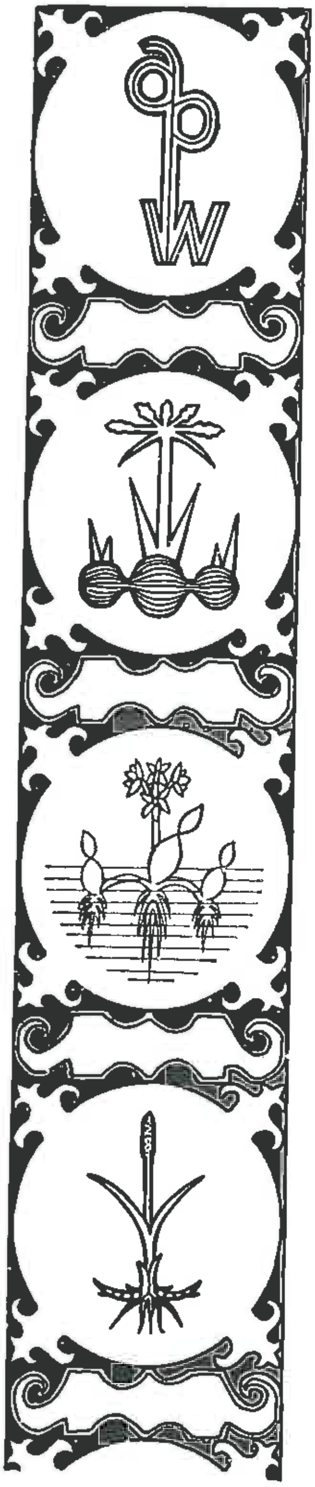
PROCEEDINGS OF THE SIXTH ASIAN-PACIFIC WEED SCIENCE SOCIETY CONFERENCE

Jakarta, INDONESIA
JULY 11 - 17, 1977

VOL. II



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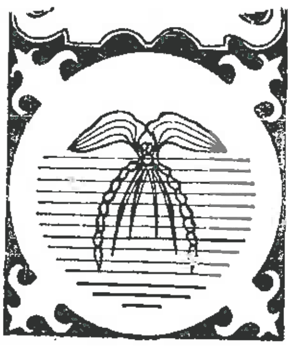

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Weed Control Trials on Taro (Colocasia esculenta Schott) in the South Pacific

M. LAMBERT [1], R. YAU [2], J. MERRICK [3], and B. KARAN [4]

ABSTRACT

In the Pacific island territories taro (*Colocasia esculenta*) is usually grown in rotation or intercropped with other crops. Often it is planted in areas cleared from bush in bush fallow system. Generally little use is made of fertilizers in traditional plantings, but organic debris from bush fallow, mulch and green manure of weeds and debris are used to increase the nutrient supply to plants. Within the region hand weeding following traditional methods, is still the established practice. Weeding on at least three occasions being common. Herbicides are in use, or under investigation in several countries. For instance in American Samoa nitrofen (2,4-dichlorophenyl-*p*-nitrophenyl ether) at 6.5 kg a.i./ha controls weeds for two or three months. In Niue paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) is used, although expensive. This chemical is used also in Fiji at the rate of 0.4 kg a.i./ha. In French Polynesia good results were obtained with diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] at 2.0 kg a.i./ha. Research on weed control is still being carried out and herbicides are under investigation in many territories.

INTRODUCTION

Weed control in dry-land crops of taro is of vital importance in the South Pacific, for taro is grown on all the islands and is the staple food of most islanders. Development of weeds in taro crops, shortly after planting and during the growing period, is highly prejudicial to yields, because not only do weeds compete with the food crop for soil nutrients and water, but they also attract and harbour insect pests.

Islands farmers have always practised hand weeding, which is a tedious, tiring, and very time-consuming process. Commercial herbicides can make the farmer's work much easier, but they must not be used indiscriminately.

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Agricultural research and extension services have tested various types of herbicides and rates of application.

In a short paper such as this it is impossible to describe all the investigations carried out in the Pacific Islands with regard to chemical weed control on dry-land taro, but we have summarized here trials conducted and results achieved in three of the territories located in the South Pacific Commission area, namely, French Polynesia, American Samoa and Fiji.

MATERIALS AND METHODS

French Polynesia Trials. Numerous trials to study chemical weed control on taro were set up at the Papara station in 1974 and 1975, particularly using diuron and nitrofen. However, due to the marked dryness of the soils on the station and invasion of the plots by nutgrass (*Cyperus rotundus* L.), the trials did not proceed normally and finally had to be discontinued.

A few trials were therefore set up on private farms, where environmental conditions were more suitable for taro cultivation. These additional trials only provided general guidelines however, because it was impossible to conduct them in accordance with accepted standards.

Several of these trials were set up in 1974 on a farm owned by Mr. François Jardonnet at Mataiea (Tahiti).

Soil characteristics of trials plots. The soils were hydromorphic mineral gley soils on recent alluvial deposits (FAO-Eutricfluvisols), moderately humiferous, slightly acid, with moderate base exchange capacity.

Taro variety. The weed control trials took place in plots planted with a local taro variety, known as "Manuara" or "Red" taro using the dry-land method of cultivation where tubers are planted in holes on unirrigated ground.

The first trial from 13 March to 13 June 1974 was conducted on a plot measuring 10 m by 10 m where taro had been planted two weeks earlier at 1 m by 1 m spacing.

Diuron was used at a rate of 4 kg a.i./ha in 800 l water. This mixture was sprayed on the ground between the rows of taro plantings on 13 March 1974.

One week after treatment some damage (leaf burn) was seen on the leaves of taros in the treated plot. After three months weed growth appeared in treated plots. The taro developed normally.

The second trial was planted with "Manaura" taro at 1 m by 1 m spacing (each plot contains 500 plants) on 16 March 1974.

Table 1. Climatological data.

1974	Rainfall (mm)	Temperature (° C)	
		Minimum	Maximum
March	192.7	21.6	29.3
April	12.0	22.8	30.3
May	162.9	21.7	29.6
June	91.1	20.6	28.9
July	66.4	20.5	25.7
August	76.6	19.3	28.0

Diuron was used at a rate of 2.5 kg a.i./ha, in 1,000 l water, on 100 m^2 on 18 March 1974 and applied over the whole area, including the young freshly-planted taros. The ground was quite clean, no weed growth having yet appeared.

Two months after application the untreated plot was covered with weed, *Paspalum conjugatum* Berg, *Euphorbia hirta* L., and *Amaranthus* sp., which impeded the taro plants. The treated plot was clean with only a few low tufts of *P. conjugatum* emerging here and there. The taro plants were well developed. Four months after application the treated plot remained relatively clean, the few tufts of *P. conjugatum* having been effectively checked by the lush growth of the taro plants. The taro plants on the untreated plot were covered with weeds.

As these trials were set up outside the experiment station, strict surveillance proved difficult and quantitative assessment of results impossible. The following recommendations, based on the observations recorded, are therefore only tentative.

Chemical weed control in dry-land taro crops:
Recommended herbicide: 2 kg a.i./ha diuron in 800 l water. Recommended time of treatment: Plots should be sprayed two days after taros are planted and before new shoots appear. Presence of weeds: Treatment must be applied before weed emerge. State of soil: Bare soil, well worked, slightly moist.

The above procedure should give good control for two to three months of the following common weeds: *Paspalum conjugatum, Cynodon dactylon, Euphorbia hirta, Amaranthus* sp.

American Samoa Trials. To further test the herbicides recommended in American Samoa previously, they were tried at higher rates, both before and after emergence of taro. An unreplicated experiment was situated near the nursery area at Taputimu Experimental Farm. Six herbicides, at two rates each, were applied on May 23, 1975. Each plot consisted of four rows of taro in an area of 10.18 m^2.

Taro has been planted one month before application of pre-emergence herbicides. This enabled an application directly onto the taro plants in one row of each plot to determine the postemergence effect on the taro.

There were a few small weeds in all plots at the time of treatment, 2 to 3 cm tall.

Table 2. Treatments.

Treatment number	Herbicides		Rates (kg a.i./ha)	
		Herbicides		
1 — 2	cyanazine	(2-[4-chloro-6-(ethylamino)-*s*-triazin-2-yl-amino]-2-methylproprionitrile)	3.3	6.5
3 — 4	diphenamid	(*N,N*-dimethyl-2,2-diphenylacetamide)	10.9	21.8
5 — 6	chlorbromuron	[3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methyl urea]	3.3	6.6
7 — 8	prometryn	(2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine)	5.5	8.2
9 — 10	metribuzin	(4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5-(4H)-one)	1.6	3.2
11 — 12	nitrofen		8.7	13.0
13 — 14	control		unweeded	

The herbicides were applied in 908 l/ha of water.

Weed control and taro damage reports were made on the first, second and third week after application.

Taro was damaged very severely by pre-emergence applications in treatments 6, 7, 8, 9 and 10, starting one week after herbicide application. Moderate damage was caused by postemergence application in all treatments. Treatments 1, 2, 3, 4, 5, 11 and 12 recovered very well from postemergence spraying. Treatment number 11 began to show signs of herbicide damage two weeks after application but the extent of this damage could not be determined because of a subsequent theft of plants.

Weed control in treatments 6, 7, 8, 9, 10, 11 and 12 was very good for the first month. After two months, weed growth had resumed in all treated areas. The weeds in plots 1 through 5 were nearly by as large and dense as those of the unweeded check. Weeds were still being controlled to some extent in plots 6 - 12, where less than half of the soil was covered by weed growth.

Taro was extremely damaged by chlorbromuron (6.6 kg a.i./ha), prometryn (5.5 and 8.2 kg a.i./ha). metribuzin (1.6 and 3.2 kg a.i./ha) and nitrofen 13.0 kg a.i./ha.

Taro was slightly damaged by postemergence sprays of all chemicals, none of which seemed to leave a long lasting effect.

Taro sprayed with cyanazine showed severe curling, but no long lasting damage was observed.

Weeds were controlled very well with chlorbromuron (6.6 kg a.i./ha), prometryn (5.5 and 8.2 kg a.i./ha), metribuzin (1.6 and 3.2 kg a.i./ha) and nitrofen (8.7 and 13.0 kg a.i./ha).

Weeds were temporarily controlled with cyanazine (3.3 and 6.5 kg a.i./ha) and chlorbromuron (3.3 kg a.i./ha), but were not controlled to any appreciable extent by diphenamid (10.9 or 21.8 kg a.i./ha).

Nitrofen at the rate of 8.7 kg a.i./ha proved to be very effective in controlling all types of weeds including nutgrass. The first weeds to come back in this plot were crawfootgrass (*Dactyloctenium aegyptium*) and nutgrass. Recommended application rate of nitrofen is 6.5 kg a.i./ha.

Fiji. In Fiji the following practices are carried out:

(a) The crop is kept weeded especially during the first three months.

(b) Weeds are controlled by hand weeding, animal or tractor drawn implements or by spraying with paraquat.

(c) When using paraquat, 2 kg is mixed with 500 l of water. This mixture is used for one hectare.

Table 3. Effect of herbicide treatment on taro in American Samoa.

Treatment number	Taro leaf area damaged, six days after spraying (%)		Weed control twenty days after spraying	Taro damage twenty days after spraying
	pre-emergent	post-emergent		
1. Cyanazine	0	10	Good	Slight curling
2. ”	0	20	Good	Severe curling
3. Diphenamid	0	10	Fair	Some curling
4. ”	0	5	Fair	Severe curling
5. Chlorbromuron	0	40	Very good	Severe curling
6. ”	15	30	Very good	Very severe curling
7. Prometryn	30	60	Very good	Very severe curling
8. ”	50	75	Very good	Very severe curling
9. Metribuzin	0	30	Very good	Very severe curling
10. ”	20	50	Very good	Very severe curling
11. Nitrofen	0	30	Very good	Severe curling
12. ”	5	60	Very good	Severe curling
13. Control	—	—	—	—
14. ”	—	—	—	—

(d) A Knapsack sprayer is used when weeds are a few cm high. It is recommended to use a spray shield and keep the nozzle down. Spray is directed on the weeds; spray contact with the taro plants must be avoided.

Active research is under way to develop postplanting pre-emergence herbicides effective in taro cultivation. Atrazine and simazine, applied at 3.6 to 4.5 kg a.i./ha, have shown promising results without being phytotoxic.

RESULTS AND DISCUSSION

In French Polynesia, diuron was sprayed between the taro rows at the rate of 3.2 kg a.i./ha or blanket sprayed over the area including the set out taro plantings at a rate of 2 kg a.i./ha.

In American Samoa, effective weed control was achieved using chlorbromuron, prometryn, nitrofen and cyanazine, but taro leaf damage was observed in each case. For the time being, the most recommended herbicide is nitrofen at the rate of 6.5 kg a.i./ha.

In Fiji, good results were obtained with paraquat at 0.4 kg a.i./ha, sprayed between the rows directly onto the weeds, using a spray shield to prevent contact with the taro plants.

The South Pacific Commission proposes to collect trial results and all available data on chemical weed control in taro crops and to disseminate them to the territories for the information and use by of agricultural extension officers and farmers.

ACKNOWLEDGEMENT

The South Pacific Commission is indebted to the Department of Rural Economy of French Polynesia, the Department of Agriculture of American Samoa and the Ministry of Agriculture of Fiji for the technical information they so kindly provided. The authors also wish to extend their personal thanks to Mr. Jean-Louis Reboul, Chief of Agricultural Research in French Polynesia. Mr. Pemerika L. Tauilili, Director of Agriculture in American Samoa, and Mr. Robin Yarrow, Director of Agriculture in Fiji.

Tools Used for Weeding in Highland Horticulture in Java, Indonesia

A. P. EVERAARTS [1]

ABSTRACT

A brief description of highland horticulture in Java, Indonesia is given. The tools being used for weed control are described and methods and improvements of weed control are discussed.

INTRODUCTION

Lately vegetable horticulture in the highlands of Java (c. 1000 m above sea level) has been gaining more significance as a means of existence and in providing a small but important part of the diet. The production areas are mainly centered around the bigger cities, which provide the chief markets. In West Java, centers of production can be found in the highlands south of Jakarta and north and south of Bandung; in Central Java, the Dieng Plateau and on the slopes of the Lawu Mountain; in East Java in the highlands around Malang.

Most of the farms are small (0.2 to 0.5 ha) and the arable land is often composed of several small terraces. The vegetables are often grown on raised beds and sometimes multiple cropping in various forms is practised. On the larger farms, mostly in the more level areas, one finds monocultures with the vegetables being cultivated in rows and often on ridges. All weeding is done by hand.

The majority of vegetables being grown are of temperate origin. In 1974, according to the available data (Anon 1975), the total harvested area of potatoes (*Solanum tuberosum* L.), cabbage (*Brassica oleracea* L.) and tomatoes (*Lycopersicum esculentum* Mill.) together amounted to about 40,000 ha, with a total production of around 350,000 tonnes, an increase of 100% compared to 1969. Other important vegetables are Chinese cabbage (*Brassica chinensis* L.), French beans (*Phaseolus vulgaris* L.) and various onions (*Allium* spp.) (together about 100,000 tonnes in 1974).

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[1] Agronomist, Agronomy Division, Horticultural Research Institute, Pasarminggu, Jakarta, in the framework of the ATA-program.

IMPORTANCE OF WEEDING

In the tropical climate of Java weeds grow vigorously. Particularly in the rainy season, weeding should be done every 10 to 20 days, until the crop canopy is closed. In the more open crops like onions, weeding should continue. Initial surveys showed that weeding in vegetable crops can consume as much as 15 to 20% (potatoes) to around 40% (cabbage) of the total invested time in cultivation. The costs however, only amount to about 2 to 8% of the total budget due to the generally low cost of labour in the rural areas and the high costs of fertilizers and pesticides.

TOOLS BEING USED AT PRESENT

The main tool being used for land clearing, tillage and weed control is the hoe (Figure 1) of which many local types exist. A tined form of the hoe (Figure 2) is sometimes used. The tilling is mostly done by men. Surface cultivation and weeding is often done by women and older children. For this, they use a small type of hoe or a normal or tined hand hoe (Figures 3, 4). For cutting and collecting the weeds of terrace walls, road sides and heavily infested arable land, various types of knives are used (Figure 5, 6). For clearing verges the knife of Figure 7 is often used. There are many local varieties of the tools depicted. A general account of the various tools being used in the tropics has been given by Hopfen (1960).

IMPROVEMENT OF WEED CONTROL

Weeding with the traditional hoe, which is primarly designed for tillage, has the disadvantage that it is heavy and large and can easily cut too deeply, thereby harming the crop roots. Moreover, most of the farmers tend to wait until the weeds are big enough to be uprooted with the hoe and collected and removed by hand. By this time most of the damage might already have been done in relatively short growing crops (Nieto *et al.* 1968, Kasasian and Seeyave 1969).

The efficiency of weeding might be improved by using a push or pull type of Dutch hoe (Figure 8). At present, these tools are being tried at the Horticultural Experimental Station Segunung in West Java. Early observations are showing that both tools can be effectively used, particularly in the younger stages of crop growth hoeing takes

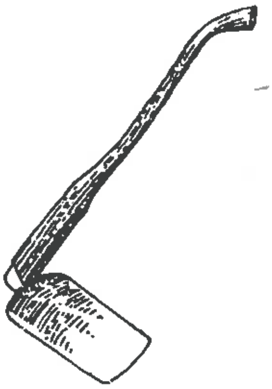
Figure 1. Hoe


Figure 2. Tined hoe


Figure 3. Hand hoe


Figure 4. Tined hand hoe

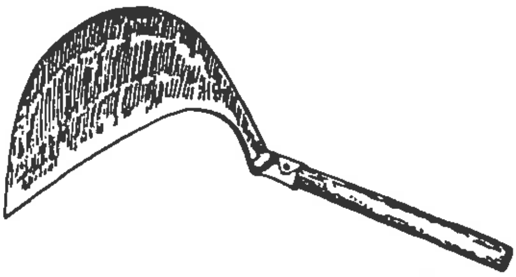
Figure 5. Weeding knife

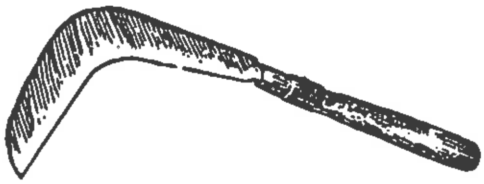
Figure 6. Weeding knife

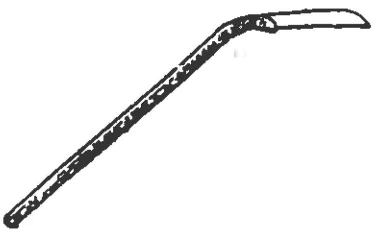
Figure 7. Weeding knife

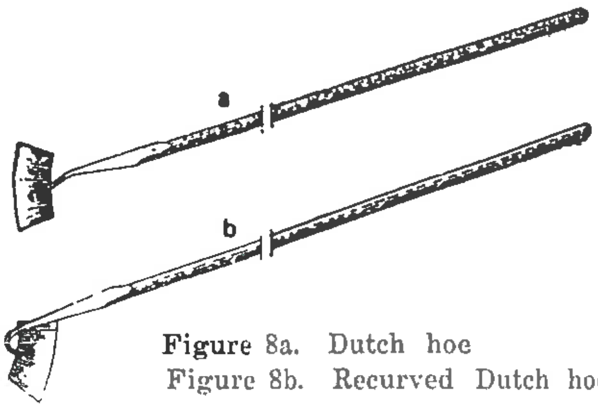

Figure 8a. Dutch hoe
Figure 8b. Recurved Dutch hoe

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less time and is less tiring. In Kenya, Druyff and Kerkhoven (1970) increased efficiency by 40% by substituting a recurved Dutch hoe for the locally used hoe. It is important that the blade angle of this hoe is such that it works easily just under the soil surface, with no tendency to alter its depth. The blade can have various widths and lengths and can be further improved by sharpening both sides.

