were calculated to represent the emergence pattern by using the formulae:

$$\begin{aligned} \text{Rate of emergence (now written R)} &= \frac{\sum (W \cdot n)}{\sum n} \\ \text{Uniformity of emergence (U)} &= \sqrt{\frac{[\sum (\bar{W} - W)^2 \cdot n]}{\sum n}} \\ \text{Percentage emergence (P)} &= \text{Arc sin } \sqrt{\frac{\sum n}{100}} \quad (\text{Grad}) \end{aligned}$$

where n equals the number emerging at week W, W equals the number of the week counted from 1 st April, and $\bar{W}$ is (R) (Heydecker 1972). In determining relative contribution of intra-plant to inter-plants variation concerning uneven emergence in the population, mean of (U) and standard deviation of (R) were calculated to estimate intra-plant and inter-plants variation respectively, and then relative contribution (RC) was obtained by calculating the formula:

$$(RC) = \text{Mean of (U)} / \text{Standard deviation of (R)}$$

where the higher the figure, the larger the factor of intraplant variation.

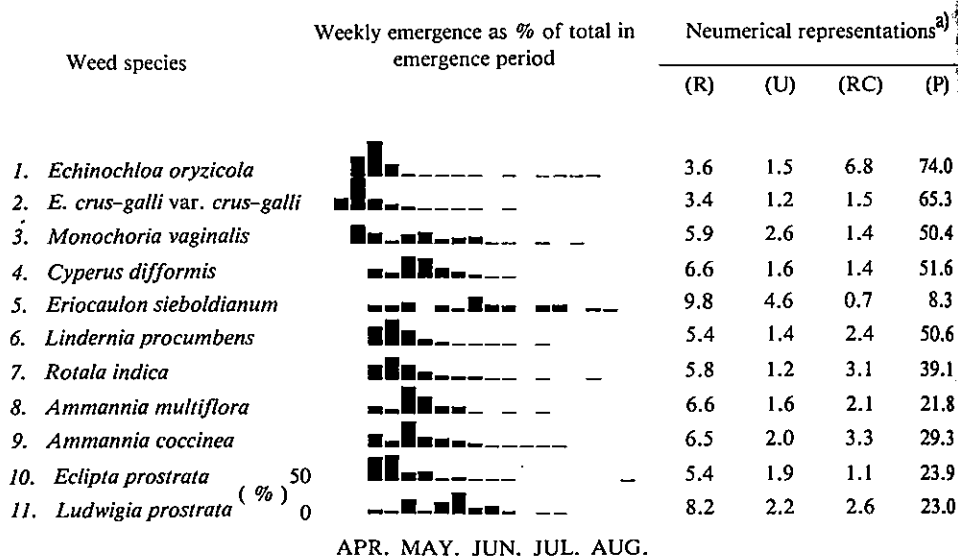
Seasonal changes in dormancy of buried seeds. The seeds collected from each plant were mixed and were buried 1 cm deep in 1/10,000 a pots sunk in the field on 10 th January 1984. The seeds were exhumed at various times and germination tests were performed in light (3 Klux) at 30°C constant temperature for 14 days. There were three replicates. At the end of the tests, seeds not germinated were checked its viability by using TTC test, and percentage germination of viable seeds was obtained.

RESULTS

Comparisons of the emergence patterns. Weed species used are summer annuals and emerged from April to August. Throughout the emergence period, the pots were not artificially disturbed and were flooded 2 cm deep. Mean temperature of

the soil surface reached 15°C, 20°C and 25°C in mid-April, mid-May and mid-June respectively. In Fig. 1, (U) represents a standard deviation of weekly distribution of seedling emergence, therefore the larger the figure, the higher the unevenness of emergence become. Three species such as *Monochoria vaginalis*, *Eriocaulon sieboldianum* and *Ludwigia prostrata* showed high unevenness, and mean emergence time (R) were early June in the latter two weeds, while peaks of emergence were observed from mid-April to mid-May in the other weeds. The total percentage emergence (P) were less than 40 % for five out of eleven weeds, then most seeds of these weeds remained in the soil as seed bank. In *Echinochloa oryzicola*, (RC) was very high because (R) were relatively uniform among twenty individual plants in contrast with such five species as *E. crus-galli* var. *crus-galli*, *M. vaginalis*, *Cyperus difformis*, *E. sieboldianum* and *Eclipta prostrata* (Fig. 1).

Fig. 1. Weekly distribution and numerical representations of emergence of seedling from seeds sown on 10 February 1984. a) See in the text.



Seasonal changes in dormancy of buried seeds. After 1 mo of dry storage at laboratory conditions, seeds of *L. prostrata*, *C. difformis* and *Lindernia procumbens* germinated to 100 %. This means that these three species have no or shallow primary dormancy, whereas the others showed deep primary dormancy following immediate awakening by cold and wet conditions in the field. The high percentage germination were kept until early August, then such weeds as *E. oryzicola*, *E. crus-galli* var. *crus-galli*, *M. vaginalis*, *E. prostrata* and *L. prostrata* entered secondary dormancy. Some of those exhibit 100 % germination again in late November, but two species of genus *Echinochloa* did not germinate before early March in the next year. In other weeds, there were no secondary dormancy (Fig. 2).

1. *Echinochloa oryzicola*
2. *E. crus-galli* var. *crus-galli*
3. *Monochoria vaginalis*
4. *Eclipta prostrata*
5. *Ludwigia prostrata*
6. *Cyperus difformis*
7. *Lindernia procumbens*
8. *Rotala indica*
9. *Eriocaulon sieboldianum*
10. *Ammannia coccinea*
11. *Ammannia multiflora*

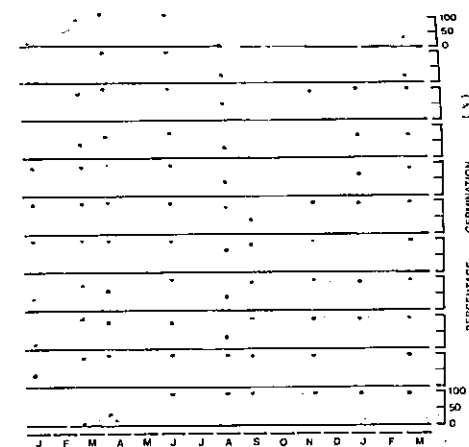


Fig. 2. Germination of seeds of annual paddy weeds. Seeds were buried on 10th January 1984, and were exhumed and tested at different times.

DISCUSSION

Salisbury (1929) have pointed out that there are three types of seed germination e.g., simultaneous, continuous and discontinuous germination, and have mentioned that the first makes up a definite danger since almost all the seedlings may be destroyed by the same adverse condition.

All the weeds used in this study exhibited uneven emergence depending on the two strategies e.g., intra-plant and inter-plants variation in germination behaviour. The latter feature is constituted of phenotypic plasticity and genetic polymorphism, therefore if regular weeding managements such as herbicide applications are repeated every year, selection for later germination may occur in those weeds which are low (RC), as Putwain et al. (1982) have demonstrated.

In the present study, five out of eleven weed species, which showed no clear secondary dormancy are classified into continuous germination type. Because in September-October soil temperatures are still within the range of those required for germination, hence the seeds enforced in conditional dormancy germinate if the soil is disturbed. This enables high rates of seed increase for the population. In these weeds, seeds are very small, less than 20 mg in 1000 seeds weight, and the plants set a great number of seeds. Small seeds may only germinate at surface area of soil, therefore accidental burial and a large amount of seed bank may be important safeguards for spreading risks of extinction of the population. Whereas for weed species of discontinuous type, which produce large size, more than 80 mg in 1000 seeds weight, and relatively small number of seeds, the secondary dormancy may lessen the risks.

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LIFE CYCLE AND SEED PRODUCTION OF *Euphorbia geniculata* IN THAILAND

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ABSTRACT

Ecological characteristics of *Euphorbia geniculata* in life cycle, growth habits and seed production have been studied as associated with four seasons and three kinds of soils in National Weed Science Research Institute (NWSRI) Project from 1982-1983 in order to have basic information for understanding the weediness of this weed against corn.

Remarkable differences in the life cycle were observed among four seasons, but there was no differences among the kinds of soils. The most vigorous growth was found in *E. geniculata* of the season from May to August. Maximum plant height and growth rates in plant height were highly correlated with temperatures and day length. Seed production of *E. geniculata* was investigated by season. The number per plant was highly variable, ranging from 100 to 800.

INTRODUCTION

Euphorbia geniculata called wild poinsettia has been one of the most noxious weeds in upland crops, especially corn in Thailand (Noda K. and M. Teerawatsakul, 1982). Yield losses of upland crops caused by weeds have been often observed in farmer's fields and previous report indicated its serious damage on corn (Teerawatsakul *et al*, 1984). The growing behaviors of this weed, however, seems to be different according to the seasons during a year. In order to obtain the basic information for establishing the weed control technique of this weed, such ecological characteristics of this weed as life cycle, growth habits, and seed production have been investigated at the National Weed Science Research Institute Project. Department of Agriculture, Bangkok, Bangkok, Thailand in 1983-1984.

MATERIALS AND METHODS

Material plants for investigation were grown in respective four seasons; September to December, December to May, April to August and July to October. Three major kinds of soils; very fine clayey soil from the central part, fine loamy soil from Northeastern part and fine clayey soil from Eastern part of Thailand were used for growing in each season. Thirty plants of *E. geniculata* were grown in Wagner pots (20 cm in diameter) in each soil with 3 replications. Measurement was made by recording plant height, leaf number in the same plant at one week interval. Further, the times of emergence, flowering, initial seed bearing as well as mean temperature, sunshine hours and day-length were also recorded.

The yield of seed production was obtained by collecting seeds from each plant by covering with vinyl bags before seed ripening.

RESULTS AND DISCUSSION

1. Seed emergence

Seed germination, there were not many differences on number of days of seed emergence from seeding to the highest number of germinated seeds (Table 1)

Table 1. Days of Sequence terms during the growing of *E. geniculata* by season and soil

Plot	Soil	Seeding date	Date and days from seeding date to			
			Emergence	Flowering	Seed bearing	AMP*
Season I	1	Sep. 20	Sep. 27(7)	Oct. 23(33)	Nov. 5(46)	Nov. 26(67)
	2	"	"	Oct. 28(38)	Nov. 5(46)	Nov. 26(67)
	3	"	"	Nov. 1(52)	Nov. 11(62)	Nov. 26(67)
Season II	1	Dec. 28	Jan. 3(6)	Mar. 19(81)	Mar. 25(87)	May 11(134)
	2	"	"	Mar. 8(70)	Mar. 16(78)	May 11(134)
	3	"	"	Mar. 22(84)	Apr. 15(108)	May 3(126)
Season III	1	Apr. 26	Apr. 29(3)	Jun. 20(55)	Jun. 28(63)	Aug. 17(113)
	2	"	"	Jun. 23(58)	Jul. 7(72)	Aug. 12(108)
	3	"	"	Jul. 7(72)	Jul. 15(80)	Aug. 17(113)
Season IV	1	Jul. 21	Jul. 23(2)	Aug. 31(41)	Sep. 8(49)	Oct. 2(73)
	2	"	"	Sep. 12(53)	Sep. 16(57)	Oct. 2(73)
	3	"	"	Sep. 12(53)	Sep. 16(57)	Oct. 2(73)

Soil 1, Very fine clayey soil Soil 2, Fine loamy soil Soil 3, Fine clayey soil

AMP*, approximate maximum plant height (), number of days from seeding date

2. Life cycle

Plant height and life cycle of *E. geniculata* were remarkable different among the four seasons but less or no significant differences among the three soil types. When the terms of sequent growing stages during a life cycle were estimated based on daily observation, (Table 1 and figure 1) The longest term were found to be from emergence to initial flowering in growing season II and season III, and the term from initial seed bearing to approximate maximum plant height (AMP) were also longer in season II and III than in season I and season IV. Thus the total number of days from seeding to AMP were 134 in the longest season II and 113, 73, 67 in seasons III, IV and I, respectively (Table 2).

3. Growth habits.

The highest average plant heights were *E. geniculata* grown in seasons III and IV followed by seasons II and I also as the average highest growth rate which were higher in season III and season IV although the growth rates were lower in soil 2 than in soil 1 and soil 3 in season II and season III (Table 2, Appendix 1)

Table 2. Some growth characters of *E. geniculata* and the environmental factors in respective growth periods

Plot	Soil	TND	AMP	Growth rate* in plant height cm/day	Mean temp. °C	Sunshine hr/day	Day-length hr/day
		day	cm				
Season I	1	67	41	0.61	27.5	6.39	11.40
	2	67	42	0.63	27.5	6.39	11.40
	3	67	62	0.92	27.5	6.39	11.40
Season II	1	134	57	0.43	27.6	8.15	12.00
	2	134	46	0.34	27.6	8.15	12.00
	3	126	85	0.67	27.2	8.28	11.95
Season III	1	113	220	1.95	29.1	5.76	12.80
	2	108	170	1.57	29.3	5.97	12.76
	3	113	210	1.86	29.1	5.76	12.80
Season IV	1	73	148	2.02	28.3	4.79	12.28
	2	73	132	1.81	28.3	4.79	12.28
	3	73	118	1.62	28.3	4.79	12.28

Note : See Table

TND = Total number of days from seeding to AMP

AMP = Approximate plant height

* AMP/TND

Appendix 1 : The result of Duncan's multiple range test at the 5% level for maximum plant height

Season I	48.3 c	Soil 1	116.5 a
Season II	62.7 c	Soil 2	97.5 a
Season III	200.0 a	Soil 3	118.8 a
Season IV	132.7 b		

Figures with the same letter are not significant.

These results of the differences in life cycle and growth rate of this weed indicated the existence of much seasonal variation in the growing pattern of *E. geniculata*. It is interesting and important that the most vigorous growth in height of *E. geniculata* took place from May to August which coincides with the main growing season of crops, especially corn.

The above described growth patterns were expected to be correlated with some meteorological factors as temperature, day-length and sunshine hour (Table 2, 3 and Figure 1). Maximum plant height and growth rate in height were highly correlated with daily mean temperature and day-length with coefficients higher than 0.9 and 0.7, respectively but correlation of them with sunshine hours was negative. The length of life cycle correlated with neither daily mean temperature nor day-length but with sunshine hour.

Table 3. Correlation coefficients between growing characters and environmental factors

	Mean temperature (°C)	Sunshine (hr./day)	Day length (hr./day)
No. days seeding to AMP*	0.0964	0.6896*	0.4221
Maximum plant height (cm)	0.9229**	-0.5593	0.9125**
Growth rate in plant height (cm/day)	0.8246**	-0.9125**	0.7449**

Note: *AMP, Approximate maximum plant height

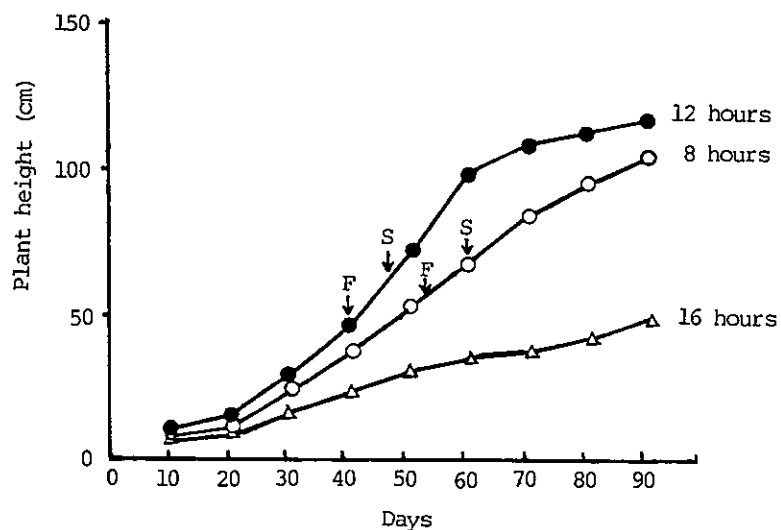


Fig. 1. Effect of Daylength on Plant Height of *E. geniculata*

Note: F, flowering S, seed bearing

4. Seed production.

Seed production of *E. geniculata* was, in general, more abundant with plants grown in seasons I and III than with those in other seasons; and in the very fine clayey soil than in the other two soils (Table 4). Seed production per plant was highly variable in each season, ranging from 100 to 800.

Table 4. Summary Data for Life-cycle Experiment

Season	Life-cycle day	Max. height	Growth rate in height cm/day	Seeds produced per plant
I (Sep. - Nov.)	66	50	0.73	610
II (Dec. - May)	133	63	0.46	270
III (Apr. - Aug.)	116	207	1.76	487
IV (Jul. - Oct.)	76	135	1.76	204

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PHOSPHATE AND THE DISTRIBUTION OF AQUATIC WEEDS IN NORTHERN MALAYSIA

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ABSTRACT

Most of the waterways in the Northern Peninsular Malaysia particularly in the padi field areas are heavily infested by aquatic weeds. Evidently, the nutrient concentration in the water can play an important role in triggering and regulating the dense growth of these weeds. Nutrient such as phosphate is generally limited to freshwater ecosystem, however, increase usage of fertilizer may result in reasonably high phosphate concentration in the water itself.

Generally three forms of phosphate are measured in the natural aquatic ecosystem, namely dissolved total phosphates, particulate phosphate and dissolved phosphate. In this particular case, dissolved total phosphate and dissolved phosphate were analysed from various sampling stations. Only soluble dissolved phosphate can be used for algal growth and also the growth of certain aquatic weeds. The soluble dissolved phosphate is also known as soluble reactive phosphate (SRP) with the majority of inorganic phosphate present in the form of orthophosphate (PO_4^{3-} ; $\text{PO}_4 - \text{P}$).

In this study, most of the waterways visited were found to be extremely high in phosphate. Consequently the tremendous increased of weed population was seen in most of the canals and also small rivers in the states of Kedah, Penang and Perak. In the state of Kedah, the maximum fresh weight of *Eichhornia crassipes* was 6128 g/m^2 at Tajar river and *Ipomea aquatica* was reaching 2928 g/m^2 at Pendang river.

INTRODUCTION

Malaysia enjoys a warm and sunny climate with considerable rainfall throughout the year. In the case of Peninsular Malaysia, the highest total precipitations annually are encountered over the foothills between the northwest coast and the Main Range (Aiken, Leigh, Leinbach and Moss - 1982). Evidently, the lowland areas in this region are largely utilized for rice cultivation. In addition to several rivers, miles of irrigation canals are constructed for the purpose of irrigating the rice fields.

It is rather unfortunate that most of the rivers and also irrigation canals are gradually infested with noxious aquatic weeds, such as *Eichhornia crassipes*, *Polygonum barbatum*, *Hydrilla verticillata* and *Ceratophyllum demersum*. Consequently many rice field areas are abandoned and one of the reasons is due to the lack of water supply. Various methods are employed to eradicate these unwanted weeds. To date no method can be considered effective enough to overcome this problem.

Ecological control measures can be considered as one of the best ways to initially ensure the various factors that involved in substantiating the proliferation of aquatic weeds. Generally the high concentration of nutrient, such as phosphate is one of the environmental factors that can play a major role in regulating the growth of

and Horne - 1983).

In this text, emphasis is given to the estimations of aquatic weeds based on geographical distribution particularly in the rice growing areas. Apart from this, phosphate concentrations were also analysed from the subsequent sampling sites, in order to establish the fact that phosphate could play a major role in governing the growth of aquatic weeds.

MATERIAL AND METHODS

Field work

Several aquatic weed infested areas in the states of Kedah, Penang and Perak were visited. It is known that most species of aquatic weeds are pronounced in the paddy growing areas, so sampling sites were chosen from these areas.

The sampling sites included the MADA irrigation scheme in Kedah, the Balik Pulau padi growing area in Penang and the Krian district in Perak. In Kedah, the samples were collected from Tajar River, Jerlun River and Padang River. For Balik Pulau and Krian areas the samples were collected from the irrigation canal.

The weeds were harvested from one square meter quadrat at the interval of 100 meter from each quadrat. A real coverage and fresh weight of the weeds were measured. In addition, the concentration of phosphate, conductivity and pH were analysed and measured.

Laboratory work

Most of the nutrient analysis was done at the School Biological Sciences, University Sains Malaysia (USM) and also MARDI Station, Bertam Seberang Prai. In this case, the total phosphate concentrations were analysed at the MARDI's laboratory. On the other hand, the soluble reactive phosphate (SRP - ($\text{PO}_4 - \text{P}$)) was analysed at the School of Biological Sciences.

The SRP was analysed based on the method by Harwood, Steenderen and Kuhn (1969). In addition, a series of experiment on the utilization of SRP by *Hydrilla verticillata*, *Lemna perpusila* and *Azolla pinnata* was monitored in the laboratory for six weeks. The concentrations of SRP ranging from 1.0, 0.1 and 0 mg/l were used.

Apparently, river water was known to contain most chemical elements including phosphate, so in this particular case, it was used as comparison to the various phosphate concentrations.

RESULT

Sample A fertilizer consists of high proportion of phosphate compare to sample B fertilizer (Table 1). Both of the fertilizers are widely used in the MADA irrigation scheme and the leaching of sample A fertilizer will obviously result in increasing the phosphate concentration in the waterways.

Table 1. The concentration of total phosphate from 1 gm of fertilizer (sample A and sample B) which was vigorously shaken for 15 minutes in 1000 ml of distilled water.

	Sample A	Sample B
No.		
1	82.25	0.75
2	65.72	1.00
3	76.45	1.05
4	46.45	0.90
5	72.35	0.65
	$A \pm SD = 68.64 \pm 12.33$	$B \pm SD = 0.87 \pm 0.15$

Note: The phosphate concentration in fertilizer sample A is about eighty times higher than the concentration in fertilizer sample B.

As the phosphate load is gradually increased, the aquatic weed species such as *Eichhornia crassipes* can take advantage of the excessive leaching nutrient and subsequently flourish well in the waterways. The dominant aquatic weed species from the various localities are shown in Table 2, Table 3, Table 4, Table 5 and Table 6. Table 7 shows the likely sources of SRP in the aquatic ecosystems.

Table 2. The dominant weed species in term of percentage coverage and g fresh weight per square meter, observed monthly at Tajar River (Stations 1 and 2) and Tajar irrigation canal (Stations 3, 4 and 5)

Station	Species	% coverage and fresh weight gm per m ² (1985)			
		April	May	June	July
1	- <i>Eichhornia crassipes</i>	100% (3065)	100% (6128)	100% (7932)	100% (8105)
2	- <i>Eichhornia crassipes</i>	70% (947)	5% (290)	5% (565)	25% (1665)
	- <i>polygonum barbatum</i>	10% (19)	-	-	-
	- <i>Ludwigia adscendens</i>	20% (60)	-	-	-
3	- <i>Nymphoides indica</i>	100% (480)	100% (640)	90% (435)	100% (684)
4	- <i>Nymphoides indica</i>	N.R.	80% (670)	80% (401)	80% (570)
	- <i>Utricularia aurcaus</i>	N.R.	-	10% (40)	10% (24)
	- <i>Ludwigia adscendens</i>	N.R.	-	2% (2)	-
5	- <i>Nymphoides indica</i>	N.R.	70% (290)	80% (585)	50% (248)
	- <i>Utricularia aureaus</i>	N.R.	10% (10)	10% (18)	10% (44)

Table 3. The dominant weed species in term of percentage coverage and g fresh weight per square meter, observed monthly at Jerlun main irrigation canal, in Kedah.

Station	Species	% coverage and fresh weight g per m ² (1985)			
		April	May	June	July
1	- <i>Eichhornia crassipes</i>	70% (752)	40% (554)	70% (715)	10% (210)
	- <i>Ludwigia adscendens</i>	20% (114)	10% (45)	-	-
	- <i>Salvinia molesta</i>	-	-	2% (7)	-
	- <i>Pistia Stratiotes</i>	-	-	8% (45)	-
	- <i>Ipomoea aquatica</i>	10% (42)	-	-	-
	- <i>Polygonum barbatum</i>	-	-	-	2% (175)
2	- <i>Eichhornia crassipes</i>	70% (947)	70% (760)	30% (192)	95% (1975)
	- <i>Polygonum barbatum</i>	10% (19)	-	-	5% (315)
	- <i>Ludwigia adscendens</i>	20% (60)	-	-	-
3	- <i>Eichhornia crassipes</i>	-	-	-	15% (155)
	- <i>Pistia stratiotes</i>	-	-	-	1% (30)
	- <i>Nymphaea nouchali</i>	100% (200)	80% (480)	100% (400)	-

Table 4. The dominant weed species in term of percentage coverage and g fresh weight per square meter, observed monthly at Padang main irrigation canal, in Kedah.

Station	Species	% coverage and fresh weight g per m ² (1985)			
		April	May	June	July
1	- <i>Nelumbo nucifera</i>	80% (377)	80% (628)	90% (685)	80% (395)
	- <i>Ipomoea aquatica</i>	20% (115)	-	-	-
	- <i>Eichhornia crassipes</i>	-	-	-	10% (140)
2	- <i>Eichhornia crassipes</i>	-	-	5% (35)	55% (1085)

Station	Species	% coverage and fresh weight g per m ² (1985)			
		April	May	June	July
	- <i>Ludwigia adscendens</i>	-	-	-	20% (40)
	- <i>Pistia Stratiotes</i>	-	-	-	10% (45)
	- <i>Ipomoea aquatica</i>	50% (1964)	-	-	1% (25)
	- <i>Polygonum barbatum</i>	20% (96)	-	-	-

Table 5. The dominant weed species in term of percentage coverage and g fresh weight per square meter, taken at Balik Pulau area, Penang.

Locality	Station	Species	% coverage	g/m ² fresh wt.
1) Permatang Pasir River	1	<i>Eichhornia crassipes</i>	100%	7422
	2	<i>Eichhornia crassipes</i>	100%	7450
2) Kampong Paya irrigation canal	1	<i>Eichhornia crassipes</i>	100%	4500
	2	<i>Hydrilla verticillata</i>	5%	100
	3	<i>Hydrilla verticillata</i>	80%	1800
	4	<i>Hydrilla verticillata</i>	100%	5500

Table 6. The dominant weed species observed in several irrigation canal in Kerian district and also Parit, Perak.

Locality	Station	Species	% coverage	g/m ² fresh wt.
Simpang Lime	1	<i>Ceratophyllum demersum</i>	100	4500
	2	<i>Ipomoea aquatica</i>	40	1000
Titi Serong irrigation canal	1	<i>Hydrilla verticillata</i>	100	5000
	2	<i>Hydrilla verticillata</i>	80	4000

Locality	Station	Species	% coverage	g/m ² fresh wt.
Parit irrigation canal	1	<i>Ludwigia adscendens</i>	20	100
		<i>Hydrilla verticillata</i>	40	300
	2	<i>Ludwigia adscendens</i>	50	1000
		<i>Hydrilla verticillata</i>	20	300
Tanjung Belanja irrigation canal	1	<i>Polygonum barbatum</i>	60	1814

Table 7. Concentration of SRP and also dominant aquatic weeds

No.	Likely sources of phosphate	SRP mg/l	Dominant aquatic weed	Locality
1.	pig wastes	15.00 ± 0.100 (12/5/85)	-	Discharge outlet Gertak Sanggul (Penang)
2.	Sago factory	4.86 ± 0.100 (10/12/83)	-	Effluent from the factory (S. Perai)
3.	Fertilizer (padi field)	0.245 ± 0.050	<i>Eichhornia crassipes</i>	Irrigation canal (padi field) B. Pulau, Penang
4.	Fertilizer (padi field)	0.235 ± 0.020	<i>Ceratophyllum demersum</i>	Irrigation canal (padi field) Krian
5.	Fertilizer (padi field)	0.268 ± 0.020	<i>Hydrilla verticillata</i>	Irrigation canal (Titi Serong)
6.	Fertilizer (padi field)	8.22 ± 0.050	<i>Eichhornia crassipes</i>	Small area (S. Tajar, Kedah)

The monthly fluctuated total phosphate concentrations are shown in figure 1. Figure 2 shows a linear correlation between the SRP concentrations with the conductivity values.

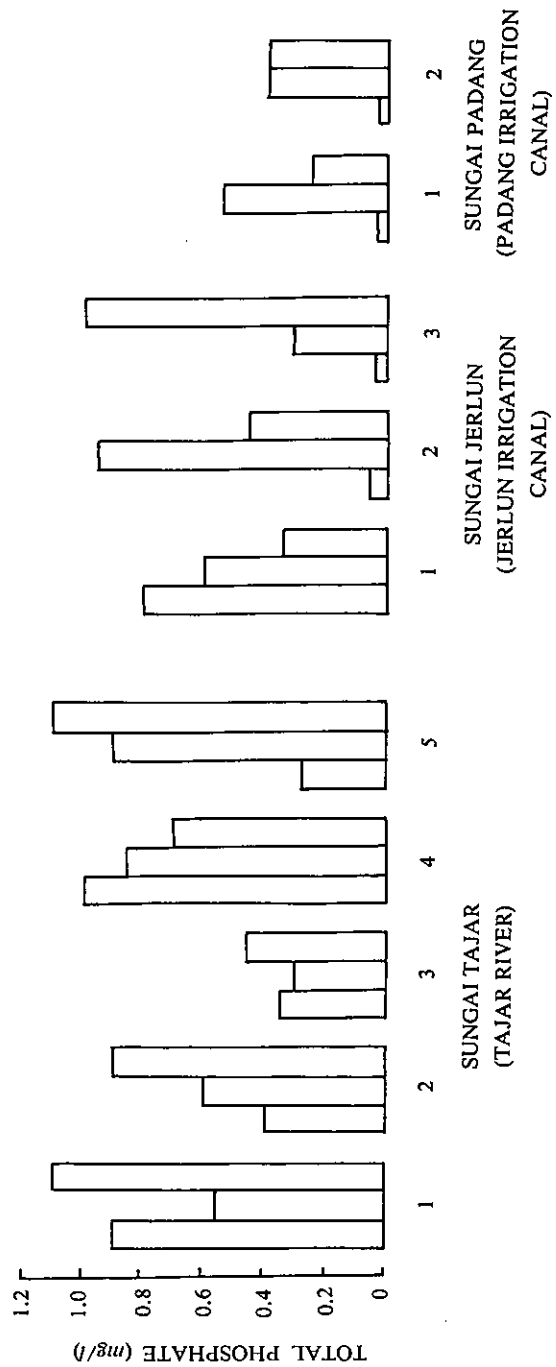


Fig. 1. The concentrations of total phosphate from the waterways in the State of Kedah.

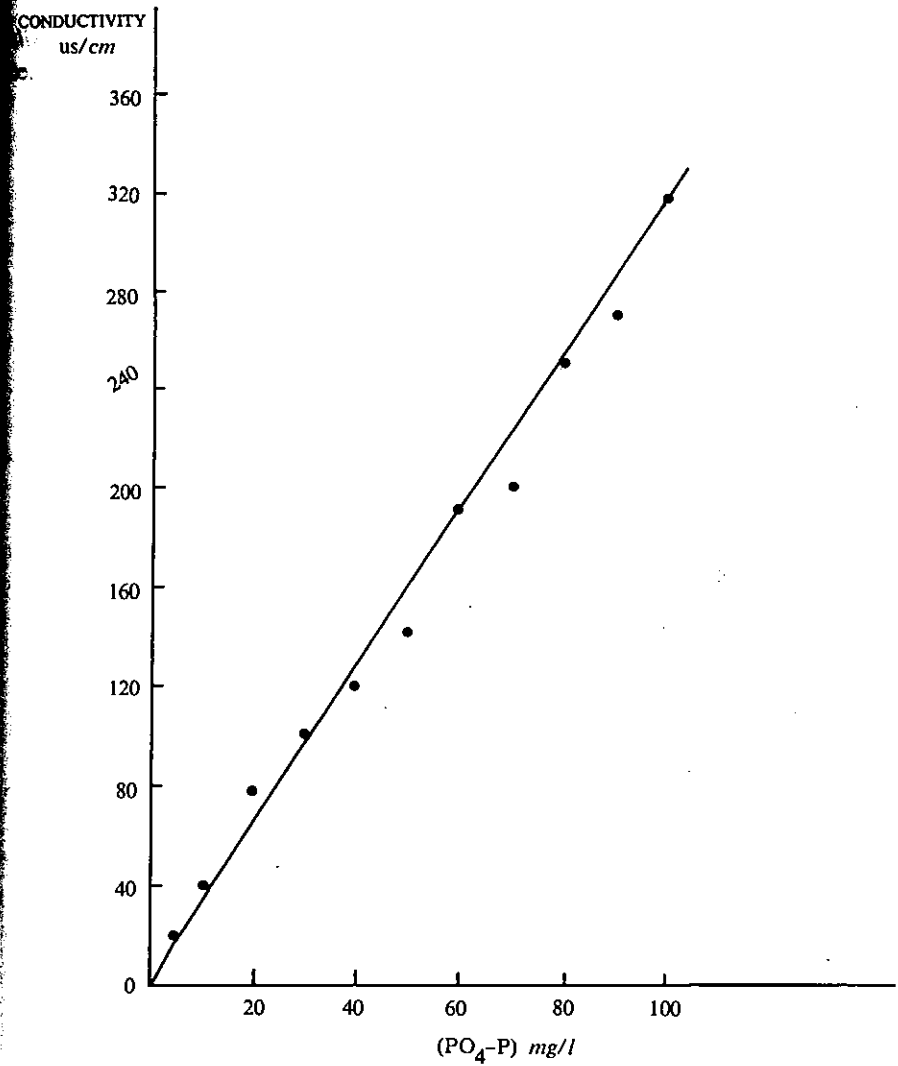


Fig. 2. A linear correlation for soluble reactive phosphate concentrations and conductivity values.

It seemed that the higher SRP concentrations in the water, the higher the conductivity values. However, the pH value remain constant with different SRP concentrations.

The percentages of increase in growth of *Hydrilla verticillata* and *Lemna perpusila* are shown in Figure 3 and Figure 4. It was observed that both of the weeds flourished well in the mg/l SRP water within six weeks.

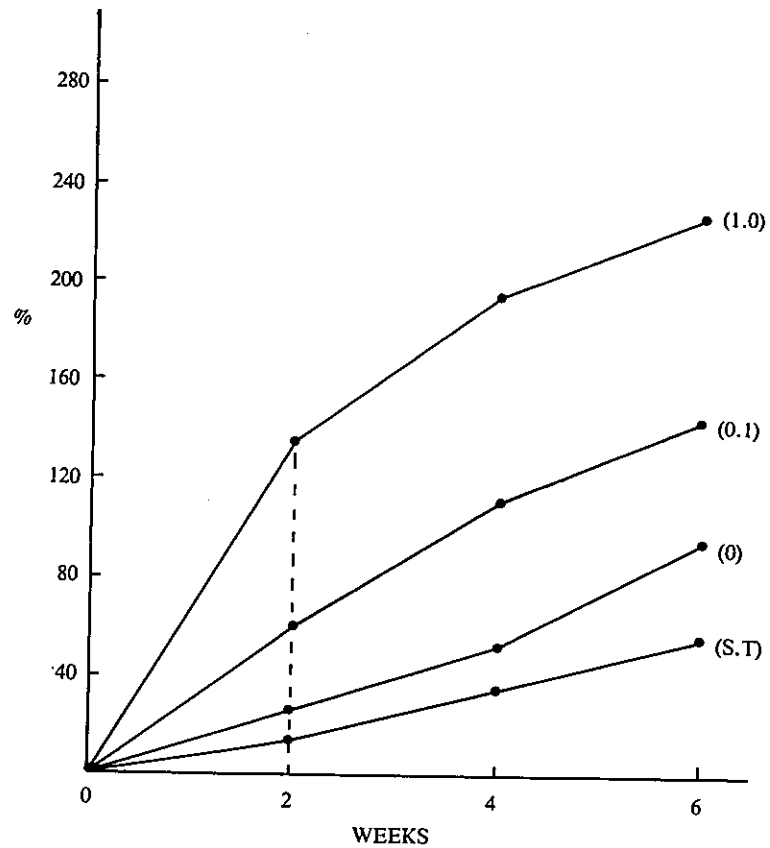


Fig. 3. The growth of *Hydrilla verticillata* in several concentrations of phosphate within 6 weeks.

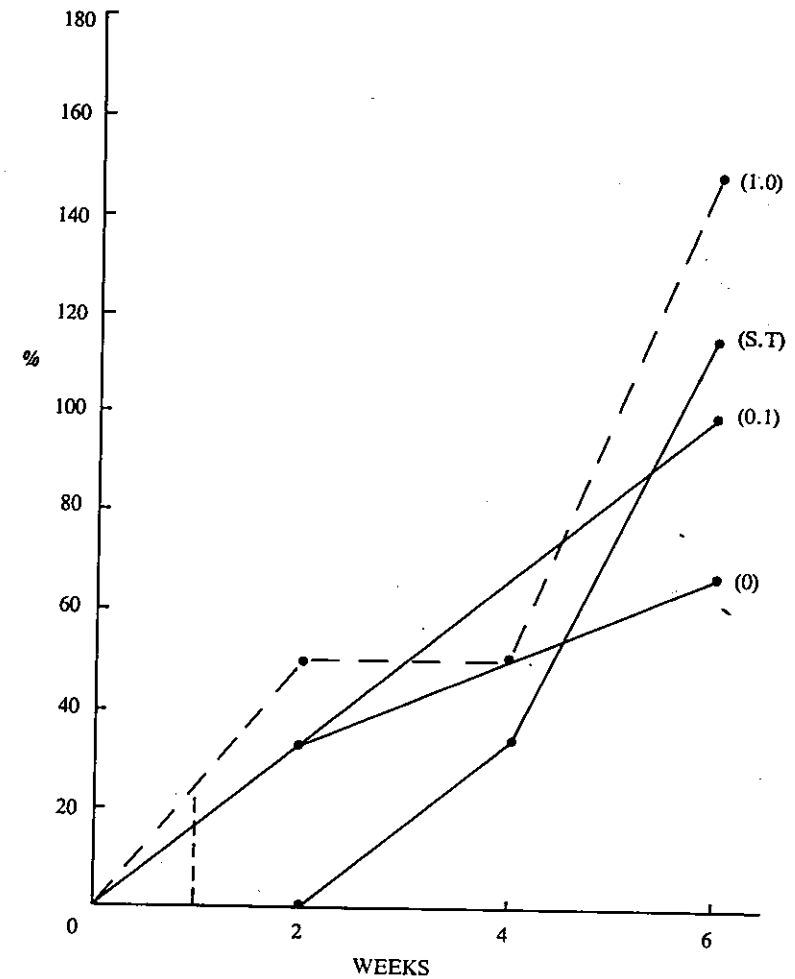


Fig. 4. The growth of *Lemna perpusila* in several concentrations of phosphate within 6 weeks.

DISCUSSION

Geographical areas

A large proportion of soil in the Northern Peninsular Malaysia is made up of coastal and alluvial soils. These types of soil seem to be suitable for padi cultivation. Ample supply of rainfall particularly during the wet season which normally extends from August to November, has greatly helped the local padi planters to irrigate their padi fields.

The MUDA irrigation scheme which is the second largest integrated agricultural development implemented by the Malaysian Government covers an area of 236,800 acres of padi land and is located mainly in the state of Kedah. The construction of MUDA irrigation scheme was completed in 1970 with approximately 540 miles long of irrigation canals. Normally, the water from several rivers is pumped into the subsequent irrigation canals.

According to Zulkifli Mohd. Ali (1980), the high rate of fertilizer application has led to a high nutrient content in the drainage water. The high level of the drainage water coupled with the sluggish water flow due to excessive silting creates an environment conducive to the proliferation of aquatic weeds. Table 1 shows the two types of fertilizers widely used in the irrigation scheme. It should be noted that some of the fertilizers contain extremely high concentration of total phosphate. Leaching of nutrient such as phosphate from adjoining padi fields could result in an adverse effect on the aquatic ecosystem particularly in helping the weeds to get sufficient supply of nourishment.

In Penang, padi is mainly grown in the agricultural areas of Balik Pulau and Seberang Perai. However, according to Mohd. Yusof Hashim (1985) the acreage under padi has declined substantially over the years from 31,000 ha in 1970 to 17,000 ha in 1983. This is largely due to the poor drainage and irrigation facilities. Undoubtedly, weeds such as *Eichhornia crassipes*, *Ipomoea aquatica* and *Pistia stratiotes* play a major role in clogging and also blocking the waterways.

In fact, the first major irrigation scheme in the Peninsula was undertaken in Krian in north western Perak. Most of the construction took place between 1899 to 1900. When completed, approximately 20,250 ha of land were available for cultivation and 140 miles of drains had been dug (Ailen et al. 1982). Most of the irrigation canals in this area has to be constantly cleared off from the prevalent aquatic weeds in order to get ample supply of water to the padi fields.

Aquatic weed

Evidently, the padi growing areas are also suitable for aquatic weeds. Furthermore, substantial input of nutrient such as phosphate which normally leach out into the waterways, will be beneficial to the massive growth of aquatic weeds.

Baki Bakar (1982) has previously indicated that several noxious aquatic weeds were found in the irrigation canals in these padi growing areas. The dominant weeds were *Eichhornia crassipes*, *Eleocharis variegata*, *Junssia repens* (*Ludwigia adscendens*), *Scirpus grossus* and *Leesia hexandra*. In the state of Kedah alone, 100%

coverage of *Eichhornia crassipes* was observed in many places. In many cases, the canals were no longer functioning due to the dense growth of the weed. At Kajang River, the gradual increase in fresh weight was seen monthly in the sampling quadrat where it reached a maximum value of 8105 g/m² in July 1985.

Nymphoides indica is normally found in the irrigation canals and the fresh weight observed from the sampling quadrat generally differs every month. *Nelumbo picea* was prevalent at Padang irrigation canal particularly at station 1 and the fresh weight reaching a maximum of 685 g/m². Apart from the weed species shown in Tables 2, 3, and 4, most of the waterways in the state of Kedah were also infested with *Lemna perpusila*, *Limncharis flava*, *Azolla pinnata*, *Ceratophyllum demersum*, *Hydrilla verticillata* and *Ludwigia octovalvis*.

The two most dominant species found in Balik Pulau rice growing area were *Eichhornia crassipes* and *Hydrilla verticillata*. In addition to the two species, *Vallisneria spiralis*, *Ottelia alimoides* and *Ceratophyllum demersum* were found abundantly in the irrigation canals and small rivers. *Limncharis flava*, *salvinia natans* and *Lemna perpusila* were normally found in the padi field plots.

The Krian district in Perak harbours several undesirable weeds, notably *Eichhornia crassipes*, *Ipomoea aquatica*, *Hydrilla verticillata*, *Ludwigia adscendens* and *Polygonum barbatum*. Generally a bigger irrigation canal like the Titi Serong irrigation canal with the width 60 meter and depth approximately 1 meter, covers heavily on both banks with *Hydrilla verticillata*. However a much smaller irrigation canal such as Simpang Lima irrigation canal with the width 20 meter and depth 0.5 meter generally covers with *Ceratophyllum demersum*, *Ipomoea aquatica* and *Lemna perpusila*. Consequently, the abandoned rice field in the area is normally overgrown with weeds such as *Cyperus pilosus*, *Cyperus imbricatus*, *Eleocharis dulcis*, *Scirpus grossus*, *Fimbristylis littoralis*, *Blyxa sp*, *Marsilea sp* and *Cabomba sp*.

Several methods are employed to eradicate the unwanted weeds. Mechanical methods such as cutting are mainly used. Due to the high cost, herbicide is seldom used. However to date, there is practically no single method that can be considered effective in combating the prevalent aquatic weeds. The only solution to this particular problem is to make aquatic weeds more useful and beneficial to mankind. Many countries have utilized aquatic weeds commercially such as in producing biogas and in manufacturing papers and cards.

Phosphate

There are several factors that governed the massive growth of aquatic weeds. Nutrient, such as phosphate and nitrate could play an important role in triggering the growth of aquatic weeds (Mashhor Mansor et al - 1983). It is naturally known that the concentration of phosphate presence in any unpolluted water body is normally low and beyond the limit of detection. Nowadays, the rate of phosphate being added to the aquatic ecosystem is greatly accelerated by the activities of man in discharging excessive nutrients to the water.

Table 7 show the likely sources of phosphate and it indicated that the effluent from the pig farm was extremely high in SRP (soluble reactive phosphate - (PO₄ - P))

LITERATURE CITED

reaching a maximum value of 15 mg/l. This sluggish water was so smelly and dirty. Fortunately, it was observed that no weed could survive in this type of water. The effluent from the Sago factory was also high in SRP reading reaching 4.186 mg/l ($\text{PO}_4 - \text{P}$). Although the SRP in the waterways in the padi field areas was reasonably high, it was still relatively low compared to the effluents of Sago factory and pig farm. Anyhow the aquatic weeds, such as *Eichhornia crassipes*, *Ceratophyllum demersum* and *Hydrilla verticillata* seemed to grow very well in this type of water with SRP concentrations ranging from 0.235 mg/l to 0.822 mg/l.

The leaching of phosphate into the waterways in the MUDA irrigation scheme was shown in Figure 2. The total phosphate concentration in Tajar River was generally higher than the other two irrigation canals and this probably be one of the reasons why aquatic weeds were more abundant in Tajar River.

Figure 2 showed that there is a correlation between SRP and conductivity values. The higher SRP concentration in the water, the higher the conductivity reading and linear regression $y = 2.98x + 5.62$ ($r = 0.995$) was established. Apart from this, a series of monitored experiments on the growth of various weeds by several concentrations of SRP are shown in Figure 4 and Figure 5. At the SRP concentration of 1 mg/l *Hydrilla verticillata* could grow to more than 200% in 6 weeks and at 0.1 mg/l *Hydrilla verticillata* could grow up to 160% in 6 weeks. Even at 0 mg/l, this plant seemed to be growing but at a slower rate.

After six weeks, *Lemna perpusila* grow extremely well in the water consisting of 1 mg/l ($\text{PO}_4 - \text{P}$). In river water, it could grow approximately more than 100% where as in 0 mg/l ($\text{PO}_4 - \text{P}$) the plant grew much slower within the six weeks period.

A similar experiment on *Azolla pinnata* did not produce any positive results. Here, within a week, most of the experimental plants died in various SRP concentration solutions. So, at least it can be concluded that certain weeds like *Azolla pinnata* do not need a high concentration of SRP in the water to grow.

CONCLUSION

- 1) Most of the irrigation canals and small rivers in padi growing areas of Northern Peninsular Malaysia are generally high in phosphate concentrations
- 2) The most dominant aquatic weeds from these areas are *Eichhornia crassipes*, *Nymphoides indica*, *Ludwigia adscendens*, *Polygonum barbatum*, *Ipomoea aquatica*, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Salvinia natans*, *Lemna perpusila*, *Salvinia molesta* and *Pistia stratiotes*.
- 3) It is known that *Hydrilla verticillata* and *Lemna perpusila* can grow very well in the water consists of 1 mg/l ($\text{PO}_4 - \text{P}$).
- 4) Some aquatic weeds, such as *Azolla pinnata* do not grow well in phosphate enriched water.

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PISCICIDAL SUBSTANCE CONTAINED IN *Ammannia baccifera* L.

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ABSTRACT

To clarify the roles of weeds as pollutant in aquatic environment, piscicidal activity of 54 weed species was investigated. As a result, *Ammannia baccifera* L. showed the strongest activity to guppy (*Lebistes reticulatus*). The methanol extract was purified by charcoal-celite column chromatography and thin-layer chromatography (TLC). The purified substance was identified as α -naphthoquinone by UV spectrum and gas chromatography-mass spectrometry (GC-MS). 78 μ g of this substance contained in 1 g fresh weight of the plant and TLM was 0.09 ppm for guppy.

INTRODUCTION

It has been reported that many plants contain piscicidal substances such as justicidin A and B in *Justicia hayatai* var. *decumbens* (Ohta et al, 1969, 1971), maingayic acid in *Callicarpa maingai* (Nishino et al, 1971), huratoxin in *Hura crepitans* (Sakai et al, 1971), vibsanine A in *Viburnum awabuki* (Kawazu and Mitsui, 1974), rotenone in *Derris elliptica*, 5-hydroxynaphthoquinone in *Juglans mandshurica* or *Callicarpa* in *Callicarpa candicans* (reviewed by Kawazu, 1972).

Recently it was found that *Polygonum hydropiper*, a weed in aquatic environment, contained polygodial which showed a strong piscicidal activity (Harada and Yano, 1983). This finding is very important from the view point of environmental pollution. Since farmers in most Southeast Asian countries, control aquatic weeds by plowing and flooding the land, where fish culture is commonly practiced. In addition, fish often die with unknown cause in Thailand, although any agrochemicals are not used in the area at all.

From these facts, we considered that piscicidal substances contained in aquatic weeds might be related to the cause of fish killing. Hence, we examined the piscicidal activity of weed species grown in tropical aquatic environment and found that *Ammannia baccifera* showed the strongest activity among 54 species tested (Zungsonthiporn et al, unpublished). A part of the results, in which an identification of the active substance contained in this species is dealt with, is presented in this paper.

Materials.

Shoots of *A. baccifera* which belongs to family *Lythraceae* were collected from a paddy field in Bangkok, Bangkok during December 1984, and kept at -30°C until use.

Bioassay for piscicidal activity.

One g of frozen material were homogenized with five times the amount (w/w) of water, hot (80°C) water, methanol, ethyl acetate, benzene or n-hexane by universal homogenizer (Nippon-seiki, type HC) for five min., twice. Filtered extracts were concentrated in vacuo. From them, an equivalent amount of 0.1, 0.5 and 1.0 g of frozen material, respectively were taken, dried out on a filter paper (Toyo No. 2, 11 cm ϕ), cut into small pieces and soaked into 200 ml of tap water in a plastic pot (11 cm ϕ , 5.2 cm H) with five guppy fish (*Lebistes reticulatus*). Mortality of the fish was checked 24 hours after the treatment.

Charcoal-celite column chromatography.

Concentrated methanol extract (equivalent to 25 g fresh material) was poured on top of the column (19 mm ϕ x 800 mm L) packed with the mixture of 10 g charcoal (Kanto Chemical Co.) and 20 g celite (Johns-Manville, No. 545). Step elution with water/acetone mixture (v/v) was employed from 50/50 to 0/100 at 10% difference. Every 100 ml of eluate was collected and concentrated in vacuo for the use of bioassay or further analysis.

Thin-layer chromatography (TLC).

Piscicidal active fraction of charcoal-celite column chromatography was developed on silica gel TLC plate (Whatman, LK6) by using n-hexane/ethyl acetate mixture (9/1 v/v) as a developing solvent. The dark violet color band under UV light was scraped off and eluted with methanol for piscicidal bioassay, UV (by Shimadzu spectrophotometer, UV-240), GC (by Shimadzu, GC7A-PTF) and gas chromatography-mass spectrometry (GC-MS) (by Shimadzu, LKB-9000) analyses.

RESULTS AND DISCUSSION

Piscicidal substance (s) was extracted from shoots of *A. baccifera* with various solvents. The results are shown in Table 1. Most extracts except water showed strong activity. It is clearly understood that the active substance(s) is widely soluble in non-polar to polar organic solvents. Methanol extract, however, killed the fish earlier than the other extracts. Hence we used methanol for extraction thereafter.

Purification of the active substance(s) was carried out by a charcoal-celite column chromatography with water/acetone step elution system. As a result, the active substance(s) came out in 0/100 (water/acetone, v/v) fraction. One g (equivalent to fresh material) of the active fraction was developed on TLC plate with n-hexane/ethylacetate mixture (9/1, v/v). The dark violet band was found at R_f 0.65 under

UV light as shown in Fig. 1. This zone was scraped off and eluted with methanol for piscicidal activity and further analysis. The substance(s) at Rf 0.65 apparently showed a strong piscicidal activity.

Table 1. Piscicidal activity of various extracts from 0.1, 0.5 and 1.0 g fresh weight of *Ammannia baccifera* shoots

Solvent	Mortality (%)		
	0.1	0.5	1.0
Cold water	0	0	0
Hot water (80°C)	0	0	20
Methanol	100	100	100
Ethyl acetate	100	100	100
Benzene	100	100	100
n-Hexane	100	100	100

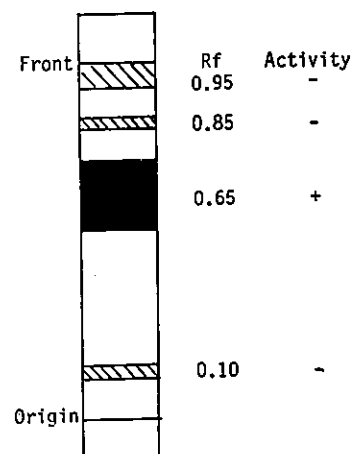


Fig. 1. Thin layer chromatogram of the active fraction from charcoal-cellulose column chromatography. Silica gel plate --- whatman LK 6, 5 x 20 cm. Developing solvent --- n-Hexane : Ethyl acetate 9:1 (v/v)

UV-absorption spectrum of the active zone is shown in Fig. 2. λ max in methanol was 244 nm. The pattern resembled to that of α -naphthoquinone. GC and GC-MS analyses, however, were carried out for identification of the substance. GC pattern is shown in Fig. 3. The active zone gave three peaks, one major and two minor. Mass spectrogram of major substance (A) gave fragment peaks 158M⁺, 130, 104, 102, 76 as shown in Fig. 4. Fragment peaks of the first (B) and the second (C) minor substances were 174M⁺, 158, 146, 130, 118, 105, 102, 89, 76, and 188M⁺, 174, 158, 130, 116, 102, 89, 76, respectively. From the results, major active substance contained in *A. baccifera* was identified as α -naphthoquinone (chemical structure is shown in Fig. 5), however, two minor substances still remain unknown.

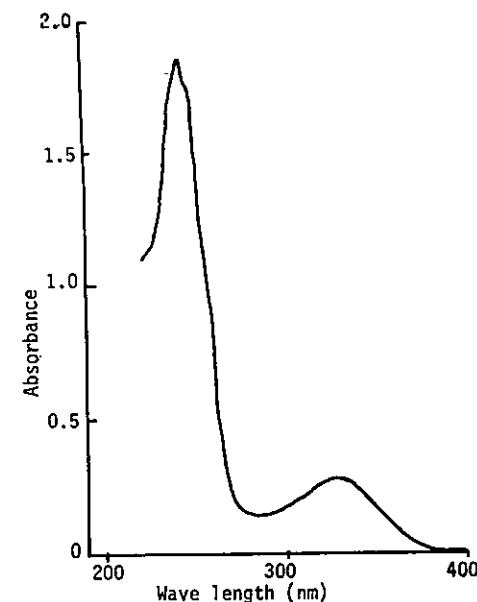


Fig. 2. UV-absorption spectrum of methanol solution of piscicidal substance isolated from *Ammannia baccifera*.

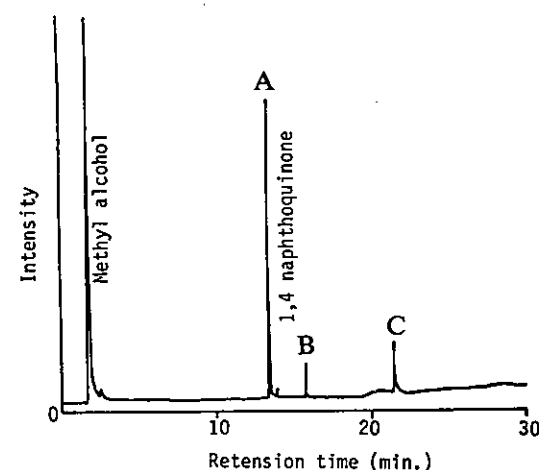


Fig. 3. Gas-chromatogram of active fraction from TLC. Column : 25 m L, 0.2 mm I.D. Temp : 100 $\rightarrow$ 280°C (6°C/min) Liquid phase : 5% phenylmethyl silicone Carrier Gas : He. Flow rate : 50 ml/min, column 0.5 ml/min Vent : 50 ml/min, split ratio : 1:100

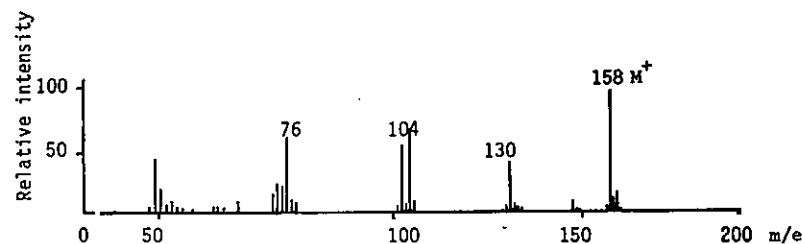


Fig. 4. Mass spectrogram of piscicidal substance isolated from *Ammannia baccifera*

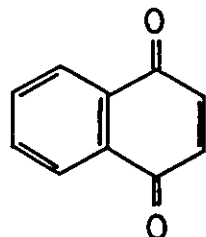


Fig. 5. Chemical structure of α -naphthoquinone

To ascertain the activity, piscicidal effect of synthetic α -naphthoquinone (Wako Pure Chem. Inc.) was examined by using guppy. As a result (Fig. 6), TLM (24 h) was about 0.09 ppm. This value is just moderate compared with other piscicidal substances; i.e. huratoxin: 0.0014, justicidin A and B: 0.02 and 0.04, callicarpone: 0.04, vibsanine: 0.1, cis-dehydromatricaria ester: 2, maingayic acid: 4.7 and inophyllolide: 5 ppm (reviewed by Kawazu, 1972).

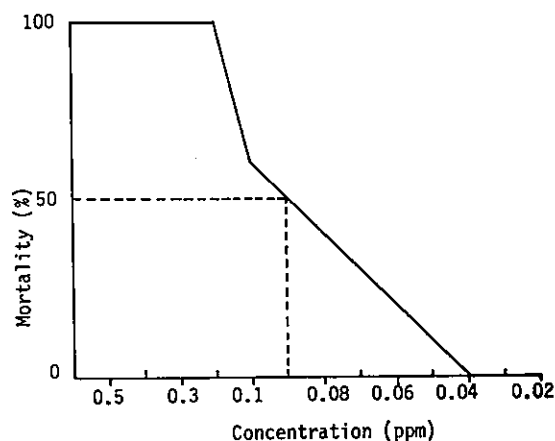


Fig. 6. Effect of synthetic α -naphthoquinone to the guppy fish

Quantitative analysis by using UV absorption spectrum revealed that one g fresh weight of *A. baccifera* shoots contained 78 μ g of α -naphthoquinone. From this point, enough amount of pollutant can be found in aquatic environment all over the country.

Our field observation in Buri Ram, Surin and Si Sa Ket, Northeastern Thailand on December 11 to 13, 1984 revealed that heavy proliferation of piscicidal aquatic weeds as well as *A. baccifera* was found in the area where large number of fish died. Further studies, however, are essential to clarify the relation between piscicidal aquatic weeds and the cause of fish killing in natural condition.

ACKNOWLEDGEMENTS

We wish to express our sincere gratitude to Mr. Yingyong Paisooksantivatana, Botany Section, Department of Agriculture and Mr. Akira Yamamoto, Shinetsu Chemical Ind. Co., Ltd., Japan, for identification of the plants and GC-MS analysis, respectively.

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PLANT GROWTH INHIBITING EFFECTS OF WEED SPECIES WITH REFERENCE TO ALLELOPATHY

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ABSTRACT

Plant growth inhibiting effects of methanolic extracts from 24 weed species were examined by rice (*Oryza sativa* L. cv. RD25) seedling bioassay. As a result, *Eupatorium odoratum* L., *Hyptis suaveolens* Poit., *Dysophylla stellata* Benth., *Ammannia baccifera* L., *Heliotropium indicum* L., *Polygonum tomentosum* Willd. and *Sphenoclea zeylanica* Gaertn showed the strongest effect. *Jussiaea linifolia*, Vahl. *Euphorbia hirta* L., *E. thymifolia* L., *Mimosa pigra* L., *Aschynomene americana* L., *Sesbania roxburghii* Merr., *Alternanthera sessilis* DC., *Sphaeranthus africanus* L., *Trianthema portulacastrum* L., and *Cleome viscosa* L. showed moderate. *Xyris indica* L., *Eclipta alba* Hassk. *Eleocharis dulcis* Henschel. and *Euphorbia geniculata* Ort. showed slightly effect. *Monochoria vaginalis* Presl., *Portulaca oleracea* L., and *Amaranthus spinosus* L., showed the least effect.

INTRODUCTION

Chemical substances contained in weeds often play an important role as one of the environmental factors which affect the growth of other weeds or crops. This phenomenon is well known as an allelopathy.

Many works on allelopathy have been reported with various weed species. Plant growth inhibiting substance contained in quackgrass (*Agropyron repens*) induced chlorosis and stunting of oat and alfalfa (Ohman and Kommedahl, 1964). Aqueous foliage extracts of leaf spurge (*Euphorbia esula*) inhibited the germination and seedling growth of wheat and pea. The toxic substance was released during leaf spurge decomposition (Le Tourneau et al, 1956). Root residues of *Setaria faberii*, *S. glauca* and *Digitaria sanguinalis* inhibited corn root growth. Among them, *S. faberii* was the most inhibitory (Schreiber and Williams Jr., 1967). Allelopathic substances contained in *Abutilon theophrasti* inhibited tomato seed germination and they were identified as free amino acids (Gressel and Holm, 1964). Sanchez et al (1973) revealed that the competition of corn and yellow nutsedge (*Cyperus esculentus*) was not due to nutrient uptake on utilization but allelopathic activity of yellow nutsedge. Active substances of this weed were identified as phenol compounds (Drost and Doll, 1980). Plant growth inhibiting substance contained in *Polygonum hydropiper* was identified as polygodial (Harada and Yano, 1983).

In Thailand, there are many kinds of weed showing high competitive ability with crop plants, some of which might be due to allelopathic effects besides the competition

for light, water, nutrients, etc. This paper deals with the results of the investigation on the existence of plant growth inhibiting substances in certain weed species in Thailand.

MATERIALS AND METHODS

Twenty four species of serious weeds were collected from paddy and upland fields and kept in a freezer (-30°C) until use. One hundred g of each frozen material was homogenized with five times (w/w) of cold methanol twice by a universal homogenizer (Nippon seiki, type HC). Filtered methanol extracts of 1, 5 and 10 g equivalent to fresh material were taken and poured into glass vial (30 mm ϕ $\times$ 120 mm H) containing 1.5 g of cellulose powder (Toyo, type D). After drying in vacuo, 5 ml of distilled water was added to each vial. Six uniformly germinated rice seeds (*Oryza sativa* cv RD 25) were placed in the vial. The vials were covered with vinyl film and placed in a growth chamber with a temperature of 30°C and a light intensity of 3500 lux at plant level. One ml of distilled water per vial was added three days later and the length of the second leaf sheath and the longest root were measured seven days after the treatment. Each treatment was triplicated.

RESULTS AND DISCUSSION

Effects of the methanolic extracts from 24 weed species on the growth of rice seedlings were examined. The results (shown in Fig. 1 and 2) revealed that all of the extracts more or less inhibited the growth of rice and the root growth was more affected than the sheath growth in most species.

Plant extracts of *Eupatorium odoratum*, *Dysophylla stellata*, *Hyptis suaveolens*, *Ammannia baccifera*, *Heliotropium indicum*, *Polygonum tomentosum* and *Sphenoclea zeylanica* showed the strongest inhibitory effect on the seedling growth, i.e. root length was about 0-12, 0-7 and 0-4 % and sheath length was about 0-16, 0-15 and 0-7 % of the untreated at 1, 5 and 10 g equivalent to fresh material, respectively.

Plant extracts of *Jussia linifolia*, *Sesbania roxburghii*, *Euphorbia hirta*, *E. thymifolia*, *Cleome viscosa*, *Mimosa pigra*, *Aeschynomene americana*, *Alternanthera sessilis*, *Sphaeranthus africanus* and *Trianthema portulacastrum* showed moderate inhibitory effect on the rice seedling growth, i.e. root length was about 0-30, 0-5 and 0-5 % and sheath length was about 10-65, 0-50 and 0-5 % of the untreated at 1, 5 and 10 g equivalent to fresh material, respectively. Plant extracts of these weeds clearly showed at lower concentration that the root growth was more affected than the sheath growth of rice seedlings.

Extracts from *Xyris indica*, *Eclipta alba*, *Eleocharis dulcis* and *Euphorbia geniculata* showed a slight inhibitory effect on the rice seedling growth, i.e. root length was about 30, 0-5 and 2 % and sheath length was about 50, 35-50 and 20 % of the untreated at 1, 5 and 10 g equivalent to fresh material, respectively.

Weeds of which extract showed the least effect were *Monochoria vaginalis*, *Potulaca oleracea* and *Amaranthus spinosus*. The extracts showed inhibitory effects on the rice seedling growth only at higher concentration.

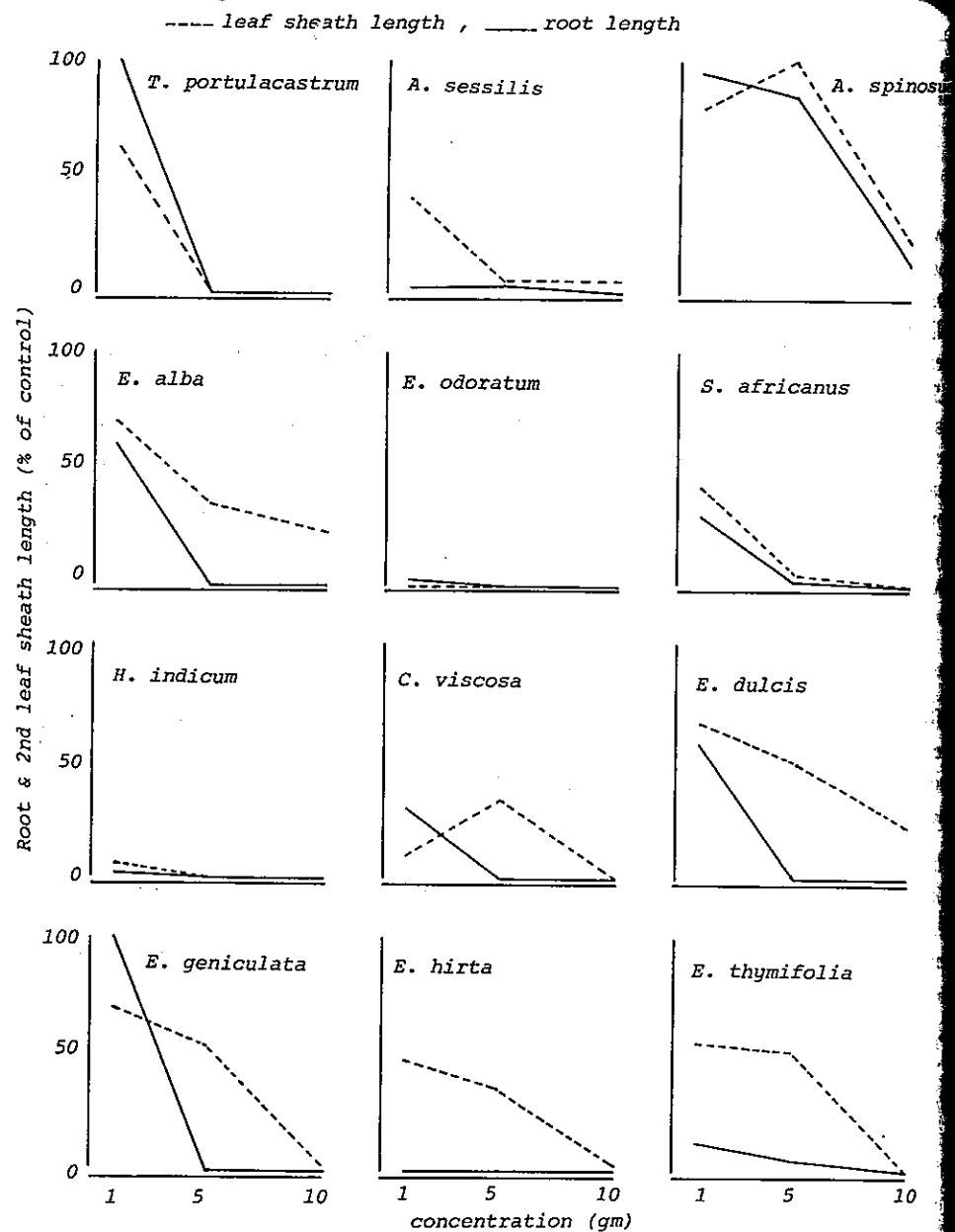


Fig. I. Effect of methanol extract of weeds on the growth of rice seedlings. CV. RD. 25

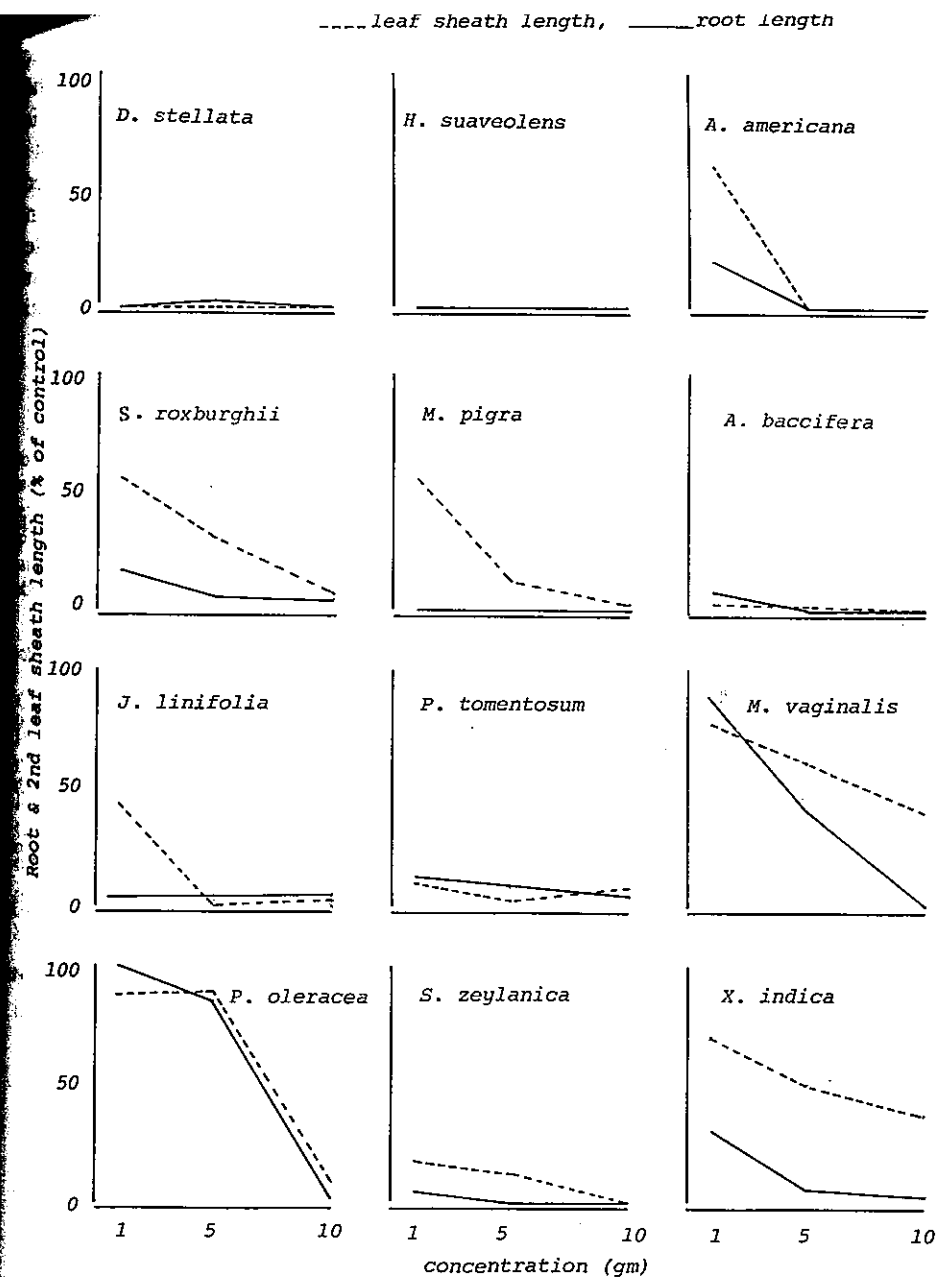


Fig. II. Effect of methanol extract of weeds on the growth of rice seedlings. CV. RD. 25

Data indicate that most weeds tested contain plant growth inhibiting substances although these substances are not always related to allelopathy. However, further investigation on the existence of plant growth inhibiting substances in weed species will be a stepping stone to reveal allelopathy. Moreover, mechanical weed control is a popular method in agricultural area of Thailand. Generally after eradication weeds are always mixed in the soil as a green manure or sometimes weeds are dried and mixed in the soil during land preparation. Horowitz and Friedman (1971) revealed that fresh or dried plant material can produce toxic substance during their decomposition. From this point of view, we must avoid to incorporate weeds which contain strong plant growth inhibiting substances, into the soil.

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PLANT GROWTH INHIBITING SUBSTANCE CONTAINED IN *Oenanthe javanica* (BLUME) DC.

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ABSTRACT

n-Hexane fraction from methanolic extract of *Oenanthe javanica* (Blume) DC. showed a strong inhibitory effect on the shoot growth of rice (*Oryza sativa* L. cv Tanginbozu) seedling. The active substance was purified by charcoal-celite column chromatography and TLC. The purified substance was identified as apiole, 1-allyl-2, 5-dimethoxy-3, 4-methylene dioxymethylene by UV-spectrum and GC-MS.

INTRODUCTION

Oenanthe javanica (Blume) DC. which belongs to family *Umbelliferae* is a serious perennial paddy weed in Japan (Numata et al, 1975). This weed often forms a pure community in paddy field or paddy levee and severely cause weed damage to rice plants. It is often observed in the direct-sown paddy field with heavy infestation of this weed that rice seedlings are extremely retarded their growth and are not able to emerge from the soil surface (Harada, unpublished). From such observation, the author presumed that *O. javanica* plant might contain allelochemicals which inhibit the growth of other weeds or crops.

This paper deals with an identification of plant growth inhibiting substance contained in *O. javanica* plant.

MATERIALS AND METHODS

Materials.

Shoots of *O. javanica* at vegetative stage were collected from the paddy fields of Hokuriku Nat'l Agr. Exp. Station, Joetsu-city, Niigata-prefecture during April through July, 1983 and kept at -80°C until use.

Bioassay for plant growth inhibiting activity.

Frozen plant material was homogenized with five times the amount (w/w) of cold methanol by a universal homogenizer (Nipponseiki, type HC) twice. Filtered methanol extract was concentrated in vacuo. Aqueous residue was partitioned with an equal volume of n-hexane five times. From original methanol extract, n-hexane phase and aqueous residue, an equivalent amount of 0.1, 1 and 5 g fresh material respectively was taken and poured into a glass vial (18 mm Ø × 118 mm H) containing 1.5 g of cellulose powder (Tovo, type D) and dried out in a vacuum chamber. Then, 6 ml of distilled

water per vial was added and uniformly germinated rice (*Oryza sativa* L. cv. Tan-ginbozu) seeds were placed in groups of six. The vials were covered with vinyl film and placed in a growth chamber with a temperature of 30 °C and a light intensity of 3000 lux at plant level. Distilled water was added at 1 ml per vial 3 days later and the length of the second leaf sheath and the longest root were measured after another 7 days. Each treatment was duplicated.

Charcoal-celite column chromatography.

Concentrated methanol extract (equivalent to 50 g fresh material) was poured on top of the column (14 mm ϕ $\times$ 300 mm L) packed with the mixture of 5 g charcoal (Wako activated charcoal powder) and 10 g celite (Johns-Manville, No. 545). Step elution with water/acetone/ethyl acetate mixture (v/v/v) was employed from 40/60/0 to 0/0/100 at 20 % difference. Every 100 ml eluate was collected and concentrated in vacuo for the use of bioassay or further analysis.

Thin-layer chromatography (TLC).

Biologically active, fractions of charcoal-celite column chromatography (water/acetone 20/80 and 0/100, v/v) was developed on a silica gel TLC plate (Whatman, LK6) by using n-hexane/ether mixture (5/1, v/v) as a developing solvent. Dark-spotted area under UV-light was scraped off and eluted with methanol for the use of bioassay. UV (by Shimadzu spectrophotometer, UV-300) and GC-MS (by Shimadzu gas chromatograph-mass spectrometer, LKB-9000) analyses.

RESULTS AND DISCUSSION

Effects of the original methanolic extract, n-hexane and aqueous phase of *O. javanica* plants on the growth of rice seedlings are shown in Fig. 1. Methanolic extract inhibited sheath growth linearly but it inhibited root growth only at higher concentration. Sheath growth inhibitor(s) was partitioned into n-hexane phase, root growth inhibitor(s) however remained in aqueous phase. Data indicate that the former substance(s) is less polar than the latter.

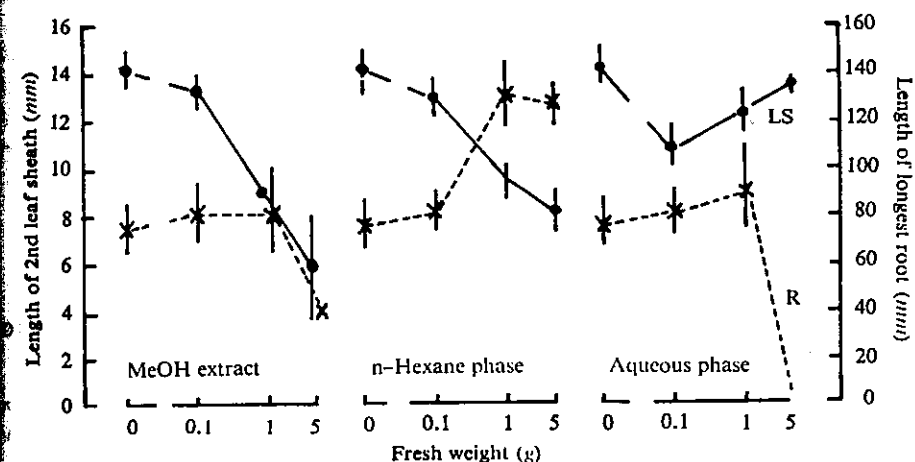


Fig. 1 Effects of the methanolic extract, n-hexane or aqueous phase from 0.1, 1 and 5 g fresh weight of *Oenanthe javanica* on the growth of rice seedling cv. Tan-ginbozu.

LS : Length of 2nd leaf sheath, R : Length of longest root

Methanolic extract was purified by charcoal-celite column chromatography with water/acetone/ethyl acetate step elution system. As a result (Table 1), root growth inhibiting activity was shown in the first eluate (water/acetone/ethyl acetate, 40/60/0, v/v/v) and sheath growth inhibiting activity was shown in the second and third eluates (20/80/0 and 0/100/0).

Table 1. Separation of plant growth inhibiting substance contained in *Oenanthe javanica* by charcoal-celite column chromatography.

Eluate				Length of 2nd leaf sheath (mm)		Length of longest root (mm)	
Water:Acetone:Et OAc (v/v/v)				1 g	5 g	1 g	5 g
40	60	0		16.2 $\pm$ 0.4	12.7 $\pm$ 0.9	67.8 $\pm$ 10.5	19.7 $\pm$ 4.7
20	80	0		9.5 $\pm$ 0.5	9.0 $\pm$ 1.2	66.2 $\pm$ 12.0	58.7 $\pm$ 11.7
0	100	0		12.8 $\pm$ 1.3	8.2 $\pm$ 2.0	102.2 $\pm$ 5.9	84.7 $\pm$ 25.0
0	80	20		17.2 $\pm$ 0.7	15.8 $\pm$ 0.9	80.5 $\pm$ 8.7	76.8 $\pm$ 14.8
0	60	40		14.2 $\pm$ 0.7	14.2 $\pm$ 1.1	60.7 $\pm$ 7.0	69.0 $\pm$ 10.4
0	40	60		12.5 $\pm$ 0.8	12.2 $\pm$ 0.9	63.5 $\pm$ 13.9	77.8 $\pm$ 16.4
0	20	80		10.5 $\pm$ 0.5	10.8 $\pm$ 0.9	59.2 $\pm$ 7.7	56.0 $\pm$ 12.7
0	0	100		11.5 $\pm$ 1.0	12.5 $\pm$ 1.1	59.7 $\pm$ 6.1	56.7 $\pm$ 6.3
Control				15.7 $\pm$ 1.0		65.5 $\pm$ 13.2	

Bioassay : rice seedling cv. Tan-ginbozu

Samples extracted from 1 and 5 g fresh materials were used

The sheath growth inhibitory eluates were combined, concentrated in vacuo, and further purified by TLC with n-hexane/ether (5/1, v/v) solvent system. As a result, four spots at Rf 0.14, 0.22, 0.36 and 0.51 were detected under UV light. Among them, only a substance which appeared at Rf 0.51 showed a strong growth inhibiting activity (Fig. 2).

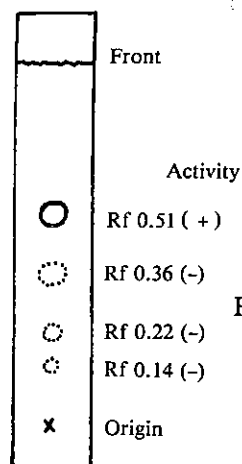


Fig. 2 Thin-layer chromatogram of the active fraction from charcoal-celite column chromatography.

Silica gel TLC plate --- Whatman LK6, 5 × 20 cm
Developing solvent --- n-Hexane : Ether 5 : 1 (v/v)

To identify the biologically active substance, UV absorption spectrum and GC-MS analysis were carried out. As a result, UV : $\lambda_{\text{max}}^{\text{MeOH}}$ 230, 280 nm (shown in Fig. 3) and fragment peaks of MS: m/e 222 M^+ , 207, 195, 191, 177, 149, 121, 106, 91, 77, 65 (shown in Fig. 4) were obtained respectively. From these data, sheath growth inhibitory substance contained in *O. javanica* was identified as an apiole, 1-allyl-2, 5-dimethoxy-3, 4-methylene dioxybenzene (chemical structure is shown in Fig. 5).

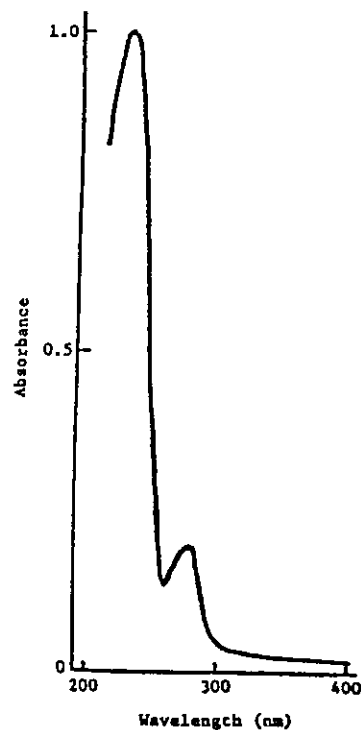


Fig. 3 UV-absorption spectrum of methanol solution of plant growth inhibiting substance isolated from *Oenanthe javanica*.

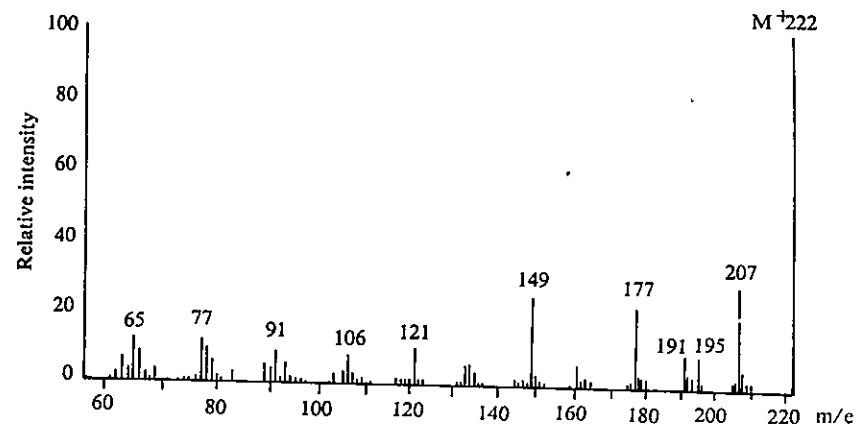


Fig. 4 Mass spectrogram of plant growth inhibiting substance isolated from *Oenanthe javanica*.

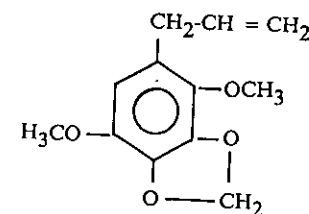


Fig. 5 Chemical structure of apiole, 1-allyl-2, 5-dimethoxy-3, 4-methylene dioxybenzene.

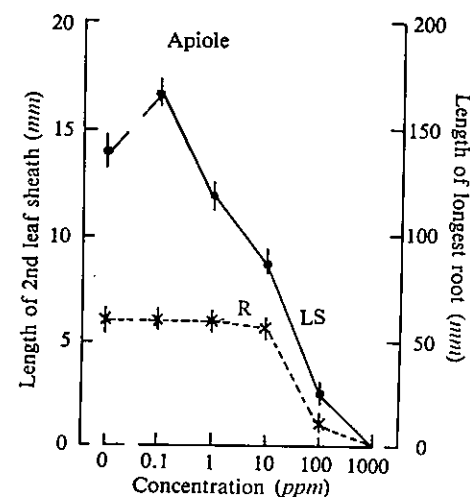


Fig. 6 Effect of apiole on the growth of rice seedling cv. Tan-ginbozu.

Recently the author isolated myristicin which possess as a similar chemical structure as apirole from parsley plants (Harada, 1984) and also both myristicin and apirole from parsley seed oil as plant growth regulators (Harada, 1984). By using this isolated apirole from parsley seed oil, effect on the growth of rice seedlings was examined. As shown in Fig. 6, an apirole inhibited only leaf sheath growth at lower concentrations although it inhibited both sheath and root growth at higher concentrations. This characteristic seems to be desirable to consider the practical use of the chemical as a plant growth regulator in agriculture.

One of the plant growth inhibiting substances contained in *O. javanica* was identified as apirole although root growth inhibitory substance remained unknown. Apirole seems to be closely related to allelopathy of this weed species, further study however, is essential to clarify the phenomenon.

ACKNOWLEDGEMENT

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SEED GERMINATION OF *Striga angustifolia* IN ROOT ELUTES OF 20 SORGHUM CULTIVARS

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ABSTRACT

Using Parker and Reid's (1979) technique, fresh and moisture pretreated seeds of *Striga angustifolia* (Don) Saldanha were germinated in root elutes of 20 sorghum cultivars in three light regimes. Fresh seeds failed to germinate in all the trials. Moisture pretreated seeds alone responded in varying degrees to the root elute stimulatory substances. In continuous darkness none germinated. In normal day-night regime, Framida, IS-2403C, 5603, 3924, 9985, N-13, SRN-6838B failed to stimulate germination. IS-4242 alone induced a maximum percentage germination of 23.20 ± 2.30 . Other root elutes of sorghum cultivars resulted in poor germination ranging from 1.36 to 9.30 ± 0.41 . In continuous light provided from an incandescent bulb, IS-4242 induced the highest germination % of 39.50 ± 6.67 followed by GPR-148 (21.50 ± 4.12). Elutes of others induced germination within a range of 6.25 (N-13), 7.44 ± 2.64 (Framida) to 19.10 ± 0.76 (IS-8686). IS-5603 failed to stimulate any germination. IS-4242 is thus most susceptible for attack while all others may be recommended for cultivation in *S. angustifolia* infested areas.

INTRODUCTION

Knowledge of germination potential of witchweed seeds is interlinked with their management programmes. Considerable work has been done on witchweed seed germination (Ayensu *et al.*, 1984; Parker, 1984; Musselman *et al.*, 1978; Hosmani, 1978; Musselman and Ayensu, 1984). However, little has been done regarding the same in *S. angustifolia* (Don) Saldanha. Kumar and Solomon (1940), Anonymous (1950), Reddy and Rao (1980), Rao and Reddy (1982), made certain experiments of *in vitro* germination. The identity and nomenclature of this imperfectly investigated species were settled as per Saldanha (1963) and Parker of WRO, Oxford (See Rao and Reddy, 1982; Reddy, 1981). This witchweed species is a local menace in cultivated fields of *Sorghum*, *Pennisetum* and other millet crops. Its phenophase calendar, breeding system and reproductive effort were communicated earlier (Rao and Reddy, 1983). The present observations deal with germination behaviour of *S. angustifolia* seeds in the root elutes of twenty cultivars of sorghum in an attempt to avoid cultivation of susceptible species.

MATERIALS AND METHODS

Witchweed seed material

Plants of *S. angustifolia* from infected lands of Nagarjunanagar ($16^{\circ} 24' N$; $80^{\circ} 30' E$) formed the source of seed. The seeds were surface sterilized with sodium

hypochlorite for 5 minutes, washed thoroughly in distilled water, dried and stored in stoppered polythene containers at room temperature ($30^{\circ}C \pm 2^{\circ}C$).

They were later preconditioned with moisture treatment (Parker and Reid, 1979). Using a cork borer, discs of 8 mm diameter were cut from Whatman No. 1 filter paper, arranged in sterile petridishes and about 50 to 60 seeds were sprinkled on each. Distilled water was added to saturate the paper discs. The petridishes were kept in polythene bags sealed compactly and maintained in darkness at room temperature. Parker (Pers. comm. letter dt. 20.2.1979) recommended a prolonged pretreatment at $33^{\circ}C$ for successful germination. These pretreated seeds were used in germination experiments.

Collection of root elutes from sorghum cultivars:

Seeds of the 20 cultivars of Sorghum (Table 1) were kindly supplied by Dr. Ramaiah, then in ICRISAT, Hyderabad, India. They were sown each in separate pots, filled with garden soil. One to three seedlings of each variety were transplanted in ten earthen pots and watered daily. After successful establishment, they were used for collection of root elute. This is collected by dipping the well washed root system (first with tap water, then with distilled water followed by sterile distilled water) in 20 ml. of double sterilized distilled water dispensed into sterilized test tubes maintained under complete aseptic conditions. The roots were allowed to exude for a period of 32 hours in normal day light. Five sets of containers were maintained for elute collection. The diffusate from all sets was mixed for further use and considered to be of 100% concentration. Nine replicates were kept for each of the sorghum cultivar elute and the results summarised in Table 1 are means of data of all the respective replicates.

Maintenance of light regimes:

The replicates of petriplates were kept in a light proof dark chamber for data due to effect of continuous darkness; in the laboratory on the table near a window to allow day-night regime and exposed to a 60 w Philips incandescent bulb to allow the factor of continuous light.

Each double layered disc is wetted with 30 micro ml of the respective exudate with the help of micrometer syringe. Germination counts were made 72 hours after keeping the seeds in the elute. The disc was so designed that the entire surface was clearly visible in the field of a Bausch and Lomb binocular microscope used to count the germination. Radicle emergence was the criterion for germination.

RESULTS AND DISCUSSION

Details of sorghum cultivars used, dates of pretreatment of witchweed seeds, dates on which crop seedlings were kept for root exudate collection, dates on which experiment was stopped and the percentages of germination under the three light regimes are presented in the Table 1.

Unconditioned seeds failed to germinate. Moisture pretreated seeds also failed to show any germination in continuous darkness. IS-5603 did not stimulate germination in anylight regime. Varieties Framida, IS-2403C, IS-3924, IS-9985, N-13 and SRN-6838B failed to induce germination in the normal day-night regime.

Table 1. Percentage germination of *striga angustifolia* under varying light conditions in root elutes of sorghum varieties.

Sr. No.	Crop variety	Date on which seeds kept for pre-treatment	Date on which <i>Striga</i> seedlings/saplings kept for elute collection	Date on which the experiment ended	Continuous light	Diffuse daylight	Continuous darkness
1.	GPR-148	20.7.1979	17.8.1979	23.8.1979	21.50 $\pm$ 4.12	4.16	0
2.	Framida	20.7.1979	17.8.1979	23.8.1979	7.44 $\pm$ 2.64	0	0
3.	IS-2403C	20.7.1979	17.8.1979	23.8.1979	16.60 $\pm$ 1.06	0	0
4.	IS-5603	20.7.1979	17.8.1979	23.8.1979	0	0	0
5.	IS-3924	20.7.1979	17.8.1979	23.8.1979	17.50 $\pm$ 4.24	0	0
6.	IS-2203	26.7.1979	10.6.1979	16.8.1979	11.30 $\pm$ 3.04	1.36	0
7.	IS-5218	10.8.1979	24.8.1979	31.8.1979	15.10 $\pm$ 4.59	1.86	0
8.	OS-9985	10.8.1979	24.8.1979	31.8.1979	14.00 $\pm$ 4.34	0	0
9.	IS-2643	27.7.1979	10.8.1979	16.8.1979	17.70 $\pm$ 5.55	7.69	0
10.	IS-7227	06.8.1979	14.9.1979	18.9.1979	18.90 $\pm$ 6.61	8.88 $\pm$ 1.63	0
11.	IS-4242	06.8.1979	14.9.1979	18.9.1979	39.50 $\pm$ 6.67	23.20 $\pm$ 2.30	0
12.	IS-2930	06.8.1979	14.9.1979	18.9.1979	17.60 $\pm$ 6.37	5.07 $\pm$ 1.10	0
13.	IS-4202	06.8.1979	03.9.1979	08.9.1979	12.50 $\pm$ 1.75	3.96 $\pm$ 0.70	0
14.	IS-8686	06.8.1979	03.9.1979	08.9.1979	19.10 $\pm$ 0.76	9.30 $\pm$ 0.41	0
15.	IS-6942	06.8.1979	03.9.1979	08.9.1979	13.90 $\pm$ 2.30	5.32 $\pm$ 0.54	0
16.	N-13	10.8.1979	24.8.1979	31.8.1979	6.25	0	0
17.	NJ-1515	20.7.1979	10.8.1979	16.8.1979	17.50 $\pm$ 4.45	4.10 $\pm$ 0.61	0
18.	Serena	06.8.1979	14.9.1979	18.9.1979	11.60 $\pm$ 2.01	5.84 $\pm$ 0.95	0
19.	SRN-6838B	10.8.1979	24.8.1979	31.8.1979	9.52	0	0
20.	SPV-103	06.8.1979	03.9.1979	08.9.1979	5.13 $\pm$ 0.22	4.75 $\pm$ 1.88	0

10-20 *Sorghum vulgare* varieties.

There are only insignificant germinations in this factor with the exception of IS-4242 which could initiate a % of 23.20 ± 2.30 germination. This variety also showed 39.5 ± 6.67 percentage in continuous light. Higher germination in continuous light shows its positive photoblastic nature.

Presence of host stimulus is not mandatory for seed germination in *S. angustifolia* (Kumar and Solomon, 1940; Anonymous, 1950; Hosmani, 1978; Reddy and Rao, 1980; Parker, 1984). However, presence of grass hosts as well as various dicot and monocot weeds induce ready germination under experimental and natural conditions. Various new host records from grasses and others of which at least eight are new for the genus *Striga* itself have been enlisted by the present workers indicating a very broad host range (Rao *et al.*, 1985 in press ready observations).

Despite this broad host range and non obligatory behaviour, it is significant that except IS-4242 cultivar, others showed significant degree of resistance. IS-5603 is highly resistant. It is also resistant to *S. hermonthica* (Reid and Parker, 1979). Varieties Framida (Williams, 1959). N-13, IS-9985, IS-8686, IS-6942, IS-2643, SRN-6838B (Ramaiah, 1978) and SPV-103 (Chowdhari *et al.*, 1980) were considered

to be resistant to various species and strains of *Striga*. The present study is in general agreement with the previous data gathered using seeds of *S. asiatica*. In fact, IS-6942, NJ-1515, Serena-1930 were selected for cropping at Kobo due to their resistance. However, Priyavratha Rao (1956) cautioned that no variety is completely immune to *Striga*.

In the tropical arable fields of this area of study IS-4242 should be avoided. All other varieties are recommended for cultivation with top preference to IS-5603.

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STUDIES ON THE ALLELOPATHIC EFFECT OF *Broussonetia papyrifera* (L.) VENT ON WHEAT AND *Phalaris minor* RETZ

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ABSTRACT

Studies were conducted in the laboratory to see the effects of *Broussonetia papyrifera* leaf extracts on the germination of wheat and *Phalaris minor*. Leaf extract of Japanese paper mulberry (*B. papyrifera*) effectively suppressed the germination of seeds of *Phalaris minor*. The inhibition was concentration dependent, higher concentrations being more phytotoxic. Also stored extract was found to be more phytotoxic than the fresh one.

The effect of pH level of the extract was also observed. Original pH of the extract was found to be 7.29. When pH of the extract was lowered, extract was found to be more phytotoxic than the original one.

An interesting aspect of the study was its selectivity for wheat. In the same extract where the germination of *P. minor* was completely inhibited, germination of wheat was affected only slightly.

Effects of different concentrations of the extract of *B. papyrifera* was also studied on the radicle and shoot length of the seedlings of wheat and *B. papyrifera*.

INTRODUCTION

Allelopathy occurs widely in natural communities (Stachon and Zimbdahl, 1980; Wittaker and Feeny, 1971). The salient feature of the process is that the inhibitory effects depend upon a chemical compound being released into the environment by an allelopathic agent (Wilson and Rice, 1968).

A rapid build up or presence of a species in pure stand is usually an indication of the species to be active allelopathically. A pure stand of *Imperata cylindrica* and rapid spread of *Chromolaena odorata* in pastures are understood to be due to allelopathic effects. Several other species such as *Sorghum halepense*, *Setaria faberi*, *Carthamus oxyacantha*, *Echinochloa* spp., *Cyperus rotundus*, *Rotboellia exaltata*, *Impatiens triloba*, *Helianthus annuus*, *Avena* spp., wheat and many others are known to interact allelopathically in one way or the other.

Allelopathic interactions are exhibited by plants in several ways. Sajise (1972) observed that the inhibiting substances produced by *Imperata cylindrica* were released from its rhizomes where as Hussain (1980) reported that exudates of roots and litter of many plants inhibit the germination of susceptible species and can also interfere with their growth processes. In soil collection experiments Wilson and Rice (1968) indicated a greater phytotoxicity in the soils after accumulation of debris than during

problem weed.

The primary objective of these experiments was to investigate the allelopathic potential of Japanese paper mulberry against wheat and little seed-canary grass.

MATERIALS AND METHODS

Leaf extract of *B. papyrifera* was used as plant material for its effect on the germination and seedling growth of *Phalaris minor* and wheat. Aqueous extract bioassay and acetone extract bioassay were tested.

An equivalent of 10 gms of fresh leaves were taken and blended in 140 ml of distilled water for one minute. The blended material was filtered through Whatman No. 1 filter paper and used as stock solution for further dilutions. 50, 20, 10 and 5% dilutions of this stock were used. In case of acetone extract 50 ml acetone was used instead of 140 ml water and 50, 30, 20, and 10% dilutions of this extract were included in the study.

Experiment 1. Effect of leaf extract of *B. papyrifera* on the, germination and seedling growth of *P. minor* and wheat.

Ten seeds of the weed and the crop were placed in 9 cms petri dishes on Whatman No. 1 filter paper and 4 ml of the extract was used for wetting. Observation on germination, radicle and shoot length were recorded 7 days after sowing (Rasmussen and Einhellig, 1977). A comparison on the effect of fresh and stored extract was also studied.

Experiment 2. Effect of *B. papyrifera* leaf extract with different pH levels on the germination of *P. minor* and wheat

The pH of the freshly prepared leaf extract was determined to be 7.29. The original pH of the extract was changed artificially to 8.29 and 6.29 with the help of 0.1N NaOH and 0.1N HCl respectively (Friedman and Horowitz 1971). The germination and seedling growth of *Phalaris minor* and wheat were observed in these pHs. As in case of experiment 1, the observations on germination, radicle and shoot length were recorded 7 days after sowing.

RESULTS AND DISCUSSION

Water extract

Japanese paper mulberry leaf extracts suppressed the germination of *P. minor* significantly. The degree of suppression was found to be concentration dependent. Fresh water extracts in its pure form (100% concentration) completely inhibited the germination of *P. minor* seeds. With the dilution of the concentration the germination improved gradually being 2.2, 28.9, 44.2 and 56.6% in 50, 20, 10 and 5% concentration of the extract, respectively (Fig. 1).

Radicle and shoot length of *P. minor* seedlings was also inhibited. A gradual increase in radicle and shoot length, as in case of germination, was observed with a

the active growth of sunflower.

Seeds have also been reported to possess some inhibitory substances. Dormant seeds of *Rottboellia exaltata* are reported to inhibit growth of cucumber seedlings when planted together (Pamplona and Mercado, 1975). Elmore (1980) also reported that alcoholic and aqueous extracts of velvet leaf seeds seriously inhibited the germination of turnip seeds. Leaf leachates of *Sorghum halepense* are also known to suppress or inhibit, the growth of several species (Abdul-Wahab and Rice 1967). A similar effect has been observed in case of *Cyperus rotundus* (Jangaard et al, 1971 ; Meissner et al, 1980). Instances have also been reported when plant residues of several species, on their decay produced phytotoxins which interfered with the life processes of the other species (Irons and Burnside, 1982).

Several chemical compounds have been identified to be responsible for their phytotoxic effects. The inhibition caused by *Avena* spp. to wild mustard was considered possibly due to exudation of scopoletin and other allelopathic compounds (Fay and Duke, 1977), however Gressel and Holm (1964) held aminoacids as potential allelochemicals. Iron and Burnside (1982) found scopolin and suspected the presence of naphthol derivative in leaf surface leachate of sunflower. In an other study ferulic, *p*-coumaric, syringic acid, vanillic acid and *p*-hydroxybenzoic acid were detected in the corn, oat, wheat and sorghum residues at varying concentrations (Guenzi and McCalla, 1966).

The selective nature of the kolines indicate that they in fact act as natural herbicides which can be exploited for wider use. The mechanism of action of known kolines are very similar to those induced by synthetic herbicides. Coumarin blocks mitosis in onion forming multinucleate cells (Cornman, 1946) and effect similar to that caused by dinitroanilines and DCPA. Scopoletin inhibits photosynthesis without significant effect on respiration (Einhelling et. al, 1970).

The growth inhibition brought about by interactions with weeds was also translated into anatomical disorganisation by Retig and his co-workers (1972). Johnson weed (*Datura stramonium*) and green foxtail (*Setaria viridis*) were observed to cause disorganisation of the cabbage roots. Similar effects were induced by *Salvia leucophylla* and as such attributed to the production of toxins exuded through the roots of these species.

An organised research in this respect can lead to very useful results, especially for the under-developed countries where chemical agriculture is still a far cry. The present study is an effort in this direction.

Broussonetia papyrifera (paper mulberry, family Moraceae) a native of upper Burma and China, is self sown in Punjab (Stewart 1972). It is cultivated in China and Japan. In the Far East this tree is used for making paper and bark cloth (Purseglove 1968). According to Holm et al (1979) this species is present in USA and behaves as a weed, but its rank of importance is not known.

Phalaris minor (little seed canary grass) is a very important weed in wheat growing areas. Because of similarity with wheat seedlings at the early growth stages, it is difficult to differentiate between crop and weed seedlings. It starts flowering just before wheat and the seeds start shedding before the harvest of wheat crop. This together with its high rate of seed production and germination make it a serious

decrease in the concentration of the extract (Fig. 1).

Germination of wheat was only slightly affected. Various concentrations showed almost the same germination as in case of control. However, radicle and shoot length was significantly suppressed at higher concentrations i.e. 100, 50 and 20%. On the contrary, lower concentrations accelerated the germination radicle and shoot lengths of wheat seedlings (Fig. 1).

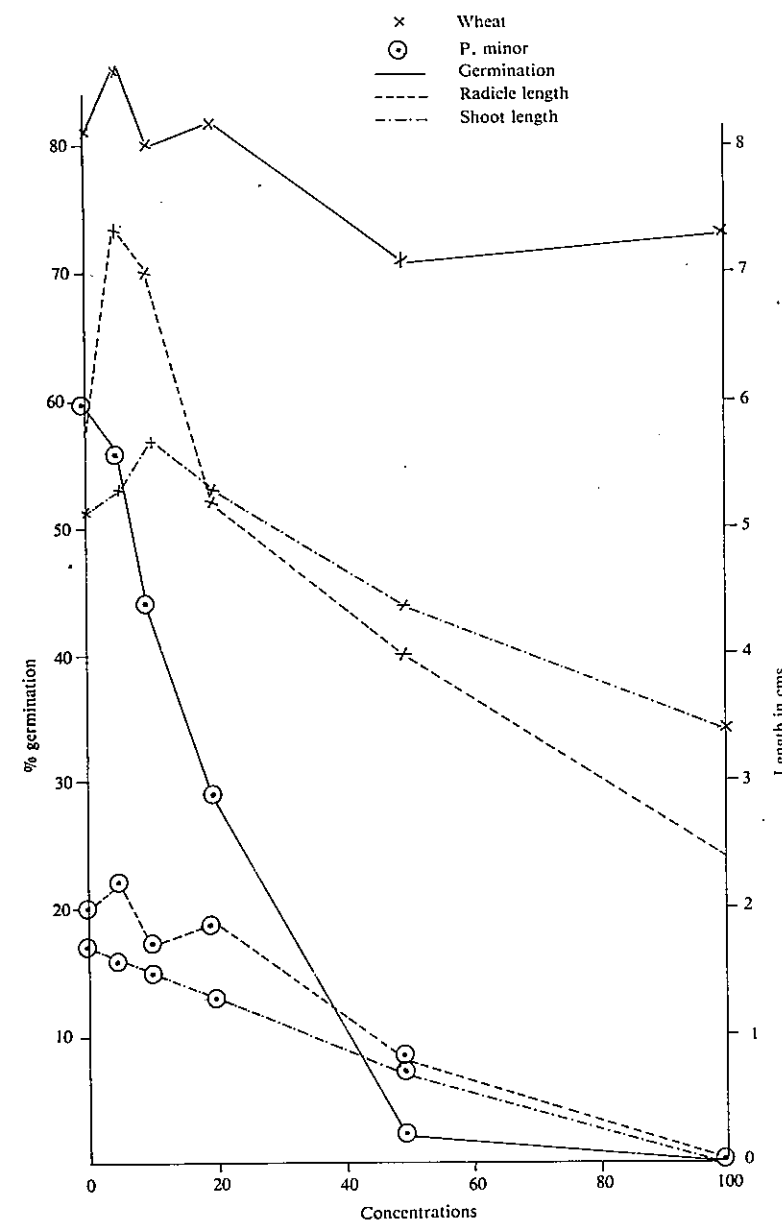


Fig. 1. Germination, radicle and shoot length of wheat and *Phalaris minor* in different concentrations of fresh extract of *B. papyrifera*.

Storage of extract in the refrigerator at 4°C enhanced its phytotoxicity. The germination of *P. minor* which was 0, 2.2, 23.9, 44.2 and 56.6% in 100, 50, 20, 10 and 5% concentrations of fresh extract was reduced to 0, 0, 0, 11.0 and 41.7 in the same concentrations of stored extract. Similarly the radicle and shoot lengths were also reduced (Fig. 2)

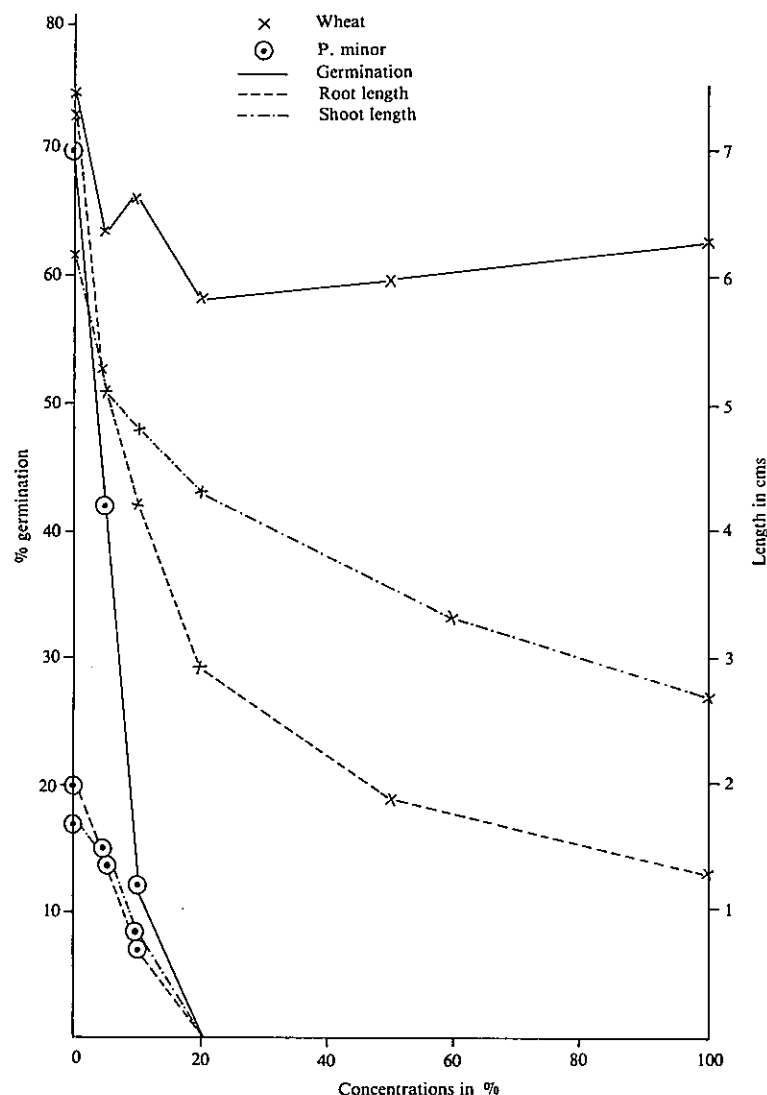


Fig. 2. Germination, radicle length and shoot length of wheat and *Phalaris minor* in different concentrations of stored extract of *B. papyrifera*.

Stored extracts was also more phytotoxic to wheat seeds. The germination of wheat seeds ranged from 71.2 to 86.7% in fresh extracts whereas it was found to be 63.3 to 66.7% in case of stored extract. However as in case of fresh extract, various concentrations of the stored extract did not differ significantly for their effect on germination of wheat seeds.

Radicle and shoot lengths of the germinating wheat seedlings decreased with the increase in the concentrations as in case of fresh extracts. However, the root and shoot length was more suppressed in stored extract as compared to fresh extract (Fig. 2). Besides this distortion of seedlings, radicle tipburn was also observed in case of stored extract as against the fresh extract where the seedlings did not show these symptoms.

Generally, elongation of root was inhibited more than the shoot and even when change in shoot growth was not significant, growth of root was still inhibited significantly. Similar effects on the root and shoot was also observed by Kimber (1973.)

Acetone extracts

Comparing the aqueous extract with the acetone extract, it was noted that seed germination of *P. minor* was higher in latter as compared to the former wheat seed germination was almost similar in aqueous as well as acetone extract. But radicle and shoot length was much higher in acetone extract compared to water extract. These data show that the phytotoxic compounds are water soluble and can be better extracted with water than acetone (Fig. 3).

Effect of pH

The phytotoxicity of *B. papyrifera* leaf extract was also found to be influenced by the pH level of the extract. Original pH of the extract was found to be 7.3. When the pH was decreased, the germination, radicle and shoot length of *P. minor* also decreased. The maximum inhibition being at pH 6.3. On the contrary, a decrease in pH slightly increased the germination, radicle and shoot length of wheat (Fig. 4).

It shows that while testing extracts of suspected allelopathic plants, pH of the extracts should be taken into consideration. Moreover, manipulation of the pH levels of extract can be exploited for the purpose of selectivity. Similar observation regarding the effect of pH has been reported by Stachon and Zimdahl (1980) and Rose et al (1984).

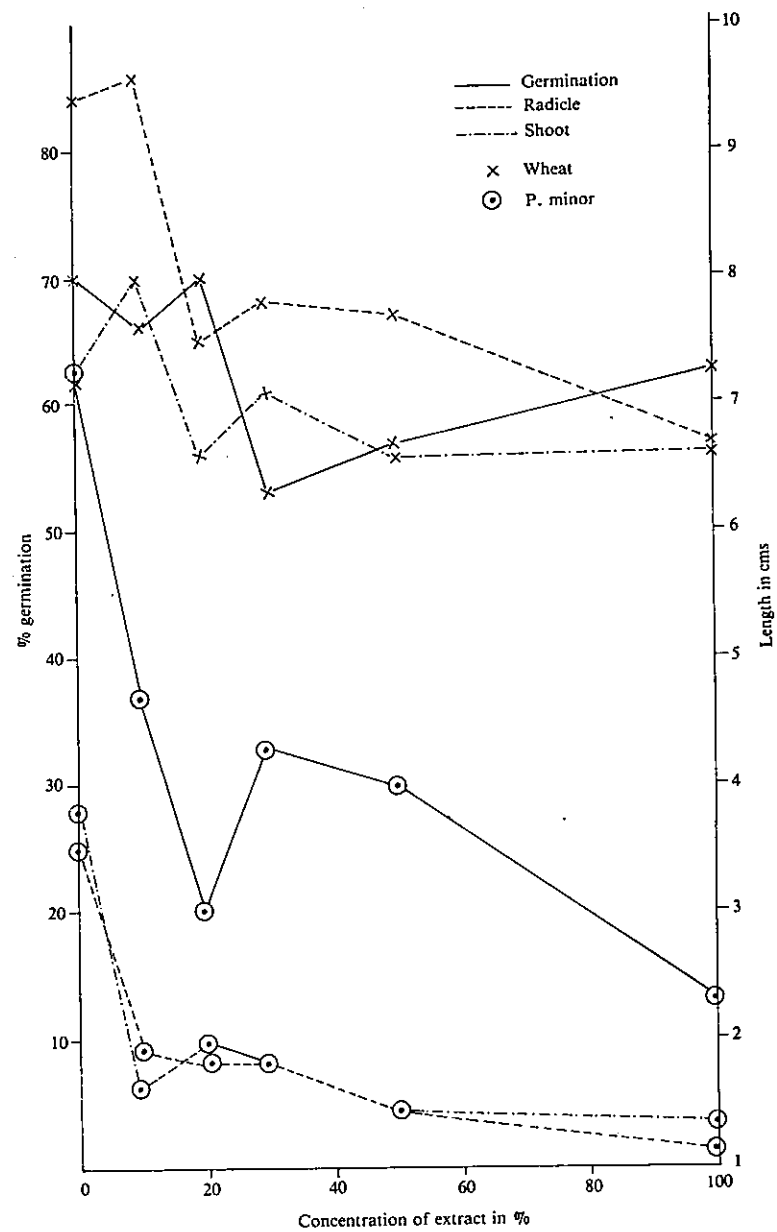


Fig. 3. Germination, radicle and shoot length of wheat and *Phalaris minor* in acotone extract of *B. papyrifera*.

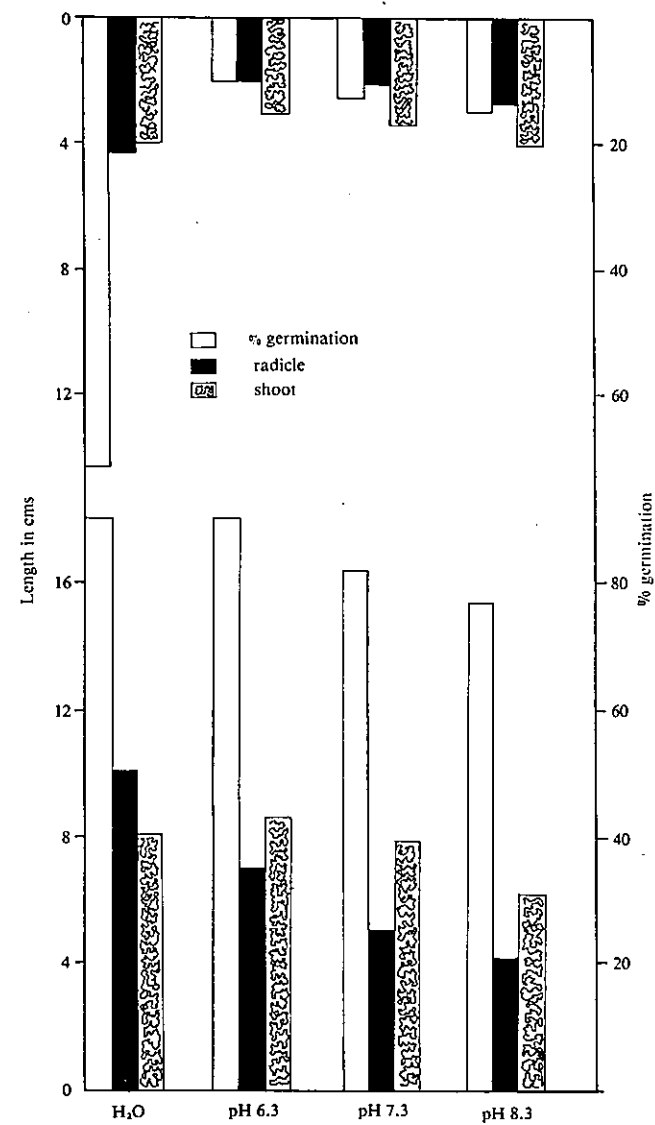


Fig. 4. Germination, radicle and shoot length of wheat and *P. minor* in *B. papyrifera* extract under different pH values.

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THE BIOLOGY OF *Mimosa pigra* L.

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ABSTRACT

A review of the literature on *Mimosa pigra* L. is presented, to highlight areas where further research is needed. We conclude that much more field-based research is required: in particular, seed longevity and seed production should be measured to aid in developing a strategy for control.

INTRODUCTION

The tropical American shrub *Mimosa pigra* L. was accidentally introduced to Australia from south-east Asia, probably in the late 1930's with illegally imported cattle (Swarbrick 1983). Its subsequent invasion of the Northern Territory of Australia, and its effects on agriculture and wildlife habitats over thousands of hectares of floodplains, have been described by Miller *et al.* (1981).

M. pigra was introduced to Thailand in 1947 (Wara-Aswapati, 1983) as a green manure and cover crop, and to control erosion (Napompeth, 1983a), and indeed can be useful in these roles (Suwignyo and Wiroatmodjo, 1983). However, *M. pigra* is now a huge problem in Thailand (Robert, 1983), and is increasing in other countries of South-East Asia. In view of its importance, we have reviewed here the significant studies dealing with the biology of *M. pigra* and highlighted areas where further study is required.

Taxonomy, evolution and distribution

Nearly a third of the species in the family leguminosae are contained in *Mimosa* (tribe Mimoseae) and five other genera which are characteristic of open and disturbed places - habitats which have expanded greatly since the Miocene (Polhill *et al.*, 1981). *Mimosa* contains 400-450 species which are largely native to Central and South America (Lewis and Elias, 1981). The basic chromosome number in this genus is $n = 13$ (Goldblatt, 1981). The tribe Mimoseae is the most primitive in the sub-family Mimosoideae (Elias, 1981), and probably diverged from the pantropical *Dimorphandra* group of the Caesalpinioideae in the early Tertiary (Polhill *et al.*, 1981).

M. pigra is native to tropical America (Burkart, 1948), but has become a pantropical weed (Napompeth, 1983a) through the ready transport of its seeds. It has two known varieties, differing slightly in pod morphology (Turner, 1959), var. *pigra* and var. *berlandieri*. The former variety has become globally distributed while the latter is apparently restricted to southern Texas and north-east Mexico (B.L. Turner, pers. comm.).

Bozome analyses of seeds suggests that populations of *M. pigra* var. *pigra* in Australia are genetically uniform, and similar to those in Thailand, but different from populations of the same variety in Brazil (J.J. Burdon, pers. comm.). The seeds of Australian and Thai populations are smaller and less variable in colour than those of Brazilian populations (Miller *et al.*, 1983).

Habitat

M. pigra has been introduced into most tropical regions of the world where it grows in comparatively open, moist sites such as floodplains, coastal plains and river banks. In Australia and Thailand it forms dense thickets covering thousands of hectares, and appears to be symptomatic of disturbed sites. In its native range it occupies similar habitats, especially in areas which have been disturbed, but usually occurs as small thickets or as individual plants (Harley, unpublished results).

In Australia *M. pigra* is not restricted to any one soil type, and Miller (1983) has reported the plant growing on alluvial red and yellow earths, silty loams and black cracking clays. It is very tolerant of seasonal inundation, although glasshouse experiments suggest that permanent inundation would prevent seedling recruitment (Shibayama *et al.*, 1983).

Miller (1983) has suggested that, except around dams and watercourses, *M. pigra* would not be a major problem in habitats with < 750 mm rainfall/yr. Because of plant competition, it is also unlikely to invade tropical rainforest, where rainfall is > 2250 mm. The temperature tolerance range of *M. pigra* has not been quantified. The coldest temperature regime experienced by populations of the plant in Australia is in the vicinity of the Daly River, which has a mean daily minimum temperature for July (the coldest month) of 13.2°C (Anon. 1975).

The precise relationship between the plant's distribution and salinity levels remains to be determined, but salinity of water near to *M. pigra* infestations on the lower Adelaide River, N.T., can reach 18,000 p.p.m. late in the dry season (Miller, 1983).

Seed and seedling biology

M. pigra is hard-seeded - that is, moisture leaves the new seed gradually, probably through the hilum, which acts as a one-way valve so that the moisture content of the seed eventually equilibrates with the lowest humidity it encounters (Harper, 1977, p.77). Once the process of drying out is completed, germination is dependent on breaking down the physical barrier to moisture formed by the impermeable seed coat.

The strophiole appears to form a weak spot in the seed coat which fractures when subjected to artificial scarification (Shibayama and Pornsuksawang, unpublished results). Soil abrasion, microbial action, or fluctuations in temperature (Dillon and Forcella, 1985) may break dormancy in the field. Seeds of *M. pigra* have a characteristic U-shaped pleurogram or fracture which is visible in dried seeds and is of uncertain significance.

Seeds of *M. pigra* weigh about 0.01 g and are usually dispersed whilst still contained in partially dehiscent pod segments. The pod segments are very hirsute and, by trapping air to give buoyancy and increase the surface tension, this character allows the dispersal units to float readily for an indefinite period. Seeds may also be transported in mud on animals and vehicles. The seeds may remain viable for more than five years in dry, laboratory conditions (Wara-Aswapati, 1983), but longevity in natural conditions remains to be determined.

Germination in *M. pigra* is phaneroepigeal with foliar cotyledons (cf. Duke and Polhill, 1981). Percentage germination is greatest from seeds sown at 1 cm depth and steadily declines to zero as sowing depth increases to 10 cm (Shibayama *et al.*, 1983). Growth rates in glasshouse conditions range from 0.619 cm d⁻¹ (recalculated from Wara-Aswapati *et al.*, 1983) to 1.079 cm d⁻¹ (from Wanichanantakul and Chinawong, 1979) in the first 90 days or so after germination.

Biology of mature plants

Nothing is known of the longevity or age-specific fecundity of *M. pigra* in the field. In glasshouse conditions, plants can begin flowering eight months after germination and produce seed continuously at a mean rate of about 8000 seeds month⁻¹ (Wanichanantakul and Chinawong, 1979). *M. pigra* plants in permanently moist sites or watered artificially will produce flower buds more or less continuously (Wanichanantakul and Chinawong, 1979), although the proportion of buds reaching anthesis may be very low during the dry season (Wara-Aswapati, 1983). The development of mature flowers occurs primarily in the wet season (Janzen, 1983; Hutchinson & Dalziel, 1958, p. 495), and takes 7–9 days while the production of mature pods requires about 25 more (Wanichanantakul and Chinawong, 1979). Little is known of the breeding system in *M. pigra*. In its native range it is bee-pollinated (Janzen, 1983). Seed production in its introduced range is prolific and it would therefore appear that *M. pigra* is self-compatible, that native insects are pollinating the flowers, or the wind pollination is occurring. The smallest pollen units in the angiosperms, at 6 μ , are found in this genus (Elias, 1981).

The growth rates of mature plants have yet to be investigated. Such plants exhibit vigorous regenerative growth and will rapidly (in 7 to 10 days) produce new stems if cut off 5 cm above ground level (Wanichanantakul and Chinawong, 1979). From the morphology of its bundle sheath cells, *M. pigra* would appear to be a C3 plant (Noda *et al.*, 1983).

M. pigra probably nodulates effectively only with a narrow range of strains of *Rhizobium* (Date and Halliday, 1980). Large, pink root nodules have been detected on *M. pigra* in Thailand (Lumyong and Petpichittakul, 1982), while small, crotonarioid nodules occur in Australia, but it is not yet possible to ascertain whether these are local or introduced strains of *Rhizobium*. The Australian nodules are, however, an effective source of nitrogen for *M. pigra* (R.A. Date, pers. comm.). The situation in the native range is as yet unknown.

The leaves of *M. pigra*, like those of several other species in the genus, are sensitive to electrical, mechanical, chemical, thermal, wounding and light stimuli, which induce

rapid movements of the pinnules, pinna rachises and the petiole. In *M. pudica* L., these movements appear to result from a wave of electrical excitation passing through the leaves, causing a loss of turgor in the primary, secondary and tertiary pulvini, although the precise mechanism is uncertain (Simons, 1981). It has been claimed that such movements will scare or shake off insect herbivores (Pickard, 1973) but, so far, there is no evidence to support this hypothesis.

Herbivory

Habeck and Passoa (1983) and Gillett, Harley and Winder (unpublished results) have made extensive collections of insects attacking *M. pigra* in its native range. It is apparent from these studies that the number of species attacking the plant in its native range is much greater than in Australia (Gillett, unpublished results) or Thailand (Napompeth, 1983b). Two species of seed-eating bruchid beetles from Mexico, *Acanthoscelides quadridentatus* (Schaeffer) and *A. puniceus* Johnson, have been released in Australia and Thailand, as part of a biological control program. The interactions of bruchids with leguminous plants have been widely studied, and levels of seed predation by bruchids of up to 86% have been recorded in the field (J.E. Mathwig, 1971, quoted in Southgate, 1979). It is to be hoped that, removed from predators, parasites and pathogens, the introduced species in Australia and Thailand may eventually cause levels of seed predation even higher than this, since the presence of a persistent seed bank and high seedling mortality in *M. pigra* mean that population growth is not very dependent on the current year's seed production. Harley (in press) has reviewed the role in biological control of insects which attack flowers and seeds.

M. pigra becomes common in overgrazed areas in Costa Rica (Boucher, *et al.*, 1983), part of its native range. This is probably because of low palatability: Janzen (1983) has reported that, in the same country, captive peccaries, whitetailed deer, and tapir will reject the foliage on the basis of its odour and that cattle and horses will not browse it even when food is very scarce. However, it appears to be a very useful source of dry-season browse for elephants and ungulates in Yankari Game Reserve in Nigeria (Geerling, 1973). It is also browsed by domestic animals in Mali (P. Hiernaux, pers. comm.). In Australia, horses have been seen browsing *M. pigra* foliage (Miller, pers. obs.), and a few lightly grazed seedlings have been found in a paddock stocked with Brahman cattle and in an area frequented by feral buffalo (Lonsdale, pers. obs.). Furthermore, buffalo fed on rice straw plus *M. pigra* foliage (Pisut, 1983) lost less weight than animals fed on rice straw only (the usual cultural practice).

Mimosine, an amino acid toxic to higher animals, has been isolated from *M. pigra* at levels of about 0.2% of leaf dry weight (B. Lowry, pers. comm.). The standard assay for mimosine may fail to detect it at this concentration (Megarrity, pers. comm.), and this could explain the absence of mimosine reported by Vearasilp *et al.* (1981). The mimosine level may be higher than 0.2% in intact leaves, but declines because of autolysis of mimosine to 3-hydroxy-4-1 (H) pyridone (DHP) during the extraction process (B. Lowry, pers. comm.).

CONCLUSION

Clearly, on every aspect of the biology of this major tropical weed, much more work is needed. Whilst further laboratory studies would be useful, particularly to investigate the taxonomic status and biochemistry of the plant, the most pressing need is for information on the longevity of seed in the soil, growth rates in the field, seasonal changes in seed output, the factors affecting seedling survival and the rate of spread of infestations. The successful management of *M. pigra* is likely to benefit from a thorough knowledge of the biology of natural populations.

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TRANSPIRATION RATE OF *Mimosa pigra* L. SHOOTS IN DIFFERENT SEASONS

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ABSTRACT

The transpiration rate of *Mimosa pigra* L. shoots slowly decreased from May in rainy season until reach its minimum rate in December which is in winter and then gradually increased to the maximum rate in April of the summer season. Changes in transpiration rate of shoots and leaves were similar because the transpiration by leaves were 95 - 98 % of the total transpiration. The percentage of transpiration by leaves were higher in rainy season than winter and summer. Transpiration rate of stem was minimum in October and maximum in April as of leaves, but the percent increase in transpiration rate by stem was higher than by leaves.

The economic loss due to the transpiration of *Mimosa pigra* L. in agricultural land was 672.12 bahts/rai/year and electricity production by water was 365.18 bahts/rai/year. From this data, the economic loss due to the transpiration in *Mimosa* infested area can be calculated.

INTRODUCTION

Mimosa pigra is native to the tropical parts of Central and South America. The plant has managed to infest in every continents of the world except Europe. But Europe's unique position may end soon, however : four or five kilograms of the seed were shipped from Thailand to Saudi Arabia in 1980 (Lamar Robert, 1982). *M. pigra* was introduced in Chiang Mai, Thailand in 1947 and from here, it has spread largely through water movement. Spread to isolated sites away from rivers has been mainly caused by the activities of man through removal of sand which contain seeds, from the river, for road and building constructions. It has been only the last ten years or so that Thailand has experienced and witnessed the spread and menaces of this weed. It was found in 20 of the 73 provinces of Thailand, with the heaviest concentrations in the northern region. Now *M. pigra* is one of the worst weeds of Thailand.

Different aspects of *M. pigra* has been studied by our teams. It was found that the weed flowers nearly all year round, the majority of fruit set and seeds production occurred in rainy season between June and October (Wara-Aswapati and Trairisilp, 1982). The mature seeds shows only 2-3 % germination due to the impermeability of the seed coat to water. Seed dormancy can be broken by different methods, but a convenient way is by immersing the seed in boiling water for 1 to 2 minutes. This gave 98 % germination (Wara-Aswapati and Kaobunsong, 1978). But the immature seeds or mature seeds before dehydration show no dormancy at all. The seed become dormant when seed moisture content drops below 10 % of the seed fresh weight (Wara-Aswapati, 1983). Growth of seedling in different types of soils and chemical control of seeds and seedlings were also reported (Nikrot and Wara-Aswapati, 1982;

Kaobunsong, Sirila and Wara-Aswapati, 1984). In this paper, the transpiration rate of *M. pigra* shoots in different months of the year will be presented and the rate in different seasons as well as the average rate of the whole year were calculated. From these data, examples of economic loss due to the transpiration of the weed were estimated.

MATERIALS AND METHODS

The transpiration rate of *M. pigra* shoots were determined by weighing method (Sutcliffe, 1979). The shoots used for all measurements were selected from 3-4 meters tall of mature trees in Chiang Mai University Campus. Ten healthy shoots which have approximately 10 mm. in diameter were cut and immediately cut again under water at 100 cm. from the tip then the base were inserted in a rubber stopper and put in two liters flask with 1800 ml. water. The transpiration rates were determined from the weight loss in 24 hours period. Another set of experiment was done on the similar shoot, but all the leaves had been removed for the determination of stem transpiration. The experiments were carried out once a week from July 1983 to June 1984. Temperature, relative humidity and light intensity were also recorded.

RESULTS AND DISCUSSION

Table 1 shows the actual value of the transpiration rate in term of grams weight loss per day per shoot sample of *M. pigra* in different months from July to June. The percent of transpiration by leaves as well as fresh weight of the whole shoot, leaves and stems only are presented. Although, all shoots samples are of the same length,

Table 1. Transpiration rate, percent transpiration by leaves and fresh weight of the whole shoots, leaves and stems of one meter long *M. pigra* shoots in different months with the average of one year. Each value is the mean of 20 replicated (shoots) from 4 experiments in each month.

month (year)	transpiration rate (gm/day/shoot)	% transpiration rate by leaves	fresh weight (gm/shoot)		
			shoot	leaves	stem
July (1983)	152.35	97.92	78.88	39.19	38.94
August	126.62	98.63	67.73	36.47	35.03
September	123.86	97.87	75.17	42.07	36.70
October	122.82	98.50	80.65	42.73	39.42
November	99.28	96.50	80.89	40.82	39.03
December	93.79	96.77	71.97	35.03	40.77
January (1984)	117.94	96.81	80.50	38.17	41.98
February	141.63	95.30	70.95	33.71	39.31
March	169.86	96.50	70.21	35.25	37.04
April	168.50	95.55	68.45	34.02	35.40
May	154.42	96.29	67.61	34.43	34.31
June	114.67	96.33	57.91	25.84	33.43
Average	131.31	96.91	72.58	36.47	37.61

their weight are varied. Therefore the transpiration rate per shoot was converted to per 100 grams fresh weight shoots, leaves and stems for better comparison and shown in Figure 1. It was known that the three important environmental factors affect the transpiration of the plants are air temperature, relative humidity and light intensity (Weier et al., 1974). Therefore the changes in these three factors in different months of the year were shown in Figure 2.

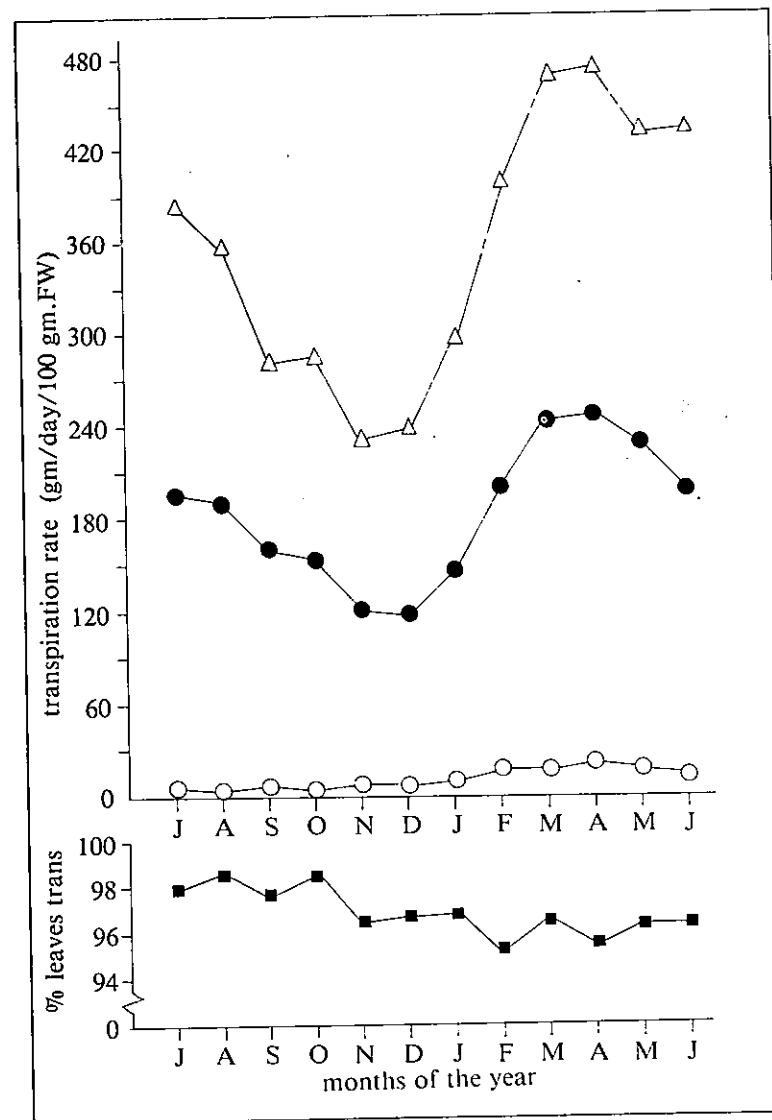


Figure 1. transpiration rate per 100 grams fresh weight of *M. pigra* shoots (●-●) leaves (△-△) stems (●-●) and percent transpiration by leaves (■-■) in different months of the year.

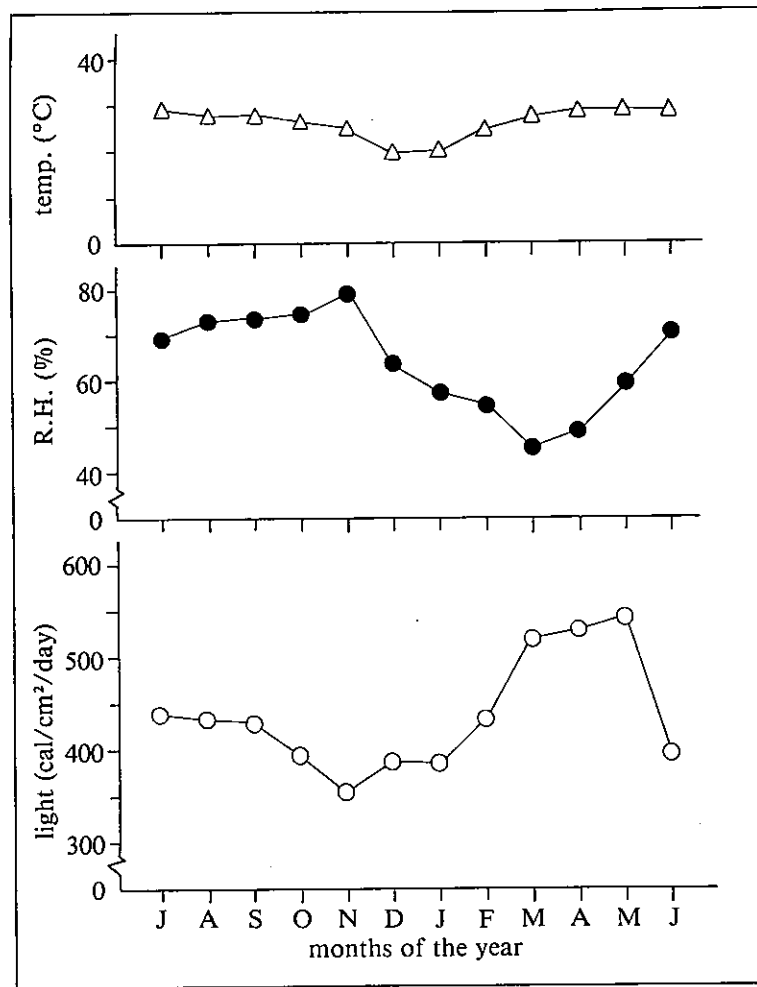


Figure 2. Average air temperature ($\triangle-\triangle$) relative humidity ($\bullet-\bullet$) and light intensity ($\circ-\circ$) in different months of the year.

Changes in the transpiration rate of leaves and the whole shoot are similar, since the transpiration rate of leaves are 95–98 % of the shoot. Rate of transpiration slowly decreased from July which is in rainy season until reach its minimum rate in November or December in the winter, because air temperature and light intensity decreased while the relative humidity increased. After December, transpiration rate increased and reach its maximum rate in April and then decreased again when rainy season arrived. The increase in transpiration rate between January and March was very rapid, because all three environmental factors are changes in favor of increased transpiration rate, namely temperature and light intensity increased, while relative humidity decreased. Although both temperature and light intensity continue to increase from March to May, but relative humidity also increase. This increase in relative humidity counter affect the temperature and light intensity, therefore the transpiration in April increased very little and thereafter decreased because the effect of relative humidity overruled

in Table 2. means of the transpiration rate, temperature, relative humidity and light intensity in different seasons were compared as well as the average value of the year. The transpiration rate of *M. pigra* shoots and leaves were highest in summer and lowest in winter, while the rate in rainy season was closed to the mean of the year. But stem transpiration in rainy season was the lowest and the mean was closed to the winter rate instead. This resulted in the higher percent transpiration by leaves in rainy season than in the winter and summer, but they were not statistically differences.

Table 2. Transpiration rate ($gm/day/100\ gmFW$) of *M. pigra* shoots, leaves, stems, percent transpiration by leaves, air temperature ($^{\circ}C$), relative humidity(%) and light intensity($calorie/cm^2/day$) in different seasons with the average of one year.

Season (months)	Transpiration rate			Temp.	R.H.	Light
	shoots	leaves	stems			
Rainy (Jun-Oct)	180.29	349.65	7.75	27.61	72.30	419.59
Winter (Nov-Feb)	146.29	292.27	10.75	22.14	63.54	390.92
Summer (May-May)	239.61	458.32	18.58	28.15	51.39	531.72
Average	183.79	357.69	11.46	25.92	64.15	438.06

From these transpiration rates in different seasons or the average rate of the year in table 2 with the total amount of *M. pigra* fresh weight found in a given area, the total water loss due to transpiration can be calculated and the economic loss can be estimated if the value of water in that particular area are known. Two examples are given here.

Lamar Robert (1982) estimated that in Chiang Mai area which infested by *M. pigra* are 3280 kg of firewood or stems and 318 kg of air dry leaves per rai. This air dry leaves are equal to 775 kg of fresh leaves and the water loss by transpiration of these leaves will be $3.5769 \times 775 \times 365 = 1,011,815 \text{ kg/rai/year}$. This will give the transpiration rate of shoot = $1,011,815/0.9691 = 1,044,076 \text{ kg/rai/year}$. The value of water in terms of crop production in Chiang Mai Valley was 0.6438 baht/1000 kg of water (Niyomyati, 1984), therefore the economic loss is 672.12 bahts/rai/year. The area infested by *M. pigra* in Chiang Mai Valley agricultural land was 47,438 rai (Lamar Robert, 1982) this will equal the loss of over 31 million bahts per year due to the transpiration. Similar estimation can be made from the value of water in electric power production. The total area of 62,500 rai in Doi Taow reservoir was infested by *M. pigra*, this will equal the loss of nearly 23 million bahts per year. These two examples showed that the loss due to the transpiration must be taken into consideration for any economic analysis of the benefits in controlling the weed.

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VIABILITY OF *Mimosa pigra* L. SEED IN DIFFERENT ENVIRONMENTAL CONDITIONS.

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ABSTRACT

Study on viability and longevity of *Mimosa pigra* L. seeds in different environmental conditions was conducted at Weed Science Branch, Botany and Weed Science Division, Bangkok, Thailand in 1981-1983. *Mimosa* seeds were stored for 3 years period in 4 different conditions. After 3 years all seeds treatments showed little decrease in seed germination but were different in seeds viability among treatments. Seeds under waterlogged condition recorded the highest germination of 89 percent while seeds stored 1 and 6 inches under sand surface and seeds in paper bag at room temperature recorded 85.5, 85.6 and 74.8 percent germinations, respectively. The reasons for this phenomenon are also described.

INTRODUCTION

Mimosa pigra L. or giant sensitive plant is a woody shrub belonging to Leguminosae. It was introduced into Thailand since 1952 to be used as cover crop in tobacco plantation and to protect ditchbank erosion in Chiangmai province (Kittipong P. 1980). Later on *Mimosa* numbers were rapidly increased to be big colonies in northern part of Thailand because of its enormous seed production. More over, it can produce seed all year long and can grow on any kinds of soil (Shibayama H. 1983).

Mimosa causes big problems on the irrigation systems by obstructing water flow from the dam or natural resources to the agricultural area. On the roadsides it would also obscure traffic sign which make the bad view for transportation.

At present, *Mimosa* has infested to many other parts of Thailand, especially to central plain area. Its infestation was certainly due to seeds distribution. Majority of *Mimosa* seed distribution are : floating of seed pod along water stream in a long distance, the removal sand from the river in northern territory for road and other constructions. *Mimosa* seeds are sometimes, stick to the wheel of trucks or road construction equipments from Chiangmai area to another part of Thailand.

It is interesting to investigate the viability and longevity of *Mimosa* seeds under various environmental conditions.

MATERIAL AND METHODS

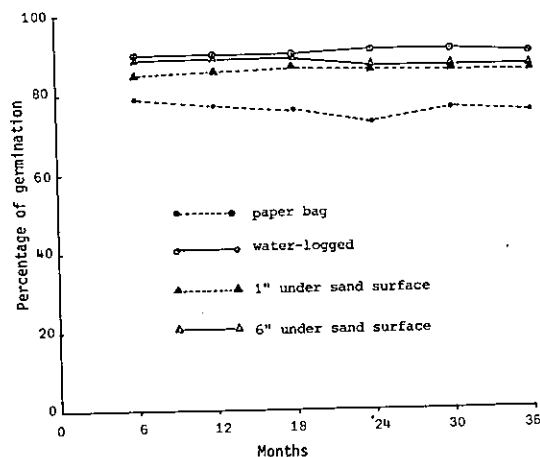
Mimosa pigra seed were collected from Chiangmai Province in February 1981. Matured seed were separated by soaking seeds in 95 percent ethyl alcohol for 10

minutes, of which would sink to the bottom. Selected seeds were cleansed by rinsing with distilled water many times, then seeds were dried out under sunlight. In March all seeds were arranged into four treatments : seeds were retained in paper bag and kept under room temperature, seeds were put in water logged condition and seeds were burried in the sand about 1 inch and 6 inches, under sand surface. Every month one hundred seeds from each treatment were picked out for germination test. Since Mimosa has a seed coat dormancy, for breaking dormancy, seeds were soaked in boiling water about 5 minutes before seeding in the medium consisting of sand and fuzz of coconut husk with 1:1 ratio contained in 25 × 40 × 10 cm. plastic pots. Watering were given 2 times per day. Each treatments were triplicated.

Generally Mimosa seeds could germinate 3 days after seeding and the highest germination was after 7 days. In this experiment germinated seeds were recorded every 7 days with in one month also as the temperature and humidity during the experiment.

RESULTS AND DISCUSSION

Germination percentage of Mimosa seeds stored under different conditions was showed in Figure 1. Within treatments, during the first 30 months there were no significant difference of seed germinations but seeds kept in waterlogged condition recorded the highest germination of 89.58 ± 3.0 , 90.50 ± 3.59 , $90.70 \pm 4.19\%$ at 6, 18, 30 month, respectively while seeds kept under 1 inch and 6 inches under sand surface record 84.73 ± 2.48 , 87.03 ± 3.51 , 86.07 ± 5.17 and 89.80 ± 2.9 , 88.79 ± 2.89 , $86.13 \pm 7.06\%$ respectively and seed in paper bag under room temperature recorded the least germinations of 79.03 ± 2.4 , 76.06 ± 6.21 , $76.31 \pm 6.18\%$. At 3 years after seed storing, all seed treatments showed little decrease in seed germination.



It is interesting that, among treatments, every germination test during 3 years seed storing, seeds under waterlogged condition always gave the highest germination about 89–91%, while seeds under 1 inch and 6 inches of seed surface gave almost the same germination percentage of 84–87 and 85–89% respectively and seeds in paper bag gave the lowest germination of 74–79%.

These phenomenon of different seeds germination under different environmental conditions may be described, according to some physiological and ecological of the seeds concerned. The germination rate of Mimosa seeds under waterlogged condition were always higher than the other treatment because of lacking or low oxygen supply which cause low matabolic activity of the seeds. Metabolic activity of the seeds are correlated with the amount of the oxygen supply, temperature and humidity. Mayer A.M. reported in 1974 that seed viability was high if the metabolic activity was low and the metabolic activity would greatly reduce under low temperature and low oxygen supplied.

For seeds under waterlogged condition, comparing to the other 3 treatments in which oxygen was lacking and the temperature was lower, could retain the viability of the seeds and gave the highest germination. Shull (1914) found that many kinds of seeds, especially seeds in Fam. Leguminosea, with a hard seed coat, were still viable after several years of submergence.

For seeds burried under 1 inch and 6 inches under sand surface. The viability of the seeds in both treatments were lower than the seeds under waterlogged condition but there was not much difference in seed germination between these two treatments eventhough the seeds in 6 inches under the sand gave little higher germination than seeds 1 inch in the sand. This could be explained that in the sands there were more oxygen and higher temperature than in waterlogged condition effecting the higher metabolic activity and the lower viability of the seeds.

For seeds stored in paper bag under room temperature, the germination tests gave the lowest numbers of germinated seeds. In this condition, the oxygen was more surplus and the temperature was better ($30-35^{\circ}\text{C}$) for the metabolic activity of the seeds than the first 3 treatments which effecting the lowest viability and germination of the seeds.

It could be seen that for Mimosa seeds being sunk under the water or buried under the sand surface where there were lacking of oxygen and low temperature could keep its viability and longivity at least 3 years after falling from mother plants and Mimosa seeds which expose to the air or higher temperature the metabolic activity would be high and lessen its viability and longivity of the seeds resulting its low germination after a long period of time falling from its mother plants. J.H. Dowson and V.F. Brunes (1975) attested that different environmental conditions could effect on the longivity of the seeds.

In Thailand, majority of Mimosa seed distribution are: seeds pods floating along the stream and sink into the sand under the water; stick to the trucks wheel or construction equipments etc. These causes of seeds distributions can retain the viability and longivity of the seeds to germinate at the long distance area and long period of time from its original place. For controlling this weeds, studies on seed production and seed distribution must be concerned

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WEED EMERGENCE PATTERNS IN A TROPICAL SOIL

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ABSTRACT

The effect of type of fallow and time of land preparation on patterns of weed emergence was studied in an experiment conducted in an upland soil in the Philippines. The type of fallow had no effect on the number of weed species that emerged but as soil moisture increased the number of weed species also increased.

Rotboellia exaltata L.f. which was the dominant weed emerged at all cultivation times and showed no distinct pattern of emergence. *Cyperus rotundus* L. which also emerged at all sampling times was most abundant in April and least abundant in November.

Distinct patterns of emergence which were related to rainfall were observed for *Ipomoea triloba* L. and *Chlopgonium mucunoides* Desv. Distinct patterns of emergence which may be related to a climatic factor other than rainfall were also observed for *Ageratum conyzoides* L. and *Digitaria* spp.

INTRODUCTION

According to Harper (1977), the supply of water to an area of land is often the least reliable (in time) of all the resources needed for plant growth. Even in areas of high annual rainfall, rainy days are difficult to predict and within a rainy season there is much day-to-day variation. In the tropics and in places where rainfall is the only source of water, moisture may have the greatest influence on weed seed germination and weed emergence. Growth of individual weed species is suppressed by soil moisture contents higher or lower than the optimum for a species. Within the range of optimum soil moisture contents, competition regulates the weed population. Outside this range, soil moisture regulates the weed population (Walter, 1979).

Knowledge of the time of emergence of weeds and of the influence of tillage on emergence can be useful in developing effective integrated weed management systems and could be useful for the timing of cultivation or postemergence herbicide applications (Ogg and Dawson, 1984).

The interacting effects of light, temperature, moisture, and nitrate bring about variation in germination and emergence of weed species. These factors explain the variations in the response of weed seedlings to cultivation done at different times of the year, the effect of which is periodicity of weed emergence. Periodicity of weed emergence has been reported by a number of authors including Brenchley and Warrington (1930), Roberts (1964), Roberts and Feast (1970), Roberts and Lockett (1978), Roberts and Ricketts (1979), Roberts and Potter (1980), Stoller and Wax (1973), and Ogg and Dawson (1984). The pattern of weed species emergence has been attributed to rainfall distribution, variation in soil temperature, and weed seed

dormancy.

Periodicity of emergence of *Veronica hederaefolia* L. was attributed to seed dormancy (Roberts and Lockett, 1978). For *Poa annua* L. there was a consistent pattern of emergence which tended to be relatively low after cultivation in the period from March to May, increased during summer and then became less after cultivation in mid-September (Roberts and Potter, 1980).

Roberts and Ricketts (1979) observed a definite pattern of emergence for *Polygonum aviculare* L. Cultivation in March and April gave rise to a seedling population which represented a high percentage of seeds in the top 10 cm of soil. The number of seedlings decreased in May and few seedlings or none emerged from July onwards.

Stoller and Wax (1973) reported patterns of emergence for eight annual weed species. Flushes of emergence of all species which occurred after May 1 were preceded by sufficient rainfall to bring the surface 10 cm of soil to field capacity. Early emergence was attributed to stimuli from general soil warming while emergence after May 1 was stimulated by favorable soil moisture from rainfall.

Ogg and Dawson (1984) reported the seasonal emergence patterns of eight weed species from April to September on plots that were irrigated weekly. Shallow tillage (5 cm) each month changed the magnitude of the species response but did not affect the pattern of emergence.

A number of authors have reported that flushes of emergence of weed species were preceded by sufficient rainfall and a rise in soil temperature (Stoller and Wax, 1973; Roberts and Ricketts, 1979; Roberts and Potter, 1980). When a dry spell followed cultivation, weed seed germination was inhibited (Roberts and Potter, 1980).

All of the previous studies on patterns of weed emergence have been conducted in the temperate region. To our knowledge no studies of this type have been carried out in the tropics. The objectives of this experiment were to determine the effect of different types of fallow on the patterns of emergence of a naturally occurring weed population in a tropical soil in the Philippines and to determine the effect of rainfall on weed species emergence.

MATERIALS AND METHODS

This experiment was conducted in an upland field at the International Rice Research Institute in 1982 and 1983. The soil was a silty clay with a pH of 5.7; CEC, 30.6 me/100 g; total N, 0.136; and organic carbon, 1.11%. The bulk density in the top 30 cm soil layer was 1.01. The field was fallowed from January 1981 to April 1982 and it was not cropped during this experiment.

A split plot design in a randomized complete block with four replications was used. The main plots were the different types of fallow. These were no treatment (no weeding), mowing at 2-week intervals, and cultivation at monthly intervals. The subplots were the different times of land preparation. Land preparation was done within the first 3 days of each month from April to November. It

consisted of rototilling three or four times to a depth of about 15 cm with a rotovator attached to a small hand tractor to obtain the desired soil tilth. Plot size was 6 m × 5 m and there was a 1.0 m alleyway between plots.

Weeds which were sampled from two 0.25 m² quadrants per plot at 2-week intervals until 12 weeks after land preparation were bulked, classified by species, counted, oven dried at 80 °C for 48 hours, and then weighed. The summed dominance ratio (SDR) for each species was determined using the following equation:

$$SDR = \frac{\text{Relative density} + \text{Relative dry weight}}{2}$$

where

$$\text{Relative density} = \frac{\text{Density of a given species}}{\text{Total density}} \times 100$$

$$\text{Relative dry weight} = \frac{\text{Dry weight of a given species}}{\text{Total dry weight}} \times 100$$

Soil moisture in the 0–10 cm soil depth was determined gravimetrically twice a week starting immediately after land preparation. The soil moisture contents at field capacity and permanent wilting point were 29.2% and 19.4%, respectively.

Rainfall data were obtained from a meteorological station located approximately 300 m from the experimental site.

RESULTS AND DISCUSSION

The rainfall pattern and the soil moisture contents during the conduct of the experiment are illustrated in Figure 1.

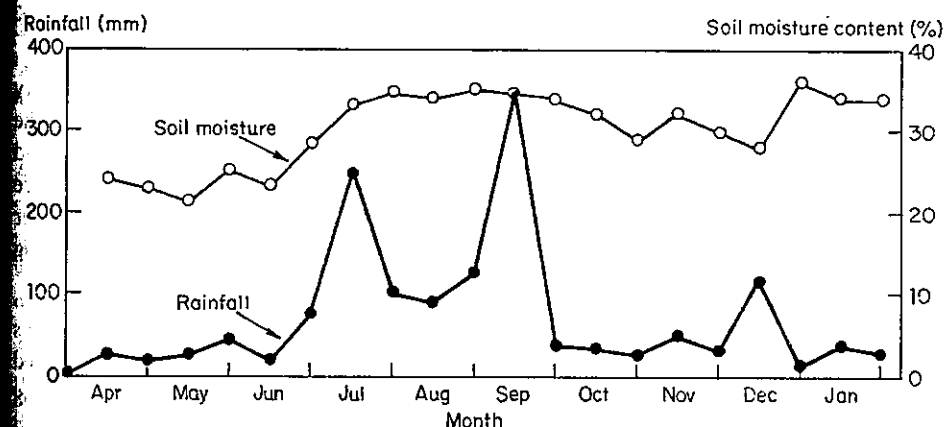


Fig. 1. Bi-weekly rainfall and soil moisture during the conduct of the experiment. April 1982 to January 1983.

The effect of the time of land preparation and the type of fallow on the number of weed species is given in Table 1. The greatest number of species observed at any one sampling time was 17 and the least was 5 (Table 1). The type of fallow had no effect on the number of weed species that emerged. Generally, more weed species emerged when the land was prepared in June, July, August, and September. This was probably due to the higher soil moisture contents that occurred during these months compared to the other months. There was a linear increase in the number of weed species that emerged with increase in soil moisture (Fig. 2). Soil moisture contents below 25% limited the number of species that emerged. Various authors (Garcia, 1931; Hoveland and Buchanan, 1973; Suzuki et al., 1975) have also reported that weed seed germination increased as the soil moisture content increased.

Table 1. Total number of weed species that emerged as affected by type of fallow and time of cultivation.^a IRRI, 1983.

Time of cultivation	Type of fallow		
	Weedy	Mown	Cultivated
April	5 d	5 e	5 c
May	7 c	8 d	7 c
June	12 a	10 cd	11 b
July	13 a	13 b	15 a
August	13 a	17 a	13 ab
September	13 a	12 bc	12 ab
October	9 bc	12 bc	11 b
November	11 ab	13 b	14 ab
Mean ^b	10 a	11 a	11 a

^aAverage of 4 replications. In a column, means followed by the same letter are not significantly different at the 5% level by DMRT.

^bIn a row, means followed by the same letter are not significantly different at the 5% level by DMRT.

The type of fallow and the time of cultivation significantly affected weed density (Table 2). No significant differences in weed density were observed among the different types of fallow when cultivation was done in April, May, June, and July. When cultivation was done in August and September, weed densities were significantly higher in the weedy fallow than in the cultivated fallow. In October and November, significant differences were observed in weed densities among all types of fallow.

Keeping the fields as a weedy fallow enabled the weeds to produce seed thus increasing weed seed reserves in the soil, whereas, periodic cultivation prevented weed seed production and encouraged weed seed germination thus reducing weed seed reserves in the soil. Some weeds, such as *R. exaltata*, flowered and produced seeds despite the mowing operation. Also, very few weed seeds germinated in this type of fallow.

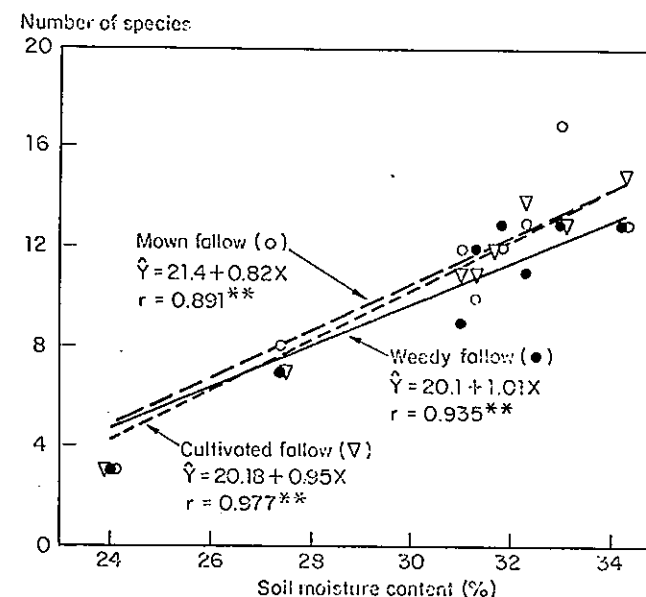


Fig. 2. Relationship between soil moisture content and number of species that emerged as affected by the types of fallow. IRRI, 1983.

Table 2. Weed density (no./m²) 6 weeks after land preparation as affected by time of cultivation and type of fallow.^a IRRI, 1983.

Fallow condition	Time of cultivation							
	April	May	June	July	August	September	October	November
Weedy	170 a	118 a	889 a	519 a	608 a	362 a	949 a	1297 a
Mown	143 a	148 a	847 a	428 a	602 ab	200 ab	435 b	631 b
Cultivated	141 a	115 a	797 a	298 a	288 b	120 b	193 c	91 c

^aAverage of 4 replications. In a column, means followed by the same letter are not significantly different at the 5% level.

Among the 17 weed species, *R. exaltata* was dominant. Other important weed species were *C. rotundus*, *C. mucunoides*, *Cynodon dactylon* (L.) Pers., *Digitaria* spp., *A. conyzoides*, *I. triloba*, and *Borreria ocymoides* (Burm. f.) DC. The other weed species were minor components of the weed flora. The patterns of emergence of some of the important weed species are discussed.

R. exaltata emerged at all cultivation times. Its abundance differed between the types of fallow (Fig. 3). In the plots that were maintained as a weedy fallow, the SDR of *R. exaltata* was lowest in April and highest in November. This was probably due to the enormous number of seeds produced during the weedy fallow period which resulted in an increase in emergence later in the year thus increasing its abundance.

Summed dominance ratio (%)

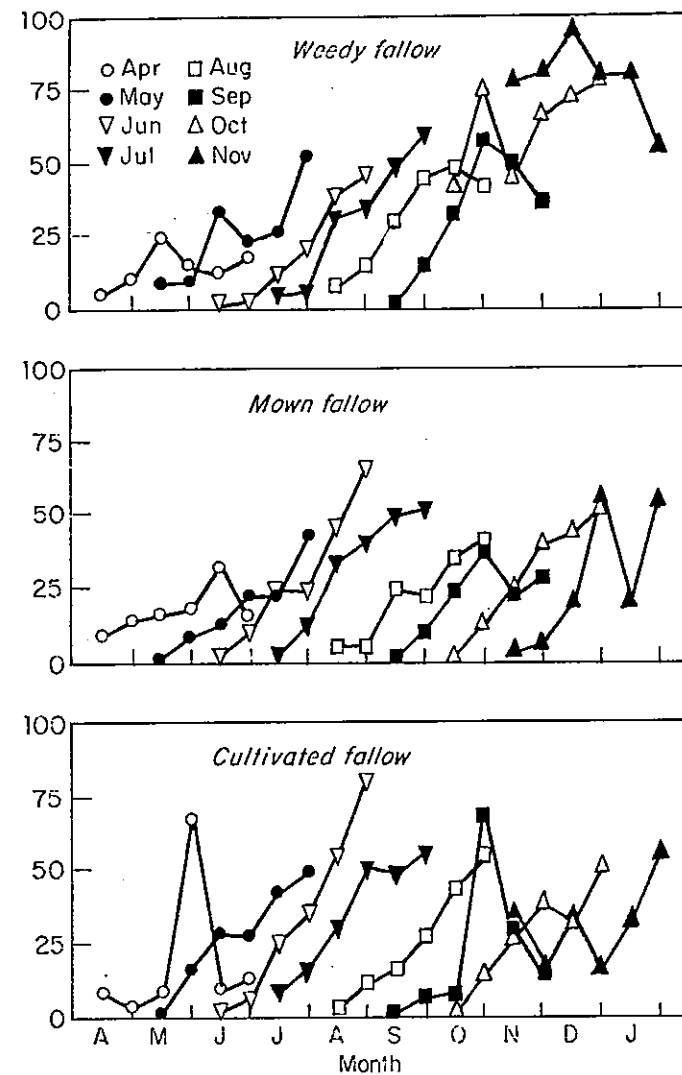


Fig. 3. Summed dominance ratio of *Rottboellia exaltata* as affected by time of cultivation and type of fallow. IRRI, 1983.

In the plots that were kept mown during the fallow period, the SDR of *R. exaltata* was lowest in the plots which were cultivated in April. In the plots that were kept cultivated during the fallow period the SDR of *R. exaltata* ranged from 50 to 80% at all times of cultivation. The highest SDR was obtained with the June cultivation. This coincided with an increase in rainfall and an increase in the soil moisture content. Despite periodic disturbance of the soil over a period of 7 months, the dominance of *R. exaltata* was not reduced indicating the high seed reserves of this weed in the soil.

C. rotundus was also observed at all cultivation times. In all types of fallow the SDR of *C. rotundus* was highest in the plots cultivated in April and lowest in those cultivated in November (Fig. 4). The abundance of *C. rotundus* in the plots cultivated in April demonstrates its ability to emerge and grow under limited soil moisture.

Summed dominance ratio (%)

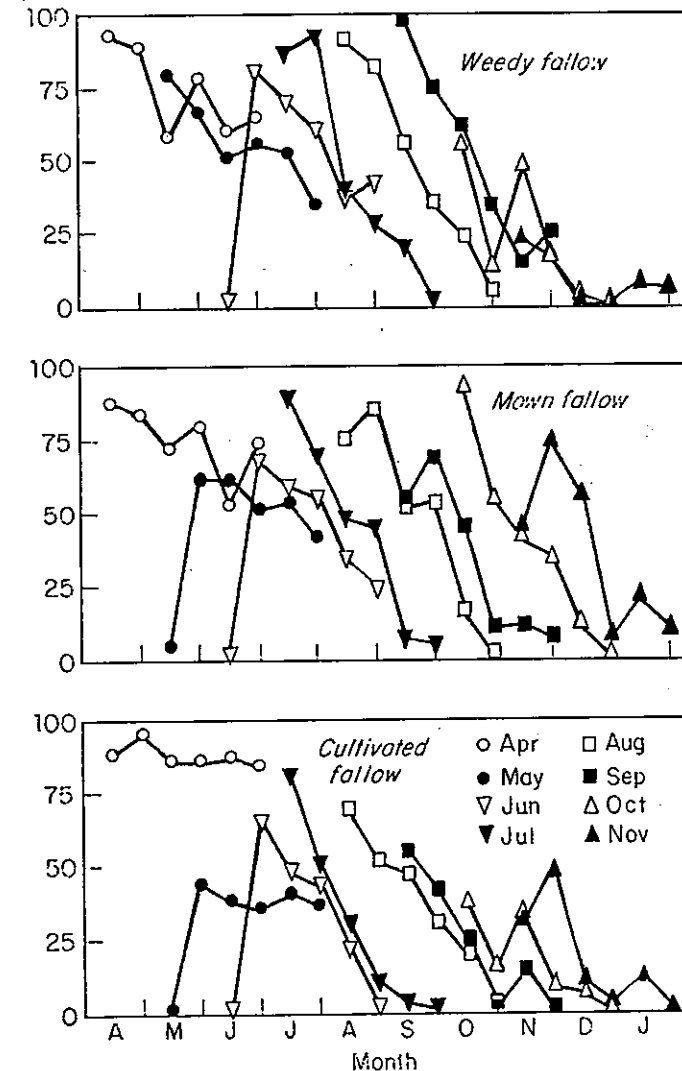


Fig. 4. Summed dominance ratio of *Cyperus rotundus* as affected by time of cultivation and type of fallow. IRRI, 1983.

C. rotundus was usually most abundant at 2 and 4 weeks after land preparation. Reduction in its abundance at the later sampling times could be due to interspecific competition from the other weed species.

In the November cultivation, the SDR of *C. rotundus* in the plots that were previously kept as a weedy fallow was lower than that in the other types of fallow. This was due to the high population of *R. exaltata* which suppressed *C. rotundus* growth. Cultivation during the fallow period also reduced the abundance of *C. rotundus* compared to those plots that were mown.

A. conyzoides which exhibited a seasonal type pattern emerged later in the year regardless of the fallow (Fig. 5). Emergence started in July and increased toward November. The SDR's tended to be greatest in October and November. Robert

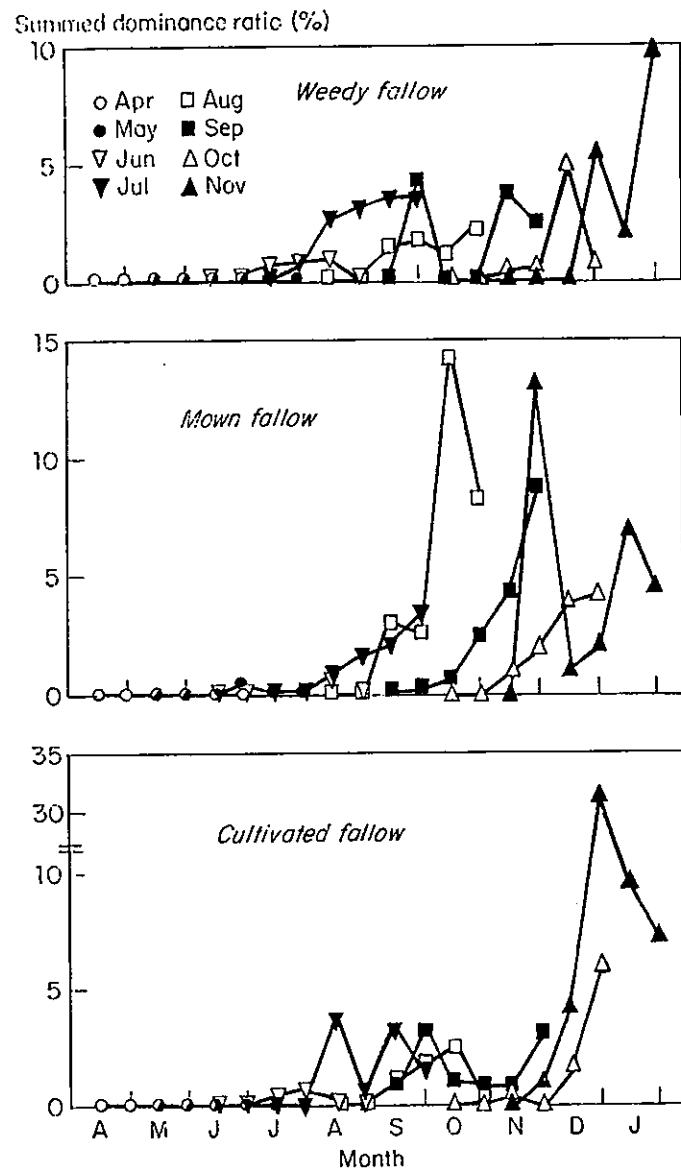


Fig. 5. Summed dominance ratio of *Ageratum conyzoides* as affected by type of cultivation and type of fallow. IRRI, 1983.

1964) stated that whether or not germination occurs must depend on the degree of innate dormancy present and on the ability of the immediate environment to supply the necessary requirements. Even though the *Digitaria* species emerged at all times of the year SDR's were also generally highest in those plots that were cultivated later in the year. Periodic disturbance of the soil in the weed free fallow plots favored germination and emergence of *Digitaria* spp. The patterns of emergence of these species appear to be related to a climatic factor other than rainfall. Further research is needed to determine which factor is involved.

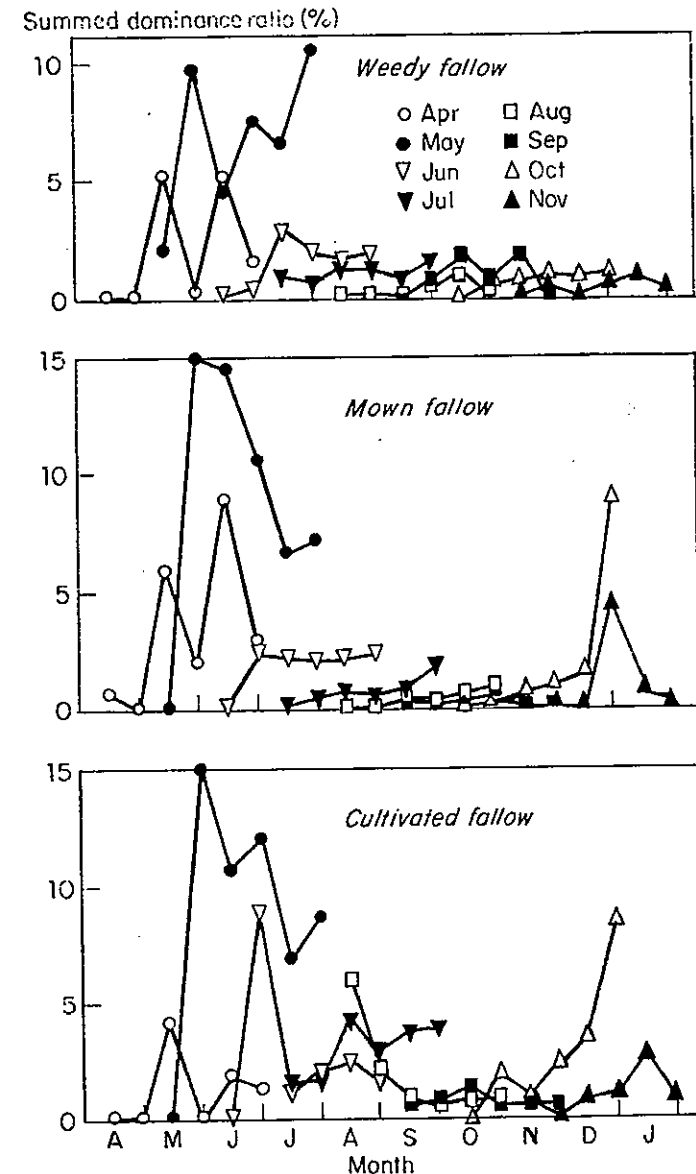


Fig. 6. Summed dominance ratio of *Ipomoea triloba* as affected by time of cultivation and type of fallow. IRRI, 1983.

The SDR's of *I. triloba* were highest in the plots that were cultivated in April and May regardless of the type of fallow (Fig. 6). They were lowest in June, July, August, and September when rainfall and soil moisture contents were highest. They increased in the mown fallow and the cultivated fallow in October and November as rainfall decreased. Even though *C. mucunoides* was present at all times of cultivation a distinct pattern of emergence was observed. SDR's were highest in May and June regardless of the type of fallow. Soil moisture contents higher than 30% reduced *C. mucunoides* emergence.

B. ocymoides did not emerge in April and May regardless of the type of fallow. At all times of the year, except when sampling was done on October 29, 1982 (8 weeks after land preparation in September and 12 weeks after land preparation in August), *B. ocymoides* was an unimportant component of the weed flora. At this sampling date the SDR's ranged from 3% for the cultivated fallow to 23.3% for the weedy fallow. This peak may be related to the heavy rainfall in September.

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WEEDINESS SYNDROME OF *Euphorbia geniculata* AGAINST CORN

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ABSTRACT

Euphorbia geniculata (= *E. heterophylla*), called with poinsettia or painted spurge, has given serious yield losses on upland crops such as corn, cotton and mungbean in Thailand, though it is a C₃-plant species that is considered to be a weak competitor when compared with a C₄-plant.

A series of experiments so far conducted revealed that *Euphorbia geniculata* gives multiple effects on corn plants based on its ecological and physiological characteristics. It can be highlighted from the following standpoints: 1) seed germination and dormancy, 2) seed productivity, 3) deep emergence of seeds in the soil, 4) root distribution in the soil, 5) root ability under a shading condition, 6) tolerance to water stress, 7) high adaptability to sunlight restriction, 8) prompt growing, 9) epicuticular wax at leaf surfaces, and 10) high potential for regrowth after harvest.

The above various factors which are able to effect adversely to corn plants would be called "Weediness Syndrome of *Euphorbia geniculata* against corn". Based on this syndrome, directions of controlling this weed were discussed.

INTRODUCTION

Wild poinsettia is a native to tropics and South America (Hutchinson and Daziel, 1958). It distributed into various upland crops growing areas and became a major weed of more than 20 countries (Nester *et al.*, 1979 and Holm *et al.*, 1977, 1979). It was introduced into Thailand since 1960 and rapidly infested and established throughout the country (Fig. 1). The growth and development of wild poinsettia widely varied with conventional cultural practices, cropping systems and climatic conditions. Many pre-emergence herbicides did not affected germination of seed (Schiller *et al.*, 1976).

Previous studies revealed that it is a C₃ plant (Welkie and Caldwell, 1970). It is strong competitive to corn, C₄ plant, in many roles. Little is known of biological characteristics of this weed in tropical conditions. A series of experiments was designed: a) to determine the growth habits of this weed and competition between *E. geniculata* and corn as influenced by ecological and physiological characteristics; b) to investigate factors promoting its competitiveness; and c) to evaluate different measures of control of *E. geniculata*. The results obtained are generally summarized and discussed.

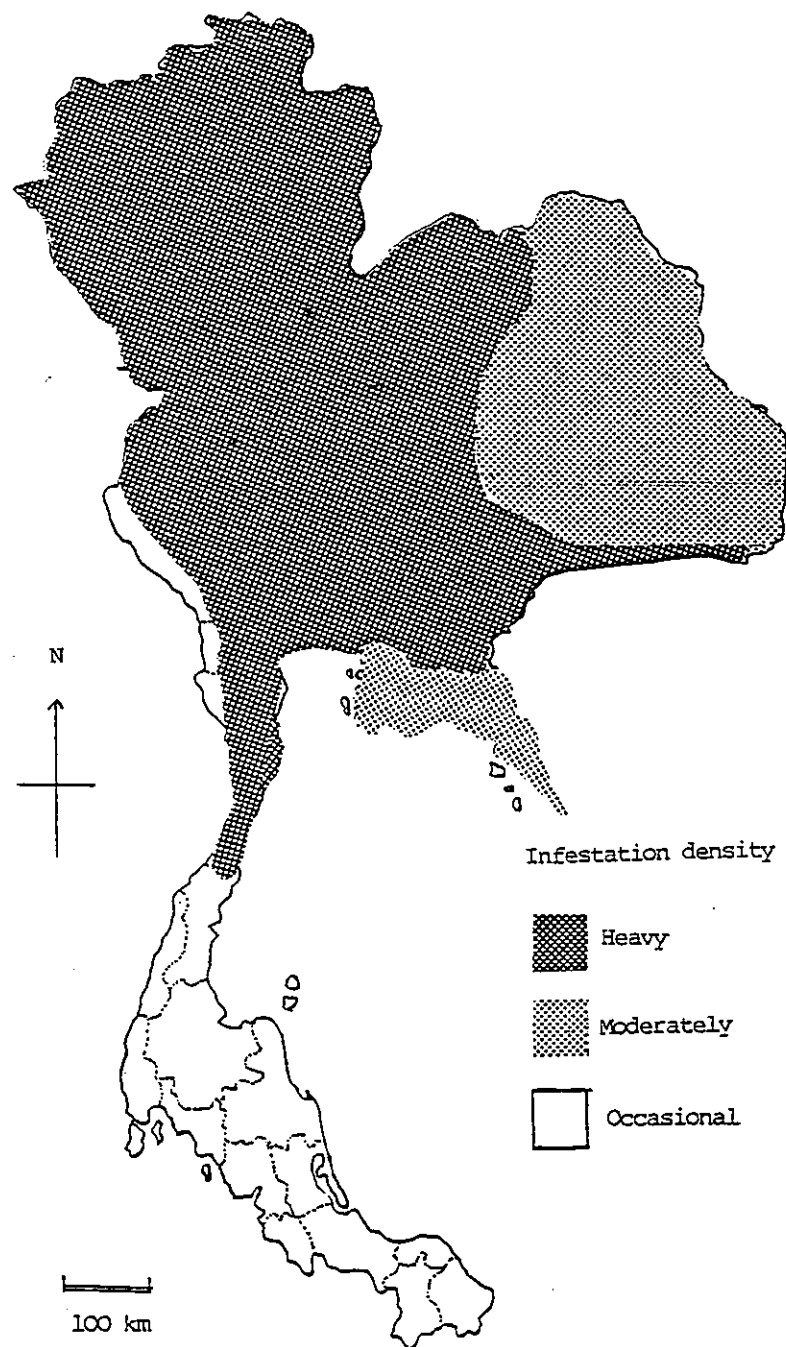


Fig. 1. Distribution of *Euphorbia geniculata* by region in Thailand

Basic point of view

When some weeds are in competition with a crop, three types of negative interference are possible: they are competition, allelopathy and parasitism (Radosevich and Holt, 1984). In the case of *E. geniculata*, parasitism is out of question. As for allelopathy on the other hand, the authors have pointed out the possibility of its existence based on two kinds of evidence: the first is a moderate degree of inhibitive activity displayed by the extracts from fresh material of *E. geniculata*, and the second is the absence of the "law of constant final yield" and instead the existence of a negative correlation between the total dry matter yield of corn plus *E. geniculata* and the population density of the later. However, it does not seem that the injury due to allelopathy can be, if any, a serious one. Therefore, at least in the combination of *E. geniculata* and corn, most of the negative interference is considered to have been realized through competition.