In multiple cropping the use of any tools for weeding is often limited by close spacing, but in general, weed problems are less severe under the denser canopy.

The use of herbicides in this highland horticulture is not yet considered feasible. Herbicides are only available at prohibitive prices. Other problems connected with the use of herbicides such as the persistence of soil residues when there is practically no time interval between the successive crops, heavy rainfall that may cause leaching of herbicides and the lack of education in proper handling of pesticides makes it difficult to recommend the use of herbicides. Multiple cropping increases the complexity of such problems.

Mulching of crops might be advantageous in preventing weed growth. Chakraborty (1971) found in India that mulching of potatoes with rice straw after earthing up gave good weed control. In practice, however, mulching is rarely used probably because of scarcity of mulching material, or unfamiliarity with the practice.

CONCLUSION

The need to control weeds in food crops, especially in the developing countries is evident (Parker and Fryer 1975), but in most of these countries weed science is still in its infancy (Holm 1969). It is suggested that the weed problem in food crops, especially on the smaller farms, can better be solved by increased attention to the improvement of mechanical and cultural methods, rather than the adoption of advanced herbicide technology which, as yet, cannot be properly applied.

ACKNOWLEDGEMENT

The author whishes to thank Mr. Sukirno for preparing the drawings.

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Performance of Several Herbicides on Soybeans

M. SUNDARU and M. SYAM [1]

ABSTRACT

The performance of several herbicides on soybean was studied in a field experiment at Muara Experiment Station, Bogor. Napropamide [2-(α-naphtoxy) -*N,N*-diethylpropionamide] caused a slight yellowing of the leaves which persisted for about two weeks. Little effect was caused by any of the other herbicides tested. A mixture of benthiocarb [*S*-(4-chlorobenzyl)-*N,N*-diethylthiolcarbamate] with prometryn [2,4-bis (isopropylamino)-6-(methylthio)-*S*-triazine] and metolachlor [2-chloro-*N*-(2-ethylphenyl)-*N*-(2-methoxy-l-methylethyl)acetamide] were the most effective treatments for controlling grasses, including *Echinochloa colonum* Link, *Cynodon dactylon* Pers. and *Digitaria adscendens* Henr, Bentazon [3-isopropyl-1H-2, 1, 3-benzothiadiazin-(4)3*H* 2,2-dioxide], napropamide and nitrofen (2,4-dichlorophenyl -*p*-nitrophenyl ether) suppressed the growth of *Cyperus rotundus* L., *C. difformis* L., and *Fimbristylis miliaceae* Vahl. Metolachlor plus chlorbromuron [3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methyl urea], metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4*H*)one], alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl) acetanilide] and bentazon controlled the existing broadleaf weeds well. Metribuzin, alachlor, benthiocarb plus prometryn, metolachlor and metolachlor plus chlorbromuron treatments all resulted in yields comparable with traditional hand weeding.

INTRODUCTION

Because of their high protein and carbohydrate content, soybeans are becoming an increasingly important crop (Moody 1976). Data collected by the Bureau of Statistics of Indonesia in 1974 (Anon 1975) indicated that the total harvested area of soybeans in Indonesia was 753,499 ha with an average grain yield of 730 kg/ha. The cultivation of soybeans was mostly concentrated in Java, 60% in East Java and 20% in Central Java. Between 60 and 75% of the crop was grown after rice (Konno 1974).

Relay cropping of soybeans after paddy rice is a common practice in East Java. Farmers broadcast the soybean seeds into the field one to three days before or immediately after harvesting the rice. Little attention is given to this crop, so that it usually makes poor growth, while weeds grow well, and poor yields result. In this system where the soybeans are grown under lowland conditions, some grasses such as *E.*

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colonum and *Paspalum paspalodes*, and sedges, such as *Cyperus iria* L. and *C. difformis*, become the major weeds. The rice itself also becomes a weed.

A similar method of soybean cropping in Taiwan has been reported (Anon 1975a). This is the so-called no-tillage, rice stubble system applied within a double rice cropping pattern. Two or three seeds are placed in the opening of shallow holes close to the rice stubble. Some farmers cover the seeds. Since no land preparation is involved, most farmers use herbicides for weed control, which are applied either before or after sowing the soybean seeds.

Moody (1976) mentioned that the cost of controlling weeds is one of the most expensive items in crop production. Losses due to weeds in soybeans in most tropical countries range from 50 to 60%.

In Indonesia, some experiments conducted over several years indicated losses ranging from 10 to 60%. The variation was mainly due to the weed species and their density. In upland conditions, the major weeds were *C. rotundus*, *Digitaria* spp., *Eleusine indica Gaertn.*, *C. dactylon*, *Mimosa* spp. and *Amaranthus* spp. Herbicide programmes based on benthiocarb, prometryn and alachlor have given promising results although *C. rotundus* present serious problems due to their habits of vegetative reproduction. Up to now few herbicides have successfully controlled latter weeds. Bentazon has shown promise by suppressing *C. rotundus* for some weeks.

This paper discusses the performance of several herbicides and their effect on the growth of soybeans.

MATERIALS AND METHODS

An experiment was conducted during the 1975 dry season at Muara Experiment Station, Bogor (Central Research Institute for Agriculture-sub Station). The soil type of this station is reddish brown latosol.

A randomized block design was marked out with four replications on land which had been cultivated twice and then levelled. Soybeans cv Orba were spaced on hills 20 by 20 cm apart, two plants per hill, in plots 3 by 5 m in size. At planting time fertilizers were applied at rates of 20 kg/ha N, 45 kg/ha P_2O_5 and 25 kg/ha K_2O in the form of urea, 'TSP' and 'ZK' respectively. Insecticides were used as necessary.

The herbicides and rates applied are given in Table 1. They were all applied pre-emergence, one day after sowing, except for bentazon which was sprayed when the broadleaf weeds had 3 to 5 leaves.

Weed coverage, phytotoxicity and degree of weed control was recorded 10, 30 and 45 days after planting the crop.

RESULTS AND DISCUSSION

The herbicides tested, caused little effect on the soybean plants. Napropamide had the highest phytotoxicity rating (Table 1) and caused yellowing of the leaves. This herbicide was applied one day before seeding by incorporating it into the soil with a simple tool, so that the chemical in the soil was not evenly distributed. The symptoms disappeared in 10 to 14 days. Thirty days after sowing, the soybean plants showed normal growth.

Dominant weeds in this experiment were *Ageratum conyzoides* L. and *Oryza sativa* L. The previous crop was rice with easily shattering grains and in nearly all plots rice seedlings were observed between the soybean plants. Other important weeds were *Crotalaria anagyroides* H.B.K, *Phyllanthus niruri* L. and *C. rotundus.* Of the herbicides tested metribuzin 1.0 kg/ha and metolachlor 1.5 kg/ha plus chlorbromuron 0.75 kg/ha gave good weed control. Forty five days after sowing these treatments showed only a 20% weed coverage (Table 2). The mixture of metolachlor with chlorbromuron gave a wider spectrum of control than metribuzin which did not completely control *O. sativa*, *Leersia hexandra* Swartz, *P. niruri* and *A. conyzoides.* Another effective herbicide was alachlor, which controlled the broadleaved weeds well, but not rice seedlings or *L. hexandra.* The mixture of benthiocarb and prometryn was promising although *A. conyzoides* and *Eleutneranthera ruderalis* survived.

Nitrofen did not control *A. conyzoides.* Napropamide, which was soil incorporated, controlled the existing sedges well including *C. rotundus* and most of the broadleaf weeds, except *A. conyzoides.* Rice seedlings, which were tolerant, covered the greater part of the plots treated with bentazon and other grass species were also found in these plots (see Table 3). Bentazon was effective against most of the broadleaf weeds present.

Except for bentazon, nitrofen and napropamide, significantly higher grain yields were obtained by the herbicide treatments when compared with untreated plots. Differences between herbicide and traditional hand weeded treatments were, however, not significant.

Table 1. Effect of herbicides on soybean vigour and weed weight.

No.	Treatment	Rate kg/ha a.i.	Time of application, days after planting	Soybean toxicity rating, *) days after treatment			Dry weed weight, g/0.12 m^2		
				10	30	45	Grasses	Sedges	Broadleaf weeds
1.	Nitrofen	3	1	2	0	0	9.30	0.15	3.75
2.	Metolachlor	1.5	2	0	0	0	1.92	0.08	4.10
3.	Metolachlor + chlorbromuron	1.5+0.75	1	2	1	1	2.68	0.43	1.71
4.	Napropamide	3	1 day before planting	3	1	1	5.60	0	0.87
5.	Metribuzin	1	1	2	1	1	1.97	0.05	2.31
6.	Alachlor	2	1	2	0	0	12.43	0.27	0.65
7.	Benthiocarb/ prometryn	7.5 product	1	2	0	0	3.31	0.12	5.20
8.	Bentazon	1.5	15	0	0	0	30.43	0	0.32
9.	Handweeded	-	21 + 42	-	-	-	0.41	0.01	1.45
10.	Untreated	-	-	-	-	-	19.18	0	3.06
	LSD 5%						10.13	0.41	3.84
	1%						12.18	0.49	4.62

*) Toxicity rating: 0 = no toxicity
10 = crop completely killed

Table 2. Effect of herbicides on weed control and soybean yield.

No.	Treatment	Weed control rating, *) days after treatment									Weed cover % age, days after treatment			Grain yield kg/ha
		10			30			45						
		Grasses	Sedges	Broadleaf	Grasses	Sedges	Broadleaf	Grasses	Sedges	Broadleaf	10	30	45	
1.	Nitrofen	8	9	9	7	8	7	7	8	6	10	20	40	1308
2.	Metolachlor	9	9	9	8	9	7	7	8	5	5	15	40	1418
3.	Metolachlor + chlorbromuron	9	9	10	8	8	8	8	8	7	5	10	20	1486
4.	Napropamide	8	8	9	8	9	8	7	8	6	5	15	35	1312
5.	Metribuzin	8	9	10	8	8	9	7	8	8	5	10	20	1589
6.	Alachlor	9	9	10	8	8	8	6	8	7	5	15	20	1529
7.	Benthiocarb/ prometryn	8	9	9	7	8	9	7	7	6	5	15	30	1464
8.	Bentazon	5	7	7	5	7	7	4	7	7	70	85	95	1122
9.	Handweeding	-	-	-	-	-	-	-	-	-	10	15	5	1347
10.	Untreated	-	-	-	-	-	-	-	-	-	15	85	90	1063
	LSD 5%													273
	1%													327

*) Weed control rating: 0 = no control of weeds
10 = excellent weed control

Table 3. Effect of herbicide treatments on weed species.

Species	Percentage Survival *)									
	Treatments (see Table 1)									
	1	2	3	4	5	6	7	8	9	10
Graminae:										
Oryza sativa L.	2	1	2	2	2	3	1	5	1	1
Echinochloa crus-galli Beauv.	–	–	–	1	1	1	–	2	–	–
Echinochloa colonum Link.	–	–	–	1	1	1	–	1	1	–
Digitaria adscendens Kem.	1	1	1	1	1	1	–	2	1	2
Cynodon dactylon Pers.	–	–	–	–	1	1	–	2	1	2
Eleusine indica Gaertn.	–	1	–	1	–	–	1	2	–	1
Eulalia amaura Hurn.	1	–	1	–	–	–	–	1	–	1
Leersia hexandra Schwartz.	–	–	–	–	2	2	–	–	–	1
Cyperaceae										
Cyperus rotundus L.	–	1	2	–	1	1	1	–	–	3
Cyperus difformis L.	–	–	1	–	1	1	–	–	–	1
Fimbristylis dichotoma Vahl.	–	–	–	–	1	1	1	1	–	1
Fimbristylis miliaceae Vahl.	–	1	1	–	–	1	–	–	–	–
Broadleaf										
Crotalaria anagyroides H.B.K.	1	–	–	–	1	–	–	–	–	4
Phyllanthus niruri L.	1	1	–	1	2	1	1	2	1	3
Physalis minima L.	–	–	–	–	–	1	–	–	–	1
Oxalis spp.	–	–	–	–	–	–	1	1	–	–
Mimosa pudica L.	1	1	1	1	–	–	1	2	–	1
Eleutheranthera ruderalis Sch.-Bip.	1	–	–	–	–	1	2	–	–	1
Heliotropium indicum L.	–	1	–	–	1	–	–	–	–	–
Typhonium spp.	1	–	–	–	1	–	–	–	–	1
Ageratum conyzoides L.	4	4	2	3	2	2	3	1	2	4
Alternanthera sessilis DC.	1	–	–	–	1	–	–	–	–	–

*) Note: 1 = 5 – 9% survival; 2 = 10 – 24% "; 3 = 25 – 49% "; 4 = 50 – 74% survival; 5 = 75 – 100% "

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Weed Succession in the Peat Swamp Forest Cleared for Pineapple Cultivation

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ABSTRACT

Studies, on the weed succession following the felling, clearing and burning of peat swamp forests, were conducted on a 40 ha field intended for pineapple cultivation. The ground flora of the original forest included 64 species from 28 families of Dicotyledons, 23 species from nine families of Monocotyledons and nine species from two families of Pteridophytes. When clearing was carried out three weeks after felling, 13 species were found and of these, 10 were new and not previously recorded in the forest. The early and noxious colonizers were *Imperata cylindrica* (L.) Beauv. *Pteridium esculentum* Nakai, *Melastoma malabathricum* L., *Nephrolepis biserrata Schott, Mikania micrantha, Stenochlaena palustris* Bedd. and *Trema orientalis Bl.*

INTRODUCTION

In West Malaysia, pineapple is planted mostly on peat. Although there are 0.8 million ha (Figure 1a) of peat in West Malaysia and 1.5 million ha (Figure 1b) in East Malaysia (Coulter 1957), only 16,000 ha are planted with pineapple. The total export value of canned pineapple is about fifty million dollars per year.

Prior to large scale cultivation of pineapple on peat, the virgin forest trees are cut, heaped and burned. The weed problems arise from the time of clearing the forest. Weeds rapidly invade newly cleared areas. To help understand the problem, it is important to compare the flora which occurs before and after clearing. Identification of the noxious or troublesome weed species immediately after forest clearing would enable early control measures to be used. The importance of weed control in pineapple was reported by Wee (1972) and Lee (1977). In the absence of weeding, a depression in fruit yield of 10 to 40% was recorded when compared to areas which were weeded monthly.

Peat has a pH of 3.40 to 3.60 under virgin forest and 3.52 to 4.10 after burning. The moisture content is 67 to 90% while the om content is 85 to 92%. The annual rainfall is 200 to 220 cm while the soil temperatures alternate between 23 and 35.8°C daily.

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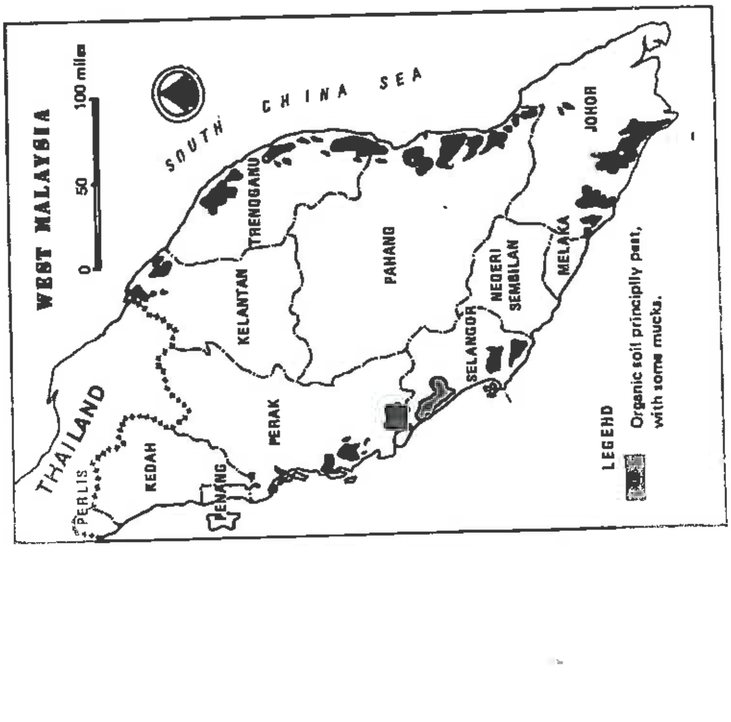

Figure 1a. Distribution of peat soil in West Malaysia.

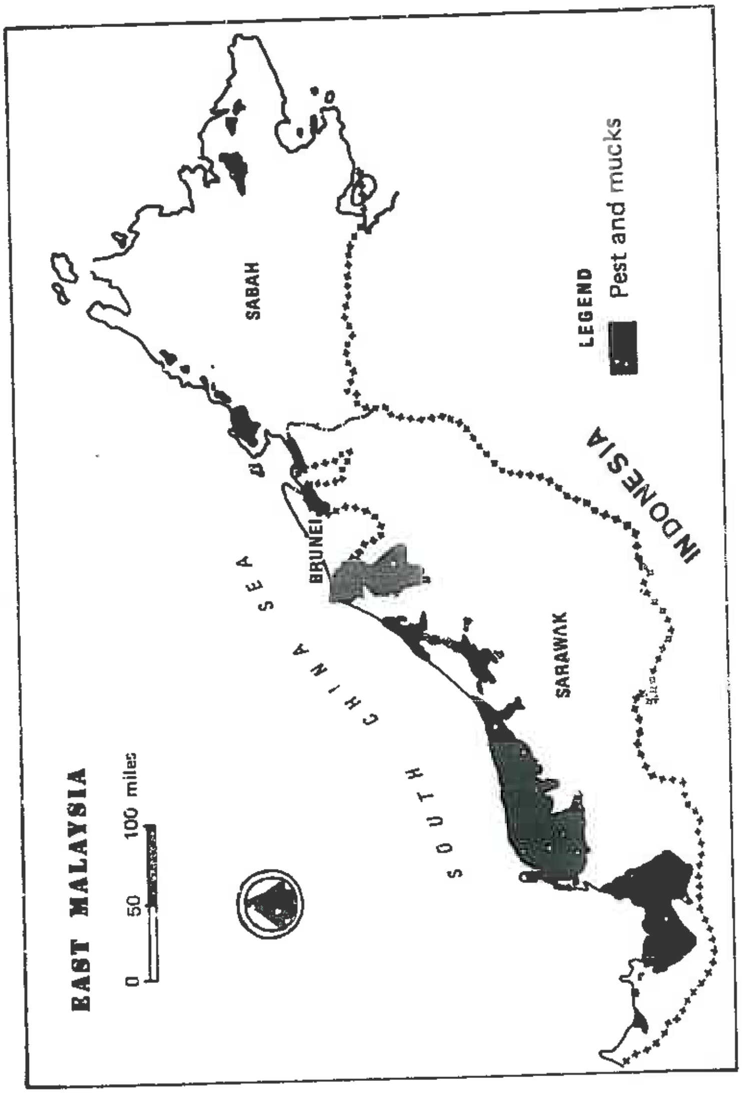

Figure 1b. Distribution of peat soil in East Malaysia.

The main objective of this study was to identify the important weeds which appear after the felling, clearing and burning of the peat swamp forest.

MATERIALS AND METHODS

The peat swamp forest of 40 ha was located near Klang (3°09' N and 101°40' E). Before felling of the forest a botanical analysis was made from 65 quadrats, each 2 m by 2 m in area. After felling, 20 quadrats were laid down, of which 10 were uncleared while the other 10 were cleared of vegetation. Nine weeks after felling, the area was burned. Another 10 quadrats were placed and the flora which appeared 3 months after burning was evaluated.

Throughout the studies, stringent measures were taken to ensure the area was entered only through four selected routes and every effort was made to avoid treading on the plots cordoned off by raffia.