The present authors have made clear the nature of various physiological and ecological characteristics of *E. geniculata* by comparing them with those of other important weeds or genetically related species. Some of the characteristics may have nothing to do with competition, but many of them have been shown to be related with competitive ability through "weediness" or the aggravation of environment.

Thus, the authors have, in the first place, i) picked up various characteristics which have been known in plant ecology to be related with competition, ii) discussed by utilizing the results of the present study as well as those reported in the literature, how they contribute to enforcing the competitive ability of *E. geniculata* against corn, and lastly, iii) made clear through which processes the competition has led to the actual yield loss of corn. Fig. 2 is a schematic illustration of the results of present studies that can be high lighted in the form of a flow chart. The following discussion and explanation will be made according to the figure.

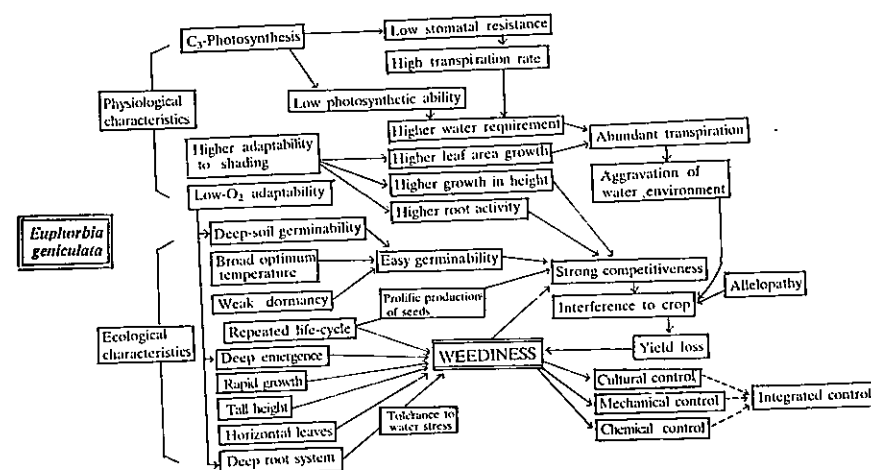


Fig. 2. Schematic illustration of the results of the Ecophysiological Studies of *Euphorbia geniculata* and Its Control in Corn Field

2) Water balance characteristics

It is difficult to think that *E. geniculata*, a C_3 plant, is more favorable than corn, a C_4 plant, in terms of photosynthesis in its competition with the latter. However, there is a basic difference in the water balance characteristics between the two species. Namely, the ratio of transpiration (Tr) to apparent photosynthesis (Ap), Tr/Ap, which is equivalent to short-term water requirement was in *E. geniculata* twice that in corn or *E. hirta*, also a C_4 plant, in accordance with the general rule (Black, 1973), although the actual difference in this case was mainly dependent on Tr rather than Ap in contrast to the general case.

In any way, it is an important fact that *E. geniculata* has a water requirement far higher than that of corn, increasing the water consumption of the mixed stand and thereby aggravating their water environment. This situation will be further intensified as competition becomes severer as will be explained below.

3) Shade tolerance

In a competitive stand, the plants are put more or less under shaded conditions due to mutual shading. It was found in the present study that *E. geniculata* has a special tolerance or adaptability for shading. The relative growth rate in plant height which is known to play an important role in competition changed from 2.8 % per day for *E. geniculata* grown under a non-shaded condition to a value as high as 3.9 % per day for those grown under shaded conditions, while the corresponding value for corn changed from 1.9 % per day to 2.7 % per day. As for the relative growth rate in leaf area, which is also known to play an important role in competition, a more striking difference was observed between the two species: the rate increased from 7.1 % per day for *E. geniculata* grown under a non-shaded condition to 9.3 % per day in shaded grown plants, while it somewhat decreased from 6.8 % per day to 6.3 % per day for corn. As for relative growth rate in dry matter which is well-known to decrease by shading, it remained almost constant from 4.0 % per day to 3.9 % per day in *E. geniculata*, while it decreased in corn from 4.9 % per day to 4.2 % per day.

In this way, it may be concluded that *E. geniculata* changes its growth rate in plant height as well as in leaf area in such a way as to further strengthen its competitive ability against corn when it is put into a severe competition, while in corn such a positive change was little observed. When the rate of leaf area expansion is accelerated under shaded conditions, water requirement of *E. geniculata* will be further increased, intensifying the water stress of the environment. Under such a situation, *E. geniculata* can remain more healthy and more competitive against corn because of their deeper and more active root system.

4) Tolerance to low oxygen concentration

The third feature in the physiological characteristics of *E. geniculata* is its tolerance to low oxygen concentration. Its seeds show the highest percentage germination at the oxygen concentration of 15 %, 10 % germination at 3.0 % to 0.5 % oxygen concentration, and 7 % germination without oxygen. This property is considered to be also responsible for its remarkable ability to emerge from a soil layer as deep as 8 cm. This implies that the tolerance to low oxygen concentration is observed not only in the

germination process but also in the growth process just after germination. As already mentioned, *E. geniculata* has a deeper root system than corn and it might be that the low-oxygen tolerance is also responsible for the development and maintenance of the deep root system.

5) High propagation ability

When *E. geniculata* is grown in various seasons in a year, the length of its lifecycle changed from 66 days to 133 days, indicating at least three cycles in a year possible with the production of 200-600 seeds per generation. Due to the broad optimum temperature range, 25°C to 35°C, with weak dormancy and tolerance or adaptability to low oxygen concentration, the seeds can germinate at any time and emerge out from any depth of soil, as long as it is less than 8 cm deep, if only humidity requirement is met. This high and flexible ability for propagation will without doubt greatly contribute to its basic competitive ability with crop plants.

6) Characteristics related to competition for light

Plant height has the primary importance in competition for light. Although under separate conditions *E. geniculata* seldom exceeds the height of corn plant, in a mixed stand their growth in height and leaf area become remarkably enhanced as discussed already. In addition, canopy geometry greatly contributes to strengthening their competitiveness for light, namely, in contrast to corn plants which have inclined leaves arranged with abundant space, *E. geniculata* plants are composed of horizontal leaves gathered densely near the top of the canopy. Thus, corn plants have comparatively low light extinction coefficient, k , of 0.67 (Monteith, 1969) and *E. geniculata* seems to have considerably a higher k value, judging from the value of cotton (1.05) which has nearly horizontal leaves.

Thus, *E. geniculata* leaves can quite effectively intercept incident light, drastically reducing the light intensity within the mixed stand. Due to such a strong depletion of light, the development of upper leaves and ears of corn are greatly affected, as shown by the experimental results.

In this way, all the physiological and ecological characteristics in Fig. 2 have been shown to work in their respective ways to strengthen the competitive ability of *E. geniculata* against corn with some influence of allelopathy added, causing as a result the loss of corn yield.

7) Mechanism of yield loss due to competition

The main cause for the yield loss of corn is, therefore, attributable to the illeffect of severe competition between *E. geniculata* and corn for light and water and, most probably, for minerals too. Taking into consideration both crop physiological information and the existence of various correlations obtained among grain yield, its components and growth parameters of *E. geniculata*, the following is postulated as a possible mechanism for yield loss.

The light-interception by the leaves as well as other parts of *E. geniculata* will affect, in the first place, the grain-number-determining processes, and then affect the initial

phase of grain-filling process when abortion of grains is very likely to occur through the limited supply of assimilates. Competition for water and, possibly, for mineral nutrients may have intensified this. However, the latter aspects remain to be elucidated.

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YIELD LOSSES OF CORN AND CHANGE OF PRODUCTIVE STRUCTURES DUE TO

Euphorbia geniculata

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ABSTRACT

The yield losses of corn due to *Euphorbia geniculata* and the change of productive structures in corn have been studied in a field to know basic information of establishing weed control technology. Summarized results are as follows :

The high density of *E. geniculata* into corn provided decrease of the total dry weight of corn leaf, stem, ear, and tassel by 54.3, 56.0, 85.4 and 78.7 %, respectively, while the low density of *E. geniculata* gave those of corn as above by 54.2, 46.6, 72.4 and 46.0 %, respectively, when compared to corn alone. The decrease in the amount of corn leaf were severely occurred in the upper from the ear-bearing position of corn. Light density in the mixed population was reduced by the dense leaf layer of *E. geniculata* and this effected to chlorophyll content in corn leaves and corn yield as well. The yield losses of corn was due to the decrease in grain number per ear which caused by both potential of grain number and lowered fertility of grain, affected by severe competition of *E. geniculata*.

INTRODUCTION

From the previous experiments reported that the yield reduction of corn caused by weeds was up to 60 % (Kanjanajirawong and Teerawatsakul, 1976). This depends on weed species and density of weeds. One of the most serious in corn is *Euphorbia geniculata* which is commonly called wild poinsettia and painted spurge (Noda et al., 1985). It competes with corn from the early stage of corn to the harvesting period.

The objectives of this research were (a) to determine the effects of *E. geniculata* on productive structures of corn and (b) to determine the yield losses and yield components of corn caused by difference populations of *E. geniculata*.

MATERIALS AND METHODS

A field experiment was conducted at Praphuttabut Field Crop Experiment Station in 1984. The soil is red-brown laterite. *E. geniculata* seeds were overseeded and incorporated, then corn "Suwan 1" was planted in drill, 75 × 25 cm with 2 plants per hill, on June 14, 1984.

E. geniculata densities were varied from 0-250 plants/m² for investigation the yield losses of corn. Two *E. geniculata* plots with stand densities of 92 and 193 plants/m² and a non-competitive corn plot were chosen to investigate the productive structures. All these plots were kept free from undesired weed species through the season.

Stratified crippling of corn and *E. geniculata* plants were made at 20 cm intervals from the soil surface with an area of 1.5 × 2.0 m on September 5, 1984. The plant materials harvested at each height were classified into leaf, stem, ear, and tassel in corn and into leaf, stem, and reproductive organ in *E. geniculata*, and weight for both fresh and dry weight. Vertical distribution of each part was expressed on dry weight basis.

Sunlight transmission into the stands was measured at every 20 cm height from the soil surface by means of Photoillumometer SPI-71 (Tokyo Rigaku) and the data were expressed in relative values (%) to the control.

Chlorophyll (a+b) content of corn leaves from the upper-most to the 9th (or 10th) leaf was measured on September 15, by means of Fuji Green Meter. Five plants of each non-competing and severely competing with wild poinsettia were used. Chlorophyll content was expressed in mg/dm².

RESULTS AND DISCUSSION

a) Productive structures of corn

Fig. 1, 2, and 3 show the vertical distribution of assimilating organs, non-assimilating ones in the mixed population of corn and *E. geniculata*, and a pure stand of corn respectively, with light distribution curves.

Mixed corn gave serious decrease in the amount of leaf, the decrease being particularly severe in the upper than in ear-bearing portion. It may be due to the specific development of *E. geniculata* leaves around the height from 100 to 140 cm. This dense leaf layer of *E. geniculata* strongly interfered with the light transmission (Fig. 1 and 2). In the pure corn stand, the rate of decline of light intensity with decreasing height was moderate (Fig. 3), while it was considerably steep in the low-density stand (Fig. 2) and steepest in the high-density mixed stand (Fig. 1). As a result, the 50 % of light intensity was found at a height around 20 cm in the pure corn stand, while it were at around 60 cm in the low-density stand and 120 cm in the high-density stand. The strong light interception of *E. geniculata* as compared to corn may be explained by the more horizontal arrangement of leaves in the former than in the latter.

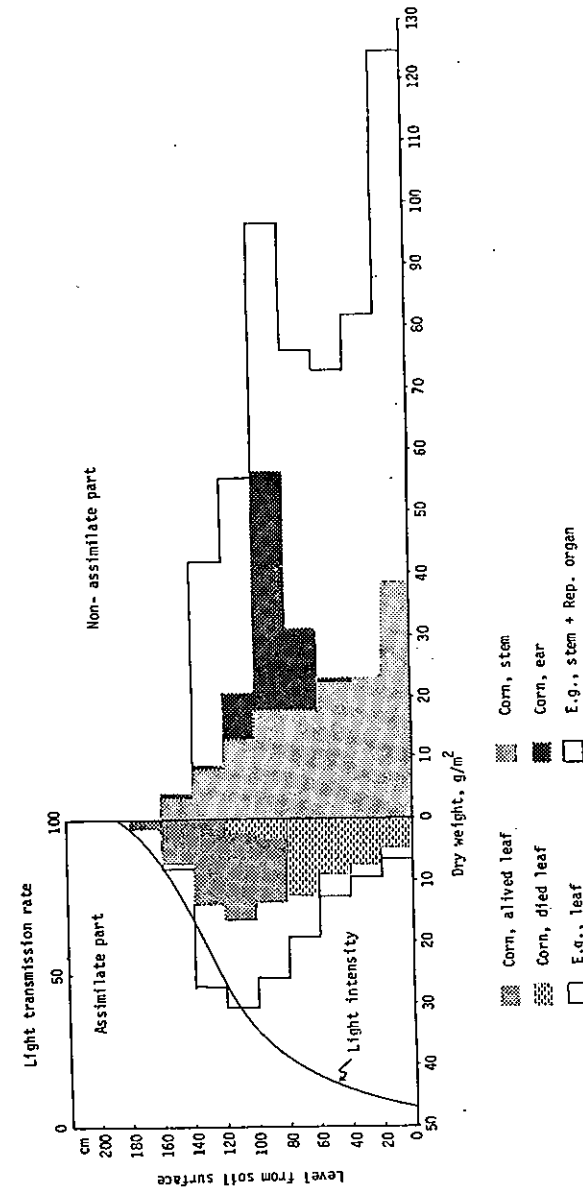


Fig. 1. Productive Structure of Mixed Population of Corn High-densed *E. geniculata*

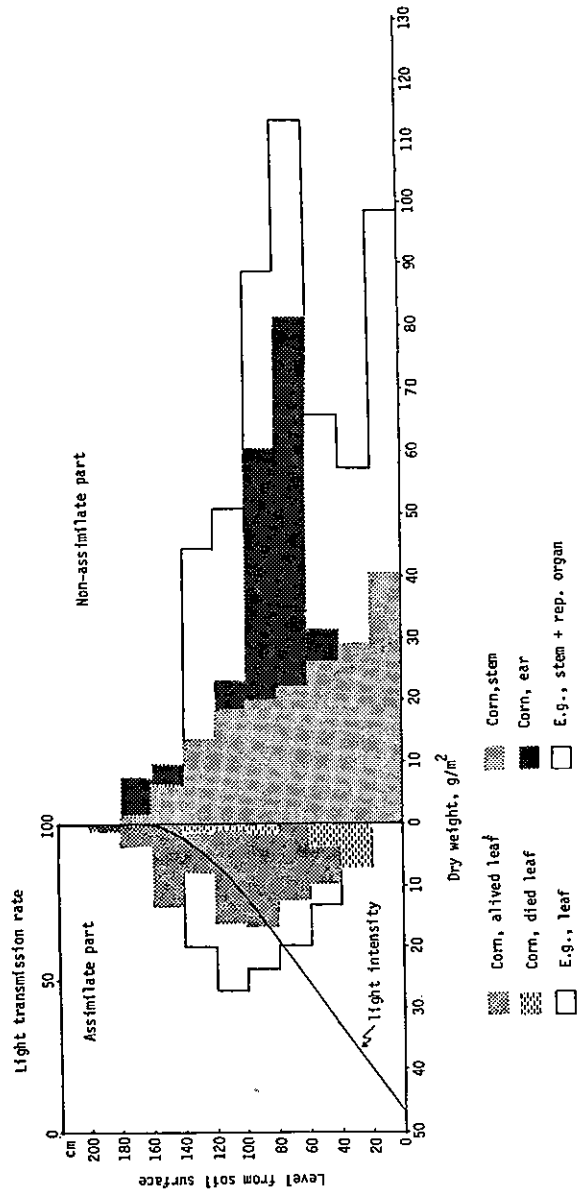


Fig. 2. Productive Structure of Mixed Population of Corn and Low-densed *E. geniculata*

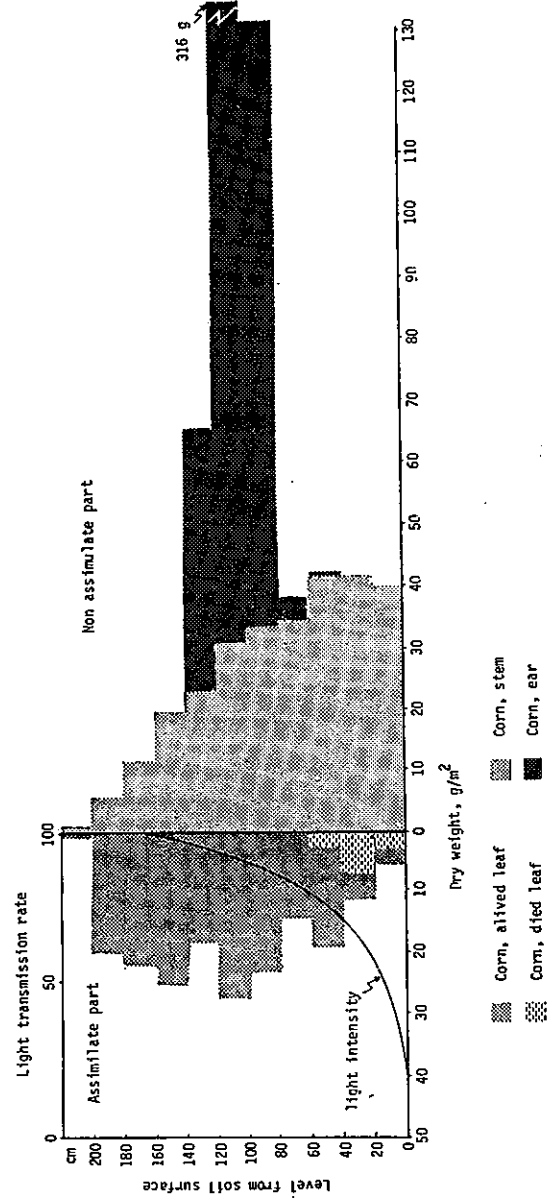


Fig. 3. Productive Structure of Corn Plants Alone

The effect of light interception by *E. geniculata* may have naturally given a deteriorating influence on the growth and development of corn plants, especially the ear. The deteriorating influence was milder in the thinly populated stand than the densely populated stand.

Chlorophyll (a+b) content shown in Table 1, there was no difference in the first leaf but distinct difference was found in other leaves. This suggests a decrease of photosynthetic activity in competitive corn plants. The chlorophyll content was found to be closely correlated with the degradation of productive structure of the mixed stand of corn competing with *E. geniculata*.

Table 1 Comparison in chlorophyll (a +b) content of corn plants

Position of leaf from top	Non competitive corn		Competitive corn*	
	Value	mg/dm ²	Value	mg/dm ²
1	0.99	2.44	0.97	2.37
2	1.38	3.88	1.06	2.70
3	1.35	3.77	1.04	2.63
4	1.45	4.14	1.06	2.70
5	1.60	4.70	1.27	3.48
6	1.55	4.51	1.18	3.14
7	1.48	4.25	1.22	3.29
8	1.41	4.00	1.12	2.92
9	1.42	4.03	0.87	2.00
10	1.48	4.25	-	-

* competitive with *E. geniculata* of 193 plants/m². Values are the average of 5 plants.

b) Yield losses and yield components of corn

Data obtained are indicated in Table 2 and 3. The yield of corn was reduced according to the degree of infestation of *E. geniculata* by 80 % at the highest correlation coefficient of some characters of corn with *E. geniculata* are shown in Table 4. Correlation coefficient of corn ear weight with the number of plants per m², fresh weight, and dry weight of *E. geniculata* were -0.7859**, -0.8135**, and -0.7879** respectively.

Table 2 Yield losses and the changes of yield components in corn due to *Euphorbia geniculata* Infestation

Plot	E. geniculata		Corn (dry matter) g/plant			No. of grain per ear (C)	Ear/plant wt. ratio	Shelling percent	wt. of 100 grains g	No. of lines/ear (A)	No. of steps/ear (B)	Grain* No Capacity (%)
	Density	Fresh wt. E.g./m ²	Dry wt. E.g./m ²	Leaves and stalks	Grain							
1	0	0	0	71.8	90.6	306.6	1.26	79.7	23.6	14.1	25.1	354
2	50	830	201.7	50.5	37.8	181.0	0.75	78.8	16.5	13.4	18.2	244
3	52	765	224.1	57.4	63.6	222.9	1.10	78.9	22.5	13.6	21.1	287
4	84	1050	268.3	66.7	59.9	208.1	0.90	79.8	23.0	12.8	19.9	191
5	102	1010	224.2	44.2	23.0	102.7	0.52	75.2	16.9	12.7	14.9	189
6	185	1300	325.0	48.0	19.3	77.2	0.40	72.5	18.1	13.6	13.5	184
7	187	1207	305.0	47.2	17.7	54.3	0.38	71.8	23.4	12.0	10.4	125
8	210	1500	375.0	47.1	29.6	100.3	0.63	74.7	22.1	13.0	17.4	226
9	226	1180	295.0	45.2	30.3	135.3	0.67	83.8	18.8	12.6	14.9	188
												86.6
												74.2
												77.7
												81.7
												54.3
												42.1
												43.5
												44.3
												72.1

Note : E.g., *Euphorbia geniculata* ; *A × B; ** $\frac{C}{A \times B} \times 100$ (%)

Table 3 Relative value of grain weight and yield components (as % of non-competition plot)

Plot	Grain wt. (A)	No. of grains per ear (B)	100-grain wt. (C)	Fertility (D)	B × C × D
1	100	100	100	100	100
2	41.3	59.1	69.9	85.7	35.3
3	69.5	72.8	95.3	89.7	62.2
4	63.9	67.9	97.5	94.3	62.4
5	24.0	33.5	71.6	63.1	15.1
6	19.4	25.2	76.7	48.6	9.4
7	17.6	17.7	99.2	50.6	8.9
8	30.6	32.7	93.6	51.1	10.1
9	35.3	44.2	79.7	82.0	28.2

Note : Correlation coefficient (**0.01 % sig.)

A and B, $r = 0.9290^{**}$

A and C, $r = 0.5126$

A and D, $r = 0.8629^{**}$

A and (B × C × D), $r = 0.9900^{**}$

Table 4. Correclation coefficient between some agronomic characters of corn and *Euphorbia geniculata*

x	y	r
1. Number of <i>E. geniculata</i> (plants/m ²)	Dry weight of corn ear (g/plant)	-0.7859**
2. Fresh weight of <i>E. geniculata</i> (g/m ²)	Dry weight of corn ear (g/plant)	-0.8135**
3. Dry weight of <i>E. geniculata</i> (g/m ²)	Dry weight of corn ear (g/plant)	-0.7879**
4. Number of grains/ear	Grain yield of corn (g/plant)	0.9784**
5. Fresh weight of <i>E. geniculata</i> (g/m ²)	100 grains weight of corn (g)	-0.2389
6. Fresh weight of <i>E. geniculata</i> (g/m ²)	Number of grains/ear	-0.8658**
7. Fresh weight of <i>E. geniculata</i> (g/m ²)	Potential number of grains/ear	-0.8099**
8. Fresh weight of <i>E. geniculata</i> (g/m ²)	Fertility of grain (%)	-0.7334**
9. Square of fresh weight of <i>E. geniculata</i>	Number of grains/ear	-0.8260**

Note : x =horizontal axis, y =vertical axis, and r =correlation coefficient value

Among the three morphological parameters of *E. geniculata*, fresh weight gave the highest correlation with the grain yield of corn. This implies that the effect of *E. geniculata* is most probably manifested itself through competition for light rather than for minerals and water absorption.

When the various corn yield components were examined, the number of grain per ear which had a correlation coefficient as high as 0.9784** with grain yield was most closely correlated with fresh weight of *E. geniculata*. On the other hand, 100-grain weight of corn was only slightly, negligibly correlated. This suggests that corn yield reduction caused by *E. geniculata* is exerted not through the grain-weight-determining process but through the grain-number-determining process. The potential number of grains per ear (No. of grain lines × No. of grain steps) was significantly correlated with the fresh weight of *E. geniculata*. On the other hand, fertility percentage of corn grain was in an interesting relationship with the fresh weight of *E. geniculata*, it was correlated with fresh weight only when the latter was larger than a certain value. This may indicate that the ill-effect of *E. geniculata* on corn grain fertility become serious only when its biomass exceeded a certain level.

Therefore, grain number per ear which is consisted of fertility percentage and potential number of grain should be doubly dependent on fresh weight of *E. geniculata*. This is indicated by the existence of a very close correlation between grain number of corn and square of fresh weight of *E. geniculata*.

Thus, the ill-effect of *E. geniculata* on the grain yield of corn is mainly exerted through the deprivation of light by its biomass, the effect being manifested as a reduction in number of grains per ear, and that in the process of the grain-number-determining, *E. geniculata* affects both the potential number of grains and their fertility.

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DEVELOPMENT OF HALOXYFOP AS A GENERAL WEED CONTROL HERBICIDE IN MALAYSIAN PLANTATION

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ABSTRACT

Haloxfop - ethyl or methyl (Ethoxyethyl 2 - (4 - [(3 - chloro - 5 - (trifluoromethyl) - 2 - pyridinyl)oxy] phenoxy) propanoate) coded as Dowco 453 is a new post-emergence grass herbicide. It was developed for use in the selective control of annual and perennial grass weeds in broadleaf crops. Intensive and extensive trials in Malaysian conditions proved that haloxfop is very effective against *Paspalum conjugatum* and in mixtures with other grasskillers is effective against *Ottlochloa nodosa* in both open and shade conditions. Haloxfop between 120-240 g ae/ha and 300-400 g ae/ha provides 3-6 months control on *P. conjugatum* and *O. nodosa* respectively. However, under Malaysian plantation conditions a general weed control herbicide must be able to control grasses (usually *P. conjugatum* and *O. nodosa* two of the most dominant grass species) and broadleaf weeds such as *Mikania micrantha* and legume creeping covers, thus combination studies were initiated to tackle this particular problem.

Various herbicide mixtures were looked into to take care of both grasses and broadleaves. In *Paspalum* dominant areas, mixtures of haloxfop: dalapon: picloram at the rate of 160-200: 2000-2500: 60-75 g ae/ha respectively and haloxfop: diuron: picloram at the rate of 168-225: 562-750: 67-90 g ae/ha respectively provide at least three months control.

In *Ottlochloa* dominant areas mixtures of haloxfop: dalapon: picloram at the rate of 200-240: 2500-3000: 75-90 g ae/ha respectively and haloxfop: diuron: picloram at the rate of 337-450: 1125-1500: 125-180 g ae/ha respectively also provide at least three months control.

Separate trials indicated that the use of diuron and dalapon at higher rates in mixtures with haloxfop have been found to be antagonistic.

The addition of surfactants such as Crop oil, L-77 and Dow Corning improved the efficacy of haloxfop either alone or in mixtures.

INTRODUCTION

Haloxfop-ethyl or methyl (ethoxyethyl 2 - (4 - [(3 - chloro - 5 - (trifluoromethyl) - 2 - pyridinyl) oxy] phenoxy) propanoate), coded as Dowco 453 is a new post-emergence, translocatory grass herbicide developed by The Dow Chemical Company. It has an excellent selectivity in broadleaf crops.

Dowco 453 has exhibited excellent herbicidal activity when applied post-emergence to a wide range of annual and perennial grasses. It is rapidly absorbed and translocated throughout the plant. The main site of activity is within the meristematic tissue.

Trials in Europe showed that Dowco 453 controlled annual grasses in rape, sugarbeet and sunflower at 125 g ai/ha but perennial grasses required double that rate (Visbecq, et. al., 1983). Trials in New Zealand indicated effective control of 7 weed species (Hartley, 1984).

Richardson, et. al., (1983) stated that Dowco 453 showed excellent selectivity for grass and volunteer cereal control in onions and a number of broadleaved crops. Resistant weeds such as *Festuca rubra* and *Poa annua* were susceptible to Dowco 453.

Earlier trials in Malaysia also showed excellent selectivity for grass control in plantations though higher rates are required for tough perennial grass.

Under Malaysian plantation conditions the general weeds commonly occurring are *Paspalum conjugatum*, *Ottlochloa nodosa* (two of the most dominant grass species) and *Mikania micrantha* and legume creeping covers are common broadleaf problems. A good general weed control herbicide must be able to control all these weeds. This study entails the development of Dowco 453 mixtures with broadleaf herbicides for general weed control in Malaysia.

MATERIALS AND METHODS

Several efficacy trials were conducted in open conditions in the inter-rows of immature oil palm. The trial sites were carefully selected to ensure uniform, well-established target weed species - *Paspalum conjugatum* and *Ottlochloa nodosa*. The trials were done in a completely randomized design with treatments replicated at least four times. Each plot measured 4x5 m.

The spray volume was fixed at 500 L/ha and was applied using a conventional knapsack sprayer with a single lance fitted with a blue flood-jet nozzle. The nozzle delivered a swath of about 2 meters when held at 45-60 cm above the weed tops. The amount of chemicals needed is calculated based on the rates tested.

Visual evaluations of weed control was done at fortnightly intervals. Control ratings were based on visual score of percentage kill and a rating scale of 0-100 were used, 0 indicates no kill and 100 indicates complete kill.

All trials were done in inland soils.

RESULTS

A. Efficacy of Dowco 453 on *Paspalum conjugatum* and *Ottlochloa nodosa*.

Results presented in Tables 1a and b, showed the efficacy of Dowco 453 under open conditions. *P. conjugatum* was more susceptible than *O. nodosa* requiring lower dose rates to give comparative % kill. The maximum control in *O. nodosa* and *P. conjugatum* was reached between 30-45 days. The length of effective control was dose related. Further observation revealed that at higher rates acceptable control was still obtained even up to four months. The kill on *P. conjugatum* was faster than *O. nodosa* and at all rates tested. In both species regeneration started at about 60 days after spraying (DAS).

Table 1a. Comparative efficacy of Dowco 453 on *P. conjugatum*

No	Treatments (G.A.E./HA)	Percent		Kill	Days	After	Spraying		(DAS)
		14	28				96	112	
1	DOWCO 453 : 60	70	75	80	65	52	32	26	9
2	DOWCO 453 : 120	75	90	92	85	75	52	42	11
3	DOWCO 453 : 240	80	92	95	93	82	62	45	12
4	CONTROL	0	0	0	0	0	0	0	0

Table 1b. Comparative efficacy of Dowco 453 on *O. nodosa*

No	Treatments (G.A.E./HA)	Percent		Kill	Days	After	Spraying		(DAS)
		13	27				95	111	
1	DOWCO 453 : 120	28	47	62	48	36	25	12	8
2	DOWCO 453 : 240	45	65	85	75	58	47	38	25
3	DOWCO 453 : 480	55	85	95	95	85	65	58	28
4	CONTROL	0	0	0	0	0	0	0	0

B. Evaluation of IWD 3753 and 3758 on *P. conjugatum* and *O. nodosa*.

IWD 3753 contains haloxyfop: dalapon: picloram in the ratio of 40: 500: 15 g ae/L formulation while IWD 3758 contains haloxyfop: diuron: picloram at 122.5: 375: 45 g ae/L formulation. These mixtures were applied on both species. Results are illustrated in Tables 2a and b.

In *P. conjugatum* dominant areas (Table 2a) with both formulation, regeneration was does related with much lower rates of IWD 3758 giving adequate control for up to 3 months. Four months after spraying, the weed seemed fully recovered to its original stand. Though slower in action the results at 30 DAS were at least comparable to Paracol^a +Tordon^b101 treatment and regeneration was faster in the later treatment. Regeneration in Scout^c treatment was slower compared to both IWD mixtures.

Table 2a. Comparative efficacy studies of Dowco 453 mixtures on *P. conjugatum*

No	Treatments	Rate L/HA	% KILL D.A.S.						
			15	32	45	63	78	93	114
1	IWD 3753	2.0	15	18	20	12	5	0	0
2	"	3.0	58	65	75	53	35	23	5
3	"	4.0	62	85	87	72	65	45	23
4	"	5.0	62	86	92	97	75	55	35
5	"	6.0	65	86	95	97	77	58	37
6	IWD 3758	0.5	8	10	15	0	0	0	0
7	"	1.0	10	25	45	48	25	10	0
8	"	1.5	26	65	85	71	48	37	25
9	"	2.0	55	88	95	97	75	57	41
10	SCOUT	3.0	55	90	99	99	89	62	52
11	PARACOL +TORDON 101	2.5 +0.5	65	95	86	79	63	45	35

Table 2b. Comparative efficacy studies of Dowco 453 mixtures on *O. nodosa*

No	Treatments	Rate L/HA	% KILL D.A.S.						
			16	29	45	62	75	92	107
1	IWD 3753	3.0	10	15	35	25	15	5	0
2	"	4.0	15	35	50	37	23	11	0
3	"	5.0	25	45	75	65	41	27	10
4	"	6.0	35	55	85	87	52	37	15
5	IWD 3758	2.0	52	75	63	38	27	9	0
6	"	3.0	55	83	71	43	37	15	11
7	"	4.0	75	85	92	73	48	24	12
8	SCOUT	3.0	57	92	92	85	55	42	10
9	PARACOL +TORDON 101	2.5 +0.5	75	95	81	57	42	15	4

For control of *O. nodosa* higher rates of both IWD 3753 and IWD 3758 were required to reach similar limits of % control to *P. conjugatum* (see Table 2b). IWD 3758 gave faster brownout but % kills were similar at 60 DAS at the higher dose rates. In this less susceptible species no dose rate provided acceptable control beyond 60 days following treatment.

Additional observation showed that the lower rates of IWD 3753 and IWD 3758 provided inadequate control of broadleaves such as *Mikania micrantha* and legume creeping covers as compared to higher rates.

IWD 3758 at highest rate was similar to Scout in % kill at 45 DAS while IWD 3753 provided a comparable control at 62 DAS.

C. Evaluation of surfactants on activity of Dowco 453.

Table 3 sets out results of a trial to examine whether the activity of various

Table 3. Dowco 453 surfactant trial on *O. nodosa*

No	Treatments	Rate G AE/ HA	% KILL D.A.S.						
			16	29	45	62	75	92	107
1	XRM 4570 (ME) +0.25 % V/V X-77	0.3	25	65	75	70	35	5	0
2	XRM 3658 (EE) +0.25 % V/V X-77	0.3	28	64	76	72	36	5	0
3	GOTEMBA XGA 2017	0.3	27	68	78	71	33	9	2
4	XRM 3658 +CROP OIL/POLYGLYCOL 0.3	0.3	28	63	72	69	28	7	3
5	XRM 3658 (EE) +L - 77 0.125 % V/V	0.3	25	69	78	72	39	12	5
6	XRM 3658 (EE) +L - 77 0.25 % V/V	0.3	30	82	85	75	42	18	10
7	XRM 3658 (EE) + DOW CORNING 0.125 % V/V	0.3	25	68	78	71	35	9	4
8	XRM 3658 (EE) +DOW CORNING 0.25 % V/V	0.3	35	83	87	74	44	22	12
9	XRM 3658 (EE) +CROP OIL 2 % V/V	0.3	38	79	81	71	39	19	10
10	XRM 3658 (EE) +IWD 3721 0.125 % V/V	0.3	25	64	76	69	33	12	5
11	XRM 3658 (EE) +IWD 3721 0.25 % V/V	0.3	30	68	76	71	35	15	8

formulations of Dowco 453 was improved with the addition of surfactants. Treatments 8 and 9 gave superior speed of brownout compared to all other treatments while Treatment 6 was slower to brownout reached similar high limits of % kill 29 DAS. This initial advantage was maintained through to 45 days. Beyond 45 DAS the level of regeneration was similar in most treatments.

- a The registered trademark of ICI Company.
- b The registered trademark of The Dow Chemical Company.
- c The registered trademark of Monsanto Company.

DISCUSSION

240 grams of Dowco 453 consistently gives excellent control of *P. conjugatum*. Double these rates are required for similar levels of control of *O. nodosa* which regenerates from the nodes. From observations made during the conduct of the trial both species are much less sensitive to treatment once flowering stage of maturity was reached.

Triple component mixtures produced a slightly better control. The mixture with diuron will give a quick knockdown of *O. nodosa* than that contains dalapon. But in the long run, the results are quite similar. These mixtures will be useful in most plantation situations as there are often many weed species found along weeding strips.

The pattern of control using the two IWD triple component mixtures as shown in Tables 2a & b show inadequate control at lowest rates due to insufficient amount of active ingredients necessary to kill the weeds.

In the surfactant trial as shown in Table 3, the non-ionic wetters improved efficacy of Dowco 453. The higher level of wetter concentration used gave better results than the lower concentration. This is true for L-77, Dow Corning and Crop oil. The use of wetters will help in better spreading of Dowco 453.

The control of the general weeds is the ultimate objective, to suppress competition between crops. In depth trial to determine regeneration and encroachment would provide beneficial information for effective weed control in plantations.

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EFFECTS OF ALACHLOR, AT SUBTOXIC DOSES, ON THE GROWTH AND YIELD OF PEANUTS.

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ABSTRACT

A field experiment was conducted with groundnut, TM V-7, with the objectives to study the effect of alachlor, at sublethal doses and to compare its efficacy with a plant growth regulant, NAA. The chemicals, each at 3 concentrations (20, 40 and 60 ppm) along with a water sprayed control were sprayed on 25th and 50th days of sowing. It was observed that the plant height was significantly increased by both the chemicals. Although NAA was found to be superior over alachlor at all the concentrations, alachlor was observed to exert hormonal effects in increasing branch number, leaf number, flower number, pod number, weight of pods and 100 kernel weight and it was significantly superior to control. Increase in nodule number and weight was found to be significantly more in alachlor than in NAA and control.

INTRODUCTION

Considerable evidence has been accumulating in the recent past as to the phytotoxic effects of herbicides on crop plants. Apart from studying the effects of herbicides on weeds, numerous studies have been done on the phytotoxic effects on crops like tomato with the herbicide 2,4-D and increased yields were reported (Mehrotra *et al.* 1970, Nair *et al.* 1974 and Joseph and Peter 1980). Herbicides like dalapon (Santakumari and Rajagopal Reddy 1979) and simazine (Upadhyay and Varade, 1978) have been found to increase yields in field crops like sorghum.

Groundnut contributes to 60 percent of the total oilseed production in India and it plays a very important role in the agricultural and industrial economy of the country. Any chemical that could boost the yield of groundnut would be of great help for the farmers and to the Nation. In groundnut also, 2,4-D tried at a subtoxic dose of 10 ppm, was found to increase pod yields and shelling percentage considerably (Gupta and Singh 1980). Alachlor is a herbicide that is extensively used in groundnut for weed control and it has been reported to have no phytotoxic effect at all (Sturkie and Buchanan 1973). Sankaran *et al.* 1974, used alachlor as a herbicide (1.5-1.75 kg a.i./ha) and found the chemical to increase nodulation significantly, besides efficient weed control. Siddaramaiah *et al.* (1980) used alachlor at subtoxic concentrations (25 ppm and above) and found more than 90% inhibition of foot rot in all the concentrations. Therefore, it seems entirely possible that alachlor at sublethal concentrations would be exerting some hormonal effect on groundnut. In order to evaluate this, a field trial was undertaken.

MATERIALS AND METHODS

A well known cultivator of groundnut, TM V-7 was chosen and a randomized block design was laid out in the field with four replications and the following 7 treatments:

- 1) alachlor at 20 ppm
- 2) alachlor at 40 ppm
- 3) alachlor at 60 ppm
- 4) NAA at 20 ppm
- 5) NAA at 40 ppm
- 6) NAA at 60 ppm
- 7) Water sprayed control.

NAA was employed as a base to judge the hormonal effect of the herbicide. The net plot size was 15 sq.m and a plant spacing of 30 x 15 cm was used. A fertiliser schedule of 18-35-53 kgs. NPK/ha was basally supplied and a regular irrigation schedule was maintained. The spraying of the chemicals was done at 25th and 50th days after sowing, using hand sprayer of 500 ml capacity. 10 plants were chosen randomly in each plot (representing 4% of the population) and data on vegetative and reproductive characters were recorded.

RESULTS AND DISCUSSION

The data on vegetative characters (Table 1) clearly indicates that alachlor at all the sublethal doses, has a definite growth promoting ability. Often, it is comparable with the auxinal effects of NAA. Pertaining to the plant height, branch number and number of leaves/plant, the results of 60 ppm alachlor are on par with 20 ppm NAA. With regard to root length, 40 and 60 ppm levels of alachlor have produced significantly longer roots than all the three levels of NAA.

Table I

T.N.O.	Treatments	Plant height (cm)	Branch No. per plant	No. of leaves/plant	Root length (cm)	Nodule No. per plant	Nodule wt. per plant (mg)
1.	alachlor 20 ppm	48.25	5.00	16.83	18.54	107.50	122.50
2.	alachlor 40 ppm	50.20	5.10	16.78	18.75	108.50	130.70
3.	alachlor 60 ppm	50.33	5.28	16.83	18.34	109.50	137.70
4.	NAA 20 ppm	51.45	5.88	17.78	18.53	97.50	119.50
5.	NAA 40 ppm	53.45	5.90	17.85	18.19	105.50	121.50
6.	NAA 60 ppm	54.65	6.05	18.13	18.00	102.00	129.00
7.	Water sprayed control	48.50	5.18	16.68	17.06	81.00	89.75
	C.D (P = 0.05)	1.11	0.23	0.71	0.12	1.33	1.43

Table II

T.NO/	Treatments	No. of flowers/plant	No. of pods per plant	No. of matured pods/plant	Wt. of Pods/ plant (g)	Wt.of 100 kernels (g)	Total yield (kg/plant)	Dry matter yield/plant (g)
1.	alachlor 20 ppm	11.23	16.38	8.32	5.90	44.78	1.94	17.10
2.	alachlor 40 ppm	12.08	15.38	7.97	5.84	44.75	1.94	17.60
3.	alachlor 60 ppm	12.48	15.00	7.92	5.68	44.63	2.16	17.58
4.	NAA 20 ppm	14.88	18.18	10.30	7.35	45.15	2.38	18.40
5.	NAA 40 ppm	15.80	19.75	11.12	7.51	45.16	2.41	19.03
6.	NAA 60 ppm	15.35	18.83	10.95	7.06	44.65	2.35	19.45
7.	Water sprayed control	10.33	14.73	7.90	5.06	44.00	1.71	14.08
	C.D (P = 0.05)	0.48	0.39	0.44	0.20	0.52	0.05	0.27

Nodule number and nodule weight seem to be the two growth attributes which are greatly influenced by alachlor treatments. All the 3 concentrations of alachlor have brought out more nodule number and weight and the results are highly significant over NAA. The nodule weight values for 20, 40 and 60 ppm levels are 35.98%, 45.08% and 52.07% over control respectively.

The data recorded on reproductive characters (Table 2) lends a clear evidence of the hormonal effect of alachlor in increasing the yield. Among the 7 characters, weight of 100 kernels with alachlor at 60 ppm level was on par with NAA at 20 ppm values. All other characters, including the total yield were found to be significantly superior to control. The total yield of pods/plant at 60 ppm level of alachlor was 26.54 % more than control.

With increasing concentrations of alachlor, the data on both vegetative and reproductive characters tend to increase as an indication of increased hormonal activity. As the data are comparable with that of an auxin, NAA, it is evident that alachlor, apart from its efficiency in controlling weeds of groundnut, also possesses excellent growth hormonal properties. At these lower doses, herbicidal effect on weeds was not observed. Although annual grasses like *Dactyloctenium aegyptium*, *Eragrostis tenella*, *E. ciliaris* and *Digitaria marginata* Var *fimbriata* were found to dry up following the spray, soon after a week they regained the normal growth. Therefore, further emphasis should be placed to fix an optimum concentration for alachlor which would be the best level for both greater bio-efficacy against weeds and greater hormonal effects on the crop.

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FLUAZIFOPBUTYL, NEW HERBICIDE FOR THE CONTROL OF GRASSY WEEDS IN GROUNDNUT.

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ABSTRACT

An investigation was carried out during Kharif 1983-1984 on the pod yield of two groundnut varietal groups (Bunch-JL 24 and Spreading-Kadiri 3) as influenced by the herbicides Fluzifopbutyl, pendimethalin, oxyfluorfen and oxadiazon in combination with weed free and weedy check treatments. The spreading variety Kadiri-3 registered significantly higher pod yield of groundnut over bunch variety JL-24. Fluzifopbutyl 0.30 kg a.i./ha recorded significantly more pod yield over oxyfluorfen 0.25 kg a.i./ha, oxadiazon 1.25 kg a.i./ha and Fluzifopbutyl 0.25 Kg a.i./ha but was on par with pendimethalin 1.50 kg a.i./ha and next best to weed free treatment. Fluzifopbutyl has not shown any phytotoxicity effect on the crops and effectively controlled the grassy weeds like *Cynodon dactylon*, *Dactyloctenium aegyptium* and *Digitaria sanguinalis* but was ineffective against the dicots like *Canthospermum hispidum* and *Lagascia mollis* weeds.

INTRODUCTION

A large number of groundnut varieties belonging to different habit groups with a wide range of growth habit are in cultivation. These varieties seem to offer varying degrees of resistance to the weeds present in the field. At the same time, some of the crop varieties have shown differential response for herbicides. For example in wheat, the herbicide methabenzthiazuron was effective against variety Arjun (Pandey and Mani, 1977). However, in groundnut such work has not yet been done. Keeping these points in view, an experiment was conducted to study the varietal response of groundnut by selecting one variety each from bunch (Spanish) and spreading (Virginia) habit groups on yield and yield attributes as influenced by different herbicides.

MATERIALS AND METHODS

Field experiment was conducted in the rainy season of 1984 at Students Farm, Rajendranagar, Hyderabad. The soil was red sandy loam of 7.5 pH with 0.59% organic carbon 287 kg^{-ha} of available nitrogen, 21.2 kg^{-ha} of available phosphorus and 281 kg^{-ha} of available potassium. Two groundnut varietal groups (Bunch variety JL-24 and Spreading variety Kadiri-3) and seven weed control treatments (Hand weeding twice, No weeding, fluzifopbutyl 0.25 Kg a.i./ha and 0.5 kg a.i./ha, Oxyfluorfen 0.25 kg a.i./ha, Pendimethalin 1.5 kg a.i./ha, oxadiazon 1.25 kg a.i./ha) were laid out in a factorial randomised block design with four replications. The herbicide fluzifopbutyl was applied as post emergence while oxyfluorfen,

oxadiazon and pendimethalin were applied as pre emergence. The total rainfall was more than the normal and distributed uniformly throughout the crop growth period.

An uniform dose of 20 Kg N, and 40 Kg P₂O₅/ha was applied as basal in the form of urea and superphosphate respectively before sowing. The crop was sown on 26th June, 1983 and harvested on 13th October, 1983 and 22nd October, 1983 for bunch and spreading groups of groundnut respectively. Gross and net plot sizes were 3.00 x 4.50 m and 1.50 x 2.25 m respectively.

RESULTS AND DISCUSSION

Commelina benghalensis, *Cynodon dactylon*, *Cyperus rotundus*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis* and *panicum repens* under monocot weeds and *Acanthospermum hispidum*, *Amaranthus viridis*, *Celosia argentea*, *Lagasca mollis*, *Euphorbia geniculata* and *Tridax Procumbens*. Under dicot weeds constituted the major weed flora.

Dry matter production of weeds (Table-2) was significantly affected on 90th day after sowing. Bunch variety JL-24 recorded 27.6% more dryweight of weeds over spreading variety Kadiri-3. Fluazifopbutyl 0.5 Kg a.i./ha (45.19 g/m²) followed by hand weeding twice (50.86 g/m²) and pendimethali 1.5 Kg a.i./ha (55.95 g/ha) recorded 77.6%, 74.8% and 72.3% less dry weight of weeds respectively over weedy check.

Groundnut pod yield (Table-2) in spreading variety Kadiri-3 (13.50 g/ha) was significantly higher than that recorded in Bunch variety JL-24 (10.85 g/ha). The spreading variety not only recorded higher mean pod yield but also recorded lower reduction of 66.33% in pod yield due to weeds as compared to that of 85.05 percent in bunch variety JL-24. This may be because the variety Kadiri-3, with more number of branches might have covered the ground completely and hence offered more resistance to weeds which ultimately resulted in less percentage reduction in yield. Kondap *et al* 1979) were also of the same opinion that spreading varieties were more tolerant to weeds as compared to bunch varieties. All the herbicides and weed free treatments registered significantly higher pod yields over weed check in both the varietal groups. Hand weeding followed by pendimethalin, Fluazifopbutyl 0.5 Kg a.i./ha, oxyfluorfen, Fluazifopbutyl 0.25 kg a.i./ha and oxadiazon treatments recorded 302.1, 253.78, 238.0, 175.5 and 167.5 percent increased yield over weedy check treatment. There was 75.74 percent reduction in yield in weedy check treatment compared to hand weeding.

Weed index (Table 2) which represents the over all percentage reduction in yield was more in bunch variety JL-24. This clearly shows that due to weeds the yield reduction was more in JL-24 (32.41%) than that in Kadiri-3 (25.16%) Kulkarni *et al* (1963) also concluded that percentage of yield reduced due to weeds was more in bunch variety, than spreading variety. Pendimethalin (12.24%) followed by Fluazifopbutyl 0.5 kg a.i./ha (15.62%) recorded significantly lesser weed index over oxyfluorfen, oxadiazon, fluazifopbutyl 0.25 kg a.i./ha and weedy check treatments.

Table 1. Yield and yield attributing characters of groundnut varietal groups as influenced by weed control treatments.

Treatments	Number of Primary branches		Number of mature pods/plant	Number of Aerial pegs/plant	Number of seeds/plant	100 pod weight (g)	100 kernel weight (g)
	30 days	60 days					
A. Varietal groups							
1. Spreading (K-3)	4.39	5.96	10.27	2.33	20.40	51.84	37.03
2. Bunch (JL-24)	4.17	5.18	8.46	1.75	17.11	50.08	34.93
B. Weed Control treatments							
1. Hand weeding twice	5.38	6.19	12.60	1.35	25.60	54.11	39.45
2. Fluazifopbutyl 0.25 kg a.i./ha	3.53	5.63	8.85	2.15	17.50	51.29	36.56
3. Fluazifopbutyl 0.50 kg a.i./ha	4.03	6.02	10.80	1.78	21.70	53.40	38.44
4. Oxyfluorfen 0.25 kg a.i./ha	4.58	5.60	8.85	2.30	17.55	51.93	37.01
5. Pendimethalin 1.50 kg a.i./ha	4.99	6.15	11.20	1.58	22.55	53.57	38.65
6. Oxadiazon 1.25 kg a.i./ha	4.59	5.67	8.85	1.95	16.50	52.80	37.70
7. No weeding	3.03	3.63	4.46	3.18	8.90	39.60	24.05
S.E.d ±	0.21	0.28	0.61	0.15	1.50	1.42	0.44
V	0.39	0.53	1.16	0.29	2.80	2.65	1.25
W	0.55	0.74	1.64	0.41	3.97	3.76	1.16
V x W	-	0.57	1.25	0.31	3.03	-	0.88
C.D. (0.05) V	0.79	1.07	2.34	0.58	5.67	5.37	2.53
W	-	-	3.31	-	-	-	-
V x W	-	-	-	-	-	-	-

Table 2. Pod yield (q/ha), weed index and weed drymatter as influenced by groundnut genotypes and weed control treatments.

Treatments	Pod yield (q/ha)			Weed index (%)			Dry matter of weeds at 90 days after sowing (g)		
	Spreading (Kadiri-3)	Bunch (JL-24)	Mean	Spreading (Kadiri-3)	Bunch (JL-24)	Mean	Spreading (Kadiri-3)	Bunch (JL-24)	Mean
1. Hand weeding twice.	18.04	16.06	17.05	—	—	—	45.64	56.08	50.86
2. Fluazifopbutyl	12.38	10.30	11.34	31.31	35.87	33.62	59.63	65.63	62.63
3. Fluazifopbutyl	15.92	12.92	14.43	11.73	29.51	15.62	40.40	49.98	45.19
4. Oxyfluorfen	13.00	10.00	11.51	27.90	37.73	32.82	75.25	88.70	81.98
5. Pendimethalin	16.51	13.49	15.00	8.48	16.00	12.24	50.70	61.20	55.95
6. Oxadiazon	12.56	10.80	11.68	30.34	32.76	31.55	91.20	100.50	95.85
7. No Weeding	6.07	2.40	4.24	66.35	85.05	75.70	159.53	244.50	202.00
Mean	13.50	10.85	12.16	25.16	32.41	28.78	74.62	95.23	84.92
S.E.d ±	V	0.54	0.92	0.92	1.73	1.73	4.85	9.08	9.08
	W	1.01	1.73	1.73	2.44	2.44	12.84	18.37	18.37
	V x W	1.43	2.44	2.44	1.86	1.86	9.82	18.37	18.37
C.D. (0.05)	V	1.09	1.86	1.86	3.49	3.49	18.37	25.98	25.98
	W	2.04	3.49	3.49	4.93	4.93	25.98	49.98	49.98
	V x W	2.04	3.49	3.49	4.93	4.93	25.98	49.98	49.98

Yield components (Table-1) such as number of primary branches, number of mature pods, number of aerial pegs, number of seeds 100 pod weight, 100 kernel weight were more in Kadiri-3 variety. However it cannot be said that it is exclusively due to its suppressing ability of weeds as the interaction effects were not significant. All the yield components were more in hand weeding followed by pendimethalin 1.5 Kg a.i./ha and fluazifopbutyl 0.5 kg a.i./ha. Which also recorded higher pod yields. Narasimha Murthy (1982) and Yadav *et al* (1983) also obtained higher yield in pendimethalin due to improvement in all the yield components. However, Kulandaivelu and Sapkarani (1981) reported that the number of pods per plant decreased in pendimethalin treatments.

Thus these results conclusively revealed that Fluazifopbutyl 0.5 kg a.i./ha and pendimethalin 1.5 kg a.i./ha which showed equal performance with hand weeding found better in controlling of grassy weeds in groundnut.

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GALLANT* (DOWCO* 453ME) - A NEW POTENT TOOL AGAINST GRASSES INFESTING TEA

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ABSTRACT

Four statistically designed field experiments and one non-replicated micro plot trial were carried out in the South Indian tea estates between 1981 and 1985 to evaluate the efficacy of a new selective post-emergent translocated grass-specific herbicide, Gallant, haloxyfop methyl (Dowco 453ME).

Gallant, even at the lowest rate of 0.125 kg ae/ha with crop oil (1% v/v), gave effective control of certain non-rhizomatous grasses. But, for the control of rhizomatous grasses like *Panicum repens* a higher rate of 0.25 kg ae/ha with crop oil was required.

In general, Gallant at the rates of 0.25 and 0.50 kg ae/ha with crop oil was on par with or superior to glyphosate and dalapon paraquat sequential applications, notably on *Eleusine indica*.

Addition of crop oil or polyglycol to Gallant increased the bio-efficacy of the herbicide in descending order.

Gallant was not phytotoxic to tea crop.

*Trademark of The Dow Chemical Company

INTRODUCTION

Different species of grasses compete severely with tea for moisture and nutrients (Glover 1952, Ranganathan and Narayanan 1975), leading to crop losses often upto the tune of 21 per cent (Venkataramani, 1972). Grass weeds retard the growth of newly planted tea plants and delay their establishment and bearing (UPASI TER, 1962). Effective control of grasses in tea fields, hence, becomes imperative, and can be achieved only by the use of appropriate chemicals.

Herbicides like dalapon, paraquat and glyphosate have been recommended and are in use for the control of grasses in tea fields in India (Sharma, 1977, 1982, Sharma and Venkataram 1982). Glyphosate has been introduced recently, while the other two have been in use for over a decade and a half. Dalapon has to be applied at a fairly high rate for an effective control of grasses, which, if followed by a heavy rain is not tolerated by young tea. Repeated applications of paraquat, at short regular intervals, are required to keep the grasses below the level of economic damage (Sharma and Venkataram 1982).

The dosage of glyphosate required for a satisfactory control of recalcitrant grasses is rather uneconomic at its present market price.

Additionally, prolonged and continual use of the same herbicide in the fields leads to secondary succession, often resulting in the evolution of a weed flora resistant to the herbicides in use (Sharma, 1975; Sharma *et al.*, 1981). Thus, the search for newer herbicides which are effective at low, economic levels continues perpetually, in any weed research programme. As a part of the programme, results of screening experiments with a new herbicide, Gallant (Dowco 453ME) are reported in this paper.

MATERIALS AND METHODS

Gallant, a new selective post-emergent, translocated herbicide, specific against annual and perennial grass species, was screened in different field trials between 1981 and 1985. Gallant (XRM 4570) as an emulsifiable concentrate containing 240 g acid equivalent (a.e.) per litre was evaluated in this trial.

Gallant was compared with glyphosate 41SL, paraquat 24WSC, Dalapon sodium salt 85% WP followed by paraquat. Crop oil (1% v/v) and polyglycol (0.25% v/v) were used as additives to Gallant in some trials.

One non-replicated, micro plot trial (each plot measuring 1 m²) in 1981 and one field trial each in 1981, 1983, 1984 and 1985 were carried out in the Anamallais, Coimbatore District. The field experiments were laid out in randomized block design; each plot measured 16 or 25 m². A permanent quadrat of 900 cm² was fixed in each replicate to record the actual number of weeds at regular intervals.

There are seven treatments and four replicates in the field trial carried out in 1981, nine treatments and three replicates in 1983 and 1985 and five treatments and three replicates in 1984.

The plots had complete ground cover with a mixed stand of weed species, of which only grasses and sedges were recorded.

While there was certain amount of variation in weed composition among the plots, grass species were dominant in all of them.

The grasses and sedges were:

Axonopus affinis Chase
A. compressus (Sw). Beauv.
Cyperus brevifolius (Rottb.) Hassk.
C. kyllingia Endl.
Digitaria adscendens (Hbk) Henr.
D. Longiflora Pers.
Eleusine indica (Linn.) Gaertn.
Fimbristylis sp.
Imperata cylindrica (Linn.) Beauv.
Panicum repens Linn.
Paspalum conjugatum Berg.
P. scrobiculatum Linn.
Setaria glauca (Linn.) Beauv.

Visual assessment of the degree of weed control was recorded by two researchers independently, at regular intervals and compared, to eliminate any error of judgement. Also, the number of shoots of grasses and sedges in the permanent quadrates fixed in the replicates were recorded at periodic intervals. The data obtained from the experiments were subjected to statistical analysis and the results are given in Tables 1, 2 and 3.

RESULTS AND DISCUSSION

The initial phytotoxic symptoms of Gallant were noticed between 10 and 15 days in the form of pronounced red pigmentation, general wilting of plant parts and leaf tip scorching, under all the treatments. The actual kill of weeds was noticed between 14 and 21 days, depending upon the rates of application. Highest kill was obtained between 28 and 40 days, the higher doses giving earlier kill and persisting at that level for longer periods of upto 112 days (Table 2).

In the experiment carried out in the year 1981, Gallant was tried at different rates without any additive, in comparison with glyphosate and the sequential application of dalapon and paraquat. The two rates of Gallant, 0.500 and 1.00 kg ae/ha were comparable amongst themselves, and superior to the lower doses of the herbicide; these rates were on par with both glyphosate and dalapon paraquat sequential application. However, they had an edge over glyphosate (Table 1). Also, Gallant exhibited a higher per cent of effective control at the end of 70 days.

Table 1. Effect of gallant on grasses: % weed control* (1981)

treatment	dosage (kg/ha)	visual 56 das	field trial assessment 70 das	actual 56 das	weed count 70 das
- gallant	0.125 ae	30b ⁺	55b	75b	57b
- gallant	0.250 ae	60c	65b	97cdef	91cdefg
- gallant	0.500 ae	90de	95cd	87bcd	82bcde
- gallant	1.000 ae	95e	85c	88bcde	67bc
- glyphosate	0.800 ae	75cd	85c	86bc	74bcd
- dalapon followed by paraquat on 14th dat	4.480 ai 0.360 ai	98e	90cd	99cdefg	88cdef
- weedy check		oa	oa	oa	oa
cd (0.05) =		16	18	17	30
cv (%)		17	15	11	31

* Average of 4 replicates

das = days after spraying

+ means followed by common alphabets not significantly different rating: 25% moderate; 50% satisfactory; 75% effective; 100% complete kill

Table 1 : Effect of gallant on grasses : % weed control (1981).

treatment	microplot trial visual assessment(non-replicated)	
	56 das	70 das
- gallant	70	50
- gallant	85	85
- gallant	90	90
- gallant	98	98
- glyphosate	95	95
- dalapon followed by paraquat on 14th day	98	98
- weedy check	0	0

Since Gallant was found to have comparable effect at the rates of 0.50 and 1.00 kg ae/ha, the higher rate was omitted in the subsequent trials.

Polyglycol and crop oil were used as additives in the field trials carried out in 1983 and 1985, while only polyglycol was used in 1984.

Addition of either of the additives appears to have expedited and advanced the kill by 10 to 15 days. Also, the highest kill under different treatments was obtained by about 28 days, particularly at higher rates. Crop oil emerged as a superior additive at different rates (Tables 2 and 3).

Table 2 : Effect of gallant on grasses (visual assessment - % weed control)*.

treatments	dosage (kg/ha)	1983	
		56 das	70 das
gallant + polyglycol	0.125 ae	40 C ⁺	25 B
gallant + polyglycol	0.250 ae	60 cd	45 bcd
gallant + polyglycol	0.500 ae	65 cde	55 cde
gallant + crop oil	0.125 ae	65 cde	40 bc
gallant + crop oil	0.250 ae	75 def	80 f
gallant + crop oil	0.500 ae	100 gh	100 fg
glyphosate	1.260 ae	95 g	80 f
paraquat	0.270 ai	10 ab	0 a
weedy check		0 a	0 a
cd (0.05) =		25	20
cv (%)		25	24

* average of 3 replicates

+ means followed by common alphabets not significantly different

rating : 25 % moderate, 50 % satisfactory, 75% effective, 100 % complete kill.

contd Table 2 : Effect of gallant on grasses (visual assessment - % weed control)

treatments	dosage (kg/ha)	56 das	1984 84 das	112 das	133 das
gallant + polyglycol	0.125 ae	45 b	70 b	65	65 b
gallant + polyglycol	0.250 ae	85 cd	90 c	85	85 c
gallant + polyglycol	0.500 ae	80 c	100 d	100	90 c
gallant + crop oil	0.125 ae	na	na	na	na
gallant + crop oil	0.250 ae	na	na	na	na
gallant + crop oil	0.500 ae	na	na	na	na
glyphosate	1.260 ae	80 c	100 d	100	90 c
paraquat	0.270 ai	na	na	na	na
weedy check		0 a	0 a	0	0 a
cd (0.05)		20	6	ns	9
cv (%)		16	4	-	6

Contd Table 2 : Effect of gallant on grasses (visual assessment - % weed control)

treatments	dosage (kg/ha)	1985 56 das	70 das
gallant + polyglycol	0.125 ae	65 c	60 c
gallant + polyglycol	0.250 ae	70 cd	65 cd
gallant + polyglycol	0.500 ae	90 de	80 defg
gallant + crop oil	0.125 ae	75 cd	75 cde
gallant + crop oil	0.250 ae	90 de	80 defg
gallant + crop oil	0.500 ae	95 ef	85 efg
glyphosate	1.260 ae	95 ef	85 efg
paraquat	0.270 ai	15 ab	5 ab
weedy check		0 a	0 a
cd (0.05) =		23	16
cv (%)		21	15

Table 3 : Effect of gallant on grasses (% weed control - actual weed counts)*.

treatments	dosage (kg/ha)	56 das	1983 70 das	1984 56 das	1984 84 das	112 das	135 das
gallant + polyglycol	0.125 ae	25	25	60	60	57	57
gallant + polyglycol	0.250 ae	45	45	93	96	87	81
gallant + polyglycol	0.500 ae	55	64	100	100	100	97
gallant + crop oil	0.125 ae	40	45	na	na	na	na
gallant + crop oil	0.250 ae	86	95	na	na	na	na
gallant + crop oil	0.500 ae	95	95	na	na	na	na
glyphosate	1.260 ae	80	83	100	100	100	86
paraquat	0.270 ai	5	7	na	na	na	na
weedy check		0	0	0	0	0	0

* average of 3 replicates
rating : 25 % moderate; 50 % satisfactory; 75 % effective; 100 % complete kill.

Contd. Table 3 : Effect of gallant on grasses (% weed control - actual weed control) *.

treatments	dosage (kg/ha)	1985 56 das	70 das
gallant + polyglycol	0.125 ae	80	70
gallant + polyglycol	0.250 ae	85	85
gallant + polyglycol	0.500 ae	95	90
gallant + crop oil	0.125 ae	90	85
gallant + crop oil	0.250 ae	95	90
gallant + crop oil	0.500 ae	100	95
glyphosate	1.260 ae	95	80
paraquat	0.270 ai	25	20
weedy check		0	0

The per cent kill obtained by the application of Gallant at 0.125 kg ae/ha in mixture with crop oil was on the same level of significance with that at different rates of the herbicide mixed with polyglycol (Table 2); the two rates of 0.250 and 0.500 kg ae/ha with crop oil were comparable amongst themselves, but superior to all the other treatments of the herbicide. These two treatments were found to be similar to glyphosate and superior to paraquat (Table 2).

The sedges, *Cyperus brevifolius*, *C. kyllingia* and *Fimbristylis* sp. were not controlled by the chemical at any dose.

Species like *Axonopus affinis* and *Digitaria longiflora* were controlled by Gallar even at the rate of 0.125 kg ae/ha, more efficiently so, with the addition of crop oil. Higher doses of 0.250 and 0.500 kg ae/ha were required for an effective control of recalcitrant grasses like *Digitaria adscendens*, *Imperata cylindrica*, *Panicum repens* and *Paspalum conjugatum*. The addition of crop oil at the dosage enhanced the phytotoxicity and is desirable.

However, as the differences between the two higher dosage rates were not significant, the lower dose of 0.250 kg ae/ha with the addition of crop oil is preferable for the control of a wide spectrum of grasses.

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INFLUENCE OF ATRAZINE ON NUTRIENT REGIME IN SOILS

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ABSTRACT

Atrazine had no adverse effect on the processes of ammonification and nitrification in soil. However, the nutrient regime of both macro (N, P, K) and micro-nutrients (Fe, Mn, Zn, Cu) were favourably influenced in soil at least for one month after its application. In red soil this stimulatory effect was more as compared to black soil and also in summer than in winter. The level of available nutrients were increased irrespective of the level of fertility (low or high) but a little more beneficial effect was observed when atrazine was applied along with NPK fertilizers.

INTRODUCTION

Extensive use of herbicides in agriculture to check weeds had prompted much research on their possible side effects in the soil environment that affect soil fertility and plant nutrition. The triazines were found to be more toxic to micro-organisms involved in nutrient transformations in soil (Chuzhderov and Zubets 1970). Atrazine has been found to persist longer in soil and is now being widely used as a substitute for simazine for selective weed control. A study on the effect of atrazine on soil nutrient regime may help in the monitoring of soil fertility problems arising out of its increased use.

MATERIALS AND METHODS

The effect of atrazine on nutrient regimes in soil was studied using red and black soils in green house under sorghum. Herbicide was applied at zero (W_0 : No herbicide) and 1 Kg a.i. ha (W) as spray to soil surface, six hours after sowing and irrigation. Two fertility levels were used, native fertility (F_0) and with fertilizer dose of 100-50-35 Kg/ha (F), and the study was in two seasons: summer (May-August) and winter (November-February) to observe the seasonal effect.

Soil samples were collected from the pots at 10, 20, 40 and 60 days and analysed for NO_3^- -N, NH_4^- -N, available N (alkaline- $KMnO_4$), $NaHCO_3$ - extractable P, N.N. amm., Acetate ext. K as per Jackson, 1967. The D.T.P.A. extractable Fe, Mn, Zn and Cu were determined using Atomic Absorption Spectro Photo meter. The initial analysis of soils is as follows.

	Mechanical Composition (%)			pH	Organic Carbon (%)	Available Nutrients (Kg/ha)		
	Sand	Silt	Clay			N	P	K
Red soil (S ₁)	62.6	5.9	31.7	7.2	0.35	168	27	162
Black soil (S ₂)	30.1	18.7	51.2	8.4	0.45	225	21	285

RESULTS AND DISCUSSION

I. Effect of atrazine on ammonification and nitrification:

Atrazine application had no significant effect on ammonification of soils in both seasons, but it stimulated nitrification upto six weeks. In summer the increase varied from 3-15% with a mean of 10% in S₁ and 8% in S₂. This effect was highest at 10 days after application (S₁ : 13, S₂ : 15%) and decreased with time recording the lowest values by 40 days (S₁ : 6, S₂ : 3%). The effect was almost similar in both soils. In winter also herbicide had a stimulatory effect on nitrification but it was less pronounced than in summer and the increase of NO₃ -N in S₁ was 8% (10), 7% (20) and 3% (40 days), while in S₂ it was significant at 20 days (6%) and 40 days (4%).

In general, herbicides had little influence on ammonification in soil (Wain Wright, 1978) but atrazine was found to have a slight stimulatory effect on nitrification (Nodorost, 1967, Markent and Kundler, 1973), which was not seen in a mechanically weeded plot. Atrazine did not effect the number of nitrifying bacteria, but by checking of weed growth it increased NO₃ -N (Amantev *et al.*, 1963). Nitrification was increased by herbicide at both levels of fertility in summer, but this effect was a little more pronounced at F level in winter. Setty *et al.* (1970) observed that atrazine increased the nitrification in soil upto five weeks, when applied along with amm. sulphate.

Table 1. Effect of atrazine on NO₃-N level in Soil (ppm).

Season	Days after application											
	10				20				40			
	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂	S ₁	S ₂
Summer	W _o	6.3	4.7	9.6	8.8	15.5	12.2	11.0	7.9	11.2	8.0	NS
	W	7.1	5.2	10.3	9.5	16.4	12.6	11.2	8.0	11.2	8.0	NS
	CD		0.3		0.5		0.4					NS
	W x SF		*		*		*					NS
Winter	W _o	5.0	4.2	6.1	5.1	11.4	8.6	9.5	8.5	9.5	8.5	NS
	W	5.5	4.5	6.5	5.9	11.8	8.9	9.8	8.6	9.8	8.6	NS
	CD		0.3		0.3		0.3					NS
	W x SF		*		*		*					NS

* Significant at P = 0.05

II. Effect on availability of major nutrients in soil.

Nitrogen: The available N in soil was stimulated due to atrazine application in the early period upto three weeks. In summer the increase was 4-5% at 10 days and 2-3% at 20 days and later it had no effect. In winter season atrazine had no effect on available N in both soils.

Phosphorus: Atrazine application stimulated the available P only during the summer season. Herbicide increased available P at 10 days in both soils by 6%, but by 20 days it was more in S₂ (11%) than S₁ (3%). In winter atrazine had no effect.

Potassium: In summer atrazine had no effect on available K in soil, while in winter it increased available K in red soil at 10 days (9%), 20 (5%) and 30 days (4%) over W₀.

The effect of atrazine with reference to fertility levels was not well pronounced. The available P was increased in most of the periods at both levels of fertility, but the effect was slightly more when applied along with fertilizers (NPK). Atrazine increased the K availability only in red soil and mostly at low fertility level (F₀).

Atrazine stimulated available N and P in soil during summer and available K in winter upto a period of one month which was highest immediately after application (10 days) and decreased with time. This early beneficial effect on available N was a result of increased microbial activity and stimulation of heterotrophic nitrification (Smith and Veeraratna, 1974). Some herbicides like metribuzin or phosate stimulated N mineralization in soil upto 9 weeks (Marsh *et al.*, 1977). Often soils treated with low levels of herbicides tended to have more free amino acid content as compared to untreated, leading to higher available N, (Blijev, 1973). The effect of atrazine on P availability was more pronounced in black soil and that of K in red soil. Atrazine increased available P in soil (Tsvetkova, 1966, Harishankar and Kumar, 1969), while the effect of 2,4-D was seen only in clay soil (Vacario, 1972). At field rate prometryne increased the NO₃-N and available P in soil after 15 days of application and the effect persisted upto 5-6 weeks (Yaroslavskaya *et al.*, 1969). Atrazine stimulated available K in soil only in winter in red soil. Many herbicides were found to have no effect on mobile K in soil (Isaeva, 1967). The effect of simazine on available P and K was inconsistent (Ivanov, 1974). Bioki *et al.* (1969) noted that elimination of weeds by simazine promoted nutrient mobilization. Simazine increased NPK availability when the soil moisture was optimum but not under moisture stress (Skazkina and Zarkov, 1966).

Table 2. Effect of atrazine on Available N, P and K in soil (ppm).

Season		Days after application					
		10		20		40	
		S ₁	S ₂	S ₁	S ₂	S ₁	S ₂
i) Nitrogen							
	W ₀	88.8	123.5	110.0	125.1	116.2	126.9
	W ₀	93.4	128.7	121.1	128.9	117.4	127.6
	CD		3.3		3.4		NS
	W x SF		NS		NS		NS
ii) Phosphorus							
	W ₀	16.6	11.9	18.5	16.5	10.7	10.7
	W ₀	17.7	12.6	19.0	18.3	10.7	10.9
	CD		0.4		0.4		NS
	W x SF		*		*		NS
iii) Potassium							
	W ₀	92.4	133.8	113.7	136.7	120.4	137.7
	W ₀	95.8	134.9	117.2	139.3	123.9	139.8
	CD		3.3		3.1		NS
	W x SF		*		*		NS
Winter							
	W ₀						
	W ₀						
	CD						
	W x SF						

III. Effect on D.T.P.A. extractable micronutrients:

Iron: Atrazine increased available Fe by 10% in red soil, upto 40 days in summer. But in winter it stimulated available Fe in both soils through out, which was 14% (20) and 8% (40 days) in S_1 and 8% (40) and 5% (60 days) in S_2 . Atrazine influenced Fe availability in early period in S_1 and this beneficial effect was less in S_2 .

Manganese: Mn availability in soil was also stimulated in the early period by atrazine. In summer atrazine increased available Mn in red soil at 20 days (3%) but only in black soil at 40 days (3%). In winter this increase was seen only at 20 days (4%) in red soil and in black soil at 40 days (9%). Thus the earlier effect of W was more pronounced upto 20 days in red soil.

Copper: Atrazine had only a slight stimulatory effect in summer at 20 days (S_1 : 6, S_2 : 8%) and later it had no effect. In winter it had no effect. Weedicides increased the DTPA extractable micronutrients in early stages both at low and high fertility levels, but the increase was slightly more with fertilizers.

Atrazine application resulted in a slight stimulatory effect on the availability of Fe, Mn, Zn and Cu upto 40 days and these changes were more influenced in red soil than in black soil. Smith and Veeraratna (1974) observed that herbicides like ioxynil and simazine increased the solubility of Mn, Ca, Mg, Fe and Cu in soil. Wain Wright and Pugh (1974) also obtained similar increase in soil with fungicides. But it is not yet clear whether these increases result from the lysis of dead cells or due to the direct solubilization action by microorganisms (Wain Wright 1978) or due to some chelation mechanism of the added chemical or its breakdown products in soil (Mortland and Raman, 1967). Further these effects occurred as long as atrazine persisted in an active form in soil (30-40 days) and decreased as the chemical degraded. These changes were more in red soil due to higher bioactivity of the pesticide. These effects were more in summer due to higher temperature that mostly decides the toxicity of the chemical in soil, besides influencing the nutrient availabilities.

Thus, soil application of atrazine at normal level (1 Kg a.i./ha) had no adverse effect on any of the available nutrients. But it had a stimulatory effect on many of the nutrients in soil upto one month after its application. These increases were higher in red soil and in summer. This increased nutrient availability in soil following atrazine treatment may eventually benefit the crop growth during the period.

Table 3. Effect of atrazine on DTPA extractable Micro nutrients (ppm).

Season		Days after application					
		Summer			Winter		
		20	40	60	20	40	60
Iron	S_1	S_2	S_1	S_2	S_1	S_2	S_1
	8.0	14.1	11.1	17.3	11.9	19.7	7.0
	8.8	14.2	12.1	17.6	11.7	19.7	8.0
	CD	0.4		0.3		0.4	0.3
	W x SF	*		*	NS	*	*
Manganese	S_1	S_2	S_1	S_2	S_1	S_2	S_1
	16.1	14.6	13.3	13.0	15.0	15.4	17.8
	16.6	14.8	13.7	13.5	15.2	15.7	18.5
	CD	0.5	0.3			0.6	0.6
	W x SF	NS	NS	NS	NS	NS	NS
Zinc	S_1	S_2	S_1	S_2	S_1	S_2	S_1
	0.74	1.23	1.09	1.48	0.99	1.41	0.74
	0.77	1.31	1.14	1.51	1.08	1.44	0.84
	CD	0.03	0.04			0.04	0.04
	W x SF	NS	*	*	*	*	*

* Significant at P = 0.05

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KUH-813, A SELECTIVE MIXTURE OF ORBENCARB AND LINURON FOR UPLAND CROPS

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ABSTRACT

An emulsifiable concentrate of the mixture of 50% orbencarb (5-2-chlorobenzyl diethylthiocarbamate) and 7.5% linuron (3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea), being developed by Kumiai Chemical Ind. Co., Ltd. under the code number KUH-813, is a new selective upland herbicide and has been shown to be extremely effective in pre-emergence application against most of annual gramineous, cyperaceous and broadleaf weeds.

Orbencarb plus linuron combination shows remarkable synergistic action against annual weeds such as *Digitaria adscendens* and *Amaranthus retroflexus*. While it has a favourable spectrum of activity against weeds, crop such as maize, soybean, peanuts, kidneybean, peas, cotton and sunflower are adequately tolerant to KUH-813.

Pre-emergence activity of KUH-813 is less influenced by temperature and soil texture.

A programme of field trials throughout Japan since 1982 have confirmed that KUH-813 shows excellent herbicidal performance at the rates of 8.0 to 10.0 litres per hectare in soybean, maize, peanuts and potatoes.

INTRODUCTION

Orbencarb (LANRAY^R) is a thiolcarbamate pre-emergence herbicide developed by Kumiai Chemical Industry Co., Ltd. and has been marketed in Japan for zoysia turf since 1975.

Orbencarb shows excellent herbicidal activity by its protein-synthesis inhibiting activity against annual gramineous weeds such as *Alopecurus aequalis*, *Poa annua*, *Digitaria adscendens*, and *Setaria viridis* etc., while its feature is the high selectivity to leguminous crops like soybean and kidneybean as well as to cereals like maize, wheat and barley. Disadvantage of orbencarb is its comparative poor effectiveness against broadleaf weeds such as *Polygonum nodosum*, *Amaranthus retroflexus*, *Chenopodium album*, *Stellaria media* and *Lamium amplexicaule*. In an attempt to develop orbencarb as an effective upland herbicide in Japan where variety of soil and climatic conditions promote existence of numerous weed species, it is thought other compounds, orbencarb plus linuron mixture has been selected as the most potential product.

Commencing in 1980, the orbencarb plus linuron mixture has been put in an extensive evaluation trial in the Western Europe region and became the subject of attention in West Germany, Denmark, Switzerland, Austria and Holland as reliable herbicide in winter cereals.

In Japan, this mixture has been in the development mainly for soybean, kidneybean and peanut as well as for cereals like maize, winter wheat and winter barley and receiving also a high valuation.

This paper introduces herbicidal properties and field trial results of the orbencarb 50% plus linuron 7.5% emulsifiable concentrate which is being developed under the code number of KUH-813.

MATERIALS AND METHODS

KUH-813 as the premixture containing 50% orbencarb and 7.5% linuron was prescribed for large scale field trial purpose. As comparative standard, products used were Lanray 50EC (orbencarb), Lorox 50WP (linuron), Lasso 43EC (alachlor), Treflan 44.5EC (trifluralin), all which are commercially available.

Pot tests

Crops and weeds were seeded at the depth of 2.0–2.5 cm and 1.5–2.0 cm respectively into plastic pots filled with Kikugawa sandy clay soil (clay : 16.7%, organic matter : 1.01%, field capacity (FC) : 45.7%). Each product with 500 g/ha of water was sprayed on the soil surface uniformly by microsprayer.

Throughout the test period, soil moisture content were kept at 50–70% FC by watering through the bottom of the pot. In all trials, simulated 10 mm rainfall was given 10 days after application. All experiments were conducted in 3 replication under 15–25 °C greenhouse condition. At the 30 days after application, visual assessment was made on a scale where 0 = no effect–10 = complete kill and top fresh weight of weeds was measured.

Field trial

Trials in soybean were carried out in volcanic ash soil around Mt. Fuji, Yamanashi prefecture (clay: 13.8%, organic matter: 13.26%, FC: 76.0%) in 1984. Seeding was made at the depth of 3 cm with 50 cm row width on May 24th. Each product was applied 400 l/ha of water with 2.5 kg/cm pressure using automatic knapsack sprayer on May 26th. Trials consist of 2 replication of 2 x 5 m plots. Visual assessment of efficacy and crop damage were made at 30 days after application.

RESULTS AND DISCUSSION

Synergistic action

The efficacy in mixed use of orbencarb and linuron against *Amaranthus retroflexus* was studied in complete factorial design. The result was shown in figure 1 as fresh weight percent of control. Herbicidal activity against *Amaranthus retroflexus* was markedly improved and clear synergism was recognized.

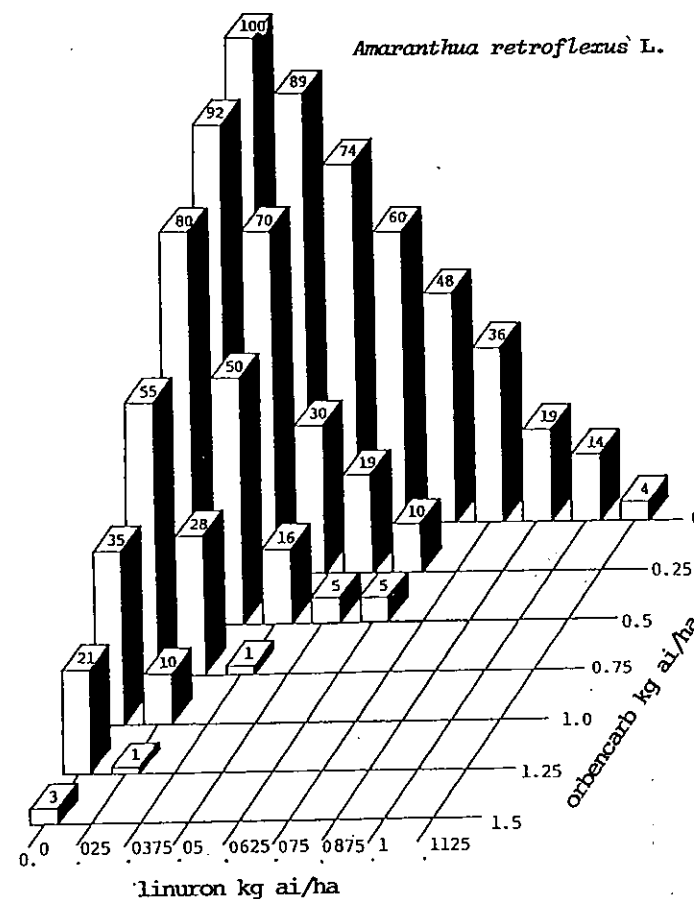


Figure 1. Effect of orbencarb and linuron on fresh weight reduction of *Amaranthus retroflexus* expressed as percent of control.

In other experiments, the similar results were obtained against *Digitaria adscendens*, *Setaria viridis*, *Chenopodium album* and *Polygonum nodosum*.

Thiobencarb which belongs to the same thiocarbamate derivative also acts as protein-synthesis inhibitor and the synergistic action has been acknowledged in mixture application with photosynthesis inhibition type compound, simetryne (Chisaka, 1975). It is thus reasonably assumed in the case of mixture of orbencarb plus linuron that protein-synthesis inhibition character and photosynthesis inhibition character worked synergistically in its herbicidal activity.

Herbicidal spectrum

In figure 2, mean ED90 value of KUH - 813 against respective weed species was plotted. There were totally 48 weed species used in these trials consisting of 18 gramineous, 29 broadleaf and 1 cyperaceous. Out of the total 48, KUH - 813 showed herbicidal efficacy of more than 90% at the rate of 6 l/ha against 43 weed

species which practically covers all important upland weeds in Japan. However, the weed species such as *Avena fatua*, *Rottboellia exaltata*, *Cassia mimosoides*, *Ipomoea purpurea* and *Xanthium strumarium* showed tolerance and, for these, KUH-813 failed to achieve more than 90% control even at the rate of 9 l/ha.

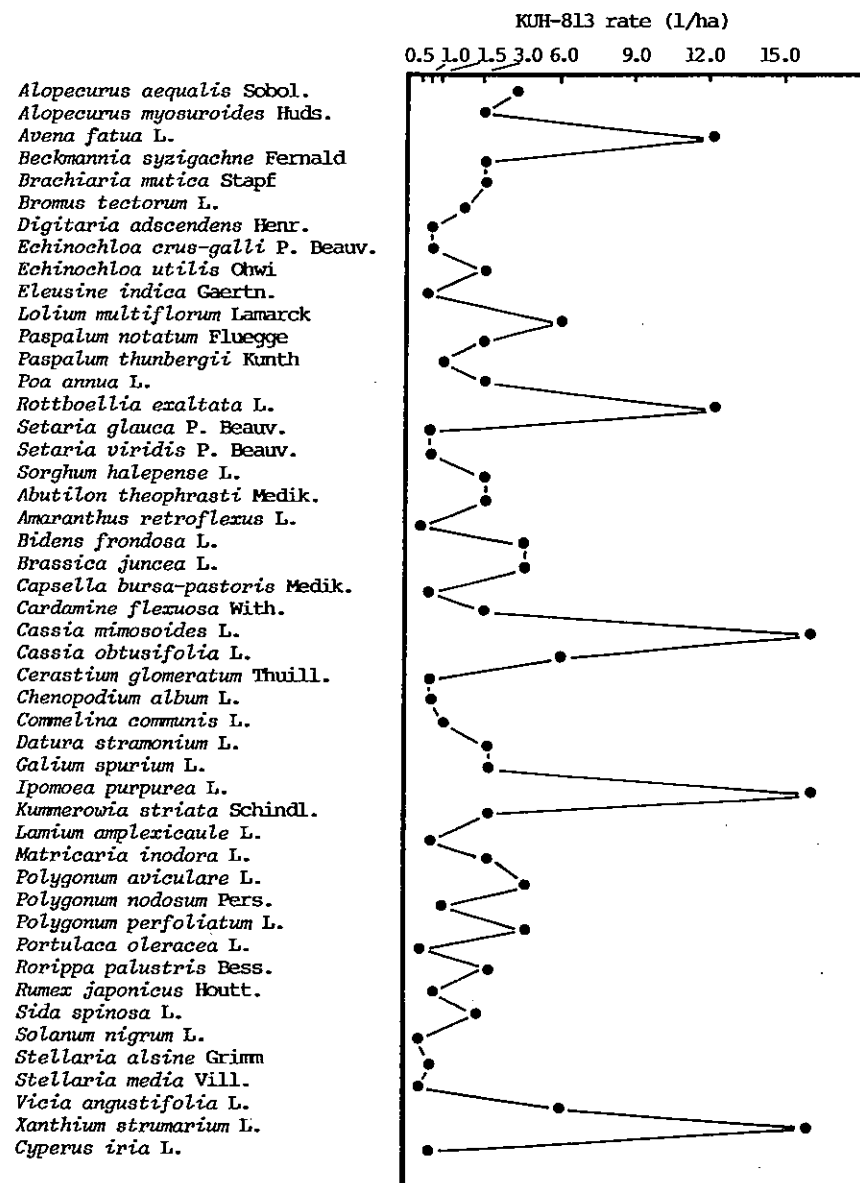


Figure 2. Herbicidal spectrum of KUH-813. Mean ED90 value against each weed species is plotted respectively.