RESULTS AND DISCUSSION

In the virgin peat forest, 96 species were recorded from the total of 65 quadrats (Table 1). The species were typical of forest vegetation except for *S. palustris,* which is normally found as a weed in pineapple areas. The families with several species were *Annonaceae, Elaeocarpaceae, Guttiferae, Moraceae, Myrtaceae, Rubiaceae* and *Vitaceae* (Dicotyledons), *Araceae, Palmae* and *Zingiberaceae* (Monocotyledons) and *Dennstaedtiaceae* (Pteridophytes). The more common genera were *Forrestia, Aeschynanthus, Alocasia, Dracaena, Zingiber, Calanthe, Calamus, Santiria, Eugenia* and *Asplenium.* Of the total number of species, 63.5% were shrubs, 18.8% were climbers and 17.7% were herbs. No gymnosperms were recorded in this particular study but they were recorded in the peat swamp forest in East Malaysia by Anderson (1964).

After felling, without clearing, the flora was largely the same as that of the forest but several new forest species were recorded. With clearing, common weed species such as *M. malabathricum, T. orientalis,, Scleria* sp., *Macaranga triloba* M.A. *N. biserrata* and *S. palustris* were found. Except for *Trema* and *Macaranga,* all the other common weed species were found in abundance at the transitional zone at the edge of the forest. Bird and animal dispersal might be responsible for the dissemination of seeds from the transitional zone to the forest zone.

The flora which appeared after burning included many weed species besides *Melastoma, Trema, Scleria, Nephrolepsis* and *Stenochlaena.* These were *I. cylindrica, P. esculentum, Erechtites* sp., *M. micrantha, Physalis minima* L., *Solanum nigrum* L., *Vitis* sp. and *Paspalum conjugatum* Berg.

Table 1. Weed succession of following the felling, clearing and burning of the peat swamp forest.

Group	Before felling[1]			After felling[2]								
				Without clearing[3]			With clearing[4]			Clearing & burning[5]		
	Fam	Spp	Plts	Fam	Spp	Plts	Fam	Spp	Plts	Fam	Spp	Plts
Dicot	28	64	169	16	24	37	4	7	19	7	11	32
Monocot	9	23	163	3	3	8	2	2	44	3	3	4
Pteridoph	2	9	68	0	0	0	1	3	19	1	3	3
Total	39	96	400	19	27	45	7	12	42	11	17	37

1) Based on 65 quadrats.
2) Based on 10 quadrats.
3) Flora sampled 2 months after felling.
4) Clearing at 3 weeks after felling.
5) Burning at 9 weeks after felling. Flora sampled at 3 months after burning.

Observations carried out 6 months after burning showed that the more dominant weeds were *I. cylindrica, P. esculentum, M. malabathricum, N. biserrata, M. micrantha, S. palustris* and *T. orientalis.*

Particular attention was focused on *I. cylindrica* as it is one of the worst perennials in South East Asia (Holm and Herberger 1969). Research on its distribution and biology have been documented by Soerjani (1970), Lee (1974) and Ivens (1973). It is the most noxious weed on peat and it is estimated that 20 to 30% of the total 60 million Malaysian dollars worth of herbicides in Malaysia is spent on the control of this weed. Except for occasional chlorosis on the foliage, it survives well on peat. The seeds (with caryopses) have a laboratory germination of about 25% on peat but the rate of germination was 84.5% within 2 weeks under alternating temperatures of 15/35 C. Rhizome fragments have a germination of 14 to 33% in the field (Lee 1977a).

The ferns, *P. esculentum* and *N. biserrata* have an extensive network of rhizomes in peat. They tolerated the semi-waterlogged conditions. In 1971, an old pineapple estate of 400 ha was completely colonized by *P. esculentum.*

The other important weed is *M. malabathricum* which regenerates rapidly from its base when cut. Root removal is a fairly expensive operation.

Although clearing and burning was carried out after the felling of the peat swamp forest, several common and noxious weeds appeared rapidly. Weed infestation was extensive six months after felling. The control of early invaders, such as *I. cylindrica, P. esculentum, M. malabathricum, N. biserrata, M. micrantha, S. palustris* and *T. orientalis,* is recommended immediately after burning.

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No - Tillage Systems for Soybeans Following Barley

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ABSTRACT

A field study was made to compare no-tillage planting of soybeans in barley stubble with conventional planting and to determine the feasibility of no-tillage practices for soybean production using a herbicide program. Better weed control was obtained in no-tillage + glyphosate [(*N*-phosphonomethyl) glycine] tilled blocks than no-tillage or no-tillage + paraquat (1,1'-dimethyl-4,4'-bipyridinium ion). Soybean yields under no-tillage, treated with glyphosate or paraquat were equal to or better than those of the conventionally tilled block. Glyphosate, applied soon after barley harvest, combined with linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] or alachlor [2-chloro-2', 6'-diethyl-*N*-(methoxymethyl) acetanilide] resulted in the highest yield of soybeans. The relative production cost was lower for the no-tillage method of soybean production. No-tillage practices provided the greatest increase in monetary return and thus would be highly desirable in double cropping systems involving soybeans.

INTRODUCTION

In Korea, upland areas have been used for growing small grains in winter following soybeans, corn, sweet potato, or potato in the summer. The principal double cropping method is soybeans planted after barley or wheat. Most Korean farms are small. Some farmers use animals as a source of power and only a few have any form of motor power. The demand for labor overlaps and is greatest during the harvesting of barley and the planting of rice or soybeans in May and June. It is usually so dry at the planting time of soybeans (Table 1) that the rate of emergence is very poor.

Growing crops without tillage not only reduces seedbed preparation problems associated with summer crops but also conserves soil moisture during periods of drought stress (Blevins *et al* 1971, Jones *et al* 1969). No-tillage practices reduce energy inputs needed to produce crops. With the development of improved herbicides to control grass and broadleaf weeds, many workers have investigated the possibility of reduced tillage, or no-tillage, for soybean production in the United States, (Hardcastle

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Table 1. Distribution and total rainfall for the growing season and the 10 year average for the same months.

Month	Rainfall, cm	
	1976	Average 1964–1973
May	3.4	9.5
June	4.8	9.1
July	15.0	37.9
August	37.6	34.3
September	4.2	14.5
October	7.9	6.7
Total	72.9	112.0

1973, Mullins *et al* 1973, Worsham 1970). Where cultivation is abandoned and soil is allowed to remain undisturbed, dormant viable weed seeds are no longer brought to the surface where they can germinate and cause weed problems. Corn yields often equal or surpass yields from conventional tillage methods, (Bennett *et al* 1973, Robertson *et al* 1976). The higher yields of no-tilled corn are usually attributed to more efficient utilization of soil water and fertilizer compared to conventionally tilled corn (Blevins *et al* 1971, Jones *et al* 1969).

No-tillage farming has not yet been practiced in Korea. The purpose of this study was to compare no-tillage methods of planting soybeans in barley stubble with conventional planting and to determine the feasibility of this new technique for soybean production following barley, using a herbicide program.

MATERIAL AND METHODS

A split plot experiment was designed with tillage systems assigned to main plots and weed control treatments assigned to sub-plots with three replications. Each plot was 6 by 5 m long and consisted of 8 rows at 75 cm spacing. Soybeans cv Kwang Gyo were hand sown in the middle of 75 cm row barley stubble in a 4 to 5 cm wide strip prepared by scraping with hoes. There were four tillage treatments, namely, conventional till, no-till, no-till + paraquat, and no-till + glyphosate. Soil in conventional tillage blocks was prepared by rotary hoeing and disking. Untilled blocks were left with barley stubble intact and were sprayed with paraquat 0.5 kg/ha or glyphosate 1.0 kg/ha to control existing vegetation before planting. Each tillage system had four weed control treatments, namely, untreated control, hand weeding, linuron 0.5 kg/ha, and alachlor 1.5 kg/ha. A fertilizer blend was uniformly applied to provide 4, 6 and 5 kg/ha of N, P and K, respectively.

Plots were trimmed to eliminate possible border effects and grain yield was determined by harvesting the center four rows of each plot. Weed samples were obtained from areas of 0.2 m^2. Data were statistically analyzed and LSD's were used in evaluating differences between treatment means.

In the experimental areas, the topsoil was a silt loam with an organic matter content of 4.1 % and a pH of 4.6.

RESULTS AND DISCUSSION

Crabgrass *(Digitaria adscendens* Back*)*, smartweed *(Polygonum pensylvanicum* L.), and barnyardgrass *(Echinochloa crus-galli* Beauv.) were the most prevalent weed species throughout the growing season. Better weed control was obtained in no-till + glyphosate and in the tilled block as compared to the no-till block, and control of weeds was slightly poorer in no-till + paraquat than in the no-till + glyphosate (Table 2).

Table 2. Effect of treatment on annual grass and broadleaf weeds.

Soil preparation	Weed control	Dry weight of weeds (g/0.2 m^2)		
		Grass	Broadleaf	Total
Tilled	Untreated control	36.0	8.9	44.9
	Hand weeding	0.1	0.3	0.4
	Linuron	4.5	0	4.5
	Alachlor	3.6	3.9	7.5
No-till	Untreated control	49.9	1.0	50.9
	Hand weeding	2.8	0.5	3.3
	Linuron	34.0	3.0	37.0
	Alachlor	40.6	3.8	44.4
No-till + Paraquat	Untreated control	29.6	10.3	39.9
	Hand weeding	0.7	0.5	1.2
	Linuron	15.4	9.9	25.3
	Alachlor	22.5	7.0	29.5
No-till + Glyphosate	Untreated control	27.4	3.7	31.1
	Hand weeding	1.4	0.1	1.5
	Linuron	8.6	0.5	9.1
	Alachlor	12.0	6.0	18.0
LSD (.05) (among weed control treatments)				16.9

Weed control in the no-till block without preplant contact herbicide application was significantly poorer regardless of weed control treatments, except for the hand weeded plot. Three times more man-hours were required for hand weeding in the no-till block compared to other tillage systems (Table 3). Alachlor and linuron gave adequate weed control in the tilled block and the no-till + glyphosate or paraquat blocks. However, weed control was not good in the no-till block since existing weeds before planting could not be controlled by pre-emergence herbicides alone.

Table 3. Comparison of man-hours required for weeding on hand weeded plots[1] under different tillage systems.

Tillage system			
Tilled	No-till	No-till + paraquat	No-till + glyphosate
1.7	3.7	1.0	1.0

[1] Hand weeding 4 weeks after planting.

Glyphosate and paraquat controlled vegetation initially present, eliminating competition for moisture and nutrients. Linuron and alachlor did not injure the soybeans. In no-till blocks treated with glyphosate or paraquat, soybeans yields were equal to or better than those of the conventionally tilled block (Figure 1). Glyphosate, applied shortly after barley harvest, combined with linuron or alachlor resulted in the highest yield of soybeans. When soybeans were treated with paraquat + linuron or alachlor, yields were about the same as conventionally planted soybeans. Paraquat, however, destroyed top growth of vegetation but was no better than glyphosate. In the no-tillage block without application of contact herbicides, pre-emergence herbicide treatment alone did not control weeds. Therefore, existing weeds making a better start grew more rapidly than later emerging soybeans, and crowded them out, resulting in little or no soybean yield.

The production costs and net return for each treatment are shown in Table 4. The herbicide costs are based on the retail prices of paraquat at US \$ 23.6/gal, alachlor at US \$ 19.7/gal, and linuron at US \$ 7.29/kg. The price of glyphosate was estimated at US \$ 47.3/gal. The relative production cost was lower for the no-tillage method of producing soybeans and the no-tillage + glyphosate system with linuron and alachlor showed

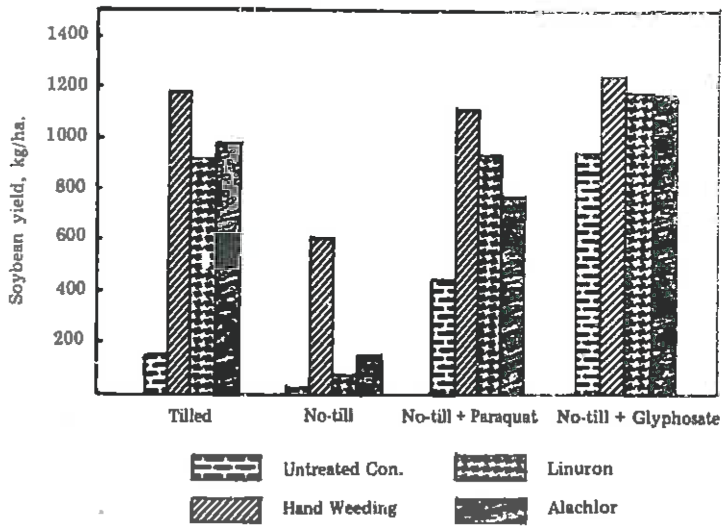

Figure 1: Effect of tillage and weed control treatments on yields of soybeans. LSD(.05) foi comparing main plot means (   ) = 290. LSD(.05) for comparing subplot means within main plot treatment - 145.

Table 4. Comparisons of variable production costs and monetary yield values under different tillage systems and weed control treatments.

Soil preparation	Weed control	Production[1] cost (A)	Gross yield[2] Value (B)	Net Return (B-A)
		US $/ha	US $/ha	US $/ha
Tilled	Untreated control	52.5	104.7	52.2
	Hand weeding	175.5	823.5	648.0
	Linuron	64.3	653.2	588.9
	Alachlor	72.6	695.8	623.2
No-till	Untreated control	0	14.0	14.0
	Hand Weeding	395.8	425.7	29.9
	Linuron	11.8	49.7	37.9
	Alachlor	20.1	106.5	86.4
No-till + paraquat	Untreated control	17.0	314.1	297.1
	Hand weeding	123.0	781.7	658.7
	Linuron	28.8	660.3	631.5
	Alachlor	37.1	539.6	502.5
No-till + glyphosate	Untreated control	33.7	670.0	636.3
	Hand weeding	106.0	894.6	788.6
	Linuron	45.5	852.0	806.5
	Alachlor	53.8	244.9	791.1

1 Production costs include tillage, herbicide and application costs.

2 Soybean price at US $ 0.71/kg.

greatest increase in net return. Labor for conventional land preparation and cultivation was eliminated in no-tillage practices.

This trial showed that soybeans can be planted soon after barley harvest by eliminating lengthy pre-crop planting cultivation, resulting in a more flexible schedule to facilitate multiple-cropping.

In short, no-tillage practices provided the greatest increase in returns and therefore no-tillage soybean production systems would be highly desirable in double cropped soybeans.

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Weed Control in Malaysian Rubber Smallholdings

C.H. YEOH and IBRAHIM BIN MAT TAIB [1]

ABSTRACT

Rubber smallholdings occupy the largest percentage of land under agriculture in Malaysia. They also contribute the major portion to Malaysia's natural rubber (NR) production. Weeds are abundant in these farms. They differ greatly from those found on estates. In a preliminary sampling involving 60 smallholdings, about 50 different species of weeds were identified and classified as major and minor weeds. The major species identified were: *Paspalum conjugatum* Berg.; *Axonopus compressus* (Swartz) P. Beauv., *Imperata cylindrica* (L.) Beauv., *Mikania cordata* (Burm. f.) B.L. Robinson, *Cyrtococcum oxyphyllum* (Steud.) Stapf., *Melastoma malabathricum* Linn. and *Borreria alata* DC. The methods of weed control on small farms range from primitive methods to the use of herbicides. The advantages and disadvantages of the different methods of weed control are described. In nurseries or in fields with young rubber where the bark is still green, 0.6 kg a.i./ha paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride) in 400 l of water was effective in the control of mixed weeds without causing damage to the rubber plants. The mixture developed by the RRIM: MSMA (monosodium methanearsonate) +2,4-D amine (2,4-dichlorophenoxyacetic acid) and [sodium chlorate ($NaClO_3$) (2.2 kg a.i./ha + 1 kg a.i./ha + 5,6 - 22.4 kg a.i./ha respectively) in 400 l of water was effective against most of the mixed weeds commonly noticed in immature rubber on small farms. The herbicide mixture has a broad spectrum of weed control. The RRIM mixture could not effectively control the spread of *I. cylindrica.* Dalapon (sodium salt of 2,2-dichloropropionic acid) at 16.8 kg a.i./ha and a wetting agent (4.2 l ha of teepol), glyphosate [*N*-(phosphonomethyl) glycine] and urea, a commercial product of 46% N, (2,2 kg a.i./ha + 16.8 kg a.i./ha respectively) were effective against alang-alang. Subsequent treatments at the correct time gave more effective control of alang-alang.

INTRODUCTION

Nearly two million hectares of land are planted with rubber and account for 52% of the total cultivated area in the country. Small rubber farms[2] account for 69% of the total rubber acreage and produce 57% of Malaysia's total rubber production[3] Rubber trees are planted 3 —4 m apart within rows and 7 — 10 m in between rows, giving a stand ranging from 440 to 600 trees per hectare. Normally, under good management rubber trees are brought into tapping after 5 to 6 years. The

1 Rubber Research Institute of Malaysia.

2 Small rubber farm has an area of 100 acres (40 ha) and below; the majority of them are 10 acres (4 ha) and less.

3 RRIM, 1975.

economic life span of the tree is about 30 years. During the first 2 to 3 years after planting, the light intensity at ground level in the interrow area is almost 100%. This is when the control of weeds is most demanding. The success or otherwise of the crop depends a great deal on effective control of weeds during the critical immaturity phase. It may take as many as 4 to 6 rounds of weeding per year along the planting rows to keep weed competition to a minimum. As the rubber trees mature and the canopy closes in, sunlight and hence the weed population under the rubber trees are progressively reduced (Figure 1).

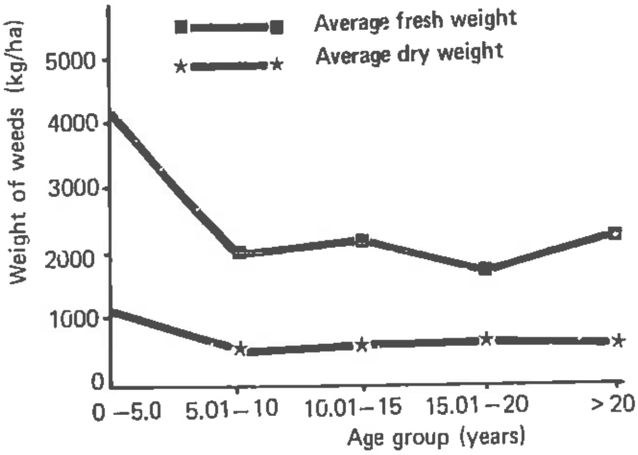

Figure 1. Average weight of weeds in rubber farms in Peninsular Malaysia in relation to age of rubber trees.

The data indicate that after the fifth year growth of weeds decreased by 50%. From the 5th year to the 20th year or more the density of weed growth was generally maintained at 50% from the control level. Consequently, one or two rounds of weeding per year were adequate. The control of weeds constitutes the major portion (about 60%) of the total expenditure during the first 5 to 6 years of establishment (Ng 1967).

WEEDS AND YOUNG RUBBER TREES

Weeds compete with young rubber trees for plant nutrients (Watson *et al* 1964). The exudation of growth inhibiting substances of *M. cordata* affects the growth of rubber trees (Wong 1964). Young rubber trees show significant response in growth when *I. cylindrica* is brought under control with herbicides (Yeoh and Pushparajah 1976). With heavy infestation of weeds the crop does not fully benefit from other agronomic inputs, particularly fertilizer.

METHODS OF WEED CONTROL

The abundant supply of cheap labour resulted in cultural means of weed control being prominent on small rubber farms in Malaysia long before the Second World War. The use of herbicides was then not common. Manual weed control with a heavy hoe (changkol) was effective and in many cases manual clean weeding in the young rubber areas was a common practice. The mechanical method of weed control using tractors, etc was economically not feasible for small farmers. Although rubber trees gained in initial growth in a clean weeded condition, soil erosion was severe (Haines 1932) and the rapid destruction of organic matter resulted in the soil being too compacted.

USE OF HERBICIDES

In Malaysia, herbicides were used after the Second World War. Sodium arsenite and sodium chlorate, both contact herbicides were reported to be used by estate owners for general weed control. Due to the high mammalian toxicity of sodium arsenite, small farmers were not allowed to use it, unless they obtained the necessary permit.

The high mammalian toxicity and its cumulative effects in soils and crops (Woo 1973) prompted the Government to ban the use of sodium arsenite in 1976. Chemical weed control using herbicides which are relatively less toxic is gaining popularity on small rubber farms in Malaysia. Both estates and small farms spend about M$60 million annually on weed control. The increased use of chemicals for weed control in small farms was due mainly to the large scale replanting programme and the development of more block new planting rubber schemes for smallholders (Table 1).

Table 1. Hectarage of new planting and replanting of small farms in Malaysia[4]

Year	Cumulative (in '000 ha)		
	New planting	Replanting	Total
1969	6.3	15.1	21.4
1970	17.2	36.7	53.9
1971	29.7	60.0	89.7
1972	39.1	83.4	122.5
1973	51.7	112.0	163.7

4 Statistics Dept. Malaysia. 1974.

With more land brought under cultivation and with the rising cost of labour, chemical weed control is expected not only to replace part of the age old method of weed control but also to play an increasingly important role in the successful implementation of the rubber schemes by the various Government agencies.

RESEARCH ON WEED CONTROL

Through research conducted by the Rubber Research Institute of Malaysia (RRIM) more effective and less toxic alternatives have been tested for weed control. For instance, the wide interrow area could be established with quick, creeping legume covers at the time of planting. Covers would not only suppress the growth of weeds but also add nitrogen and organic matter to enrich the soil, leaving only the planting rows to be weeded. To allow the legume covers to develop almost pure, both pre-emergence and postemergence herbicides have been tested.

The use of pre-emergence herbicides such as methabenzthiazuron (1-benzthiazol-2-yl-1,3-dimethylurea) and alachlor [2-chloro-2',6'-diethyl -*N*-(methoxymethyl) acetanilide] at 2.2 kg a.i./ha on seed drills of a mixture of legume covers of *Pueraria phaseoloides* Bth. and *Centrosema pubescens* Bth. followed with postemergence herbicides applications such as MSMA + 2,4-D and sodium chlorate (2.2 + 1.1 + 5.5 kg a.i./ha) on the space between the legume drills gave the best results in terms of vigor and dry matter content (RRIM 1975).

MANAGEMENT OF RUBBER INTERROW AREA

Although it is an acceptable practice to grow legumes in the interrow area, small farmers may not follow this system or may find it difficult to maintain the legume pure. In most cases noxious and non-noxious weeds regenerated to such an extent that the legume covers were suppressed. Eventually noxious weeds like *Imperata* spp., *M. cordata* or others may dominate. Alternatively, non-noxious weeds were allowed to grow in the interrow area with the noxious ones brought under control.

Animals and intercropping. The other exciting area of research carried out lately by the RRIM is the introduction of animals in the interrow areas.

Animals such as goats and sheep grazing the undergrowth, act as biological agents of weed control, with an extra gain of manure and animal proteins to the small farmers (Ani Arope 1976). The mixed weeds under rubber were analysed and found to contain 12—14% of crude protein and 28% of crude fibre. The normal requirement of small ruminants in Malaysia is about 10% crude protein[5]. The introduction of intercropping in the interrow area at the early stage of rubber planting helped to suppress the growth of weeds and also brought in extra income for the small farmers during the immaturity phase of their rubber trees.

MAJOR WEEDS IN SMALL RUBBER FARMS

A preliminary study conducted on 160 selected smallholdings scattered throughout the country revealed the following major weed species in order of importance:

Botanical name	Common name	Percentage
Grasses		
Paspalum conjugatum Berg.	Buffalo grass	6.8
Axonopus compressus (Swartz) P. Beauv.	Carpet grass	5.1
Imperata cylindrica (L.) Beauv.	Lalang	3.4
Cyrtococcum oxyphyllum (Steud.) Stapf. (Panicum pilipes)	Shining panic grass	2.9
Broadleaf		
Mikania cordata (Burm. f.) B.L. Robinson	Mile-a-minute	2.5
Melastoma malabathricum Linn.	Straits rhododendron	1.3
Borreria alata DC.	Broadleaf button weed (Pig weed)	0.5

EXPERIMENTAL WORKS

The RRIM has developed the use of mixtures of systemic and contact herbicides; 2,4-D amine + sodium chlorate and MSMA + 2,4-D amine + sodium chlorate have been sufficiently tested and found to control a broad spectrum of weeds normally found in small rubber farms (RRIM 1967). So far, no single herbicide has been proven to control all weeds effectively. Forty-six, single replicate trials were conducted in small rubber farms with young rubber trees of between 2 and 4 years old. A hand-operated knapsack sprayer with PP 062 fan jet size nozzle was used to spray strips of the planting rows 2 m width. Care was taken to direct the spray solution containing sodium chlorate away from the base or stem of rubber trees. Direct contact of herbicide mixtures

[5] Wan Mohamad 1977, personal communication.

containing sodium chlorate had been shown to cause considerable damage to bark of immature rubber trees.
The volume of water used was about 400 l/ha.

Herbicide Treatments

A. MSMA (2.2 kg a.i./ha) + 2,4-D amine (1 kg a.i./ha) + sodium chlorate (5.6 kg — 22.4 kg/ha).

B. 2,4-D amine (1 kg a.i./ha) + sodium chlorate (20-35 kg/ha).

C. MSMA (2.2 kg a.i./ha) + 2,4-D amine (1 kg a.i./ha) + dalapon (2.2 kg/ha).

D. Paraquat used at 0.6 to 1.2 kg a.i./ha for weed control in rubber nurseries and for certain specific weeds in the planting rows were used.

MSMA (2.2 kg a.i./ha) + 2.4-D amine (1 kg a.i./ha) + sodium chlorate (5.6 kg to 22.4 kg/ha) mixture in 400 l/ha of water gave very effective control for an average of 10 weeks in young rubber areas of the following weed species:

Grasses	Broadleaf	Sedges/ferns
Main weeds	Broadleaf	Sedges/Ferns
Paspalum conjugatum	*Mikania cordata*	
Ottochloa nodosa	*Ageratum conyzoides* L.	
	Eupatorium odoratum L.f.	
Axonopus compressus		
Cyrtococcum oxyphyllum	*Melastoma malabathricum*	
Minor weeds		
Digitaria longiflora Pers.	*Ipomoea* spp.	*Dicranopteris linearis*
		Cyperus kyllingia Endl.
Fimbristylis spp.	*Passiflora foetida* L.	
Ischaemum timorense Kunth.	*Cleome rutidosperma* DC.	
	Lantana camara L.	

I. cylindrica, *Eleusine indica* Gaertn. *Paspalum commersonii* Lamh. and *Sporobolus indicus* were not effectively controlled by the herbicide mixtures. However, with the subtitution of sodium chlorate in the mixture with 2.2 kg/ha dalapon, *E. indica*, *P. commersonii*, *S. indicus* together with *P. conjugatum* and *A. conyzoides* were effectively controlled. *I. cylindrica* remained persistant and, in a short period of time, became a dominant weed. Weeds such as *Panicum trigonum*, *A. conyzoides*, *E. odoratum*, *M. malabathricum*, *M. cordata* were reported to be effectively controlled by the mixture of 2,4-D amine (1 kg a.i./ha) + sodium chlorate

(20-35 kg/ha) (RRIM 1967, 1968) which also gave very effective control of *P. conjugatum*, *A. compressus* together with *Tetracera scandens* (young plants) and *O. nodosa* for a period ranging from 4 to 10 weeks.

The majority of the mixed weeds grew together on a small rubber farm. The noxious ones could be singled out and if no action was taken to control them, they eventually predominated and colonised the entire area. For example, *I cylindrica* appeared scattered with other mixed weeds and if not brought under effective control, it predominated over others within a short period of time and formed sheet lalang which costs more to control.

CONTROL OF WEEDS IN A RUBBER NURSERY

Paraquat at the rate of 0.6 kg/ha in a 400 l of water without the use of a protective shield was used to control weeds in a rubber nursery planted with two-month-old seedlings. The spray solution was directed at the weeds but wetting some of the young rubber seedling stems. Damage to the seedlings was negligible compared with manual weeding with a hoe (changkol). The control of broadleaf weeds such as *B. alata*, *A conyzoides*, *E. odoratum* (all at seedling stages) was rapid and effective with paraquat. The other advantage was that only 5 rubber seedlings were damaged with the use of herbicide when compared with 200 seedlings by manual weeding out of 20.000 seedlings in the nursery. The budding success was not affected by the chemical method of weeding prior to green budding at 4 months old when compared to seedlings in manually weeded areas.

CONTROL OF *IMPERATA CYLINDRICA* (LALANG)

Lalang is considered to be one of the ten worst weeds in the world (Holm and Herberger 1966). Failure of many block new planting schemes and individual rubber farms is due to lalang which is widely distributed in Malaysia. A considerable amount of work on the control of lalang has been done. Recent work has shown that dalapon is more effective in the control of lalang than sodium arsenite or lallicide (RRIM 1957). In 1974 glyphosate was introduced and found equally effective against lalang. Results of trials set up by the RRIM showed that glyphosate used at the rate of 2.2 kg a.e./ha in 1000 l of water gave about the same result as dalapon used at 16.8 kg/ha with the addition of 4.2 l Teepol, a wetting agent, and 0.7 l of sticker/ha (Figure 2). However, the effective control of lalang improved with the increase in rate of glyphosate used from 1.65 to 3.3 kg a.e./ha. Additionally, an early re-spray at five weeks for dalapon and a wetting agent and sticker had a slight advantage over a similar application at nine

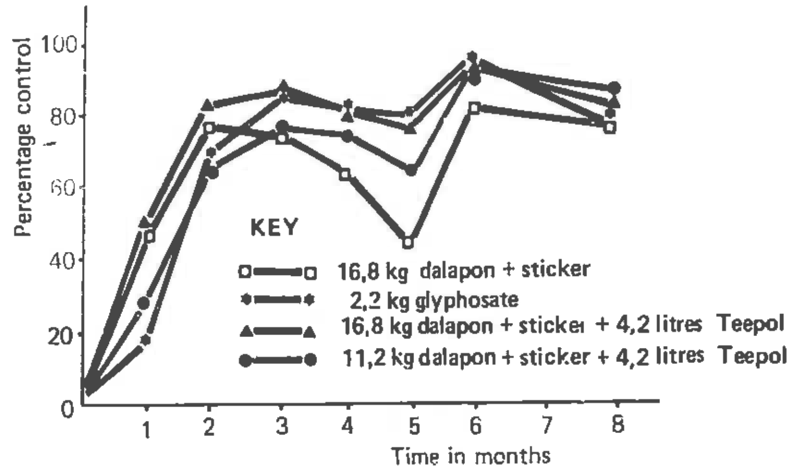

Figure 2. Effect of surfactants on efficiency of dalapon.

weeks. For glyphosate the re-spray at the ninth week gave better and more effective control than a later re-spray at the 15th week (Figure 3).

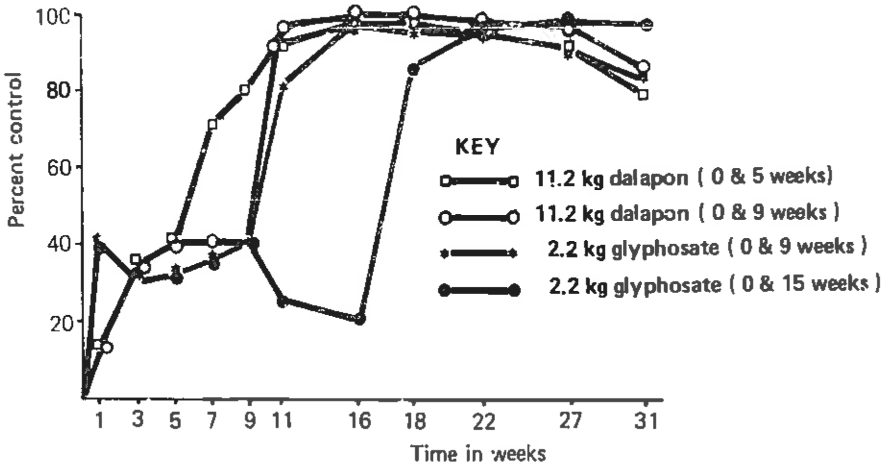

Figure 3. Effect of timing of repeat applications on control of Imperata.

In separate detailed trials, 16.8 kg of urea per hectare was added separately to 16.8 kg/ha dalapon and 2.2 kg/ha glyphosate. Lalang rhizomes were extracted from 0.5 m^2 in the trial plots 100 days after treatment and planted out separately. Preliminary results of the shoot count showed that glyphosate used at 2.2 kg with the addition of 16.8 kg urea/ha gave very effective control and was better than glyphosate (2.2 kg) used alone. The addition of urea to dalapon gave disappointing results (Table 2).

Table 2. Shoot count of lalang rhizomes from lalang plants treated with herbicides + urea.

Treatments	Time in days after planting of rhizomes				
	20	30	40	50	70
	Average number of shoots				
1. Glyphosate 2.2 kg a.i. + urea 16.8 kg + sticker 0.7 l/ha	0.33	1.33	1.33	2.00	3.67
2. Dalapon 16.8 kg + urea 16.8 kg + wetting agent 4.2 l + sticker 0.7 l/ha	14.33	18.33	19.33	20.33	39.00
3. Glyphosate 2.2 kg a.i. + sticker 0.7 l/ha	5.33	9.33	11.00	11.33	18.90

WEED SUCCESSION

The succession by other weeds after the control of lalang or other mixed weeds is inevitable but attempts should be made to ensure that other noxious weeds like *M. cordata*, *E. odoratum* and *M. malabathricum* do not replace lalang or other weeds that are brought under control. A typical example of the regeneration of other weeds after the control of lalang is shown in Figure 4. In a situation where *M. cordata* or *M. malabathricum* appeared as a single noxious weed, the use of 2,4-D amine (1 kg) or 2,4,5-T respectively gave better results than the mixtures..

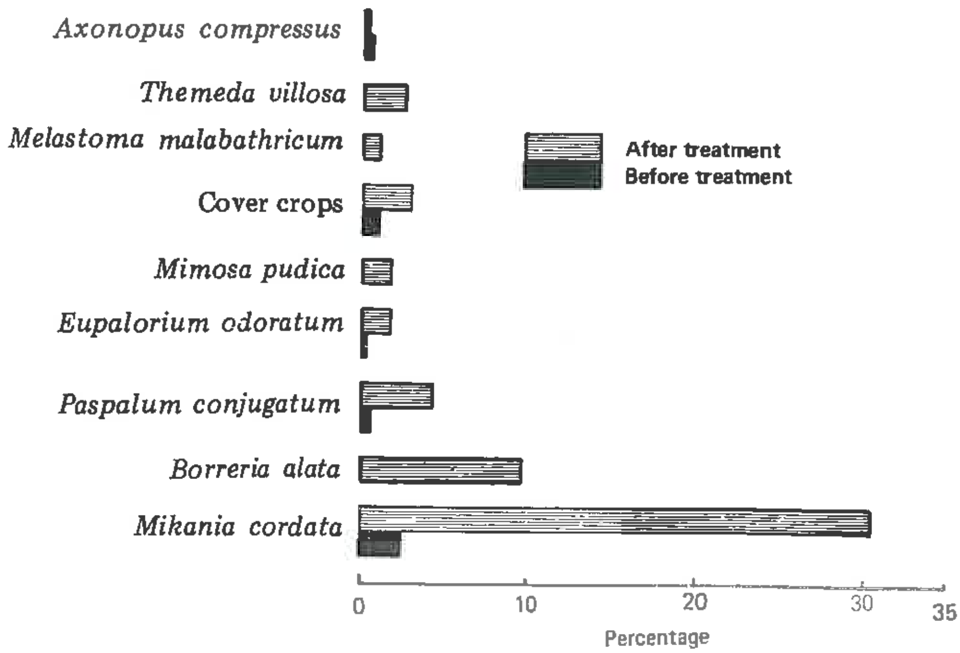

Figure 4. Weed regeneration after control of *Imperata cylindrica*

The establishment of creeping legume covers after the control of noxious weeds may help to overcome this problem.

DISCUSSION

Although the hectarage and total production of small rubber farms in Malaysia are more than the estate sector, the yield per unit area from smallholdings still fall short of that of estates. This is due to the poorer planting materials used and poor management of the small farms. Weed control constitutes the major item in management. If there is adequate control of weeds the rubber can be successfully tapped much earlier and eventually increased yield of rubber in smallholdings can be assured.

Weed control by chemical methods will undoubtedly play an increasingly important role in the smallholder sector. Apart from effectiveness of weed control, research workers should also bear in mind that the cost of herbicides should be within the reach of small farmers. The improvement of weed control by the use of pre-emergence herbicides before the planting of legume creeping covers in between rubber rows is equally important. The use of animals as a biological method of control of weeds is another area which will also increase the supply of animal proteins to smallholders in Malaysia.

Imperata cylindrica is the most troublesome weed in smallholdings. It can be brought under control by either dalapon (16.8 kg/ha) with wetting agent (4.2 l/ha) or glyphosate (2.2 kg a.e./ha) with urea 16.8 kg/ha). Repeat treatments are necessary followed by wiping or spot spraying of sporadic shoots until the weed is completely brought under control. Less noxious weeds are allowed in the interrows but weeds in the planting rows have to be controlled. The RRIM herbicide mixtures of MSMA (2.2 kg a.i./ha) + 2,4-D amine (1 kg a.i./ha) + sodium chlorate (5.6 — 22.4 kg/ha) and 2,4-D amine (1 kg/ha) + sodium chlorate (20 — 35 kg/ha) can effectively control a large number of mixed weeds. Repeat treatments of between 3 and 5 rounds per year, depending on age of the rubber trees and the light intensity at ground level have to be considered.

The danger of using a fixed regime of chemicals resulting in the growth of resistant weed species is well known. The control of weeds has become more sophisticated. Weeds need to be identified before the use of herbicides. Extension personnel and small farmers alike should be made aware of such problems.

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Asulam and Metribuzin in Regional Tests for Control of Grass Weeds in Sugarcane in Taiwan

SHENG Y. PENG and L.T. TWU [1]

ABSTRACT

After having been recognized as an especially effective treatment for the control of annual grass weeds in sugarcane, the herbicides asulam (methyl-4-aminobenzene-sulphonyl carbamate) and metribuzin (4-amino-6-*tert*-butyl-3-(methylthio)-1,2,4-triazin-5-(4*H*)-one) were put in regional tests over 4 and 3 locations (plantations) in the 1974 1975 and 1975-1976 autumn-planting cane crops respectively as the basis for recommending for general use in cane plantations. Both herbicides in pre-emergence applications at 1.6 kg a.i./ha each, in combination with the same dose of 2,4-D Na [sodium (2,4-dichlorophenoxy) acetate], achieved over 96.2% kill when only annual grasses were present and without interference of the immediate monsoonal rains. However, the postemergence application of these chemicals gave almost perfect control irrespective of monsoonal rain and were nearly 2 times more effective than pre-emergence applications against mixed populations of both annual and perennial weed species. Increasing the dose of metribuzin to 3.2 kg a.i./ha caused severe injury to young cane; while asulam at 2.5 kg a.i./ha was still safe when both the products were used as over-all postemergence sprays. This suggests that metribuzin is less selective than asulam and probably has higher translocative and residual activity.