Crop safety

Mean ED20 value of KUH-813 against crops were shown in figure 3. Peanut, kidneybean, soybean, sunflower, barley and wheat were highly tolerant and cotton, peas, oat and rye were adequately tolerant. However, crops such as edible burdock, rice, Japanese radish, sugarbeet, azukibean, chinese cabbage, garland crysanthemum, sorghum and spinach were severely damaged and it was assumed that applicability of KUH-813 is rather low in these crops.

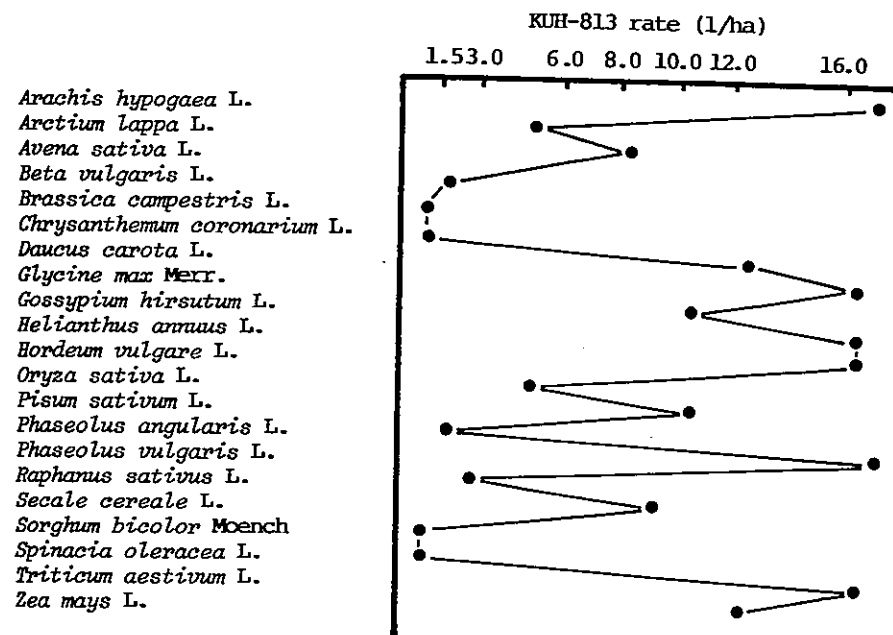


Figure 3. Crop safety of KUH-813. Mean ED20 value against each crop is plotted respectively.

Influence of temperature on herbicidal efficacy

Herbicidal efficacies against *Echinochloa utilis* and *Polygonum nodosum* influenced by temperature were shown in Figure 4. The efficacy of KUH-813 against *Echinochloa utilis* at the rate of 6 l/ha was moderate in low temperature (15–25 °C) and the tendency of stimulation in the efficacy was observed as the temperature goes higher.

Alachlor, used as standard product, showed excellent efficacy against *Echinochloa utilis* at all temperature range but was less effective against *Polygonum nodosum* under lower temperature.

Trifluralin showed the lesser effectiveness against both *Echinochloa utilis* and *Polygonum nodosum* as the higher the temperature went. It was assumed the efficacy of trifluralin was affected by the increased vapor-loss from soil surface as temperature goes up (Jikihara *et al.*, 1985).

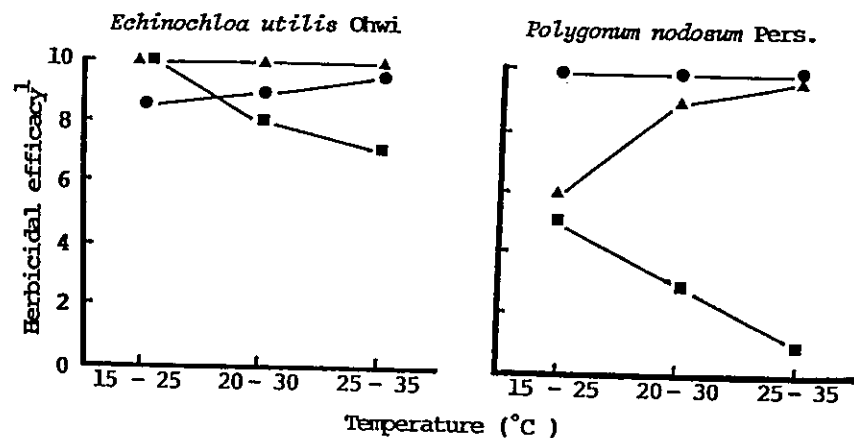


Figure 4. Herbicidal efficacy of KUH-813, alachlor and trifluralin on *Echinochloa utilis* and *Polygonum nodosum* influenced by temperature. ¹Herbicidal efficacy assessed on a scale of 0-10 where 0 = no effect and 10 = complete kill. ●—●: KUH-813 6 l/ha, ◆—◆: alachlor 3 l/ha, ■—■: trifluralin 3 l/ha.

Influence of soil texture

Results of herbicidal efficacy against *Echinochloa utilis* and *Polygonum nodosum* influenced by soil texture were shown in Figure 5. The soil used in this test were; Gotemba silty loam (clay: 0%, organic matter: 14.47%, FC: 70.3%), Kakegawa clay loam (clay: 23.1%, organic matter: 2.45%, FC: 46.0%) and Hamaoka loamy fine sand (clay: 7.8%, organic matter: 1.43%, FC: 50.5%), and the prepared mixture of Kakegawa clay loam + Hamaoka loamy fine sand in the ratio of 2:1 and 1:1 (v/v) and soil moisture was managed to maintain at 40-50% field capacity. KUH-813 showed high herbicidal efficacy without being influenced by the contents of clay. KUH-813's highly stable efficacy was also obtained in the Gotemba silty loam which has different origin from others and high ratio of organic matter.

On the other hand, as has been reported that the efficacy of both alachlor and trifluralin tend to vary in different soil texture (Hollist *et al.*, 1971. Parochtti, 1973) the decline of herbicidal efficacy in this experiment was observed against *Polygonum nodosum* with Kakegawa clay loam of high clay content and Gotemba silty loam of high organic matter content.

Field trial

Results were shown in table 1. Although it was quite dry soil condition with 11 mm rainfall for 4 weeks after application, heavy infestation of *Digitaria adscendens*, *Echinochloa crus-galli*, *Chenopodium album* and *Polygonum nodosum* were observed.

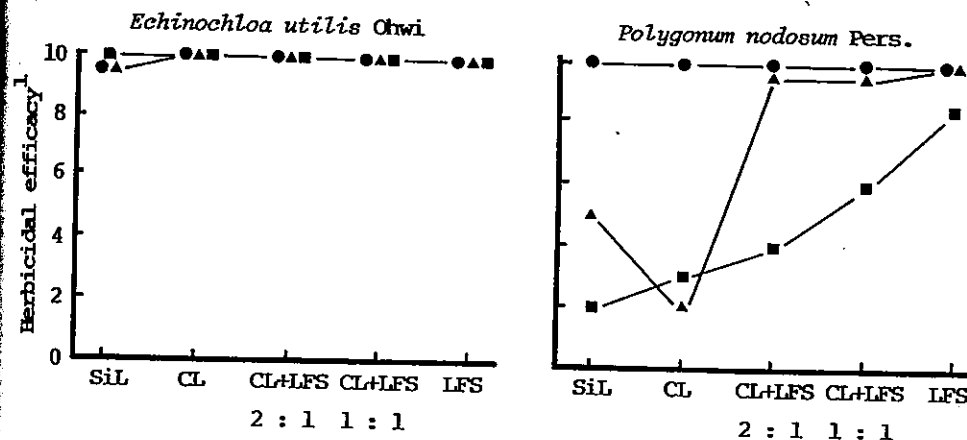


Figure 5. Herbicidal efficacy of KUH-813, alachlor and trifluralin on *Echinochloa utilis* and *Polygonum nodosum* influenced by soil texture. ¹Herbicidal efficacy assessed on a scale of 0-10 where 0 = no effect and 10 = complete kill. SiL: Gotemba silty loam, CL: Kakegawa clay loam, LFS: Hamaoka loamy fine sand. ●—●: KUHw813 6 l/ha, ◆—◆: alachlor 3 l/ha, ■—■: trifluralin 3 l/ha.

Table 1. Herbicidal performance of KUH-813, orbencarb, linuron, alachlor and trifluralin in soybean.

Product	Rate (l, kg/ha)	Herbicidal activity ²				
		Soybean damage ¹	Ech.	Dig.	Che.	Pol. ³
KUH-813 57.5EC	6	0	9	10	10	10
	8	0	10	10	10	10
	10	0	10	10	10	10
	16	1	10	10	10	10
orbencarb 50EC	8	0	9	10	8	9
	10	0	10	10	9	10
linuron 50WP	1.2	0	5	8	9	9
	1.5	0	9	9	10	10
alachlor 43EC	3	0	9	10	8	9
	6	1	10	10	10	10
trifluralin 44.5EC	3	0	9	10	9	8
	6	1	10	10	10	10

^{1,2} Soybean damage and herbicidal efficacy assessed on a scale of 0-10 where 0 = no effect 10 = complete kill.

³ Abbreviation of weeds: Ech.; *Echinochloa crus-galli* P. Beauv., Dig.; *Digitaria adscendens* Henr., Che.; *Chenopodium album* L., Pol.; *Polygonum nodosum* Pers.

KUH-813 showed excellent control against *Digitaria adscendens*, *Chenopodium album* and *Polygonum nodosum* and adequate control against *Echinochloa crusgalli*. KUH-813 showed slight damage to soybean in early stage at the rate of 16.0 l/ha, double of standard dose, but phytotoxicity symptom disappeared and soybean plant recovered completely at 30 days after application.

Orbencarb 10 l/ha and linuron 1.5 kg/ha, used comparison, were found less effective against broadleaf weeds and gramineous weeds respectively.

From these trials, KUH-813 was found to possess high selectivity to soybean and excellent herbicidal efficacy against annual gramineous and broadleaf weeds. At the same time, remarkable synergism and stimulation of efficacy in the orbencarb plus linuron combination were observed in comparison with their single use.

Official field trials by JAPR

The summary shown in Table 2 is the JAPR (The Japan Association for Advancement of Phyto - Regulators) official field trial conducted at 23 official experimental stations throughout Japan in 1982 and 1983.

Table 2. Summary of JAPR official field trial of KUH-813 in soybean in 1982-1983.

Rate (1/ha)	Grade of herbicidal efficacy ¹	Number of trials on each grade Weed species ²											Average of yield ³		
		Dig	Ech	Ele	Set	G	Cyp	Ama	Pol	Che	Por	Ecl		Ste	Bl
8	Excellent	14	9	4	3	7	11	6	6	6	6	3	5	20	98.2
	Good	1	2	1	0	0	0	0	0	0	0	2	0	1	
	Fair	2	0	0	0	0	0	0	0	1	0	0	1	3	
	Poor	1	3	0	0	2	0	1	1	0	0	1	0	1	
10	Excellent	17	10	5	3	7	11	7	6	7	6	6	5	24	98.7
	Good	0	0	0	0	0	0	0	1	0	0	0	0	0	
	Fair	1	1	0	0	0	0	0	0	0	0	0	1	0	
	Poor	0	3	0	0	2	0	0	1	0	0	0	0	1	

¹ Excellent = less than 10% of untreated control, Good = 11-20%, Fair = 21-40%, Poor = more than 40%.

² Abbreviation of weeds: Dig; *Digitaria adscendens* Henr., Ech; *Echinochloa crus-galli* P. Beauv., Ele; *Eleusine indica* Gaertn., Set; *Setaria viridis* P. Beauv., G; grasses, Cyp; *Cyperus* spp., Ama; *Amaranthus* spp., Pol; *Polygonum* spp., Che; *Chenopodium album* L., Por; *Portulaca oleracea* L., Ecl; *Eclipta prostrata* L., Ste; *Stellaria media* Vill., Bl; broadleaf others

³ % of hand-weeding

In Japan where variety of climatic conditions and numerous weed species infest, KUH-813 was given an official biological approval for practical use at the rate of 8.0 to 10.0 l/ha as a pre-emergence herbicide against annual gramineous and broadleaf weeds for its high selectivity to soybean. The official field trials for peanuts, maize and potato started in 1984 and KUH-813 has also been recognized for its high adaptability in these crops.

From the above results, KUH-813 has been proved to possess not only an expanded weed spectrum owing to the mixing of orbencarb and linuron but also, in its manifestation of herbicidal efficacy, an apparent synergistic action and a stability of herbicidal efficacy against variable environmental circumstances. These characteristic features of KUH-813 have also been confirmed by JAPR trials throughout Japan.

From now on, KUH - 813, together with KUH - 813 fine granular (orbencarb 8% plus linuron 1.2%), is expected to be put in practical use in many upland crops in South East Asian countries.

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MEFENACET - A NEW PADDY HERBICIDE

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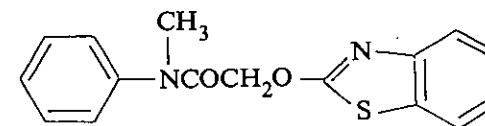
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ABSTRACT

Mefenacet, 2-(2-benzothiazolyloxy)-N-methyl-N-phenylacetamide is a new selective paddy herbicide being developed by BAYER AG AND NIHON TOKUSHU NOYAKU SEIZO K.K. for use in various rice growing countries.

The chemical structure of mefenacet is:



Mefenacet is also known as FOE 1976 and NTN 801 (granular formulation). Its proposed trade-names are: Hinochloa® (Nihon Tokushu Noyaku Seizo K.K.); Rancho® (Bayer AG)

The technical product is colorless crystalline with a melting point of 134.8°C and a low water solubility of 4 ppm at 20°C. The acute oral and dermal LD₅₀ are 5,000 mg/kg for mice and rats. The TLM 96 - hr - value for Japanese carp is 6.3 ppm.

Mefenacet was evaluated for the first time in field screening tests in Japan, in 1978. Since 1980, it has been tested at official test stations for use with transplanted rice in cooperation with the Japan Association for the Advancement of Phytoregulators.

Mefenacet at 1.2 - 1.6 kg ai/ha applied by water surface treatment was effective against grasses, sedges and some species of monocotyledonous broadleaf weeds. Mefenacet is characterized by its outstanding effectiveness against *Echinochloa crus-galli*.

Mefenacet was well tolerated by transplanted rice. However, high temperatures after treatment and extremely shallow planting in soils which are very low in organic matter content or have the properties of rather high leaching loss are considered to be the factors affecting the crop tolerance of mefenacet.

Mefenacet was well tolerated by transplanted rice even in the reduced soil conditions resulting from the incorporation of straw into the soil after the harvest.

Phytotoxicity of mefenacet on the susceptible crops within the vicinity of the treated paddy fields has not been reported.

Several combination granules of mefenacet with known paddy herbicides are being successfully developed in order to improve the effectiveness against the weeds tolerant to mefenacet.

INTRODUCTION

Mefenacet is the common name for 2 - (2 - benzothiazolyloxy) - N - methyl - N - phenylacetamide synthesized by BAYER AG (Schmidt *et al.*, 1984). In Japan mefenacet is being developed by NIHON TOKUSHU NOYAKU SEIZO K.K. as a new selective herbicide for use in paddy rice.

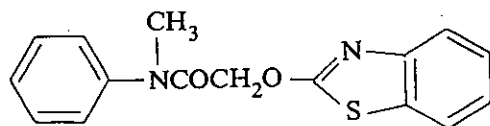
Mefenacet was evaluated in 1978 for the first time in field screening tests in Japan. Since 1980, mefenacet and several combinations have been successfully tested at official test stations in cooperation with the Japan Association for the Advancement of Phytoregulators (JAPR).

Mefenacet at 1.2 kg ai/ha was effective against paddy weeds, in particular *Echinochloa crus-galli*, with good crop safety.

This paper describes the biological properties of mefenacet in addition to the physico-chemical and toxicological properties of this herbicide.

Physico - chemical and toxicological properties

The chemical structure of mefenacet is:



Mefenacet is also known as FOE 1976 and NTN 801.

The technical product is a colorless crystalline with a melting point of 134.8 °C and a low water solubility of 4 ppm at 20° C. It is insoluble in n - hexane and readily soluble in dichloromethane.

The acute oral and dermal LD₅₀ are both 5,000 mg/kg for mice and rats.

The TLm 96 - hr - and TLm 3 - hr - values for Japanese carp and water flea are 6.3 and 18.4 ppm, respectively.

Proposed trade-names are: Hinochloa® (Nihon Tokushu Noyaku Seizo K.K.) Rancho® (Bayer AG)

Biological properties

Herbicidal activity

Field evaluation in 1978 - 84 showed that mefenacet at 1.2 - 1.6 kg ai/ha applied by water surface treatment was effective against grasses and sedges such as *Echinochloa crus-galli*, *Cyperus difformis* and *Eleocharis acicularis* with good selectivity under Japanese rice growing conditions. Besides, grasses and sedges, some species of the monocotyledonous broadleaf weeds such as *Monochoria vaginalis* and *Alisma canaliculatum* were also controlled by mefenacet (Table 1).

Table 1. Weed control spectrum of mefenacet at 1.2 kg ai/ha based on field evaluation in Japan

ECHOR	+++	SCPJU	++
CYPDI	+++	ROTIN	++
ELOAL	+++	LIDPY	++
MOOVP	+++	CYPSE	+
ALSCA	+++	SAGPY	-

Weed control: +++; > 95%, ++; > 85%, +; > 50%, -; < 50%

Weed Code. ECHOR; *Echinochloa crus-galli* P.B. var. *oryzoides* Ohwi, CYPDI; *Cyperus difformis* L., ELOAL; *Eleocharis acicularis* (L.) R. et S. var. *longiseta* Svenson, MOOVP; *Monochoria vaginalis* Presl var. *plantaginea* (Roxb.) Solms-Laub., ALSCA; *Alisma canaliculatum* A. Br. et Bouche, SCPJU; *Scirpus juncoides* roxb. ssp. (Ohwi) T. Koyama, ROTIN; *Rotala indica* (Willd.) Koehne var. *ulginosa* (Miq.) Koehne, LIDPY; *Lindernia pyxidaria* L., CYPSE; *Cyperus serotinus* Rottb., SAGPY; *Sagittaria pygmaea* Miq.

The herbicidal action of mefenacet is characterized by its outstanding effectiveness against *Echinochloa crus-galli* which is the most troublesome paddy weed in Japan. Mefenacet at 1.2 kg ai/ha applied by water surface treatment can control grass growing up to the 3 leaf stage (Figure 1).

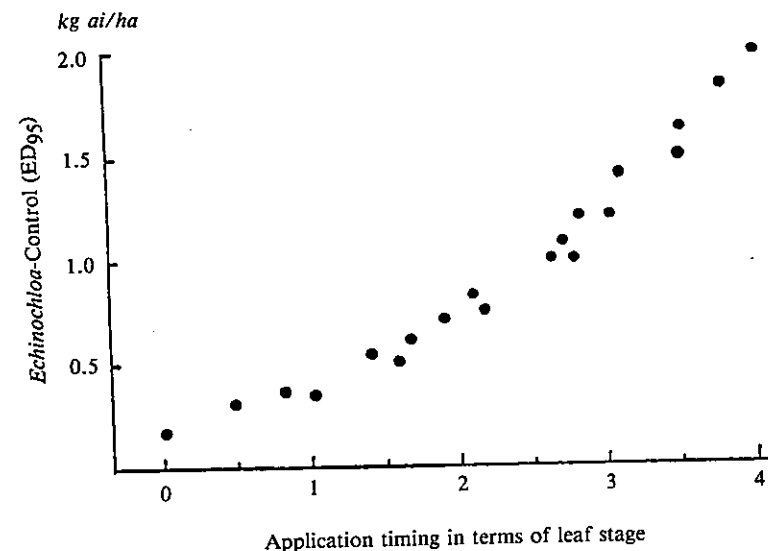


Figure 1. Summary of herbicidal activity of mefenacet against *Echinochloa crus-galli*, based on field evaluation in 1980-84, Japan

Based on the results of numerous field trials, mefenacet 4% GR (NTN 801) has been officially tested by JAPR since 1980 and it has displayed good performance in those trials (Tables 2 and 3).

Table 2 Herbicidal activity of mefenacet 4% GR at 30 - 40 kg/ha - a summary of 1981-84 official tests, Japan

Application Timing	Weed Control in Ratings				
	ECHOR	CYPDI	ELOAL	MOOVP	BBBBB
3 - 5 DAT	+++	+++	+++	+++	++
6 - 8 DAT	+++	+++	+++	++	+
9 - 12 DAT	+++	+++	+++	++	+
14-18 DAT	+++	+++	++	+	+

Weed Control: +++; > 95%, ++; > 85%, +; > 50%, -; < 50%
DAT; days after transplanting, BBBBB; annual broadleaf weeds

Table 3. Crop tolerance of mefenacet 4% GR at 30-40 kg/ha on transplanted rice (various japonica cultivars) - a summary of 1981-84 official tests, Japan

Application Timing	Number of Trials		
	no	Crop Injury acceptable	slight-moderate
3 - 5 DAT	25	4 ^{a)}	0 ^{b)}
6 - 8 DAT	16	1 ^{b)}	1 ^{b)}

a) Out of 4 trials, 1 trial was conducted in the soil of Andosol with extremely low organic matter content and 3 trials were conducted in sandy or loamy soil with leaching loss around 2 cm/day.

b) Conducted in the soil of a type of Andosol with extremely low organic matter content.
DAT; days after transplanting

Several combination granules such as mefenacet & naproanilid (NTN 804), mefenacet & pyrazolate (FS 356), mefenacet & DPX 84 (DPX 84T) and mefenacet & simetryne & MCPB (NTN 806) are also being developed for the control of the weeds which are tolerant to mefenacet.

Crop Tolerance

In the 1980-84 official test, mefenacet at rates up to 1.6 kg ai/ha applied after transplanting presented good crop tolerance to rice. In a few trials, however, acceptable to moderate crop injury was recorded. Mefenacet resulted in stunting and/or suppression of tillering. The testing conditions of those trials were investigated and greenhouse pot-tests have been conducted to examine some possible factors affecting crop tolerance such as water temperatures after treatment, leaching loss of water, planting depth and soil textures. (Figures 2, 3 and 4).

High water temperatures after treatment and extremely shallow planting in soils which are sandy or have the properties of rather high leaching loss are considered to be the factors affecting crop tolerance of mefenacet.

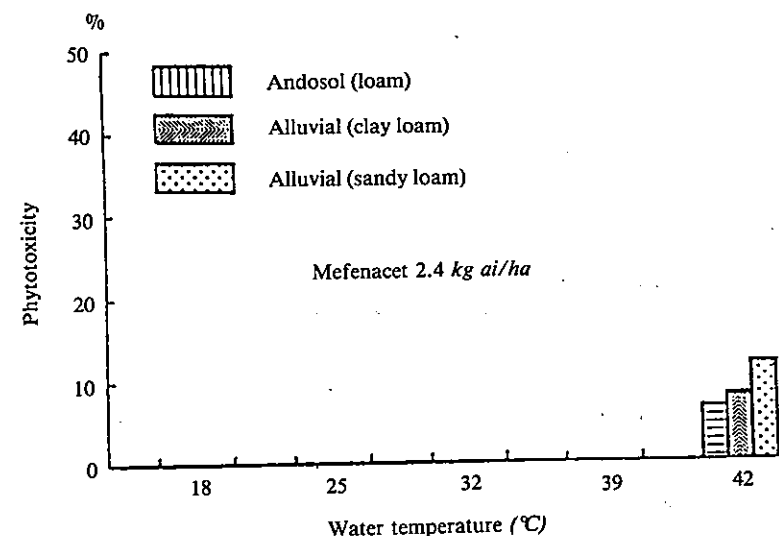


Figure 2. Plant compatibility as related to water temperature in different soils (pot-test)
At temperatures below 40°C, there was no incompatibility.

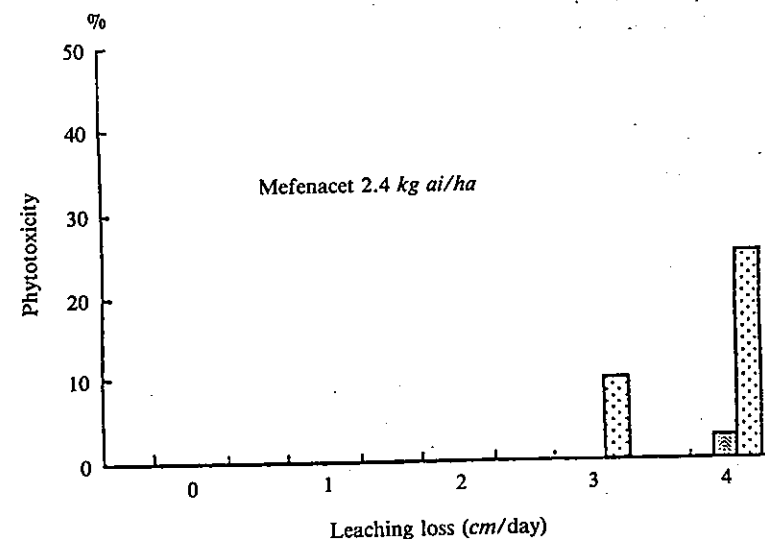


Figure 3. Plant compatibility as related to leaching loss different soils (pot-test)
At leaching loss below 3 cm/day, there was no incompatibility.

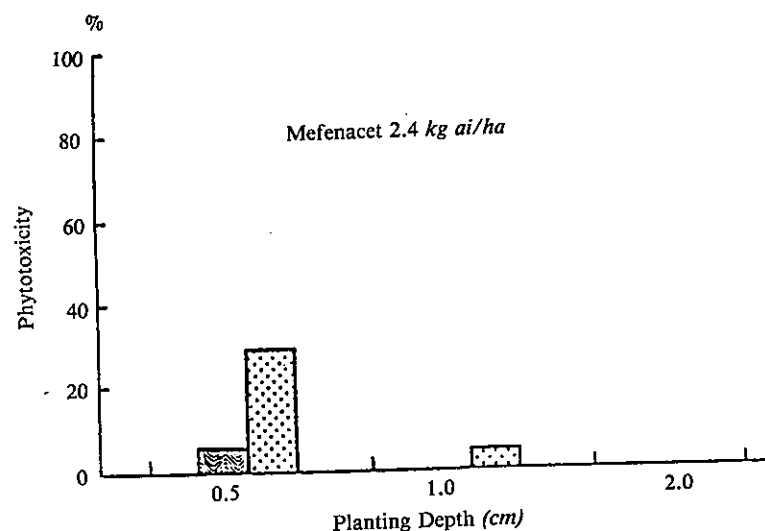


Figure 4. Plant compatibility as related to planting depth in different soils (pot-test)
At planting depth over 1.5 cm, there was no incompatibility.

In connection with crop tolerance, the leaching of mefenacet in soil was chemically studied using a soil column simulating paddy fields (Figure 5).

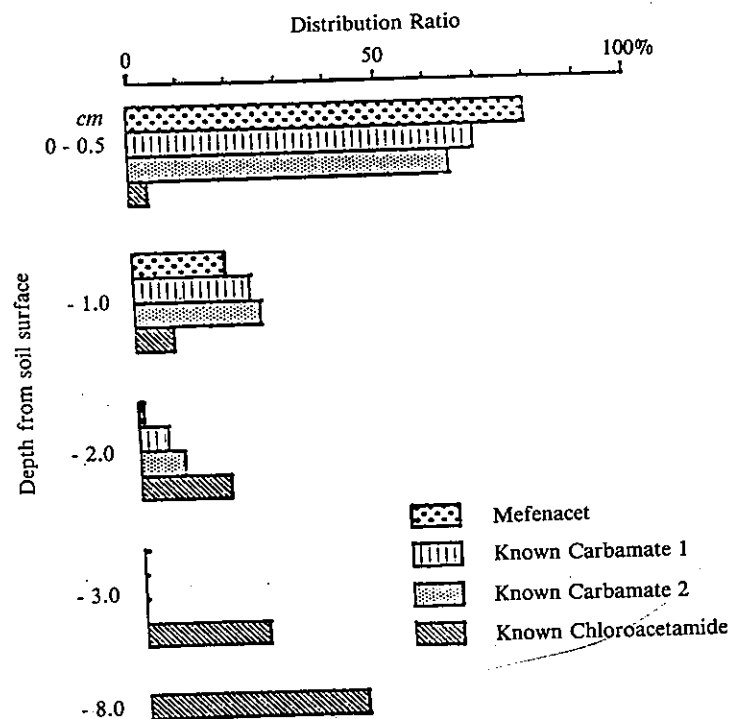


Figure 5. Leaching of mefenacet in soil column simulating paddy field

The glass column was packed with alluvial soil from paddy field. The soil was watered and stirred before starting leaching experiment in order to simulate puddling. Mefenacet 4% GR and the commercial paddy herbicides at 30 kg/ha were applied in water in the column and washed with water for 5 days with a leaching loss of 3 cm/day. The active ingredients each in the soil segments were simultaneously analyzed at the end of the experiment.

This leaching experiment revealed that mefenacet was adsorbed to the top soil layers and showed little movement.

In Japan, with the popularization of combine-harvestors, rice straw is often cut and incorporated into the soil after the harvest. This cultural practice transforms the soil to a reduced condition after the fields are flooded for the next rice cultivation (Hamada, 1979).

Mefenacet is well tolerated by rice in the reduced soil conditions (Table 4)

Table 4. Crop tolerance in reduced soil condition - a summary of two trials in Kochi prefecture, west Japan, 1982

Herbicide	Dose kg/ha	Rice	
		Plant Height*	Yield*
Mefenacet 4% GR	30	100.8%	98.2%
Known Carbamate 7% GR	30	62.3%	91.1%
Mefenacet 4% GR fb. Mefenacet SM GR	30	108.5%	99.0%

Mefenacet SM; mefenacet 6% & simetryne 1.5% & MCPB 0.8% GR

*As compared with handweeded

Phytotoxicity of mefenacet on the susceptible crops within the vicinity of the treated paddy fields has not been reported.

In the greenhouse, mefenacet was evaluated for its vapour phase activity (Table 5). This test showed that mefenacet does not exert any herbicidal activity via the vapour phase.

Table 5. Crop tolerance on cucumber plants in airflow system from aqueous solution of herbicides (Yukimoto et al, 1979)

Herbicide	Crop Injury*
Mefenacet	-
Known Thiocarbamate	+++

* Marginal or interveinal chlorosis and cupping of young leaves
Crop Injury: -, no; +, +, +, severe

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RESIDUAL EFFECTS OF NINE HERBICIDES TO FIVE CROPS

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ABSTRACT

2,4-D, dalapon, alachlor, pendimethalin, diphenamid, linuron, diuron, atrazine and aziprotryn were investigated for their residual toxicity to corn, rice, soybean, cucumber and Pai-tsai at the recommended rate by bioassay. The herbicides were sprayed on the upland farms and then the soils were brought back to the greenhouse at the regular intervals to seed the tested plants. Corn and soybean were the most tolerant to the tested herbicides. Both crops could grow on the soil sample collected 30 days after herbicides spraying as well as on the non-treated soil. Alachlor still made rice dead at 30 days after spraying. Diuron, atrazine and aziprotryn could inhibit the growth of rice. Cucumber was the most sensitive to atrazine. As to Pai-tsai, linuron and diuron could inhibit its growth to the extent of 50-70% while atrazine killed the plants.

INTRODUCTION

Recent introduction of herbicides for controlling weeds in crop land in Taiwan has prompted speculation concerning the possible residual effect of these chemicals on the performance of the succeeding crops¹. Farmers concern the rapid increase in the use of herbicides in recent years. Paddy fields treated with herbicides increased from 1.4% in 1969 to 91.2% in 1978³. It appears worthwhile, therefore, to understand the role played by herbicide residues in crop land. The objective of this research was to compare the sensitivities of tested crops to these upland herbicides used extensively.

MATERIALS AND METHODS

This experiment was conducted from February to June of 1984 at Wufeng farm of Taiwan Agricultural Chemicals and Toxic Substances Research Institute. Dalapon, 2,4-D, alachlor, pendimethalin, diphenamid, linuron, diuron, atrazine and aziprotryn were sprayed on the upland field at recommended rates (x) (Table 1.), 2x and 3x. The experimental design was RCBD with four replications. The field soil were brought back to the greenhouse at 0, 10, 20, and 30 days after herbicides application. Corn, soybean, rice, cucumber and Pai-tsai (*Brassica chinensis*) were seeded immediately in 10 x 5 cm (diam.-depth) pots. Plant height, fresh weight and dry weight of each crop were measured at 20 days after seeding. Data were presented by regression lines, and line 1, 4, 7 were X concentration; line 2, 5, 8 were 2X concentration and line 3, 6, 9 were 3X concentration.

Table 1. Recommended rate of herbicides tested.

Herbicide	Formulation	Rate of application Kg (l)/ha
2,4-D	80% WP	1.39
Dalapon	85% WP	10.00
Alachlor	43% EC	4.06
Pendimethalin	31.7% EC	4.42
Diphenamid	50% WP	6.00
Linuron	50% WP	1.50
Diuron	50% WP	0.50
Atrazine	50% WP	1.00
Aziprotryn	50% WP	2.00

RESULTS

The data in this experiment were presented by percent suppression based on control and the plant height, fresh weight and dry weight of non-treated crops at 20 days after seeding were showed in Table 2.

Table 2. The plant height, fresh weight and dry weight of controlled crops at 20 days after seeding.^{a)}

Crops	Plant Height (cm)	Fresh Weight (g)	Dry Weight (g)
Corn	25	0.81	0.10
Soybean	22	0.43	0.09
Rice	13	0.10	0.01
Cucumber	7	0.75	0.09
Pai-tsai	5	0.25	0.03

a) Average of four replications.

Pendimethalin caused the most injury to corn in plant height, but diuron and aziprotryn, especially heavier application (3x), also suppressed the fresh weight and dry weight of corn as pendimethalin. As to other herbicides, they showed slight influence to corn growth (below 20% suppression) (Fig. 1.). It appeared significantly the inhibition of most herbicides to the growth of corn declined to below 5% suppression as sampling time prolonged until surveyed 30 DAA (days after application) (Fig. 1.).

Soybean was the most sensitive to atrazine (over 50% suppression in heavier application even 30 DAA) (Fig. 2). Other herbicides would inhibit the growth of soybean below 20% suppression at 20 DAA (Fig. 2).

Fig. 3 showed rice was more sensitive to the tested herbicides except dalapon, 2,4-D and diphenamid than corn and soybean. Especially alachlor made rice can not grow even at 30 DAA (Fig. 3). Pendimethalin, linuron, diuron, atrazine and aziprotryn showed severe toxicity to rice at heavier rates (30–100% suppression at 30 DAA) (Fig. 3).

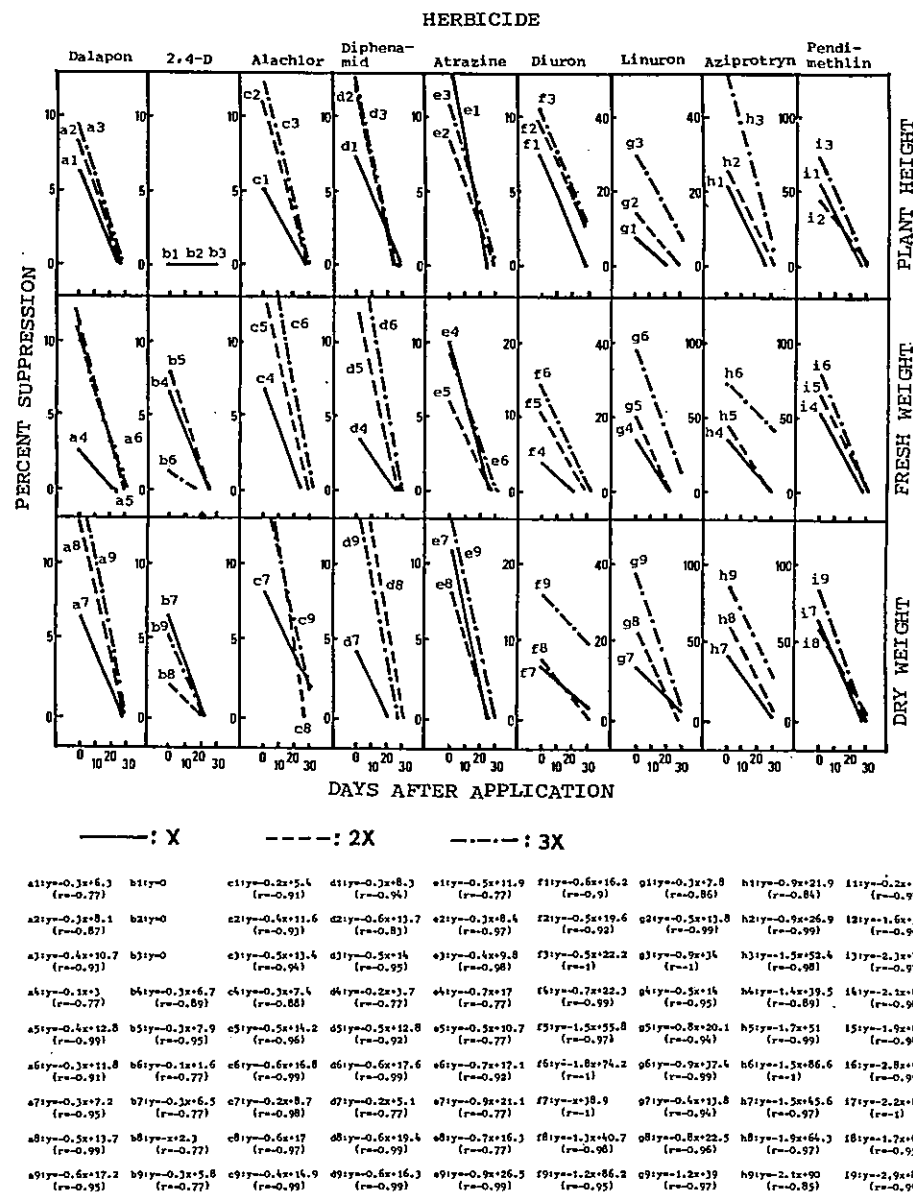
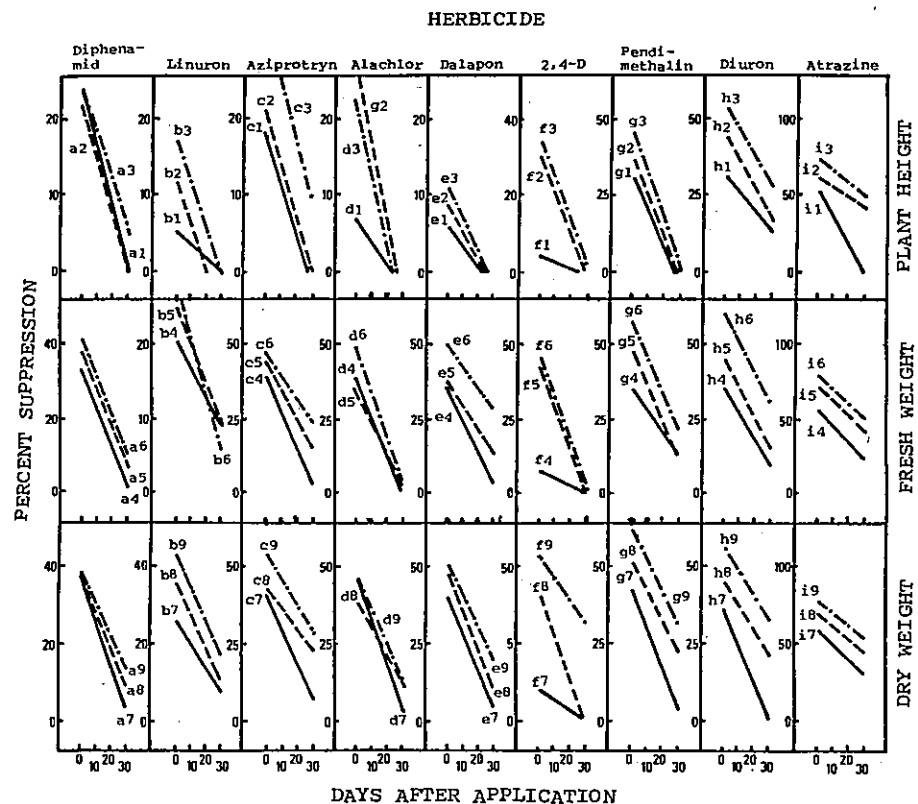
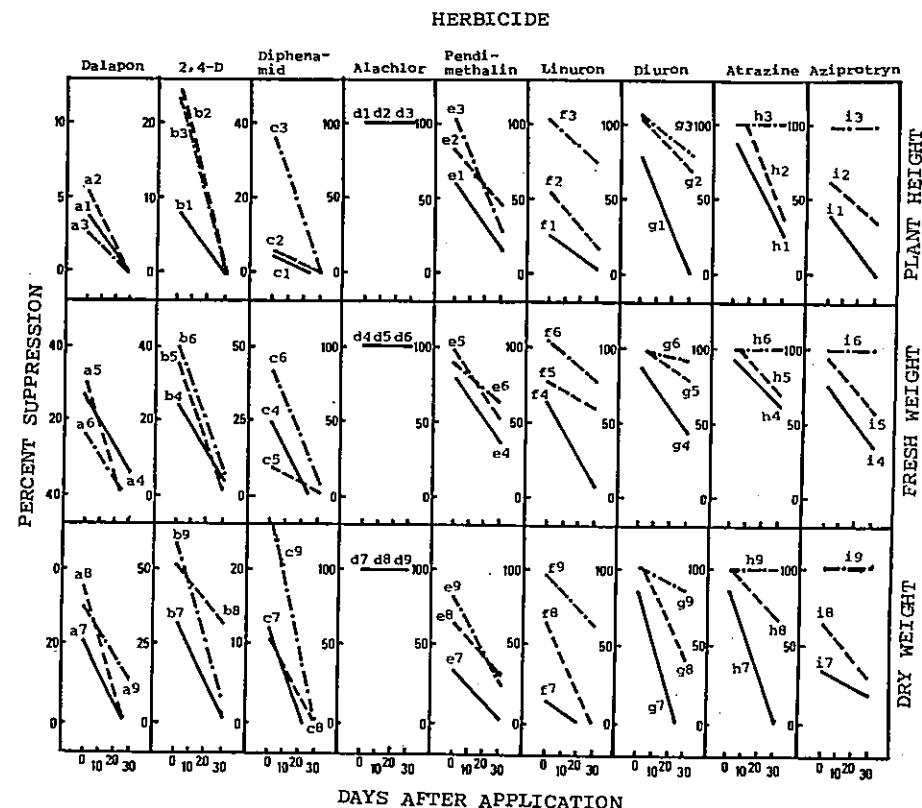


Fig. 1. The suppression of nine tested herbicides to corn in plant height, fresh weight and dry weight, with different application rates.



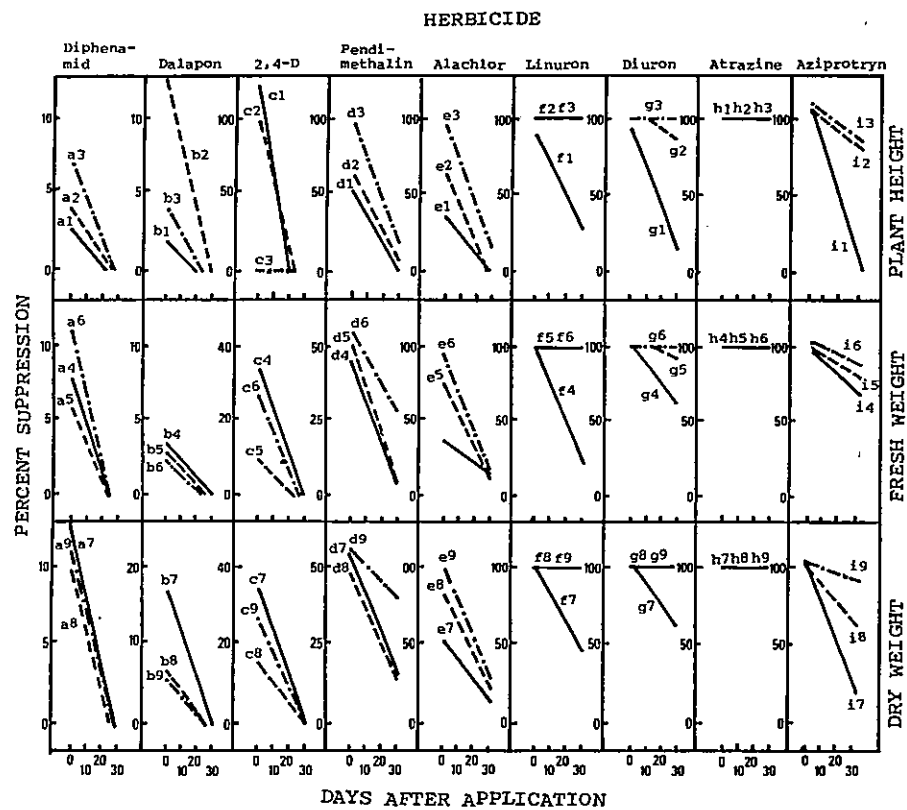
a1y=-0.8x+24.6 (r=-0.98)	b1y=-0.2x+6 (r=-0.92)	c1y=-0.8x+20.1 (r=-0.92)	d1y=-0.3x+7.2 (r=-0.77)	e1y=-0.6x+12.8 (r=-0.78)	f1y=-0.3x+5.8 (r=-0.77)	g1y=-0.8x+24.6 (r=-0.98)	h1y=-0.7x+3 (r=-0.99)	i1y=-1.2x+57.4 (r=-0.99)
a2y=-0.9x+24.4 (r=-0.94)	b2y=-0.5x+13 (r=-0.84)	c2y=-0.8x+23.8 (r=-0.95)	d2y=-1.2x+28.6 (r=-0.85)	e2y=-0.9x+19.8 (r=-0.78)	f2y=-1.4x+39.8 (r=-0.94)	g2y=-0.9x+24.4 (r=-0.94)	h2y=-1.1x+65.6 (r=-0.99)	i2y=-x+65.6 (r=-0.97)
a3y=-0.7x+25.3 (r=-0.97)	b3y=-0.7x+19.5 (r=-0.96)	c3y=-x+34.6 (r=-0.95)	d3y=-x+23.6 (r=-0.81)	e3y=-0.9x+23.1 (r=-0.88)	f3y=-1.6x+44.5 (r=-0.92)	g3y=-0.7x+25.3 (r=-0.97)	h3y=-x+58.3 (r=-0.99)	i3y=-x+75.6 (r=-0.98)
a4y=-x+32.1 (r=-0.99)	b4y=-0.4x+20.6 (r=-0.99)	c4y=-1.2x+37.9 (r=-0.99)	d4y=-1.1x+38.5 (r=-0.94)	e4y=-1.1x+37.9 (r=-0.97)	f4y=-0.3x+7.4 (r=-0.97)	g4y=-x+32.1 (r=-0.99)	h4y=-x+35.1 (r=-0.97)	i4y=-x+54.9 (r=-0.98)
a5y=-1.1x+36.8 (r=-0.99)	b5y=-0.6x+24.8 (r=-0.98)	c5y=-1.1x+45.8 (r=-0.99)	d5y=-1.3x+36.7 (r=-0.99)	e5y=-0.9x+40.4 (r=-0.99)	f5y=-1.3x+44.2 (r=-0.99)	g5y=-1.1x+36.8 (r=-0.99)	h5y=-1.2x+45.2 (r=-0.99)	i5y=-1.1x+70 (r=-0.99)
a6y=-1.2x+40.3 (r=-0.99)	b6y=-0.8x+28.1 (r=-0.99)	c6y=-1.1x+52.1 (r=-0.99)	d6y=-1.6x+47.8 (r=-0.99)	e6y=-0.9x+52.2 (r=-0.99)	f6y=-1.4x+44.5 (r=-0.98)	g6y=-1.2x+40.3 (r=-0.99)	h6y=-1.1x+59 (r=-0.99)	i6y=-1.2x+80.1 (r=-0.99)
a7y=-x+34 (r=-0.99)	b7y=-0.7x+25 (r=-0.99)	c7y=-1.2x+60.3 (r=-0.99)	d7y=-1.5x+45.8 (r=-0.99)	e7y=-1.3x+42.1 (r=-0.99)	f7y=-0.3x+7.5 (r=-0.99)	g7y=-x+34 (r=-0.99)	h7y=-1.2x+36.1 (r=-0.98)	i7y=-1.1x+55.8 (r=-0.97)
a8y=-1.1x+37.9 (r=-0.99)	b8y=-1.1x+35.9 (r=-0.99)	c8y=-0.8x+41.8 (r=-0.97)	d8y=-1.2x+38.4 (r=-0.92)	e8y=-1.4x+40.9 (r=-0.99)	f8y=-1.4x+40.9 (r=-0.99)	g8y=-1.1x+37.9 (r=-0.99)	h8y=-x+67.4 (r=-0.99)	i8y=-0.9x+66.7 (r=-0.97)
a9y=-1.2x+38.6 (r=-0.99)	b9y=-x+43.3 (r=-0.99)	c9y=-1.1x+55.2 (r=-0.99)	d9y=-1.3x+46.3 (r=-0.99)	e9y=-1.1x+51.4 (r=-0.95)	f9y=-1.7x+55 (r=-0.98)	g9y=-1.2x+38.6 (r=-0.99)	h9y=-x+57 (r=-0.98)	i9y=-x+76.6 (r=-0.99)

Fig. 2. The suppression of nine tested herbicides to soybean in plant height, fresh weight and dry weight with different application rates.



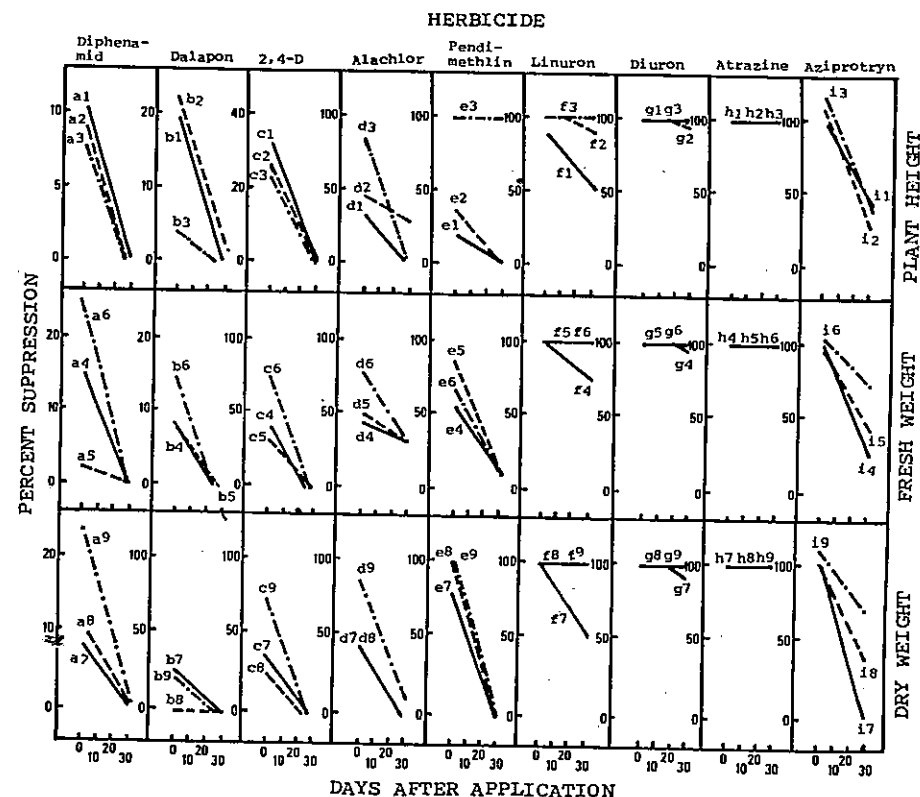
a1y=-0.2x+3.7 (r=-0.77)	b1y=-0.3x+8.1 (r=-0.87)	c1y=-0.2x+5.8 (r=-0.77)	d1y=100	e1y=-1.6x+61.6 (r=-0.96)	f1y=-0.6x+26.9 (r=-0.89)	g1y=-2.9x+79.7 (r=-0.86)	h1y=-2.4x+89.9 (r=-0.94)	i1y=-1.3x+40.3 (r=-0.99)
a2y=-0.2x+4.9 (r=-0.87)	b2y=-x+23.3 (r=-0.86)	c2y=-0.2x+6.5 (r=-0.92)	d2y=100	e2y=-1.5x+88.5 (r=-0.88)	f2y=-1.5x+58.5 (r=-0.86)	g2y=-1.5x+107.2 (r=-0.93)	h2y=-2.6x+117.2 (r=-0.93)	i2y=-1.6x+74.4 (r=-0.95)
a3y=-0.1x+2.3 (r=-0.77)	b3y=-0.9x+22.5 (r=-0.91)	c3y=-1.5x+40.8 (r=-0.91)	d3y=100	e3y=-2.7x+106.5 (r=-0.91)	f3y=-1.2x+108 (r=-0.77)	g3y=-0.9x+106.2 (r=-0.77)	h3y=100	i3y=100
a4y=-0.8x+27.4 (r=-0.99)	b4y=-0.7x+24.1 (r=-0.91)	c4y=-1.2x+30.4 (r=-0.93)	d4y=100	e4y=-1.4x+80.1 (r=-0.94)	f4y=-2x+64.3 (r=-0.97)	g4y=-1.7x+90.9 (r=-0.91)	h4y=-1.1x+95.1 (r=-0.93)	i4y=-1.5x+74 (r=-0.99)
a5y=-1.3x+30.9 (r=-0.81)	b5y=-1.3x+34.6 (r=-0.9)	c5y=-0.3x+10 (r=-0.93)	d5y=100	e5y=-1.5x+97.2 (r=-0.86)	f5y=-0.8x+81.1 (r=-0.96)	g5y=-0.8x+103 (r=-0.94)	h5y=-1.3x+106.8 (r=-0.77)	i5y=-1.2x+92.6 (r=-0.89)
a6y=-1.3x+38.7 (r=-0.77)	b6y=-1.5x+38.7 (r=-0.95)	c6y=-1.4x+45.5 (r=-0.95)	d6y=100	e6y=-1.2x+96.2 (r=-0.95)	f6y=-1.1x+10.76 (r=-0.77)	g6y=-0.4x+102.4 (r=-0.77)	h6y=100	i6y=100
a7y=-x+23.2 (r=-0.77)	b7y=-1.1x+32.4 (r=-0.99)	c7y=-0.5x+11.9 (r=-0.8)	d7y=100	e7y=-1.2x+33 (r=-0.94)	f7y=-0.5x+11.4 (r=-0.77)	g7y=-3.3x+83.7 (r=-0.92)	h7y=32x+82.4 (r=-0.98)	i7y=-0.5x+34.8 (r=-0.99)
a8y=-1.4x+34.6 (r=-0.81)	b8y=-1.6x+49.2 (r=-0.99)	c8y=-1.5x+11.9 (r=-0.8)	d8y=100	e8y=-2.2x+68.3 (r=-0.99)	f8y=-2.6x+68.2 (r=-0.94)	g8y=-2.2x+111.8 (r=-0.94)	h8y=-1.5x+110 (r=-0.77)	i8y=-1.3x+64.6 (r=-0.97)
a9y=-1.3x+30.2 (r=-0.79)	b9y=-1.6x+54.8 (r=-0.98)	c9y=-1.1x+28.3 (r=-0.94)	d9y=100	e9y=-2x+74 (r=-0.9)	f9y=-1.5x+110 (r=-0.77)	g9y=-0.8x+105.2 (r=-0.77)	h9y=100	i9y=100

Fig. 3. The suppression of nine tested herbicides to rice in plant height, fresh weight and dry weight, with different application rates.



a1y=0.1x+10 (r=0.77)	b1y=0.1x+2.3 (r=0.77)	c1y=0.5x+12.6 (r=0.77)	d1y=2.1x+59.9 (r=0.95)	e1y=1.5x+56.4 (r=0.99)	f1y=3x+86.4 (r=0.93)	g1y=3.3x+113 (r=0.95)	h1y=3.7x+110.7 (r=0.92)	i1y=100
a2y=0.2x+4.2 (r=0.88)	b2y=0.4x+13.5 (r=0.97)	c2y=0.4x+9.9 (r=0.77)	d2y=2.3x+77.5 (r=0.99)	e2y=2.4x+68.1 (r=0.99)	f2y=100	g2y=0.7x+104.4 (r=0.77)	h2y=100	i2y=100
a3y=0.3x+7.4 (r=0.88)	b3y=0.2x+4.4 (r=0.77)	c3y=0.04x+0.9 (r=0.75)	d3y=2.9x+104.6 (r=0.96)	e3y=2.8x+99.4 (r=0.93)	f3y=100	g3y=100	h3y=100	i3y=100
a4y=0.3x+7.9 (r=0.77)	b4y=0.1x+2.7 (r=0.63)	c4y=1.4x+36.7 (r=0.95)	d4y=1.5x+50.5 (r=0.97)	e4y=0.9x+60.3 (r=0.86)	f4y=2.8x+103 (r=0.94)	g4y=1.6x+105.4 (r=0.94)	h4y=100	i4y=1.4x+107.6 (r=0.89)
a5y=0.2x+5.8 (r=0.77)	b5y=0.1x+2.8 (r=0.77)	c5y=0.5x+10.7 (r=0.77)	d5y=1.7x+55.7 (r=0.97)	e5y=2.5x+80.5 (r=0.98)	f5y=100	g5y=0.4x+102.4 (r=0.77)	h5y=100	i5y=x+106.4 (r=0.77)
a6y=0.4x+10 (r=0.77)	b6y=0.2x+3.3 (r=0.77)	c6y=x+26.8 (r=0.96)	d6y=0.9x+61 (r=0.97)	e6y=2.7x+99.5 (r=0.94)	f6y=100	g6y=100	h6y=100	i6y=0.6x+104 (r=0.77)
a7y=0.5x+13.2 (r=0.95)	b7y=0.7x+37.3 (r=0.95)	c7y=1.3x+35.2 (r=0.97)	d7y=1.4x+51.7 (r=0.90)	e7y=1.3x+50.5 (r=0.89)	f7y=2x+101.6 (r=0.96)	g7y=1.5x+106.3 (r=0.95)	h7y=100	i7y=1.3x+115 (r=0.94)
a8y=0.6x+10 (r=0.77)	b8y=0.3x+6.5 (r=0.77)	c8y=0.5x+4.5 (r=0.95)	d8y=1.2x+49.3 (r=0.96)	e8y=2.5x+85.5 (r=0.99)	f8y=100	g8y=100	h8y=100	i8y=1.9x+112.4 (r=0.77)
a9y=0.4x+11.6 (r=0.97)	b9y=0.3x+6.4 (r=0.82)	c9y=x+26.4 (r=0.95)	d9y=1.1x+66.7 (r=0.94)	e9y=2.6x+99.7 (r=0.91)	f9y=100	g9y=100	h9y=100	i9y=0.4x+103 (r=0.77)

Fig. 4. The suppression of nine tested herbicides to cucumber in plant height, fresh weight and dry weight, with different application rates.



a1y=0.6x+10 (r=0.94)	b1y=0.8x+30.7 (r=0.93)	c1y=1.1x+31.5 (r=0.96)	d1y=1.1x+32 (r=0.98)	e1y=0.7x+19.5 (r=0.98)	f1y=2.1x+111.7 (r=0.88)	g1y=100	h1y=100	i1y=2.6x+115.5 (r=0.84)
a2y=0.4x+9.3 (r=0.94)	b2y=0.7x+22.1 (r=0.97)	c2y=x+27.9 (r=0.92)	d2y=1.7x+150.4 (r=0.91)	e2y=1.4x+36.8 (r=0.94)	f2y=0.9x+106 (r=0.77)	g2y=0.1x+101 (r=0.77)	h2y=100	i2y=3.2x+113.2 (r=0.94)
a3y=0.3x+8.1 (r=0.87)	b3y=0.2x+4.4 (r=0.77)	c3y=0.9x+23.6 (r=0.93)	d3y=3x+85.7 (r=0.96)	e3y=100	f3y=100	g3y=100	h3y=100	i3y=2.7x+116.3 (r=0.86)
a4y=0.6x+15 (r=0.93)	b4y=0.3x+9.4 (r=0.99)	c4y=1.9x+7.7 (r=0.88)	d4y=1.5x+45.1 (r=0.99)	e4y=1.6x+59.1 (r=0.98)	f4y=1.3x+101.6 (r=0.99)	g4y=0.1x+101 (r=0.77)	h4y=100	i4y=3.5x+108.8 (r=0.97)
a5y=0.3x+1.6 (r=0.87)	b5y=0.4x+8.8 (r=0.87)	c5y=1.4x+35.7 (r=0.92)	d5y=2.1x+58.7 (r=0.89)	e5y=2.4x+84.9 (r=0.97)	f5y=100	g5y=100	h5y=100	i5y=2.5x+109.7 (r=0.93)
a6y=0.2x+4 (r=0.89)	b6y=0.7x+15.8 (r=0.89)	c6y=2.9x+76.6 (r=0.95)	d6y=2.8x+82.6 (r=0.97)	e6y=2.5x+85.1 (r=0.94)	f6y=100	g6y=100	h6y=100	i6y=1.4x+108.6 (r=0.82)
a7y=0.3x+8.1 (r=0.78)	b7y=x+25.9 (r=0.91)	c7y=x+50.8 (r=0.9)	d7y=1.8x+50.5 (r=0.97)	e7y=1.5x+43.4 (r=0.99)	f7y=1.8x+101.9 (r=0.98)	g7y=0.4x+102.4 (r=0.77)	h7y=100	i7y=3.2x+99 (r=0.99)
a8y=0.3x+7.8 (r=0.98)	b8y=0	c8y=1.1x+26.1 (r=0.77)	d8y=1.8x+49.2 (r=0.96)	e8y=1.7x+50.8 (r=0.99)	f8y=100	g8y=100	h8y=100	i8y=2.1x+101.5 (r=0.99)
a9y=0.8x+24.4 (r=0.99)	b9y=x+23.8 (r=0.79)	c9y=2.8x+11.7 (r=0.95)	d9y=2.6x+92.4 (r=0.97)	e9y=2.3x+61.2 (r=0.97)	f9y=100	g9y=100	h9y=100	i9y=1.5x+109 (r=0.83)

Fig. 5. The suppression of nine tested herbicides to Pai-tsai in plant height, fresh weight and dry weight, with different application rates.

Dalapon, 2,4-D and diphenamid had slight influence on the growth of cucumber (recovery to normal condition at 30 DAA) (Fig. 4). Alachlor and pendimethalin would inhibit cucumber growth about 20-30% suppression at 20 DAA (Fig. 4). Linuron, diuron and aziprotryn showed significant suppression to 50% at 30 DAA by recommended rate, and cucumber could not grow in heavier rates (2x and 3x) of these three herbicides even at 30 DAA (Fig. 4). Atrazine had the most injury to cucumber growth, it even made cucumber dead up to 30 DAA at any rates of application (Fig. 4).

Pai-tsai had similar, but more pronounced responses to these test herbicides than cucumber, especially diuron (Fig. 5).

DISCUSSION

Corn was the most tolerant crop to nine tested herbicides, and soybean was the second. Rice was the most sensitive to alachlor. Linuron and atrazine caused much severe injury to cucumber and Pai-tsai. The similar phenomena had been reported⁵.

For nine tested herbicides, 2,4-D and dalapon degraded completely in short time and did not persist in soil over 30 days^(2,4). Alachlor's residual time was about 2 months^(2,7), pendimethalin and diphenamid degraded to 10% of application rate about 3 months². Linuron, diuron, atrazine and aziprotryn could persist in soil over one year^{2,6}.

In this experiment, sampling time is too short to indicate significantly the difference of the residual effect of the tested herbicides on these crops, but it showed the different sensitivities of the tested crops to these herbicides and the change of tendency with different sampling times after application.

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STUDIES ON THE EFFICACY OF CERTAIN NEW HERBICIDES IN RELATION TO SLOW RELEASE NITROGENOUS FERTILIZERS IN RICE.

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ABSTRACT

The experiment conducted at College Farm, Hyderabad, consisting of seven herbicides along with weed free and weedy check in relation to prilled urea and urea super granules has shown that weed free recorded the highest grain yield of paddy cv. Tellahamsa but was on par with Anilophos (HOE-30374), Mollinate+Propanil (SC-9910), Butachlor and Thiobencarb. The weeds like *Echinochloa colonum*, *Lippia nodiflora* and *Panicum repens* were effectively controlled by the above herbicides. The slow release nitrogenous fertilizer urea super granules has shown better performance and recorded lesser dry matter production of weeds as compared to prilled urea. The herbicides used in the trial have not shown any phytotoxic effect on the crop.

INTRODUCTION

Among the various factors responsible for low yield of rice, weeds are important. Gopala Krishna Pillai and Rao (1974) reported 20% yield losses due to weeds in transplanting method under puddled condition. In various methods of weed control, the age old practice of hand weeding is slow, laborious, cumbersome which results in delayed weeding and causes sufficient damage to the crop. More over, there are chances of regeneration of new shoots from rhizomes or roots that are left behind in the field. Large number of investigations have been made on the use of herbicides in the last 25 years to control weeds. In recent years in India, slow release nitrogenous fertilizers like urea super granules, briquettes, sulphur coated urea, neem coated urea are recommended on large scale due to their better efficiency in supplying of nitrogen to the crop than ordinary urea. The effect of such fertilizers on emergence of weeds and its growth are not observed. Hence, it is essential to study the effect of such slow release nitrogenous fertilizers along with the new herbicides applied to the rice crop and with these ideas in view the present experiment was planned.

MATERIALS AND METHODS

Field experiment was conducted on the Farm, College of Agriculture, Rajendranagar, Hyderabad during rabi 1984-'85 on a clay loam soil having neutral pH with 0.60% organic carbon, 40.52 kg ha⁻¹ of available phosphorus and 140.68 kg ha⁻¹ of available potassium. The herbicides Thiobencarb, Anilophos, Butachlor, Basalin + 2,4-D EE applied 3 days after transplanting and new herbicide formulations

SC 9907, SC 9908, SC 9909, SC 9910 (Mollinate + Propanil) applied 10 days after transplanting were tested along with weed free and weedy check. Hand weeding was done twice on 30th and 50th day after transplanting. The slow release form of nitrogen (urea super granules) was compared with ordinary urea. These ten weed control treatments and two forms of nitrogenous fertilizer were replicated thrice in a factorial randomised block design. The paddy cv. Tellahamsa was transplanted on 3rd January, 1985 with a spacing of 20 x 10 cm in puddled condition and harvested on 8th May, 1985. The entire recommended dose of 100 Kg N in the form of Urea and Urea super granules, 60 kg P₂O₅ in the form of Superphosphate and 30 kg K₂O in the form of Muriate of Potash per hectare was applied at the time of transplanting.

RESULTS AND DISCUSSION

Weed studies

Among the weed flora *Echinochloa colonum*, *Panicum repens*, *Lippia nodiflora*, *Cesulia auxillaris* and *Cyperus rotundus* constituted the maximum.

The dry matter accumulation of weeds (Table-1) was significantly influenced due to forms of nitrogen and weed control treatments. Application of mollinate + Propanil, Butachlor, Anilophos and thiobencarb proved quite effective against grasses and sedges but recorded 78.64, 74.64, 74.11 and 73.89% control of weeds over weedy check. Langeluddeke, P *et al.* 1981. also observed the control of grasses and sedges by Butachlor and Anilophos herbicides. Hand weeded plots recorded the lowest weed drymatter (24.38 g/m²) and was on par with the above treatments. In the two forms of nitrogen fertilizer, urea super granules recorded significantly lesser weed drymatter (58.62 g/m²) than ordinary urea. The weed drymatter recorded in ordinary Urea was 16.4% more as compared to slow release nitrogenous fertilizer i.e. urea super granules. The effect of interaction was not significant.

Effect on grain yield

The grain yield rice (Table-1) differed significantly due to weed, control treatments and forms of fertilizer nitrogen. Mollinate + propanil (SC 9910) Butachlor, Anilophos (HOE-30374) and thiobencarb recorded 28.2, 28.2, 25.6, 23.07% more grain yield of rice over weed check and was on par with hand weeding twice. The weedy check recorded the lowest grain yield of rice (3900 kg ha⁻¹). Hand weeded plots registered the highest grain yield of rice (5533 kg ha⁻¹) and was significantly superior over Basalin + 2,4-D EE, SC 9907, SC 9908 and SC 9909 treatments. Out of the two forms of nitrogen fertilizer, Ordinary urea recorded the lowest grain yield (4513 kg ha⁻¹). The slow release nitrogen fertilizer (urea super granules) registered significantly more grain yield (4760 kg ha⁻¹) and it was 5.47% more than ordinary urea. Straw yield was also observed in the same manner like grain yield in the two forms of nitrogen and weed control treatments.

Plant height

The plant height was not affected significantly by the treatments. However maximum plant height (77.3 cm) was observed in hand weeded plots followed by Mollinate + propanil (74.3 cm) Butachlor (74.0 cm), Thiobencarb (73.9 cm), Anilophos (73.8 cm) and the weedy check recorded the lowest. Urea super granules

Table 1. Weed drymatter, Yield and Yield attributing characters of rice as influenced by the forms of nitrogen and weed control treatments.

Treatments	Plant height (cm)	Weed dry-matter g/m ²	Productive tiller/m ²	Panicle length (cm)	1000 grain weight (g)	Grain Yield (Kg/ha)	Straw Yield (kg/ha)
1. Thiobencarb @ T Lit./ha 3 days after transplanting	73.9	41.41	538.4	20.1	22.62	4800	5000
2. Basalin 45 EC (20% a.i.) + 2,4-D EE (25% a.i.) @ 0.4 KG a.i./ha, 3 days after transplanting.	71.7	79.41	507.5	19.4	21.86	4466	4800
3. Butachlor 50% a.i. @ 2.5 Lit./ha 3 days after transplanting	74.0	40.21	546.3	20.0	22.50	5000	5233
4. Anilophos (HOE-30374) 0.3 Kg a.i./ha 3 days after transplanting.	73.8	41.06	527.5	19.9	22.69	4900	5233
5. SC 9907 @ 4 lit./ha 10 days after transplanting.	72.9	82.10	506.3	19.3	22.07	4300	4800
6. SC 9908 @ 4 Lit./ha 10 days after transplanting.	72.7	63.98	499.0	19.1	22.21	4433	4933
7. SC 9909 @ 5 lit./ha 10 days after transplanting.	72.5	74.11	479.5	19.5	21.99	4266	4833
8. SC 9910 (Mollinate + Propanil) @ 5 lit./ha 10 days after transplanting.	74.3	33.87	563.0	20.4	22.65	5000	5366
9. Hand weeding twice	77.3	24.38	596.5	20.8	22.71	5300	5533
10. Weedy check	69.8	158.58	443.3	18.3	21.10	3900	4500
S.Em ±	1.2	6.7	25.7	0.4	0.03	146.7	178.5
C.D. at 5%	NS	18.6	71.4	1.1	0.08	406.7	494.6
Urea super granules	74.1	58.2	547.6	20.1	22.3	4760	5160
Prilled Urea	72.5	69.6	494.1	19.4	22.2	4513	4887
S.Em ±	0.5	3.0	11.5	0.2	0.01	60.0	79.8
C.D. at 5%	NS	8.3	31.9	0.5	0.03	180.0	221.7

recorded more plant height than ordinary urea. The interaction effect of two forms of nitrogen and herbicides was not found to be significant.

All the herbicides tried in the experiment did not show any phytotoxic effect on the crop.

Yield attributes

The yield contributing characters (Table-1) such as productive tillers, panicle length and test weight were also significantly affected. Hand weeding twice registered significantly higher number of productive tillers ($596.5/m^2$), maximum panicle length (20.8 cm), and test weight (22.71 g) over weedy check and was on par with mollinate + Propanil (SC 9910), Butachlor, Anilophos (HOE-30374) and thiobencarb treatments. The slow release nitrogen fertilizer (Urea super granules) recorded significantly higher productive tillers ($547.6/m^2$), and panicle length (20.1 cm) over ordinary urea but the test weight between the two forms of fertilizer nitrogen was not found to be significant.

In general, the herbicides Mollinate + Propanil (SC 9910) 5 lit./ha applied 10 days after transplanting, Anilophos (HOE-30374) 0.300 kg a.i./ha, Butachlor 50% a.i. 2.5 lit./ha and Thiobencarb 4 lit./ha applied 3 days after transplanting were found effective in controlling the weed growth. The slow release nitrogenous fertilizer has shown better performance over ordinary urea, for getting higher yields of rice.

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CHEMICAL WEED CONTROL IN COTTON IN WEST AFRICA RESEARCH RESULTS AND USE BY FARMERS

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ABSTRACT

In the savannah areas of francophone West Africa, farms are usually small, ranging from 1 to 2 ha, but larger farms ranging from 10 to 20 ha are beginning to appear. Stable and mechanized farming is gradually replacing the traditional shifting cultivation. These changes are confronting the farmers with weeding problems and chemical weed control is increasing. Cotton, the cash crop, is the first to be weeded by this means but progressively the food crops such as maize, groundnut and upland rice, that are integrated with cotton in the cropping systems, are also chemically weeded. This has become possible as a result of research work on improved cotton by IRCT, one of the CIRAD departments, which has organised an international network of trials. The trials were carried out using a methodology that allowed a study of the herbicidal efficiency of the products, their phytotoxicity to the crops, carry over to subsequent crops and economical approach to herbicide use. Consequently, extension services have distributed several products including fluometuron, dipropetryn, dipropetryn + metolachlor and pendimethalin. Farmers now apply preemergence sprays on 40 to 50 thousand ha of cotton, using C D A hand-sprayers. This represents 15 to 20% of the total cotton growing areas such as the Ivory Coast and Cameroon where this development is most advanced.

INTRODUCTION

In french-speaking West Africa, the cultivation of cotton has been developping for the last 25 years and covers almost 700.000 ha. It is mainly a rainfed crop and the varieties that are used are those with a medium staple which have been selected by the IRCT and which give a yield after ginning of 40 to 42% for a fiber length that goes from 1" 1/32 to 1" 1/4. The average yields in seed cotton ranges from about 1000 to 1200 kg/ha. It can reach up to 1300 kg/ha in the Cameroons.

The traditional shifting cultivation on small farms of 1 to 2 ha tends to regress in favor of farms ranging from 10 to 20 ha. They are carried out either by oxen driving cultivation or motorized traction.

This brings about a new approach to weeding because the weeds increase along with the number of cultivation years and the farmers are not able any more to maintain their fields weed free with the traditional weeding technics. Chemical weeding could be a solution to this problem and at the moment we are witnessing

* CIRAD : International Cooperation Center of Agricultural Research for Development
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its application in the rural environment. For reasons more linked to extension constraints than to technical problems, the cotton cultivation is the one that uses chemical weeding the most and in a cropping system it is often the only one that uses this type of treatment. It has been made possible thanks to the research works carried out in cotton cultivation by one of the CIRAD Department, the IRCT, which has set up a network of interstate trials enabling the choice of the most suitable products.

MATERIALS AND METHODS

The study of the herbicide products is carried out in a progressive way in order to evaluate their different characteristics (Braud 1971; Dubernard 1971; Deat 1981).

The efficiency of the products on the weeds is studied by using the method of the adjacent check plot. Each product is spread in three doses, the N dose is usually considered to be efficient depending on climatic and soil conditions; then the 3/4 N followed by the 3/2 N doses. Once the trial is set up, the treated plots are next to the check plot. They will never be weeded and the efficiency of the products is appreciated by observations of two different types:

- The quantitative aspect of weed proliferation in the plots is grade 0 (total weed proliferation, herbicide effect null) to 10 (weed proliferation null, herbicide effect total), the grade 7 reflecting a satisfactory result that would not need additional weeding. These observations are done on the 15th, 30th and 45th day after sowing,
- the qualitative aspect of weed growth is determined by floristic sampling and the effect of the products on the main adventices is taken note of.

The selectivity of the efficient products is studied in trials done at random following the method of blocks.

Three doses are being tested : the dose D known to be efficient, and the doses 2 D and 3 D. The eventual action of the treatment on the cotton plants is appreciated by comparing a check plot that has not been treated. Every plot is kept clean by weeding in order to eliminate the influence of weeds on the cotton plants. The phytotoxicity is appreciated by the action on the emergence of the cotton plants, the visual symptoms shown by the plants, graded from 0 (phytotoxicity null) to 10 (total destruction of the cotton plants) on the 15th, 30th and 45th day after sowing. A study of the obtained yields completes these observations.

The carry over of the herbicides on the subsequent crops is studied by sowing these crops where the selectivity trials have been carried out. The same observations are then noticed.

The economical value of the products that have successfully passed the three first tests is studied on a real environment according to the method of the dispersed blocks. Each test plot is divided into two : one half is treated with the product that is to be observed, the other half is treated according to recommended cultural technics. The farmers carry out the tests themselves and observations on the dates and the time of weeding as well as on the yields thus obtained are done.

RESULTS

The research that has been undertaken for the last 5 years tends to find products which, though being sufficiently selective of the cotton plants, destroy most species of weeds and when used alternatively would avoid too rapid floristic changes. This has encouraged the mixing of different products that are best suitable to this expectation. In order to ease the farmer's work, preemergence products have been chosen. But for the last three years, mixtures combining a contact effect with a residual effect and used in preemergence and early post emergence, have been tested in order to allow a correct weeding of the fields where the land preparations are mediocre and where the sowing is carried out when weeds have already emerged.

Twenty six chemical components have been tried and those having given satisfactory results are gathered in Table 1. The products that are applied in preemergence are quite efficient on the yearly Poaceae like *Digitaria horizontalis*, *Brachiaria lata*, *Setaria pallide fusca*, *Dactyloctenium aegyptium*, but are insufficient or fair on *Rottboellia exaltata*.

Their action varies on the broadleaved weeds. We notice that *Commelina benghalensis* resists all products except oxyfluorfen + prometryn which reduces the infestations of it. Diethatylethyl + fluometuron, fluoroachloridone + diuron and fluometuron, prometryn + fluometuron have an interesting effect on the Asteraceae (*Acanthospermum hispidum*, *Ageratum conyzoides*, *Tridax procumbens* and *Vernonia galamensis* which are frequent in West Africa. *Euphorbia heterophylla*, rampant in Ivory Coast, is sensitive to oxyfluorfen + prometryn only if the rains fall regularly. Fluometuron + prometryn and fluoroachloridone + diuron slightly reduce their populations but on the other hand are quite satisfactory against *Ipomoea eriocarpa*. The adding of paraquat to the binary mixtures dipropetryn + metolachlor and terbutryn + metolachlor reinforce their herbicide action in case of the treatment of a weeded soil and allows the destruction of broadleaved weed not sensitive to these mixtures like the Asteraceae, *Commelina benghalensis*, *Euphorbia heterophylla*, *Cassia obtusifolia* and *Tephrosia bracteolata*.

Among these efficient products, five are not sufficiently selective to the cotton plant (Table 1), which led us to advice against their use and moreover, two of them, the norflurazon and the mixture norflurazon + cyanazin present a carry over (Table 1) on the cereals (maize, millet and sorghum).

The tests carried out at the farms show that in a real environment, the plots treated with herbicides get a better yield than those that are weeded (Table 2). This is due to the fact that the farmers are at the moment in a critical situation : the early weedings needed for the cotton plants are competing with other cultural interventions on the food crops and are then postponed to a time when the cotton plants are most sensitive to weeds. It is also noticed that the gains in yields thus obtained are higher than the cost of the treatments. Studies carried out in Benin (Gaborel 1985) have shown that the herbicide treatments can replace weeding in 70% of the cases and reduce the duration of working by 17 days/ha. Similar results have also been noticed in the maize cultivation.

Table 1 : Efficient herbicides against weeds of the cotton plant in West Africa. Selectivity of these products towards the cotton plants.

	Commercial products	Active ingredients	Concentrations	Formulations	Doses to be used according to the countries	Selectivity	Carry over
premergence	Cotofor	Dipropetryn + metolachlor	500 240 + 160	F.W. E.C.	1250 a 2000 1200 a 1600	Good Good	no no
	Cotonon ou Cotonex	Fluometuron	500	F.W.	1250 a 1750	Good	no
	Cotogard	Prometryn + fluometuron	250 + 250	F.W.	1300 a 2000	Good	no
	Stomp	Pendimethalin	330	E.C.	1000 a 1320	Good	no
	Vertal	Pendimethalin + cyanazin	200 + 200	W.P.	1200 a 1600	insufficient	no
	Igran combi	Terbutryn + metolachlor	200 + 200	E.C.	1200 a 1800	insufficient	no
	Zorial	Norflurazon	600	F.W.	1200 a 1620	insufficient	yes
	Zoriadex	Norflurazon + cyanazin	300 + 400	F.W.	1750 a 2100	insufficient	yes
	Autor	Diethatyl-ethyl	480	E.C.	2880 a 3840	Good	no
	Diflucal	Diethatyl-ethyl + fluometuron	275 + 225	F.W.	1500 a 1750	Good	no
	Goal + *	Oxyfluorfen + prometryn	240 + 500	E.C. F.W.	400 + 1500		no
	Ciesagard						
	Racer + Karmex	Fluorochloridone + diuron	250 + 500	E.C. F.W.	400 + 600 a 500 + 750	not yet studied	idem
	Racer + Cotonan	Fluorochloridone + fluometuron	250 + 500	E.C. F.W.	450 + 600 a 600 + 750		

premergence and early post emergence	Cotonon mix	Dipropetryn + metolachlor + paraquat	189 + 126 + 42	E.C.	1200 a 1800	Good	no
	Igran Combi mix **	Terbutryn + metolachlor + paraquat	131 + 263 + 42 +	E.C.	1656	Good	no

* only in Ivory Coast

** only in Senegal

Table 2 : Tests on farms. Yields in *kg/ha* seed cotton. Cost of the herbicide treatment in *kg* of seed cotton.

Country	Number of tests	Tested products	Seed cotton	Cost of treatment
Ivory Coast	9	Fluometuron 1750 <i>g/ha</i> without herbicide	1297 1027	155
Benin	49	Dipropetryn + metolachlor 1600 <i>g/ha</i> without herbicide	2135 1678	180

DISCUSSION

If the trials showed that it was worth using chemical weed control in the Savannah cultivations; their extension was possible only through the introduction of CDA hand sprayers in order to apply mixtures of about 20 *l/ha*. In fact, the treatments are done at the beginning of the rainy season, at a time when there isn't yet too much water and moreover, it is difficult to apply the conventional 400 *l/ha* with a knapsack sprayer. The farmers welcomed this new technic and, at the moment, several products are being used (Table 3) on cotton cultivations as well as on food crops that are being integrated with them in crop rotations. The areas treated have progressively improved (Table 4) first in Cameroon, then in Ivory Coast, then in Senegal and Mali, by following the evolution of cultural technics and the structures of the farms. The chemical weed control of the cotton plant was chosen because this crop is a cash crop but we are now witnessing an increasing number of fields with food crop cultivations that are treated in this way, for example, in Ivory Coast. These areas reached 5,000 *ha* for maize and 6,600 *ha* for upland rice, representing thus 60% of the area treated for the cultivation of cotton in 1983. When the trade of the food crops is assured one notes that herbicides are used as often as in the cotton cultivations.—It is the case in Mali where in 1984, 7,447 *ha* of maize were chemically weeded, against 7,294 *ha* in cotton cultivation. One can only hope that this tendency will be pursued because one cannot always treat the same cultivation of a cropping system because invading plants would appear, selected by the repeated use of products having similar effects.

Table 3 : Herbicides and doses (*g/ha a.i.*) being extended in West Africa

Country	Cotton plant	Maize	Upland rice	Groundnuts
Ivory Coast	Fluometuron 1750 Pendimethalin Dipro. + metol. 1600	Prometryn + metol. 2000 Prometryn + cyanazin 2000	Oxadiazon 1000	Diprop. + metol. 1600
Senegal	Dipro + metol + paraquat 135 + Terbu + metol + paraquat 1657	Prometryn + metol. 2000	-	Prometryn + ametryn 1250
Mali	Fluometuron 1250	Prometryn + metol. 1750	Oxadiazon 1000	-
Cameroon	Dipropetryn 1000 Dipropetryn + metol. 1200	Atrazin + metol. 2000	Diathametryn + pyperophos 1500	Prometryn + ametryn 1250
Burkina Faso	Dipropetryn + metol. 1400	Prometryn + metol. 2000	-	Dipropetryn + metol. 1600
Togo	Dipropetryn + metol. 1600	Prometryn + metol. 2000	-	-
Benin	Dipropetryn + 1600	Prometryn + metol. 2000	-	Dipropetryn + metol. 1600

Table 4 : Evaluation of the areas treated with herbicides in ha (Cotton) ; % of area being treated against area having been sown

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985 previsions
Ivory Coast	0	1692	2576	3833	7471	7770	10442	18997	24135	32000
	-	1.9%	2.0%	1.8%	5.6%	5.7%	8.1%	13.9%	16.5%	20.0%
Burkina-Faso	0	0	0	0	0	0	0	28	16	373
	-	-	-	-	-	-	-	<0.5%	<0.5%	0.5%
Mali	0	0	0	0	3230	3733	5631	2955	7294	13600
1.0%	-	-	-	-	3.0%	3.9%	4.2%	2.8%		6.9%
Senegal	0	0	83	277	261	323	933	6248	12100	16500
	-	-	<0.5%	1.0%	1.3%	0.8%	2.0%	18.7%	26.0%	29.3%
Togo	0	0	0	0	0	0	0	0	12	125
	-	-	-	-	-	-	-	-	<0.5%	*
Benin	0	0	0	0	0	0	0	0	15	7000
	-	-	-	-	-	-	-	-	<0.5%	10.0%
Cameroon	35	450	5608	10031	11352	9175	8534	9425	*	*
	<0.5%	0.9%	11.9%	17.7%	17.5%	14.5%	15.7%	14.8%		

* informations not given.

CONCLUSION

The research works carried out during the last few years have encouraged the extension of the herbicides in the rural environment. Thanks to this technic many pieces of land will not be abandoned. It is one of the stabilizing factors of the farms. But it would be dangerous to think that the chemical weed control would solve all the weeding problems of a cropping system. One has to envisage a real management of the weed control including cultural successions, the use of cleaning or easy to weed cultivations as well as the use of herbicides.

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CONTROL OF ANNUAL GRASS WEEDS IN CROPS AND IN THE FALLOW WITH HALOXYFOP ETHOXYETHYL, IN AUSTRALIA.

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ABSTRACT

Field trials with haloxyfop ethoxyethyl ester (EE) (DOWCO* 453) (2-ethoxyethyl 2 - [4 - (3-chloro-5-trifluoromethyl-2-pyridyloxy) phenoxy] propanoate), between 1982-85 have shown that reliable control of grass weeds can be obtained in winter crops (lupins, field peas), summer crops (cotton, sunflower, sugarcane, soybean, peanuts, lucerne) and in the fallow.

In winter crops and winter fallow haloxyfop EE at 60g ae/ha consistently gave 100% control of young (two to three leaves to early tillering) wild oats (*Avena fatua*) and ryegrass (*Lolium rigidum*). When compared to fluazifop-butyl on an active ingredient basis, 50% less haloxyfop EE was required to give similar grass control.

When applied to seedling (three to five leaves) barnyard grass (*Echinochloa colona*), liverseed grass (*Urochloa panicoides*) and crowfoot grass (*Eleusine indica*) growing in summer broadleaf crops, haloxyfop EE gave good control at 30g ae/ha to 100g ae/ha. Activity was influenced by environmental conditions at application. Grass weeds exhibiting slow growth caused by low soil moisture required 60g ae/ha of haloxyfop EE for commercially acceptable control. Haloxyfop at rates as high as 240g ae/ha did not significantly damage lupins, field peas, sunflowers, soybeans, peanuts and sugarcane. Results indicated a degree of phytotoxicity to cotton when applied at 240g ae/ha.

In summer fallow, in the absence of crop competition, higher rates of haloxyfop EE (100-150g ae/ha) were required to give commercially acceptable grass control. Glyphosate at 180g ae/ha gave a comparable level of grass control. Haloxyfop EE was found to be at least twice as active as fluazifop-butyl.

In all trials haloxyfop EE treatments contained either non ionic surfactant (0.125% - 0.25%) or crop oil (1.0%) in the spray volume. Haloxyfop EE has given excellent control of annual grass weeds with boom spraying at 60 to 200 L/ha. The effect of heavy and moderate simulated rainfall 30 and 90 minutes after spraying was variable on the activity of haloxyfop EE, depending on grass species and herbicide rate. Reduced control with watering was generally slight and paspalum (*Paspalum dilatatum*) was affected more than narrow leaf carpet grass (*Axonopus affinis*). Spray volume was investigated on these two perennial grasses and haloxyfop gave effective control with 58-417 L/ha, but with adequate surfactant higher spray volumes were more effective.

Results from Australian field trials show that haloxyfop EE can be applied to annual grasses anytime from emergence through to heading although the optimum stage of growth for application has been found to be when grass weeds are growing actively in the 3 leaf to early tillering stage of growth.

* Trademark of The Dow Chemical Company.

INTRODUCTION

Haloxyfop ethoxyethyl (DOWCO 453* EE) is one of several new selective post-emergent herbicides being developed for the control of grass weeds in broadleaf

crops. The activity of post-emergent applications of haloxyfop to both annual and perennial grasses and its selectivity to most broadleaf crops has been reported. (Handly and Hammond, 1983; Hunter and Barton, 1983 and Pongponratin, 1983). The experiments reported here are from work carried out to determine the efficacy of haloxyfop on the common grass weeds found in Australian broadleaf cropping systems. Data is also presented from experiments carried out to determine tolerance of lupins, field peas, sunflowers, soybeans, peanuts, sugarcane and cotton to haloxyfop EE.

MATERIALS AND METHODS

Crops and fallow. Field trials were laid down at a number of locations representative of the major broadacre cropping regions of Australia from 1982 to 1985. Several formulations of haloxyfop EE were applied to grass weeds growing in broadleaf winter and summer crops and fallow to establish dose response data, and crop tolerance. Grasses at application ranged in size from seedling (3-5 leaves) to tillering. Commercial standards included glyphosate, fluazifop-butyl and diclofop-methyl. Trials were mainly in a randomized complete block design with adjacent unreplicated constant rate or logarithmic screening plots.

Treatments were applied with an Azo propane sprayer and volume ranged from 60 to 200 L/ha but was mostly 100 L/ha. Nozzles used included Teejet 8001, Albuz 90 yellow and Albuz 110 flat fan brown (60 L/ha), Hardi 4110-10 to give 100 L/ha, and Hardi 4110-16 (200 L/ha), mounted at 50 cm centres and 50 cm above target weeds and operated at 200-250 kPa.

Unless noted otherwise all haloxyfop EE treatments were applied with the addition of either non-ionic (Agral 60) surfactant at the rate of 0.125-0.25% of the spray volume or crop oil at the rate of 1.0% of the spray volume.

Assessments of weed control and crop tolerance were taken four to six weeks post application. Visual ratings were recorded on a 0 to 10 scale with 10 representing complete control. Where possible plant counts were taken from five random 0.1 m² quadrats per plot. Crop tolerance was assessed from visual ratings and at some sites by obtaining yields from a 1.25 m swath with a Hege small plot harvester.

Rainfastness and spray volume. Trials were conducted on mixed grasses in Sydney in summer 1984/85 and autumn 1985. Haloxyfop EE was sprayed at 125-500 g EE/ha and simulated rainfall was applied through spraying systems 43H handgun with D8 orifice to give heavy rain (6.5 mm in 10 minutes at site 1 (12-12-84), 4.5 mm in 10 minutes at site 2 (4-4-85), and moderate rain (2 mm in 10 minutes at site 1, 1.5 mm in 10 minutes at site 2), each close to 30 and 90 minutes after spraying haloxyfop, and these were compared to no simulated rainfall. Paspalum (*Paspalum dilatatum*) and narrow leaf carpet grass (*Axonopus affinis*) were assessed for brownout on a 0-10 rating where 10 = complete brownout.

For spray volume, three trials were conducted in 4 x 4 Latin square plots. In trial 1, sprayed 14-12-84, haloxyfop 125 and 250 g EE/ha were each compared at 85 and 293 L/ha. In trial 2, sprayed 4-4-85, haloxyfop formulation containing

surfactant and 375 g EE/ha was applied at 58, 149, 240 and 417 L/ha with spraying systems 8001E, 8002E and 8006E nozzles and surfactant concentration was 2.7, 4.8, 7.6 and 19.6 mL/L respectively. Trial 3, sprayed 10-4-85 was a repeat of trial 2 except that surfactant was kept constant at 19.6 mL/L.

RESULTS AND DISCUSSION

Crops and fallow. Haloxypop EE applied at 60 g ae/ha gave satisfactory control of liverseed grass and barnyard grass (Table 1). When the rate was increased to 120 g ae/ha the level of control was increased with less variability. These two grasses are considered to be the dominate annual summer grass weeds of Australian cropping systems. Traditionally they have been controlled by preemergent applications of trifluralin. The advent of reduced tillage practices in Australia has necessitated the need for herbicides which do not require incorporation. Haloxypop EE and related compounds will enable growers to confidently control grass weeds post-emergence.

Table 1. Annual grass control following post-emergent application of haloxypop EE in Australia 1982-85.

Treatment	g ae/ha	Mean percentage control four to six weeks post application (Coefficient of variation* amongst means)				
		Liverseed Grass	Barnyard Grass	Wild Oats	Rye Grass	Brome Grass
1. haloxypop EE [No. of Sites]	30	(-)	(-)	82 (17.5%) [8]	71 (33%) [10]	75 (30%) [6]
2. haloxypop EE [No. of Sites]	60	80 (27%) [8]	70 (28%) [11]	88 (14%) [14]	88 (17%) [10]	85 (25%) [6]
3. haloxypop EE [No. of Sites]	120	85 (21%) [8]	89 (10%) [8]	(-)	(-)	(-)

* Coefficient of variation according to method from Steel and Torrie (1980, p 26-29).

(-) Treatment not included.

To achieve satisfactory control of wild oats, ryegrass and brome grasses 60 g e.e./ha of haloxypop EE was required. Variability was too great with haloxypop EE at 30 g ae/ha on the above grasses. These annual winter grasses have become a major weed problem in winter legume crops such as lupins and field peas, which have become significant crops in Australia. The yield improvement of lupins and field peas following application of haloxypop EE is shown in Table 2. Haloxypop EE applied at 30 and 60 g ae/ha gave a mean yield increase of 156 and 143% respectively. At several sites haloxypop EE was compared against fluazifop-butyl and glyphosate. Results in Table 3 show that comparable levels of grass control are achieved with haloxypop at 60 g ae/ha to fluazifop at 120 and glyphosate at 180 g ae/ha, on winter grasses. The activity range on summer grasses is increased by a factor of two.

Table 2. Grain yield following application of haloxypop EE in Australia 1982-85.

Treatment	g ae/ha	Percentage grain yield untreated expressed as 100%						
		Lupins	Lupins	Lupins	Lupins	Lupins	Lupins	Field Peas
1. haloxypop EE	0	100	100	100	100	100	100	100
2. haloxypop EE	30	195	262	600	104	373	121	140
3. haloxypop EE	60	200	341	650	98	135	116	162

Table 3. Comparative annual grass control in Australia 1982-85.

Treatment	g ae/ha	Mean percentage control four to six weeks post application			
		Liverseed Grass (4)	Barnyard Grass (5)	Wild Oats (4)	Rye Grass (3)
1. haloxypop EE	60	36	(-)	86	79
2. haloxypop EE	120	75	84	(-)	(-)
3. fluaxifop-butyl	125	(-)	(-)	75	72
4. fluaxifop-butyl	212	80	86	(-)	(-)
5. glyphosate	180	80	80	87	80
6. glyphosate	360	93	100	(-)	(-)
7. diclofop-methyl	562	(-)	(-)	65	(-)

(X) Number of sites.

(-) Treatment not included.

Rainfastness. In trial 1 the effect of simulated rainfall and haloxypop 125, 250 and 500 g EE/ha on paspalum (P) and narrowleaf carpetgrass (CG) was assessed 21, 30, 41, 65 and 78 days after treatment (DAT). For P watering slightly reduced the effect 21 DAT and this was more evident with 250 and 500 g EE. At 78 DAT both heavy and moderate watering 30 and 90 minutes after spraying reduced the effect on P with haloxypop 500 g EE/ha. With 250 g EE heavy watering reduced the effect at both times but moderate watering did not. Watering did not have any effect on the result with haloxypop 125 g EE/ha.

For CG 78 DAT heavy watering at both times and moderate watering at 30 minutes had most effect with 125 g EE. The effect on higher rates of haloxypop was negligible and moderate simulated rain 90 minutes after spraying improved the control of CG with haloxypop 500 g EE/ha.

In trial 2, haloxypop 250 and 500 g EE/ha was applied and effect of watering assessed at 21, 56 and 89 DAT. Moderate watering 90 after spraying improved control of P and CG with haloxypop 250 g EE/ha.

Spray volume. Handly and Hammond (1983) showed that giant foxtail (*Setaria faberi*) was controlled equally with 67 g ae/ha haloxypop ME + 2.33 L of crop oil concentrate in 93, 186 and 392 L/ha. In trial 1 in Sydney, 293 L/ha was superior to 85 L/ha with both rates of haloxypop 28 DAT. The higher volume was better on CG 78 DAT but there was no difference on P.

In trial 2, 30 DAT the highest spray volume (417 L/ha) was significantly inferior and was marginal at 55 DAT. 58, 149, 240 and 417 L/ha gave similar grass control 88 DAT, 93-95% brownout.

In trial 3, difference in spray volume was slight 24 and 49 DAT but at 82 DAT control of P and CG was superior with the two highest volumes, 240 and 417 L/ha. The following grasses were present at the time of spraying rainfastness and spray volume trials and are written in order of decreasing susceptibility to haloxyfop EE, narrow leaf carpet grass, paspalum, kangaroo grass (*Themeda australis*) slender pigeon grass (*Setaria gracilis*), brown's love grass (*Eragrostis brownii*) and rats tail grass (*Sporobolus africanus*).

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FLUROXYPYR, PICLORAM, TRICLOPYR AND CHLORPYRALID FOR BROADLEAF WEED CONTROL IN MALAYSIAN PLANTATION

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ABSTRACTS

Fluroxypyr, picloram, triclopyr and chlorpyralid, developed by Dow Chemical Co., have similar biological activities against broadleaf weeds. Field trials in other parts of the world indicate that these chemicals are very active against broadleaf weeds, brushes and as tree killers in forestry.

Intensive and extensive field trials under Malaysian plantation conditions confirmed that fluroxypyr, picloram, triclopyr and chlorpyralid are very effective against major soft and hard-to-kill broadleaves.

Generally, picloram is more active than fluroxypyr followed by triclopyr and chlorpyralid on all treated weed species.

Asystasia sp., soft but troublesome and increasingly becoming the major weed in Malaysian plantation - can easily be eradicated with 2-3 rounds of either picloram, triclopyr or fluroxypyr between 30-45 g ae/ha each round.

Picloram, fluroxypyr and triclopyr at 100 g ae/ha and chlorpyralid at 150 g ae/ha provide four months excellent control against three species of legume creeping covers (*Pueraria phaseloides*, *Centrosema pubescens* and *Calopogonium mucunoides*) while *Mikania micrantha*, requires at least picloram 75 g ae/ha, fluroxypyr 150 g ae/ha, triclopyr 300 g ae/ha and chlorpyralid 300 g ae/ha for four months excellent control. Efficacy studies on hard-to-kill woody brushes eg. *Melastoma malabathricum*, *Clidemia hirta*, *Lantana camara*, *Eupatorium odoratum* and wild rubber seedlings are currently in progress.

The rate indicated for each individual weed species above is effective when applied either by conventional knapsack spraying (400-500 L/ha) or CDA applicators (25-60 L/ha).

Current trials are in progress for a combination of each one of these broadleaf herbicides with a suitable grasskiller for use as a general weed control herbicide.

INTRODUCTION

Up-to-date toxicological and environmental studies conducted by the Dow Chemical Co. indicate that fluroxypyr (4-Amino-3,5-Dichloro-6-2 pyridioxyacetic acid), Picloram (4-amino 3,5,6 Trichloropicolinic acid), Triclopyr (3,5,6-Trichloro-2-pyridyloxyacetic acid) and chlorpyralid (3,5-Dichloropicolinic acid) are not likely to cause any serious environmental and safety problems.

Studies to-date indicate that fluroxypyr, triclopyr and chlorpyralid degrade under field conditions considerably much faster than picloram. They degrade quite rapidly in the soil under temperature and moisture conditions favourable for microbial activities.

These chemicals are absorbed by both leaves, roots, and stems and are readily translocated within plants, inducing characteristic auxin-type responses. They are systemic herbicides which do not only destroy the leaves of the weeds but are also absorbed into the branches and completely destroy the whole plant. Broadleaf plants exhibit typical twisting and curling of leaves and stems.

Triclopyr is being used extensively in oil palm where its selectivity is remarkable. However, the effects of fluroxypyr and chlorpyralid are currently being studied in oil palm and up-to-date preliminary results are encouraging.

Oil palm is a sensitive crop; translocated and/or hormonal type of herbicides are seldom –if any – being used. This means that fluroxypyr, triclopyr and chlorpyralid will be good substitute – either alone, in sequential or in combination with other grasskillers – to the current practice of manual pulling (in cases of leguminous creeping covers) or manual weeding or the use of contact herbicides for maintenance of circles and harvestors' paths. They also open the way to the use of chemicals in effectively controlling noxious and fast spreading *Asystasia* spp, hard-to-kill broadleaves like *Mikania micrantha*, *Clidemia hirta* and woody brush weeds like *Melastoma malabathricum* Linn., *Lantana camara* Linn. and wild rubber seedlings in the inter-rows of oil palm and rubber plantations.

This paper reports on the comparative efficacy studies of fluroxypyr, picloram, triclopyr and chlorpyralid against three major species of leguminous creeping covers (*Pueraria*, *Calopogonium* and *Centrosema* species) *Asystasia* sp. and *Mikania micrantha*.

MATERIALS AND METHODS

All trials were conducted in the inter-rows of either immature oil palm or immature rubber areas (ie. exposed to full sunlight). In site selections, appropriate care was taken to make sure that the target weed species were matured, uniform and well-established, growing in sheet with as little of other species present as possible. Trials were done in a complete randomised block design with treatments replicated at least four times with each plot measuring 6 × 4 sq.m.

Application volume was fixed at 500 litres per hectare. All chemical applications were done with a shoulder knapsack sprayer equipped with a single nozzle lance, with a flood jet type (ICI Blue polyjet size 0.062) that could deliver a swath 2 meters wide if held 45-60 cm above the weed tops. The quantity of herbicide delivered per plot was calculated on the rates tested and the volume of diluted spray per plot based on the volume of application stated. By this method, the quantity of herbicide applied per sprayed hectare was always kept constant and conforms to the rates tested.

Visual evaluations of weed control were done fortnightly (where possible) by two persons standing at opposite ends of each plot. Control ratings were based on visual score of percentage kill and a rating scale of 0-100 were used, 0 = indicating no kill and 100 = complete kill. The Malaysian Standard practice on descriptive terms such as Satisfactory (70-80%) Good (80-90%) and Excellent (90% above) control were adopted in this paper. Where possible, trials were repeated or at least some desired treatments repeated on a different site to ensure there was consistency in results obtained.

Please note that unless otherwise stated all rates quoted in this paper are given as gm. acid equivalent in 50 litres spray volume per hectare.

RESULTS

1. *Asystasia* species

The excellent performance of fluroxypyr, picloram and triclopyr are illustrated in Tables 1A and 1B. Their biological activities seemed to be very similar with all the rates tested. Maximum kill occurred between 2-4 weeks depending on the rates used. These are true for both young and mature stand of *Asystasia* and under various soil types where the trials were conducted. *Asystasia* propagates profusely from seeds.

Table 1A Comparative efficacy studies fluroxypyr, picloram, triclopyr & chlorpyralid Mature *Asystasia* spp – 1985

No.	Treatment	Rate g ae/ha	% Control W.A.S.		
			2	4	6
1.	fluroxypyr	30	65	85	25
2.	"	45	95	95	45
3.	"	60	100	95	50
4.	picloram	30	65	85	25
5.	"	45	75	95	50
6.	"	60	100	100	55
7.	triclopyr	30	55	75	15
8.	"	45	65	90	25
9.	"	60	90	100	45
10.	chlorpyralid	30	0	0	0
11.	"	45	0	0	0
12.	"	60	0	0	0

Table 1B Comparative efficacy studies fluroxypyr, picloram, triclopyr & chlorpyralid Young *Asystasia* spp – 1985

No.	Treatment	Rate g ae/ha	% Control W.A.S.		
			2	4	6
1.	fluroxypyr	30	70	95	35
2.	"	45	100	100	60
3.	"	60	100	100	60
4.	picloram	30	70	95	25
5.	"	45	85	100	55
6.	"	60	100	100	55
7.	triclopyr	30	60	95	25
8.	"	45	70	95	35
9.	"	60	100	100	55
10.	chlorpyralid	30	0	0	0
11.	"	45	0	0	0
12.	"	60	25	35	0

Regeneration from the original stand was not observed. The decline in control ratings were due to germination (and consequent rapid growth aided by the disappearance of original stand) from the vast reservoir of seeds in the soil. Repeated (2-3) applications needed for complete eradication.

Chlorpyralid at various rates tested did not seem to have any control effect on *Asystasia*.

2. Leguminous Creeping Covers – *Pueraria* sp. *Calapogonium* sp. and *Centrosema* sp.

Four trials were conducted with leguminous creeping covers – two each in the inland (sandy clay loam) and coastal (heavy clay) areas of Peninsular Malaysia. Only results from two trials are presented here as they are similar.

Tables 2A and 2B indicate that fluroxypyr, picloram and triclopyr have similar biological activities against L.C.C. at various rates tested. Under various soil-types

Table 2A Comparative efficacy studies fluroxypyr, picloram, triclopyr & chlorpyralid L.C.C. – coastal soil – 1984

No.	Treatment	Rate g ae/ha	2	4	% Kill W.A.S.		10	12
					6	8		
1.	fluroxypyr	50	52	85	75	67	85	48
2.	"	100	75	85	95	95	95	95
3.	"	150	75	90	100	100	100	100
4.	picloram	50	30	55	75	82	55	35
5.	"	100	68	95	100	100	100	100
6.	"	150	75	100	100	100	100	100
7.	triclopyr	50	28	45	72	35	25	20
8.	"	100	75	85	95	90	85	82
9.	"	150	85	100	100	100	100	100
10.	chlorpyralid	50	10	35	15	10	5	0
11.	"	100	35	45	62	58	35	10
12.	"	150	65	85	95	96	95	85

Table 2B Comparative efficacy studies fluroxypyr, picloram, triclopyr & chlorpyralid L.C.C. – inland soil – 1984

No.	Treatment	Rate g ae/ha	2	4	% Kill W.A.S.		10	12
					6	8		
1.	fluroxypyr	50	55	80	85	75	65	54
2.	"	100	75	90	100	100	95	85
3.	"	150	75	90	100	100	100	100
4.	picloram	50	35	60	75	85	65	55
5.	"	100	65	90	100	100	100	100
6.	"	150	70	95	100	100	100	100
7.	triclopyr	50	25	55	65	45	35	15
8.	"	100	75	95	100	95	85	75
9.	"	150	80	98	100	100	100	100
10.	chlorpyralid	50	15	45	25	15	0	0
11.	"	100	30	50	75	65	35	10
12.	"	150	69	85	95	98	95	85

75 g ae/ha did not provide acceptable control while rates of 100 g ae/ha and above is sufficient to provide excellent control for a period of at least 4 months. The rate of browning off is slow and maximum kill is only observed for all rates tested between 4-6 weeks. At 150 g ae/ha, no regeneration of L.C.C. was observed while those that were found within the experimental plots at the end of the 4 months were encroachment from the sides. Grasses (mainly *Paspalum conjugatum*) emerged during the third month and occupied the plots 4 months after chemical application.

Chlorpyralid is less effective and a minimum of 150 g ae/ha is needed for adequate and acceptable control.

3. *Mikania micrantha*

Tables 3A and 3B indicate that for *Mikania micrantha*, there are differences in the rate of effectiveness between the four chemicals in both soil types. Picloram is the most active followed by fluroxypyr and triclopyr and chlorpyralid, the latter two

Table 3A Comparative efficacy studies fluroxypyr, picloram, triclopyr & chlorpyralid *Mikania micrantha* – inland soil – 1984

No.	Treatment	Rate g ae/ha	Weeks after spraying					
			2	4	7	9	11	13
1.	fluroxypyr	75	45	81	73	62	43	15
2.	„	150	92	95	100	100	97	95
3.	„	300	95	100	100	100	100	100
4.	picloram	75	85	95	100	100	100	100
5.	„	150	95	100	100	100	100	100
6.	„	300	95	100	100	100	100	100
7.	triclopyr	75	25	35	15	0	0	0
8.	„	150	33	75	55	48	0	0
9.	„	300	55	95	99	99	85	75
10.	chlorpyralid	75	25	43	38	15	0	0
11.	„	150	25	50	55	45	35	5
12.	„	300	55	95	98	99	86	78

Table 3B Comparative efficacy studies fluroxypyr, picloram, triclopyr & chlorpyralid *Mikania micrantha* – coastal soil – 1984

No.	Treatment	Rate g ae/ha	Weeks after spraying					
			2	5	7	9	12	14
1.	fluroxypyr	75	39	75	61	35	28	12
2.	„	150	85	92	100	100	95	94
3.	„	300	95	100	100	100	98	95
4.	picloram	75	75	88	100	100	100	100
5.	„	150	95	100	100	100	100	100
6.	„	300	95	100	100	100	100	100
7.	triclopyr	75	19	25	10	0	0	0
8.	„	150	35	75	45	35	0	0
9.	„	300	62	92	99	95	86	78
10.	chlorpyralid	75	19	41	35	15	0	0
11.	„	150	26	45	52	35	25	0
12.	„	300	49	85	98	99	87	75

have similar rate of activities. The maximum kill is achieved between 2-4 weeks in case of picloram and fluroxypyr whereas triclopyr and chlorpyralid between 4-6 weeks indicating slow rate of browning. Excellent control is achieved with 75 g ae/ha of picloram and this is equivalent to fluroxypyr and 150 g ae/ha and triclopyr and chlorpyralid both at 300 g ae/ha.

CDA Applications

All the trials with L.C.C., *Asystasia* and *Mikania micrantha* were repeated using CDA applicators. The volume used varies between 25-60 litres per hectare. The effect of the weeds on CDA is similar to that of conventional knapsack spraying.

DISCUSSIONS

Fluroxypyr and triclopyr (100 g ae/ha) provide at least four months excellent control of three Leguminous Creeping Covers (*Pueraria*, *Calopogonium* and *Centrosema* spp.) commonly planted as cover crops in Malaysian oil palm and rubber plantations. *Asystasia* is currently becoming a major weed appearing in sheets in both open immature areas and shady mature areas of oil palm and rubber. Because of its seeding capacity and rapid germination, sequential applications (at least 3 rounds) are needed for complete eradication. Fluroxypyr and triclopyr between 30-45 g ae/ha will provide acceptable control. Field practice have proved that 3 applications between 30-45 g ae/ha at 4-6 weeks interval are enough for complete eradication - 4 weeks interval is advised when the lower rate of 30 g ae/ha is used. *Mikania micrantha* is becoming less important as a weed can be effectively controlled with low rates of fluroxypyr (150 g ae/ha) and picloram (75 g ae/ha).

The use of phenoxy and other hormonal types of herbicides are limited only to non-sensitive crop like rubber and seldom, if any, being used in the oil palm due to the sensitive nature of the crop. Only contact herbicides (mainly paraquat), triclopyr and manual weeding are currently practised in oil palm circles and harvesters' paths. Triclopyr is unique in that it has been proven to be non-phytotoxic to oil palm at rates about 12x that were used in these efficacy studies. Fluroxypyr and chlorpyralid are currently being tested for safety in oil palm and preliminary results indicate very good margin of safety.

This will open the way to large scale chemical weeding in oil palm areas not only in L.C.C., *Mikania* and *Asystasia* but also include weeds like *Eupatorium odoratum*, *Melastoma malabathricum*, *Clidemia hirta* which are usually found in the inter-rows of not-so-well-managed oil palm plantations.

The current good husbandry practices of planting cover crops in oil palm and other plantation crops demand intensive use of labour to keep them away from circles and harvesters' paths. Triclopyr and fluroxypyr would find ready use in these areas due to its high effectiveness (even at low rates) to leguminous covers. As a consequence, this would help to solve current labour shortage problems and savings of supervisory and other "overhead" costs.

Current knowledge indicates that most grasses are resistant to triclopyr and fluroxypyr

and also current studies indicate that they are compatible with most grass herbicides. In actual field situations both broadleaves and grasses appear together. In order to broaden the spectrum to include grasses, trials are now in progress to find suitable combinations for a triclopyr fluroxypyr either as a tank-mix, in one formulation or sequential sprays for use as a general weed control herbicide that would be safe in the sensitive crops especially oil palm.

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HERBICIDE EVALUATIONS FOR WEED CONTROL IN COWPEAS

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INTRODUCTION

Cowpeas (*Vigna unguiculata* L.) are one of the most important crops grown in the United States (5) and throughout the world (2). Cowpeas are produced on approximately 12 million acres in the world. The popularity of the crop is gradually increasing in the developing countries due to its high protein content. It is consumed as dried or green beans, canned or frozen (4,5).

Due to increased demands for cowpeas (3), the need exists for efficient production of this crop. However, one of the limitations farmers have to face is weed infestation. So far very little attention has been given to chemical weed controls in cowpeas (1). Therefore, the objectives of this study were:

1. to evaluate the effects of herbicides on weed control in cowpeas, and
2. to evaluate the effects of weed control treatments on injury and yield of cowpeas.

MATERIALS AND METHODS

In 1982 and 1983 field experiments were conducted on the Tuskegee University Farm in Alabama on Norfolk Sandy Loam to which one ton of lime and N P K at 30, 30, 50, and 30, 50, 50 *lbs/acre* were added each year. Both experiments consisted of three chemicals applied at three concentrations and an untreated control. The herbicides were Dual [2-chloro-N-(2-ethyl-S-6-methyl phenyl) N-(2-methoxy-1-methyl ethyl acetamide)] at 2, 4 and 6 *lbs/acre*; Bicep (metachlor atrazine 2 (chloro-4-(ethylamino)-6-isopropylamino s-triazine) at 2.25, 4.50, and 6.75 *lbs/acre*; and Surflan (3, 5-dinitro-N4, N4-dipropyl sulfanilamide) at 1, 2, and 3 *lbs/acre*. The preplant herbicides were applied with knapsack sprayers in 24 inch bands at the rate of 240 gallons/acre water and were incorporated with garden rakes. The two cultivars of cowpeas were Mississippi Silver and Pinkeye Purple Hull. The study was conducted as a randomized complete block design with four replications. Seeds were planted in 15 foot rows, 3 per plot spaced 3 feet apart.

Weed control was rated by comparing the treated plots with the untreated control. An area of one square foot was used as the unit to be compared. Three readings were taken per plot and the average used to compute the ratings. Readings were

taken at two week intervals up to the eighth week of growth. Readings were converted to percentages and rated on a scale of 0 to 100 with 0 equalling no control and 100 equalling excellent control. The predominant weeds in the plots were pigweed (*Amaranthus* sp.), broomweed (*Sida* sp.), large crab grass (*Digitaria decumbens*), morning glory (*Ipomea* sp.), common pusley (*Portulaca oleracea*), bermuda grass (*Cynodon dactylan*), carpet weed (*Mollugo verticulata* L.), nut grass (*Cyperus rotundus*), and goose grass (*Eleusine indica* L. Gaertn.). Crop injury was rated by comparing the treated plots with the untreated control; based on the degree of injury observed a rating of 0 to 100 was assigned, 0 being no injury and 100 being total crop loss. Readings were taken every two weeks until the eighth week. Ripe pods were picked several times during the harvest and the total pounds of marketable fruits per plot were used as the avaluation criterion for yield in each experiment.

RESULTS AND DISCUSSION

Weed control

Both broadleaved and grass-type weeds with the exception of nut grass were controlled by all the herbicides used; none of the herbicides controlled nut grass. Control ranged from 55% to 100% in 1982 and 77% to 100% in 1983. The higher weed control rating in 1983 could be due to heavier rainfall early in the season. At the final reading in 1982 weed seedlings were much larger than those at the same period in 1983. The plots treated with Dual at 2 *lbs/acre* had the largest number of weed seedlings. The average weed control rating in Table 1 indicated Dual to be the least effective herbicide for controlling weeds, with ratings of 55% to 85%. Bicep showed ratings of 85% to 100% and Surflan 90% to 100%.

Table 1. The effect of herbicide concentration on weed control in cowpeas.

Treatment	Rate <i>lbs/ac.</i>	Control Rating %	
		1982	1983
Dual	2.00	55	77
Dual	4.00	80	88
Dual	6.00	85	85
Bicep	2.25	85	87
Bicep	4.50	90	92
Bicep	6.75	100	100
Surflan	1.00	90	92
Surflan	2.00	94	100
Surflan	3.00	100	100
Untreated control	0	0	0

Crop injury

All the herbicides tested proved injurious to the crop at the highest rates of application, with Bicep causing the greatest injury. Seed germination in both years was approximately 100%. By the end of the second week in 1982, seedlings began

showing signs of injury. Seedlings that were fully emerged wilted, while those just emerging showed signs of chlorosis with necrotic margins. In 1983 by the end of the first week of growth, injury was prominent. This could be due to heavy rains six days after planting, resulting in seeds absorbing more of the chemicals in 1983 than in 1982, when there was no rainfall until the sixth week after planting. Although water was added in 1982 it was apparently not of the magnitude to cause as much injury.

Cultivar injury data (Table 2) show that in 1982 Mississippi Silver plots treated with Dual developed injuries of 10–45%. Bicep injured up to 96% of the plants, with the 2.25 *lbs/acre* application causing injuries equivalent to the highest rate of Dual. Injuries caused by Surflan ranged from 13–50%. Pinkeye Purple Hull showed less injury at the higher rates, with injuries ranging from 20–28% with Dual, 58–89% with Bicep, and 20–28% with Surflan. In 1983 (Table 3) Mississippi Silver sustained injuries of 48–50% from Dual, 70–99% from Bicep, and 40–50% from Surflan. Pinkeye Purple Hull, on the other hand, suffered injuries ranging from 26–39% with Dual, 58–89% with Bicep and 34–39% with Surflan. Mississippi Silver in 1983 sustained much more injury than Pinkeye Purple Hull.

Table 2. The Effect of weed control treatment on Cowpeas injury (1982)

Treatment	rate <i>lbs/ac.</i>	% injury	
		MS	PPH
Dual	2.00	10	20
Dual	4.00	25	22
Dual	6.00	45	28
Bicep	2.25	44	58
Bicep	4.50	95	86
Bicep	6.75	96	89
Surflan	1.00	13	34
Surflan	2.00	37	34
Surflan	3.00	50	39
Untreated control	0	0	0

MS = mississippi Silver, PPH = Pinkeye Purple Hull.

Table 3. Effect of Weed Control Treatment on cowpeas Injury (1983)

Treatment	Rate <i>lbs/ac.</i>	% injury	
		MS	PPH
Dual	2.00	48	26
Dual	4.00	48	35
Dual	6.00	50	38
Bicep	2.25	70	58
Bicep	4.50	90	86
Bicep	6.75	99	89
Surflan	1.00	40	34
Surflan	2.00	49	34
Surflan	3.00	50	39
Untreated control	0	0	0

MS = Mississippi Silver PPH = Pinkeye Purple Hull

Uncontrolled weed growth reduced yields by 65–86%. In 1982 yields from the untreated plots were reduced by 80–86%, while in 1983 yields were reduced by 65–67%. The fact that yield reductions were higher in 1982 could be due to a drier growing season in 1982 than in 1983.

Cultivar response to treatments (Table 4) in 1982 showed that Mississippi Silver plots treated with Dual steadily declined in yield as the herbicide concentration increased. At 6 *lb/acre*, yield was reduced by 50%. This was 54% lower than the highest yield for that cultivar in the study. With Bicep, yields at 6.75 *lb/acre* were significantly less than the others; reduction was by 97%. Yields from the Surflan treated plots were the highest, with the lowest yield occurring at 3 *lb/acre* and equalling 50% of the yield at 1 *lb/acre*.

Table 4. Effect of Weed Control Treatment on Cowpeas yield (1982)

Treatment	Rate <i>lb/ac.</i>	Yields (<i>lb/ac.</i>)	
		MS	PPH
Dual	2.00	3973.7a	2868.9ab
Dual	4.00	2879.6bc	3569.9a
Dual	6.00	1931.6d	3079.1ab
Bicep	2.25	2155.9cd	2502.2bc
Bicep	4.50	692.6c	652.6d
Bicep	6.75	134.9e	174.4d
Surflan	1.00	4194.8a	2959.0ab
Surflan	2.00	3467.8ab	2909.9ab
Surflan	3.00	2108.0d	2161.9c
Untreated control	0	524.0e	706.2d

Means in the same column followed by the same letter are not significantly different at 5% level as determined by Duncans Multiple Range Test.

Pinkeye Purple Hull produced its highest yields with Dual at 4 *lb/acre*, with yields at 6 *lbs/acre* higher than those at 2 *lbs/acre*. The lowest yields were obtained from the Bicep treated plots, with a drastic decline as the concentration increased. The yields from the Surflan treated plots, although reduced as the rate of application increased, were not significantly different.

In 1983 (Table 5) the highest yields were produced by Mississippi Silver when plots were treated with 2 *lb/acre* of Dual. The yields resulting from all the rates of application were not significantly different. Bicep caused a drastic decline in yield as the concentration increased. Yields from the Surflan treated plots were not significantly different.

Pinkeye Purple Hull produced decreasing yields as the rate of Dual increased. The yield at 6 *lb/acre* was 9% less than that at 2 *lb/acre* and 28% lower than the highest yield of the cultivar. Bicep again caused a significant reduction. Surflan treated plots had the highest yields, with yields at 3 *lb/acre* being 72% of those at 1 *lb/acre*.

Table 5. Effect of weed control treatment on Cowpeas yield (1983)

Treatment	Rate lbs/ac.	Yield (lbs/ac.)	
		MS	PPH
Dual	2.00	2664.7a	2737.6a
Dual	4.00	3047.1a	2726.3a
Dual	6.00	2309.5ab	2535.9b
Bicep	2.25	1729.9c	1678.5bc
Bicep	4.50	595.8c	121.2c
Bicep	6.75	474.3c	217.1c
Surflan	1.00	2756.9a	3498.9a
Surflan	2.00	2799.9a	2870.4a
Surflan	3.00	2128.8ab	2516.9b
Untreated Control	0	1051.8bc	1148.8bc

Means in the same column followed by the same number are not significantly different at the 5% level of probability according to Duncans Multiple Range Test.

CONCLUSIONS

Surflan at 1 lb/acre gave the best control, followed by Dual at 4 lb/acre; Bicep was found to be toxic at all levels tested. Pinkeye Purple Hull was found to be more tolerant than Mississippi Silver to all the herbicides used.

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PADDY RICE WEED CONTROL WITH HERBICIDE MIXTURES OF NAPROANILIDE

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ABSTRACT

Naproanilide was developed as a herbicide for perennial weeds and annual broadleaf weeds in paddy fields, and has been used with other herbicides which control annual weeds such as *Echinochloa crus-galli*. These herbicide mixtures are called "one shot herbicides."

The mixture of naproanilide and butachlor is called Ohza in Japan, Shingran in Korea and Wangtso in the Republic of China. The mixture of naproanilide and pretilachlor is called Yohtol in Japan and Puljabi in Korea. The mixture of naproanilide and benthocarb is called Granock in Japan, Korea and the Republic of China.

Other herbicide mixtures, Sinzan (naproanilide, mefenacet and bromobutide), NTN-804 (naproanilide and mefenacet) and RPJ-842 (naproanilide and bifenox) have been developed.

In this report, we discuss the characteristics of these combination herbicides, especially efficacy against perennial weeds and weed control in direct-seeding rice production.

INTRODUCTION

Weed flora was affected by controlling only annual weeds for a long time in Japan, and we began to worry about perennial weeds such as *Sagittaria pygmaea*, *Sagittaria trifolia*, *Cyperus serotinus*, *Eleocharis kurogawai* and *Oenanthe javanica*. A similar problem exists in other countries where annual weed-herbicides have been used.

Naproanilide was developed for *Sagittaria pygmaea* in paddy fields by Mitsui Toatsu Chem. The herbicidal activity of naproanilide was already reported. Naproanilide controls annual broadleaf weed and *Sagittaria pygmaea*, but cannot control *Echinochloa crus-galli*, so naproanilide is used with other herbicides which control *Echinochloa crus-galli*.

These herbicide mixtures provided a broad spectrum of long-lasting weed control, but there is a difference in perennial weed control of these herbicides. In this report, we discuss their efficacy against some perennial weeds and application in direct seeding.

MATERIALS AND METHODS

(1) Control of perennial weeds

We used *Sagittaria trifolia*, *Cyperus serotinus*, *Eleocharis kuroguwai* and *Oenanthe javanica*. These tubers were collected in Chigasaki city. Four or 5 tubers were placed in each of a number of 50 × 50 cm concrete pots. We treated herbicides pre- and post-emergence. After about one month of treatment, we investigated each pot. Two replications were applied. Water depth was 3 to 5 cm at application time and was maintained at this depth with drainage of 1 to 2 cm/day.

Application time

<i>Sagittaria trifolia</i> :	pre-emergence	7 days after planting
	early post-emerg.	up to true leaf
<i>Cyperus serotinus</i> :	early post-emerge.	1-3 cm height
	post-emergence	around 7 cm height
<i>Eleocharis kuroguwai</i> :	early post-emerg.	below 1 cm height
	post-emergence	below 4 cm height
<i>Oenanthe javanica</i> :	post-emergence	below 2 cm height and 2.2 leaf stage

Herbicide mixture

Ohza G.	naproanilide/butachlor	2.1/1.05 kg ai/ha
Yohtol G.	naproanilide/pretilachlor	2.1/0.6 kg ai/ha
Granock G.	naproanilide/benthiocarb	3.0/2.1 kg ai/ha
Sinzan G.	naproanilide/mefenacet bromobutide	2.1/1.05/1.2 kg ai/ha
Shouron M.G.	chloronitrofen/dymron	2.7/2.1 kg ai/ha
Kusakarín G.	pyrazolate/butachlor	1.8/0.75 kg ai/ha

(2) Application of naproanilide mixture herbicides in direct seeding

Calcium peroxide coated rice seedlings were planted by machine. Plot size was 5 × 2 m and 2 replications were applied. When rice seedlings were at the 1, 2, 3 and 4 leaf stage, herbicides were applied and evaluated at 15 and 30 days after treatment.

Weed control and crop safety were evaluated by visual observation at regular intervals.

RESULTS AND DISCUSSION

(1) Control of perennial weed

Naproanilide mixtures control annual and troublesome perennial weeds such as *Echinochloa crus-galli*, *Scirpus juncoides*, *Monochoria vaginalis*, *Alisuma canaliculatum*, *Cyperus difformis* and *Sagittaria pygmaea* with one application in Japan.

There is no difference in the herbicidal efficacy on these weeds except for Sinzan G., which can control the high leaf stage of *E. crus-galli* and has good efficacy on

Cyperus spp. We compared the herbicide's efficacy on other perennial weeds.

Table 1 shows the efficacy of naproanilide mixture with various herbicides. Yohtol G. (naproanilide/pretilachlor) and Ohza G. (naproanilide/butachlor) had good efficacy at pre-emergence treatment of *S. trifolia*. At post-emergence treatment of *S. trifolia*, Yohtol G. and Sinzan G. (naproanilide/mefenacet/bromobutide) showed good weed control.

Table 1. Effects of naproanilide mixtures on perennial weeds

Treatment	Sag-T		Cyp-S		Ele-K		Oen-J
	pre	e-post	e-post	post	e-post	post	post
Ohza	12	25	0.04	8	10	25	14
Yohtol	9	13	0.2	8	16	17	26
Granock	46	58	2.6	11	5	3	34
Sinzan	1	4	0	5	0.1	1	0.7
Kusakarín	10	7	0.14	13	-	-	38
Shouron M.	-	-	-	-	16	37	-
No treatment							
dry weight (g)	23.280	16.872	53.767	93.477	28.927	28.972	41.826

1. Dry weight percent of control

2. Sag-T : *Sagittaria trifolia*
 Ele-K : *Eleocharis kuroguwai*
 Cyp-S : *Cyperus serotinus*
 Oen-J : *Oenanthe javanica*

3. pre : pre-emergence treatment
 e-post : early post-emergence treatment
 post : post-emergence treatment

4. See "Materials and Methods"

Regarding the efficacy of these herbicides on *Cyperus serotinus* at early post-emergence treatment, every herbicide showed good weed control. At post-emergence treatment, Sinzan G. and Ohza G. and Yohtol G. showed good weed control.

Regarding the efficacy of these herbicides on *Eleocharis kuroguwai* at early post-emergence treatment, every herbicide showed good weed control especially Sinzan G. and Granock G. (naproanilide/benthiocarb). Sinzan G. and Granock G. also showed good weed control at post-emergence treatment of *E. kuroguwai*.

Regarding the efficacy of these herbicides on *Oenanthe javanica* at post-emergence treatment, Sinzan G. showed good lethal efficacy with Ohza G. showing second best lethal efficacy.

Table 2. Efficacy of Sinzan in Water-seeded rice culture

Application time	Treatment	Ech-C		Cyp-D		Mon-V		BL		Sol-J		Sag-P		Crop safety	
		I	II	I	II	I	II	I	II	I	II	I	II	I	II
1 leaf stage	Sinzan	10	10	10	10	10	10	10	10	9	10	10	10	4	4
	Granock	9	10	10	10	10	10	10	10	9	10	9	8	2	1
	Sanbird	9	9	10	10	10	10	10	10	9	9	10	10	0	0
2 leaf stage	Sinzan	10	10	10	10	10	10	10	10	10	9	10	9	3	4
	Granock	8	10	10	10	8	9	9	10	6	8	7	7	1	2
	Sanbird	5	6	10	10	10	10	10	10	7	9	10	10	0	1
3 leaf stage	Sinzan	10	10	10	10	10	10	10	10	8	10	9	9	1	2
	Granock	9	10	10	10	7	8	10	9	7	8	7	8	0	1
4 leaf stage	Sinzan	10	10	8	10	10	10	10	10	7	10	8	9	0	1
	Granock	8	9	7	8	6	6	7	8	6	7	6	7	0	0
No treatment	No/m ²	15		200		37		582		92		107			
	g/m ²	36.8		24.8		22.4		24.3		34.8		10.1			

1. Evaluated by visual observations at regular intervals.

I =after 15 days

II =after 30 days

3. Sinzan : naproanilide/mefenacet/bromobutide 2.1/1.05/1.2 kg ai/ha
 Granock : naproanilide/benthillocarb 3.0/2.1 kg ai/ha
 Sanbird : pyrazolate 1.8 kg ai/ha

4. Ech-C : *Echinochloa crusos-galli*
 Mon-V : *Monochoria vaginalis*
 Sci-J : *Scirpus juncoides*
 Cyp-D : *Cyperus difformis* L.
 BL : *Broad Leaves*
 Sag-P : *Sagittaria pygmaea*

These herbicides have the same efficacy on annual weeds and some perennial weeds. Sinzan G. has better efficacy on *E. crusgalli* and *Cyperus* spp. like *S. juncoides* than other naproanilide mixtures (not shown in this report).

We will be able to control troublesome weeds in paddy rice production with the selection of certain herbicide mixtures, shown in Table 1.

(2) Application of naproanilide mixture herbicides in direct seeding

Granock G. (naproanilide/benthillocarb) and Sinzan G. (naproanilide/mefenacet/bromobutide) were applied and tested in water-seeded rice cultures.

Table 2 shows the results of the application in direct seeding. Sinzan G. was phytotoxic to rice below the 2 leaf stage, but above the 3 leaf stage rice damage was negligible. In every treatment, Sinzan G. showed excellent weed control. When Granock G. was applied to weeds before the 3 leaf stage, it showed good weed control.

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RICE WEEDS AND THEIR CONTROL IN IRAN

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ABSTRACT

The rice growing fields in Iran occupy a surface area of 470,000 *ha* and most of which are located in the northern part of the country, around the Caspian sea. The most dominant weeds present in rice fields are; *Echinochloa crus-galli*, *Cyperus difformis*, *Alisma plantago-aquatica*, *Sagittaria sagittifolia* and *Paspalum distichum*.

Untill 15 years ago, hand weeding and water management were the only weed control measures known by the farmers, now more than 70% of the rice fields are applied by herbicides such as oxadiazon, butachlor, thiobencarb, or molinate. The common method of application is sprinkling the EC formulation of herbicides right from the bottle to the fields' water.

INTRODUCTION

Rice is the staple food in Iran after wheat. It is produced on more than 470,000 *ha* annually. Its average yield is 2-3 tonnes per *ha*. 85% of this acreage, equivalent to 380,000 *ha* located in Northern provinces, around the Caspian Sea. About 10% is grown in the South and the remainder is distributed throughout the country. The climate in the North is wet and temperate with temperature ranges between -7° in winter and 40° C in summer. Average precipitation rate varies annually between 600 and 1800 *mm*. The climate of the other rice growing areas is relatively dry with low precipitation.

Rice irrigation is by continuous submersion in 5-15 *cm* water. The common cultural method is transplanting with some exceptions in South, where direct seeding is done by some farmers. the native cultivars which are grown by most of the farmers are of the indian type with long, slender, nonsticky grains. In recent years several hybrid varieties with high yield potential have been introduced.

Rotation is hardly practiced but double cropping with wheat, barley or clover is done by many farmers.

The average rice field holding per family is 1.8 *ha*.

Major Weed Problems

The most troublesome weeds of rice fields are listed in table 1. *Echinochloa crus-galli* brings about the main problem in rice throughout the country. *Cyperus difformis*, *Alisma plantago-aquatica* and *Sagittaria sagittifolia* cause damage in the North while *Scirpus maritimus* and *Amania multiflora* in Esfahan (Fatemi 1983). In a trial conducted in North the weeds have reduced 49% of the grain yield (Moussavi 1975).

Table 1. Common weeds found in rice fields in Iran

Name	Importance
<i>Alisma plantago-aquatica</i> L.	++
<i>Alisma lanceolata</i> With.	+
<i>Ammania multiflora</i> Roxb.	+++
<i>Alternanthera sessilis</i> L.	++
<i>Butomus umbellatus</i> L.	+
<i>Cyperus difformis</i> L.	+++
<i>Cyperus longus</i> L.	+
<i>Echinochloa crus-galli</i> (L.) Beoux.	+++
<i>Echinochloa colonum</i> (L.) Link.	++
<i>Eleocharis microcarpa</i> Steud.	++
<i>Eragrostis ciliarum</i> L.	+
<i>Fimbristylis littoralis</i> Gaud.	++
<i>Juncus articulatus</i>	+
<i>Lemna minor</i> L.	+
<i>Marsilia minuta</i> L.	+
<i>Paspalum paspaloides</i> L.	+++
<i>Potamogeton distinctus</i> A. Benn.	+
<i>Sagittaria sagittifolia</i> L.	++
<i>Scirpus maritimus</i> L.	+++
<i>Scirpus mucronatus</i> (L.) Palla.	++
<i>Scirpus juncoides</i> L.	+
<i>Typha latifolia</i> L.	+

Importance degree + little ++ medium +++ much

Paspalum paspaloides is also a problem especially in sloping fields or in places where shortage of water occurs.

Chemical control

The trials with herbicides begun in 1964 with propanil and continued with other herbicides comparing their rate, time and method of application with hand weeding (Mirkamali 1967, Mazaheri 1971, Bischoff 1971, Moussavi 1974-75, Fatemi 1981).

Investigations resulted in the recommendation of several herbicides which are listed in table 2. As shown, propanil and molinate are used in seedbeds. Molinate is also used in fields but not as widespread as other herbicides.

Table 2. Common herbicides recommended for transplanted rice

Place	Herbicide	Application	
		Rate (kg ai./ha)	Time
Seed beds	Propanil	4.5-5	1.5-2 leaf stage of <i>E. crus-galli</i>
	Molinate	3.5-4.5	1-1.5 leaf stage of rice or soil incorp. 3 days before seeding
Fields	Oxadiazon	0.36-0.48	1 day before or 3-7 days after transplanting
	Butachlor	1.8-2.4	3-7 days after transp.
	Thiobencarb	2.5-3	3-7 days after transp.
	Molinate	3.5-4.5	3-7 days after transp.

Oxadiazon, despite its initial phytotoxicity, still is well accepted by farmers. Butachlor and thiobencarb are also used as well as oxadiazon. Our recent experiments has shown that thiobencarb at rate of 2.5-3 kg ai./ha and Molinate at rate of 4 kg a.i./ha are suitable for direct seeding, either 3 days before seeding or at 1.5 leaf stage of rice seedlings.

2,4-D and bentazone are also recommended for controlling broad leaves or cyperaceus weeds.

There have been experiments for the control of *Paspalum paspaloides* and shown that this weed can be controlled by glyphosate before transplanting or by dalapon after harvest.

Farmers weed control technology

Up to 1965 because of abundant labor supply herbicides were unknown to rice growers and 2-3 times hand weeding and water management were the only control measures practiced.

In the early 1970s the cost of hand weeding became higher than chemical weed control (Maddah 1977), tables 3-4. It was around these years that chemical control became a component of rice growing operations in many farms. It is estimated that in 1985 herbicides will be applied to more than 70% of rice fields. The farmers unwilling to use herbicides will be among large families who possess ample free labor. Application of herbicides by farmers generally followed by hand weeding as a supplement to remove the survived weeds. With this method our farmers have managed to stop any flora shift and after about 15 years of applying herbicides in rice fields the weeds flora is unchanged in general.

Table 3. Average costs of rice production per ha in Iran (in 1985)

details	cost in US dollars	percent
Land preparation	700	21
Crop establishment	800	25
Weed control	250	7.5
(Hand weeding + Herbicide)		
Only hand weeding	400	--
One time herbicide	110	--
Harvest	1150	35
Other costs	400	11.5

Source; Agricultural extension report 1984

Table 4. Change of weed control costs in Iran 1964-84 (in us dollar)

details	1964	1975	1984
Chemical control	45	50	110
Hand weeding	40	80	400
One herbicide application	---	70	250
+Hand weeding			

Application of herbicides is usually done by sprinkling of the EC formulations right from the bottle to the field water. This simple method is well accepted by farmers, because it has solved their problems regard to spraying equipment and transportations. Our experiment has shown that there is not significant difference in effectiveness of herbicides between sprinkling or spraying of EC formulations in transplanted rice.

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SUCCESSFUL BIOLOGICAL CONTROL OF THE FLOATING WEED *Salvinia molesta* MITCHELL USING THE WEEVIL *Cyrtobagous salviniae* SANDS IN KERALA (INDIA)

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ABSTRACT

Salvinia molesta Mitchell, a non-flowering floating weed of South American origin, is found all over Kerala. Kerala Agricultural University started a scheme for the biological control of this noxious weed in 1972 and attempts using the aquatic grass-hopper, *Paulinia acuminata* DeGeer, failed.

The first shipment of *Cyrtobagous salviniae* Sands weevils arrived here on sixth October, 1983. They were released at different centres in the state. The insect has successfully established in all the centres of release. Yellowing of the weed mat was evident in four to six months after the release. Decaying and sinking of salvinia started ten to twelve months after the release. Twelve to sixteen months after the release nearly ninety-nine percent clear weed free areas were visible in certain localities. It is interesting to note that even a single fertile female has established under field conditions in some of the release sites.

INTRODUCTION

Salvinia molesta Mitchell is a non-flowering plant of South American origin. It is a member of Salviniaceae family, a family of two genera - *Salvinia* and *Azolla*. Wrongly identified as *Salvinia auriculata*, *S. molesta* has been reported from a wide range of nations like South Africa, Zambia, Kenya, Malaysia, Indonesia, New Zealand, Singapore, Australia, India and Sri Lanka.

S. molesta is seen all over Kerala. Its spread is most extensive in the districts of Alleppey, Kottayam, Ernakulam, Trichur, Quilon and Trivandrum. A recent survey in collaboration with the Department of Botany, University of Calicut, on the nature and extent of spread of salvinia in Kerala indicated that out of a total area of 38,900 sq.kms. in the State, salvinia infestation occurs in nearly 7,150 sq.kms.

Salvinia causes much damage to the nation in many ways. It is estimated that this molesting weed affects the daily life of about five million people in Kerala. Spilling on them, they lay waste fertile fields, enhance cost of cultivation, reduce crop yields, clog canals and water ways, impede navigation, irrigation and fish production, choke intake screens of hydroelectric projects, spread diseases and interfere with recreation pursuits and even domestic washing (Joy, 1978).

Surveys conducted by the Commonwealth Institute of Biological Control, Trinidad, singled out an aquatic grass-hopper, *Paulinia acuminata* De Geer, a pyralid borer, *Samea multiplicalis* Guenee, and a weevil, *Cyrtobagous singularis* Hulst, as the most

promising natural enemies of salvinia in South America (Bennett, 1966). Room *et al.*, (1981) reported successful biological control of salvinia in Australia using the weevil *C. singularis*. Dr.D.P.A.Sands, CSIRO Division of Entomology, Australia, found that the successful insect is not *C. singularis* but a new species to be called *Cyrtobagous salviniae* (Personal communication from Dr.P.M.Room, Principal Research Scientist, CSIRO, Division of Entomology, Australia).

MATERIALS AND METHODS

Breeding: Placed five pairs of weevils each in small plastic basins of 20cm. diameter containing fresh salvinia for oviposition. The weevils were transferred at weekly intervals using a camel's hair brush. The oviposited plants were placed in large cement tanks for emergence of the weevils.

Collection: The weevils were collected by immersing the rotting salvinia in water using a chicken wire mesh for three days. One or two bits of fresh salvinia may be floated on the water for collecting the emerging weevils.

Release: Open release method was adopted for releasing the weevils. Cages were found unnecessary and the number of weevils released at one site varied from one to two thousand.

RESULTS

The first shipment of 350 *C. salviniae* weevils arrived here from the National Centre for Biological Control, Bangalore, on sixth October, 1983. The second shipment of 75 weevils reached here on 28th October and the third shipment of 185 weevils on tenth November, 1983.

For field release and monitoring, the following sites were selected in Trichur, Kottayam and Alleppey districts, representing the areas facing the maximum threat of salvinia infestation.

- i. Panancherry and Elanjikulam (Trichur District)
- ii. Kumarakom and Athirampuzha (Kottayam District)
- iii. Moncompu (Alleppey District)

Panancherry: The pond at Panancherry is having an area of 272m². Altogether six releases were made at monthly intervals starting from October, 1983 and the total number released was 1577. Discolouration and yellowing of the plants due to feeding of the weevil grub was evident by March, 1984. Death and decay of the weed started by May and fairly widespread decaying by July, 1984 i.e., about eight months after the first release. The average weevil population was about 150/m² in July and the weight of the weed mat was about 11Kg/m². Nearly ninety nine per cent of the leaf buds were dead at that time. By January, 1985, the weevil population decreased to about 137/m² and the weed mass to 7 Kg/m². Sinking of the weed mat was partial and clear water pockets were not visible even by April 1985.

Elanjikulam: This pond is larger in size. Length 110m. and breadth 70m. with full

of tender actively growing salvinia at the time of release. Five releases were made commencing from January, 1984, and a total of 2102 weevils were released. By March, about twenty per cent of the leaf buds at the vicinity of the release site were found dead and by April, there were plenty of larvae and pupae at the site of release. Fairly widespread yellowing was visible by May and by July nearly thirty percent of the area of the pond turned brownish yellow indicating the death and decay of salvinia there. Almost hundred percent kill of the leaf buds was noted at the release site; nearly seventy five percent kill of the buds in the nearby areas of the release site where yellowing was evident and about forty per cent of the buds were found dead where no yellowing was noted. The weevil population was about $136/m^2$ at the release site; $62/m^2$ at the nearby areas having yellowing of the weed mat and $47/m^2$ where yellowing was not visible. The weight of the weed mat was 8, 8.34 and 9.41 Kg/m^2 respectively at the three locations. The pond was uniformly brownish by October 1984 and the sinking of the weed mat started by January, 1985. The average weevil population at this time was $120/m^2$ and weed weight $5.36 kg/m^2$. By February about thirty per cent area of the pond was cleared off and by late March, 1985, ninety nine per cent area of the pond was clear, leaving only a few bits of salvinia.

Kumarakom: Five pairs of weevils were released in a cement tank of about $0.6m^2$ on seventh October, 1983. Considerable feeding and damage of the weed mat inside the cement tank was observed in late December and the whole tank was emptied into a narrow canal, about 3m. wide and several meters long on December 30th, 1983. The weed mat in this area was fairly thick but of tender age. After about four months, conspicuous browning of the weed mat was visible for about 3m. length and after six months, nearly 12m. length of the canal showed clearly the decay symptoms. Twelve months after, the browning and decay further extended to a length of about 25 meters. Sinking of the weed mat started by February, 1985 and by March, clear water pockets were visible at the original site of release.

Athirampuzha: The canal at Athirampuzha is 2.5 meters wide and 90 meters long. Released fifty weevils on fifth November, 1983. The weed mat was tender and succulent and in about two months time, colour changes were evident. By the middle of January, 1984, yellowing was fairly widespread to about six meters. However, two more releases were made in January and March of one hundred and five hundred weevil respectively. By March, the death and decay of salvinia at the release site was conspicuous and by June (seven months after the first release) about ten percent surface area was weed free and the insect infestation was visible for a length of 12 meters. In another four months time, nearly ninety percent of the salvinia at the original site of release was cleared and the yellowing was visible to about twenty meters. By March, 1985, nearly ninety nine percent of the weeds in the area have disappeared for a length of about thirty meters.

Moncompu: Five pairs of weevils were released in a small canal of two meters wide and hundred meters long on October tenth, 1983. The weed mat was tender and succulent. Mild yellowing was visible by January 1985 and clear browning by March. The infestation spread to about six meters by June and to fifteen meters by October. By this time there was considerable death and decay at the release site. However, the trial here was abandoned later for various reasons.

DISCUSSION

Thus *C. salviniae* has established in all the centres of release but the degree of control obtained varies. At Panancherry the weed mass has been reduced considerably but weed free water pockets are not visible even eighteen months after the release. Under laboratory conditions also similar phenomenon was observed where the reduction in the weed growth was partial in a few experimental tanks with tender salvinia even eighteen months after the release. The reason for this is not clear yet. It appears that the nutrient factors are responsible for this as reported by Sands *et al.* (1983). But the water sample analysis showed that there is no significant difference in the content of major nutrients (NP&K). Further studies are in progress.

Forno *et al.* (1983) observed that the first instar *Cyrtobagous* weevils feed on young terminal buds for three to fourteen days and then only it turned inside the rhizomes and sometimes the petioles. This may be the reason for the quicker establishment of the weevils on tender salvinia where plenty of young buds will be available for the insect to feed and grow. More over the young growth of salvinia contain more of nitrogen which is favourable for the development of *Cyrtobagous* larvae (Sands *et al.* 1983). Thus it took nearly six months for the robust mature salvinia mat at Panancherry to show clear symptoms of yellowing whereas it took only four months to produce similar symptoms at Elanjikulam, Kumarakom and Moncompu where the salvinia was young and succulent. At Athirampuzha clear yellowing was visible about three months after the release.

The tropical climatic conditions in Kerala State seem congenial for the establishment of *Cyrtobagous* and the insect has successfully established in all the three districts selected for release. The temperatures in these areas vary from 23 to 34°C and it agrees with the preferred temperature range of *C. salviniae* (Forno *et al.*, 1983).

During the study the number of weevils released ranged from five pairs to one thousand. This shows that a number as low as five pairs of weevils is sufficient for establishing a colony of *Cyrtobagous*. Further studies in this line showed that even one fertile female is sufficient to establish a colony, both under laboratory and under field conditions. This quality of the insect may be due to its slow dispersal habit.

Room *et al.* (1981) reported a weevil population of 60 to 100 in lake Moondarra in northern Queensland. During the present study it was found that the weevil population ranged between 47 to 160. The larger weevil population in some of the ponds in Kerala may be due to the thicker weed mat which can support a larger insect population.

ACKNOWLEDGEMENTS

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THE APPLICATION OF AN IMIDAZOLINONE HERBICIDE AT LOW VOLUMES TO *Imperata cylindrica* (L.) Beauv.

P. Bacon

UK/Indonesia *Imperata* Project

INTRODUCTION

There is increasing evidence that the new group of imidazolinone herbicides show potential for controlling the perennial grass *Imperata cylindrica* (Bacon, P.S. 1984a, Bacon, P.S. 1984b, Bacon, P.S. and P.J. Terry 1984, Minimtim, M.B. *et al.* 1984). These herbicides are undergoing a period of rapid commercial development with intensive efforts being made to understand better their potential uses, mode of action and limitations (Fine, R.R. *et al.* 1983, Shaner, D.L. *et al.*).

Compared with existing herbicides recommended for controlling *Imperata* such as glyphosate (N-(phosphonomethyl)-glycine) and dalapon (2,2-dichloropropionic acid) imidazolinone herbicides have not been widely tested. Little is known so far about techniques which might be suitable for applying optimal doses of these herbicides in the field. Preliminary studies in the Philippines (Manimtim *et al.* 1984) indicate that application at intermediate volumes (100-200 l/ha) using low volume nozzles on knapsack sprayers may reduce activity. Glyphosate has been tested on *Imperata* using a range of low volume application techniques (Arif, A. and Sutomo, T. 1982, Arif, A. *et al.* 1984, Bacon, P.S. and P.J. Terry, 1984). Some of these low volume application techniques are now becoming accepted by plantation owners and are likely to gain wider acceptance due to their many significant advantages over conventional application methods.

For these reasons a number of experiments were included in the research programme of the U.K. Overseas Development Administration *Imperata* project based in Sumatra, Indonesia following on from tests with the herbicide AC 252925 (2-(4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl)-3-pyridine-carboxylic acid). Preliminary evaluations indicated that this herbicide could provide good long-term control of *Imperata* if applied at 1.0 kg a.e./ha in 350 l/ha water using conventional application methods (Terry, P.J. and P.S. Bacon, 1983). During a second year of testing it appeared that lower doses (0.5 and 0.75 kg a.e./ha) were not so successful when applied at approximately the same volume. There seemed to be a clear correlation between the dose applied and the resulting suppression of shoot regrowth. A separate trial established that low volume applications of AC 252925 at 1.0 kg a.e./ha in 20 l/ha water by spinning disc sprayer (Micron-herbi) could provide good control of *Imperata* which was emerging from a recent burn (Bacon, P.S. and Terry, P.J. 1983). Subsequent to this an experiment was initiated to determine the dose-response relationship

of AC 252925 when applied at low volumes using a spinning disk device. Details of this experiment are outlined below.

The possibility of using AC 252925 in mixtures with other herbicides has been discussed in earlier work (Bacon, P.S. 1984a). A small-scale field trial was initiated to determine if such mixtures would be suitable for applying to *Imperata* swards at low volumes. Details of this study are also outlined below.

MATERIALS AND METHODS

Experiment 1

Evaluation of the dose response relationship of AC 252925 when applied to *Imperata* swards at low volumes.

Experimental Design: randomised complete block four replicates

Plot Size: 5 m x 3.6 m

Treatments:

Herbicide	Dose (kg a.e./ha)	Volume (l/ha)	Application Device
1. AC 252925	0.5	20	SD
2. AC 252925	0.75	20	SD
3. AC 252925	1.0	20	SD
4. AC 252925	1.0	350	KS
5. Glyphosate	1.08	20	SD
6. Glyphosate	2.16	20	SD
7. Glyphosate	2.16	350	KS
8. Untreated control			

SD = Spinning Disc
KS = Knapsack Sprayer

Management:

Assessments were taken 55 days after application. After 100 days the weed growth on all plots was flattened with an empty oil drum. Regrowth from plots was assessed 165 days after application.

Application notes:

Knapsack applications were made with a CP3 sprayer with a red Polijet nozzle. Spinning-disc treatments were applied with a Micron-herbi. A yellow nozzle was used. The available formulation of AC 252925 is rather viscous and the Herbi has to be calibrated carefully to ensure even flow to the disc and correct dosage.

There were some application irregularities for treatment 5 which is reflected in the subsequent low level of *Imperata* control.

Site details:

Slightly sloping but weed cover uniform. Larger shrubs such as *Eupatorium odoratum* and *Melastoma malabathricum* were cut back prior to application. The mean height of the *Imperata* was approximately 85 cm and the shoot density

was approximately 200 per m². The main species recorded before application were *Aphaenandra uniflora*, *Cheilanthes tenuifolia*, *Scirpus mucronata* and *Scleria laevis*. Twenty-five species of flowering plants and ferns were recorded at the site prior to application.

Experiment 2

Evaluation of herbicide mixtures to determine their suitability for application at low volumes.

Experimental design: randomised complete block, two replicates.

Plot Size : 4.8 m x 2.0 m

Treatments: These are given in Table 1 with the results.

Site details : as for experiment 1 above.

Table 1. Emergence of main weed species 70 days after application.

treatment	dose (kg a.e./ha)	additive	dose	<i>Imperata</i> per m ²	<i>Aphaenandra</i> <i>uniflora</i> per m ²
1. AC 252925	0.5	none		49.6	6.8
2. AC 252925	0.5	glufosinate ammonium	1.2 kg a.i./ha	44.8	17.2
3. Glyphosate	1.08	none		50.4	55.6
4. Glyphosate	1.08	Ethokem	3 l/ha	48.0	70.4
5. Glyphosate	1.08	ammonium sulphate	3 kg/ha	75.2	72.4
6. Glyphosate	2.16	none		39.6	41.6
7. Untreated				132.0	24.8
8. Hand-hoe				123.6	46.0
LSD 0.05				37.78	34.6
C.V.				28%	35%

Application techniques:

All treatments were applied at a total volume of 20 l/ha using a spinning-disc device (Micron-herbi) with a yellow nozzle.

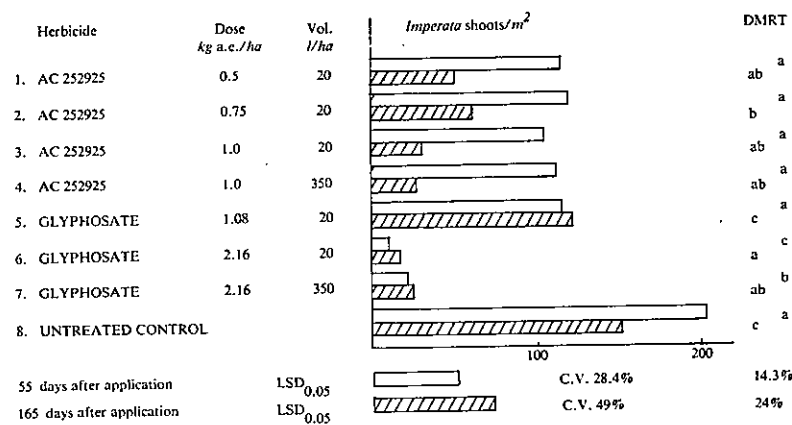
RESULTS

Experiment 1

These are outlined in Fig 1.

The first date of assessment after application reveals little difference between treatments other than that predictably high levels of destruction are obtained with

Fig. 1. Growth of *Imperata* shoots 55 and 165 days after application



* Any two treatments followed by the same letter are not significantly different at the 5% level of probability. Duncans multiple range test performed on data transformed to loge

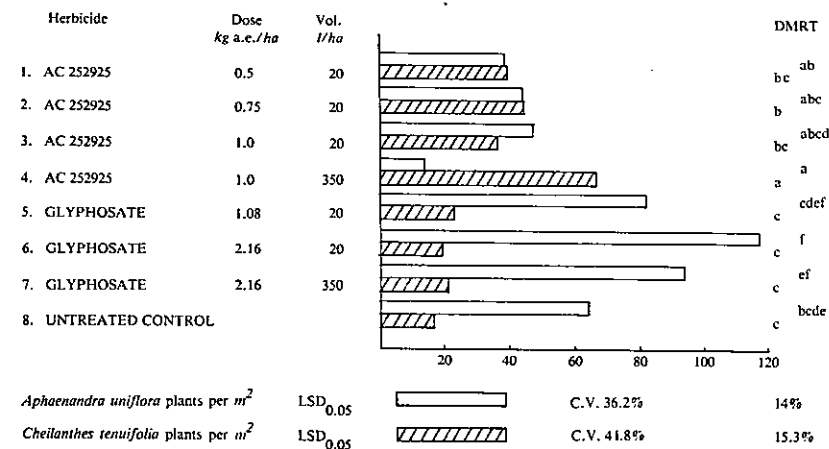
the highest dose of glyphosate. The lower dose did not appear to provide promising levels of control. The low volume application of glyphosate appeared to give better control than the high volume application even though the dose was the same.

The apparent lack of activity of the AC 252925 treatments is common and is a reflection of its very slow rate of destruction. At the first assessment date the sward was dull green in colour becoming necrotic but there were still living shoots. By 155 days after application, sward kill was complete and the level of destruction high particularly at the high dose of 1.0 kg a.e./ha. The lower doses appeared to provide good levels of destruction when applied at low volumes. There was no difference between the high dose applied at high volume and the same dose applied at low volume.

Changes in weed flora have been noted in previous studies where AC 252925 and glyphosate have been applied. These shifts were very strongly marked in this experiment as can be seen in Fig 2 where data for two of the more important species are presented. 160 days after application control of *Aphaenandra uniflora* is very good. At the high dose *A. uniflora* is almost eliminated whereas on plots treated with glyphosate the cover becomes so dense as to take up 90% of the living ground cover. This mat of foliage may well suppress regrowth of *Imperata* shoots. It is notable that the high volume application of AC 252925 gives significantly better control of *Aphaenandra* than the low volume treatments. Control of the *Cheilanthes tenuifolia* is very poor with AC 252925 applied at high or low volumes. Possibly this is due to the removal of competitive species, particularly, the *Imperata* and *Aphaenandra uniflora*. Application of glyphosate appears to have little effect on the control of *Cheilanthes*, compared with the untreated control. One species for which data is not presented (due to its sporadic

occurrence) is *Vitex* sp. This seemed to have a high level of resistance to AC 252925.

Fig. 2. Growth of two weed species 160 days after application



The response of treatments 1 to 6 was roughly the same and all gave significantly better control of *Imperata* than the control or the hand hoe treatment. The AC 252925 performed well and the mixture with glufosinate ammonium seemed to perform as well as the AC 252925 when applied alone. There was no evidence for any improvement of glyphosate activity by mixing with the additive Ethokem. There was no significant difference between the glyphosate applied at 1.08 kg and glyphosate applied at the same rate with 3 kg/ha ammonium sulphate but the trend was for the mixture to provide worse control. The low and the high rates of glyphosate performed similarly in this trial.

Control of other weed species followed the pattern found in other trials: Destruction of *Aphaenandra uniflora* was almost 100% 70 days after application where AC 252925 was used in the spray mixture. Where glyphosate was used there is massive infestation by *Aphaenandra*. A similar effect also occurs after hand-hoeing.

There were no obvious changes in other weed species following herbicide application.

DISCUSSION

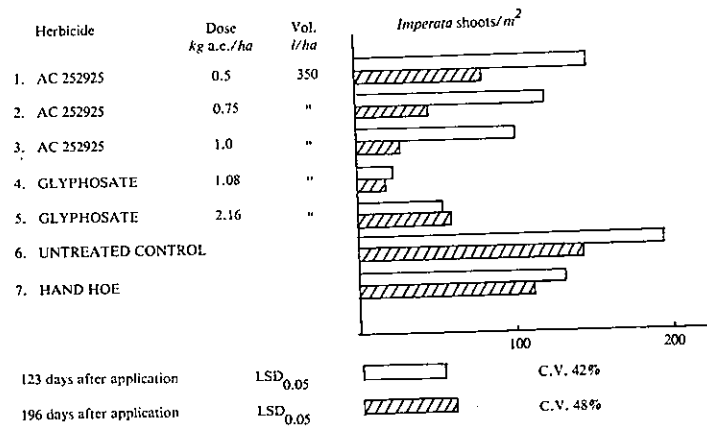
Experiment 1

The data presented for this trial makes an interesting comparison with that obtained from a previous trial (see Fig. 3) where the same range of doses of AC 252925 was applied at high volumes in a preliminary evaluation. The shoot kill obtained at the low volumes appears to be better than those obtained when

the same doses were applied at high volumes. This result is also obtained in further evaluations (see Fig. 4) where AC 252925 is applied at 0.5 kg a.e./ha at high volumes. This tendency is reversed for *Aphaenandra*. This may be because at low volumes there is relatively less movement of small spray droplets to ground level. This would reduce the rate of impaction of spray droplets on to the leaves of the low growing *Aphaenandra*. Clearly high and low volume applications of AC 252925 at these rates need to be compared in the same trial.

A summary of results from two years of herbicide evaluation

Fig. 3 Growth of *Imperata* shoots 123 and 196 days after application



The relative importance of herbicide uptake through the roots and through the shoots is not known for the herbicide AC 252925. However both points of entry seem to be important to effect adequate activity of the herbicide.

CONCLUSIONS

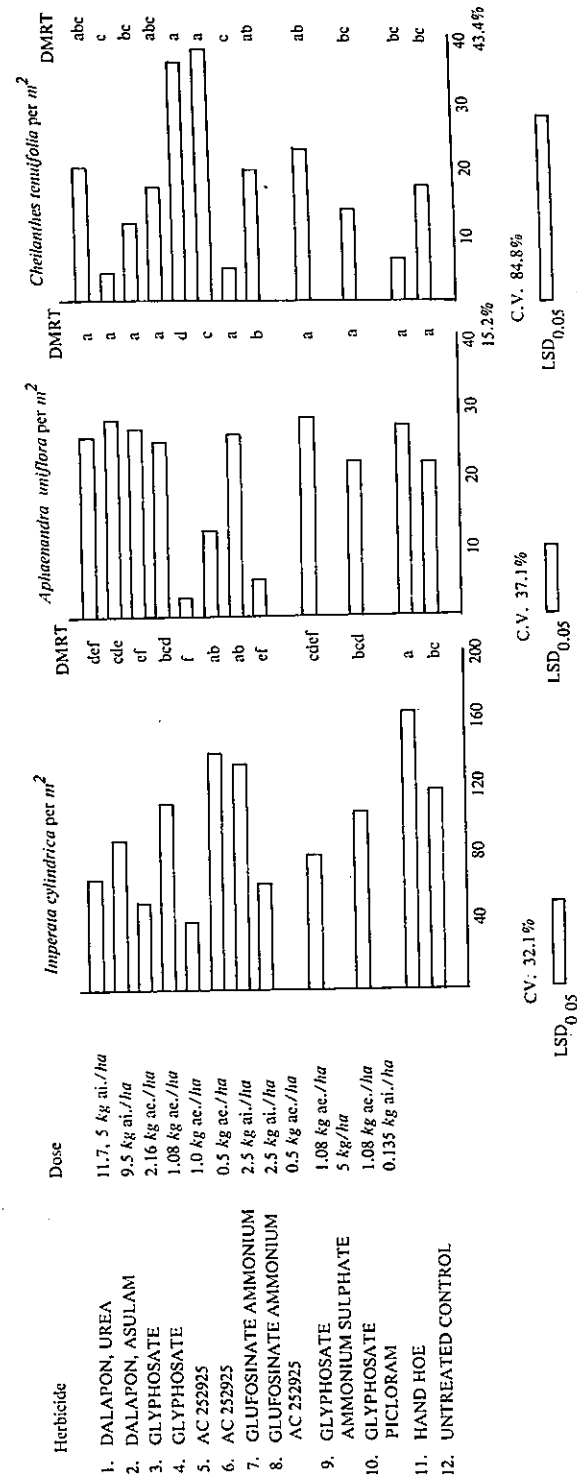
Experiment 1

The herbicide AC 252925 can be applied successfully at low volumes using spinning-disc applicators. Good kill of *Imperata* can be obtained by applying 0.5 kg a.e./ha using this method.

Experiment 2

1. The mixture of AC 252925 and glufosinate can provide effective control of *Imperata* when applied at low volumes.
2. Either of the additives Ethokem or ammonium sulphate do not enhance activity of glyphosate against *Imperata* or *Aphaenandra uniflora* when applied at low volumes.

Fig. 4. Weed counts 140 days after application



Summary of conclusions from both experiments

1. AC 252925 provides good control of *Imperata* when applied at low volumes.
2. There are indications that good control can be obtained at lower doses when the herbicide is applied at low volumes.
3. Mixtures of AC 252925 and glufosinate ammonium can provide good control of *Imperata* when applied at low volumes.

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THE CONTROL OF *Imperata cylindrica* (L.) BEAUV. BY GLYPHOSATE, SULFOSATE AND AC 252,925

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ABSTRACT

A field experiment evaluated two dosages each of glyphosate, sulfosate and AC 252,925 on the control of *Imperata cylindrica* (L.) Beauv. on peat. The most effective control was given by AC 252,925 at 1.25 kg a.e./ha, which provided 87.3% control 12 months after foliar application. In contrast, glyphosate at 2.16 and 4.32 kg a.e./ha and sulfosate at 1.85 and 3.70 kg a.e./ha provided less than 31 % control at 10 months. Four months after treatment, it was found that glyphosate at 4.32 kg/ha and AC 252,925 at 0.75 and 1.25 kg a.e./ha provided extensive kill of the rhizome systems, but some regrowth of rhizomes was already evident. Eight months after treatment, all herbicide treatments provided a significant reduction in the dry weight of undecayed rhizomes over the untreated control; the greatest reduction of 99.88 % was given by AC 252,925 at 1.25 kg a.e./ha. The significance of these findings are discussed.

INTRODUCTION

Imperata cylindrica (L.) Beauv., is considered to be the worst perennial weed in South-east Asia (Eussen and Wijahardja, 1973). In Malaysia, it is undoubtedly the most troublesome weed found in cultivated and non-cultivated land (Anon, 1976), and it is widely distributed in pineapple, rubber, oil palm and coconut (Lee, 1977). Of particular importance in more recent times has been the incidence of this noxious weed on the newly cleared peat swamp forests being used for the cultivation of banana, coffee, pineapple and vegetables. Its control is therefore of primary importance.

During the last decade, herbicides, particularly glyphosate have been used on an increasing scale for the control of *I. cylindrica* on peat. Wong (1975) reported that glyphosate at 1.7 kg a.e./ha provided 90-95% control in young rubber; in densely infested areas, a dosage of 3.3kg a.e./ha provided 94-96% control under unshaded conditions. Apart from glyphosate, two coded compounds have been introduced into Malaysia in 1983 for preliminary field tests. Sulfosate (SC - 0224), a product of Stauffer chemical company is a non-selective post-emergence herbicide for controlling both annual and perennial broadleaf and grass weeds. The perennial weeds controlled by sulfosate include *Sorghum halepense*, *Cyperus rotundus*, *Pennisetum purpureum* and *Convolvulus arvensis*. AC 252,295 is a broad spectrum herbicide which controls a wide range of annual and perennial weeds (Orwick *et. al.* 1983). Lapade *et. al.* (1983) reported that excellent control of *I. cylindrica* was

obtained at dosages of 0.5 to 1.0 kg a.e./ha of AC 252,925 in rubber and oil palm plantations in the Philippines. Bacon (1984) found that 1.0 kg a.e./ha appeared to be rate for the destruction of the weed under field conditions in Indonesia. This paper reports the findings of a field experiment which dealt with the effects of two dosages each of glyphosate, sulfosate and AC 252,925 on the aerial and underground organs of *I.cylindrica*, and the weed succession after chemical treatment.

MATERIALS AND METHODS

Experimental site

The experimental area in MARDI Research Station, Kelang has been colonised uniformly by the weed since the beginning of 1983 and herbicides have not been used. The weed, which was up to 1.4 m in height, was in its vegetative stage when spraying commenced in May, 1984. The soil was peat which had 85% organic matter and a pH of 3.9. The area was well drained throughout the experimental period of 12 months.

Experimental design and plots

A randomised complete block design with an untreated control and six herbicide treatments, all replicated four times, was employed. The six herbicide treatments consisted of three herbicides each at two dosages (Table 1). Plot size was 6m × 6m but only the inner 5m × 5m was used for evaluation of treatment effects. The gap between plots was 2m, and the shoots and rhizomes of *I. cylindrica* between the plots were cleared by hoeing at periodic intervals.

Application of herbicides

The herbicides were mixed with tap water and sprayed at a volume of 550 litres/ha using a conventional knapsack sprayer fitted with a fan jet (5/64 inch nozzle). Rain did not occur on the day of spraying for 24 h and the temperatures during spraying ranged from 28.5° C to 30° C.

Assessment of treatment effects

i) Percentage kill of aerial shoots

Visual assessment of the aerial shoots was carried out monthly for 12 months, and a 100 % kill indicated that the shoots were completely brown, with an absence of green or chlorotic regrowth.

ii) Stage of collapse of shoots

Three and five months after spraying, the stage of collapse of brown shoots was assessed using a scale from 1 = erect shoots to 9 = completely collapsed shoots.

iii) Decay and regrowth of shoot-rhizome systems

Four months after spraying, ten strands of rhizomes varying in length from 10 to 50 cm were sampled at random from a small sub-plot (1m × 1m). These rhizomes consisted of shoots and axillary rhizomes ending in sharp or broken tips or ending in

erect shoots. A visual assessment of the percentage kill of the rhizomes was performed. The regions of the shoots and rhizomes which decayed were recorded. In some instances, scale leaves were removed, and buds were excised so that observations on their colour and decay could be carried out.

iv) Dry weight of undecayed rhizomes

Eight months after spraying, a soil corer measuring 30cm × 30cm × 60cm in depth was used to sample the rhizomes. Four cores were taken from every plot and the soil adhering to the rhizomes was washed away by using a jet of water. The shoots were excised at node 1, which was subtended by the second lowest leaf. The decayed regions of the rhizomes which were soft and brown/black were discarded. Only firm and white/pale yellow rhizomes were retained and kept at 105° c for 24 h, followed by weighing.

v) Weed succession

Weed succession was studied by recording the main weed species before and after the application of herbicides. All weeds present before spraying were removed using a hoe, and care was taken in order to avoid disturbing the *I.cylindrica* shoots and rhizomes. Eight months after treatment, all the weed species and the percentage cover of each plot by all weeds except *I. cylindrica* were recorded.

RESULTS

Percentage kill of aerial shoots

One month after spraying, glyphosate at 4.32 kg a.e./ha provided 93.8% kill, and sulfosate at 3.70 kg a.e./ha provided 92.3% kill; however, AC 252,925 at 1.25 kg a.e./ha provided 36.3% kill only (Table 1). The necrosis caused by the latter herbicide proceeded slowly over the initial 10 weeks, after which a 99.5% kill was recorded at three months. From the third months onwards, regrowth of new shoots was evident in plots treated with glyphosate and sulfosate. In contrast, the kill by AC 252,925 increased until the seventh month. Twelve months after spraying, the highest kill of 87.3% was obtained with AC 252,925 at 1.25 kg a.e./ha.

Stage of collapse of shoots

Table 2 shows that three months after spraying, plots treated with the higher dosages of glyphosate and sulfosate showed almost complete collapse of shoots, while plots treated with AC 252,925 had partially-collapsed shoots. However, at five months, all herbicide-treated plots showed completely-collapsed brown shoots.

Decay and regrowth of shoot-rhizome systems

Four months after spraying, the best kill of rhizomes was obtained with a "one-shot" application of AC 252,925 at 1.25 kg a.e./ha which provided 96.3% decay compared with 82.5% for glyphosate at 4.32 kg a.e./ha and 78.8% for sulfosate at 3.70 kg a.e./ha (Table 3).

Table 1. Effect of glyphosate, sulfosate and Arsenal on the percentage kill of *Imperata cylindrica* under field conditions. (Means of 4 replicates).

Treatments	Months after spraying											
	1	2	3	4	5	6	7	8	9	10	11	12
K1 Untreated control	5.0	5.0	6.5	6.8	6.0	6.0	7.0	6.3	6.8	7.5	7.8	8.0
K2 Glyphosate 2.16 kg a.e./ha	84.5	89.8	92.8	82.5	75.5	63.8	53.8	32.5	18.8	8.8	5.5	5.5
K3 Glyphosate 4.32 kg a.e./ha	93.8	97.8	98.0	96.3	94.3	88.8	80.8	67.5	47.5	28.8	21.3	19.3
K4 Sulfosate 1.85 kg a.e./ha	84.0	90.0	90.3	78.8	61.3	60.0	43.8	25.0	12.5	6.3	5.0	5.0
K5 Sulfosate 3.70 kg a.e./ha	92.3	96.8	97.5	95.0	91.3	82.8	72.5	58.8	37.5	30.0	13.8	12.5
K6 Arsenal 0.75 kg a.e./ha	23.8	46.3	97.8	100.0	100.0	99.8	99.3	96.3	92.5	88.8	81.3	72.5
K7 Arsenal 1.25 kg a.e./ha	36.3	57.5	99.5	100.0	100.0	100.0	100.0	98.8	96.3	92.5	90.0	87.3
5% L.S.D.	5.9	8.6	5.6	9.41	12.3	12.2	10.5	10.2	7.9	7.9	8.7	10.9
s.e. of a treatment mean	1.974	2.898	1.895	3.169	4.126	4.115	3.537	3.437	2.668	2.671	2.937	3.67

Table 2. Effect of glyphosate, sulfosate and AC 252,925 on the stage of collapse of *I. cylindrica* three and five after spraying.

Treatment	Stage of collapse*	
	3 months	5 months
Untreated control	2	2
Glyphosate 2.16 kg a.e./ha	6	9
Glyphosate 4.32 kg a.e./ha	8	9
Sulfosate 1.85 kg a.e./ha	6	9
Sulfosate 3.70 kg a.e./ha	8	9
AC 252,925 6.75 kg a.e./ha	5	9
AC 252,925 1.25 kg a.e./ha	5	9

* From 1 = erect to 9 = complete collapse

2 = only the leaf tips droop slightly

5 & 6 = Partially-collapsed shoots

8 = Almost complete collapse

9 = Completely collapsed shoots

Table 3. Effects of glyphosate, sulfosate and AC 252,925 on the percentage kill of rhizomes 4 months after spraying.

Treatments	%kill
Untreated	6.3 f
Glyphosate 2.16 kg a.e./ha	63.8 d
Glyphosate 4.32 kg a.e./ha	82.5 bc
Sulfosate 1.85 kg a.e./ha	58.8 e
Sulfosate 3.70 kg a.e./ha	78.8 c
AC 252,925 0.75 kg a.e./ha	86.3 b
AC 252,925 1.25 kg a.e./ha	96.3 a
5% L.S.D.	4.5
s.e. of a treatment mean	1.507

Figures followed by the same letter do not differ significantly at 5%

There was extensive kill of rhizomes by glyphosate at both dosages. Shoot and rhizome apices were killed easily, the latter giving rise to the appearance of tipless rhizomes. Some rhizomes 15-38 cm in length and ending in erect or semi-erect tips were killed completely. However, a few short rhizomes up to 14 cm in length grew out from the apical region of rhizomes ending in brown (treated) shoots.

Sulfosate at both dosages provided a pattern of kill which was broadly similar to that obtained with glyphosate. From buds positioned in the apical region of rhizomes ending in brown (treated) shoots, usually one grew out to become a secondary rhizome with a 3-leaf shoot, and from the apical region of this secondary rhizome, tertiary rhizomes up to 31 cm in length have developed. Clumps of three new green shoots were observed, some reaching 24 cm in height.

AC 252,925 at both dosages caused a very extensive kill of shoot-rhizome systems. The most disintegrated region was the base of the treated shoot, i.e. the shoot apices. Some tipless rhizomes were also observed, but other rhizomes up to 13 cm in length had decayed completely. Many interconnecting strands of rhizomes with shoots and sharp rhizome tips showed a complete decay. In some instances, the apical and/or the mid-regions of the rhizomes ending in apical (treated/brown) shoots were apparently firm and white; when the scale leaves were removed, white or pale yellow buds were observed and these might be capable of further development. Several new rhizomes which were less than 2 mm in diameter (compared with 3.5 mm for rhizomes of untreated plots) and wavy in nature had grown out from buds located on apical nodes of rhizomes ending in brown shoots. In one instance, the apical tip of an axillary rhizome had decayed, but one bud located in the mid-region had developed into a small green shoot.

Dry weight of undecayed rhizomes

Eight months after spraying, it was found that all the herbicide treatments caused a significant reduction in the amount of undecayed rhizomes (Table 4). The greatest reduction was caused by AC 252,925 at 1.25 kg a.e./ha.

Table 4. Effects of glyphosate, sulfosate and AC 252,925 on the dry weight of undecayed rhizomes 8 months after spraying.
(Means of 16 soil cores/treatment).