INTRODUCTION

Because of continuous use of diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], atrazine [2-chloro-4-ethylamino-6-isopropylamino-s-triazine] and 2,4-D sodium in past years for general weed control in sugarcane, the weed populations in cane fields of Taiwan have undergone great shifts. Being much more susceptible to these herbicides the previously common dicotyledonous species gradually diminished and gave way to the resistant monocotes which are now the dominant weeds. In recent years, in our annual evaluation trials with new products for control of resistent weeds, the herbicides asulam and metribuzin in combination with 2,4-D Na or Actril-D (mixture of ioxynil octanoate and 2,4-D isooctyl ester) always showed special effectiveness particularly against the gramineous weeds.[2,3]

1 Taiwan Sugar Research Institute, Tainan, Taiwan.

2 Peng, S.Y., W.B. Sze, H.J. Yeh and L.T. Twu 1975. Control of gramineous weeds in sugarcane in Taiwan with asulam. Taiwan Sugar, Sept. — Oct. 1975.

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However, before these two new products could be accepted for general use, establisment of the consistency of their performances in different years and locations is very important. Accordingly, these products are assigned to the regional tests over 7 locations (plantations) in 2 crops through 1973 - 1975. The results thus obtained are discussed in this report.

MATERIALS AND METHODS

The 1974 - 1975 cane crops planted in September 1973 were treated in the first regional tests over 4 locations representing main districts of this cane-producing region. The dates at which operations were conducted and the soil types and cane varieties planted for each location were as follows:

	Locations (plantations)			
	Kan-tien (K)	Shi-hu (S)	Chun-nan (C)	Nan-chow (N)
Planting cane	Sep. 2nd 1973	Sep. 3rd	Sep. 9th	Sep. 9th
Application pre-em.	Sep. 7th	Sep. 4th	Sep. 11th	Sep. 10th
Application post-em.	Sep. 25th	Sep. 26th	Sep. 27th	Sep. 28th
Harvesting weeds	Oct. 5th	Oct. 11th	Oct. 12th	Oct. 13th
Harvesting cane	Feb. 23rd 1975	Jan. 11th 1975	Dec. 14th 1974	Nov. 27th 1974
Soil type	Clayeyloam	Sandyloam	Loamy	Loamy
Cane variety planted	F 160	60 — 980	F 156	F 160

The two new herbicides asulam and metribuzin were tested at one or two economic dosages in combination with a constant 1.6 kg a.i./ha of 2,4-D sodium which should bring about satisfactory weed control as determined in past screening trials. In addition the standard diuron plus 2,4-D Na at 1.6 kg a.i./ha each and hand weeding were included as controls. The field layout was a split-plot design for all locations with pre-emergence applications assigned to the main plots and different herbicides to the sub-plots. Each treatment was replicated 4 times and the plot size was 10 m row length x 1.25 m row spacing x 4 rows or 50 m^2.

The second regional test with the next crops planted in September 1974 was carried out over 3 more locations as follows:

Because this time it was mainly for purpose of introducing the two products for general use to the plantation growers, the plot size of a randomized complete block layout was especially expanded to 20 rows and 40 m row length. Only 2 replicated plots for each treatment were used. Since yields of cane were never affected by any of the two herbicides in this regional test only measurements of cane growth were entered for assessment of treatment effects on crop plants.

	Locations		
	Hew-lyan (H)	Ai-lyau-chi (A)	Kan-tien (K)
Soil type	Clayey loam	Sandy loam	Loamy
Cane variety planted	F 160	F 156	F 160
Date of planting cane	Sep. 7th 1974	Sep. 7th	Sep. 17th
Date of pre-em. appl.	Sep. 9th	Sep. 17th	Sep. 17th
Date of postem. appl.	Sep. 27th	Oct. 3rd	Oct. 3rd

In all cases regrowth of surviving individual weed species was assessed usually before breaking of field ridges to establish the efficacy of herbicidal treatments.

RESULTS AND DISCUSSION

The results of both the regional tests in 1974 - 1975 and 1975 - 1976 cane crops are shown in Tables 1 and 2.

Table 1. Comparison between performance of asulam and metribuzin over 4 locations with 1974-75 cane crops, average of 4 replications.

Aplication	Treatment no. (a)	Harvest of survived regrowths (b) at locations								Cane yields harvested at locations (t/ha)			
		(K)		(S)		(C)		(N)		(K)	(S)	(C)	(N)
		t/ha	%	t/ha	%	t/ha	%	t/ha	%				
A	1	0.26	11.26	0.33	20.89	0.46	13.82	0.01	0.19	93.50	86.10	107.30	102.12
	2	0.29	12.55	0.63	39.87	0.64	13.82	0.03	0.56	90.35	80.00	107.30	98.42
	3	0.18	7.79	0.20	12.66	0.18	3.89	0.04	0.74	102.30	85.10	94.60	115.56
	4	0.61	26.41	1.04	65.82	0.18	3.89	0.19	3.52	84.45	96.60	109.65	104.18
	5	2.31	100	1.58	100	4.53	100	5.40	100	100,25	76.40	69.55	98.82
LSD	(.05)	0.25	10.82	0.44	27.85	0.97	20.95	1.02	18.89	-	-	-	-
	(.01)	0.41	17.75	0.72	45.57	1.45	31.32	1.72	31.48	-	-	-	-
B	1 (c)	0.38	14.96	0	0	0	0	0	0	100.00	82.65	108.35	105.36
	2 (d)	0.41	16.14	0.06	1.30	0	0.08	0.02	0.30	95.60	95.60	95.80	110.12
	3 (e)	0.33	12.99	0.07	1.63	0	0	0.03	0.48	100.95	84.50	116.60	117.48
	4	1.54	60.63	0.68	15.81	0.09	1.50	0.18	6.79	104.15	83.35	104.95	94.76
	5	2.54	100	4.30	100	5.99	100	2.65	100	96.70	88.45	93.40	94.44
LSD	(.05)	0.28	11.02	0.56	13.02	0.35	5.84	0.55	20.75	-	-	-	-
	(.01)	0.46	18.11	0.93	21.63	0.58	9.68	0.90	33.96	-	-	-	-

(a) In ai/ha and in mixture with a constant 1.6 kg ai/ha of 2,4–D Na: (1) metribuzin 3.2 kg, (2) metribuzin 1.6 kg, (3) diuron 1.6 kg, (4) asulam 1.6 kg and (5) hand-weeding,

(b) Main annual grass weeds best controlled in locations C and N: goose grass, tropical crabgrass, Chinese pennisetum and sour paspalum; less controlled perennials occurred in locations K and S: torpedo grass (*Panicum repens* L.), Bermuda grass (*Cynodon dactylon* Pers.) and the nut grass.

(c) Caused severe to mild injury of young cane in all locations.

(d) Caused mild injury of cane seedlings on variety 60-980 at locations S.

(e) Caused severe toxicity on F 160 in location K.

A Preemergence

B Postemergence

Table 2. Demonstration of weed control performance by asulam and metribuzin in 3 locations with 1975 - 76 cane crops

Treat. no. (a)	Types of appl.	Harvest of survived weed regrowths (49 days after planting cane) (b) (H)		(A)		(K)		Effect on cane growth (2-mo.-old) (c) (H)		(A)		(K)	
		t/ha	%	t/ha	%	t/ha	%	no. of tillers	plant ht.(cm)	no. of tillers	plant ht.(cm)	no. of tillers	plant ht.(cm)
1.	Pre	0.11	1.49	15.90	78.3	0	0	479	24.8	400	27.6	226	20.9
	Post	0.24	3.24	0	0	0	0	517	26.0	384	24.9	296	23.8
2.	Pre	0.14	1.89	9.34	46.0	2.0	23.4	460	25.5	403	27.7	239	23.4
	Post	0.20	2.70	0	0	0	0	453	25.8	395	24.2	296	25.6
3.	Pre	0.20	2.70	10.40	51.2	0	0	484	26.0	368	22.9	311	23.7
	Post	0.07	0.95	1.87	9.2	0	0	474	23.8	592	22.2	342	23.1
4.	Pre	0.31	4.18	6.63	32.7	1.63	19.1	444	27.5	446	28.7	294	23.2
	Post	0.10	1.35	0	0	2.50	29.3	492	26.0	365	24.8	261	25.8
5.		20.30	1.00	20.30	100	8.53	100	497	23.3	321	29.3	243	22.3

(a) Dosages of herbicides in amount of product per ha: (1) asulam + Actril–D 7 + 1.25 litres, (2) asulam + 2,4–D Na 7 litres + 2 kg, (3) metribuzin 2 kg, (4) metribuzin + 2,4–D Na 2 + 2 kg and (5) Hand-weeding.

From Table 1 it noted that all treatments of asulam and metribuzin at the standard dose of 1,6 kg a.i./ha in mixture with 2,4-D Na at also the same dose, either in pre-emergence or postemergence, significantly killed such principal annual grass weeds as goosegrass *(Eleusine indica)*, tropical crabgrass *(Digitaria adscendens* Henr*)*, Chinese pennisetum *(Pennisetum alopecuroides* Spreng.*)* and sourgrass *(Paspalum conjugatum* Berg.*)* from 96.2% to 100% in locations C and N where these species were dominant. In locations K and S where the perennial grasses as torpedograss *(Panicum repens)* and bermudagrass *(Cynodon dactylon)* as well as the *Cyperus* were eqally abundant, the two compounds (and the standard diuron too) showed less effectiveness. Their postemergence treatments were however almost two times as effective as pre-emergence which killed only about 35 to 70% of the weeds, on an average. The double dose of metribuzin was only insignificantly better than its standard dose in control of the annual grasses.

When examining effects on cane seedlings, metribuzin and diuron caused mild injury of young cane at the standard doses and severe toxicity was resulted by double dose of metribuzin, under all the over-all postemergence sprays. While the standard dose of postemergence asulam caused no plant injury at all, even though its efficacy of weed control was a little lesser than other products. The cane yields were by no means influenced, however, by any treatment effects.

From the large-scale field demonstration replicated on 3 locations shown in Table 2, it is observed that asulam whether combined with

Actril-D or 2,4-D Na at its recommendation dose of 7 l/ha (2.5 kh a.i./ha) in over-all postemergence sprays decisively achieved almost perfect control of the annual weeds. While its pre-emergence treatments were somewhat influenced by monsoonal rains occurred within a few days of application. Metribuzin at the standard dose of 1.6 kg a.i./ha showed the same results whether combined with or without 2,4-D sodium. The foliage-treated 2-month-old cane appeared as normal as the treated before germination and the unsprayed as well.

Summarizing the two field trials, it is recommendable that asulam and metribuzin be extended to general uses for the standard early postemergence treatments of sugarcane cultivation. Asulam at 5—7 l/ha + Actril-D (1 - 2 l/ha) and metribuzin at 2 kg/ha with or without addition of 2.4-D Na depending on presence of *Cyperus* species, can be used. However precautions should be taken against possible injury of cane seedlings by metribuzin when the susceptbie varieties like F 160 and 60 - 980 are planted.

Use of Glyphosate for Selective Control of Paspalum conjugatum and Ottochloa nodosa in Established Legume Cover Crops

I. HUSSEIN and W.P. WENG [1]

ABSTRACT

At 0.5 kg use of glyphosate [*N*-(phosphonomethyl) glycine] is effective in controlling the grasses, *Ottochloa nodosa* and *Paspalum conjugatum* Berg. but is relatively safe to established *Pueraria phaseoloides* Bth. a legume cover crop. Therefore it is possible to maintain the purity of legume cover crops by using glyphosate.

INTRODUCTION

The majority of the large planting industries in Malaysia has a policy or establishing and maintaining good legume cover crops during the immature stages of rubber and oil palm planting. One of the reasons for establishing legume is that they provide a good source of nutrients particularly nitrogen (Watson *et al* 1964). At the same time, the legumes help to reduce soil erosion and minimize the invasion of unwanted weeds. Current methods of maintaining legumes require several hand weedings per year. Most of the time, with shortage of labour or delays in weeding due to wet weather, many grasses and particularly *Ottochloa nodosa* and *Paspalum conjugatum* invade these legumes. It is thus difficult for estate managers to maintain pure legume cover crops. At certain stages of grasses infestation, it is impossible to hand weed as it requires more money than the estate has budgetted for.

The objective of this paper is to show how glyphosate can be successfully used to selectively remove grasses such as *P. conjugatum* and *O. nodosa* which will simplify legume cover crop management. Initial indicators of this development were reported by Wong[2].

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1 Monsanto (Malaysia) Sdn. Bhd., 116, Jalan Semangat, Petaling Jaya, Selangor, West Malaysia.

2 Wong S. H. 1974. Selective effect of Roundup on legume cover crops and grasses. University of Malaya Project. Unpublished.

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MATERIALS AND METHODS

The glyphosate postemergence weedicide used in this program is a liquid formulation containing 3.0 lbs a.e. of glyphosate per US gallon or 4.0 lbs of the isopropylamine salt of glyphosate (4.0 lb a.i.) per US gallon. Experimental design: A complete randomized block design of 3 replications of 6 treatments per trial site; control, 0.25 kg, 0.33 kg, 0.75 kg, 1 kg/ha of glyphosate sprayed over several locations in Peninsular Malaysia, where most of the rubber and oil palm is located. Trial sites: Four sites were chosen. Two from very young rubber areas and two from very young oil palm areas, where the *Pueraria phaseoloides* legume cover crops were infested with 51% — 65% grasses. Plot size: 0.1 ha per replication in 2 trials. 0.8 ha per replication in 2 trials. Spray equipment: An ordinary 4 gallon knapsack sprayer fitted with a 5/64" orifice diameter polyjet. Spray volume: All spraying was carried out in 400 litres of water per hectare. Method of spraying: The entire legume grass mixture was blanket sprayed. Time of spraying: The actual spraying was done on 4 days at the rate of one day per trial when the weather was suitable for spraying. All the trials were sprayed in late April and early May of 1976. Method of evaluation: Visual 0, 30, 60, 90, 120, 150 days after treatment.

RESULTS AND DISCUSSION

Average control of grasses—*P. conjugatum* and *O. nodosa.* Glyphosate at 0.25 kg/ha gave very poor control of grasses. The percent grass coverage was reduced from 57% to 31% at 0 to 30 days after treatment but subsequently it increased to 54% coverage at 90-150 days.

Glyphosate at 0.33 kg, was effective but slow acting (Figure 1). It required 120 days for the presence of grasses to be reduced from 53% to 7%-9%. Glyphosate at 0.5 kg killed the grasses faster. It took 90 days to reduce the presence of grasses from 65% to 6%. Glyphosate at 0.75 kg gave almost the same result as the 0.5 kg rate. Glyphosate at 1 kg/ha was extremely effective. Grass coverage was reduced from 50% to 0% within 30 days (Figure 1).

Observations of *P. phaseoloides* (legume cover crop) (Figure 2). Glyphosate at 0.25 kg/ha did not damage the legume at all. The percentage of the legumes did not drop below the 42% level observed at beginning of the trial. Glyphosate at 0.33 kg/ha caused negligible damage to the legumes. The maximum reduction in legume coverage was only 13% from 47% to 34% at 30 days. Subsequently, percentage of legumes increased rapidly. The final percentage at 120-150 days was 79%-80%. The same trend was observed for the 0.5 and 75 kg/ha. Glyphosate at 1 kg/ha was very damaging to the legume cover crop. The legume coverage dropped from 45% at the start of the trial to 15% at 14 days and there was no recovery until 120 days.

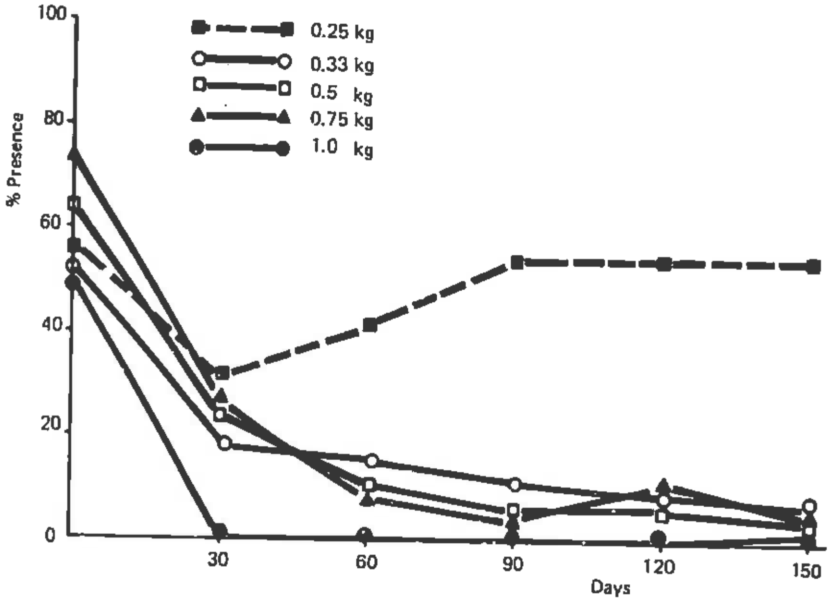

Figure 1. Percentage of *Paspalum conjugatum* and *Ottochloa nodosa* (Grasses).

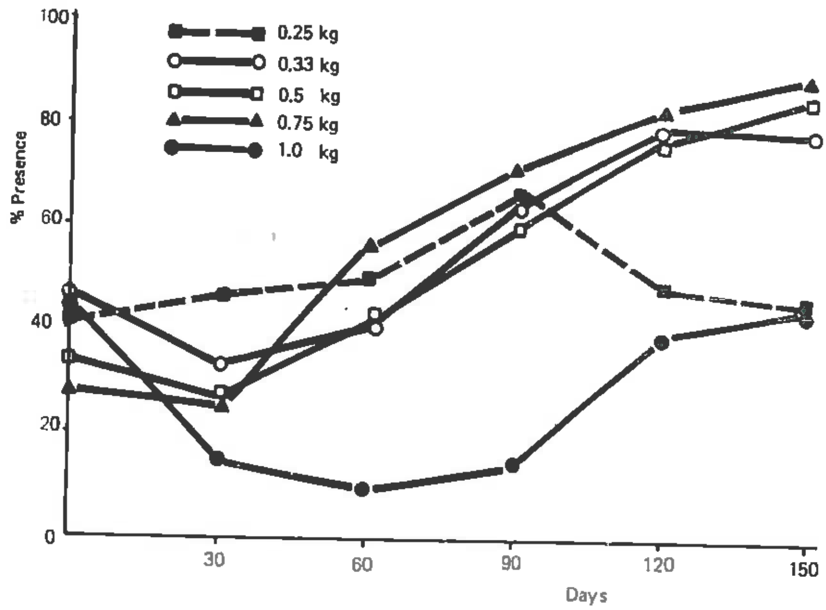

Figure 2. Percentage of *Pueraria phaseoloides* (Legume cover crop).

Practical application: From the data obtained, when glyphosate at 0.33 kg, 0.5 kg and 0.75 kg/ha was blanket sprayed over an area of a mixture of legume and major grasses *P. conjugatum* and *O. nodosa*, initially up to 30 days after spraying, both the amount of legume cover crop and grasses were reduced. Subsequently, the coverage of grasses continued to decrease while the legume cover crop started to increase again. In the absence of competition from the grasses, the final coverage of the legume cover crop was significantly higher than what was initially observed at the time of spraying. The end result was that the areas which started with a mixture of legume cover crop and grasses ended up with almost pure legume. It is possible to use glyphosate for replacement of several rounds of hand weeding in established legume cover crop or to use glyphosate to rehabilitate legumes so heavily invaded by grasses to the extent that it becomes uneconomical to continue hand weeding. For this purpose, it appears that glyphosate at 0.5 kg/ha would be a suitable dosage. It ensures adequate safety to the legume cover crop plus consistent grass control with and adequate margin for error due to underspraying.

Table 1. Average % presence of legume and grasses.