Treatments	Dry weight (g/core)
Untreated	27.147
Glyphosate 2.16 kg a.e./ha	7.737
Glyphosate 4.32 kg a.e./ha	2.030
Sulfosate 1.85 kg a.e./ha	8.705
Sulfosate 3.70 kg a.e./ha	2.842
AC 252,925 0.75 kg a.e./ha	0.592
AC 252,925 1.25 kg a.e./ha	0.032
5% L.S.D.	2.600
s.e. of a treatment mean	0.872

Weed succession

Prior to spraying, the weed species in the *I. cylindrica* plots were *Erechtites hieracifolia*, *Erechtites valerianifolia*, *Blechnum indicum*, *Nephrolepis biserrata*, *Pteridium esculentum* and *Stenochlaena palustris*. They were sparse in distribution and constituted less than 5% in each plot. All weeds were removed manually before spraying.

Eight months after spraying, untreated plots had nine weed species compared with 15 species (glyphosate-treated plots), 18 (sulfosate-treated plots) and 16 (AC 252,925 - treated plots) (Table 5). Regrowth of ferns like *Blechnum*, *Nephrolepis*, *Pteridium* and *Stenochlaena* took place mainly from the rhizomes. Broadleaf weeds, grasses and sedges established themselves in plots from seeds.

Table 5. Weed species occurring in untreated plots and plots sprayed with glyphosate, sulfosate and AC 252,925 after 8 months.

	Control plots	Plots Sprayed with glyphosate	Plots Sprayed with sulfosate	Plots Sprayed with AC 252,925
Broadleafed weeds				
1. <i>Cleome</i> sp.		×	×	
2. <i>Erechtites hieracifolia</i> (L.) Reffin ex DC	×	×	×	×
3. <i>Erechtites valerianifolia</i> (Wolf) DC	×	×	×	×
4. <i>Euphorbia hirta</i> L.			×	
5. <i>Hedyotis</i> sp.				×
6. <i>Lindernia crustacea</i> (L.) F.V. Muell		×		×
7. <i>Macaranga</i> sp.		×	×	
8. <i>Melastoma malabathricum</i> L.	×	×	×	×
9. <i>Mikania micrantha</i> M.B.K.			×	×
10. <i>Passiflora foetide</i> L.			×	
11. <i>Physalis minima</i> L.				×
12. <i>Solanum nigrum</i> L.		×		
13. <i>Vernonia cinerea</i> (L.) Less		×	×	×
14. <i>Vitis</i> sp.		×		
Ferns				
1. <i>Blechnum indicum</i> Burm.	×	×	×	×
2. <i>Lygodium</i> sp.			×	
3. <i>Nephrolepis biserrata</i> Sw. (Schott)	×	×	×	×
4. <i>Pityrogramma calomelanos</i> (L.) Link			×	
5. <i>Pteridium esculentum</i> (Forst) Nakai	×	×	×	×
6. <i>Stenochlaena palustris</i> (Burm) Bedd.	×	×	×	×
Grasses				
1. <i>Paspalum commersonii</i> L.			×	×
Sedges				
1. <i>Cyperus zollingeri</i> Steud.	×	×	×	×
2. <i>Fimbristylis pauciflora</i> R.Br.				×
3. <i>Scleria</i> sp.	×	×	×	×
Total	9	15	18	16

× indicates that at least one plant was present in at least one plots.

The more effective the destruction of *I. cylindrica*, the greater was the area covered by other weeds. Thus, eight months after spraying, a significantly greater area of plots treated with AC 252,925 was covered by weeds when compared to plots treated with the other herbicides (Table 6).

Table 6. Percentage of total plot area covered by broadleaf weeds, ferns, grasses and sedges at eight months after chemical treatment.

Treatments	Percentage cover
K1 Untreated control	3.8 f
K2 Glyphosate 2.16 kg a.e./ha	45.0 d
K3 Glyphosate 4.32 kg a.e./ha	65.0 bc
K4 Sulfosate 1.85 kg a.e./ha	30.0 e
K5 Sulfosate 3.70 kg a.e./ha	55.0 cd
K6 AC 252,925 0.75 kg a.e./ha	77.5 ab
K7 AC 252,925 1.25 kg a.e./ha	85.0 a
5% L.S.D.	8.92
s.e. of a treatment mean	4.246

Means followed by the same letter do not differ significantly.

DISCUSSION

The finding that AC 252,925 provided a slow kill of *I. cylindrica* during the initial two months is similar to that reported by Bacon (1984) in Indonesia. Despite rapid translocation of this herbicide (Fine *et al.* 1983), the symptoms of necrosis proceeded slowly, starting with the leaf tips and margins. However at four months after spraying, the same herbicide at 0.75 kg a.e./ha provided 100% kill; this figure compares with 99% control in the Philippines (Lapade *et al.* 1983) and 97% control in Japan (Hasui *et al.* 1983).

The symptoms of necrosis induced by glyphosate may be related to its mode of action. Glyphosate causes toxicity perhaps by inhibiting protein synthesis via an interference in aromatic acid formation (Cole *et al.* 1980).

The present results throw new light on the translocation of sulfosate and AC 252,925 from shoots into the rhizomes of *I. cylindrica*. Both herbicides and/or their metabolites were extensively translocated throughout the shoot-rhizome system. The decay of rhizomes was greatest in rhizomes sampled from plots treated with AC 252,925. Fine *et al.* (1983) reported that AC 252,925 was absorbed by both foliage and roots and was translocated rapidly throughout the rhizomes of *Sorghum halepense* and *Cyperus rotundus*. Glyphosate has been reported to move in the phloem together with the photosynthate in a source to sink relationship (Sprankle *et al.* 1975). In anatomical studies on *I. cylindrica*, and using ¹⁴C labelled glyphosate, Lee (1983) showed that there were no anatomical and physiological barriers to the entry of the label into the rhizome buds.

Nevertheless, the exact mechanisms by which glyphosate, sulfosale and AC 252,925 influence bud development in this weed remain obscure. Did the axillary buds on the rhizomes die because of (i) toxicity of these herbicides and/or their metabolites, or (ii) disruption of the vascular system, resulting in the starvation of these axillary organs?

New information has been obtained on the sites of regrowth of shoots following herbicide treatment. From buds positioned close to the treated (dead or partially dead) shoots, new ones grew out after the foliar application of the three herbicides. The regrowth of chlorotic and green shoots from apical buds after glyphosate treatment has been previously reported (Lee, 1983). In the present study, it is postulated that dormant buds which were present at the time of application of glyphosate, sulfosate and AC 252,925 were weak sinks; consequently these buds drew in non-lethal or sub-lethal amounts of the herbicides, and regrowth took place subsequently. Initially, new shoots which arose after the application of glyphosate or sulfosate were chlorotic and some showed "die-back", but new shoots produced subsequently became vigorous in growth, and later on, longer rhizomes were produced.

The pattern of weed succession was also of interest. The weeds which regenerated after the application of herbicides were broadleaf, ferns, grasses and sedges. Bacon (1984) found that plots treated with glyphosate were rapidly invaded by broadleaf weeds and grasses but plots sprayed with AC 252,925 were colonized partially by weeds even at 250 days after treatment. This finding contrasted with the results of the present study, which showed a slightly greater infestation of weeds in plots treated with AC 252,925 compared with glyphosate (Table 5). In one of the field trials, Lapade *et al.* (1983) reported that at 139 days, plots treated with AC 252,925 at 1.25 kg a.e./ha had 37% cover by other weeds compared with 32% for plots treated with glyphosate at 2.5 kg a.e./ha.

CONCLUSION

The new herbicide AC 252,925 is very effective on *I. cylindrica*, which is still widespread in South-east Asia. Although the destruction of the aerial shoots takes up to three months, the kill of the rhizomes is very extensive. A one shot treatment at 0.75 kg/ha controlled *I. cylindrica* for ten months. Regrowth took place primarily from buds positioned close to the treated shoots. The weeds species which infested plots treated with glyphosate, sulfosate and AC 252,925 were broadly similar. Further studies on the use of lower dosages of AC 252,925 on *I. cylindrica* and its safety to crops grown after application of the herbicide are suggested.

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WEED CONTROL IN DRY-SEEDED WETLAND RICE AS AFFECTED BY TIME AND METHOD OF TILLAGE

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ABSTRACT

Land preparation during the dry season did not result in a reduction in weed weight but the composition of the weed flora was altered; perennial weeds decreased and annual weeds increased as the degree of land preparation increased. The number of herbicides that gave excellent weed control decreased with decrease in the amount of land preparation.

In all experiments, substantial yield losses occurred when no weeding was done irrespective of the method of land preparation. Postplant herbicide performance was better when land preparation was done during the dry season and when the stale-seedbed technique was used.

Further research is still needed to develop an appropriate integrated weed management technology for dry-seeded wetland rice (*Oryza sativa* L.).

INTRODUCTION

Dry-seeded wetland rice refers to the planting of ungerminated rice seed in fields that have been prepared dry and will subsequently become flooded. It is difficult to delineate the time of flooding but its cumulative duration is long enough to exclude the growing of major dryland crops in most seasons when inundation occurs (Moormann and van Breemen, 1978).

One of the primary objective of soil tillage is weed control. Vargas (1978) and Lacsina (1980) reported that upland rice suffered from severe weed competition and lower grain yields were obtained when the number of rotations were reduced from two to one. However, for dry-seeded wetland rice, weed growth did not decrease as the number of rotations increased from one to three (Vargas, 1978).

A common practice in rainfed rice growing areas is to leave the field as a weedy fallow during the dry season after rice harvest. Weeds grow and shed their seed or multiply vegetatively. As a result, intense weed problems may be encountered in the dry-seeded rice crop sown at the start of the rains if the weeds that grow in the crop are the same as those that occur during the dry season (Moody, 1982). Tourte et al. (1967 cited in Curfs, 1976) stated that tillage at the end of the wet season was superior to tillage at the start of the wet season in reducing weed problems. Moody (1979) stated that plowing after the previous wetland rice crop was only possible if the vegetative cycle of the rice crop was shorter than the rainy season or if sufficient residual moisture remained after rice harvest so that the soil was still moist to permit land preparation.

Partohardjono and Herahap (1979 cited in Moody, 1982) reported that weed infestations were reduced in dry-seeded rice when tillage was done during the dry season to control weeds. In contrast, Moody and Mian (1979) reported that there were significantly less perennial weeds and significantly more annual weeds in plots that were maintained weed free by tillage than in plots that were kept as a weedy fallow during the dry season. Moody (1982) stated that land preparation during the dry season appeared to have only limited effectiveness in reducing weed problems in the following dry-seeded rice crop.

Moody (1982) reported that the stale-seedbed technique reduced the weight of *Echinochloa colona* (L.) Link by 78% compared to conventional land preparation. Superior weed control was obtained with butachlor (*N*-butoxymethyl-2-chloro-2',6'-diethylacetanilide) and less time was required to hand weed the stale-seedbed plots.

Zero tillage has been used successfully for upland rice establishment in India (Sahu and Lenka, 1969) and Nigeria (Wijewardene, 1980). In contrast, Moody and Mukhopadhyay (1982) reported heavy weed infestations and poor weed control in zero tillage plots in Nigeria and the Philippines. Castin *et al.* (1983) concluded that zero tillage cannot be practiced in upland rice until a suitable herbicide technology involving both pre- and post-plant treatments is developed.

In the past, attempts to introduce dry-seeded wetland rice have failed because of the lack of an appropriate weed control technology (Moody, 1979). Moody and Mian (1979) reported that weed control obtained with a single herbicide application have been variable. Better weed control with tank mixtures of butachlor + propanil (3',4'-dichloropropionanilide), thiobencarb (*S*-4-chlorobenzyl diethylthiocarbamate) + propanil, and pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] + propanil than with single applications of any of these herbicides has been reported by Sheppard (1981) and Lubigan and Moody (1982).

The objectives of these studies were:

- to compare different methods of land preparation for weed control in dry-seeded wetland rice,
- to determine whether the composition of the weed flora was altered by different land preparation methods, and
- to determine the effect of different land preparation methods and postplanting weed control treatments on crop yield.

MATERIALS AND METHODS

General cultural practices, experimental design, and sampling methods

The experiments which were conducted at the experimental farm of the International Rice Research Institute from 1980 to 1982 were laid out in a split-plot design which was replicated three times with tillage treatments as the main plots and weed control treatments as the subplots. Subplot size was 6 x 3 m. The plowing operations were done using a tractor-drawn disc plow while a tractor-hitched Howard rotovator was used for the rotovations.

In 1980, rice seeds were sown in rows spaced 25 cm apart. A Planet jr. seeder was used in all trials except for the experiment comparing different methods of land preparation where an inclined plate seeder was used in 1981 and in 1982 a rolling injection planter was used. Distances between hills were 25 x 25 cm. For all experiments, the seeding rate was 100 kg/ha and the test cultivar was IR50.

Fertilizer was applied at the rate of 100 kg N, 40 kg P₂O₅, and 40 kg K₂O/ha. Forty kilograms of N and all of the P₂O₅ and K₂O were applied as a basal application. The rest of the N was split equally and topdressed 30 days after rice emergence (DAE) and at panicle initiation.

Insect pests were controlled by applying carbofuran (2,3-dihydro-2,2-dimethyl-benzofuran-7-ylmethylcarbamate) at 1.0 kg a.i./ha 1 day before seeding (DBS) or endosulfan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzo [e] dioxathiepin 3-oxide) was applied postplant at 0.75 kg a.i./ha when necessary.

Weeds were sampled from two 0.25 m² quadrats per plot. The samples were bulked, classified by species, counted, oven dried at 70-80 C for 48 hr, and weighed. The relative dry weight (RDW) or relative density (RD) was calculated using the following equation:

$$\text{RDW (or RD)} = \frac{\text{Weight (or density) of each species}}{\text{Total weight (or density) of all species}} \times 100$$

The harvest area for grain yield was 5 m². After processing, the grain yield per plot was converted to t/ha at 14% moisture.

Specific details for each experiment

1. Degree of land preparation

In 1980, land preparation in the dry season which consisted of one plowing and one rotovation or one plowing and one rotovation followed by weekly spike-tooth harrowings was compared with land preparation in the wet season. In May, immediately before seeding, the plots that were not plowed in the dry season received one plowing and two rotovations while the other treatments were rotovated once. The postplant weed control treatments are given in Table 2.

2. Time of land preparation

Two experiments dealing with time of land preparation were conducted in 1980 and 1981. In 1980, land preparation which consisted of one plowing followed by one rotovation was done in March, April, or May. In May, all plots were rotovated immediately before seeding. For each tillage treatment, six weed control methods were compared (see Table 3).

In 1981, land preparation which consisted of one plowing and one rotovation was done in February, March, April, or May and compared with the application of paraquat (1,1'-dimethyl-4,4'-bipyridylium ion) at 0.75 kg a.i./ha in February. Immediately before seeding in May, the plots that were treated with paraquat received one plowing and two rotovations; the other plots were rotovated once. The postplant weed control treatments are given in Table 5.

3. Methods of land preparation

Five land preparation methods were compared for 3 years (1980–1982). These were:

- Reduced tillage – One plowing in March followed by one rotovation 1 DBS.
- Conventional tillage – One plowing in March followed by two (in 1980) or three rotovations (in 1981 and 1982) at 2-week intervals.
- Stale-seedbed – Paraquat was applied at 0.75 kg a.i./ha.
- Stale-seedbed – Shallow rotovation.
- Zero tillage – Glyphosate [*N*-(phosphonomethyl) glycine] was applied at 1.5 kg a.i./ha in May.

In the stale-seedbed plots, initial land preparation was the same as for the conventional tillage treatment. After the final harrowing, weeds were allowed to germinate and grow for 2 weeks and then killed. In 1980 and 1981, the stale-seedbed plots were planted 2 weeks after the other land preparation methods. In 1982, all the land preparation methods were planted at the same time. The postplant weed control treatments are given in Tables 8, 11, and 13.

RESULTS

Degree of land preparation

Land preparation during the dry season did not cause a reduction in weed weight at 40 DAE but the composition of the weed flora was altered (Table 1). *Ipomoea aquatica* Forsk., a perennial broadleaf weed, which was an important component of the weed flora in the plots that were not prepared in the dry season was completely eliminated by dry season tillage. *Paspalum paspaloides* (Michx.) Scribn., a perennial grass, became less important as the degree of tillage increased. The annual weeds, *E. colona* and *Ipomoea triloba* L., were important components of the weed flora when land preparation during the dry season consisted of one plowing + one rotovation and one plowing + one rotovation + weekly harrowings, respectively.

Table 1. Relative dry weight (%) of different weed species in the unweeded plots 40 days after emergence as affected by method of land preparation.^a IRRI, 1980 wet season.

Weed species	Land preparation in the dry season		
	None	One plowing + One rotovation	One plowing + one rotovation + weekly harrowing
<i>Ipomoea triloba</i>	27.7	25.4	53.5
<i>Paspalum paspaloides</i>	26.7	14.6	5.6
<i>Ipomoea aquatica</i>	20.3	0.0	0.0
<i>Echinochloa glabrescens</i>	16.3	12.9	17.9
<i>Echinochloa colona</i>	2.1	31.3	1.1
Others	6.9	15.8	21.9
Total weed weight (g/m ²)	112.6	181.6	139.8

^aAv. of three replications.

Moody and Mian (1979) and Castin *et al.* (1983) reported that there was decrease in perennial weeds and an increase in *E. colona* and *I. triloba*, respectively, as a result of dry season land preparation.

Yields in the hand weeded plots were not affected by dry season land preparation. All the herbicide-treated plots yielded significantly higher than the untreated check when dry season land preparation consisted of one plowing + one rotovation + weekly harrowings (Table 2). Only the plots treated with thiobencarb yielded significantly less than the hand weeded check.

Table 2. Grain yield (t/ha) of dry-seeded wetland IR50 as affected by land preparation methods and weed control treatments.^a IRRI, 1980 wet season.

Weed control treatment ^b	Land preparation in the dry season		
	None	One plowing + one rotovation	One plowing + one rotovation + weekly harrowing
Weeded (14 & 35 DAE)	4.3 a	4.3 a	3.7 a
Propanil (2.5), 2–3 LSG	3.2 ab	4.4 a	4.3 a
Oxadiazon (0.75), PE	2.9 abc	3.8 a	3.5 a
Thiobencarb + propanil (2.5 + 1.25), 2–3 LSG	1.5 cd	4.2 a	3.4 ab
Butachlor + propanil (1.5 + 1.25), 2–3 LSG	2.6 bc	2.3 b	3.4 ab
Thiobencarb (3.0), PE	1.8 bcd	2.1 b	2.0 b
Butachlor (2.0), PE	0.0 e	2.2 b	3.1 ab
Unweeded	0.6 de	0.0 c	0.0 c

^aIn a column, means followed by the same letter are not significantly different at the 5% level by DMRT.

^bDAE = days after emergence, LSG = leaf stage of grasses, PE = preemergence. Herbicide rate in kg a.i./ha indicated in parentheses.

When dry season land preparation consisted of one plowing + one rotovation, yields from the plots treated with propanil, oxadiazon (5-*tert*-butyl-3 (2,4-dichloro-5-isopropoxyphenyl)-1,3,4-oxadiazol-2-one), and thiobencarb-propanil were not significantly different from the hand weeded check. Yields from the other herbicide-treated plots were significantly lower than those from the hand weeded check but significantly higher than the unweeded check which gave no yield.

In the plots that were maintained as a weedy fallow during the dry season, only those that were treated with propanil or oxadiazon gave yields that were not significantly less than the hand weeded check. Four of the herbicide treatments yielded significantly less than the hand weeded check; three of these did not yield significantly higher than the unweeded check. Thus, as the degree of dry season land preparation was reduced the number of herbicides that gave excellent weed control also decreased.

Time of tillage

In 1980, the time of land preparation had no effect on the weed density and the weed biomass at 14 DAE, and on the composition of the weed flora 40 DAE in the unweeded plots (data not presented). Castin *et al.* (1983) stated that cultivation during the dormancy period of weed seeds or during the dry season will have little effect on their control and with the return of favorable conditions, they will appear in large numbers.

Yields from the hand weeded plots were higher than or equal to those from the other treatments at all times of land preparation (Table 3). When the land was prepared in March or April, all the plots treated with herbicides except those treated with pendimethalin yielded significantly higher than the untreated check and not significantly different from the hand weeded check. The yields from the pendimethalin-treated plots were not significantly different from the untreated check.

Table 3. Effect of time of land preparation on the yield of dry-seeded wetland IR50 rice.^a IRRI, 1980 wet season.

Weed control treatment ^b	Time of land preparation		
	March	April	May
Weeded (14 & 35 DAE)	4.3 a	4.7 a	3.5 a
Propanil (2.5), 2-3 LSG	3.1 ab	3.5 a	3.5 a
Thiobencarb (3.0), PE	3.4 ab	3.0 a	3.3 ab
Butachlor (2.0), PE	2.9 ab	3.5 a	1.7 bc
Pendimethalin (2.0), PE	2.4 bc	1.7 b	0.4 c
Untreated check	1.2 c	1.4 b	0.5 c

^aIn a column, means followed by the same letter are not significantly different at the 5% level by DMRT.

^bDAE = days after emergence, LSG = leaf stage of grassy weeds, PE = preemergence. Herbicide rate in kg a.i./ha indicated in parentheses.

When the land was prepared in May, yields from the plots treated with propanil and thiobencarb were not significantly different from the plots that were hand weeded twice. The yields from the plots treated with butachlor and pendimethalin were not significantly different from the untreated check. Castin *et al.* (1983) reported that for upland rice butachlor was not as effective in controlling weeds when the land was prepared in May than when it was prepared in March or April.

In 1981, the time and method of land preparation did not affect weed weight at 35 DAE (Table 4) but the composition of the weed community was affected. Curfs (1976) and Castin *et al.* (1983) made similar observations for upland rice. The earlier that land preparation was commenced, the more important *I. triloba* was in the weed flora. It was least important in the plots treated with paraquat. Castin *et al.* (1983) also reported that plowing during the dry season encouraged germination of this weed.

Table 4. Total weed weight and relative dry weight (%) of the major weed species 35 days after emergence as affected by land preparation method.^a IRRI, 1981 wet season.

Weed species	Time of land preparation				Paraquat (0.75 kg a.i./ha)
	February	March	April	May	
<i>Ipomoea triloba</i>	57.2	52.4	27.4	22.3	18.7
<i>Echinochloa colona</i>	34.6	20.2	33.8	43.4	65.2
<i>Macropitium lathyroides</i>	40.0	5.8	15.9	2.7	5.6
<i>Melochia concatenata</i>	2.6	17.6	11.0	3.4	6.1
<i>Digitaria</i> sp.	1.2	3.2	5.2	25.8	3.8
Others	0.4	0.8	6.7	2.4	0.6
Total weed weight (g/m ²) ^b	282.6 a	258.0 a	203.6 a	170.2 a	273.4 a

^aAv. of three replications.

^bIn this row, means followed by the same letter are not significantly different at the 5% level by DMRT.

A *Digitaria* sp. was an important component of the weed flora only when land preparation was done in May while *E. colona*, a major weed in all land preparation methods, was a more important component of the weed flora when paraquat was used for weed control in the dry season. This may have been caused by higher soil moisture contents in the paraquat-treated plots at planting. This is in contrast to the findings of Moody and Main (1979) who reported that dry season land preparation encouraged *E. colona* germination and growth.

None of the postplant herbicide treatments controlled *I. triloba*. To prevent complete yield loss from this vigorously growing weed all plots were hand weeded at 35 DAE. Moody and Mukhopadhyay (1982) also commented on the inability of residual herbicides to give sustained weed control in dry-seeded wetland rice and the necessity to hand weed to save the crop.

The mean yields in the plots where land preparation was done at different times were not significantly different from each other but all yielded significantly less than the plots that were sprayed with paraquat during the dry season (Table 5). Zandstra and Price (1977) reported that tillage encouraged evaporation of residual moisture resulting in poor crop establishment when there was no rain soon after planting.

Table 5. Grain yield (t/ha) as affected by the time of land preparation and weed control treatments.^a IRRI, 1981 wet season.

Weed control treatment	Time of land preparation				Paraquat (0.75 kg a.i./ha)	Mean
	February	March	April	May		
Hand weeding (14 DAE)	3.4	3.2	3.7	2.4	3.9	3.4 a
Thiobencarb + oxadiazon	2.6	2.9	3.4	2.7	3.6	3.1 ab
Butachlor + oxadiazon	2.7	2.8	2.2	2.8	3.2	2.7 b
Pendimethalin + oxadiazon	1.4	2.0	1.7	2.5	2.8	2.0 c
Untreated check	2.5	2.0	2.4	2.9	3.3	2.6 b
Mean ^b	2.5 b	2.6 b	2.7 b	2.7 b	3.4 a	

^a In a column, means followed by the same letter are not significantly different at the 5 % level by DMRT. DAE = days after emergence. All plots were hand weeded 35 DAE.

^b In this row, means followed by a common letter are not significantly different at the 5 % level by DMRT.

In the plots that were hand weeded twice, yields were lower when the land was prepared in May. This was caused by reduced crop stand due to poor tith and the difficulty in weeding when the *Digitaria* sp. was present. Castin *et al.* (1983) made similar observations for upland rice. Pablico and Moody (1983) reported that yields were low when hand weeding was used for weed control due to the infestation of *Digitaria* sp. and *E. colona* late in the growing season.

Mean yields from the plots treated with thiobencarb + oxadiazon were not significantly different from the hand weeded check. The other herbicide treatments and the untreated check yielded significantly lower than the hand weeded check even though all plots were hand weeded 35 DAE. Thus, dry-seeded wetland rice cannot completely recover from an initial setback due to weed competition. Others (Moody, 1976; Castin *et al.*, 1983) have also reported that rice was unable to overcome the effects of early weed competition when weed control was delayed. Initial phytotoxicity from which the crop never fully recovered and poor control of broadleaf weeds were the reasons for the low yields obtained with the pendimethalin + oxadiazon treatment.

Method of land preparation

In 1980, the weed density and the weed biomass at 2 weeks after rice emergence (WAE) in the unweeded plots were significantly lower in the stale-seedbed plots than in the other plots (Table 6). The composition of the weed flora 40 DAE was also altered (Table 7). A *Paspalum* sp. which was the major weed in all plots except the stale-seedbed plots and *I. triloba* which was important in the zero tillage plots were replaced by *Commelina diffusa* Burm. f., *Cyperus rotundus* L., and *Ludwigia octovalvis* (Jacq.) Raven in the stale-seedbed plots.

Table 6. Weed density and weed biomass 2 weeks after emergence in the unweeded plots as affected by method of land preparation in dry-seeded wetland rice.^a IRRI, 1980 wet season.

Land preparation method	Weed density (no. / m ²)	Weed weight (g / m ²)
Zero tillage		
(glyphosate, 1.5 kg a.i. / ha)	182.6 a	90.0 a
One plowing fb one rotovation	280.6 a	153.0 a
Two plowings fb two rotovations	290.6 a	132.8 a
Stale-seedbed (harrow)	73.4 b	13.4 b
Stale-seedbed (paraquat, 0.75 kg a.i. / ha)	36.0 b	8.2 b

^a Av. of three replications. In a column, means followed by a common letter are not significantly different at the 5 % level by DMRT. fb = followed by.

Table 7. Relative dry weight (%) and total weed weight of the major weed species 40 days after emergence as affected by land preparation method.^a IRRI, 1980 wet season.

Weed species	Zero tillage (glyphosate, 1.5 kg a.i. / ha)	One plowing fb one rotovation	Two plowings fb two rotovations	Stale-seedbed (harrow)	Stale-seedbed (paraquat, 0.75 kg a.i. / ha)
Relative dry weight					
<i>Paspalum</i> sp.	36.5 ab	61.1 a	52.6 a	5.2 bc	1.0 c
<i>Ipomoea triloba</i>	20.5 a	7.0 ab	5.2 ab	1.8 bc	0.0 c
<i>Digitaria</i> sp.	13.4 a	4.3 ab	4.8 ab	6.2 ab	0.7 b
<i>Commelina diffusa</i>	3.4 b	16.8 ab	9.0 ab	17.9 ab	35.5 a
<i>Cyperus rotundus</i>	0.8 b	0.6 b	0.3 b	25.7 a	19.9 a
<i>Ludwigia octovalvis</i>	0.0 b	0.0 b	0.0 b	19.7 a	12.4 a
Others ^b	25.4 (11)	10.2 (11)	28.1 (6)	23.5 (11)	30.5 (14)
Total weed weight (g/m ²)	382.8 a	337.6 a	460.8 a	87.8 b	82.2 b

^a Av. of three replications. In a row, means followed by a common letter are not significantly different at the 5 % level by DMRT. fb = followed by.

^b Number of species indicated in parentheses.

Although weed growth was reduced and the composition of the weed flora was changed in the stale-seedbed plots, competition in the unweeded plots was so severe that little or no yield was obtained (Table 8). Only temporary relief was obtained from weed competition in dry-seeded wetland rice as a result of good land preparation. Suitable postplant weed control methods must be combined with good land preparation to prevent yield losses. Castin *et al.* (1983) reported similar results for upland rice.

Table 8. Grain yield (*t/ha*) of dry-seeded wetland IR50 as affected by land preparation methods and weed control treatments.^a IRRI, 1980 wet season.

Land preparation method	No weeding	Weed control treatment ^b			
		Butachlor (2.0 kg/ha) fb 2, 4-D (0.75 kg/ha)	Thiobencarb (3.0 kg/ha) fb 2, 4-D (0.75 kg/ha)	Pendimethalin (2.0 kg/ha) fb 2, 4-D (0.75 kg/ha)	Two hand weeding (14 & 35 DAE)
Zero tillage (glyphosate, 1.5 kg a.i. / ha)	0 a	0 b	0 b	0.8 b	3.5 a
One plowing fb one rotovation	0 a	0 b	0 b	1.1 b	2.0 b
Two plowings fb two rotovations	0 a	0.5 b	0.8 b	0.9 b	3.2 ab
Stale-seedbed (harrow)	0 a	1.9 a	2.7 a	2.9 a	2.9 ab
Stale-seedbed (paraquat, 0.75 kg a.i. / ha)	0.5 a	2.5 a	3.5 a	2.6 a	2.7 ab

^a In a column, means followed by the same letter are not significantly different at the 5 % level by DMRT. fb = followed by, DAE = days after emergence.

Significantly higher yields were obtained in the stale-seedbed plots that was treated with herbicides than in the other land preparation methods. Finer soil tilth, a difference in the weed flora, and reduced weed growth resulted in improved herbicide performance in the stale-seedbed plots.

The highest grain yield in the hand weeded plots was obtained in the zero tillage plots. However, over 1700 *hr/ha* were required for these weeding operations compared to the 700 *hr/ha* that were required for the stale-seedbed plots that were sprayed with paraquat.

In 1981, the weed biomass at 2 WAE was significantly lower in the stale-seedbed plots than in those that received one plowing + one rotovation and in the zero tillage plots because of a delay in weed emergence and a change in the weed flora

(Table 9). No significant differences were observed in the weed density between tillage treatments. Curfs (1976) also observed changes in the weed flora due to land preparation methods but weed density was not reduced.

Table 9. Weed density and weed biomass 2 weeks after emergence in the unweeded plots as affected by method of land preparation in dry-seeded wetland rice.^a IRRI, 1981 wet season.

Land preparation method	Weed density No. / m ²	Weed weight (g / m ²)
Zero tillage (glyphosate, 1.5 kg a.i. / ha)	244.8 a	43.2 a
One plowing fb one rotovation	211.2 a	33.6 ab
One plowing fb three rotovations	211.6 a	21.6 bc
Stale-seedbed (harrow)	191.2 a	9.6 d
Stale-seedbed (paraquat, 0.75 kg a.i. / ha)	187.2 a	17.6 cd

^a Av. of three replications. In a column, means followed by a common letter are not significantly different at the 5 % level by DMRT. fb = followed by.

Grasses (*Digitaria* sp. and *Paspalum* sp.) dominated in the zero tillage plots and in those that were plowed and rotovated once (Table 10). Broadleaf weeds dominated in the other land preparation methods.

Table 10. Relative dry weight (%) and total weed weight of the major weed species 40 days after emergence as affected by land preparation method.^a IRRI, 1981 wet season.

Weed species	Zero tillage (glyphosate, 1.5 kg a.i. / ha)	One plowing fb one rotovation	Two plowings fb three rotovations	Stale-seedbed (harrow)	Stale-seedbed (paraquat, 0.75 kg a.i. / ha)
<i>Relative dry weight</i>					
<i>Melochia</i>					
<i>concatenata</i>	5.4 b	23.1 ab	52.0 a	11.9 b	13.2 ab
<i>Digitaria</i> sp.	39.3 a	27.5 a	10.1 a	17.7 a	9.8 a
<i>Ipomoea triloba</i>	8.5 a	8.7 a	19.7 a	26.2 a	12.5 a
<i>Paspalum</i> sp.	20.2 a	34.7 a	15.9 a	2.3 b	0.8 a
<i>Commelina</i>					
<i>diffusa</i>	0.2 b	3.5 b	1.2 b	9.0 ab	28.2 a
<i>Murdannia</i>					
<i>nudiflora</i>	0.4 b	0 b	0.1 b	9.4 a	11.5 a
Others ^b	26.0 (4)	25.8 (8)	1.0 (6)	23.5 (7)	24.0 (8)
Total weed weight (g/m ²)	307.2 a	284.4 a	287.4 a	82.2 a	97.4 a

^a Av. of three replications. In a row, means followed by a common letter are not significantly different at the 5 % level by DMRT. fb = followed by.

^b Number of species indicated in parentheses.

None of the postplant herbicide treatments controlled *I. triloba*. Therefore, to prevent complete yield loss all plots except those were hand weeded were sprayed 35 DAE with 2,4-D (2,4-dichlorophenoxy acetic acid) at 0.75 kg a.e./ha. Complete control was obtained with this treatment.

At 60 DAE, in all the herbicide-treated plots, there were significantly less weeds in the stale-seedbed plots than in the other plots (Table 11). Regardless of the tillage treatment, the best weed control was usually obtained with hand weeding. This indicates the difficulty in finding suitable herbicide treatments for use in dry-seeded wetland rice. The time required to hand weed the zero tillage plots was significantly greater than that required to hand weed the other land preparation methods (data not presented).

Table 11. Total weed weight (g/m²) 60 days after emergence (DAE) as affected by land preparation methods and postplanting weed control techniques.^a IRRI, 1981 wet season.

Land preparation method	Weed control treatment ^b				
	No weeding	Butachlor (1.5 kg/ha) + propanil (1.5 kg/ha)	Pendimethalin (1.5 kg/ha) + propanil (1.5 kg/ha)	Thiobencarb (2.5 kg/ha) + propanil (1.5 kg/ha)	Two hand weeding (14 & 35 DAE)
Zero tillage (glyphosate, 1.5 kg a.i. /ha)	1037.2 a	230.8 a	226.6 a	255.6 a	90.6 a
One plowing fb one rotovation	1091.8 a	169.4 a	118.6 ab	415.6 a	97.6 a
One plowing fb three rotovations	818.0 ab	250.0 ab	164.8 ab	302.4 a	46.2 ab
Stale-seedbed (harrow)	293.6 bc	64.0 b	132.6 ab	15.4 b	18.0 bc
Stale-seedbed (paraquat, 0.75 kg a.i. /ha)	215.0 c	37.8 b	45.0 b	40.4 b	10.6 c

^a Av. of three replications. In a column, means followed by the same letter are not significantly different at the 5 % level by DMRT. fb = followed by.

^b 2, 4-D was applied to all plots 35 DAE except those that were hand weeded, + = applied as a tank mixture.

No grain yield was obtained because the crop suffered severe moisture stress during heading and grain filling.

In 1982, in contrast to the previous years, the stale-seedbed technique did not result in a significant reduction in weed biomass or weeding time compared to the other land preparation methods (Table 12). Rainfall following seedbed preparation was insufficient to germinate the weed seeds before paraquat was applied or the plots were rotovated. Germination of most of the germinable weed seeds is essential for the success of the stale-seedbed technique.

Table 12. Total weed weight (g/m^2) 30 days after emergence (DAE), relative dry weight (%), weed density, and time required for weeding as affected by land preparation method.^a IRRI, 1982.

Weed species	Zero tillage (glyphosate, 1.5 kg a.i. /ha)	One plowing fb one rotovation	One plowing fb three rotovations	Stale-seedbed (harrow)	Stale-seedbed (paraquat, 0.75 kg a.i. /ha)
<i>Digitaria</i> sp.	2.6	7.2	21.2	23.7	4.2
<i>Echinochloa</i> <i>colona</i>	35.3	14.8	31.5	47.3	69.1
<i>Melochia</i> <i>concatenata</i>	1.6	5.9	3.0	4.6	1.7
<i>Macroptilium</i> <i>lathyroides</i>	0.3	3.7	11.2	2.6	1.5
<i>Cyperus rotundus</i>	16.7	6.0	0.7	10.9	10.1
<i>Ipomoea triloba</i>	3.9	16.5	15.5	2.9	0.0
Others ^b	39.6 (17)	45.9 (17)	16.9 (15)	8.0 (14)	13.4 (13)
Total weed weight (g/m^2)	179.2 ab	118.0 b	110.6 ab	213.6 ab	297.8 a
Weed density, 14 DAE (no/ m^2)	148b	222ab	216ab	394 a	376 a
Weeding time, 14 DAE (hr/ha)	859ab	802b	809b	1116a	844 ab

^a In a row, means followed by a common letter are not significantly different at the 5 % level by DMRT. fb = followed by.

^b Number of species indicated in parentheses.

The significant reduction in weed density in the zero tillage plots compared to the stale-seedbed plots may have been caused by the fact that glyphosate was applied twice. The first application during the dry season controlled weeds poorly. Better weed control was obtained when the second application was made after the onset of the monsoon. Chase and Appleby (1979) reported that during the dry season herbicide effectiveness is reduced because humidity is lower and plants are subjected to water stress. Glyphosate activity is enhanced when the plant processes which are disturbed by soil moisture stress have recovered (Moosavi-Nia and Dore, 1979).

As in the previous years, there was a change in the weed flora as a result of the different land preparation methods used (Table 12). *E. colona* was the major weed in all the plots but it was most important in the stale-seedbed plot to which paraquat had been applied. *C. rotundus* was less important and *I. triloba* was more important in the plots that were plowed and harrowed than in the other plots.

Complete yield loss occurred irrespective of the land preparation method when the plots were not weeded (Table 13). As in 1980, weed control was better and yields were higher in the stale-seedbed plots than in the other land preparation methods when herbicides were used for post-plant weed control. The highest yields were again obtained in all land preparation methods when the plots were hand weeded.

Table 13. Grain yield (t/ha) of dry-seeded wetland IR50 rice as affected by land preparation methods and weed control treatments.^a IRRI, 1982 wet season.

Land preparation method	Weed control treatment ^b				
	No weeding	Butachlor (1.5 kg/ha) + propanil (1.5 kg/ha)	Pendimethalin (1.5 kg/ha) + propanil (1.5 kg/ha)	Thiobencarb (2.5 kg/ha) + propanil (1.5 kg/ha)	Two hand weeding (14 & 35 DAE)
Zero tillage (glyphosate, 1.5 kg a.i. /ha)	0.0 a	0.9 b	1.7 bc	2.1 a	3.3 a
One plowing fb one rotovation	0.0 a	0.0 b	1.0 c	0.5 b	2.1 b
One plowing fb three rotovations	0.0 a	0.5 b	1.6 bc	0.6 b	3.4 a
Stale-seedbed (harrow)	0.0 a	2.6 a	3.0 a	2.7 a	3.8 a
Stale-seedbed (paraquat, 0.75 kg a.i. /ha)	0.0 a	2.5 a	2.2 ab	2.8 a	3.7 a

^a In a column, means followed by the same letter are not significantly different at the 5 % level by DMRT. fb = followed by.

^b + = applied as a tank mixture.

DISCUSSION

Based on the results obtained in these studies, land preparation methods by themselves cannot reduce weed problems in dry-seeded wetland rice. Complete yield loss is likely to occur if they are used in isolation. They need to be combined with other weed control techniques for good weed control and suitable yields.

The stale-seedbed technique usually resulted in a change in the weed flora, reduction in weed growth, reduction in the time required for weeding, and superior herbicide performance. When weed control was good as with hand weeding, method of land preparation had little effect on crop yield. However, the time required for hand weeding was usually significantly higher when zero tillage was used for land preparation due to increased weed growth. Even though satisfactory yields were obtained with zero tillage, such a practice cannot be used for dry-seeded wetland rice until a suitable herbicide technology is developed. Castin *et al.* (1983) made the same observation for upland rice.

Further research is still needed to determine suitable postplant weed control methods to use in combination with an appropriate land preparation method to develop an integrated weed management technology for dry-seeded wetland rice that is acceptable to the small-scale farmer.

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CHEMICAL IMPLICATION IN THE HARDINESS OF *Spirodela spp.*

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ABSTRACT

The aquatic weed *Spirodela spp.* is a very hardy weed, as hardy as water hyacinth. These two weeds are common pollutants in water areas.

Analysis of *Spirodela spp.* was carried out for chemical compounds that are implicated in contributing to its hardiness in order to know if these compounds are present in sufficient amounts to account for its hardy characteristic. A very interesting finding that might be important in contributing to the hardiness of *Spirodela spp.* is its unusually high content of anthocyanin. It is so high as to yield 12.0% anthocyanin on a dry weight basis upon acid hydrolysis. This value is about three times that of water hyacinth. From the chemical tests it is concluded that the anthocyanin in *Spirodela spp.* is a glycoside of cyanidin. This kind of anthocyanin is reported in the literature to be a major factor in the resistance of cotton to tobacco budworm and thus it has been suggested that anthocyanins in general may be a basis for selecting for resistance to related insects in other crops.

INTRODUCTION

The aquatic weed, *Spirodela spp.*, is a hardy plant and is a common pollutant in water areas.

Analyses for some chemical compounds in *Spirodela spp.* were carried out in order to know if their concentration is sufficient to account for its hardy characteristics. Knowing the factors that contribute to hardiness would facilitate its eradication. Looking further ahead, genetic engineering methods could be employed to introduce the genes for this trait to agricultural crops to increase their resistance to pests or to some unfavorable conditions.

In Thailand there are two species of the genus *Spirodela*, *S. polyrrhiza* (L.) Schleiden and *S. oligorrhiza* (Kurz) Hegelm. They are very small, freshwater aquatics floating on the water surface. The plant body consists of a small thallus with one or several roots suspended from a point on the undersurface. Each thallus has a dorsal and ventral scale. Inflorescence and daughter thalli are borne in two budding pouches. The inflorescence of one female and two male flowers are enclosed in a membranous sheath. Brown pigment cell and star-shaped crystals of calcium oxalate are present in the thallus tissue. The undersurface is usually reddish and anthocyanin is found in the ventral mesophyll.

Samples of *Spirodela spp.* were collected from ponds in the Kasetsart University compound. Samples were washed in running water and then in distilled water. They were blotted with toilet paper to remove excess water and then freed of foreign particles. Moisture, protein, and glucose were determined according to the AOAC methods (1984); chlorophyll by the spectrophotometric method of Comar and Zscheile (1942); total phenols by the Folin-Denis method (Schultz, *et al.*, 1981); hydrolyzable tannins by the procedure of Haslam (Bate-Smith, 1977) and anthocyanidin determination by the method of Bate-Smith (1977). Anthocyanin and tannins were qualitatively identified by Sephadex G-25 chromatography (Somers, 1966). Thin layer chromatography and qualitative tests were done to identify cyanidin (Harborne,)

RESULT AND DISCUSSION

The results of the chemical analysis of *Spirodela spp.* are shown in Table 1. The average moisture content is 92.0%. The total chlorophyll is 0.79 mg per gram fresh weight. This value, on a dry weight basis, is comparable to that of corn. The glucose content is 8.5%. Glucose, together with fructose and sucrose, is the main carbohydrate nutrient for insects. Favorable concentration of glucose will thus render the leaf more susceptible to insect attack. The amount of protein (20.0%) approaches that of water hyacinth leaves (24.0%). Tannins and anthocyanins are polyphenolic compounds and are widespread in tissues of herbaceous plants. Tannins contribute to hardiness because they reduce the digestibility of tissues to insect or vertebrate herbivores by complexing with the plant proteins, because they complex with digestive enzymes, and because they act as behavioral antifeedants. Total phenols and tannins were thus analyzed, but the result showed that tannins, both hydrolyzable and condensed, are not present in *Spirodela spp.* Anthocyanidin may occur as constituent monomers of condensed tannin. In the Sephadex G-25 chromatography, only the anthocyanin band appeared, no tannin band was evident. The absence of the tannin band agrees with the finding that there is no hydrolyzable tannin. However, the anthocyanin content is high as shown by the value of 11.8% anthocyanidin. That of water hyacinth is only 3.8% (Bate-Smith, 1973). The phenols of *Spirodela spp.* (11.6%) is thus all accounted for by the anthocyanin content. Anthocyanin yields anthocyanidin upon acid hydrolysis.

Table 1 Average values* for some chemical components *Spirodela spp.*

Moisture	92.0%
Chlorophyll	0.79 mg/g fresh leaf
Glucose	8.5%
Protein	20.0%
Total phenols, as catechin	11.6%
Hydrolyzable tannins	0.0
Anthocyanidin	11.8%

*all values, except that for chlorophyll, are on dry weight basis.

From the thin layer chromatography and chemical tests (Table 2) it is concluded that the anthocyanin in *Spirodela spp.* is a glucoside of cyanidin. This is the most common anthocyanin in nature. Scientists of the Delta States Area Boll Weevil Research Laboratory in the United States (Chen, 1982) have reported that a kind of this anthocyanin, cyanidin-3- β -glucoside, is a major factor in the resistance of cotton to the tobacco budworm. They suggested that anthocyanins in general may be a basis for selecting for resistance to related insects in other crops. Therefore, in the case of *Spirodela spp.* the high anthocyanin content, probably together with its oxalic acid component, may play a role in its hardness.

Table 2 Properties of cyanidin

R_f (x 100) in	
Forestal	49
Formic	22
Butanol-HAC-H ₂ O	68
Visible color	magenta
Visible max. in MeOH-HCl	535 nm
Colour shift with AlCl ₃	+

Source: Harbone, 1973.

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DEVELOPMENT OF A HERBICIDE SCREENING METHOD THROUGH TISSUE CULTURE

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ABSTRACT

This study was attempted to establish the possible herbicide screening method through tissue culture. An appropriate medium, succinate dehydrogenase response and callus growth were detected using callus of different plant species such as rice (*Oryza sativa* L.), *Echinochloa crusgalli* L. and *Digitaria sanguinalis* L. under the treatment of various rates of metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] and butachlor [N-(butoxymethyl)-2-chloro-N-(2,6-diethylphenyl) acetamide]. MS(Murashige and Skoog) medium seems to be the most appropriate to induce callus from embryo of grass plants such as rice, *E. crusgalli* L. and *D. sanguinalis* L., by using 2,4-D about 5.5 mg/liter as hormone source. Succinate dehydrogenase in callus treated with metolachlor and butachlor showed the positive reaction against TTC regardless of concentrations used. Percent inhibition of callus growth markedly increased as the concentrations of both herbicides increased from 10^{-6} to 10^{-3} M. No callus was induced from all plant species under 10^{-3} M in both herbicides except rice in 10^{-3} M of butachlor. Among plant species, significantly different response was observed at the lower concentrations such as 10^{-6} and 10^{-5} M in both herbicides. Rice was highly selective to both herbicides, showing no inhibition at all, followed by *E. crusgalli* L. and *D. sanguinalis* L. in order. At the concentration of 10^{-6} M, *D. sanguinalis* and *E. crusgalli* L. showed the inhibition of 23 and 9% in butachlor, and 40 and 0% in metolachlor, respectively. *D. sanguinalis* L. was the most susceptible to both herbicides, suggesting that difference in response to herbicide may be used as a tool to evaluate a new herbicide.

INTRODUCTION

Herbicide screening is a long and costly process. In addition to the conventional methods, development of an alternate method is worthwhile to save time and cost. In recent years, plant cell or tissue culture has often been used in the study of herbicide selectivity and resistance in plant. Zilkah et al.(6) conducted comparative works on phytotoxicity of herbicides on callus or suspension culture and whole plant, and reported existence of fairly good correlations between the effects of phytotoxic compounds on seedlings and those on callus with the exception of some photosynthetic inhibitors.

A great difference in response of rice seedlings and rice callus to tetrapion [sodium 2,2,3,3,-tetrafluoropropionate] was reported(3). 1,000 mg of tetrapion/liter resulted in very slight growth inhibition in rice callus although 50 % growth inhibition in rice seedling was observed in the concentration of 2 mg/liter. Swanson et al.(4) reported that callus derived from susceptible line of *Lotus corniculatus* L. in field was greatly inhibited by 2,4-D than that of tolerant line. However, growth in both callus cultures were severely inhibited at high level of 2,4-D. Hirono et al.(2) also reported that alloxidium [2-(1-allyloxyamino) butylidene-5,5-dimethyl-4-methoxycarbonyl cyclohexane-1,3-dione-Na] having effective herbicidal effect to grass weeds, showed greater

callus inhibition in grass plants than that of broad-leaf plant such as soybean (*Glycine max.*). Tacheuchi et al.(5) reported the similar results that the newly synthesized compounds such as dymuron, bromobutamide and SG-5 resulted in the selective inhibitory effect on Cyperaceae weeds rather than gramineous plants tested through tissue culture derived from seeds or young buds.

Advantages of selecting or screening a new herbicide from tissue culture can be suggested that a large number of compounds can be evaluated in a small space and in a short time. However, it may be restricted to preemergence herbicides which mostly inhibit seed germination or early seedling growth. Thus, this experiment was attempted to investigate the response of callus growth derived from seeds of the Gramineae to acid amide herbicide such as butachlor and metolachlor.

MATERIALS AND METHODS

Selection of appropriate medium for callus induction. MS, Miller and N6 were used as the basal medium, added with 2,4-D as a hormone source at amount of 5.5, 11 and 22 mg/liter for *E. crusgalli* L. and *D. sanguinalis* L., respectively and MS medium only for the rice. Unhulled seeds of rice, *E. crusgalli* L. and *D. sanguinalis* L. were sterilized at 8 % $\text{Ca}(\text{OCl})_2$ solution for 20 minutes and washed 3 times with sterilized water. After removal of water from seeds on sterilized filter paper, 10 seeds were inoculated in test tube containing 20 ml medium and incubated at $25 \pm 1^\circ \text{C}$ in darkness. Fresh weight of callus was determined 20 days after incubation.

Reaction of succinate dehydrogenase against TTC [2,3,5-triphenyltetrazolium chloride] in herbicide treated callus. 10^{-6} , 10^{-5} , 10^{-4} and 10^{-3}M of sterilized butachlor and metolachlor by filtering through millipore filter having GS 25 Toyo filter paper were added to mineral salts of MS medium and then osmotic potential was adjusted with 13 % manitol. 20 ml of these solutions was placed in 50 ml Erlenmeyer flask and the small fragment of subcultured callus was transferred to Erlenmeyer flask. These flasks were incubated for 20 hours at the flatform shaker, about 100 strokes per minute at 30°C . These solutions containing callus were centrifugated with 5,000 rpm for 10 minutes and its precipitate was crashed with glass homogenizer and centrifuged again, and its supernatant was used as the crude enzyme. 3 ml supernatant was put to main chamber of Thurnberg tubes and then was vacuumed with the vacuum pump for 3 minutes and color reaction was checked against TTC reagent which was composed of 2,3,5-triphenyltetrazolium chloride (1 %) 1 : succinate- Na_2 (0.2M) 2 : Phosphate buffer solution(0.1M, pH 7.6) 2.

Callus growth affected by herbicides. Seeds of 3 kinds of plant species such as rice, *E. crusgalli* L. and *D. sanguinalis* L. were used to induce callus, and sterilized the same as mentioned in the above experiment. The final concentrations of herbicide in medium were adjusted to 10^{-6} , 10^{-5} , 10^{-4} and 10^{-3}M by filtering through millipore filter and 10 seeds of each plant species were inoculated and incubated at $25 \pm 1^\circ \text{C}$ for 30 days in darkness. Callus growth was measured by weighing induced callus excluding seeds at 30 days after incubation.

RESULTS AND DISCUSSION

Callus tissue was initiated from the embryos of *E. crusgalli* L. and *D. sanguinalis* L. seeds using MS, Miller and N6 medium, and MS medium only used for callus induction from rice seed. Within the same basal medium used, 2,4-D levels used did not influence callus growth derived from the various seeds (Table 1). However, the highest callus growth was obtained in the seed grown on medium containing 5.5 mg 2,4-D/liter, followed by 11.0 mg/liter regardless of mediums and plant species. Chen et al.(1) reported that 5 mg 2,4-D/liter could be applicable for callus induction from big bluestem (*Andropogon gerardii* Vitman) using Linsmaier and Skoog medium, and supporting callus growth. Among the mediums tested, the highest callus was obtained medium grown on the MS. From this result, it can be suggested that MS supplemented with 5.5 mg of 2,4-D/liter appeared an appropriate basal medium for callus initiation from the Graminae. our recent showed that 2,4-D rate less than 5.5 mg/liter can be effective as much as 5.5 mg/liter. (Data not included)

Response of succinate dehydrogenase which may be one of the enzymes responsible for callus growth was detected by TTC reaction. Regardless of herbicide concentrations, all the species showed positive reaction to TTC (Table 2). The positive reaction indicates that callus may be all alive, and this is only thing which can be interpreted from this result. Thus it can't be possible to apply for this reaction test to detect difference in callus growth as affected by the treatments of both herbicides. Hirono (2) also reported that alloxidum showing difference in callus growth between soybean and *D. sanguinalis* resulted in the same positive reaction to succinate dehydrogenase.

Figure 1 shows % inhibition of callus growth cultured on MS medium supplemented with 5.5 mg 2,4-D/liter. Percent inhibition markedly increased as the concentrations of butachlor and metolachlor increased from 10^{-6} to 10^{-3}M . There was no difference in response of plant species to both herbicides at the highest concentration such as 10^{-3}M . Initiation and growth of callus were entirely inhibited at this concentration. Significantly different response among the plant species were observed at the lower concentrations such as 10^{-6} and 10^{-5}M in both herbicides. Especially, rice was highly selective to both herbicides, showing no inhibition at all, followed by *E. crusgalli* L. and *D. sanguinalis* L. However, at the 10^{-6}M , *D. sanguinalis* L. and *E. crusgalli* L. were inhibited by butachlor about 23 and 9 %, and by metolachlor 40 and 0 %, respectively. Percent inhibition in both weeds increased as the concentration increased from 10^{-6} to 10^{-5}M although no inhibition was observed in rice. This further indicates, among the gramineous plants, existence of difference in response at the cellular level to both herbicides.

The selective inhibition of callus has been reported by several workers (2,3,5). Hirono (2) reported that alloxidum herbicide which is mainly used for control of grass weeds in soybean crop resulted in selective inhibition effect on callus of *D. sanguinalis* L. and *Setaria viridis*. Further, there was difference between *D. sanguinalis* L. and *S. viridis* in response to it belonging to the same grass that may be attributed to difference in cellular levels. The growth of undifferentiated cells like callus was greatly affected at the lower concentrations of metolachlor or butachlor. This inhibition may be related to influence of acid amide herbicides on the basal metabolism-protein and nucleic acid metabolism, and energy transfer process, etc. which are required for activities

Table 1. Fresh weight of callus derived from seeds of rice, *Echinochloa crusgalli* L. and *Digitaria sanguinalis* L. under various mediums.

2,4-D (mg/l)	medium plant species	Fresh weight (mg/seed)						Miller	
		MS		N6					
		Rice	E.c.1)	D.s.2)	E.c.	D.s.	E.c.	D.s.	
5.5	54.42 ^a 3)	31.59 ^a	22.0 ^a	29.42 ^a	22.0 ^a	9.08	22.32 ^a	24.15 ^a	
11.0	40.31 ^a	37.09 ^a	17.53 ^a	19.46 ^a	17.53 ^a	8.16 ^a	16.09 ^b	15.05 ^a	
22.0	2.01 ^b	12.94 ^a	14.89 ^a	22.37 ^a	14.89 ^a	3.85 ^a	9.13 ^b	13.16 ^a	

1) E.c. : *Echinochloa crusgalli* L.

2) D.s. : *Digitaria sanguinalis* L.

3) Means within a column with the same letters are not significantly different at 0.05 level (Duncan's multiple range test)

Table 2. Reaction of succinate dehydrogenase against TTC in various callus derived from various plant species treated with butachlor and metolachlor. 1)

plant species	Herbicide	conc.	10 ⁻⁶		10 ⁻⁵		10 ⁻⁴		10 ⁻³	
			B.	M.	B.	M.	B.	M.	B.	M.
Rice			+	3)	+	+	+	+	+	+
<i>E. crusgalli</i> L.			+	+	+	+	+	+	+	+
<i>D. sanguinalis</i> L.			+	+	+	+	+	+	+	+

1) Duration of butachlor and metolachlor treatment : 20 hrs.

2) B : Butachlor

M : Metolachlor

3) + : positive reaction to TTC [2,3,5-triphenyltetrazolium chloride]

at the cellular level. Tetrapion, a selective herbicide applying to gramineous weeds resulted in 50 % growth inhibition when treated in rice seedlings at the concentration of 2 mg/liter, but even at the 1,000 mg/liter only slight growth inhibition was observed in rice callus(3). The negligible inhibition of tetrapion in rice callus means that inhibition target of this herbicide may not be related to basal metabolism, but it may be linked with morphogenetic process including skeleton structure construction like cell wall synthesis in tissue and organ(3). From these results, it can be postulated that difference in callus growth among the Gramineae against acid amide herbicide may be attributed to the difference in the cellular level of each grass plant, indicating that this difference can be possibly used as a tool to screen a new herbicide through tissue culture in addition to greenhouse and field screenings.

Further studies on cellular levels of callus may shed more light on understanding of difference in susceptibility in callus growth when treated with herbicides.

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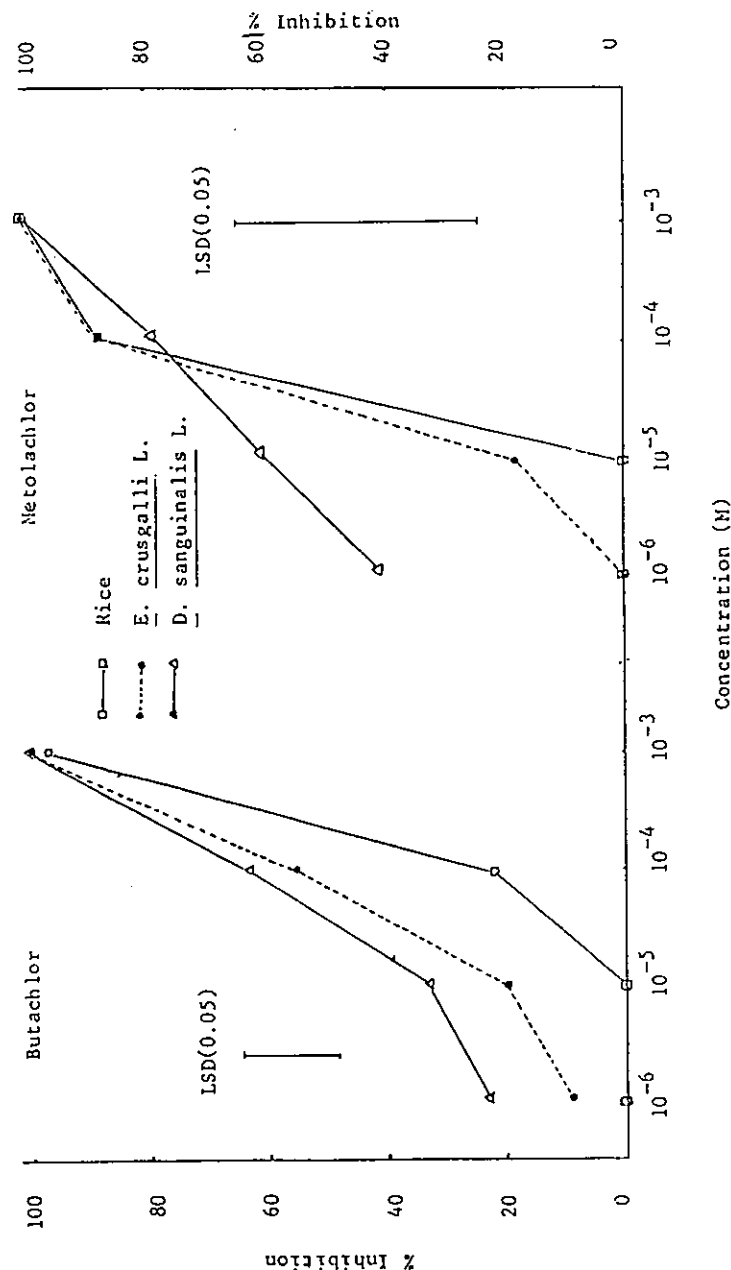


Figure 1. Percent inhibition of callus growth as affected by the treatment of various concentration of butachlor and metolachlor.

DIFFERENCES IN NUTRIENT ABSORPTION AMONG PADDY WEEDS

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ABSTRACT

In order to clarify the mechanism of competition among weedy plants in the paddy field, several experiments have been conducted using the noxious paddy weeds in the northeast Japan.

There were no differences in the competitive power among the weed species grown in the mixed planting, which reflects difference of the capacity of absorbing nitrogen fertilizer. Nitrogen utilization efficiency defined by the relationship between nitrogen absorption and dry weight increase, varied with the weed species, and three groups of weeds could be classified. The most efficient group was belonging to the C₄ plants and the least one was found in the family of *Alismataceae*. Other species showed an intermediate efficiency between the above two groups.

The responses to light and temperature of the weed species were investigated in the experiments of the shading and temperature treatment with a growth chamber. The species tolerant to low temperatures presented rapid initial growth in the field condition. Those sensitive to shading showed the depressed growth in the mixed planting with rice when the latter grew vigorously under a high fertilizer level.

The light curve of the photosynthesis was also studied to clarify the ecological adaptation of weed species.

INTRODUCTION

The assessment of damages due to weeds is essential in the establishment of reasonable weed control. Among the many factors which influence the interaction between rice and weeds, competition for nutrient seems to be one of the major factors.

In the present paper, the growth and nitrogen absorption of paddy weeds in mixed planting was studied as associated with light and temperature conditions.

MATERIALS AND METHODS

Eight species of paddy weeds (*Echinochloa crus-galli*, *Monochoria vaginalis*, *Cyperus serotinus*, *C. difformis*, *Eleocharis kuroguwai*, *Sagittaria trifolia*, *Alisma canaliculatum*, *Scirpus juncooides*) which are noxious in the north-eastern district of Japan were used as materials.

1) Competition between weed species in mixed planting.

Two weed species (each one seedlings) were transplanted in 1/5000a Wagner pot containing 0.26g of each fertilizer (N, P₂O₅, K). 35 days after transplanting, dry weight and the amount of absorbed nitrogen of each weed species were investigated.

Seedlings of rice and weeds were transplanted in 1/5000 α Wagner pot and were subjected to temperature or shading treatment for 30 days.

Temperature treatments were conducted by growing the materials in the growth chambers of 25, 20 and 15°C.

Shading treatments were conducted by restricting the light intensity with cheese cloth. Those were 100 % (non-shaded), 65 % and 35 % of full sunlight. A relation of photosynthesis to light was investigated with oxygen electrode according to the method of Saka and Chisaka (1981).

RESULTS

1) Competition between weed species in mixed planting

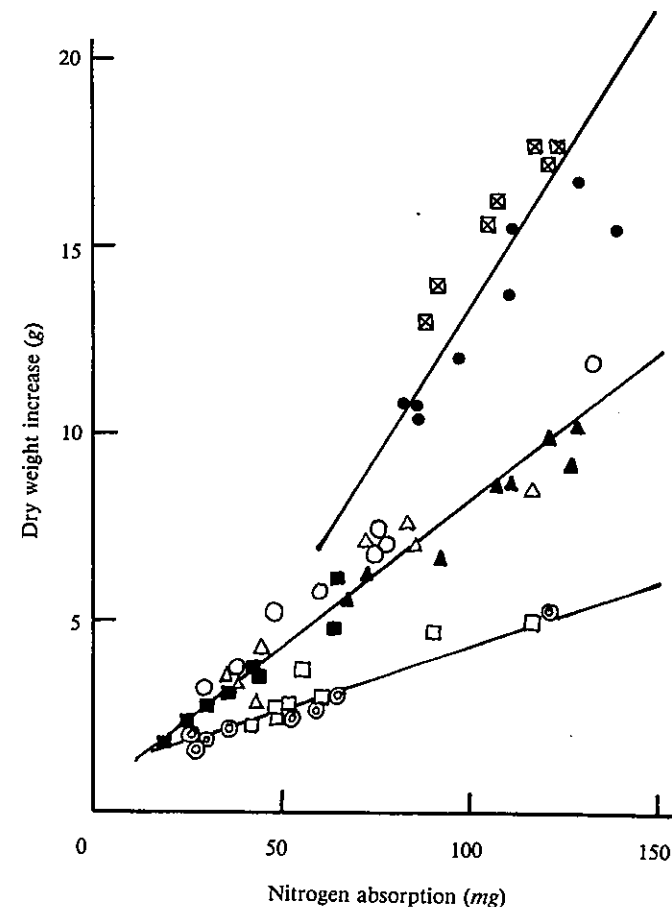
Notable differences were observed in competitive power between weed species grown in mixed planting. *Echinochloa crus-galli*, *Monochoria vaginalis* and *Cyperus serotinus* had a great capacity of nitrogen absorption dominating the other species (Table 1).

Table 1. Competitive power* in mixed planting

	Dry Weight (%)	Nitrogen absorption (%)
<i>Cyperus difformis</i>	16.7	29.7
<i>Echinochloa crus-galli</i>	51.9	62.0
<i>Scirpus juncooides</i>	30.1	38.3
<i>Monochoria vaginalis</i>	53.0	61.7
<i>Sagittaria trifolia</i>	26.6	36.6
<i>Alisma canaliculatum</i>	31.6	39.4
<i>Eleocharis kuroguwai</i>	21.7	29.6
<i>Cyperus serotinus</i>	44.0	56.7

* Competitive power was calculated from average percent of growth inhibition of the other weeds in mixed planting.

Nitrogen utilization efficiency defined by the relationship between nitrogen absorption and dry weight increase varied with the weed species, three groups of which could be classified. The first group was *Echinochloa crus-galli* and *Cyperus serotinus* with a high efficiency in nitrogen utilization. *Sagittaria trifolia* and *Alisma canaliculatum* formed the third group with a low efficiency. The second group was the remaining weeds which showed an intermediate efficiency between the above two groups. (Fig. 1).



Cyperus serotinus ($\square$)
Cyperus difformis ($\circ$),
Scirpus juncooides ($\triangle$),
Sagittaria trifolia ($\circ$),
Echinochloa crus - galli ($*$)
Eleocharis kuroguwai ($\circ$)
Monochoria vaginalis ($\circ$)
Alisma canaliculatum ($\square$)

Fig. 1 Relationship between nitrogen absorption and dry weight increase

2) Response of weed species to temperature and light

Depression of the growth of weeds by low temperature varied with weed species. *Cyperus serotinus*, *Sagittaria trifolia* and *Alisma canaliculatum* grew vigorously compared with the other species (Fig. 2).

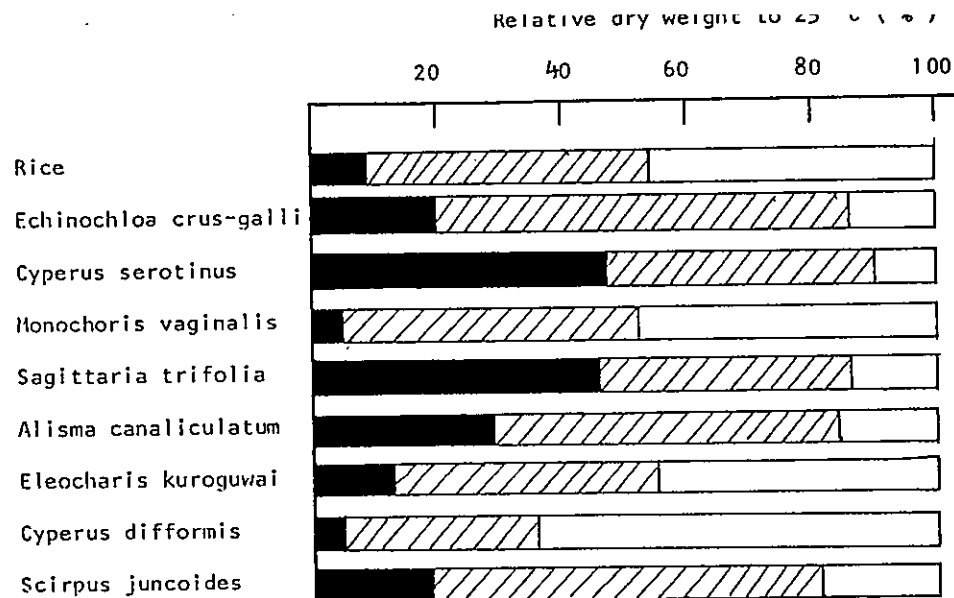


Fig. 2 Effect of temperature on the growth of weed species

: 20 °C

: 15 °C

The relative ratio of shaded plants to non-shaded plants in dry weight increase was considerably different according to weed species. *Sagittaria trifolia* and *Eleocharis kuroguwai* were comparably tolerant to shading compared with *Cyperus difformis* and *Scirpus juncooides* (Fig. 3). Photosynthesis of shaded plants was higher than that of non-shaded plants at a low light intensity in both *Sagittaria trifolia* and *Alisma canaliculatum* (Fig. 4).

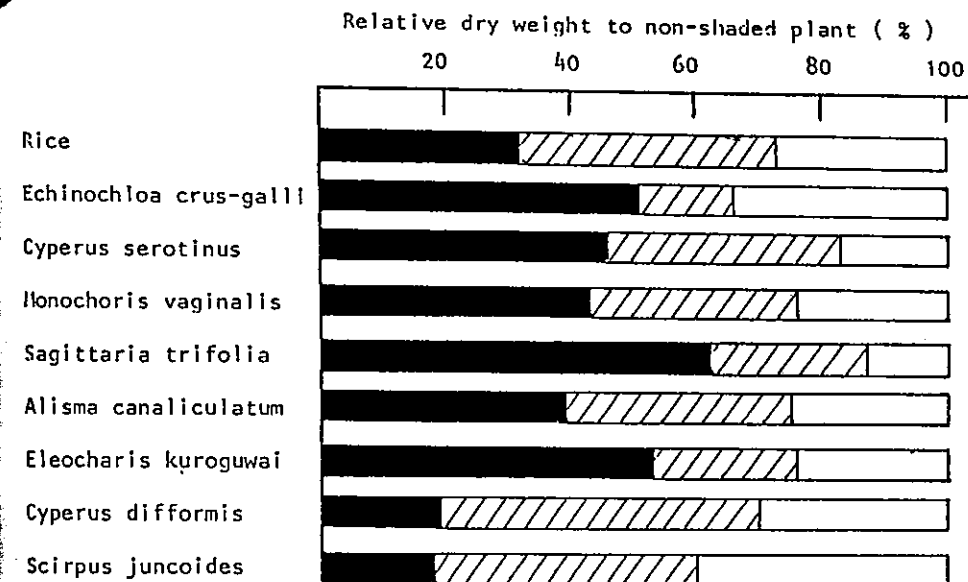


Fig. 3 Effect of shading on the growth of weed species

: 65 % sunlight

: 35 % sunlight

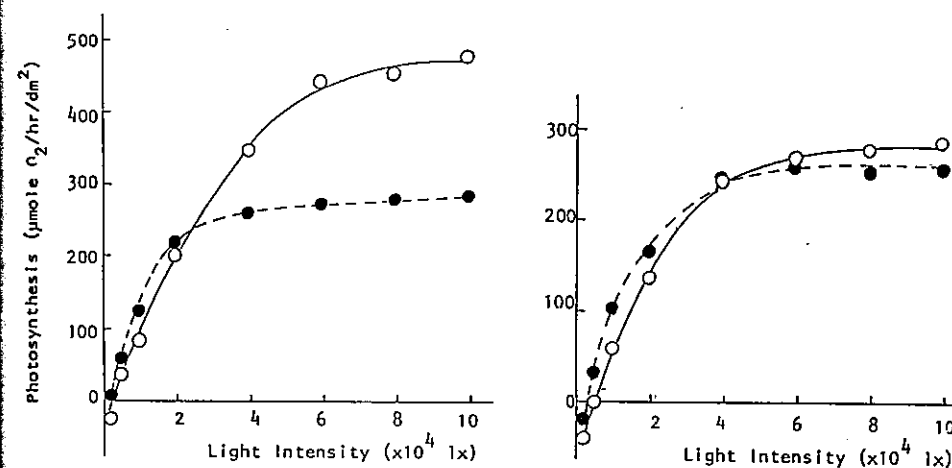


Fig. 4 Effect of shading on the light-curve of photosynthesis

○ : Non-shaded plant

● : Shaded (65 % sunlight) plant

It is known that weed species differently affect rice. Chisaka (1966) investigated the differences of damages on rice among weed species and indicated that the weed species affect the growth of rice similarly from the standpoint of nitrogen absorption. Competitive power in nitrogen absorption was investigated directly in this experiment. As a result, the weed species which showed high capacity of nitrogen absorption provided more serious weediness in the field.

Determination of nitrogen utilization efficiency was effective to elucidate the mode of nitrogen absorption in weed species. *Echinochloa crus-galli* and *Cyperus serotinus* belong to C_4 plants which reported to have high efficiency in nitrogen utilization due to the effective CO_2 fixation system (Brown 1978). The reason of low efficiency in Alismataceae weeds was unknown. These weeds seems to favor the high fertilizer condition.

Meteorological factors such as temperature and light affect greatly the growth and nitrogen absorption of weed species. Tolerance to low temperature gives advantage to weeds in north-eastern district of Japan because of being in low temperature in general. The low temperature-tolerant weeds used in this experiment show the rapid emergence in the field condition.

Tolerance to low light intensity seems to be attributed to the form of reproductive organ such as tubers or seeds. *Cyperus difformis* and *Scirpus juncoides* germinate from small seeds, whereas *Sagittaria trifolia* and *Eleocharis kuroguwai* have big tubers which contain high amount of carbohydrate.

Weed species which belong to Alismataceae are reported to grow vigorously under slightly shaded condition (Itoh and Kusanagi 1978). Adaptation of photosynthesis at low light intensity which was observed in this experiment seems to play an important role in the tolerance to shading in these weeds.

ACKNOWLEDGEMENT

We thank Dr K. Noda, Project leader of Thai-Japan Weed Science Research Project, for his kind suggestion in preparing this report.

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POTENTIALITY OF *Eichornia crassipes*

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ABSTRACT

Analysis of the water from the irrigation canal around the vicinity where the hyacinth were harvested indicated very low levels of the minerals Ca, Fe, K, Mg, Mn and P. However, the shoot and root of hyacinth on the contrary contained high levels of Ca, 2,500 and 12,500 ppm; Fe, 2,300 and 540 ppm; K, 13,000 and 24,500 ppm; mg, 5,000 and 9,667 ppm; Mn, 966.1 and 500 ppm and P, 2,700 and 3,200 ppm, respectively, indicating their capability to bioconcentrate them. Protein, lipids and steroid contents of plant were found to be ca. 9,403, 1.8 and 0.23%, respectively.

Comparison of the amino acids composition in the shoot indicated high proportions of val., 5.4%; ala, 7.6%; gly., 7.0%; glu., 7.4% and asp., 9.1% while in the root their contents are ala., 7.1%; gly., 5.5%; pro., 6.4% and asp., 7.2%. The data also indicated that the essential amino acid tryptophan is lacking in the hyacinth. Fatty acid composition analysis of total lipids demonstrated large proportions of an unknown acid between the 12:0 and 14:0 acids in gaschromatograms amounting to 21.4 and 51.2% respectively in the shoot and root. This ratio was followed by the 16:0 (10.6% and 9.0%), 16:1 (7.3% and 3.7%), 20:2W9 (6.1% and 2.5%) and 18:2W6 (5.8% and 2.3%) acids. Similarly, steroid gas chromatographic analysis showed the existence of cholestane, cholesterol, ergosterol, stigmaterol, β -sitosterol and two unknown moieties. Amongst them cholesterol was the least in amount (0.0221 μ g/g) while β -sitosterol was the highest (0.8838 μ g/g).

Feeding trials of hyacinth on chickens for a period of 8 weeks at various amended levels in a normal marketed feed indicated that a 5, 10 and 15% amendment decreased meat production by 40.4, 47.20 and 46.96%, respectively. On the contrary, the economics was such that the control has a beneficial income against total expenditure by 33% while the 5, 10 and 15% amendments of hyacinth by 2, 4 and 11%, respectively.

Soil amendment studies of hyacinth shoot and root on the growth of sorghum var. DOBB6 indicated enhancement effects to be most by 1.5% amendment in both cases. This effect is 46 and 40% for shoot and root treatments respectively.

The biochemical soil amendment and chicken feed trials support the feasibility in utilizing water hyacinth for the benefit of the rural community at Muda-Pedu Reservoir and canal system area.

INTRODUCTION

Throughout the world about 150 different varieties of aquatic weeds are considered to be pollutants in one way or another. Depending on their habitat they are grouped into three categories, viz. (a) dense filamentous algae growing on concrete walls, on rocks in ponds, streams and impoundments; (b) submerged weeds such as pondweeds, elodeas and water milfoils (*Egeria* and *Hydrilla*) and (c) large floating water weeds such as water hyacinth and water lettuce (*Pistia stratiotes*). In most cases, the large floating water weeds are a considerable problem because they

drastically reduce water quality; hamper recreation; impede flood control; drainage and irrigation; and disrupt fish and wildlife management and disease-vector control. To combat this situation, the normal control measures are basically biological for alligator weed, *Alternanthera philoxeroides* (Mart.), Grisob, using *Agasicles hygrophila* Selman & Vogt. (Weldon *et al.*, 1973) float beetle, *Vogtia* thrips, *Amnothrips andersoni* O'Neill, and moths, *Vogtia malloi* Pastrana, while chemical measures are used for water hyacinth, *Eichornia crassipes*, using one of the amine salts and the butoxy ethanol of 2,4-dichloro-phenoxyacetic acid (2,4-D) and 2-(2,4,5-trichlorophenoxy) propionic acid (Silvex). At certain times, two other herbicides such as endothall and diquats are also employed.

In the United States a five-year pilot project under the Aquatic Plant Control Program (APCP) was implemented in 1958 at eight south eastern, coastal states from North Carolina at Texas. This project successfully treated 200,000 acres of water hyacinth and alligator weed with 2,4-D and Silvex at an annual cost of ca. US\$4,000,000 which yielded a benefit return of ca. US\$14,000,000. The use of phenoxy herbicide is believed to be relatively non-persistent (Gangstad *et al.*, 1975) but there are reports (Rawls; 1965, Butler; 1963 and 1964) which indicate 2,4-D formulation between 1 and 10 ppm in aquatic organisms such as oysters, shrimp and blue crabs. However, a concentration of 0.5 ppm of 2,4-D is considered to be the maximum if no harm is to come to estuarine organisms (Rawls; 1964, Butler; 1963). There is also evidence that 2,4-D will biodegrade into 2,4 dichlorophenol, a nondegradable and highly toxic compound. The threshold for this compound is 2-5 ppb and; therefore, steps must be taken to limit the spread of chlorinated phenols in the environment. Norris (1966) and Norris and Greiner (1967) have indicated that the percent of degradation of 2,4-D and 2,4,5T are 89 and 23% respectively for 312 hr and only 53% at 690 hr for 2,4,5T. Based on this information we can see that economic gains are possible through chemical control of floating water weeds but that chemical control does have many shortcomings.

Another means of weed control is by the use of biological pathogens. Fungal blight, incited by *Rhizoctonia solani*, is a potential organism for water hyacinth control. Similarly, *Fusarium rosenum*, a leaf-spotting disease of water hyacinth could also serve this particular purpose. Diseases of alligator weed, water milfoil and *Hydrilla* could play similar roles (Gangstad *et al.*, 1974) in weed control. However, this mode of biological control is yet in its infancy.

In the MUDA area, the rice-bowl of Malaysia, aquatic weeds, especially the water hyacinth (Plate 1), pose problems in the irrigation canal systems, both in inhibiting easy flow of water into the paddy fields and in reducing water quality. To overcome these problems chemical and biological control can be considered; however, their eventual effect on the aquatic environment would greatly jeopardize the agricultural community. As such, the author proposes the utilization of this aquatic weed, *Eichornia crassipes*, for animal feed, human consumption and soil conditioning. In this connection, a complete biochemical analysis, feeding trials and plant growth experiments were conducted using hyacinth harvested in one of the irrigation canals in the Muda Scheme. This paper discusses the results of these experiments.

MATERIALS AND METHODS

Hyacinth was harvested at Alor Janggus in the Muda area and brought back to the laboratory where they were thoroughly cleared under running tap water before being used in the various experiments.

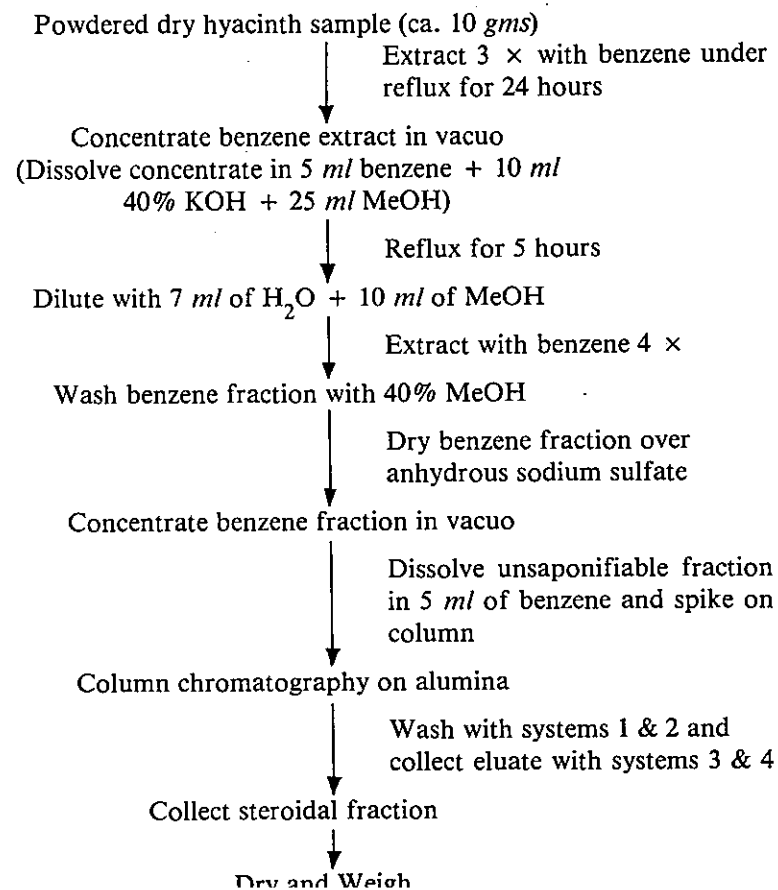
Analysis of mineral content in the water in the vicinity of hyacinth plants

Water collected in the vicinity of hyacinth plants in the irrigation canal at Alor Janggus was analyzed for its Ca, Fe, K, Mg, Mn and Na contents using a Varian Techtron AA120 atomic absorption spectrophotometer. The phosphate content, on the other hand, was calibrated using the method of Strickland and Parsons (1968).

Analysis of minerals, proteins, lipids and steroid content in shoots and roots of hyacinth

Al, Ca, Fe, K, Mg, Mn and P contents in shoots and roots of hyacinth were determined as mentioned previously. To determine protein and lipid content the Kjeldahl and Soxhlet methods were employed. Steroid content, was determined according to the methods of Ikekawa *et al.* (1968) and Isabelle Chardon-Lariaux *et al.* (1967) as illustrated (on the followings)

Extraction procedure for steroid content determination



Note: Solvent System for Column Chromatography

System 1 : Hexane : benzene, 5 : 2.6)

) Discard

System 2 : Hexane : benzene, 5 : 3)

System 3 : Benzene (ca. 150 ml)

) Steroidal Fraction

System 4 : Diethyl ether (ca. 150 ml)

Analysis of steroid composition of hyacinth plants

The extracted steroidal fraction was injected directly into a Shimadzu gas chromatograph GC-6A with a hydrogen flame ionization detector for the determination of its steroid composition. The conditions of the gas chromatograph were as follows: column packing, 1.5% OV-1 Shimalite W; column temperature, 240°C; injection port and detector temperature, 290°C; N₂ flow, 60 ml/min.; H₂ flow, 60 ml/min. and air flow, 1 lit₂/min. The obtained chromatogram was quantitatively determined for the various steroid content against authentic compounds.

Amino acid analysis of shoots and roots of hyacinth plants

Dried shoots and roots of hyacinth plants (ca. 5 mg) were hydrolyzed separately in 6N HCl under vacuo at 110°C for 24 hours. After removing the HCl in vacuo and drying over NaOH the residue was dissolved in 3 ml of 0.01M citrate buffer pH 2.2 and aliquots of 0.5 ml and 0.3 ml were analysed for basic, acidic and neutral amino acids using a 6 channel JEOL-JLC-5AH automatic amino acid analyser.

Fatty acid composition analysis of total lipids

The Soxhlet extracted total lipids of shoots and roots of hyacinth were initially methylated with boron trifluoride in methanol and subjected to GLC analysis under the following conditions.

Apparatus	Shimadzu gas chromatograph GC-6A attached with a hydrogen flame ionization detector.
Column	Glass tube 2.0 m × 3 mm ϕ
Packing	15% DEGS on 80/100 mesh Shimalite
Carrier gas	Nitrogen
Flow rate	
Nitrogen	2.2 kg/cm ²
Hydrogen	0.8 kg/cm ²
Air	1.0 kg/cm ²
Temperature	
Detector	220°C
Injection port	220°C
Column	Isothermal 190°C

Plant growth experiments

The effects of dried shoots and roots on plant growth of sorghum var. DOBB6 through various amendments as a soil conditioner was carried out over a culture period of 2 weeks. The levels of amendments ranged from 0.5, 1, 1.5 to 2%, respectively. Each experimental lot consisted of at least 20 plants. After 2 weeks of culture the plants were harvested and dried before comparison of their weights.

Chicken feed experiments

As a means of utilizing *Eichornia crassipes* for animal feeds, chicken feed trials were carried out through various amendments of it in marketed chick grower mash produced by a local company, Chee Kheng Stock Feeds. The constitution of the marketed feed is maize, wheat, bran, beans, minerals, yeast, fish meal, milk powder, cod liver oil containing vitamin B, complex A & B and antibiotics. The levels of amendment of dried hyacinth were in the ratio of 5, 10 and 15%, respectively. Normally, the daily ration for the first 4 weeks of breeding was equivalent to the total weight of chicks × 1.07 gms, while for the following 4 weeks the amount was the total weight of chicks × 1.5 gms. Every week the increase/decrease in total weight was noted and the final protein yield after 8 weeks of breeding was calculated for economic gains.

RESULTS

Table 1 shows the mineral content of H₂O in the irrigation canal near the vicinity where *Eichornia crassipes* was harvested. It is evident that most of the examined parameters are low in concentration. However, these parameters are fairly high in shoots and roots of hyacinth plants (Table 2). Out of these parameters Al, Fe and Mn are low in concentration in the root. Also, the crude proteins and lipids are high in the shoot as compared to those in the root. It should also be noted that the lipid content is only 1.9%, which would normally inhibit rancidity, if stored as silage. The carbon content on the other hand seems to be higher in the root than in the shoot.

Table 1. Mineral content of H₂O from the irrigation cannal at Alor Jangus where *Eichornia crassipes* was harvested.

Parameter	Content (ppm)
Ca	1.09
Fe	0.67
K	1.83
Mg	11.0
Mn	BDL*
Na	9.5
P	0.023

*BDL; Below detectable level.

Table 2. Crude proteins, lipids, steroids and mineral contents of shoots and roots of *Eichornia crassipes*.

Section of Plant	Crude Proteins (%) (N × 6.25)	Lipids (%)	Steroids (%)	C %	Al	Ca	Fe %	K	Mg	Mn	P
Shoot	9.7	1.9	0.23	40.08	66,000	2,500	2,320	13,000	5,000	966.6	2,700
Root	9.105	1.7	0.24	42.96	1,066	12,500	540	24,500	9,667	500	3,200

In Table 3 the amino acid composition of proteins in both shoots and roots are given. For comparison related values of soyabean meal and rice are also tabulated. Evidently, both shoots and roots of *Eichornia crassipes* are lacking in the essential amino acid tryptophan. Further the shoots indicate high proportions of valine, alanine, glycine, glutamine and asparagine while the roots are high in alanine, glycine, proline and asparagine.