Treatment	Average % of *Paspalum conjugatum* & *Ottochloa nodosa*						Average % of *Pueraria phaseoloides* (legume cover crops)					
	D A T											
	0	30	60	90	120	150	0	30	60	90	120	150
glyphosate, 0.25 kg	57	31	41	54	54	54	42	46	50	67	49	46
glyphosate, 0.33 kg	53	18	15	11	9	7	47	34	41	64	80	79
glyphosate, 0.50 kg	65	23	11	6	6	4	34	28	41	60	78	86
glyphosate, 0.75 kg	74	26	9	5	9	6	29	26	56	72	84	90
glyphosate, 1.00 kg	50	0	0	0	0	2	45	15	10	15	40	45
Control	65	—	—	—	—	70	35	—	—	—	—	30

The most important finding from this project is that glyphosate at 0.5 kg/ha can selectively remove the major grasses *P. conjugatum* and *O. nodosa* growing within established *P. phaseoloides* legume cover crop on rubber and oil palm plantation in Malaysia. This can be applied in practice to simplify legume cover crop management.

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The Effects of Dalapon-Sodium and Glyphosate on Young Clove Trees

A. ARIF [1] and I. M. PUTRAWAN [2]

ABSTRACT

A field experiment was conducted to obtain information on the effects of two herbicides, dalapon (sodium 2,2-dichloropropionate) and glyphosate [*N*-(phosphonomethyl)glycine] on alang-alang (*Imperata cylindrica* (L.) Beauv.) in young cloves. This was followed by greenhouse studies in the Jakarta area during the dry season of 1976. Two to three year-old clove seedlings were used in these trials. The seedlings were treated in the field after a 2 month growth and in the greenhouse one month after being placed on the benches. Results showed that there were no clear effects of dalapon and glyphosate through soil application. Foliar sprays of dalapon caused severe damage or death of the clove trees at concentrations of 1.5%. At 0.75% concentration they seemed less phytotoxic to the clove plants. Regrowth started after several months. Glyphosate applied as a foliar application at an 0.8% concentration caused damage to the plants, when applied twice at an interval of 3 weeks. Based on these results, alang-alang control with dalapon between young clove trees should be done outside the clean weeding-circle. Spray contact with clove foliage should be avoided. The safe recommendation for dalapon in cloves is 3 applications at 0.75% concentration at intervals of 3 to 4 weeks.

INTRODUCTION

Indonesia has a unique cigarette industry where clove spice or essence is blended with tobacco. This cigarette industry consumes more than 20,000 metric tons of cloves each year, and this amount cannot be supplied by domestic production. An increasing amount of this commodity is imported from East Africa every year. Farmers are attracted by the high price of cloves and grow them on any available land they have. Nowadays a farmer in Indonesia who has several clove trees will be considered a rich farmer [3] (Anon 1975).

In reality it is not as easy as many people think to grow a clove tree. Pest problems and the growing conditions required by the clove are

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3 Anon 1976. Percobaan penggunaan herbicida Dowpon di pertanaman cengkeh. Badan pembina proyek pengembangan cengkeh Lampung. (Unpublished report).

complicated. Certain soil conditions and special cultural practices need to be utilized. A major disease called "mati bujang" or die-young with die-back symptoms is often encountered. Alang-alang grass (*Imperata cylindrica*) is a real competitor with cloves, especially in the young stage The common control practice is to clean weed around the tree in a circle or square. Outside the weeding circle alang-alang grows well if the shade is not sufficient to suppress it. There is no doubt that alang-alang competes with clove roots for nutrients and water because of the fast growth of its under-ground rhizomes. Research reports have stated that alang-alang competition with other plants is allelopathic. For these reasons, plantations consider (Eussen and Wirjaharja 1973, Eussen *et al* 1974, Eussen and de Groot 1974) alang-alang a serious weed problem.

In plantation areas chemical control of alang-alang with dalapon is a standard practice, but for smallholders control of this grass in their fields is difficult. Outside Java, this is especially true because labor is short and relatively expensive . Manual methods of clearing the underground rhizome are not easy (Arif and Subagio 1976, Soedarsan 1975, Soepadiyo 1976, Soerjani 1970).

A government project in the southern part of Sumatra has introduced the use of dalapon in its clove planting scheme with no problem of phytotoxicity on clove tree itself. However, when this chemical is used by small farmers special guidance and precautions should be provided.

MATERIALS AND METHODS

The phytotoxicity effects were studied in the greenhouse and in the field. In green house studies, 2-and 3-year old seedlings were treated with soil and foliar applications of dalapon and glyphosate. Six-month old seedlings were planted in plastic pails together with alang-alang. After 2 month growth the seedlings were treated with a dalapon concentration of 0.75% (product) twice at an interval of 3 weeks. Glyphosate was also applied twice at an 0.8% concentration (product).

Field studies were also conducted using a microplot test of cloves growing in sheet alang-alang. To determine the phytotoxic effects of the two herbicides on the cloves in the field, 2 and 3 year old seedlings were planted at a 4 m by 4 m spacing. After a two month growth they were treated with the chemicals by foliar and soil application. Dalapon and glyphosate were applied to control alang-alang without protecting the cloves.

RESULTS AND DISCUSSION

1. Direct foliar spray tests of dalapon at concentrations of 0.75% and 1.5% applied one to three times produced symptoms ranging from light to severe phytotoxicity. Glyphosate foliar sprays at concentration of 0.8% applied once or twice also caused light toxicity symptoms on the seedlings (Table 1). In practice the spray is normally directed at the target species, and the crop is shielded from the spray.

Table 1. The phytotoxic effect of dalapon-sodium and glyphosate on clove seedling.

Treatment	2 years seedling		3 years seedling	
	10 DAT	40 DAT	10 DAT	40 DAT
A. Dalapon 0.75%	0.6	2.0	1.0	3.0
B. „ 0.75%/0.75%	1.0	2.2	1.2	3.2
C. „ 0.75%/0.75%/0.75%	1.0	3.0	1.2	3.2
D. „ 1.5%	1.2	3.5	1.2	3.7
E. „ 1.5%/1.5%	1.8	4.0	2.2	3.5
F. „ 1.5%/1.5%/1.5%	1.8	4.0	2.3	4.0
G. Glyphosate 0.8%	1.1	1.0	1.0	1.7
H. „ 0.8%/0.8%	1.1	1.0	1.2	2.0
I. Control	0.0	0.0	0.0	0.0

Note: Foliar application: DAT = days after first treatment
Rating 0 = no effect, 5 = dead.

2. The objective of the soil application test was to find out the phytotoxic effects of dalapon and glyphosate when applied to soil and subsequently taken up by clove roots. Results (Table 2) showed that from 27 DAT (days after treatment) to 4 DAT, the concentration of 0.75% dalapon applied three times caused very light symptoms, and 1 or 2 sprays caused no phytotoxic symptoms. Solutions of 1% to 1.5% showed only slight symptoms. Glyphosate treatments gave confusing results. One spray gave very light symptoms, but two applications gave no symptoms.

3. In the microplot test where clove and alang-alang were sprayed directly, all treatments caused phytotoxic symptoms on the cloves. Low concentrations of dalapon caused light phytotoxicity and high rates gave medium toxicity. The effect decreased after 9 weeks when plants

Table 2. The herbicidal effect of dalapon-sodium and glyphosate sprayed on alang-alang and cloves.

Treatment	Average rating (weed control).			
	7 DAT	14 DAT	30 DAT	37 DAT
A. Alang-alang with clove no treatment	0.00	0.00	0.00	0.00
B. Alang-alang with clove sprayed with 0.75% dalapon, 2 ×	2.25	2.25	9.75	10.00
C. Alang-alang with clove sprayed with 0.8% glyphosate	6.50	9.25	10.00	10.00
D. Control	—	—	—	—

Note: Interval was 3 weeks
Rating : 0 = no effect; 10 = complete kill of alang-alang.

from all treatments showed some regrowth. Glyphosate caused some degree of phytotoxicity (Table 3).

Table 3. Phytotoxic effect of dalapon-sodium and glyphosate on the clove seedlings planted in the alang-alang.

Treatment	Weekly rating of clove (phytotoxicity)									
	1	2	3	4	5	6	7	8	9	10
A. Dalapon 0.75%	1.50	1.37	1.50	1.50	1.50	1.87	1.87	1.87	0.90	0.37
B. „ 0.75%/0.75%	1.62	1.62	1.62	2.25	2.62	2.37	2.37	2.37	1.25	0.62
C. „ 0.75%/0.75%/0.75%	1.12	1.50	1.62	1.75	2.12	2.37	2.37	2.37	1.07	0.25
D. „ 1.5%	1.87	2.37	2.62	2.65	2.15	3.00	3.00	3.00	2.37	0.75
E. „ 1.5%/1.5%	1.90	2.25	2.75	2.75	2.87	3.25	3.25	3.25	2.75	0.75
F. „ 1.5%/1.5%/1.5%	1.75	2.25	2.25	2.25	2.25	3.50	3.33	3.37	2.75	1.12
G. Glyphosate 0.8%	0.75	0.75	1.25	1.25	1.25	1.25	1.25	1.37	0.75	0.25
H. „ 0.8%/0.8%	0.75	0.75	1.00	1.00	1.25	1.62	1.37	1.37	0.75	0.25
I. Control	—	—	—	—	—	—	—	—	—	—

Note:
Rating: 0 = no effect; 1 = very light toxicity; 2 = light toxicity; 3 = medium toxicity; 4 = heavy toxicity; 5 = dead.

4. Competition trials with alang-alang and clove seedlings showed that dalapon 0.75%/0.75% product and glyphosate at 0.8%/0.8% product gave excellent control of alang-alang without any phytotoxicity. The growth of cloves appeared to be promoted after the control of alang-alang. This was shown by a count of leaves per clove plant at 150 DAT. In the alang-alang plus seedling plot the average number of leaves was 80; in the dalapon treatment plots it was 91; in the glyphosate treatment it was 123; and in the clean weeded plot it was 93. The measurement of seedling height showed that in the plots where dalapon and glyphosate were sprayed the seedlings were a little bit shorter than in the control plots, but the differences seem slight. Leaf size in the alang-alang plot was smaller than that in the control alang-alang plot and the no alang-alang plot.

One can conclude from these results that uncontrolled alang-alang suppresses the growth of clove seedlings.

5. Observation in the field trial showed that foliar spray of dalapon at concentrations of 0.75% caused light symptoms of phytotoxicity on

Table 4. The phytotoxic effect of dalapon and glyphosate application on young clove by rating system.

Treatment	Observation by rating				
	16 DAT	30 DAT	44 DAT	58 DAT	72 DAT
1. D_1S_w	0.00	0.00	0.00	0.00	0.00
2. D_1S_o	0.00	0.00	0.00	0.00	0.00
3. D_1F	0.75	1.00	1.25	1.50	2.90
4. D_2S_w	0.00	0.00	0.00	0.00	0.00
5. D_2S_o	0.00	0.00	0.00	0.00	0.00
6. D_2F	1.00	4.00	4.75	5.00	5.00
7. G_3S_w	0.00	0.00	0.00	0.00	0.00
8. G_3S_o	0.00	0.00	0.00	0.00	0.00
9. G_3F	0.00	0.00	0.00	0.00	0.00
10. C	0.50	1.00	1.00	1.50	2.00

Note:

DAT = days after first treatment
G = glyphosate
S = soil application
O = no watering
1 = doses 0.75% + 0.75% product
2 = doses 1.5% + 1.5% product
0 = no effect

D = dalapon
F = foliar application
W = watered after spraying
C = control
3 = doses 0.8% + 0.8% product
5 = total toxicity, plant is dead

clove, but in soil application no symptoms appeared. Concentrations of 1.5% dalapon product at around 50 DAT caused complete necrosis. Glyphosate at a concentration of 0.8% as a foliar spray caused light phytotoxicity to cloves, but none with soil applications.

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Mile-a-minute [Mikania cordata (Burm.f.) B.L. Robinson] Eradication in Immature Rubber

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ABSTRACT

Mile-a-minute [*Mikania cordata* (Burm. f.) B.L. Robinson] is one of the most troublesome weeds in plantation crops in North Sumatra, because it competes strongly for available water and nutrients and contains allelopathic substances. Its complete eradication from immature rubber is important to ensure the normal growth of the trees. This paper describes experiments undertaken for mile-a-minute control under immature rubber. Four translocated herbicides 2,4-D[(2,4-dichlorophenoxy) acetic acid] amine, 2,4-D Na, ioxynil (4-hydroxy-3,5-diiodobenzonitrile), and MCPA ([(4-chloro-*o*-tolyl) oxy] acetic acid) and one contact herbicide paraquat (1,1'-dimethyl-4,4'-bi-pyridinium ion) were tested. In all cases the initial application was followed by second application. The best control was observed on the plot which had received 0.75 kg/ha 2,4-D amine applied in two applications at four week intervals. The other effective treatments were 2,4-D Na and ioxynil at 0.75 kg/ha also sprayed twice at 4-week intervals.

INTRODUCTION

It is becoming increasingly clear that mile-a-minute under rubber is detrimental to both growth and yield of rubber as it competes strongly with the main plant for available water and nutrients, mainly for nitrogen. According to Wong (1964) it not only competes for water and nutrients but it also contains allelopathic substances, which on leaching or excretion can depress the growth of rubber. Mangoensoekarjo and Soewadji (1973) showed that mile-a-minute retarded the growth of a immature rubber and this effect could be seen from the reduced girth, fewer yellowish leaves and the developed canopy; opening for tapping had to be delayed for at least a year. It can be seen then, that it must be eradicated.

Hand weeding is costly and chemical control has proved to be the most efficient method for eradication. Chemical control of mile-a-minute in rubber plantations in North Sumatra has been practiced for many years and 2,4-D amine has been used on a large scale; this is one of the herbicides recommended for mile-a-minute both in North Sumatra (Mangoensoekarjo and Kadnan 1973, Soewadji and Butar-butar 1975), and in Malaysia (Ramachandran *et al* 1968, Pushparajah 1970).

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The trial reported in this paper was undertaken to compare 2,4-D amine with some selected new herbicides for the control of mile-a-minute under immature rubber.

MATERIALS AND METHODS

The trial was conducted at Deli Muda Estate, PT Indah Poncan (private rubber estate) Medan, Indonesia, during the period of August 1976 to January 1977 on alluvial soil, pH 5.5.

Area of heavy sheet mile-a-minute between the rows of immature rubber trees was divided into plots of 6 by 8 m. The design was randomized block (RBD), with ten treatments and four replications (Table 1).

Table 1. Treatments, rate and interval of application.+)

	Treatments	Rate a.e. or a.i. kg/ha	Interval between first and second, application (weeks)
1.	2,4–D amine	0.75 fb 0.75	4
2.	2,4–D Na	0.75 fb 0.75	4
3.	Ioxynil	0.75 fb 0.75	4
4.	MCPA	0.75 fb 0.75	4
5.	Paraquat	0.40 fb 0.40	2
6.	2,4–D amine fb. paraquat	0.75 fb 0.40	4
7.	2,4–D Na fb. paraquat	0.75 fb 0.40	4
8.	Ioxynil fb. paraquat	0.75 fb 0.40	4
9.	MCPA fb. paraquat	0.75 fb 0.40	4
10.	Hand weeding	–	

+) fb = followed by (sequential) . . . weeks after first application.
2,4–D amine = Herbazol 72%, 2,4–D Na = U 46 D– powder 80%.
ioxynil = Actril D 35%, MCPA = U 46 M Fluid 71.87%, paraquat = Gramoxone 20%.
The herbicides were applied in 600 l per hectare.
Treatments no. 1, 2, 4, 6, 7 and 9 were added with Agral (wetting agent) 0,05%.

Spraying was done with a Knapsack sprayer fitted with a blue (1.575 mm) polijet tip nozzle. To ensure equal spray per plot, the pressure was kept constant at 1 kg/cm^2 by the use of a gauge and the walking speed of 2 — 3 km/hr was controlled by a stop-watch.

The effect on mile-a-minute was recorded from two to eight weeks after spraying by visual estimation of the percentage score relative to the unsprayed control: 0 — indicating no effect and 100 — complete dessication. After 13 weeks the percentage of regrowth was recorded up to the 21st week.

The effect of treatment on rubber leaves was assessed visually. The data were analysed using Duncan's multiple range test.

RESULTS AND DISCUSSION

Phytotoxicity. No toxicity symptoms were observed on the rubber leaves two weeks after spraying or at the final observation.

Mile-a-minute control. (Table 2). The effect of paraquat on mile-a-minute appeared two days after spraying, when the leaves tended to dry out. Treatments with 2,4-D amine, 2,4-D Na, ioxynil and MCPA after two weeks caused mile-a-minute to wither and dry out. But the effect caused by MCPA was significantly lower than the other (50% control). In the previous trial Mangoensoekarjo and Kadnan (1973) found that 1.5 kg/ha MCPA at 20 days after spraying gave the lowest control compared with 0.75 kg/ha 2,4-D amine and 0.75 kg/ha ioxynil. The observations on mile-a-minute control after eight weeks, showed that application of 2,4-D amine, 2,4-D Na and ioxynil at 4-week intervals were significantly different from treatments followed by paraquat. It was proved that in case of 2,4-D amine, 2,4-D Na and ioxynil best results were obtained if the first and second spraying were with the same herbicide.

Mile-a-minute regrowth. (Table 2). The effect of 2,4-D amine, 2,4-D Na and ioxynil followed by the same herbicides at 17 weeks after spraying showed that mile-a-minute regrowth was significantly different from plots treated with other herbicides and from hand weeded plots. But at 21 weeks after spraying, plots sprayed with 2,4-D amine were significantly different again when compared with the treatments tested.

It was indicated that at application of 2,4-D amine 0.75 kg/ha followed by the same herbicide four weeks after the first application, provided maximum control (97.25%) eight weeks after spraying and minimum regrowth (26.25%) 21 weeks after spraying. So this herbicide can inhibit mile-a-minute regrowth for a long period.

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Table 2. Mean percentage control of mile-a-minute and regrowth.

	Treatments	Mile-a-minute control*)								Mile-a-minute regrowth*)							
		2 weeks		4 weeks		6 weeks		8 weeks		13 weeks		15 weeks		17 weeks		21 weeks	
		%	.05	%	.05	%	.05	%	.05	%	.05	%	.05	%	.05	%	.05
1.	2,4–D amine 0.75/0.75	83.75	ab	81.75	ab	96.50	a	97.25	a	16.25	d	16.25	f	22.50	d	26.25	d
2.	2,4–D Na 0.75/0.75	80.00	a-c	76.25	a-c	93.25	a	91.75	a	25.00	cd	28.75	ef	32.50	cd	53.75	c
3.	Ioxynil 0.75/0.75	86.25	a	62.50	c	96.00	a	94.25	a	23.75	cd	42.50	de	38.75	cd	56.25	c
4.	MCPA 0.75/0.75	50.00	d	31.25	c	58.75	c	61.25	e	75.00	a	78.75	ab	78.75	ab	85.00	a
5.	Paraquat 0.40/0.40	71.25	c	86.25	d	22.50	d	16.25	f	78.75	a	86.25	a	82.50	a	80.00	ab
6.	2,4–D amine/paraquat 0.75/0.40	87.50	a	83.75	a	83.75	b	78.75	c	58.75	ab	65.00	bc	66.25	ab	57.50	a
7.	2,4–D Na/paraquat 0.75/0.40	80.00	a-c	82.50	ab	85.00	b	81.25	bc	50.00	b	57.50	cd	63.75	b	63.75	bc
8.	Ioxynil/paraquat 0.75/0.40	88.75	a	66.25	bc	80.00	b	72.50	cd	57.50	ab	65.00	bc	66.25	ab	72.50	a-c
9.	MCPA/paraquat 0.75/0.40	57.50	d	33.75	d	68.75	c	50.00	e	73.75	a	71.25	a-c	75.00	ab	81.25	ab
10.	Hand weeding	76.25	bc	28.75	d	22.50	d	90.00	ab	38.75	bc	41.25	de	40.00	c	61.25	bc

*) Original data, analysis of variance based on values transformed to arcsin $\sqrt{\%}$
Any two treatments means in a column followed by the same letter are not significantly different at the 5% level (Duncan's multiple range test).