Table 3. Amino acids of shoots and roots of *Eichornia crassipes* in comparison with soyabean meal* and rice*

Amino acids	Section of hyacinth		Soyabean Meal (%)	Rice (%)
	Shoot (%)	Roots (%)		
Phe.	2.5	2.4	5.7	6.3
Tyr.	2.6	1.7	4.1	5.6
Leu.	4.7	4.8	6.6	9.0
Ileu.	3.3	3.0	4.7	5.1
Met.	0.3	0.2	2.0	3.4
Val.	5.4	4.8	4.2	6.4
Cys.	0.0	0.0	0.6 ± 1.4	1.4
Ala.	7.6	7.1	-	-
Gly.	7.0	5.5	-	-
Glu.	7.4	2.8	-	-
Pro.	3.9	6.4	-	-
Ser.	4.0	2.5	-	-
Thr.	4.1	2.8	4.0	3.9
Asp.	9.1	7.2	-	-
Arg.	2.1	1.6	5.8	7.2
NH ₃	31.0	43.1	-	-
His.	1.4	0.8	2.3	1.5
Lys.	3.6	3.3	5.8	3.2
Tryp.	-	-	1.6	1.3

* Adapted from Block, R.J. and Boiling, D. "Amino Acid Composition of Proteins and Foods: Analytical Methods and Results". 2nd ed., Charles Charles C. Thomas, Springfield, Ill., 1951.

The steroid composition of the steroidal fraction of *Eichornia crassipes* is as indicated in Table 4 and Fig. 1. The components are cholestane, cholesterol, ergosterol, stigmasterol, β -sitosterol and two unknown moieties. From this evaluation it is evident that the concentration of cholesterol is the lowest (0.0221 $\mu\text{g/g}$) while β -sitosterol is the highest (0.8838 $\mu\text{g/g}$). This indicates that when hyacinth is consumed by humans it would not lead to disease caused by high concentrations of cholesterol in the diet.

Table 5 indicates the fatty acid composition of total lipids from shoots and roots of hyacinth. A large proportion of an unknown acid which falls between the 12 : 0 and 14 : 0 fatty acids in the gas chromatogram is present in the shoots and roots in a ratio of 12 : 4 and 51 : 2, respectively. The other fatty acids present in fairly large amounts are the 16 : 0, 16 : 1, 18 : 2W6, 18 : 3W3 and 20 : 2W6 acids. In all instances, the aforementioned acid concentrations are proportionately larger in the shoots than the roots.

Table 4. Amount of different steroids found in the steroidal fraction of *Eichornia crassipes*.

Steroids	Content (μ g)
Cholestane	0.0259
Cholesterol	0.0221
Ergosterol	0.2556
Stigmasterol	0.3237
B-sitosterol	0.8838 μ g
Unknown a	-
Unknown b	-

Table 5. Fatty acids composition of total lipids from shoots and roots of *Eichornia crassipes*.

Fatty Acid	Shoots	Roots
12:0	2.6	0.9
?	21.4	51.2
14:0	3.3	1.9
14:1	0.8	0.1
15:0	1.5	1.2
16:0	10.6	9.0
16:1	7.3	3.7
18:0	1.9	0.7
18:1w9*1	3.9	4.0
18:2w6	5.8	2.3
18:2w4	0.6	-
18:3w6	0.1	-
18:3w3	5.1	0.4
?	4.7	4.1
18:4w3)	0.7	-
20:0)		
20:1	4.5	2.2
20:2w9	1.6	0.9
20:2w6	6.1	2.5
20:3w9	0.9	1.0
20:3w6	1.1	0.3
?	1.1	1.1
20:3w3)	0.1	0.1
20:4w6)		
20:4w3	0.6	-
20:5w3	2.6	1.7
22:0 ?	0.7	0.2
22:1	0.5	0.7
22:5w6	tr	-
22:5w3	0.4	-
?	3.3	4.9
22:6w3	0.8	1.1

*1 Small amounts of the other monoenes were included.

Results of soil amendment studies on the effect of hyacinth shoots and roots on the growth of sorghum var. DOBB6 are indicated in Table 6. Both treatments enhance plant growth by 46 and 40% respectively at an optimum amendment of 1.5% in garden soil.

Table 6. Effect of *Eichornia crassipes* shoots and roots on the growth of sorghum var. DOBB6.

Percent Treatment	Shoot treatment		Root treatment	
	wt. per plant (gm)	% Increase	wt. per plant (gm)	% Increase
0	0.35	-	0.35	-
0.5	0.39	12	0.37	6
1	0.47	35	0.43	23
1.5	0.51	46	0.49	40
2	0.34	-2	0.32	-8

Chicken feed trials indicate that a 5, 10 and 15% addition to normal, marketed, complete chicken feed results in a drop in meat production by 40.4, 47.20 and 46.96% (Table 7 and Fig. 2), respectively. However, from the economical stance the highest amendment shows a 11% gain in income compared to a gain of 33% with normal complete feed (Table 8). Based on these results, it is obvious that the hyacinth could be used as an animal feed if supplemented by the lacking essential amino acid tryptophan for higher meat production.

DISCUSSIONS

The results indicate that, though the protein content of hyacinth is only ca. 9.4%, roughly 40% lower in content than that of beef, it is fairly high considering it is a waste product. However, it could be consumed as a local dish in the form of salad. This is a normal practice of the rural agricultural community to obtain a source of vegetable proteins low in cholesterol content. In this connection since there is a deficiency in the essential amino acid tryptophan in the hyacinth, the nutritive value of this plant could be elevated if a certain proportion of it was added to it.

As a soil conditioner, hyacinth augments plant growth in sorghum plant DOBB6 by a fair margin. However, if additional amendments of P, N and K are done there is a possibility of expanding this margin. In this regard there are reports (Iswaran and Sen; 1973a & 1973b, Sirkar and Kundu; 1959 & 1960, Dirkar and Ray; 1960 and Sen; 1975) which indicate the existence of *Azotobacter chroococcum* in the phyllosphere of water hyacinth, certain growth substances in root extracts and show the yield enhancement for brinjal, wheat and padi. A similar report was published by Iswaran *et al.* (1978). Based on this information it is feasible to recycle water hyacinth into the Muda agricultural land as a soil conditioner to augment rice yield.

Table 7. Effect of amendment of *Eichornia crassipes* in normal chicken feed on their growth.

% Amendment of hyacinth	Initial wt. per chicken (gm)	Increase in weight each week (gm)							
		1st Week	2nd. Week	2rd. Week	4th Week	5th Week	6th Week	7th Week	8th Week
Control*	53.667	63.33	88.32	131.667	185	250	403.33	610	853.33
5%	53.667	63.21	87.26	115.04	150.74	194.4	293.54	396.67	511.7
10%	53.667	61.92	79.93	101.73	134.43	174.4	268.87	363.33	450.53
15%	53.667	70.27	82.67	111.69	124	186.00	260.4	347.2	452.6

* Chick grower mash produced by Chee Kheng Stock Feeds containing maize, wheat, bran, beans, minerals, yeast, fish meal, milk powder, cod liver oil containing vitamin B, complex A & B and antibiotics

Table 8. Economics of amending *Eichornia crassipes* in normal chicken feeds for 8 weeks

% Amendment	Total amount of feed used (kgms)	Cost of feed (\$)	Total wt. of chicken (gms)	Marketable price of chickens (\$)	Final gain/loss in income (\$)	% gain against cost incurred
Control	3.2615	1.81	853.33	2.40	0.59	33
5	2.5645	1.42	511.7	1.44	0.01	2
10	2.1956	1.22	450.53	1.27	0.05	4
15	2.0683	1.15	452.6	1.27	0.12	11

From the economical aspect it seems that using hyacinth as an animal feed is a beneficial and viable endeavour even though the growth rate of chicks are retarded. The author believes that with the addition of the lacking essential amino acid tryptophan growth retardation would parbably be eliminated. The idea of using hyacinth as animal feed is supported by the report of Minano (1966) which indicates its effectiveness in the breeding of sows and boars. He believes that though the hyacinth is low in nutrient content it could be fed profitably as forage to pregnant sows. Further, it could be stored as silage for long periods due to its low lipid content which precludes rancidity. Therefore, the water weed, *Eichornia crassipes*, could be converted into an economic commodity.

Finally, instead of resorting to biological/chemical control of water hyacinth in the Muda area which will eventually create new problems, there is the possibility of utilizing it as a soil conditioner to augment paddy yield, and as an animal feed as well as for human consumption.

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THE CONVERSION OF *Imperata* DOMINATED AREA INTO A RUBBER PLANTATION

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ABSTRACT

A field experiment was conducted to investigate the suitability of various methods to convert areas dominated by *Imperata cylindrica* into rubber plantation.

A split plot design with *Imperata cylindrica* control techniques as the main plot and inter cropping as subplots was used. Five different methods of *Imperata* control, i.e. glufosinate (4 kg ai/ha) glyphosate (3.6 kg ai/ha), dalapon (12.6 + 8.4 kg ai/ha + 1% urea), mechanical control, and manual cultivation; and four different techniques of intercropping, i.e. food crop, pasture, legume cover crops and pineapples were utilized. The treatments were replicated 3 times. The experiments were carried out with plots measuring 25 x 20 m on red yellow podzolic soil.

The regrowth of *Imperata*, the yield of intercrops, the growth of rubber were assessed and the possibility of adopting various methods in actual practice is discussed.

INTRODUCTION

The existence of a vast area dominated by alang-alang (*Imperata cylindrica* (L.) Beauv.), an anthropoceres in nature, represents an environmental mis-management. The area becomes unproductive, able to give only a marginal benefit, in the form of temporary vegetation cover, or a low quality of pasture.

Shoot density of alang-alang can reach 600 shoot/m² with its weight of about 11 tons/ha, beside the underground rhizome which can reach 7 tons/ha of more (Tjitrosemito *et al.*, 1980; Soerjani, 1970). Its productivity is approximately 0.11 gg⁻¹ day⁻¹, when measured in the laboratory, but may be lower in the field since usually 60% of its leaf is in the stage of senescence (Eussen, 1980; Mitchell, 1964).

Control practices have been researched and done extensively and single method of control usually is not successful; an integrated approach is therefore advocated. Principally the area should be planted with crop immediately after its control. Mechanical control has been reported to be successful when done correctly (Mangunsong *et al.*, 1975). However, in areas where the land is dominated by red yellow podzolic soil which is prone to erosion, chemical control may be more beneficial. The benefit will be greater when followed by zero tillage technique for crop establishment.

This paper reports several alternatives of clearing alang-alang for crop establishment mainly small holder rubber plantation.

Conceptual management

Areas under *Imperata* dominated vegetation in Indonesia may be situated under different jurisdiction, provincial government or central government through the Department of Forestry. *Imperata* also grows in areas of different environment in terms of soil, topography, or water regime. In its management, therefore, the establishment of a productive system must be suited to the existing condition, ecologically, as well as socio-economically or even politically. In this respect Tjitrosemito *et al.* (1980) developed a conceptual management as shown in a block diagram at Figure 1.

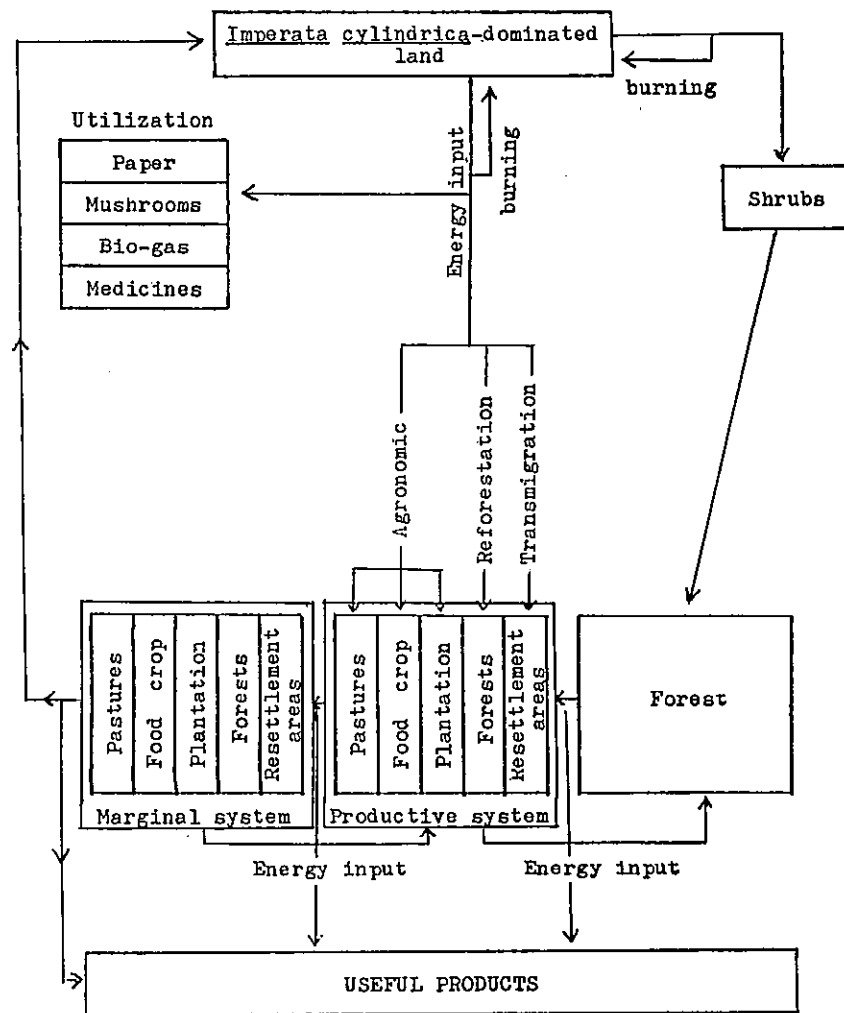


Fig. 1. Block diagram model for the management of *Imperata cylindrica*-dominated land

The management is basically aimed at establishing a sustained productive system. Three basic strategies are considered important to achieve the objective, i.e. (a) improvement of management of the existing production system of our natural resources; (b) conversion of the existing area under *Imperata* dominated vegetation into a productive system; and (c) prevention of fire to facilitate natural succession of *Imperata* dominated vegetation into secondary forest.

The improvement of management practices

The expansion of areas under *Imperata* dominated vegetation is due to practices in agriculture, plantation, pasture and forest with insufficient input to keep the system sustainable. Shifting cultivation, abandonment of expired plantation, neglected forest areas are among practices conducive to *Imperata* infestation. Resettlement of shifting cultivators, rehabilitation of expired plantation and proper re-forestation should be worked out to establish a good environmental management and to prevent the expansion of *Imperata* dominated vegetation.

Conversion of *Imperata* dominated vegetation into a productive system

The system may be in the form of food crop, plantation, pasture, forest or even residential area. In all cases beside correct techniques, sufficient inputs are required to establish sustained productive system.

Natural succession

Actually when left alone and prevented from fire, *Imperata* dominated vegetation will revert back to secondary forest. However, when it burns frequently the vegetation will be dominated by *Imperata cylindrica*, as an anticlimax of the succession.

These three strategies should be carried out simultaneously and in a well coordinated program to avoid unnecessary conflict of interest whether a particular *Imperata* dominated area by converted to rubber plantation, pasture or forest. When the strategies are carried out properly the problem of *Imperata* dominated land will be confined to a certain acceptable degree in a particular area.

MATERIALS AND METHODS

The experiment was done at the experimental area in the Plantation Research Institute at Sembawa, South Sumatra (BPP Sembawa) on a red yellow podzolic soil dominated by along-alang vegetation. The area is about 9 m above sea level with an average annual rainfall of 2240 mm, with double peaks of rainfall in March and November. Before applying treatments, vegetation analysis was done using line-intercept methods. The area (about 9 ha) was diagonally transected and vegetations were recorded along the lines at 10 m intervals in a square of 2 × 2 m.

Prior to experimentation the area was cleared from shrubs mainly *Dillenia excelsa* (Jack) Gily., *Tetracera indica* (Christ. & Pans.), *Melastoma malabathricum*,

Eupatorium odoratum, *Merremia* sp., *Dioscorea* sp., *Macaranga* sp., *Passiflora foetida*, *Trema orientalis*, *Uraria crenata*, also *Lantana camara*, and *Schima wallichii*.

The area was selected for uniformity and measured to have plots measuring $20 \times 25 \text{ m}^2$. To delimit the plot a path measuring 15 m between plots was tractor-drawn.

The experimental design was split-plot with along-along clearing as the main plot consisting of:

- (1) glyphosate as Roundup at 10 lt/ha coded as G;
- (2) glufosinate as Basta at 20 lt/ha coded as B;
- (3) dalapon as Dowpon-M at 30 kg/ha coded as D;
- (4) mechanical cultivation coded as M;
- (5) manual cultivation coded as L,

and intercropping as subplot consisting of four treatments:

- (1) food crop pattern developed by CRIA and modified slightly coded as F;
- (2) legume cover crops coded as C;
- (3) pasture coded as P;
- (4) local system coded as S.

There were 20 treatments altogether and replicated 3x.

Main plot

The mechanical cultivation was done in late November 1983 with wheel tractor to a depth of 20–25 cm. The cultivation was repeated two weeks later with the direction of the plow perpendicular to the first plow; the following two weeks the cultivated soil was harrowed twice with an interval of two weeks. Manual cultivation was done by first slashing all vegetation, let them dry out under the sun and burnt one week later. The hoeing was done twice with an interval of three weeks. A particular precaution was closely observed to prevent fire from spreading into the adjacent plots.

Dalapon was sprayed twice; the first spray was done in late November 1983 at 15 kg Dowpon-M/ha + 1% urea followed by correction spray at 5 kg/ha two weeks later, using knapsack sprayer CP-15, high pressure, yellow nozzle. The main spraying was done using power sprayer (Mitsubishi, 3.5 HP, Samco spraying unit), in 1,000 lt of water mixed with 1% urea. The second spray was done three weeks after the first at 10 kg/ha. Glyphosate at 8 lt/ha was applied in December with CP-15, high pressure, yellow nozzle and 600 lt water per hectare. The correction spray was done two weeks later using 2 lt/ha of Roundup. Glufosinate was applied at 15 lt Basta/ha followed by correction spray of 5 lt/ha using CP-15, high pressure, yellow nozzle at 600 lt water/ha.

In January all *Imperata* under herbicide treatments was smoothened by rolling drums over, followed by preparing holes for planting rubber measuring $50 \times 50 \times 50 \text{ cm}$. Rubber (clone PR 300) was planted at a distance of $3 \times 7 \text{ m}$ in early February in the form of "high stump".

Intercroppings were done between rows of young rubber at a distance of 1.5 m away from the rubber strip. Soils under mechanical and manual cultivation were once more cultivated manually to remove rhizome from the plots.

Corn (c.v. Arjuna) was planted at a distance of $200 \times 50 \text{ cm}$, fertilized with 25 kg urea/ha and 50 kg TSP/ha at planting and another 50 kg urea/ha at 30 days after planting. Mungbeans (c.v. local) was planted in between corn at a distance of $23 \times 30 \text{ cm}$ fertilized with 25 kg urea/ha and 50 kg TSP/ha at planting time. Lime was given at 1,000 kg/ha in rows of corn and mungbeans.

Legume cover crops consisting of *Centrosema pubescens*, *Calopogonium mucunoides* and *Pueraria javanica*, at the rate of 8, 8, 4 kg/ha were planted in strips of 50 cm apart and 1.5 m away from the rubber strip, fertilized with 30 kg urea/ha, 30 kg TSP/ha, and KCl of 10 kg/ha.

The grass pasture in the form of *Setaria* sp. was planted in rows of 50 cm apart from its bunch and fertilized with 30 kg urea, 30 kg TSP, and 10 kg KCl/ha. While the local system was merely planting pineapple in rows of 50 cm apart in the form of plant cutlet. The fertilizer was similar to that of pasture.

Variable collected

The regrowth of *Imperata*, the performance of rubber and the intercrops were recorded. *Imperata* population was sampled using a quadrat of $50 \times 50 \text{ cm}$ ten times in each plot; while the growth of rubber was assessed by measuring the girth at 50 cm above the occulation. Labours and approximate cost were also calculated. Soils analyses were carried out and the population of arthropods were also estimated. For this purpose soil samples were collected using hoe to a depth of at most 7.5 cm, to have samples of 2 kg collected from 5 places in each plots. The arthropods were extracted using tullgreen funnel as developed by MacFadyen (1961).

Maintenance of experimental plot

A reasonable fence was constructed around the experimental site to keep wild pigs, monkeys, and cattle out of the plot.

RESULTS AND DISCUSSION

Imperata control efficiency

The results of vegetation analysis of the area will be reported in the technical journal of BIOTROP, for the purpose of relevant discussion it was found that the population was about $350 \pm 42 \text{ shoot/m}^2$ with the dry weight of shoot more than $1,000 \text{ g/m}^2$ and that of rhizome was 960 g/ha, therefore, in 1 ha there were approximately 10 tons of shoot and rhizome respectively.

When land clearing was completed (one month after spraying) the population of *Imperata* is as shown in Table 1.

Table 1. Mean alang-alang population at the beginning of planting

Treatments	Population means/ m^2
1. Glyphosate	3.9
2. Glufosinate	8.8
3. Dalapon	5.8
4. Mechanical control	19.3
5. Manual control	18.9
L S D	3.1
C.V.	20.0

The regrowth of *Imperata* under manual and mechanical control were quite high compared to those under herbicide treatments. However, this is still good since it is still able to reduce the population more than 90% leaving the population less than 10% of the initial population. Herbicide control plots showed better results, with glyphosate showing the lowest regrowth. It seems that mechanical and manual control of *Imperata* is less effective when done during the wet season.

The growth performance of rubber

The girth of rubber trees measured at 50 cm above the occulation when recorded six months after planting did not show any difference, with the whole average of about 7.12 cm. It seems that at this very young stage the alang-alang clearing methods have not in any way affected the growth of rubber. At the same time the variation was so big due to new replacement of rubber stump and due to damage by cattle which unknowingly destroyed part of the fence and the herd trampling the plots.

The performance of food crops

The yield of corn and mungbeans were shown in Table 2.

Table 2. The yield of corn and mungbeans (kg/ha)

Treatments	Corn	Mungbeans
1. Glyphosate	2,200	967
2. Dalapon	1,314	857
3. Glufosinate	714	914
4. Mechanical control	428	1,185
5. Manual control	571	1,064

The yield of corn and mungbeans could not be taken as a measure of treatment effect since some plots of corn were heavily damaged by wild pigs despite fences and a watchman appointed during the experimentation; but it can be taken as an indication that food crop can actually be planted with reasonable yield using zero tillage technique. The experiment has been continued to see further the effect on upland rice planted after mungbeans in the following wet season.

The yield of *Setaria* herbage was good and no difference was detected among treatments with the average yield of 1 kg herbage/ m^2 . It is rather unfortunate that this grass contains too much oxalic acid so it is not so favourable to ruminants. It also grows strongly; it is interesting to see the effect on the growth of rubber in two years time.

Imperata regrowth at the end of the growing season

Wishfully we thought that there would not be any more *Imperata* after the control. But in fact *Imperata* still persist after corn and mungbeans have been harvested. The population at the end of the first year of land clearing is shown in Table 3.

Table 3. Mean alang-alang population at harvest time of corn and mungbeans (plants/ m^2)

Treatments	Population mean
1. Glyphosate	18.9
2. Glufosinate	27.3
3. Dalapon	22.9
4. Mechanical control	8.2
5. Manual control	39.6
L S D	4.1
C.V.	15.2

Second manual cultivation seems able to remove most of the alang-alang rhizome under the mechanical control; this is probably facilitated by a deeper soil cultivation than in manual cultivation. The deeper the cultivation, the greater the rhizome proportion taken out. In this stage regrowth of *Imperata* under glyphosate treatment still showed the lowest among the herbicides.

Approximate cost of alang-alang clearing

It is difficult to estimate the cost since a lot of figures will be greatly affected by the efficiency of the labourers. The approximate cost of alang-alang clearing is shown in Table 4.

Table 4. Approximate cost of alang-alang clearing

Items	Treatment			Glyphosate			Glufosinate			Dalapon			Mechanical			Manual		
	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.	Md/ha	Rp.
1. Surveying	2	3000			2	3000				2	3000		1	3000		2	3000	
2. Shrub slashing	25	38500	25	38500	25	38500	25	38500	25	38500	25	38500	-	-	-	20	30000	-
3. Spraying	12	19500	12	19500	12	19500	(6+3)	21500	(6+3)	21500	(6+3)	21500	-	-	-	-	-	-
4. Water	(800 lt)	1600	(900)	1800	(900)	1800	(2200)	4400	(2200)	4400	(2200)	4400	-	-	-	-	-	-
5. Herbicides	(10 lt)	260500	(20 lt)	(PM)	(20 lt)	(PM)	(30 kg)	105000	(30 kg)	105000	(30 kg)	105000	-	-	-	-	-	-
6. Urea	-	-	-	-	-	-	30	3000	30	3000	30	3000	-	-	-	-	-	-
7. Sprayer/fuel	-	500	-	500	-	500	-	10000	-	10000	-	10000	-	-	-	-	-	-
8. Burning	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	7500	-
9. Hoeing (I + II)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	150	225000	-
10. Mechanical (tractor)	-	-	-	-	-	-	-	-	-	-	-	-	17	212500	-	-	-	-
11. Wiping	2	3000	10	15000	10	15000	10	15000	10	15000	10	15000	-	-	-	-	-	-
12. Rolling off <i>Imperata</i>	2	3000	2	3000	2	3000	2	3000	2	3000	2	3000	-	-	-	-	-	-
Total cost		329.600		81.300 PM.		81.300 PM.		203.400		203.400		215.500		215.500		265.500		265.500
		\$275/ha						\$170/ha		\$170/ha		\$180/ha		\$180/ha		\$221/ha		\$221/ha

Alang-alang clearing using glyphosate at 10 lt/ha was very expensive. Low volume technique of glyphosate application may be able to reduce the cost.

The price of glufosinate is currently not available yet, while that of dalapon, i.e. Rp 3,500/kg may not be accurate.

The price of glufosinate is currently not available yet, while that of dalapon, i.e. Rp 3,500/kg may not be accurate. The application of dalapon using power sprayer can reduce the cost of labour although it required two sprayings. However, the operators must be reasonably skilled to avoid accidents while using the power sprayer.

The mechanical cultivation was probably still cheap, but its application can be well limited not only by topography but also by time, as it was shown that mechanical cultivation during the wet season is less favourable. Manual cultivation can be costly also.

As it was pointed out that while the application of various methods could temporary control *Imperata*, unless it is followed by further control, this *Imperata* still gives persistent troubles. In assessing the methods, therefore, it is advocated to see until its eradication is achieved. In this preliminary work it is important to give a strong emphasis on the regrowth of *Imperata*. Technique of control which is still able to facilitate *Imperata* regrowth will have less value than those which are able to prevent a long regrowth, or killing it. Cost calculation is, therefore, cannot be based only on single application, but should be based on eradicating the *Imperata*.

The aspects which are worth considering in using herbicide to control *Imperata* for crop establishment using zero tillage technique is diagrammatically shown in Figure 2.

Imperata usually grows in association with some shrubs and members of Cyperaceae family. Successful control of *Imperata* will leave the associated vegetation growing better, since the competition stress is left off, more light is available and this condition, besides facilitating greater photosynthetic rate for the living associated vegetation, also induces seeds of other vegetations to germinate. A new composition of weed species will arise.

The dead *Imperata* will constitute a considerable amount of litter, it may reach more than 20 ton/ha of dry matter. This litter will provide a sum of substrate for soil fauna. The population of soil fauna may increase, but early in the process of decomposition, some organic acids may be produced, beside possible allelopathic substances, or even the residual effect of herbicides. These production of organic acids, allelopathic substances, or residual effects of herbicides negatively effect crop growth, their effects on crop growth are difficult to separate individually and may be masked by nitrogen deficiency due to immobilization by decomposing organisms.

Nitrogen content of *Imperata* litter is very low, therefore, in its decomposition, the decomposing organisms may take up nitrogen from soil, hence reducing the nitrogen availability to crops.

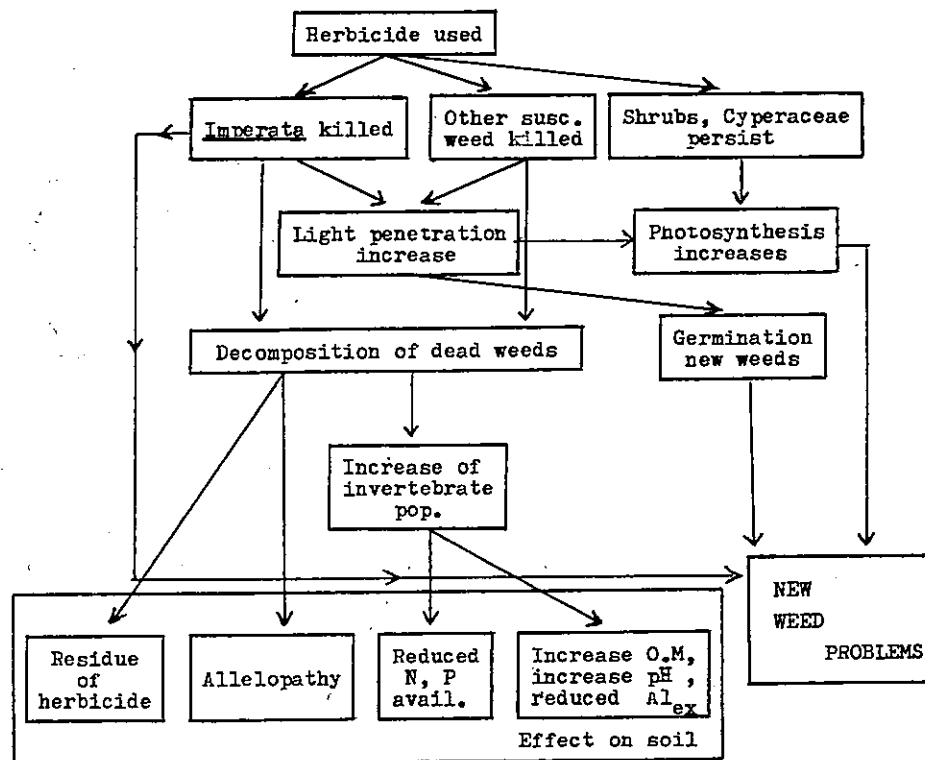


Fig. 2. Simple block diagram showing consequences on the application of herbicide on *Imperata*

It seems that extra fertilizers (nitrogen, phosphorous and possibly also other micro nutrients) are required for a successful crop establishment using zero tillage technique.

Beside the negative effects to crop growth, it has also positive effects. The dead *Imperata* will function as mulch, preventing soil erosion, conserving soil moisture and later on increasing soil organic matter, which in the tropical condition is of paramount importance. Perhaps these positive effects can be given a greater weight than those of its negative effects.

It seems that appropriate herbicide applications may be used for *Imperata* clearing before establishment of rubber plantation or even food crops using zero tillage technique. However, it should be followed by appropriate activities such as sufficient fertilizer including liming, further *Imperata* control or proper vegetation management.

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WATER HYACINTH-ITS DANGEROUS AND BENEFICIAL ASPECTS IN INDIAN AGRICULTURE

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ABSTRACT

Water hyacinth (*Eichhornia crassipes*, Mart. Solms.), one of the most noxious aquatic weeds of the world, is the foremost aquatic weed in West Bengal and entire North Eastern States of India. The reported annual loss of 110 million rupees of low land paddy and 45 million kilograms of fish in W. Bengal reveals the acute danger from this weed in Indian agriculture in addition to its rapidly increasing invasion of long length canal systems of irrigation projects.

Researches on its control showed that paraquat at 1.0 kg ai/ha was quickest to destroy it (3-5 days), while 2,4-D at 2 to 4 kg took 8-10 days and the new herbicide AC 252925 (Arsenal) needed at least a month for its complete destruction.

This dangerous weed is at the same time a vast resource in India, for useful purposes, primarily in Agriculture. Among the various uses, shown to be possible, the utilization of water hyacinth as compost, green manure and mulch, highly nutritive livestock feed in appropriate amount in the livestock ration, composted material as fish food, biogas, sources of leaf protein and growth promoting substances, antipollutant and scavenger of waste from water, bedding material for mushroom cultivation, material for preparation of rough paper products and dried fibre for interior decoration are the important ones.

The strategy perhaps most appropriate in India, is to make people of all walks of life, from farmers to administrators, thoroughly aware of the useful aspects of this weed so that they are attracted for its utilization and this way the urgent necessity, in India, to clear the important water bodies will also be achieved. However, this weed should not be introduced or transported to new areas even for its utilisation since the risk to become a great menace is very high.

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*, Mart. Solms), Family - Pontederiaceae, local names in different places in India are "Kacchuripana" (Bengali), "Jalkumbhi" (Hindi), "Akasa thamarai" (Tamil), "Pishacha thamarai" (Telugu) and "Kola vazha" (Malayalam) is a native of South America and is now widely distributed over the warm region of all over the world. This aquatic monocotyledon weed is one of the world's worst weeds. It is a free floating weed, has fine roots and produces stolons and viable seeds. The leaves are 10-15 cm. across bright green, shiny leaves and their upright stature help to serve as sails before the wind. The flowers are beautiful, pale lilac or mauve with yellow patch at the centre.

Its propagation is primarily by vegetative reproduction. In one experiment two parent plants produced 30 offspring after 23 days and 1200 offspring at the end

of 4 months. A plant may flower at the age of 26 days and will normally produce viable seeds. Seed production varies from a few to as many as 5000 seeds per plant. Seeds sink to the bottom and can remain viable for at least 15 years (Holm and Yeo, 1980).

Infestation in India and the world

In India, water hyacinth is the foremost aquatic weed in the state of W. Bengal and entire north-eastern states. Miles of stretches of this weed are a common sight in all kinds of water bodies in the state of West Bengal. Besides the general water bodies, water hyacinth invades heavily, the deep water paddy fields of West Bengal causing tremendous loss of paddy production. Estimates revealed an annual loss of 110 million rupees worth of low land paddy (Basak 1948) and 45 million kilograms of fish (Vass, 1951) in the state of W. Bengal itself. In Bihar, the long length of canal system and reservoirs of irrigation projects of Gondak river is heavily covered with water hyacinth. In the state of U.P., the famous Kitham lake near Agra with an area over 300 ha. has been covered almost 70 percent by water hyacinth in its shore lines. In Delhi, even the beautiful large concrete water tanks for recreational purposes at India-Gate, are also being infested with water hyacinth. At the Okhla water complex, water hyacinth has become a serious weed. The catchment tributary canals of Jamuna river is also severely infested with water hyacinth.

The infestation of water hyacinth when considered globally is also alarming. In south-east Asian countries, of the ten serious aquatic weeds, water hyacinth infests canals, road side ditches, lakes and all water bodies. The Bhumipol dam, one of the largest dams of Thailand and the hydroelectric generation lakes of the country are threatened with water hyacinth (Tjitrosocdirdjo *et al.* 1983). In Indonesia, awareness of the danger of aquatic weed problem began in 1932 when the serious infestation of water hyacinth was noticed in Rawa Penning Lake, Central Java (Soerjani, 1975). In Bangladesh, water hyacinth is the most predominant aquatic weed in all kinds of water bodies and low land paddy fields. In Philippines and Vietnam, irrigation system are facing problems due to gradual increase of water hyacinth (Gupta, 1979). In Australia and New Zealand, water hyacinth also has become a problem in the water reservoirs. Water hyacinth was reportedly introduced into the United States of America in 1884 as part of a horticultural exhibit. It spread rapidly and by 1897 was creating enough havoc to navigation to prompt an investigation. Funds for control of the weed became available in 1899 (Holm and Yeo 1980). This weed is mainly a problem in lakes, flood control channels and rivers of the warm South Eastern States interfering primarily the navigational and recreational utility of U.S.A. In Africa, the water hyacinth has been introduced at the delta of Nile and in Natal at the beginning of the 20th century. It is now generally distributed in Africa. Water hyacinth was first reported in the Congo river in 1952 and in less than 3 years it has spread sixteen thousand kilometers from Leopold Ville to Stanley Ville. The first report of this in the White Nile was in 1958 at Sudan. During the early 1960's the water hyacinth team of the Sudan in Co-operation with the neighbouring countries of Congo, Egypt and Ethiopia has prevented water hycinth in the White Nile from spreading beyond Jebel-Aulia Dam into the Blue Nile by an efficient quarantine system

(Kaske 1972, and Holm and Yeo 1980). Water hyacinth also interfere by its presence with man's activities in many lakes and streams and reservoirs of Central and South America.

Harmful effects of water-hyacinth

Water hyacinth weed is the scourge of some of the world's major rivers and water bodies.

Its infestation disturbs fisheries and causes hunger and starvation by blocking movement of small craft to fishing grounds and by hindering supply ships which urgently carry food particularly to riverine communities.

Its growth checks irrigation and drainage channels hindering agriculture production. Water hyacinth consumes and wastes tremendous quantities of water through the leaves. The loss of water through evapotranspiration from the leaves has been measured as 3.2 to 3.7 times greater than free evaporation from a surface. Such rates could cause the loss of $18,275 m^3$ of water per hectare in six months period when water hyacinth weed mat is present. In the dry atmosphere of India, the loss of water from water hyacinth from a reservoir can result in an entire river inflow being wasted back into the atmosphere with a result that water is not available for hydro electric power and irrigation schemes.

Huge mats of water hyacinth can destroy bridges, block ports and stop large commercial ships (Holma and Yeo, 1980).

Control of water hyacinth

Chemical control

The technology of controlling water hyacinth weed by chemical method is already known and it is quite effective. Several weed scientists in India have shown by their research results the effectiveness of the chemical method of control. But its execution so far is very little since it is a massive work to apply chemicals to control this enormously huge vegetation of water hyacinth scattered all over the country. Again, the knowledge of the effective methods to control this weed by chemicals is so far confined to the laboratory of the scientists and very little extension work programme to disseminate this information has been done in India.

Chemicals like 2, 4-D (Phenoxy acid herbicides), paraquat (bipyridylum herbicides), aminotriazole, etc. are quite effective herbicides to destroy water hyacinth vegetation effectively (Mukhopadhyay and Taraphdar, 1976, Mukhopadhyay, 1982; Hari and Srinivasan, 1966; ICI, 1868; Joshi and Paharia 1969; Moolani and Singh, 1966 and Saha *et al.* 1958).

In a most recent trial at Visva-Bharati, Palli Siksha Bhavana (College of Agriculture), Sriniketan, West Bengal, India (Table 1) it was found that 2, 4-D sodium salt at 2 kg ai/ha completely destroyed the weeds within 8-10 days. At higher rate (4 kg. 2, 4-D ai/ha) the weed vegetation was fully killed and decomposed into water within 5-6 days. While paraquat (in the form of Gramoxone - S at 3 lit/ha) completely destroyed the weeds as early as in a period of only 3 days, new herbicide AC 252,925 (Arsenal) showed complete kill of this weed in 30 days showing its

slow action. In other words, this new herbicide unlike the previous herbicides gradually checks the growth and kills the weed in about a month's time (Mukhopadhyay and Bhattacharya 1983-84).

Table 1 Effectiveness of different herbicides on the rate of mortality of water hyacinth-
(Mukhopadhyay and Bhattacharya 1983-84)

Treatments	Days after treatments																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
T ₁ -2,4-D at 2 kg	2	3	4.7	6	7	8	8.3	9.3	10																	
T ₂ -2,4-D at 4 kg	2.2	4.5	7.2	8.2	9	9.5	10																			
T ₃ -Gramoxone																										
S ₁ 3 lit	3.2	5.7	9.2	10																						
T ₄ -AC 252,925	0	0	0	0	0	0	0	.5	.7	1	1.5	2.2	2.7	3	4	4.2	4.5	4.7	5	5.2	5.2	5.7	5.7	6.7	6.7	7.5
at 0.125 kg																										
T ₅ -AC 252,925	0	0	0	0	0	0	0	.7	1	2	2	3.2	4	4.2	5	5.2	5.5	6	6.2	6.7	7.2	7.5	8.2	8.2	8.5	8.7
at 0.250 kg																										
T ₆ -AC 252,925	0	0	0	0	0	0	0	1	1.7	2.2	2.5	3.5	4	4.5	5.5	5.7	5.7	6	6.5	6.7	7.5	8.5	7.5	7.7	8	8.5
at 0.375 kg																										8.7
T ₇ -2,4-D IPEG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 kg																										
T ₈ -Aqueous spray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T ₉ -No Spraying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

27	28	29	30	31	32
7.7	8	8.2	8.7	9.5	10
9	9.7	9.7	10	10	10
9	9.3	9.5	10	10	10
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Scale of mortality 0 to 10. 0 =No kill 1 =10 % kill 2 =20 % kill 10 =100 % kill.

It may be remembered that whatever chemical method is applied, complete eradication of inexhaustible amount of water hyacinth vegetation in India is impossible coupled by the reason of its nature and vigour of propagation by a small piece of vegetative part of its body and by viable seeds.

Biological control

Julien (1982) of the CSIRO division of Entomology, Australia in the World Catalogue of agents and their target weeds on biological control of weeds mentioned the insects *Neochetina bruchi* Hustache released in Panama and USA, *Neochetina eichhorniae* Warren released in Australia, Egypt, Fiji, Indonesia, Republic of South Africa, Sudan, Thailand, USA, 'Zambia, Zimbabwe; *Orthogalumna terebranti* Wallwork released in Egypt and USA, and *Samodes albiquittalis* Warren released in Australia, Panama, USA, Zambia with various degrees of success.

For water hyacinth control in North East Asia, the insects *Neochetina eichhorniae*, Warner., showed better results contained with spores of *Myrothecium roridum* and fungus, *Alternanthera eichhorniae*, Nag Ray and Ponappa., was specific to this weed and the Grass carp fish *Ctenopharyngodon idella* Val. retarded the growth of water hyacinth by eating the roots as reported by Napometh, 1983 and Pheang 1975).

Utilisation for useful purposes

If research evidences can prove that water hyacinth weed is useful in many ways and can be utilized for various purposes, the campaign to remove the huge water hyacinth accumulation in India from our useful water bodies will be very much appealing for encouraging physical removal in preference to chemical control by herbicides.

Thus the "strategy" which appears to be perhaps appropriate in India, is to inform people of all walks of life, the various uses of water hyacinth so that the crop husbandry farmers, livestock farmers (cattle, sheep, goat, pig farmers) industrialists, environmentalists, and the administrators and policy makers of the country become interested to utilize this aquatic vegetation hitherto known as worst weed as a vast resource for useful purposes. In this way, the urgent necessity to clear the important water bodies and water ways infested badly by this weed will also be achieved.

However a point of great caution is to be always kept in mind while utilizing this weed. The huge water hyacinth weed already present needs to be utilized but this weed should not be introduced into new areas. The risk of its becoming great menace as dangerous weed is too great.

Use as compost, green manure and mulch

(soil additives, soil conditioners or soil amendments):

Water hyacinth may be composted to use as organic manure. Like other compost, water hyacinth compost also has the same advantages of improving soil fertility and physical properties of soil. Rodriguez *et al* (1973) from Puerto Rico reported that composted water hyacinth roots could be used as a good propagation medium for house plants. The fact that compost requires much moisture makes it an ideal

use for aquatic weeds – the weeds do not have to be dewatered except wilting for a few days in the sun.

The average level of major nutrients (Table 2) is considered adequate for these material to be used as soil amendment (Parra and Hortenstine, 1973). The average C : N ratio (23 : 1) compares favourably with C : N ratio of legumes (20 : 1) and better than C : N ratio of straw (90 : 1).

Table 2. Chemical composition of oven-dried water hyacinth percent oven-dried weight (After Frank 1976).

C/N	Ash	C	N	P	K	Ca	Mg	Na
23	25	35	1.6	0.3	3.0	1.7	0.6	0.6

Parra and Hostenstine (1973) from series of experiments in Florida, U.S.A. inferred that water hyacinth was a good soil amendment or soil conditioner or soil additive.

The use of water hyacinth as a green manure by harvesting from water bodies and transporting to crop fields has the potential danger of their spread to new situation. Thus its use as a decomposed compost or ash for its high potassium content or fully dried mulch as interwood or fallow land in dry land agriculture or erodable land is more desirable. The fresh water hyacinth or other aquatic plants should not be introduced since they become risky of their becoming an unmanageable problematic weeds.

Use as nutritive livestock feed

Water hyacinth plant contains high protein and other mineral. The individual amino acids and their constituents are present in about same percentage as a land forage of similar crude protein content (National Academy of Sciences, 1976). Experiments in Florida reveal that phosphate, manganese, copper, zinc, magnesium were present in water hyacinth in about the same concentration as they are found in land forages, however sodium was 10–11 times higher, iron 4–19 times higher and potassium 3–6 times higher and calcium was also higher, Research work by Taylor and Robbins (1968) showed lysine content in water hyacinth equal to that found in milk.

However, high nutrient composition (Table 3.) is not enough to consider as animal feed but high digestibility is the essential factor to make the nutrients available to animals. In an experiment it was found that in the water hyacinth the organic matter digestibility by rumen microbes of fresh whole plant leaf, petiole and submerged parts were 55.7, 50.8, 58.7 and 51.2% respectively (National Academy of Sciences, 1976).

Table 3. Composition of unprocessed water hyacinth (After Frank 1976)

Components	Percent of dry weight water hyacinth
Crude protein	16
Cellulose	28
Available CHO	8
Ash	17
Ether extract	3.5
Phosphorus	0.4
Calcium	1.0
Magnesium	1.0
Potassium	4.4

Even nonruminant animals like pigs are fed rations containing water hyacinth in Indonesia. Pig farmers in China, boil chopped water hyacinth with vegetable waste, rice bran, copra cake and salt to make a suitable feed. In Malaysia, Philippines, Thailand, fresh water hyacinth is cooked with rice bran and fish meal and mixed with copra meal as feed for pigs, ducks and pond fish (Anuwarbin Mohmed, 1967; Hora, 1951, Villa dolid and Dunag, 1953).

Problems and difficulties to use as animal feed are its high mineral content and high moisture content.

The reason why animal refuses to eat enough quantities of aquatic weeds is thought to be over abundance of the mineral. An animal getting only 10–20 % aquatic plant in its diet would be receiving its full requirement of minerals.

High mineral content may result in mineral imbalance of the livestock. Water hyacinth used in excessive amount as animal feed becomes a laxative.

Results of research concluded that aquatic weeds can be used to supplement animal feeds but they cannot comprise entire diet because of the high mineral content.

Unprocessed water hyacinth dewatered by chopping and pressing can be fed directly to livestock like cattle, buffalo, sheep and goat. Partially dewatered water hyacinth weed can be ensiled. Extensive experiments in Florida, U.S.A. have shown that these water hyacinth produces a palatable digestable and nutritious silage that is readily accepted by cattle and sheep.

Because silage in bulky, the advantageous location for water hyacinth silo appears to be near the water bodies. The government of India can take initiative to build chain of such silos near the water hyacinth infested rivers, lakes, ponds and canals.

The additional milk and meat by feeding water hyacinth to buffalo, cattle, goat, sheep and pig will supply animal protein to the people of India who on average now get only about a 4th of such protein per day. Thus water hyacinth may be converted for human nutrition through its feeding to livestock.

Use as paper and fibre

Water hyacinth does not look promising as an immediate source of pulp. At the University of Florida, exhaustive attempts with many different pulping conditions have been made to make paper from water hyacinth. But it failed because moisture clings to the fibre and the pulp cannot be drawn or dewatered by using paper making rollers. Because of low cellulose content, the aquatic weed pulp does not appear to be suitable for making quality paper but might be used for making card boards of rough paper products.

Leaf protein from water hyacinth

In India, Central Food Technology Research Institute, Mysore and Indian Statistical Institute, Calcutta have been working to extract protein from water hyacinth. Although water hyacinth has a low protein nitrogen extractibility but it could be exploited as it produces a high and regular yield per unit area (a standing crop of 10,000 kg/ha is common).

Table 4. Protein from water hyacinth (After Matai-1976)

Weed	Wet yield in kg/ha	Total extractable N as % of total N in Pulp	Extractable protein N as % of total N in Pulp	% of Ash on dry leaf protein concentrate (LPC)
<i>Eichhornia crassipes</i>	120,000	11.7	6.3	5.3

Growth promoting substances from water hyacinth

Research work at the Department of Botany Laboratory, Calcutta University by late Dr. S. M. Sircar and his associates showed the presence of bound or complex growth promoting substances in the root extract which on hydrolysis identified as 1) X A A 2) Indole positive and located at the position of Indole acetonitrile (I A N) 3) Tryptophan (Bhanja *et al.* 1968).

The root extract of water hyacinth growth substances after partial purification when used for treatment to rice seedlings for 10 days showed promotion of root and shoot length (Gopalkrishnan and Sircar, 1968).

Bedding material for mushroom cultivation

Dry water hyacinth can be successfully used as bedding material for cultivation of Volvacea mushroom (*Volvariella* sp.).

Material for interior decoration

Dried water hyacinth plant is potential to use as materials for interior decoration. Woven dry water hyacinth plant have been reported to be used as decorative cover of bottles and flower vases.

Use of water hyacinth for production of fish food planktons

Laboratory experiments with composts of water hyacinth showed to promote

greater plankton flora and fauna production to provide more food and nutrition to fish in aqua culture (Mitra and Banerjee, 1976).

Use as a source of energy (biogas)

Water hyacinth might one day provide a new source of energy. In a pioneering effort of great significance, researchers at the N A S A (National Aeronautics and Space Administration), U.S.A. are working to convert water hyacinth and other aquatic weeds into biogas rich in methane. Methane is the main ingredient in natural gas which is used world wide as fuel and as a major item in international trade. Recovery of fuel from aquatic weeds even on a small scale has interesting implication, specially for rural areas in developing countries. As many developing nations have apparently inexhaustible supply of aquatic weeds within their countries, this potential energy source deserves further research and testing.

The results of NASA experiment showed that water hyacinth harvested from one hectare would produce more than 70,000 m³ of biogas. Each kg of water hyacinth (when taken as dry weight basis) yields about 370 litres of biogas which have average methane content of 69% and calorific (heating) value, when used as fuel, of about 22,000 kg/mg (580 Btu/ftg.). The biogas formed from water hyacinth burns rapidly. It can be used for virtually every application where animal gas is used *i.e.*, for cooking, heating and also as a source of power. However, before the gas can be comprised into cylinder for use on equipment, the CO₂ must be removed. Unless production is large, this biogas may not be applicable for use as fuel for engines. Methane producing bacteria must be nurtured because they required such nutrients as NPK. The work at NASA has shown that water hyacinths provide these elements in the quantities and proportions adequate for good gas production. In developing countries some animal manures may be used for digesting to methane (National Academy of Sciences, 1976).

Use of water hyacinth for waste treatment and reduction in water pollution

Raw sewage is usually discharged into river or lake or water bodies with little thought of consequences. Today, however, the growing world population and an increasing demand for an improved environment make better disposal of wastes virtually necessary. Aquatic weeds including water hyacinth can scavenge inorganic and some organic components from water. The weeds absorb and incorporate the dissolved materials into their own structure. The plant culture units clean water so rapidly and effectively that they are now considered for use in sewage treatment.

Under ideal conditions, water hyacinth has been found to recover the considerable amount of elements from polluted water (table-5).

Table 5. Recovery of nutrients by water hyacinth (After Wolverton, 1976)

N	P	K	Ca	Mg	Na
kg/ha/day					
22-44	0-17	22-44	11-22	2-2	10.34

For developing countries like India, this can become extremely important. Nitrates, ammonium compounds, phosphate and organic carbon discharged from sewage treatments contain nutrients often needed in agriculture. The nitrate and phosphate are the primary ingredients in fertilizers which today cost developing countries increasing amount of precious foreign exchange to import. Fertilizer manufacture is intensive and is increasingly expensive. For many rural areas the price of the foreign product is prohibitive. Aquatic plant promises to provide an indigenous source of cheap fertilizers and soil conditioners available within the rural region that needs it most.

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WEEDS-HERBICIDES AND THE ENVIRONMENT

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ABSTRACT

Weed control, whatever may be the method adopted, should not exhibit harmful effects on soil, on non target crop plants to animals and to man. To achieve the above objective, one has to use the herbicides with great care. It has been seen from various studies that lack of sound knowledge of herbicidal technology and its proper use are creating ecological imbalance in the environment. Required dose of the appropriate herbicide used at proper time by correct method are a must to prevent the ill-effects of herbicides on environment. Herbicides have to be tested in all respects, like persistence, residual toxicity etc. before releasing it for the general use so that the environment is not adversely affected. It has been observed through various investigations that there is no evidence that the use of herbicides today contributes to deterioration of the environment.

INTRODUCTION

Man is competing with weeds ever since he started cultivating the land for his sustenance. In this struggle for existence, weeds always surpass the man and create numerous problems for effective crop production. Vegetation management including weed management is essential for the betterment of human kind. Knowledge about weed control is not new, but the realisation of its importance has been felt very late.

Composition of the flora and fauna in the botanical environment is generally altered by the weed management practices. Thus main concern should be to achieve the objective of controlling weeds without producing harmful effects on soil and on non-target vegetation. The use of herbicides in weed management is gaining importance these days. Care has to be taken that proper herbicides are used at suitable doses at proper stage of the weeds to avoid their ill effects on the environment. Certain chlorinated hydrocarbon pesticides, such as DDT, have relatively long persistence in the environment and enter food chains in organisms. Weeds in the environment affect the agro-ecosystem in two ways. Firstly direct effect due to weeds itself and secondly by cumulative effect of herbicides.

1. Environmental contamination by weeds :

Weed competition with crop plants and the costs of their management increase the cost of production of food, feed and fibre crops. Weeds also pose problems in farm ditches, ponds and industrial areas and in other non cropped areas. They adversely affect the health of human beings by causing allergies and other ailments.

Several weeds of grasslands and forage crops contain high contents of alkaloids, tannins, oxalates, glucosides, nitrates etc. These toxins pose a serious threat to the existence of other organisms in the environment.

Parthenium hysterophorus, observed for the first time in India in 1956 is a potential pollutant and cause deleterious effects to crop plants, animals and human beings. Different parts, including pollens of this weed exert allelopathic influence on neighbouring species. Toxins of *parthenium* inhibit growth of *Indigofera*, Beans, cowpea, tomato, eleusine and wheat. It inhibits germination and fruit set in *Crotalaria* spp.

Losses due to weeds are not only limited to the reduction in palatable fodder but also cause losses by imparting undesirable flavour to dairy products and also by causing mechanical injury to grazing animals and death from poisonous weed species. Research shows that abortions were caused by weeds that contained sub lethal amounts of nitrate. Quality of wool is seriously impaired by Cocklebur which causes entanglement of wool of the sheep by their well curved hooks. Silky lupin, *latana camera*, *Rhododendro* *Halogeton*, and *Xanthium* are some of the poisonous weeds which cause ill-effects in the animal body.

Weeds, such as poison ivy, rag weed, poison oak etc. cause ill-effects such as cause Asthma, hay fever and allergies etc. to human beings by their pollens.

Aquatic weeds such as *Eichornia crassipes*, *Hydrilla* and *Nymphaea* spp. form breeding grounds for abnoxious insects such as mosquitoes etc. They reduce recreational values of water bodies by interfering with fishing, swimming, boating and navigation.

Weeds also serve as alternate hosts for many plant parasitic organisms that cause diseases, and as hosts for parasitic nematodes which cause tremendous loss to agriculture each year.

II. Environmental contamination by herbicides

The environmental contamination by herbicides may be discussed under following headings.

Herbicidal entry into the environment:

Effective herbicides will enter the target plants and kill either by contact or by translocation. To affect subsequent crops, the herbicide must persist in land or in the soil for long time. Herbicides with less persistence in nature are easily detoxified in the tissues of the target plant (weed), and those with longer persistence remain in the plant residues and in the surrounding soil and effect the subsequent crops. Environmental contamination is also observed by spray drifts and volatalisation of various chemicals.

Persistence in the environment :

Herbicidal effectiveness is estimated by the extent of suppression of weeds over length of time. An herbicide with good weed control in the standing crop may have deleterious effects on subsequent crops. Persistence of herbicides is affected by six factors viz., micro organism decomposition, chemical degradation, absorption to soil colloids or organic matter, leaching, volatility and photo decomposition. The dose of pesticide

is also an additional factor which affects the activity of the herbicide. The duration of persistence in soil is influenced by the rate of the herbicide used. At the lower rate of application, Flurodifen, linuron, fenuron and pebulate could be recovered upto 40, 60, 50 and 60 days respectively, while at higher rate recovery was obtained upto 50, 90, 60 and 90 days respectively (Table I).

Table I Recovery of different herbicides when applied at different concentration.

days after application	Recovery in $\mu\text{g}/\text{m}^2$ (from 2.5-7.5 cm depth of soil and rate of application of herbicides in kg a.i./ha)							
	Flurodifen		Linuron		Fenuron		Pebulate	
	L.R.	H.R.	L.R.	H.R.	L.R.	H.R.	L.R.	H.R.
	1.5	3.0	1.00	2.00	1.00	2.00	3 kg	6 kg
	kg a.i./ha	kg a.i./ha	kg a.i./ha	kg a.i./ha	kg a.i./ha	kg a.i./ha	kg a.i./ha	kg a.i./ha
40	4.90	7288	8928	34800	2609	6039	71152	115608
50	0	452	3903	28740	924	1120	1603	72060
60	0	0	742	1963	0	716	632	49168
90	0	0	0	1092	0	0	0	240

Source : Abbas and Ghosh.

Residues in the environment :

Numerous monitoring surveys have been made to study the herbicidal residues in the environment. In a residual study conducted on Phenoxy herbicides, only four samples contained 2, 4-D out of 264 with an average concentration of 0.032 ppm and none contained 2,4, 5-T. In another study which was conducted to test the residual concentrations of 2, 4-D in the grain fields, only four out of 100 samples showed 2,4-D with a fraction of a ppm. There has been no clear indication of excessive accumulation of any herbicide in the soil environment. In 1969, consumer and marketing services of the USDA, monitored residual studies in the animal products, wherein 96 percent of the 240 samples of red meat fatty tissues from 44 locations across the USA for 2, 4-D showed no residue. There is also no evidence of accumulation of herbicidal toxins in milk, even when 2,4-D was fed directly to lactating cows.

Limited study had been made regarding herbicidal residues in the air. Only certain plants such as cotton trees and certain grape varieties have been found affected by the contamination of herbicides through air. A careful study at Washington State revealed a maximum concentration of about 2 ppm of 2,4-D in the air during the spraying season, but considerably less than 1 ppm on average concentration over a period of 9 days.

Balyan *et al* (1981) reported that 2,4-D amine at 1.5 ppm concentration when applied through herbigation proved to be the safest in an experiment conducted on few important crops of, wheat, barley, oat, gram, peas, lentil, linseed, brassica, sugarbeet. All these crops were found sensitive to concentration above 1.5 ppm. (Table II).

Table II Effect of 2,4-D on different crops when applied through herbigation.

Crops	2,4-D concentrations in irrigation water (ppm) and yield in g/ha (biological)			
	0 ppm	1.5 ppm	4.5 ppm	C.D. at 5 %
Wheat	138.63	145.67	143.18	NS
Barley	99.99	113.63	102.27	NS
Oat	431.81	469.09	264.10	NS
Gram	39.99	56.36	34.10	7.71
Peas	26.73	28.56	20.77	6.61
Lintil	42.94	15.64	15.90	10.13
Linseed	23.60	23.00	13.05	7.33
Brassica	40.00	42.50	13.50	214.07
Sugarbeet	3331.20	360.80	196.60	100.51

N.S. Not significant.

Source : Balyan *et al.* (1981)

There was no effect on yield of cotton in the succeeding season by the residual effect of herbicides applied in the preceding season. It has also been reported by some Scientists that the recovery of atrazine decreased with increasing time of incubation at 25°C.

Divekar and Mani (1967) made a detailed study on simazine residues in potato tubers to investigate the presence of unhydrolysed simazine residues in the tubers. Phytotoxicity symptoms appeared more rapidly in the plants grown in full sunshine than in the shade. 0.25 Kg a.i./ha dose of simazine proved to be the optimum dose for potato crop. Residues of atrataf (Triazines), 2,4-D(Phenoxy) and Aresin (Urea) were found to be non-toxic to maize and were toxic to pigeonpea, as the increase in chlorophyll occurred in the first case and the reversal is true with the other, when applied at three different doses of herbicides viz., 1 kg a.i./ha, 3 kg a.i./ha and 5 kg a.i./ha (Dubey and Rao 1976). Among the three herbicides, triazines were found to have high residual toxicity to pigeonpea. Next comes aresin and then 2-4-D. In another study Gita *et al* observed that mustard was found highly sensitive to the residual toxicity of atrazine and simazine than gram, peas, lentil, wheat, oats and barley.

Jai prakash (1977). reported a study on herbicides and pollution problems in India. The emphasis is placed on the part of using the herbicides with caution and it is likely to bring pollution problems in atmospheric and edaphic environments. It was also pointed out that some of the herbicides gets accumulated in the soil as degraded products having different chemical composition.

Germination of Bajra was seriously affected by the application of pre-emergence of herbicides like Stomp 330-E (1 kg/ha) and weedazol (5 lb/ha) when compared to atrataf (1 kg/ha) and avenge (1 kg/ha) (Sen *et al*). This is due to severe chlorosis in bajra seedlings, Chlorophyll and carotenoids were drastically inhibited (Table -III).

Table III Effect of different weedicides on germination of bajra.

Weedicides	Bajra	
	Germination %	Total Chlorophyll in mg/gram
Control	90.0	1.920
Atrataf	76.6	1.456
Avenge	70.0	1.582
Stomp 330-E	—	No
Tok-E-25	80.0	1.185
Veedzol	66.6	0.148

No : No germination.

Residual studies in rice crop were studied by Sankaran and Ali, to study the residual effects of butachlor, benthocarb, applied at the rate of 1.0 kg a.i./ha and penorcelin, 0.75 kg a.i./ha as pre-emergence to the weeds. It has been evidently clear that the residual toxicity of this herbicide in the rice and also in the succeeding crops of cotton and finger millet was not found.

CP 44939 was found to be toxic to the crops like sorghum, bajra, okra and cotton (Singh and Rao 1974). Atrazine toxicity was clearly observed in cotton and okra. It has been seen that the toxicity of the chemicals is directly proportional to the concentration as indicated by the fresh weight of the plant material. 2,4-D at a concentration of 1000 ppm was seen to have injurious effects on bringal pollen grains. It damaged the pollen to an extent of 70 percent when compared to other herbicides such as pendimethalin, AMS and Monolinuron (Dubey 1977).

Effects of herbicidal contamination on organisms in the environment :

Organisms in the environment are affected in several ways. An extensive bibliography on toxic effects of herbicides to a wide variety of organisms was published by the National Agricultural Library in 1968. We use herbicides to change the botanical composition of our environment. Selective herbicides are used to kill weeds with a minimum of injury to crop species. Even intensive use of herbicides has produced changes in only limited areas and there are no known instances of the disappearance of any plant species through the use of herbicides.

With the exception of a few herbicides, such as sodium arsenite and the dinitro phenols, which are acutely toxic to animals, the majority of current herbicide may be consumed in large quantities before toxic symptoms appear. Extensive feeding tests are run on all herbicides prior to registration and the hazards, if any, are known. The only animal deaths reported in the last two decades from herbicide use involved sodium arsenite, the use of which is now strictly regulated. This should be contrasted with the many livestock losses from poisonous plants over the same period. At normal recommended rates of application, currently used herbicides appear to have no direct effects on wild life or farm animals. Residues have not appeared in milk and eggs. There is no evidence of wildlife destruction. On the contrary there are many reports on the beneficial

effects of brush and weedy-tree removal on the carrying capacity of ranges and growth of protected forest trees. Changes in plant cover on limited areas have caused population movements to other untreated areas; movement of livestock on the other hand is usually to the treated land. There has been only limited use of herbicides for improving forage on wildlife areas, a practice that justifies much study.

For man, the only toxic effects reported on the direct ingestion of herbicides have concerned intentional suicide by adults or accidental ingestion by children through carelessness. And so, in the final analysis there is no evidence that the use of herbicides today contribute to deterioration of the environment.

Rao and Dad (1979) made a study on herbicide toxicity in some fresh water fishes and ectoprocta. The effects of herbicides viz. Tafazine (Atrazine), Bladex (2, 4-D), Aresin (monolinuron) and Dalopon were studied, Tafazine was found to be toxic to some of the fresh water fishes.

Safe guards for the user, the public and wildlife in relation to herbicides.

The introduction and use of herbicide products must be controlled in some way to reduce the risks associated with their use to a minimum.

Most developed countries control the introduction of herbicidal products, through some type of registration scheme and although the basic principles employed in various countries may not be very different, there are considerable differences in the ways in which laws are used to exercise control.

In the United Kingdom, control is achieved through two separate but closely linked schemes. The pesticide safety precautions scheme examines the toxicity of pesticide products and the hazards they may offer. The agricultural chemicals approval scheme is concerned with the effectiveness of pesticide products including herbicides and enables users to select efficient and appropriate proprietary bands. Neither of these schemes is written into United Kingdom legislation although various acts effect the sale, labelling and use of herbicides.

The Royal Commission on Environmental pollution in its seventh report (1979) recommended that these schemes should be integrated so that safety and efficiency would be considered together, within a joint scheme. Some of the following acts and schemes have been passed in U.K. are as follows :

1. The pesticides safety precautions scheme.
2. Agricultural Chemicals approval scheme.
3. The British Agrochemical Supply Industry Scheme Limited (BASIS).
4. Statutory controls on herbicides and their use.
5. The health and safety at work etc. Act 1974. and the Health and Safety Agricultural Poisonous Substances) Regulations.
6. The Poisonous Act 1972.
7. Rivers (Prevention of Pollution) Acts 1951-1961.
8. The control of Pollutions Act 1974.

Although the losses from weeds are serious, some aspects of the use of herbicides require restraints and regulations. The use of 2,4-D while greatly relieving the farmer of the losses from weeds, had another side. In some places and in certain crops drift of spray or vapors from the light esters of 2,4-D, caused injury. The earliest signs of danger came from the drift and volatilisation of 2,4-D compounds as they affected neighbouring crops. Very soon after its introduction as a selective spray, 2,4-D growth regulatory symptoms were noted on grapes, cotton, tomatoes, alfalfa, melons and other susceptible crops.

A number of other types of herbicides have also brought some difficulties. The substituted urea and symmetrical triazine materials when used on road sides or drain ditches, have caused injury or death of road side ornamentals and orchard trees. Similarly propanil has also side effects.

At this instance United States Department of Agriculture (USDA) has enforced some laws restricting herbicidal use and its manufacturing : some of them are :

- 1) The Federal Insecticide, Fungicide, and Rodenticide Act of 1947.
- 2) The Miller Pesticide Residue Amendment to the Federal Food, Drug and Cosmetic Act of 1938 was passed in 1954.
- 3) Environmental Protection Agency (EPA) was formed on July 9, 1970.

On December 2, 1970, EPA was established to mount a front line attack on environmental problems and air and water pollution pesticide regulation, solid waste management and radiation and noise abatement.

It is necessary that other countries should also enforce some laws restricting proper herbicidal use to avoid various losses and affect environment.

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BIOLOGICAL STUDIES ON THE THORNY SENSITIVE PLANT, *Mimosa invisa* MART.

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ABSTRACT

Studies on biological aspects of the thorny sensitive plant, *Mimosa invisa* Mart. were conducted under laboratory, field and natural conditions. It was found that *M. invisa* seeds started to germinate from the beginning of rainy season (late May to early June) and reached the flowering and pod formation stages during October and December, respectively. The pods ripened and dried in January each year. The maximum percentages of seed germination occurred about 49 days after blooming onwards.

M. invisa seeds immersed in 98°C water for 1.5 minutes as well as in 98% Sulfuric acid for 20-30 minutes gave the highest percentages of germination. The botanical characteristics of *M. invisa* were also described.

INTRODUCTION

Mimosa invisa Mart. (Mimosaceae) is known as thorny sensitive plant and giant sensitive plant (Holm *et al.*, 1977). This species is a native of Brazil (Skinner and Anderson, 1956; Holm *et al.*, 1977) and was introduced into Thailand from Indonesia in 1952. It was first planted in Chiang-Mai for the purpose of increasing soil fertility of tobacco seedbed (Kittipong, 1978). Afterward, other areas have been infested with *M. invisa*. It has since become a weed of corn, soybean, peanut, vegetables, sweet potatoes, longan and lychee etc. Infested fields can not be easily cultivated and harvesting is made extremely difficult because of the presence of sharp recurved spines or thorns on plants' stems. Also they can cause severe injuries to the body of the unwary farmer. *M. invisa*'s invasion also occurs along roadsides and waste places where animals are grazed. Due to the sharp spines of the plant, animals can neither safely step on nor eat them. And nor can grasses be harvested by man (Doungsa-ard, 1982). It has also been reported that *M. invisa* is a weed of rubber, upland rice, cassava, soybeans, corn and tea in Indonesia; of sugar-cane, pastures, tomatoes, abaca and pineapples in the Philippines; and of sugar-cane and pastures in Australia (Holm *et al.*, 1977).

At present, *M. invisa* is widely spread and is becoming a serious weed especially in the northern part of Thailand. The objectives of this experiment are to investigate biological aspects concerning botanical characteristics, life cycle, and growth habits. This information would be useful in the development of the program for controlling of *M. invisa*.

MATERIALS AND METHODS

Seed dormancy breaking:

This experiment was conducted by immersing *M. invisa* seeds in 98% sulfuric acid for 10, 20 and 30 minutes; in 98 °C water for 1.5 minutes, in 80 °C water for 3 minutes, in 70 °C water for 5 minutes; in 50% hydrochloric acid for 10 minutes; and in absolute ethanol for 2 hours. Treated seeds were washed in water before germinating on top of papers in petri-dishes. The experiment was of completely randomized design. There were four replicates of 100 seeds for each treatment.

Botanical characteristic studies:

Five seeds were sown in each of ten 12-inch diameter pots after breaking dormancy in 98 °C water for 1.5 minutes (experiment 1). After germinating for one week, seedlings were thinned to one plant in each pot. Botanical characteristics of *M. invisa* were recorded simultaneously under natural conditions.

Life cycle and growth habit studies:

Similar to experiment 2, these studies were carried out in 20 pots and under natural conditions. Field conditions of 5 x 5 m² were also included.

RESULTS AND DISCUSSION

Seed dormancy breaking:

Having a hard seed-coat *M. invisa* seed can not germinate without scarification. The seeds immersed in 98 °C water for 1.5 minutes gave the highest germination percentage (96.25%), followed by the seeds immersed in 98% sulfuric acid for 30 and 20 minutes which were 94.5% and 91.75% germination, respectively (table 1). Similar results have been reported in *M. pigra* that seed dormancy can

Table 1. Germination percentages of *Mimosa invisa* seeds from different dormancy breaking treatments.

Treatments	Replicates				mean ^{1/}
	1	2	3	4	
Control	4	6	4	7	5.25 ^a
Conc. sulfuric acid 30 min.	97	92	94	95	94.5 ^e
Conc. sulfuric acid 20 min.	95	87	92	93	91.75 ^{de}
Conc. sulfuric acid 10 min.	65	76	60	64	66.25 ^b
98 °C water 1.5 min.	96	98	96	95	96.25 ^e
80 °C water 3 min.	87	89	89	89	88.5 ^{cd}
70 °C water 5 min.	78	79	92	81	82.5 ^c
Hydrochloric acid 10 min.	0	1	1	0	0.5 ^a
Absolute ethanol 2 hr.	4	5	3	3	3.75 ^a

^{1/} Differences between any two means not followed by the same subscripts are significant at 0.05 level.

effectively be broken by immersing the seeds in hot water and concentrated sulfuric acid. (Kongrueng, 1977; and Kaobunsong, 1978). Kaobunsong (1978) suggested that *M. pigra* seeds which were produced in the dry season gave 99.6% germination by immersing in boiling water (98 °C) for 1-2 minutes. However, the highest germination percentage was also found in concentrated sulfuric acid immersed seeds for 20 minutes (Kongrueng, 1977). This study agrees with them.

Botanical characteristic studies:

Some botanical characteristics are shown in table 2 and described descendingly.

Table 2. Botanical characteristic data of *Mimosa invisa* Mart.

Characteristics	Number (n)	X ± S.E.	Range
Stem height, m. ^{1/}	10	2.40 ± 0.35	1.5-4
Stem diameter, cm. ^{1/}	10	1.35 ± 0.15	1.0-1.6
No. of branches/plant ^{1/}	10	13.80 ± 1.93	9-17
No. of pinnae, pairs/leaf	38	6.68 ± 0.38	4-9
No. of leaflets/pinna	38	20.50 ± 1.12	14-28
Leaf length (+petiole), cm.	38	14.30 ± 1.06	9.3-25.2
Pinna length, cm.	254	3.46 ± 0.10	2.2-5.3
Leaflet length, mm.	53	5.84 ± 0.35	2.2-8.5
Leaflet width, mm.	53	1.49 ± 0.65	1.0-2.0
Stipule length, mm.	50	4.34 ± 0.16	3.0-6.3
No. of heads/leaf axil	36	2.20 ± 0.12	1-3
Head diameter, cm.	36	1.53 ± 0.04	1.3-1.75
No. of florets/head	10	53.40 ± 1.99	41-64
Flower stalk length, cm.	36	0.75 ± 0.05	0.4-1.25
No. of pods/head	103	18.80 ± 1.97	1-43
Pod length, cm.	48	2.30 ± 0.11	1.0-2.9
Pod width, cm.	48	0.34 ± 0.07	0.4-0.5
No. of seeds/pod	151	3.75 ± 0.16	1-7

^{1/} = 5 months of age in pot

Stem : *M. invisa* stem is an erect, climbing, ascending or prostrate, much-branched herbaceous shrub which is slightly woody at the base. Its stem and branches are angular with five distinct corners throughout the length, up to 1.5-4 m. tall with many sharp recurved spines 3-5 mm. long, along their ridges.

Root : *M. invisa* has a strong tap-root system with numerous similar length branches. Nitrogen fixation is also found in this species.

Leaf : Bipinnately compound leaves, 9-25 cm. long arranged along their stem as a spiral type. The phyllotaxy of leaf arrangement is 2/5. In a bipinnately compound leaf, there are four to nine pinnae attached opposite along their rachis. Each pinna is composed of 14-28 pairs of leaflets. A leaflet is dark green, sessile, lanceolate or acute with smooth margin, 2.2-8.5 mm. long and 1.0-2.0 mm. wide. A petiole is angular with four corners lined up with spines, 5-6 cm. long. Each compound leaf has one pair of 3-6 mm. long hairy brown-green stipule. Also each pinna has one pair of unequal length needle-like brown-green or green stipel.

Flower : Flower of *M. invisa* is borne in head without sepals. It is pink and 1.5–1.6 cm. diameter at the full bloom stage. There are one to three heads in each axil. Its stalk is hairy, spiny, 4–12.5 mm. long. A head is composed of 40–60 florets. There are four petals united at base (gamopetalous), eight stamens and one pistil. Corolla and style are only $\frac{1}{3}$ and $\frac{8}{10}$ the length of their filament, respectively.

Fruit : *M. invisa*'s fruit is a linear, flat pod of 2.2–2.4 cm. in length and 0.35–0.5 cm. in width covered with rough hairs, and borne in cluster. The colours of which may be green, red–brown, light–brown or dark–brown depending on pod's age. A head bears 1–43 pods. Each pod has one to seven seeds. It is splitting transversely into one-seeded sections that separate at grooves or seams.

Seed : *M. invisa* has a flat, ovate, 2–2.5 mm. long and light–brown seed. The one hundred seed weight is only 740 mg. It has very hard seed-coat which renders the seed dormant.

Life cycle and growth habits:

Life cycle and growth habit studies showed that *M. invisa* found in Chiang-Mai (Thailand) was normally annual whose seeds started to germinate in the early rainy season (May to June). The plant needed at least one month for their vegetative growth. Flowers were found from October through December. Maximum flowering occurred in November. The pods ripened and dried during December and January each year. On the other hand, Holm *et al.* (1977) have reported that *M. invisa* is biennial or perennial which flowers all year round in the Philippines and very young seedlings a few weeks old can produce viable seeds.

The 5–7 cm. high young seedlings were round in shape and brown–green in colour at the base of stems and green at the young part. Afterwards, the development of spines would be noticed as well as the appearance of their ridges. A main stem 5 months old, grown in a pot, bore about 9–17 branches in similar length to stem and among them. Shrub canopies were only 1–1.5 m. high while climbing stems were much higher, about 8 metres have been observed under natural conditions. However, *M. invisa* stems can crawl or climb to a length/height of up to 12 metres or more which has been reported in Australia. It may ultimately completely cover a tree (Skinner and Anderson, 1956).

Flower formations occurred around 50–100 cm. in length up to the end of each branch depending on the size of their stems. Usually lengths of 60–75 cm. were found. As a result, flower formations began from the base to the end of the branches, their pods matured and dried upwards accordingly. Therefore, the percentage of pod formations at the end part of the stems or branches is always low due to lack of water and food reserve.

It was observed that young green flowers developed continuously and became dark red at one day before blooming. They were bright pink at the full bloom stage. As a style is $\frac{8}{10}$ the length of its filament, *M. invisa* is a self-pollinated plant. After pollinating for 1–2 days, these bright pinkish flowers changed to pale pink and fell off eventually.

Young seeds increased their size until they reached maximum at maturity. After

that matured seeds became smaller due to drying out. Although seeds could be obtained from 40 days after blooming (DAB), the germination percentages were low and vigorous seedlings were hardly found. The maximum percentages of seed germination and vigorous seedlings occurred at 49 days after blooming and onwards (Table 3). These results indicated that *M. invisa* seeds reached their physiological maturity at 49 days after blooming.

A ripened seed is light brown. The seed-coat is very hard and possesses dormancy. Thus *M. invisa* seeds can remain viable for years (Holm *et al.*, 1977). To confirm this, stored seeds were tested for their germination capacity in the laboratory. The results showed that about 70% of seeds stored for one, two, three and four years could germinate, corresponding with the report of Skinner and Anderson (1956) that *M. invisa* seeds could remain viable in the soil for lengthy periods of four or more years.

CONCLUSION

Mimosa invisa Mart. is an annual climbing shrub which has a herbaceous thorny angular stem; a tap-root system; and pink flowers formed in head. The pods were borne in clusters, the matured and dried pods are splitting transversely. The seeds shatter readily and possess seed dormancy. Under laboratory, seed dormancy can effectively be broken by immersing in hot water and concentrated sulfuric acid.

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EFFECT OF GLYPHOSATE ON GERMINATION AND SEEDLING GROWTH OF RICE

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ABSTRACT

Isopropylamine salt of glyphosate (*N*-(phosphonomethyl) glycine) is officially recommended in Taiwan for control of water hyacinth, weeds in paddy levees, citrus and many other fruit trees and fallow or non-crop land since 1973. Because the use of this herbicide is very popular, and especially it is widely used in paddy levees or areas nearby paddy fields, experiments were carried out on the effect of glyphosate on germination of rice seeds and on the growth of rice seedlings in the laboratory. Field trial on residual status of this herbicide in the paddy levee and water in the paddy field was also performed.

In the laboratory experiments, glyphosate did not affect the germination of rice seeds up to a concentration of 50 ppm. No difference was observed between Japonica and Indica types. The growth of rice seedling was affected at the concentration of 0.5 ppm and 1.0 ppm for Japonica and Indica type respectively.

In the field tests, no glyphosate was detected from the soils collected in the paddy levee even with the soil sample collected at 1 hr after application with the officially recommended rate (5 l of 41% isopropylamine salt diluted with 100 times of water per ha). Residues in the paddy water was found to be 1,475 and 76 ppb for 30 cm and 3 m distance from paddy levee, respectively, 1 hr after application, but no glyphosate was detected after 24 hr.

MATERIALS AND METHODS

To clarify the effects of herbicide glyphosate *N*-(phosphonomethyl) glycine on germination and seedling growth of rice (*Oryza sativa* Linn.), two varieties of rice, cv. Tainan No. 5 (*Japonica* type) and cv. Taichung No. 3 (*Indica* type) were used in laboratory experiments for evaluating the effects of glyphosate on germination and seedling growth of rice.

After selection and sterilization, 50 rice seeds were cultured in petri dishes with different concentrations of 20 ml aqueous glyphosate solution on filter paper at room temperature. Effects of glyphosate on the growth of rice seedlings were examined by cultivating 3 seedlings with Hoagland's nutrient solution containing from 0.5 to 10 ppm of glyphosate at $25 \pm 2^\circ\text{C}$ under 6,400 lux illumination.

Paddy levee was sprayed with the recommended rate of glyphosate (5 l of 41 % isopropylamine salt diluted with 100 times of water per ha). Sampling was made at designed intervals with soils from paddy levee and of water from paddy fields 30 cm and 3 m distant from the levee. Residue analysis of glyphosate was carried out by FPD-GC.

Table 1. Effects of glyphosate on germination of rice seeds. a)

Conc. of glyphosate, ppm	Germination, %		Length of seedlings, d) mm	
	Taichung No. 3b)	Tainan No. 5c)	Taichung No. 3 (Index)	Tainan No. 5 (Index)
0	95	98	39.0 $\pm$ 4.7 (100)	23.2 $\pm$ 1.4 (100)
10	94	95	39.6 $\pm$ 0.3 (102)	20.1 $\pm$ 1.5 (87)
15	90	99	37.3 $\pm$ 3.1 (96)	13.1 $\pm$ 0.5 (56)
20	86	96	29.0 $\pm$ 1.0 (74)	11.5 $\pm$ 0.5 (50)
25	87	92	24.1 $\pm$ 0.7 (62)	10.9 $\pm$ 1.0 (47)
30	85	96	20.0 $\pm$ 0.7 (51)	9.0 $\pm$ 0.2 (39)
50	91	96	17.6 $\pm$ 0.5 (45)	6.7 $\pm$ 0.1 (29)

a) Means of two replications.
c) After 12 days.

b) After 6 days.
d) With 25 seedlings.

Table 2. Growth of rice seedlings after transplanting in nutrient solution containing different concentrations of glyphosate for 10 days (Tainan No. 5) and 11 days (Taichung No. 3).

Concentration, <i>ppm</i>	Taichung No. 3				Tainan No. 5			
	Length, <i>mm</i>		Fresh wt., <i>g</i>		Length, <i>mm</i>		Fresh wt., <i>g</i>	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
0	29.5	14.0	0.79	0.180	28.6	14.9	0.50	0.055
0.5	29.5	14.6	0.80	0.205	29.4	13.3	0.59	0.070
1.0	28.5	13.5	0.78	0.115	27.0	11.8	0.53	0.078
2.5	27.5	11.3	0.68	0.060	28.3	10.8	0.47	0.045
5.0	24.0	7.5	0.38	0.020	20.8	11.1	0.30	0.025
10.0	19.1	9.9	0.22	0.020	17.9	10.0	0.32	0.023

Table 3. Residue of glyphosate in the nutrient solution after cultivating Taichung No. 3 rice seedling for 11 days.

Conc. of glyphosate in nutrient solution, <i>ppm</i>	Residue, <i>ppm</i>
0	ND ^{a)}
0.5	ND
1.0	ND
2.5	0.039 ± 0.011
5.0	0.288 ± 0.091
10.0	0.720 ± 0.242

a) Not detected ($<10 \text{ ppb}$).

In the field tests, no glyphosate was detected in all soil samples collected in the paddy levee. Residue in the paddy water was found only in first samples collected 1 *hr* after application and was 1,475 *ppb* and 76 *ppb* for the samples 30 *cm* and 3 *m* from the paddy levee, respectively.

CONCLUSIONS

Application of glyphosate at the recommended rates would not have a harmful effect on the germination of rice seeds or on nursery beds or young seedlings of rice in paddy fields.

GERMINATION AND RESPIRATION RATE OF *Mimosa invisa* MART. AND *Mimosa pigra* L. SEEDS.

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ABSTRACT

On average each inflorescence of *Mimosa invisa* Mart. has 52 flowers which develop to produce 26 pods, each pod has 4 seeds. Germination of seeds in normal laboratory conditions are not more than 12% due to its dormancy by seed coat being impermeable to water. This dormancy can be broken by soaking the seed in hot water. It was found that the seed coat at the strophiole became swollen or split longitudinally so that water could enter the seed in the same way as found in *Mimosa pigra* L. seeds. The *Mimosa invisa* Mart. seeds can be divided into three groups according to seed coat color, namely light-brown, brown and dark-brown. When the seeds were soaked in hot water at 70 C., 80 C or boiling water (98 C) for different periods of time, all three types of seeds gave similar patterns of changes in percent germination but the light-brown seeds were more tolerant to boiling water than the brown and dark-brown seeds, respectively. Seeds soaked in hot water at 80 C for 1 or 2 minutes gave the highest percentage of germination with all normal seedlings.

Changes in rate of respiration and respiratory quotient (RQ) during 8 days of germination of both *Mimosa pigra* L. and *Mimosa invisa* Mart. seeds followed. Changes in respiration rates of the germinating seeds can be divided into 3 phases. In the first phase (12 hours), the respiration rate was increased in *Mimosa pigra* L., but not significantly increased in *Mimosa invisa* Mart. seeds. In the second and third phases, the changes were similar in both seeds. The respiration rate rapidly increased in the second phase to give the highest value in the third day after the beginning of germination, thereafter it was decreased to the end of experimental period in the third phase.

INTRODUCTION

Both *Mimosa pigra* L. and *Mimosa invisa* Mart. were introduced to Thailand in 1947 as a green manure and cover crop (Watanadajaree, 1985). Although *M. invisa* was found on waste lands and plantation crop lands throughout Thailand (Noda *et al.*, 1985) there was essentially no report on studies or control of this weed. Much attention were concentrated on the studies of *M. pigra* due to its conspicuous and large area of infestation in northern Thailand (Wara-Aswapati, 1982 and Robert, 1982). In this paper, the effects of hot water treatment on seed germination and respiration rate during seed germination of *M. invisa* will be reported in comparison with *M. pigra* seeds.

MATERIALS AND METHODS

M. invisa and *M. pigra* inflorescences and dry pods were collected from mature plants in Chiang Mai University campus for all studies. Germination test of seeds were carried out in 10 cm. diameter petri dish with two layers of tissue paper and

10 ml. water. There are 30 seeds per replicate for *M. pigra* and 50 seeds for *M. invisa*, and there are 5 to 10 replicates for each treatment. Hot treatments were done by soaking the seeds in a water bath at 70, 80 or 98 C for different periods of time. The percent germination of seeds were recorded after 8 days at 25 C.

Changes in respiration rate at 25 C during seed germination after the seeds were treated with 80 C hot water for 2 minutes were followed by measuring both carbon dioxide output and oxygen uptake on a Warburg respirometer (Umbriet *et al.*, 1972).

RESULTS AND DISCUSSION

Table 1 shows the mean number of flowers per inflorescence, pods per inflorescence and seeds per pod with their standard deviation and range found in *M. invisa* in comparison with *M. pigra*. On average, each inflorescence of *M. invisa* has 52 flowers which develop to produce 26 pods, each pod has 4 seeds, while *M. pigra* has 108 flowers but produce only 5 pods per inflorescence and each pod has 20 seeds. This makes both species give similar yield of about 100 seeds per inflorescence, in spite of their differences in number of flowers and pods per inflorescence.

All *M. pigra* seeds are olive green in color, while *M. invisa* seeds show more variation in seed coat color from light-brown to dark-brown. If they are divided into three groups, namely light-brown, brown, and dark-brown, there are 55% light-brown, 27% brown and only 18% dark-brown seeds.

Table 1. Mean number of flowers per inflorescence, pod per inflorescence and seeds per pod with their standard deviation and range found in *M. invisa* in comparison with *M. pigra*.

plant	number of	mean $\pm$ SD	range	No. of samples
<i>M. invisa</i>	flowers/inflorescence	52.1 $\pm$ 5.9	38-60	30
	pod/inflorescence	26.0 $\pm$ 11.2	3-54	50
	seeds/pod	4.0 $\pm$ 0.1	1-6	1301
<i>M. pigra</i>	flowers/inflorescence	108.6 $\pm$ 9.8	84-118	20
	pod/inflorescence	5.4 $\pm$ 2.8	1-16	577
	seeds/pod	19.7 $\pm$ 2.8	11-24	56

Table 2 shows the effects of hot water treatment at 70, 80 and 98 C (boiling water) for different periods of time on percent germination of all three *M. invisa* seed groups. The untreated light-brown seeds shown no germination at all, while the brown and dark-brown seeds gave 1.2% and 6.6% germination on average. The maximum percent germination found in dark-brown seeds was only 12%. The majority of the seeds are in dormancy state. This dormancy can be broken by soaking in hot water. When seeds were soaked in hot water at 70, 80 or 98 C for different periods of time, all three types of seeds gave similar changes in percent germination, but the light-brown seeds were more

tolerant to boiling water than the brown and dark-brown seeds. Seeds which were soaked in 80 °C hot water for 1 to 2 minutes gave the highest percent germination with all seedlings normal. Longer treatments decreased percent seed germination and gave abnormal seedlings, probably due to damage of embryo by hot water. All light-brown seeds were killed after 10 minutes in boiling water, while the brown and dark-brown seeds required only 3 or 2 minutes.

Table 2. Effects of different hot water treatments on percent germination of the three different colours of *M. invisa* seeds.

hot water treatment		seed germination (%)		
temp. (°C)	time (min)	light-brown	brown	dark-brown
70	0	0	2.0	6.0
	1/6	77.2	76.0	62.8
	1/2	88.4	78.4	64.0
	1	86.8	90.8	71.2
	2	94.4	92.8	86.8
	3	95.2	95.6	90.4
	5	96.4	92.4	77.2
	10	95.2	89.7	72.0
	15	91.6	84.0	70.4
80	0	0	0.8	8.8
	1/6	88.4	80.0	73.2
	1/2	98.4	98.0	90.0
	1	99.6	97.6	93.2
	2	99.6	99.2	90.4
	3	98.8	98.4	90.0
	5	99.2	93.6	88.0
	10	96.0	58.4	63.2
	15	31.2	28.4	5.6
90	0	0	1.2	5.2
	1/12	100.0	93.6	78.8
	1/6	100.0	78.0	46.8
	1/3	98.0	72.0	22.4
	1/2	97.2	56.0	6.8
	1	78.0	18.8	0.4
	2	31.6	5.6	0
	3	22.4	0	0
	5	2.8	0	0
	10	0	0	0

Similar results on the germination of *M. pigra* seeds from different seasons are shown in Table 3. The tolerance to hot water increases from rainy-season to winter and summer seeds respectively and related to seed moisture content and relative humidity of the atmosphere during the ripening period of the seeds (Threerakulpisut and Wara-Aswapati, 1984).

Table 3. Effects of different hot water treatments on percent germination of three different season *M. pigra* seeds.

hot water treatment		seed germination (%)		
temp. (°C)	time (min)	rainy season	winter	summer
70	0	2.5	0.8	0.8
	1/6	76.6	15.8	25.0
	1/2	75.8	25.0	34.1
	1	80.0	45.8	40.0
	2	84.1	64.1	47.5
	3	83.3	67.5	49.1
	4	84.1	63.3	47.5
	5	82.5	63.3	48.3
	10	85.0	62.5	59.1
80	0	1.6	0	2.5
	1/6	91.6	83.3	79.1
	1/2	93.3	89.1	81.6
	1	93.3	93.3	89.1
	2	93.3	94.1	91.6
	3	94.1	95.8	91.6
	4	81.6	90.8	94.1
	5	78.3	91.6	92.5
	10	51.6	88.3	92.5
98	0	2.5	0	1.6
	1/6	32.5	94.1	86.6
	1/2	17.5	73.3	99.1
	1	10.8	54.1	98.3
	2	5.8	43.3	93.3
	3	5.8	30.0	65.8
	4	4.1	23.3	55.8
	5	3.3	16.6	43.3
	10	0	5.0	15.8

When seed dormancy was broken by soaking in hot water, the outermost layer of seed coat, namely the palisade cells at the strophiole swelled or split longitudinally (Figure 1) so that water could enter the seed and germinate.

Changes in rate of respiration, respiratory quotient (R.Q.), seed moisture content, fresh weight and dry weight during 8 days of germination in both *M. invisa* (Figure 2) and *M. pigra* (Figure 3) seeds were followed. Changes in respiration rate of the germinating seeds can be divided into 3 phases. In the first phase (12 hours), the respiration rate was increased in *M. pigra*, but not significantly increased in *M. invisa* seeds. In the second and third phases, the changes were similar in both seeds. The respiration rate was rapidly increased in the second phase to the highest value in the third day after the beginning of germination, thereafter it was decreased to the end of experimental periods in the third phase.

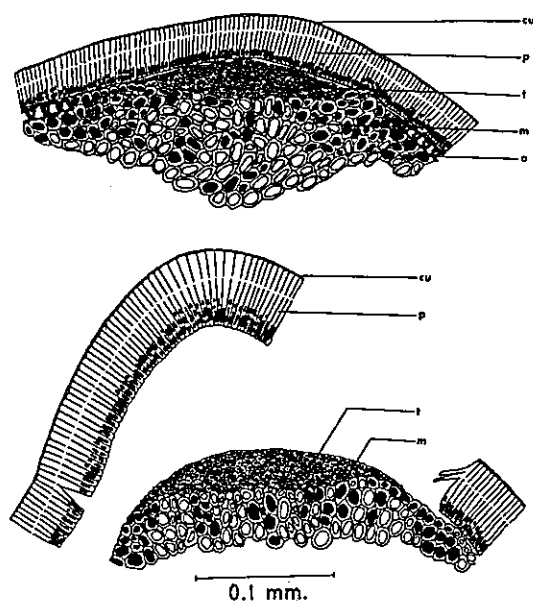


Figure 1. Cross section of *M. pigra* seed coat at the strophiole.

Top - Untreated dormant seed.
 Bottom - Seed treated with 80°C hot water for 2 minutes showing the palisade cells swelling and splitting.
 (CU = cuticle, p = palisade cells, t = tracheid cells, m = mesophyll cells, o = osteoscleried cells)

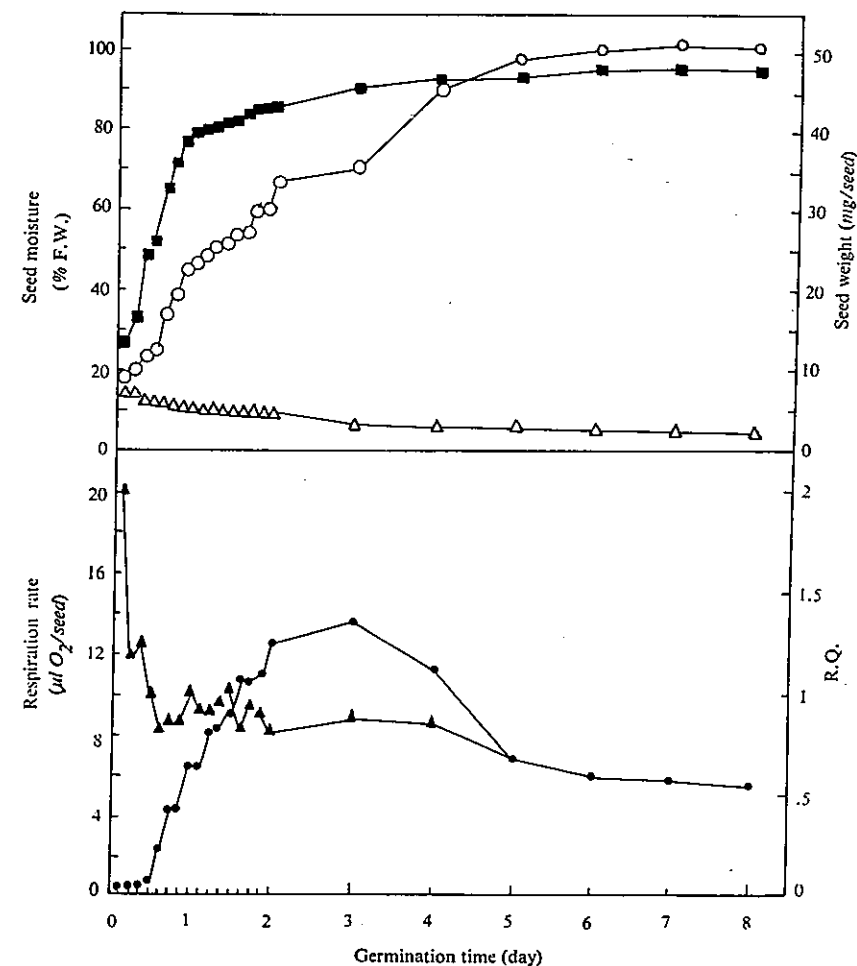


Figure 2. Change in respiration rate (●—●), R.Q. (◆—◆), seed moisture (■—■), fresh weight (●—●) and dry weight (△—△) during the germination of *M. invisa* seeds.

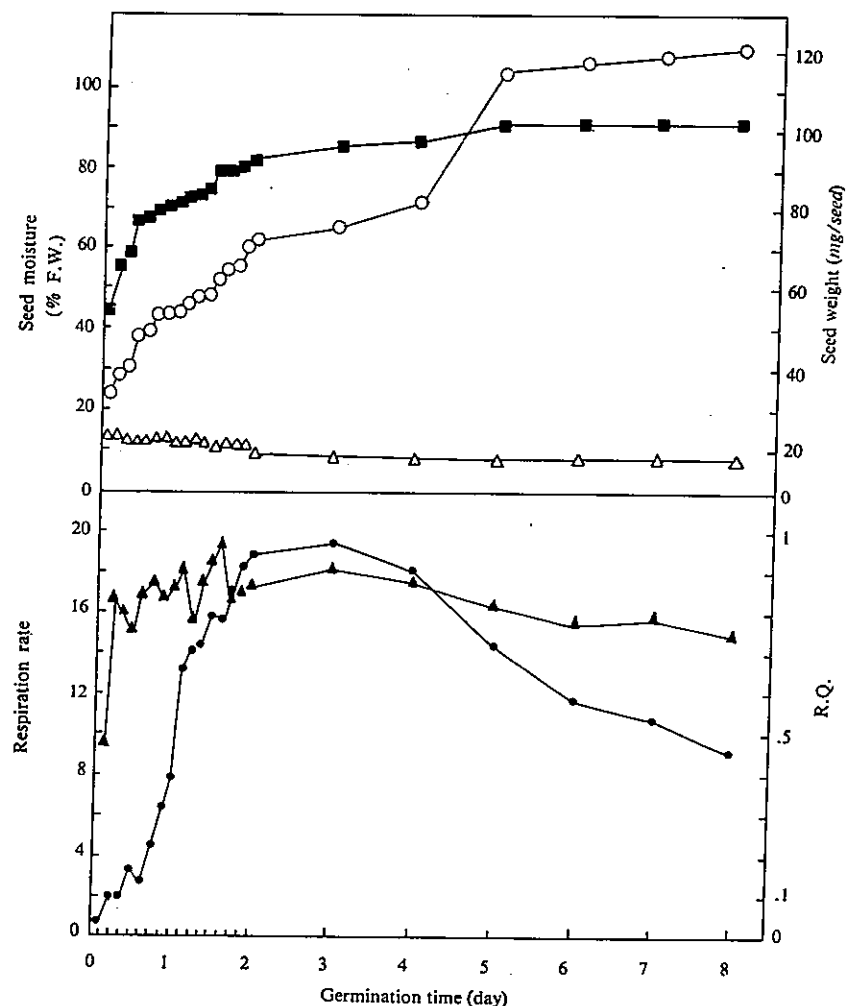


Figure 3. Change in respiration rate (●—●), R.Q. (◆—◆), seed moisture (■—■), fresh weight (○—○) and dry weight (△—△) during the germination of *M. pigra* seeds.

The initial R.Q. of *M. invisa* seed was about 2.0 and decreased sharply to the value of 1.0 after 12 hours, and thereafter gradually decreased to 0.6 after 8 days of germination. The high R.Q. of *M. invisa* seed may due to the limitation of seed coat to oxygen diffusion (Mayer and Pojakoff-Mayber, 1982) which prevent the increased in respiration rate in the first 12 hours of germination. The lower R.Q. value accompanied with rapidly increased in respiration rate of *M. pigra* seedling during the same period are in accordance with this suggestion. Changes in seed moisture content, fresh weight and dry weight of both seeds during germination were similar, except the initial seed moisture content of *M. invisa* was lower than that of *M. pigra* seeds.

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NEW APPROACH TO THE EFFECTIVE CONTROL OF *Mimosa pigra* L. BY HERBICIDES

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ABSTRACT

One of the promising methods to control giant mimosa (*Mimosa pigra* L.) was studied. Cutting the trees down and injecting various concentrated herbicide into the mature specimens of the plant (cut stump treatment). The giant mimosa regenerated rapidly from cut stump. It can be killed by dropping 1-2 ml of herbicides recommended for woody plants immediately after cutting. This method caused less disturbance to both the soil and the surrounding plants than the other treatments. It was also much quicker and required less labour.

INTRODUCTION

Giant mimosa (*Mimosa pigra* L.) is native to the tropical parts of Central and South America. It was introduced into Thailand from Indonesia in 1947 as a ground cover to improve soil quality and prevent bank erosion in the northern region. It can grow and survive in every kind of soils especially moist sandy soil. In 1985 it infested 20 provinces, with the heaviest concentrations along streams, rivers and reservoirs especially in the northern part (Robert, 1982). Investigations to find effective methods of controlling giant mimosa were necessary.

Objectives

1. to determine the effective dosage of herbicides
2. to compare the concentration of herbicides for an effective application.

MATERIALS AND METHODS

Mimosa pigra seeds were planted in the experimental plot of Weed Control and Research Branch, Royal Irrigation Department, Nonthaburi in September 1984. These plants were allowed to establish for ten months, average 4 metres high and diameter 8 cm., then cut 30 cm. above the bole of the plants (Mowatt, 1981). For statistical analysis, an experiment was chosen as a completely randomized design. Each treatment was applied to five plants in three replications that were randomly selected. The herbicides were applied by dropping 1 ml per stump the same day after cutting at the following rates in Table 1.

Table 1. Herbicides and Concentrations in water

Herbicides dilution by product	Concentration in water as per cent active constituents			
	1:9	1:4	1:1	pure solution
chopper ae 25%	2.5	5.0	12.5	25
dicamba ae 48%	4.8	9.6	24	48
glyphosate ae 36%	3.6	7.2	18	36
hexazinone ai 25%	2.5	5.0	12.5	25
triclopyr ae 48%	4.8	9.6	24	48
triclopyr & picloram + 2, 4-D	3.745	7.48	18.725	37.45

RESULTS

Table 2. Effect of herbicides on control of *M. pigra* by cut stump treatment, 30 days after treatment as percentage kill

Herbicides	Concentration of dilution			
	1:9	1:4	1:1	pure solution
chopper ae 25%	42.6 ^{cd}	50.6 ^{bc}	82.0 ^{ab}	84.6 ^{ab}
dicamba ae 48%	37.3 ^{cd}	44.6 ^c	64.0 ^{abc}	93.3 ^a
glyphosate ae 36%	44.0 ^c	51 ^{bc}	96.0 ^a	92.6 ^a
hexazinone ai 25%	8.0 ^{de}	1.3 ^e	2.6 ^e	1.3 ^e
triclopyr ae 48%	81.0 ^{ab}	65.3 ^{abc}	66.0 ^{abc}	73.0 ^{abc}
triclopyr & picloram + 2, 4-D	36.0 ^{cde}	45.6 ^c	84.6 ^{ab}	88.0 ^a
control				0 ^e

Table 3. Effect of herbicides on control of *M. pigra* by cut stump treatment, 60 days after treatment as percentage kill.

Herbicides	Concentration of dilution			
	1:9	1:4	1:1	pure solution
chopper ae 25%	70.6 ^{ab}	71.3 ^{ab}	97.3 ^{ab}	100 ^a
dicamba ae 48%	70.0 ^{ab}	94.0 ^{ab}	98.0 ^{ab}	100 ^a
glyphosate ae 36%	71.3 ^{ab}	92.0 ^{ab}	99.3 ^{ab}	100 ^a
hexazinone ai 25%	86.6 ^{ab}	68.0 ^b	91.3 ^{ab}	94.6 ^{ab}
triclopyr ae 48%	92.6 ^{ab}	86.0 ^{ab}	38.6 ^{ab}	96.6 ^{ab}
triclopyr & picloram + 2, 4-D	66.3 ^b	30.6 ^{ab}	96.6 ^{ab}	100 ^a
control				0 ^c

Table 4. Effect of herbicides on control of *M. pigra* by cut stump treatment, 90 days after treatment as percentage kill.

Herbicides	Concentrations of dilution			
	1:9	1:4	1:1	pure solution
chopper <i>ae</i> 25%	95.3 ^{ab}	95.3 ^{ab}	100 ^a	100 ^a
dicamba <i>ae</i> 48%	81.3 ^{ab}	100 ^a	100 ^a	100 ^a
glyphosate <i>ae</i> 36%	93.3 ^{ab}	96 ^a	100 ^a	100 ^a
hexazinone <i>ai</i> 25%	83.6 ^{ab}	73.3 ^b	94 ^{ab}	100 ^a
triclopyr <i>ae</i> 48%	98 ^a	92 ^{ab}	100 ^a	100 ^a
triclopyr & picloram + 2, 4-D control	77 ^{ab}	83.3 ^{ab}	100 ^a	100 ^a 0 ^d

CONCLUSION

Cut stump treatment with giant mimosa with chopper 2.5% *ae*, dicamba 4.8% *ae*, glyphosate 3.6% *ae*, hexazinone 2.5% *ae*, triclopyr 4.8% *ae* and triclopyr & picloram + 2, 4-D 3.745% or higher were very effective. This method leaves no residue of herbicides in the soil and aquatic environments.

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TOPOGRAPHY OF THE SURFACE STRUCTURE OF WEED LEAVES

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ABSTRACT

A topographical study of the leaves of tropical weeds was made during 1983 to 1984 with a scanning electron microscope. The material plants were main tropical weeds of 77 species distributed throughout Thailand. They are classified into grassy weeds of 24, *Cyperaceae* weeds of 13, and broadleaved weeds of 40 species.

Similarities within Family and/or Genus could be to some extent observed. Some characteristics can be summarized as follows :

Grassy weed have stomata on both adaxial and abaxial surfaces. Wax deposits were very different according to weed species. Macrohairs and microhairs exist in the majority of grassy weeds.

Outstanding characteristics of *Cyperaceae* weeds were the absence of stomata on the adaxial surface, and no deposits of wax at the both surfaces.

The surface structures of broadleaved weeds taken are very variable. Number of stomata at the adaxial and abaxial surfaces varies from 1 to 10 per $(100\mu)^2$ according to species. Existence of wax deposits is very different from weed species. Further, several kinds of trichomes such as macrohair, microhair, secretory gland, stellate and so on could be observed.

The results obtained seem to contribute to identification and classification of weed species, but at present it may be somewhat difficult to discuss the relationship of topography to the physiological function of weed plants.

INTRODUCTION

A scanning electron microscope was used to observe the topographical characteristics of leaf surface, and to take pictures of three dimensional aspects. Micrographs in this studies indicated the size and arrangement of stomata, silica-containing structures, various shapes of epicular wax deposits, frequency and morphology of trichomes and the feature of cuticle arrangements on both adaxial and abaxial leaf surfaces. These information are not only useful to know the biological characteristics of weed species, but also effective to understand penetration, distribution and/or retention of herbicides on the leaf surface. For details of illustrations the "Topography of the seeds and leaves of Tropical Weeds" (1985) should be referred to.

MATERIALS AND METHODS

Leaves of weedy plants for this observation were collected and prepared throughout Thailand, mainly concentrating on major weedy plants. The number of weed materials

for leaves amounted to 77 species comprising 24 grassy weeds, 13 *Cyperaceae* weeds and 40 broadleaved weeds. Leaf specimens, after cleaning and cutting into small pieces, were fixed for about 2 hours with 2-2.5 % glutaraldehyde using phosphate buffer, followed by ordinary procedures of washing with distilled water and dehydrating with alcohol after which, the alcohol is substituted by amyl acetate. Afterwards, dehydrated materials were treated by a critical point drying method with Critical Point Dryer, HCP-2. Dried leaf specimens were placed on sample holders, followed by ion sputtering of gold with Ion Coater, Eiko IB-3, at vacuum 0.05-0.1 Torr, for three to five minutes. Then observations were made by a scanning electron microscope, APHPA-9 (Akashi). All photographs were taken by Polaroid films at various magnifications from 50x to 30,000x. Adaxial and abaxial surfaces of a leaf were illustrated at low, moderate and high magnifications. In particular, the detail of epicuticular wax in leaf surfaces seems to be clearly imaged at higher magnification of more than 3,000x.

Results and Conclusion

Illustrations were mainly focussed on the existence and size of stomata, the existence, degree and/or appearance of epicuticular wax deposits and specific properties on the surface such as hairs, trichomes, papillae, silica bodies, etc., based on the adaxial and abaxial surfaces of a leaf.

In general, variegated configurations were illustrated from different weed species. Similarities in family or genus could be, however, observed to some extent. A summarized description of the results in respective groups of weed species illustrated is made as follows:

Grassy weeds: All grassy weed species observed have the parallel rows of stomata and epidermal cells (Fig. 1). Stomata present on both adaxial and abaxial leaf surfaces but varying from approximately 10 to 30 *microns* in the size of aperture of a stomata, as seen in Table 1. Many species in this grassy weeds group have larger apertures as seen in *Coix aquatica* and *Pennisetum* spp.

Table 1. Summary of the Surface Structure of Weed Leaves

Scientific Name	Stomata Ad. Ab.	No. of stomata	Length of aperture	Wax Ad. Ab.	Appendages, etc.
1. Grassy Weeds					
			micron		
<i>Brachiaria mutica</i>	e e	1-2	10	3 1	mi, ma
<i>B. reptans</i>	e e	2-4	7	3 1	mi
<i>Cenchrus echinatus</i>	e e	1-2	20	1 1	mi, d
<i>Chloris barbata</i>	e e	2-3	8	3 1	pr, pa
<i>Coix aquatica</i>	e e	2	30	1 1	mi, ma, d
<i>Cynodon dactylon</i>	e e	3	15	4 4	pa, pr
<i>Dactyloctenium aegyptium</i>	e e	3-5	10-15	2 2	ma, pa
<i>Echinochloa colonum</i>	e e	1-2	10	4 4	pa
<i>E. crusgalli</i>	e e	2-4	25	4 2	mi
<i>Eleusine indica</i>	e e	2-4	15	4 1	
<i>Eragrostis viscosa</i>	e e	2-3	8	4 1	mi, pr

(continued)

Scientific Name	Stomata Ad.	No. of Ab.	Length of stomata aperture	Wax Ad.	Appendages, Ab. etc.
			micron		
<i>Eriochloa procera</i>	e	e	2	20	3 1 mi
<i>Imperata cylindrica</i>	e	e	4-5	10	4 1 mi, pa
<i>Ischaemum rugosum</i>	e	e	4-5	10-15	3 3 mi, pa
<i>Leersia hexandra</i>	e	e	4	14	3 3 mi, pa, pr, si
<i>Leptochloa chinensis</i>	e	e	2	10	3 3 pa, pr, si
<i>Panicum repens</i>	e	e	4	10	3 3 pr, si, ma
<i>Pennisetum pedicellatum</i>	e	e	2-4	30	1 1 mi, pr
<i>P. polystachyon</i>	e	e	2-4	30	1 1 ma, mi, pr, d
<i>P. purpureum</i>	e	e	2-4	30	1 1 mi, ma, pr
<i>Rhynchelytrum repens</i>	e	e	2-4	20	4 2 mi, pr
<i>Rottboellia exaltata</i>	e	e	2-3	25-30	1 1 pr, mi
<i>Saccharum spontaneum</i>	e	e	?	12	3 3 pr
<i>Setaria pallide-fusca</i>	e	e	2-3	20	4 1 pr, mi
2. Cyperaceae Weeds					
<i>Cyperus compactus</i>	n	e	2-4	12	2 2 w
<i>C. difformis</i>	n	e	2-4	20	1 1 w
<i>C. distans</i>	n	e	2-4	15	1 1 w
<i>C. imbricatus</i>	n	e	3-5	20	1 1 w, pr
<i>C. iria</i>	n	e	2-4	20	1 1 w
<i>C. pulcherrimus</i>	n	e	2-3	18	1 1 w
<i>C. rotundus</i>	n	e	2-3	20	1 1 w
<i>Eleocharis dulcis</i>		(e)	4-6	15	(1) w
<i>E. spiralis</i>		(e)	4-6	17	(1) w
<i>Fimbristylis miliacea</i>		(e)	1-2	35	(1) w
<i>Fuirena ciliaris</i>	n	e	3-5	35	1 1 w
<i>Scirpus articulatus</i>		(e)	3	15	(1) w
<i>S. grossus</i>	e	e	2-4	15	1 1 w
3. Broadleaved Weeds					
<i>Abutilon indicum</i>	e	e	1-2	8	1 1 se
<i>Aeschynomene americana</i>	e	e	8-10	10	2 1
<i>A. indica</i>	e	e	8-10	6	4 3
<i>Ageratum conyzoides</i>	e	e	3-5	15	1 1 ma, mi
<i>Alternanthera philoxeroides</i>	e	e	2-3	20	1 1 ma, mi
<i>A. sessilis</i>	e	e	2-3	25	1 1 ma
<i>Amaranthus viridis</i>	e	e	2-3	10	1 1 st
<i>Boerhavia diffusa</i>	e	e	2-4	15	1 1 st, tr
<i>Commelina benghalensis</i>	e	e	1	30	1 1 st, ma, mi
<i>C. diffusa</i>	e	e	1	25	1 1 mi, pa
<i>Eclipta alba</i>	e	e	2-3	15	1 1 ma
<i>Eichhornia crassipes</i>	e	e	1-2	35	1 1
<i>Emilia sonchifolia</i>	e	e	3	10	3 3
<i>Eupatorium odoratum</i>	e	e	2-3	15	1 1 ma, mi, tr
<i>Euphorbia geniculata</i>	e	e	8-10	8	3 3 ma, si

(continued)

Scientific Name	Stomata		No. of stomata	Length of aperture	Wax		Appendages, etc.
	Ad.	Ab.			Ad.	Ab.	
				<i>micron</i>			
<i>E. hirta</i>	e	e	1-3	8	1	4	ma
<i>E. thymifolia</i>	e	e	2-5	4	3	3	si, ma, mi
<i>Gomphrena celosioides</i>	e	e	2-4	8	1	1	ma
<i>Heliotropium indicum</i>	e	e	3-8	12	1	1	ma, pr, tr
<i>Hyptis suaveolens</i>	e	e	7-10	15	1	1	ma, mi, st, tr
<i>Ipomoea aquatica</i>	e	e	3-5	10	1	1	st, tr
<i>Jussiaea linifolia</i>	e	e	3-10	8-10	1	1	st
<i>J. repens</i>	e	e	5	8-10	1	1	st
<i>Marsilea crenata</i>	e	e	2	8	3	3	
<i>Mimosa invisa</i>	e	e	2-4	5	2	2	ma
<i>M. pigra</i>	e	e	5	8	3	3	ma
<i>M. pudica</i>	e	e	1-2	5-7	3	3	ma
<i>Monochoria hastata</i>	e	e	3-4	17	1	1	st
<i>M. vaginalis</i>	e	e	4	10	1	1	st
<i>Paederia linearis</i>	n?*	e	0*-5	15	1	1	st, ma, mi
<i>Passiflora foetida</i>	e	e	4-5	10	1	1	ma, mi
<i>Phyllanthus amarus</i>	e	e	2-3	5	4	4	
<i>Pistia stratiotes</i>	e	e	1-2	10	3	?	ma
<i>Polygonum tomentosum</i>	e	e	3-6	12	1	1	ma, st, pa
<i>Portulaca oleracea</i>	e	e	1-2	20	1	1	st
<i>Sida acuta</i>	e	e	1-2	8	1	1	st, se
<i>Sphaeranthus africanus</i>	e	e	1-2	15	1	1	mi, tr
<i>Sphenoclea zeylanica</i>	e	e	3-5	6	3	3	
<i>Tridax procumbens</i>	e	e	2-3	20	1	1	pr, mi
<i>Vernonia cinerea</i>	e	e	1-3	10	1	1	mi, ma, tr, st

Notes: Ad. = adaxial surface, Ab. = abaxial surface.

e = existence of stomata, n = no existence of stomata.

Wax deposits; 1 = no, 2 = little, 3 = moderate, 4 = dense.

() are in the cases of no distinction of adaxial and abaxial surfaces.

No. of stomata is per (100 micron)²

Appendages; mi = microhair, ma = macrohair, pr = prickles, pa = papilla, si = silica body,

w = wart, se = stellate, st = striae, tr = trichome, d = dumb-bell-shaped substance.

* ; observed on the adaxial only.

Wax deposits on the leaf surfaces were very different according to weed species. Dense wax deposits on both leaf surfaces as seen in *Echinochloa colonum* (Figs. 2 and 3), moderate ones in *Panicum repens* (Figs. 4 and 5) and no wax deposits in *Coix aquatica* (Fig. 6) and *Rottboellia exaltata* (Fig. 7) were observed. Generally, however, more dense deposits of wax were found on the adaxial surface of a leaf compared with the abaxial one.

Table 1 indicates the existence of several kinds of appendages on the leaf surface which were observable in the micrographs taken. Macrohairs and microhairs existed in the majority of grassy weeds, for instance in *Coix aquatica* (Fig. 8). Microhairs composed of a single cell and some undeveloped cells, seem ontogenically to be the same as macrohairs. Prickles may be also a kind of metamorphosis of the hair were also found in many grassy weed species, for instance, in *Chloris barbata* (Fig. 9). The other appendages which were often seen in this grassy weed group were silica deposits, as seen in *Panicum repens* (Figs. 4 and 5).

Cyperaceae weeds : When compared with grassy weeds, one of the characteristics of *Cyperaceae* weeds, especially in the genus of *Cyperus*, was the absence of stomata on the adaxial surface, for instance in *Cyperus imbricatus* (Figs. 10 and 11), except *Scirpus grossus* (Figs. 12 and 13) has stomata on both adaxial and abaxial leaf surfaces. The length of stomata varies between species of this *Cyperaceae* group, but *Fimbristylis miliacea* and *Fuirena ciliaris* were shown to have the maximum length of apertures which are longer than grassy weeds. Further, the majority of this group is featured by no deposits of wax on either adaxial or abaxial surface as well as the existence of paralld rows of warty cuticular substance (Figs. 14 and 15).

Broadleaved weeds : All broadleaved weeds examined have stomata on both adaxial and abaxial surfaces, but differ in the number per unit area, ranging from 1 to 10, as seen in the Table 1. It could be sometimes observed that the number of stomata on the abaxial is more than that on the adaxial; for instance, *Paederia linearis* (Figs. 16 and 17), *Vernonia cinerea* (Figs. 18 and 19). Further, the size of stomata indicated by the length of aperture is very varied, and the largest stomata can be seen in *Eichhornia crassipes* (Fig. 20), on the other hand, the smallest stomata was found in *Euphorbia thymifolia* (Fig. 21). There seems to be no relation between the number and size of stomata. Differences in the existence or non-existence of wax deposits between adaxial and abaxial surfaces were hardly seen, excluding in *Euphorbia hirta* (Figs. 22 and 23). Generally, weed species without wax deposits are rather more numerous than those with them, and *Phyllanthus amarus* is only one species in this broadleaf weed group which has dense wax deposits on both leaf surfaces (Figs. 24 and 25). The shapes of wax deposits were found to be diverse; flakes, scales, rodlets, striae and reticulum etc. were seen as in Figs. 26, 27, 28 and 29.

The majority of broadleaved weeds have macrohairs and/or microhairs. Specific macrohairs entirely marked by many small knobs were found in *Eclipta alba* (Fig. 30) and macrohairs composed of 10 to 15 cells was indicated in *Pistia stratiotes* (Fig. 31). Several kinds other specific trichomes were found in broadleaved weeds. A bi-body trichome existed in *Vernonia cinerea* (Fig. 19), stalked glandular balloon-typed trichomes exist in *Heliotropium indicum* (Fig. 32) and *Hyptis suaveolens* (Fig. 33). The head sometimes splits into four portions. A trichome existing in *Polygonum tomentosum* (Fig. 34) may be a globular, striae papilla indicated by Metcalfe and Chalk (1979), and trichome in *Abutilon indicum* was stellate trichome (Fig. 35).

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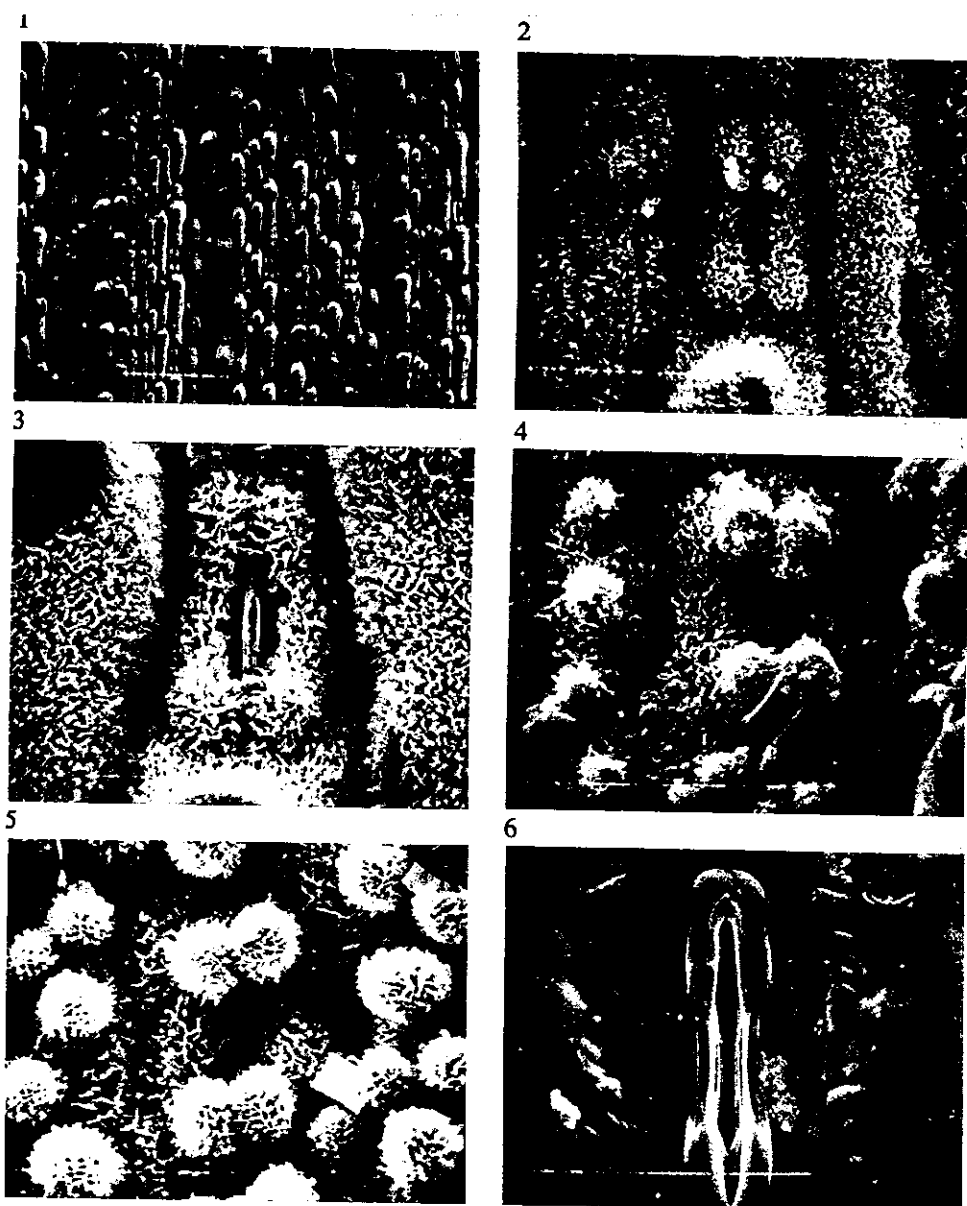


Fig. 1. *Echinochloa colonum*. Adaxial leaf surfaces, with the parallel rows of stomata and epidermal cells (x 200).

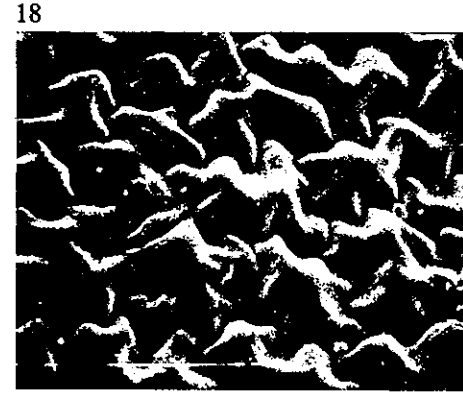
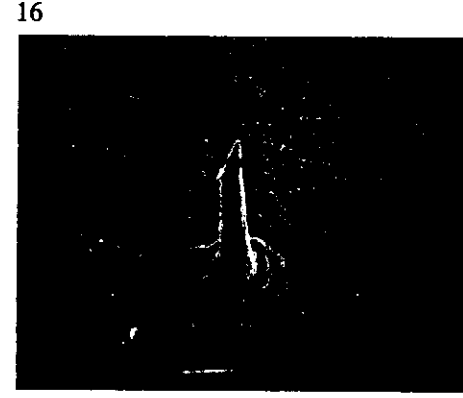
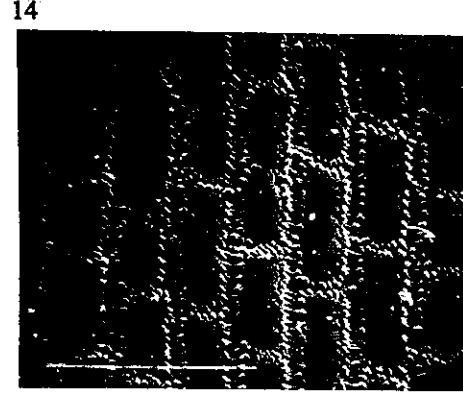
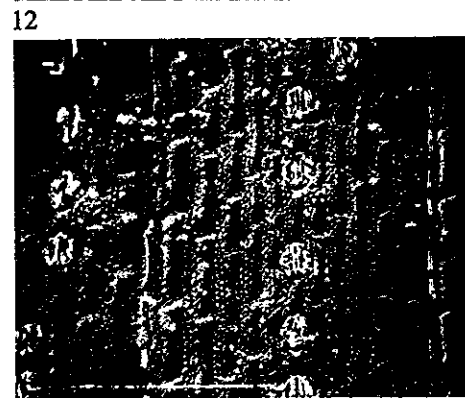
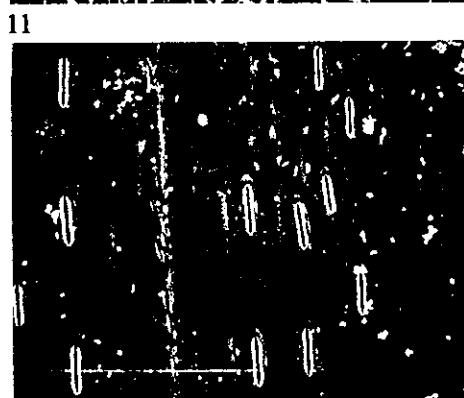
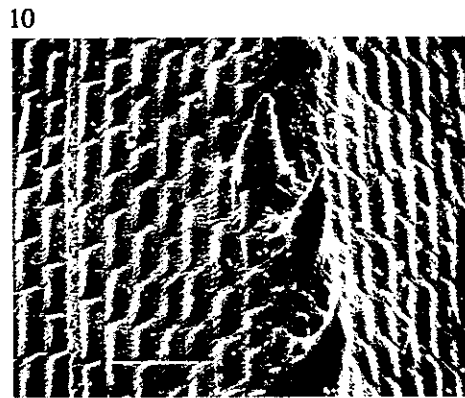
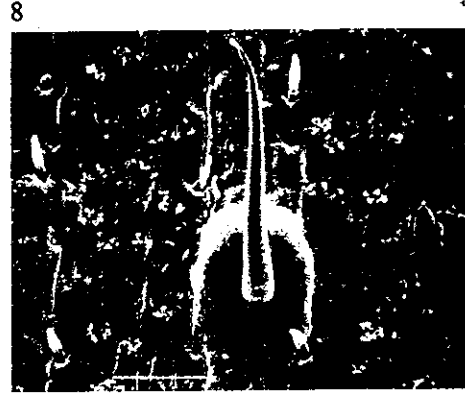
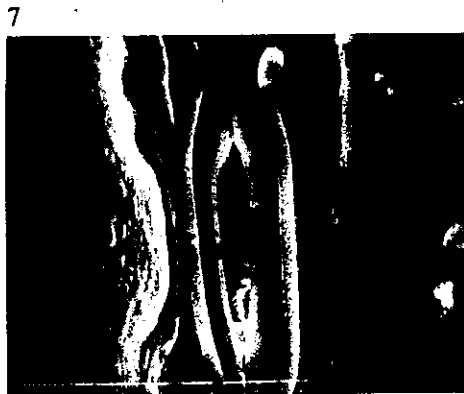
Fig. 2. *E. colonum*. High magnification of adaxial surface densely covered with flakes of wax (x2,000).

Fig. 3. *E. colonum*. High magnification of abaxial surface densely covered with flakes of wax (x3,000).

Fig. 4. *Panicum repens*. High magnification of the abaxial surface, covered with moderate wax deposits and with many silica knobs (x3,000).

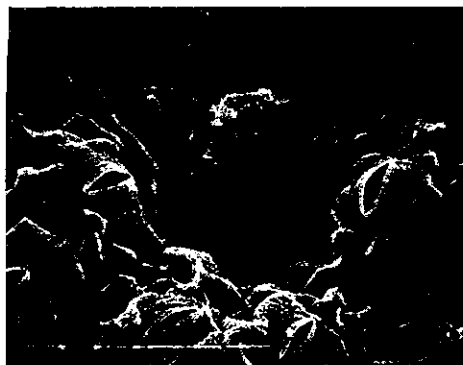
Fig. 5. *P. repens*. High magnification of the adaxial surface, covered with moderate wax deposits and with many silica knobs (x3,000).

Fig. 6. *Coix aquatica*. High magnification of adaxial surface with no deposits of wax (x2,000).



- Fig. 7. *Rottboellia exaltata*. High magnification of adaxial surface without wax deposits (x2,000).
 Fig. 8. *Coix aquatica*. Abaxial surface, with rows of stomata, prickles, microhair, and macrohair (x2,000).
 Fig. 9. *Chloris barbata*. Adaxial leaf surface, with the rows of prickles prominent (x400).
 Fig. 10. *Cyperus imbricatus*. Adaxial leaf surface, with the parallel rows of rectangular cuticular cells bounded by warty knobs, without stomata (x200).
 Fig. 11. *C. imbricatus*. Abaxial leaf surface, similar to the adaxial one, but with the rows of stomata (x400).
 Fig. 12. *Scirpus grossus*. Adaxial leaf surface, with the parallel rows of protuberant rectangular cuticular cells bounded by warty knobs and stomata (x400).

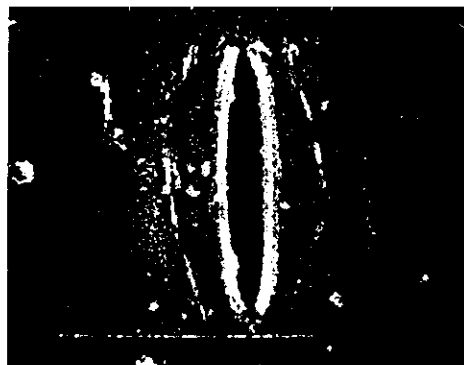
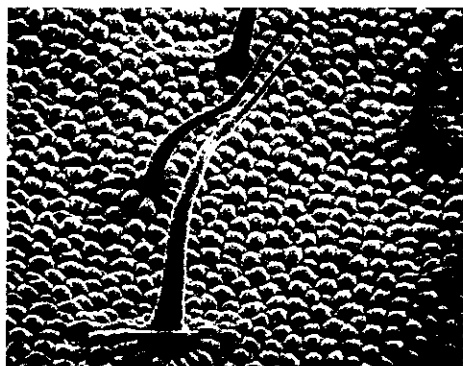
- Fig. 13. *Scirpus grossus*. Abaxial leaf surface, similar to the adaxial one (x400).
 Fig. 14. *Cyperus distans*. Adaxial leaf surface, with rows of epidermal cuticular cells bounded by warty knobs and no wax deposits (x400).
 Fig. 15. *Cyperus iria*. Abaxial leaf surface, without wax deposits, similar to Fig. 14.
 Fig. 16. *Paederia linearis*. Adaxial leaf surface with a bristle and no stomata on the surface (x100).
 Fig. 17. *Paederia linearis*. Abaxial leaf surface with many stomata. Macrohairs and microhairs exist over a midrib (x100).
 Fig. 18. *Vernonia cinerea*. Adaxial surface, configured with various shapes of protuberances and few stomata on the surface (x1,000).



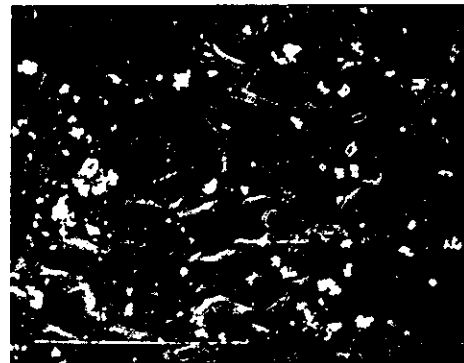
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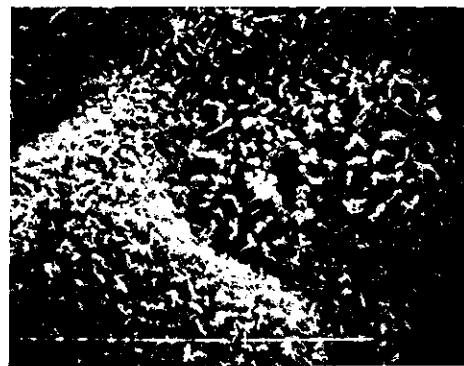
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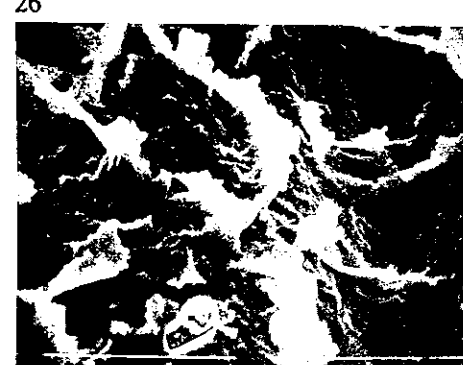
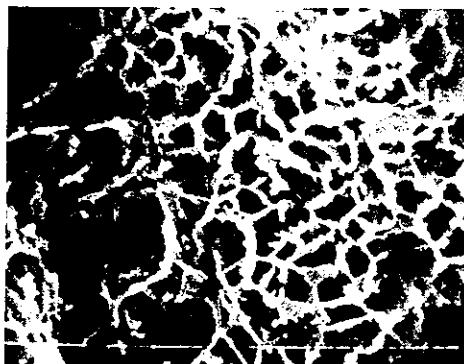
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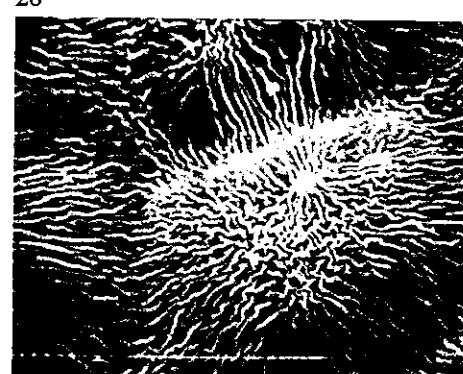
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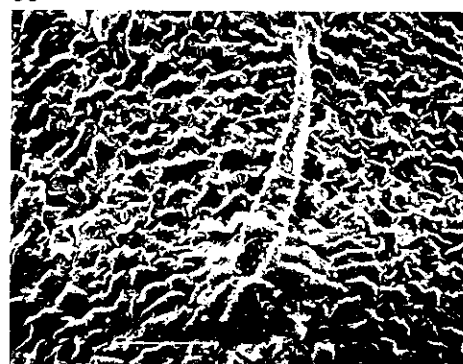
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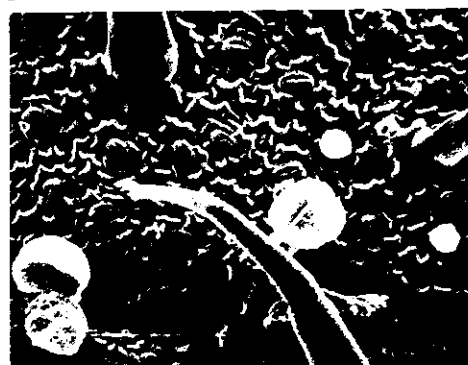


- Fig. 19. *Vernonia cinerea*. Abaxial surface, with a bibody glandular trichome and raised stomata (x1,000).
 Fig. 20. *Eichhornia crassipes*. High magnification of a stoma on the adaxial leaf surface (x2,000).
 Fig. 21. *Euphorbia thymifolia*. High magnification of a stoma and its surroundings on the adaxial leaf surface (x3,000).
 Fig. 22. *Euphorbia hirta*. Adaxial leaf surface, with scattered stomata and no wax deposits (x400).
 Fig. 23. *Euphorbia hirta*. Abaxial leaf surface, covered with dense wax deposits (x200).
 Fig. 24. *Phyllanthus amarus*. High magnification of a stoma on the abaxial surface. Flakes of wax cover the entire surface (x3,000).

- Fig. 25. *Phyllanthus amarus*. High magnification of a stoma on the adaxial surface. Flakes of wax cover the entire surface except the area of an aperture (x5,000).
 Fig. 26. *Mimosa pigra*. High magnification of the flakes of wax on the abaxial surface (x10,000).
 Fig. 27. *Emilia sonchifolia*. Very high magnification of wax, shaped with flakelike, scales, rodlets, lumps etc. (x15,000).
 Fig. 28. *Paderia linearis*. High magnification of the adaxial surface, densely covered with radiating striae of wax-like substance (x2,000).
 Fig. 29. *Marsilea crenata*. Higher magnification of surface wax on the adaxial, configured with reticulum (x10,000).
 Fig. 30. *Eclipta alba*. Adaxial surface, with many stomata and macrohairs. The entire macrohair has many small projections (x200).



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Fig. 31. *Pistia stratiotes*. Adaxial leaf surface, with many multicellular hairs existing on the surface (x60.)

Fig. 32. *Heliotropium indicum*. High magnification of a stalked glandular balloon-type trichome on the abaxial surface (x2,000).

Fig. 33. *Hyptis suaveolens*. Adaxial leaf surface with stomata, macrohairs and roundish trichomes. Developed trichomes often have four-divided head (x400).

Fig. 34. *Polygonum tomentosum*. High magnification of glandular trichomes on the adaxial surfaces (x1,400).

Fig. 35. *Abutilon indicum*. Adaxial leaf surface, with stellate trichomes (x400).



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TOPOGRAPHY OF THE SURFACE STRUCTURE OF WEED SEEDS

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ABSTRACT

A topographical study of seeds of tropical weeds, especially of Thailand's weeds, was made during 1983 to 1984 with a scanning electron microscope. Material plants comprise 29 grassy weeds, 17 *Cyperaceae* weeds, 70 broadleaved weeds and 6 others, totalling 122 weed species.

Illustrations were made on the whole shape of a seed, complexity at the surface, typical configuration and appendages such as hair, bristle and deposit by respective groups of weeds. Micrographs are generally very variable, though some similarities are there within families or genera.

As for the complexity of surface, grassy weeds are relatively simple compared with *Cyperaceae* and broadleaved weeds.

Definite tendency of the surface configuration by group can not be observed, but many weed species appear to have the configuration of papilla-like, reticulum and protuberance. Specific configuration seems to be effective to identify respective weed species.

INTRODUCTION

This paper deals with the descriptions and illustrations of principal weed seeds distributed in Thailand based on the topographies of weed seeds by means of a scanning electron microscope. This would be a useful information not only for the identification of weedy plants and biological studies but also for practical experiments leading towards the establishment of advanced weed control technology.

MATERIALS AND METHODS

Weed seeds for this observation were collected throughout Thailand, mainly concentrating on major weedy plants. The number of weed species amounted to 122 species, mature and complete seeds of which were selected for the observation.

Dry seed specimens, after adhering to sample holder were coated by ion sputtering of gold with Ion Coater, Eiko IB-3, at vacuum 0.05–0.1 Torr, for three to five minutes. After the process of coating, the specimens were golden in color.

The topographical structure of the seeds of 122 weed species comprising 29 grassy weeds, 17 *Cyperaceae* weeds, 70 broadleaved weeds and 6 others was illustrated with a scanning electron microscope under magnifications from 30x to 10,000x.

Illustrations were made of ventral and dorsal sides in as many cases as possible, and under high and low magnifications because smooth configurations under a low magnification are often differently observed, as are complicated ones under a high magnification. Further, Table 2 indicated three classifications of complexity of surface structure when generally observed because this may relate to the physiological aspects of seeds in water or water soluble substances. Unified results concerning surface structure among the same species groups seem to be difficult to state exactly, but generally summarized description of the results can be made as follows :

Grassy weeds :

The shapes of whole seeds in grassy weeds comprise 9 kinds as shown in Table 1, weed species belonging to the same genera usually have the same shape, for instance, elliptical in *Brachiaria* spp. (Fig. 1), lanceolate in *Pennisetum* spp. (Fig. 2). The other five shapes of this grassy group are seen in Fig. 3., Fig. 4, Fig. 5, Fig. 6 and Fig. 7 which indicate to be oblong, ovate, turbinate ovoid and peculiar, respectively.

The topography of seed surface in these grassy weeds show various configurations. When generally observed, these configurations can be classified into 3 levels according to complexity as showed in Table 2. The grassy weeds illustrated have relatively moderate and simple configurations as showed in Table 2. The complex configuration in this grassy group is seen in only one species.

Table 1. Summary of the Surface Structure of Weed Seeds

Scientific name	Shape * ¹	Class * ²	Configuration * ³	Appendage
I. Grassy Weeds				
<i>Acrachne racemosa</i>	OB	B	pro + de	(hair)
<i>Brachiaria mutica</i>	EL	B	pap	
<i>B. reptans</i>	EL(br)	B	ste-pap	
<i>Cenchrus echinatus</i>	O	C	st-pap	
<i>Chloris barbata</i>	OB(na)	C	ri	deposit
<i>Chrysopogon orientalis</i>	OB(na)	B	obs-ret	
<i>Dactyloctenium aegyptium</i>	P	B	cu-ra	
<i>Digitaria adscendens</i>	LA	B	gem-pap	
<i>D. sanguinalis</i>	OB	B	st-pro	
<i>Echinochloa colonum</i>	EL(br)	C	gem-pap	
<i>E. crusgalli</i>	EL(br)	C	un-ra	
<i>Eleusine indica</i>	TU	A	pro	
<i>Eragrostis viscosa</i>	OB(br)	C	sm	
<i>Eriochloa procer</i>	EL(br)	B	gem-pap	
<i>Hymenachne pseudointerrupta</i>	OB	B	fre-ret	hair
<i>Imperata cylindrica</i>	LA(na)	—	(dum)	(microhair)
<i>Ischaemum rugosum</i>	OB	C	st-fur	
<i>Leersia hexandra</i>	OB	B	zig-ri	
<i>Leptochloa chinensis</i>	OV	B	obs-ret	
<i>Panicum cambogiense</i>	OV	C	st	
<i>P. repens</i>	LA	B	war-pr	

Scientific name	Shape * ¹	Class * ²	Configuration * ³	Appendage
<i>Paspalidium flavidum</i>	EL(br)	B	pr	
<i>Paspalum scrobiculatum</i>	EL(br)	B	pap	
<i>Pennisetum pedicellatum</i>	LA	C	st	
<i>P. polystachyon</i>	LA	C	st	
<i>P. purpureum</i>	LA	C	sm + fir	bristle
<i>Rhynchelytrum repens</i>	LA	C	con	
<i>Rottboellia exaltata</i>	TU	B	he	
<i>Setaria geniculata</i>	EL(br)	B	gem-pap	
2. Cyperaceae Weeds				
<i>Cyperus compactus</i>	FU	B	ret + gem-pap	
<i>C. compressus</i>	OBO(tri)	B	pap + ret	
<i>C. difformis</i>	EL(br, tri)	A	ret-pro	
<i>C. distans</i>	OB(li)	A	pun	deposit
<i>C. imbricatus</i>	EL	B	ret	
<i>C. iria</i>	EL(br, tri)	B	pap	
<i>C. procerus</i>	EL(na)	A	pun	deposit
<i>C. pulcherrimus</i>	EL(br, tri)	A	ret + pap	
<i>C. rotundus</i>	OD	B	gem-pap	
<i>Eleocharis dulcis</i>	OBO	C	un	bristle
<i>E. spiralis</i>	OBP	C	us	bristle
<i>Fimbristylis acuminata</i>	OBO	A	ret-con	
<i>F. miliacea</i>	OBO	A	fre-ret	deposit
<i>Futrena ciliaris</i>	EL(br, tri)	C	sm	
<i>Scirpus articulatus</i>	EL(br, tri)	A	ret-ri	
<i>S. grossus</i>	EL(br, tri)	B	pr	
<i>S. juncooides</i>	OBO(br, tri)	A	fur+st	
3. Broadleaved Weeds				
<i>Abutilon indicum</i>	CO	B	ret-ri	
<i>Aeschynomene americana</i>	RE	C	ret-ri	
<i>A. aspera</i>	RE	C	wr	
<i>A. indica</i>	RE	C	ste	
<i>Ageratum conyzoides</i>	OB	A	ri + pap	
<i>Alternanthera philoxeroides</i>	RO(se)	C	ret	
<i>A. sessilis</i>	RO(se)	C	str	
<i>Amaranthus spinosus</i>	RO(se)	B	st	
<i>A. viridis</i>	RO(se)	B	pro	
<i>Ammannia baccifera</i>	P	B	ret	
<i>Boerhavia diffusa</i>	OBL(an)	B	mu-pro	
<i>B. erecta</i>	OBL(an)	B	ret-war	
<i>Cleome viscosa</i>	GL(p)	A	ret	
<i>Commelina benghalensis</i>	RE	B	war + obs-ret	
<i>C. diffusa</i>	EL	A	obs-ret	
<i>Corchorus olitorius</i>	RO(se)	A	con	
<i>Crotalaria striata</i>	RE	C	sm	
<i>Cyanotis axillaris</i>	TU	A	con	
<i>Eclipta alba</i>	OB	A	pro + ret	
<i>Eichhornia crassipes</i>	OB(br)	A	sta-ret	
<i>Emilia sonchifolia</i>	OB(li)	A	ret + cl	
<i>Eupatorium odoratum</i>	OB(li)	A	gem-pap + dep	
<i>Euphorbia geniculata</i>	TU	A	ir-ret + dep	
<i>E. hirta</i>	O(na)	A	pap	
<i>E. thymifolia</i>	OV	A	cy-pap	

Scientific name	Shape *1	Class *2	Configuration *3	Appendage
<i>Gomphrena celosioides</i>	OV	B	st-pro + bl	
<i>Heliotropium indicum</i>	P	B	ret	
<i>Hyptis suaveolens</i>	P	B	ret	
<i>Ipomoea aquatica</i>	OV(se)	A	fr	hair
<i>I. gracilis</i>	RO(se)	A	ret-ri + fr	hair
<i>Jussiaea linifolia</i>	EL(na)	A	ret + pro	
<i>J. repens</i>	SQ	A	ret-st	
<i>J. suffruticosa</i>	GL(p)	B	ret + pro	
<i>Lasagea mollis</i>	LA	B	fre-ret	
<i>Limncharis flava</i>	P	A	ret + f	
<i>Melochia corchorifolia</i>	OV	B	st-ri + de	
<i>Mimosa invisa</i>	RO(se)	C	cr + wr	deposit
<i>M. pigra</i>	OB(br)	C	cr + pro	OB(br)
<i>M. pudica</i>	RO(se)	C	cr + zig-st	
<i>Mimulus orbicularis</i>	OB(na)	A	ret + ri	
<i>Mollugo pentaphylla</i>	SQ(se)	B	con	
<i>Monochoria hastata</i>	OB(br)	A	sta-ret	
<i>M. vaginalis</i>	OB	A	sta-ret + war	
<i>M. vaginalis</i> var. <i>plantaginea</i>	OV	A	sta-ret + war	
<i>Mucuna pruriens</i>	RE	C	ir	
<i>Murdannia nudiflora</i>	RE(se)	A	con + pap	
<i>M. scapiflora</i>	OB	A	ret-ri	deposit
<i>Nymphoides indica</i>	RO	C	wa-pro	
<i>Ottelia alismoides</i>	OB	B	ret + war	
<i>Passiflora foetida</i>	P	B	wa	deposit
<i>Pentapetes phoenicea</i>	RO(se,tri)	B	cr + ret	
<i>Phaseolus lathyroides</i>	RE(se)	B	ret-re	deposit
<i>Phyllanthus amarus</i>	P	A	ret	
<i>Physalis minima</i>	RO	A	ret-zig-st + pro	
<i>Polygonum tomentosum</i>	RO	C	un	prickle
<i>Portulaca oleracea</i>	RO(se)	A	ste-pro + gem-pap	
<i>Potamogeton malaianus</i>	P	B	war	
<i>Pueraria phaseoloides</i>	RE	B	ret	
<i>Richardia brasiliensis</i>	OB(br)	A	tub	
<i>Ruellia tuberosa</i>	RO(se)	B	ir-ret	hair
<i>Sesbania aculeata</i>	RE	C	ru	
<i>Sida acuta</i>	CO	B	ret-ri	
<i>Sphaeranthus africanus</i>	CL	A	s	deposit
<i>Sphenoclea zeylanica</i>	OB	A	ret-ri + pi	deposit
<i>Stachytarpheta jamaicensis</i>	OB(br)	B	ir + rou	
<i>Striga asiatica</i>	OBO	A	no-st	
<i>Trianthema portulacastrum</i>	P	B	ret	
<i>Tridax procumbens</i>	OB(na)	B	ret	hair
<i>Vernonia cinerea</i>	OB(na)	A	ret	bristle
<i>Xanthium strumarium</i>	EL	C	ret-ri	
4. Miscellaneous Weeds				
<i>Eriocaulon cinereum</i>	EL	A	ret + pap	
<i>Limnophila heterophylla</i>	OBO	A	pro-ret + pap	
<i>Najas graminea</i>	OB	A	ret-con	deposit
<i>Typha angustifolia</i>	FU	B	riv	

Scientific name	Shape *1	Class *2	Configuration *3	Appendage
<i>Utricularia aurea</i>	RO(se)	A	ret + pap	
<i>Xyris indica</i>	EL	A	fre-ret	

Notes : *1 Abbreviated capitals indicate the whole shape and letters in parenthesis are the supplementary explanation of whole shape; i.e., CL=club-shaped, CO=cordate, EL=elliptic or ellipsoidal, FU=fusiform, GL=globose, LA=lanceolate, O=ovate, PB=oblong, OBL=oblanceolate, OBO=obovoid, OBP=obpyriform, OV=ovoid, P=peculiar shape, RO=round or roundish, RE=reniform, SQ=square TU=turbinate, and in parenthesis, an=angular, br=broad, li=linear, na=narrow or narrowly, p=pressed, se=semi, tri=trigonus.

*2 Classification in the complexity of surface configuration in general; A=complex, B=moderate and C=simple.

*3 Abbreviation for typical configuration is as follows: bl=blob, cl=club-shaped, con=concave, cr=crevice, cu=curved, cy=cylindrical, de=depression, dum=dum-bell shaped, f=frill, fr=fragment, fre=fret-work, fur=furrow, gem=gemmate, he=heap, ir=irregular, mu=muricate, no=nodular, obs=obscure or obscurely, pap=papilla, pi=pit, pro=protuberance or protuberant, pr=projection, pun=punctate or punctation, ra=range, ret=reticulate or reticulum, ri=ridge, riv=rivulus, rou=roughly, ru=rugose, s=stream-liked, sm=smooth, st=striae, sta=stair, ste=stellate, str=stripe, tu=tubercle, un=undulate, wa=wavy, war=wart, wr=wrinkled, zig=zig-zag.

"Deposit in Appendage" indicates the deposits of any external or secretory substance. () is in the case of spikelet.

Table 2. Classification Rate of Weed species by the Complexity of seed surface Configuration.

Weed group	Total	Complex	Moderate	Simple
Grassy weeds	28	1 (4)	16 (57)	11 (39)
Cyperaceae weeds	17	8 (47)	6 (35)	3 (18)
Broadleaved weeds	70	31 (43)	25 (37)	14 (20)
Miscellaneous weeds	6	5 (93)	1 (7)	0 (0)

Note : Parenthesis indicates percentage.

Further, some characteristics can be observed in the surface structure of this grassy group. A considerable number of the grassy weeds indicated a pattern of arrangement of dots at both ventral and dorsal sides, which are due to papilla-like protuberances, for instance in *Brachiaria* spp. (Fig. 8), *Digitaria adscendens* (Fig. 9), *Echinochloa colonum* (Fig. 10), *Eriochloa procera* (Fig. 11) and *Paspalum scrobiculatum* (Fig. 12). Besides this configuration, other typical characteristics of these grassy weeds seem to be reticulum as seen in *Chrysopogon orientalis* (Fig. 13), striae in *Pennisetum pedicellatum* (Fig. 14) and protuberant patterns in *Eleusine indica* (Fig. 15).

Cyperaceae weeds :

The shapes of entire seeds in this *Cyperaceae* weeds comprise 5 kinds such as fusiform, obovate, ellipsoidal, oblong and obpuriform as shown in Table 1. Most of the whole seed shapes are ellipsoidal, obovate and oblong as shown in Fig. 16, 17 and 18 respectively. Besides these seed shapes, many species indicate trigonous form.

Surface structure is complex and moderate, featured by some roughness. The typical configuration of *Cyperaceae* weeds is papilla-like or punctation, especially in *Cyperus* spp. as shown in Fig. 19 and 20. Two species of *Eleocharis* are marked by bristles in appendage (Fig. 21).

Broadleaved weeds :

This group is composed of many different families. Therefore, the shape and configuration are very variegated as seen in Table 1. The whole seed shape of weed species in the same genus, however, are very similar; e.g. "reniform" in *Aeschynomene* spp. (Fig. 22), "semi-roundish" in *Altermanthera* spp. (Fig. 23), "Angular-oblong" in *Boerhavia* spp. (Fig. 24).

The complexity of surface structure is shown in Table 2, a large number of weed species in this group belonging to the complex and moderate configuration.

There are various configurations of surface structure in broadleaved weeds. Some of them, however, indicate symbolic configurations; for instance, stair-reticulum in *Monochoria* spp. (Fig. 25) and *Eichhornia crassipes* (Fig. 26), specific reticulum in *Cleome viscosa* (Fig. 27), concaves in *Cyanotis axillaris* (Fig. 28), fragment-like in *Ipomoea* spp. (Fig. 29), peculiar configuration in *Limnocharis flava* (Fig. 30), concave + papillae in *Murdannia nudiflora* (Fig. 31), abundant gemmate papillae in *Portulaca oleracea* (Fig. 32), tubular outgrowth in *Richardia braziliensis* (Fig. 33) and reticulant pits in *Sphenoclea zeylanica* (Fig. 34) etc.

Miscellaneous weeds :

This weed group comprised 6 genera of aquatic weeds, which are different in the whole seed shape as shown in Table 1. Most of the weed species indicated a complex configuration, except one species belonging to a moderate configuration. Some genera have an obvious configuration; for instance, *Eriocaulon cinereum* (Fig. 35) and *Limnophylla heterophylla* (Fig. 36).

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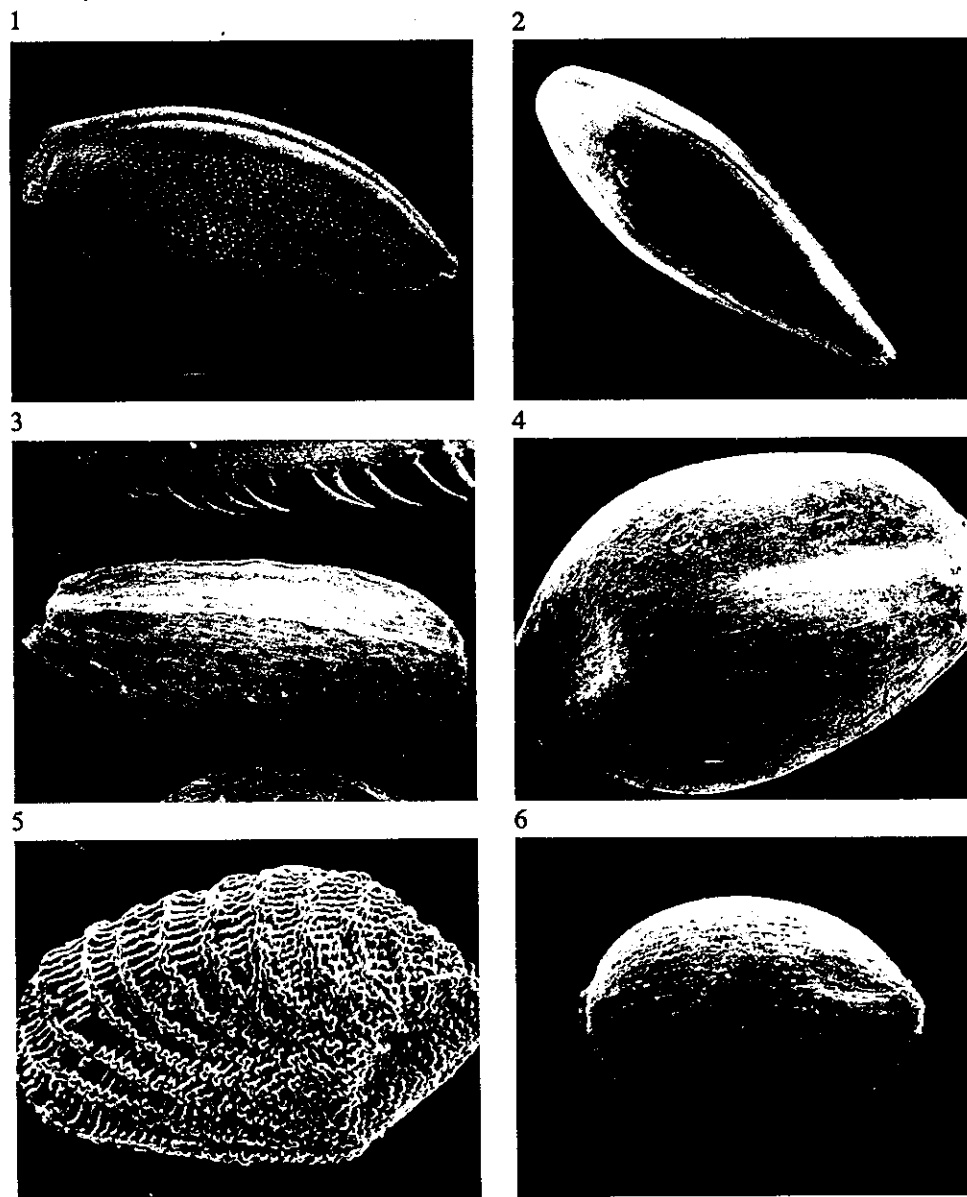


Fig. 1. *Brachiaria mutica*. Whole seed (caryopsis), ventral side elliptic, with many papillae (x 50).
 2. *Pennisetum polystachyon*. Whole seed (caryopsis) side, ventral side (x 50).
 3. *Leersia hexandra*. Whole seed (caryopsis), lateral side, oblong (x 50).
 4. *Cenchrus echinatus*. Whole seed (caryopsis) ovate, with rather smooth surface (x 50).
 5. *Eleusine indica*. Whole seed (caryopsis) turbinate, with peculiar configuration (x 100).
 6. *Leptochloa chinensis*. Whole seed (caryopsis), dorsal side, ovoid (x 100).

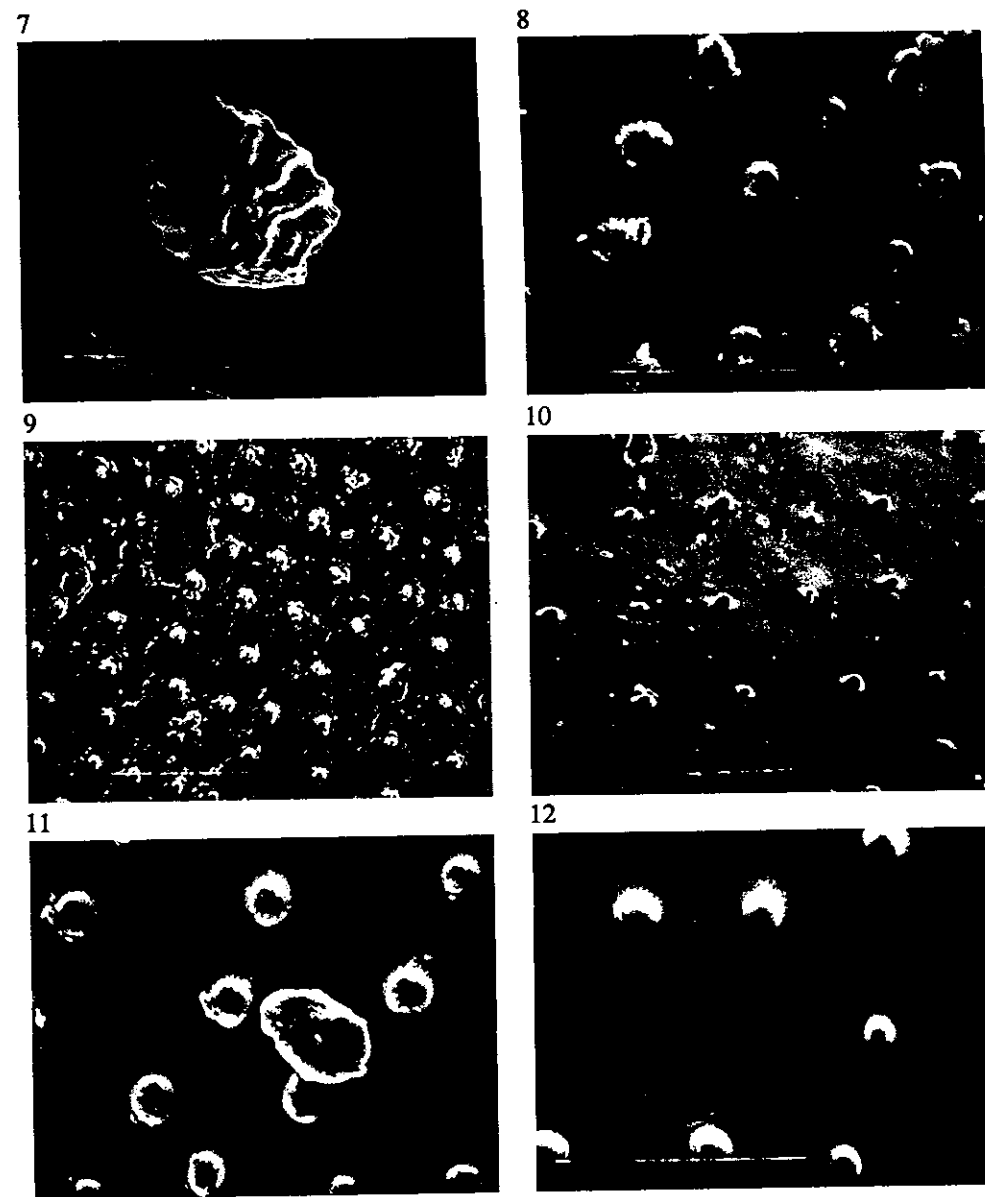
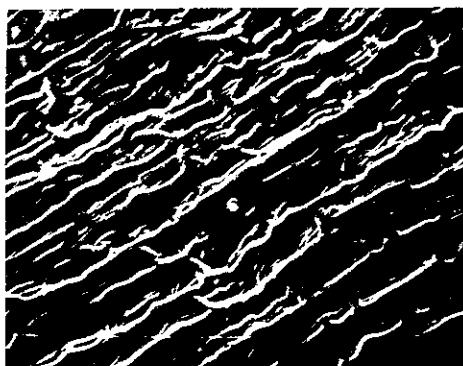
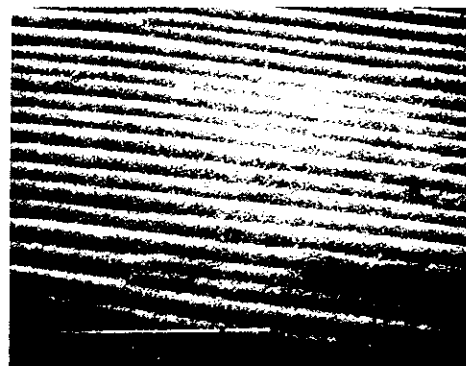


Fig. 7. *Dactyloctenium aegyptium*. Whole seed (caryopsis) shell-shaped, with radiating range of protuberance (x 50).
 8. *Brachiaria mutica*. High magnification of the seed surface, with linearly arranged papillae (x 1000).
 9. *Digitaria adscendens*. High magnification of the seed surface, with gemmate papillae regularly arranged (x 400).
 10. *Echinochloa colonum*. High magnification of the seed surface, smooth, with linearly arranged gemmate papillae (x 700).
 11. *Eriochloa procera*. High magnification of gemmate papillae. A nonbiological blob exists (x 1000).
 12. *Paspalum scrobiculatum*. High magnification of the papillae over smooth surface (x 1000).

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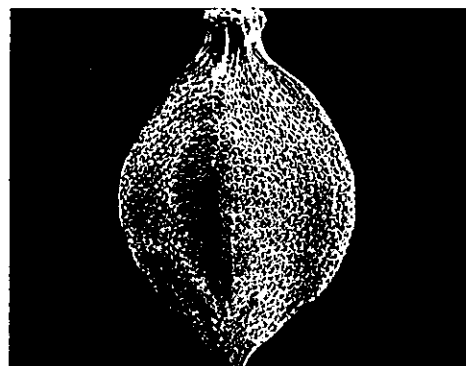
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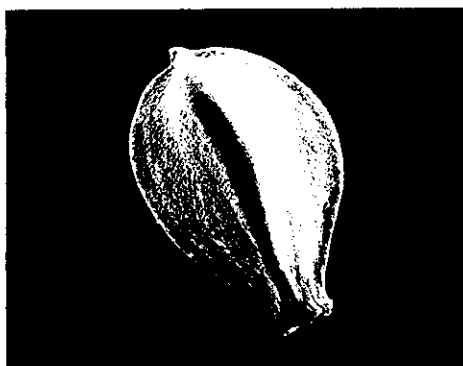
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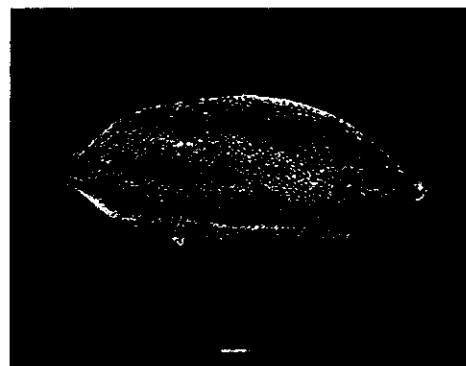
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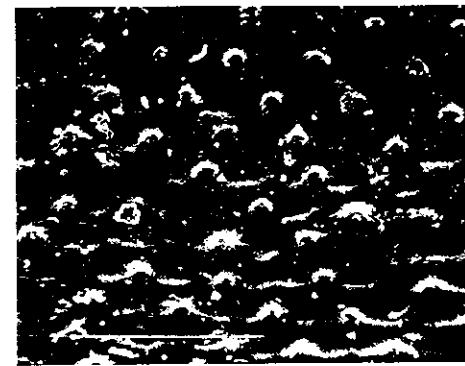
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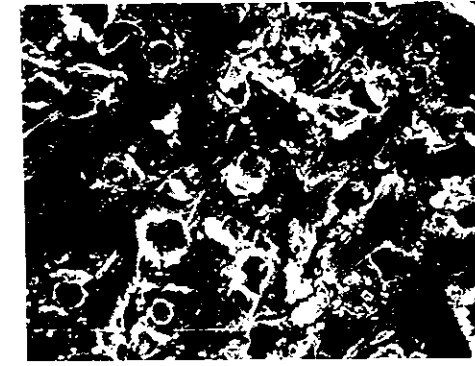
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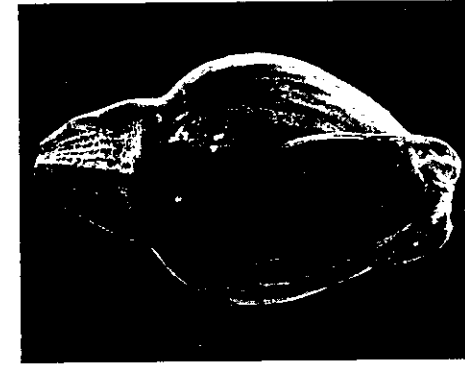
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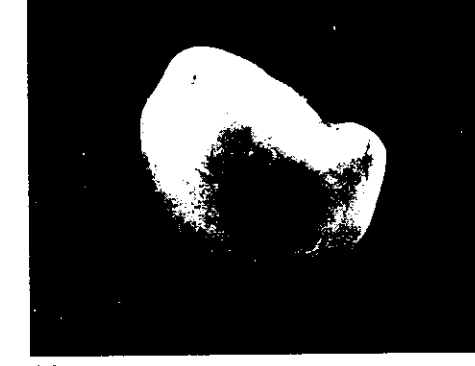
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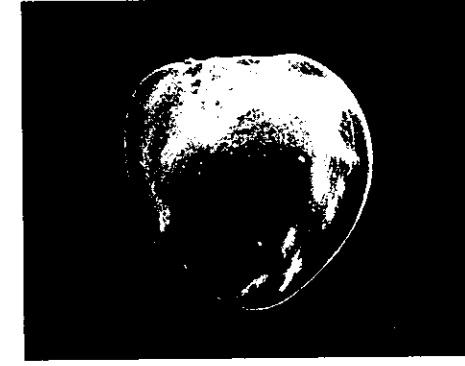
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Fig. 13. *Chrysopogon orientalis*. High magnification of the seed surface obscurely reticulate, with striae of ridges (x 700).

14. *Pennisetum pedicellatum*. High magnification of the seed surface, with straight striae of furrows (x 1000).

15. *Eleusine indica*. High magnification of the seed surface, with lump-like protuberance (x 1000).

16. *Cyperus pulcherrimus*. Whole seed (achene) broadly elliptic, trigonous, with a pointed apex and distinct reticulum (x 200).

17. *Cyperus compressus*. Whole seed (achene) trigonous obovoid with the apex short-pointed (x 50).

18. *Cyperus rotundus*. Whole seed (achene) oblong, configured by dots (x 60).

Fig. 19. *Cyperus iria*. High magnification of the seed surface, with papillae over wavy lines (x 700).

20. *Cyperus distans*. High magnification of linearly arranged punctation filled with some round deposits (x 1000).

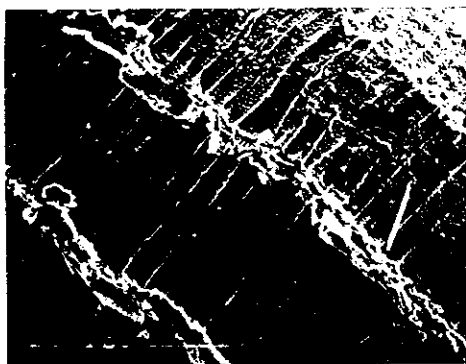
21. *Eleocharis spiralis*. Whole seed (achene) obpyriform, with smooth surface and bristles at the base (x 50).

22. *Aeschynomene indica*. Whole seed reniform, with smooth-looking surface (x 30).

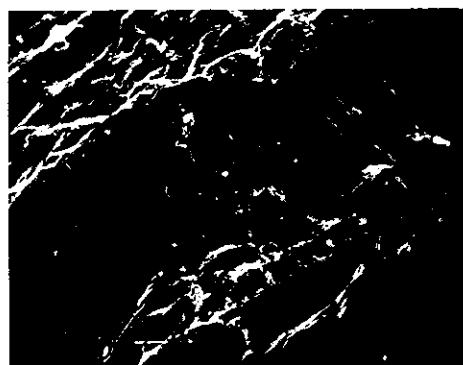
23. *Alternanthera sessilis*. Whole seed semi-roundish, with smooth surface (x 60).

24. *Boerhavia diffusa*. Whole seed angularly oblanceolate, rhombic-shaped on a cross section (x 30).

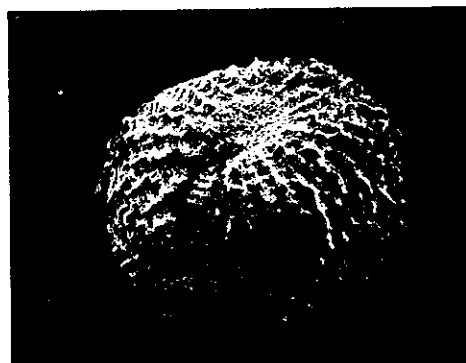
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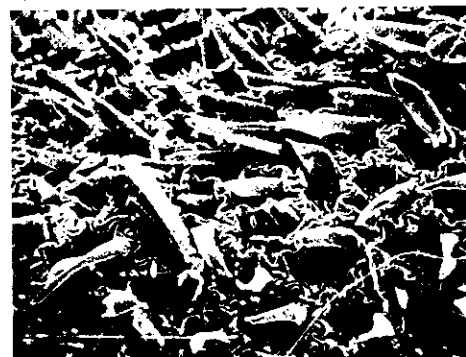
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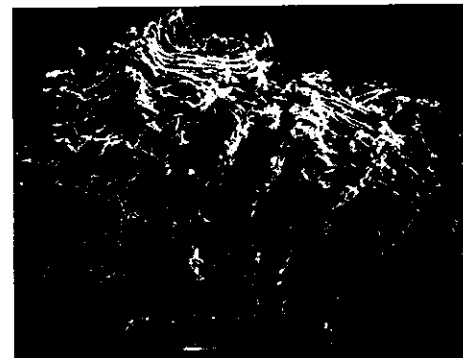
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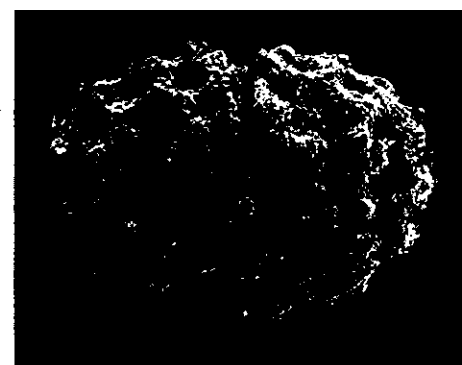
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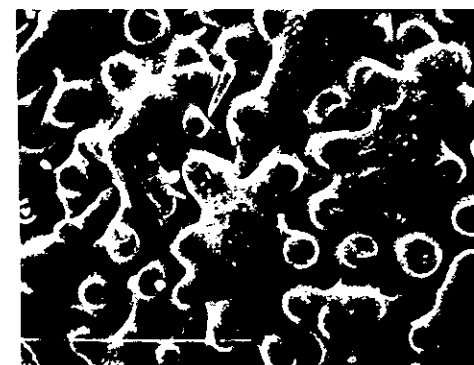
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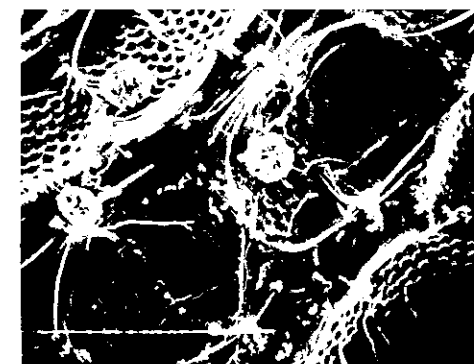
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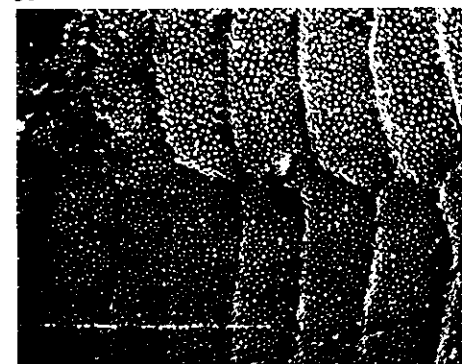
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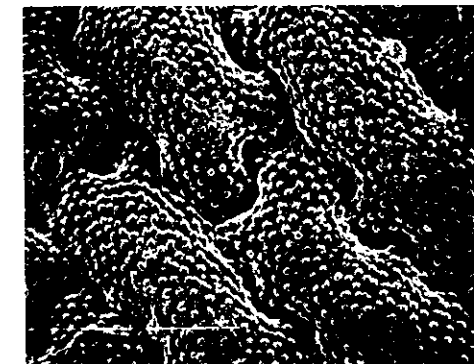
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- Fig. 25. *Monochoria vaginalis* var. *plantaginea*. High magnification of the surface, with stair reticulum and many small warts existing into the reticulum, configuration as *M. vaginalis*. (x 400).
 26. *Eichhornia crassipes*. High magnification of the surface with stair reticulate (x 200).
 27. *Cleome viscosa*. Whole seed pressed-globose, with stair configuration between vertical ridges (x 50).
 28. *Cyanotis axillaris*. Whole magnification of the surface, with fragment like hairs and zig-zag ridge (x 400).
 30. *Limnocharis flava*. Whole seed peculiar-shaped, with frills in transverse lines (x 100).

- Fig. 31. *Murdannia nudiflora*. Whole seed in a dorsal side, semi-reniform configured with concaves (x 50).
 32. *Portulaca oleracea*. High magnification of the surface, with stellate protuberance, at the terminal of which gemmate papillae exist (x 700).
 33. *Richardia braziliensis*. High magnification of the seed with surface, various-sized, tubercular outgrowth (x 700).
 34. *Sphenoclea zeylanica*. High magnification of seed surface, with a lot of small pits distributed on the reticulum of ridge (x 700).
 35. *Eriocaulon cinereum*. High magnification of the seed surface, with fretwork reticulum, covered with many dots (x 1000).
 36. *Limnophila heterophylla*. High magnification of the seed surface, with zig-zag combination of protuberant fragment covered with many gemmate papillae (x 400).

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