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Velpar Used Alone and in Combination with Diuron for the Control of Weeds in Rubber Plantations

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ABSTRACT

Exploratory work was conducted in rubber in 1975 in Malaysia with Velpar (= hexazinone 3-cyclohexyl-6-(dimethylamino)-1- methyl-1,3,5,-triazine-2,4(1H, 3H)-dione) a new triazine dione for which a generic name has not yet been established. From the promising results obtained further investigations were carried out in 1976 — 1977 in 3-year old and over rubber plantations with Velpar used alone and in various combinations with diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea]. The chemicals were applied as postemergence to weeds under a varied set of climatic conditions and soil types. From those trials it is recorded that Velpar at low rates of application in combination with diuron provided better weed control than Velpar used alone. The most effective combination of Velpar with diuron was the 1 : 5 ratio applied at the rates of 1.80 — 2.10 kg a.i./ha. Phytotoxicity effects as evaluated by visual symptoms and girth measurements showed that Velpar and its combinations with diuron had no adverse effect on crop growth at the rates used in those trials. Studies in progress on the residual activity of the Velpar-diuron combination in the soil have indicated no phytotoxic effect 3 months after the second spray at the same rates of application and in the same experimental plots.

INTRODUCTION

Velpar is a new triazine dione for which a generic name has not been established. Its trade name "Velpar" will therefore be used for the presentation of investigational work conducted with this chemical in rubber. As its physical chemical and toxicological properties have already been described elsewhere, it might only be necessary to recall here that it is available as a 90% soluble powder with a solubility of 32,000 ppm in water at 25°C and that it is non-flammable, non-volatile and non-corrosive.

Velpar being an exceptionally active herbicide, highly effective when applied to plant foliage as well as when applied to the soil, exploratory work on it was started in 1974 — 1975 in Malaysia to evaluate its effectiveness for controlling weeds in rubber. Preliminary data obtained

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on its performance when applied postemergence of weeds either alone or in combination with diuron proved most satisfactory and stimulated further investigations to be conducted furing the years 1976—1977. However as it was established in earlier work that Velpar and its combinations with diuron could prove phytotoxic to young plantings under 3 year old, further work was, therefore, carried out only in plantations 3 or more years old.

The paper presented reviews the experimental data obtained during these last two years with this triazine dione used alone and in combination with diuron.

MATERIALS AND METHODS

Some 30 trials were conducted in Malaysia under a varied set of climatic conditions and soil types. The statistical layout for the trials was a randomized block with 4 replications. Plot size consisted of a strip 10.5 m long by 2.4 m wide and there were 3 trees in each experimental plot. Velpar used alone was tested at rates 0.30 kg a.i./ha to 0.72 kg a.i./ha and when applied in combination with diuron the ratio of Velpar to diuron in terms of active ingredient varied from 1 : 4 to 1 : 5. The experimental work was conducted in postemergence weeds and the herbicides were applied with Knapsack sprayer fitted with fanjet nozzles.

Weed control effectiveness was evaluated by a new scoring technique evolved by the writer (unpublished) which registered effect on established weeds, regeneration from underground and above ground parts of perennial plants and regeneration from seeds from both annual and perennial weeds.

Crops tolerance was evaluated in two ways:

(1) By visual assessment of phytotoxic symptoms in terms of numerical values or indices related to a rating scale whereby "0" means no crop injury, "5" severe leaf chlorosis associated with a stunting effect and "10" complete kill.

(2) By measurement of tree circumference at the standard height of 1.52 m above ground level.

Of the 30 trials conducted only 6 will be presented of which 3 illustrate weed control efficacy and crop response when Velpar was applied alone at rates from 0.30 kg a.i./ha to 0.72 kg a.i./ha and in various combinations with diuron. The other 3 trials presented demonstrate the weed efficacy of Velpar in combination with diuron when applied in the ratio of 1 : 4 and 1 : 5 respectively, and in these trials effects on weeds and crop tolerance after a second application are also presented.

Comparative performance trials. These trials were conducted in 3—4 year old rubber plantations with abundant weed growth at the time of herbicide application and the results obtained are presented in Table 1. In these trials Velpar was applied alone at rates 0.30, 0.42, 0.60 and 0.72 kg ai/ha. In combination Velpar was used at rates 0.25, 0.30, 0.36, 0.42, 0.60 and 0.72 kg a.i./ha with diuron at 1.20, 1.25, 1.44, 1.50, 1.68, 1.75, 2.88 and 3.00 kg a.i./ha to satisfy the combination ratio of Velpar to diuron 1 : 4 and 1 : 5 respectively.

Cumulative toxicity trials. In the second series of trials presented only the Velpar-diuron combinations were tested at rates more likely to be used in general application. The objective was to repeat treatment every 3—4 months on each respective experimental plot in order to observe the effect on the residual activity on crop growth.

Results obtained are presented in Tables 2 and 3. In those trials Velpar was applied at rates 0.30, 0.35 and 0.36 kg a.i./ha with diuron at rates 1.20, 1.44, 1.50 and 1.75 kg a.i./ha (Test 4). In Tests 5 and 6 in order to promote an accelerated response of the crop to the toxic effect of those combinations Velpar at 0.60 — 0.72 kg a.i./ha with diuron 3.00 and 2.88 kg a.i./ha respectively were applied at the two spraying times. Results from Table 2 are those recorded at 6 — 16 weeks after the first spraying and those in Table 3 are those recorded at 6 — 13 weeks after the second spraying.

RESULTS

Comparative performance trials. Crop response. Velpar and its combinations with diuron had no effect on crop growth as determined by visual assessment of phytotoxic symptoms.

Weed response. From the weed angle the data presented in Table 1 show that in general Velpar at low rates of application in combination with diuron provided better weed control than Velpar, used alone. In all the trials under review the annual grass species *Ottochloa nodosa* was the most abundant species at the experimental sites and in Test 2 it was the only dominant species and was about 0.75 m high at the time of spraying. From the data presented for that test however it will be observed that all Velpar-diuron combinations were still giving excellent weed control of this species 3 months after application. Other major weed species present at the two other experimental sites (Test 1 and Test 3) were *Mikania cordata* B.L. Robinson, *Borreria alata* DC, *Eleusine indica* Gaernt, *Gayratia* Gagu, and the legumes *Pueraria phasoloides* Bth, *Calopogonium caeruleum* Gagu. and *Centrosema pubescens* Bth. Occasional species were *Cynodon dactylon* Pen, *Cyperus rotundus* L, and *Paspalum conjugatum* Berg.

The Velpar-diuron combinations proved effective on all the major weed species present but had only a suppressing effect on *C. rotundus* and *C. dactylon,* the degree of control exercised being related to rate of application used. At the combination rate of Velpar (0.72) plus diuron (2.88) growth suppression of those species was effective over 10 weeks. It must be noted that the standard treatments consisting of paraquat + diuron and MSMA (monosodium methanearsonate + sodium chlorate + diuron or 2,4-D amine [amine(2,4-dichlorophenoxy) acetate] provided a good knock down effect but showed little residual activity 6 — 8 weeks after application.

The best rates of Velpar plus diuron in the ratio of 1 : 4 were Velpar (0.36 — 0.42) to diuron (1.44 to 1.68) and in the ratio 1 : 5 was Velpar (0.30 — 0.35) to diuron (1.50 to 1.75). It must be observed that those combinations applied at twice those rates also proved safe to the crop (Tests 5 and 6)

Cumulative Toxicity Trials. Crop response. No crop phytotoxicity was recorded in these trials at any of the rates if application of the Velpar-diuron combinations was used both at 12 weeks after first spraying and at a further 12 weeks after the second spraying. It is most interesting to note that in Tests 5 and 6 the first and the second spraying at double the rates of application of the combination Velpar (0.60 — 0.72) and diuron (3.00 — 2.88) respectively, also proved safe to the crop. This accelerated phytotoxicity test suggests that 4 applications of the combinations of Velpar (0.30 — 0.36 kg a.i./ha) and diuron (1.44 — 1.50) during the year would lead to no crop damage. As these experiments are still in progress for a third and fourth spray more information regarding residual activity in relation to crop tolerance will become available.

Weed response. Weed distribution in the second series of trials was typified by *O. nodosa* being again the dominant grass species. Other species occurring were *P. conjugatum, B. alata, M. cordata* and the legumes *P. phaseoloides, C. pubescens.* In general all Velpar-diuron combination rates applied proved effective but the combination Velpar (0.30 — 0.35 kg a.i./ha) with diuron (1.50 to 1.75 kg a.i./ha) showed more consistent effectiveness over the 12 weeks period. *P. conjugatum* was effectively controlled at the highest combination rates but *M. cordata* was only severely suppressed with chlorotic shoots regenerating 12 weeks after the application from the trailing above ground stems. In general the trend in effectiveness of the Velpar-diuron combinations was the same as in the first series of trials. The use of double rates of the combination (Table 1 and 2 — Tests 5 and 5a, 6 and 6a) gave outstanding weed control of all species present for over a 12-week period.

Table 1. The effect of Velpar used alone and in combination with diuron on the control of weeds in rubber.

Table 1. The effect of Velpar used alone and in combination with diuron on the control of weeds in rubber.

Treatment (kg a.i./ha)	Test : 1 Location: Malacca Crop age: 4 years old Soil type: lateritic No. rainy days: 29 Togal rainfall: 343 mm			Test : 2 Location: Malacca Crop age: 3 years old Soil type: sandy loam No. rainy days: 26 Total rainfall: 527 mm			Test: 3 Location: N. Sembilan Crop age: 3 years old Soil type: sandy clay loam No. rainy days: 39 Total rainfall: 684 mm		
	% Weed control			% Weed control			% Weed control		
	2 Weeks after	6 Weeks after	12 Weeks after	2 Weeks after	6 Weeks after	12 Weeks after	2 Weeks after	6 Weeks after	12 Weeks after
Velpar (0.30) + diuron (1.20)	71.7	82.5	78.0	73.9	88.4	58.0	78.9	87.6	43.4
Velpar (0.36) + diuron (1.44)	77.7	83.0	78.9	83.8	92.8	83.4	78.2	85.7	67.3
Velpar(0.42) + diuron (1.68)	80.8	80.8	83.4	85.8	94.0	88.0	83.5	89.5	73.0
Velpar (0.25) + diuron (1.25)	83.1	90.5	80.2	76.7	88.9	70.3	69.2	72.9	49.8
Velpar (0.30) + diuron (1.50)	84.3	86.3	83.3	70.3	85.3	85.7	78.1	86.6	67.3
Velpar (0.35) + diuron (1.75)	79.2	56.3	80.2	82.2	82.3	83.1	80.3	87.3	74.3
Velpar (0.60) + diuron (3.00)	94.0	96.4	89.2	84.3	95.6	88.0	81.8	89.8	78.4
Velpar (0.72) + diuron (2.88)	89.7	94.8	87.3	86.3	94.8	91.5	80.5	89.7	83.0
Velpar (0.30)	58.8	46.9	50.2	57.7	56.5	43.1	67.6	43.0	6.1
Velpar (0.42)	64.7	59.2	62.7	75.0	85.2	66.4	61.0	41.3	11.7
Velpar (0.60)	67.8	72.9	76.7	74.0	77.5	68.6	70.3	65.6	40.0
Velpar (0.72)	-	-	-	84.7	91.7	82.9	67.9	75.9	41.4
Paraquat (0.56) + diuron (0.45)	82.0	38.6	13.4	92.1	69.4	27.1	89.5	75.4	23.8
MSMA (2.24) + 2,4–D amine (2.0) + sodium chlorate (5.60)	-	-	-	-	-		91.6	58.0	0.0
MSMA (2.24) + diuron (0.45) + sodium chlorate (5.60)	-	-	-	81.6	66.9	25.0	-	-	-

Table 2. The effect of Velpar in combination with diuron on the control of weeds and on crop growth response 12 weeks after 1st spraying.

Treatment (kg a.i./ha)	Test : 4 Location: Malacca Crop age: 3 years Soil type: sandy loam No. rainy days: 26 Total rainfall: 517 mm				Test : 5 Location: N. Sembilan Crop age: 3 years Soil type: sandy loam No. rainy days: 39 Total rainfall: 684 mm				Test : 6 Location: N. Sembilan Crop age: 3 years Soil type: sandy loam No. rainy days: 35 Total rainfall: 784 mm			
	% Weed control		Mean girth (cm)		% Weed control		Mean girth (cm)		% Weed Control		Mean girth (cm)	
	6 weeks after	12 weeks after	Prior to spray	16 weeks after spray	6 weeks after	12 weeks after	Prior to spray	13 weeks after spray	6 weeks after	12 weeks after	Prior to spray	15 weeks after spray
Velpar (0.30) + diuron (1.20)	76.7	47.8	20.8	24.2	92.6	68.8	23.7	26.6	86.3	58.3	19.2	24.2
Velpar (0.36) + diuron (1.44)	92.5	70.7	20.5	24.6	92.2	69.3	21.8	24.5	78.5	68.8	21.0	26.5
Velpar (0.30) + diuron (1.50)	94.0	88.7	20.5	23.5	98.7	78.3	21.9	24.6	86.4	70.8	20.2	24.6
Velpar (0.35) + diuron (1.75)	91.4	82.7	18.9	21.7	91.6	72.8	22.0	24.8	89.1	74.4	20.3	25.4
Velpar (0.60) + diuron (3.00)	-	-	-	-	90.5	83.5	23.1	25.6	94.3	88.9	20.3	25.0
Velpar (0.72) + diuron (2.88)	-	-	-	-	90.5	88.9	23.1	25.9	93.6	87.0	22.7	27.7
Paraquat (0.56) + diuron (0.45)	49.2	16.7	18.1	21.1	85.0	13.3	22.4	25.3	78.5	29.5	20.9	26.0
MSMA (2.24) + 2,4–D amine (2.0) + sodium chlorate (5.6)	-	-	-	-	-	-	-	-	49.8	2.3	20.3	25.4
LSD (P = 0.05)				NS					NS			NS

Table 3. The effect of Velpar in combination with diuron on the control of weeds and on crop growth response 12 weeks after 2nd spraying.

Treatment (kg a.i./ha)	Test: 4a Location: Malacca Crop age: 3 years Soil type: sandy loam No. rainy days: 31 Total rainfall: 552 mm				Test: 5a Location: N. Malacca Crop age: 3 years Soil type: sandy loam No. rainy days: 20 Total rainfall : 459 mm				Test: 6a Location: N' Malacca Crop age : 3 years Soil type: sandy loam No. rainy days: 12 Total rainfall: 134.6			
	% Weed Control		Mean girth (cm)		% Weed Control		Mean girth (cm)		% Weed Control		Mean girth (cm)	
	6 Weeks after	12 Weeks after	Prior to spray	13 Weeks after spray	6 Weeks after	12 Weeks after	Prior to spray	13 Weeks after spray	6 Weeks after	12 Weeks after	Prior to spray	12 Week after spray
Velpar (0.30) + diuron (1.20)	51.0	41.1	24.2	26.9	77.6	54.1	26.6	30.3	71.7	70.0	24.2	25.8
Velpar (0.36) + diuron (1.44)	71.2	79.7	24.6	28.2	80.0	68.1	24.5	28.2	78.5	76.4	26.5	28.2
Velpar (0.30) + diuron (1.50)	69.7	72.0	23.5	26.4	76.8	75.6	24.6	27.9	77.8	75.7	24.6	27.9
Velpar (0.35) + diuron (1.75)	71.3	75.1	21.7	24.6	86.0	70.0	24.8	28.1	82.5	79.3	25.4	28.0
Velpar (0.60) + diuron (3.00)	-	-	-	-	83.9	70.4	25.6	29.0	90.8	80.5	25.0	26.9
Velpar (0.72) + diuron (2.88)	-	-	-	-	80.3	76.5	25.9	29.7	92.2	90.9	27.7	29.5
Paraquat (0.50) + diuron (0.45)	29.1	20.8	21.1	24.1	74.4	46.4	25.3	28.7	64.3	48.6	26.0	27.8
MSMA (2.24) + 2,4–D amine (2.0) + sodium chlorate			-		-	-	-	-	32.1	22.7	25.4	27.4
L S D (P = 0.05)				NS				NS				NS

DISCUSSION

From the data presented in these trials it was established that Velpar plus diuron combinations are effective on the major weed species occurring in rubber plantations. Those combinations have shown excellent knock down effects on the weeds and also provided satisfactory residual herbicide activity for over 12 weeks depending on the weed spectrum and density of the weed canopy at the time of application. At all rates of the combinations tested in these trials no crop injury was recorded as determined by visual phytotoxicity symptoms and tree girth measurements. Outstanding crop tolerance in 3-year old plantings was shown when the combinations Velpar at 0.60 — 0.72 kg a.i./ha with diuron at 3.00 and 2.88 kg ai/ha were applied in an accelerated phytotoxicity test. The amount of diuron in these combinations would appear to be of significance and in general it seems to be in the vicinity of 1.50 kg a.i./ha.

Results from Table 2 and Table 3 would appear to support the conclusion that the best combination rate under Malaysian conditions would appear to be Velpar-diuron in the ratio 1 : 5 applied at rates of Velpar 0.30 — 0.35 kg a.i./ha with diuron at 1.50 — 1.75 kg a.i./ha respectively.

From the weed angle the Velpar-diuron combinations gave outstanding control of the most important and widespread weed species of rubber, that is, *O. nodosa* which is imperfectly controlled by the actual standard treatments in use.

Depending on the density of the weed canopy varying degrees of control of *C. dactylon* and *C. rotundus* were recorded. When the Velpar-diuron combination treatments were applied over a dense canopy with *Cynodon dactylon* and *C. Cyperus rotundus* occuring in the lower stratum of the weed population it could well be that the chemicals are intercepted by the weed canopy consequently a toxic concentration at cell level for those species might not be reached because smaller quantities of the chemical become deposited on the soil surface. This point will have to be verified in further experimental work.

It will be observed in Table 1, that the addition of diuron to Velpar provided a better knock down effect than Velpar used alone. This was more evident when the following field conditions were met:

(1) adequate soil moisture.
(2) a humid micro climate over weed foliage.
(3) when shaded situations are prevailing.
(4) when temperatures are relatively high.

To conclude it may be said that the combination exhibits the best knock down activity under optimum growing conditions.

Problems and Control of Weeds on Young Tea in Indonesia

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ABSTRACT

The undesirable effects of manual or mechanical weed control on young tea, traditionally applied in Indonesia, could be avoided by using herbicides. Pre-emergence herbicides proved to be very useful in controlling weeds propagated by seeds. The triazine group appeared to be the best for this purpose, without affecting young tea plants. Further investigations and field trials on the application of diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] are still needed to obtain a clear picture of the effect of this herbicide on young tea plants. Postemergence herbicides such as paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) and other contact herbicides are also recommended for use in young tea. A special application technique to avoid plant damage is required. Glyphosate [*N*-(phosphonomethyl) glycine] proved to give good results in controlling many species of weeds and was not harmful to the young tea plants.

INTRODUCTION

The rehabilitation of the tea (*Camellia sinensis* var. *assamica* (Mast.) Steen.) industry in Indonesia was started in 1970 by the government tea estates, and in 1974 by the smallholder and private tea estates. Replanting of abandoned areas and block infilling on a large scale is one of the objectives of the rehabilitation program. It is expected that in the future, the hectarage of young tea will increase steadily.

Based on past experience, special attention must be paid to the upkeep of young tea plants. Weed control plays an important role as the upkeep cost is much higher in young tea compared with that in mature tea. Weeds in young tea are considered to be the most important problem due to the fact that they suppress tea growth and prolong the non-productive period (Sharma 1967, Anon. 1969, Soedarsan *et al* 1975).

Chemical weed control had been used in producing fields since the 1970's, and seems to give effective results. Due to the risk of plant damage and limited data, chemical control is not applied in young tea. Insufficient mechanical weed control in young tea is found on many tea estates as well as in smallholder plantings. Plant damage, loss of top soil to erosion and retardation of growth are usually observed. In a large part of the young

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tea plantings, mechanical weed control is difficult to affect at the right time because the method of weeding is very labour intensive (van Staalduine 1972). There is a need for more labour in the producing fields as well as in the factory, due to the increased production resulting from the rehabilitation programme.

Chemical weed control has been used in young tea in East Africa and South India (Anon. 1969, Sharma 1967). Some preliminary experiments and field trials which have been carried out in the Research Institute for Tea and Cinchona (RITC) — Indonesia, showed that certain herbicides applied correctly give good weed control without affecting the young tea plants[2].

WEED PROBLEMS IN YOUNG TEA

New tea plants are planted in the field at a spacing of 120 cm by 60 cm, leaving a large area of soil surface open to full sunlight. This condition lasts for 2 years and is very favourable for weed growth before the canopy of the tea bushes completely covers the soil. As in other crops, weeds in young tea compete for nutrients, water (in the dry seasons) and occasionally for light (Sharma 1967, Soedarsan *et al* 1975). It is mentioned by Venkataramani (1973), and Soedarsan *et al* (1975) that there is a possibility that toxic exudates of weeds could play an important role in retarding the growth of young tea plants.

Various weeds in tea plantations were identified by Backer and van Slooten (1924). According to Soedarsan *et al* (1974), the weed composition differs from one tea estate to another. Perennial grasses create the greatest problem in tea plantations (Sharma 1967, Anon. 1969). It is due to the fact that these grasses propagate not only by seeds, but often by ground runners and underground parts such as stolons, rhizomes, tubers or bulbs which all make these grasses difficult to eradicate.

Grasses with shallow fibrous roots and soft broadleaf weeds appear to be less troublesome in comparison with the deep rooting perennial grasses. The eradication of deep rooting perennial grasses by mechanical weeding is very difficult because pieces of rhizome left in the soil can sprout and start a new plant. Moreover, insufficient mechanical weeding of grasses, such as alang-alang (*Imperata cylindrica* (L.) Beauv.) and *Panicum repens* L., might stimulate the growth of these weeds.

Soedarsan *et al* (1975) reported, that there are indications that the growth retardation of the young tea plant is related to nutrient uptake

2 Martosupono M, M. Sanusi, K. Suhargiyanto and R. Purnama 1976. Pengujian beberapa herbisida "pra-tumbuh" pada tanaman teh muda. Research Institute for Tea and Cinchona. Unpublished.

of the weed. He also stated that the production of organic matter by weeds should be in some way related to the extent of nutrient uptake.

In an effort to understand and cope with the weed problems in young tea plantations it should be noted that most of the tea plantations in Indonesia are located on steep areas with a relatively high rainfall so soil erosion is an important consideration.

WEED CONTROL IN YOUNG TEA

Most weed control in young tea plantations in Indonesia is carried out mechanically, either by slashing, forking and digging, or by handpulling. To obtain adequate control, this effort must be carried out at least 8 to 10 times per year requiring 100 to 200 man days/ha/year or more for special grasses such as alang-alang (van Staalduine 1972).

On many estates, due to the shortage of labour, weeding operations on large areas of young tea is often carried out too late and with unskilled labour. Most of the areas are in an undesirable weed condition where some woody weeds need to be removed by digging or perhaps by deep soil cultivation. Van Staalduine (1972) described the undesirable effects of mechanical weed control practices, as follows :

1. Late weed removal suppresses growth of young tea, due to competition.
2. Serious damage to the roots of young tea retards the plants growth.
3. Decreasing soil fertility by soil erosion.

Strip weeding has also been done on many tea estates, particularly on the steep slopes in order to control soil erosion. In practice this system is often not performed in a correct manner as in the case of mechanical clean weeding. Insufficient labour and rapid growth of weeds in strip weeding systems, often cause the weeding operations to be carried out after weed damage has occurred.

Mulching with leaves of Guatemala grass *(Tripsacum laxum)* or other materials on young tea could suppress weed growth and control soil erosion. It is not applicable on a large scale due to its high cost. Planting a cover crop between tea rows is more applicable in a large area. Two kinds of cover crops are usually planted in young tea areas, *Tephrosia vogelii* Hook. f. and *Crotalaria anagyroides* H.B.K. A regular pruning should be done to avoid competition to the young tea plants.

CHEMICAL WEED CONTROL AND ITS PROSPECT

In producing fields, as mentioned above, chemical weed control has been widely applied in Indonesia. Even so, further research on this subject still needs to be done due to the fact that continual spraying with the same herbicide, such as paraquat, from year to year has changed the weed composition and enhanced the growth of dominant weeds which are now resistent to paraquat. The continuous use of only one herbicide over a long period, will create new weed problems.

Very limited data on the use of herbicides in young tea, seem to be the reason that chemical control is not applied widely in Indonesia. In East Africa and South India, the use of certain herbicides to control weeds in young tea has been recommended since 1967 (Sharma 1967, Anon. 1969).

Pre-emergence herbicides, which persist in the soil, could be very useful to prevent growth of various weeds. Triazine herbicides have been shown to be safe for young tea and keep the treated area in an acceptable condition for 2 to 4 months after spraying (Sharma 1967, Anon. 1969). In North Sumatra, several pre-emergence herbicides have been tested in young tea plants. Van Staalduine (1972) reported that simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) at 1.5 kg/ha and other triazines at the same rate are safe for young tea plants. Sharma (1967) recommended higher doses of 4 to 6 kg/ha of simazine and 3 to 4 kg/ha of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) which were effective in controlling broadleaf weeds and shallow rooted grasses without adversely affecting the tea. It is also mentioned that simazine can be sprayed safely in 6-month old young tea plants in the field.

Another pre-emergence herbicide is diuron, which showed good results in controlling weed which propagated generatively. According to van Staalduine (1972) in North Sumatra the use of diuron at to 2.4 kg/ha damaged the young tea plants. It is also recommended by Venkataramani (1973) that even in mature tea, use of diuron should not be more than 0.5 kg/ha per application, and not more than 1 kg/ha/year. The effect of diuron on tea plants differs depending on the type of the soil and the organic matter content. There is also a possibility that the susceptibility of different tea clones to diuron is different. Further experiments with this herbicide are needed.

Paraquat, a contact herbicide which is directly inactivated in the soil, could be very useful in controlling weed growth in young tea. A special technique of spraying must be used to avoid plant damage caused by contact with the herbicide (Anon. 1969). Paraquat kills only the green parts of a plant, so in a high population density of broadleaf weeds and perennial grasses with deep rooting systems, applications need be applied at close intervals (Sharma 1967, Venkataramani 1973).

Dalapon (2,2-dichloropropionic acid) which is effective in controlling alang-alang and perennial grasses, is not recommended on tea less than 2 years old because of it systemic action and persistence in the soil (Anon. 1969).

To eliminate harmful effects of perennial grasses, mechanical weeding by pulling out the underground parts of the weeds and removing these parts from the field is still recommended in combination with chemical (spot) spraying using a contact herbicide. This method of control is expensive but must be done to enhance the growth of the young tea plants so that the canopy of the bushes will cover the soil as soon as possible. It is known that some perennial grasses do not grow well under shade.

A prospective herbicide to control weeds in young tea is glyphosate, a broad spectrum postemergence herbicide. Rahman *et al* (1975) reported that glyphosate has no apparent residual soil activity or pre-emergence effect when sprayed on soil or if it comes in contact with soil indirectly through decomposing weed vegetation. He also found that glyphosate has no visual adverse effects on tea when applied at rates of up to 2.88 kg/ha on the soil or when sprayed directly to the foliage at rates of up to 1.44 kg/ha. From our experiments under normal weed conditions 3 applications of glyphosate at 1 to 2 kg/ha/year gives sufficient weed control in young tea. This herbicide also showed good control of *Saccharum spontaneum* L. which is not controlled by other herbicides and has become a serious problem on several tea estates.

Whatever method or herbicides used, weed control must be a continuous programme with a set schedule of operations. In the case of chemical weed control, incorrect weed control management would not only cost more but would increase or create new weed problems.

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Biological Control of Weeds in Queensland, Australia

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ABSTRACT

The use of biological factors for weed control in Queensland dates from early in the century. Current research is by the Sir Alan Fletcher Research Station of the State Department of Lands, and a Federal body, the Commonwealth Scientific and Industrial Research Organization (CSIRO), maintains a biological control unit in Queensland to investigate weed problems on a national level. Biological control techniques are considered concurrently with other control measures — chemical, mechanical and, particularly property management — and these are developed to integrate with biotic suppression. Three stages are involved in biological control programmes; overseas exploration and assessment of enemies, the determination of host-specificity of candidate species, and the introduction, establishment and evaluation of acceptable organisms; generally 10 years will elapse between initiation of the project and review of its results. Host-specificity cannot be determined absolutely but the margin of risk can be reduced to an acceptable level by cage feeding and oviposition tests, review of published and documented records of pests of economic plants, the host plant and related species, and a judgement made using all information about the candidate and related species; this latter item applies particularly in countries where the fauna and flora are not well known. A minimum quarantine period of one full generation prevents the accidental importation of parasites, predators and extraneous species.

Current projects include :

A. Prickly pears *(Opuntia* spp.*)* Effective control is claimed although some manual dispersal of colonies is necessary.

B. *Lantana camara* L. Twelve insect species have been released since 1956, seven are now established and two leaf-mining beetles are exercising significant control. Further species are to be released.

C. *Xanthium pungens* Wallr. Two stem-borers are ineffective but a new rust fungus gives promise.

D. *Eupatorium adenophorum* Spreng. Effective control by insects and a fungus is claimed.

E. *Baccharis halimifolia* L. Seven insect species have been released with disappointing results. Further releases of these and other species will be made.

F. *Eriocereus martinii* (Lab) Ricc. Optimism is felt about three insect species now established and dispersing.

G. *Parthenium hysterophorus* L. Several promising insect enemies are reported from the Americas. Host-specificity determination will commence shortly.

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INTRODUCTION

Queensland was the site of the spectacularly successful prickly pear (*Opuntia* spp.) campaign in the 1930's (Dodd 1940), and in this State biological control techniques have been popular, both scientifically and socially, since that time.

Following the disbandment of the Commonwealth Prickly Pear Board in 1940, the functions of this body in Queensland were assumed by the Department of Lands and a Biological Section, (subsequently the Sir Alan Fletcher Research Station) was created. Research was broadened to include all aspects of weeds and their control in non-crop (rangeland) situations and the use of biological control techniques became part of a general overall approach towards major weed problems. All aspects of this technique (including overseas investigations) were undertaken and it was possible to consider the potential and results of biological control in conformation with other methods of control including chemical, mechanical, land usage and property management. With some minor exceptions, Queensland was the only Australian State to undertake studies of biological methods of weed control, and the other States relied on investigations undertaken on their behalf by the CSIRO. There has been close collaboration between the Sir Alan Fletcher Research Station and the CSIRO and the areas of interest of these two bodies have overlapped. In recent years the CSIRO has set up a biological control laboratory in Brisbane and investigations have been undertaken in the biological control of weeds of national importance.

BIOLOGICAL CONTROL PROGRAMMES

There has been a tendency for many laymen, and many weed scientists, to regard biological control techniques as either something to attempt when all else fails or as a panacea which will cure all weed ills completely independently of other actions. I would submit that neither of these attitudes is correct and that the use of biological factors should be included for consideration when the initial studies of a weed problem are being made. This method would receive only brief attention in situations where eradication was desirable and feasible, but in general it should be carefully considered where the weed is established widely and would pose a continuing threat. Biological control programmes are long-term but can be undertaken concurrently with the development of other control measures.

A standard pattern has been adopted by the Sir Alan Fletcher Research Station for biological control programmes, and in this three basic stages are recognised; (A) the systematic exploration for and assessment of enemies of the weed, (B) the determination of host-specificity and the introduction of acceptable species and (C) their establishment and evaluation in the field; these three steps can be quite separate, consecutive or even concurrent when several species are involved.

The exploration phase is usually short-term and involves limited field surveys (about six weeks duration) during the main periods of activity of the weed (peak vegetative growth and flowering); the timing and duration of these surveys will depend on its biology and occurrence. Investigations are usually commenced in the areas where the plant is considered to have evolved but may be extended to the same or closely related species in geographically isolated areas. Assessment of potential and host-specificity at this stage is largely speculative and its value depends to a considerable extent on the experience of the investigator. From this report decisions can be made about :

(a) whether further investigations are warranted;
(b) where the investigations should be located;
(c) the order of priority of study to be given to the various candidate species.

The host-specificity of candidate species can never be determined absolutely and in the relatively limited time allotted to an overseas programme (usually 3 years) indications of restriction of feeding are as important as the results of cage tests or official records which may be far from complete or even incorrect when the country being explored is undeveloped. Evidence on which to determine host range is obtained from:

(a) official records of scientific organisations and instrumentalities;
(b) interviews with workers in agricultural or other scientific fields;
(c) published papers on the host-plant and the candidate enemies;
(d) the host-range of closely related species;
(e) field observations on the biology and ecology of the candidate species;
(f) detailed biology studies;
(g) multiple-choice cage tests using a selected list including plants of economic importance, particularly within the same family.

In Australia the final decision on whether a phytophagous or pathogenic species can be introduced is made by the Federal Government Department of Health. All imported species are subjected to a minimum quarantine period of one complete generation to preclude the accidental introduction of parasites, diseases or extraneous species.

Establishment in the field usually is slow as it involves the growth of relatively small colonies through several generations before numbers are sufficient to have any significant effect on the host plant. As a general rule the period from initiation of a project to a review of its results is about 10 years, although in exceptional cases it may be shorter or much longer.

CURRENT PROJECTS

Current biological control projects being undertaken by the Sir Alan Fletcher Research Station include :

A. **Prickly pears** *(Opuntia* spp.). The prickly pear biological control programme in Australia has been well documented (Dodd 1940 and Mann 1970), and the excellent control achieved by *Cactoblastis cactorum* (Berg) and the cochineal insects *(Dactylopius* spp.) has continued. Of interest is the fact that effective control of two species *O. aurantiaca* Lindley and *O. monacantha* (Haworth) can only be maintained by manual distribution of cultures of *Dactylopius* sp. near *confusus* Cockerell and *D. ceylonicus* Green. It is assumed that poor powers of dispersal have limited the efficiency of these two species, and the populations of the host plant can reach major proportions in their absence.

B. **Lantana** *(L. camara* L.). Progress in this long-term (Wilson 1960) programme is now encouraging and significant control of the weed has been recorded from several areas of Queensland (Willson 1976). Recent exploration in Central America and South America has revealed a further number of host-specific insect species and of these, three have been forwarded to Queensland from Costa Rica (Sir Alan Fletcher Research Station project) and four from Brazil (CSIRO project); the species shown in Table 1 have been released in the field.

C. **Noogoora burr** *(Xanthium pungens* Wallr.). The only insect species known to be specific to *Xanthium*, *Euaresta aequalis* Loew, is established in restricted areas but causes no significant control of its host (Wilson 1960). Two stem-boring beetle species, *Mecas saturnina* Le.C. and *Nupserha antennata* Gahan, although shown to be oligophagous within related Compositae, were imported in 1957 (Wilson 1960) and, following further investigations, were released in the field (Haseler 1970). *M. saturnina* has survived at one site but shows little potential as a control factor. *N. antennata* is established widely at several sites and, although large populations are very destructive in mid-summer, the short adult emergence period is not synchronised with the much longer noogoora burr germination and the plant persists as a major weed. Further, rainfall in Queensland is very variable in time and volume and the annual host population fluctuations may be so extreme as to severely limit the long-term efficiency of biological control factors. A "rust" fungus, *Puccinia xanthii* Schw., was recorded from noogoora burr in Queensland for the first time in 1975 (Alcorn 1975) and dispersal is now widespread. Although reservations are held about its host-specificity (Alcorn 1976) this pathogen gives considerable promise as a control factor and major damage is reported to dense stands of the host.

D. **Crofton Weed** [*Eupatorium adenophorum*) Spreng]. A significant, although not complete degree of biological control of this weed by three factors, a stem-gall fly, *Procecidochares utilis* Stone, a stem-boring beetle *Dihammus argentatus* Auriv. and a fungus *Cerospora eupatorii* Peck, has been achieved (Haseler 1966). This plant is now only a significant weed in shaded, damp environments or on damp hillsides with a southern aspect. No significant dispersal of the plant has been recorded since 1952.

E. **Groundsel bush** (*Baccharis halimifolia* L.). Following surveys of insects of *Baccharis* spp. in North and South America (Bennett 1964), and host-specificity investigations in Florida, USA, between 1967 to 1969, six species of insects were introduced into Australia (McFadyen 1973). Of these, three, a foliage-feeding beetle *Trirhabda baccharidis* Weber, a foliage-feeding moth, *Aristotelia* sp,., and a stem-boring moth, *Oidaematophorus balanotes* Meyrick, were released in the field and the former two species are established, although in limited numbers and without significant effect. Further investigations in Brazil during 1973 to 1976 resulted in the selection of a further 7 host-specific insect species for introduction into Australia, and 4, including three foliage feeding beetles *Anacassis fuscata* Klug., *Anacassis phaeopoda* Buzzi and *Metallactus* sp., and a stem-boring beetle, *Megacyllene mellyi* Chev., have been released in southern Queensland. Releases of all species are continuing.

F. **Harrisia cactus** (*Eriocereus martinii* (Lab.) Ricc). Following reports that several destructive insect species were present on *Eriocereus* spp. in South America (Bennett 1972; Fidalgo and Zimmermann 1972), four host-specific insects were imported into Queensland; three species, *Alcidion cereicola* Fisher; and *Ericereophaga humeridens* O'Brien, both stem-boring beetles, and *Hypogeococcus festeriana* Lizer and Trelles, a mealy bug, are now established. Although populations of all three species are still in a dispersal phase, indications of significant control are already present.

G. **Parthenium weed** (*Parthenium hysterophorus* L.) *P. hysterophorus* is widespread in North and South America although seldom is it a weed of economic significance (Bennett 1977; McFadyen 1976). A large insect fauna and disease organisms of unknown host-specificity are present in both the Mexico/United States (Bennett 1977) and Brazil/Argentina (McFadyen 1976) regions. A three year programme to investigate the host-range and biological control potential of the insect and other enemies is planned to commence in South America in mid-1977.

Table 1. Species released on *L. camara* in Queensland since 1956.

Species	Family	Date of introd.	Type of damage	Results
Catabena esula Druce	Noctuidae, Lepidoptera	1956	Foliage feeder	Widespread but population low due to native parasites. Ineffective.
Syngamia haemorrhoidalis Guen	Pyraustidae, Lepidoptera	1956	Leaf roller	Population limited due to native parasite attack. Ineffective.
Diastema trigris Guen	Noctuidae, Lepidoptera	1956	Leaf feeder	Colonies lost through disease.
Hypena strigata Fabr.	Noctuidae, Lepidoptera	1964	Leaf feeder	Indistinguishable from a native species. No change in effects of native sp. observed.
Plagiohammus spinipennis Thoms.	Cerambycidae Coleoptera	1966	Stem borer	Field conditions apparently unsuitable.
Octotoma scabripennis Guerin	Hispidae, Coleoptera	1966	Leaf miner	Effective control in some areas of cooler part of State. Still dispersing.
Uroplata girardi Pic.	Hispidae, Coleoptera	1966	Leaf miner	Effective control in several areas of State. Still dispersing.
Leptobyrsa decora Drake	Tingidae, Hemiptera	1969	Foliage feeder	Some damage reported in North Qld. Still dispersing.
Teleonemia elata Drake	Tingidae Hemiptera	1969	Foliage feeder	No field survival reported.
Teleonemia scrupulosa Stal (biotypes)	Tingidae Hemiptera	1969	Foliage feeder	Indistinguishable from a previously introduced species. No change in effects of established sp. observed.
Teleonemia harleyi Froeschner	Tingidae Hemiptera	1969	Foliage feeder	No field survival reported.
Teleonemia prolixa Stal	Tingidae Hemiptera	1972	Foliage feeder	Limited field survival to date.
Phytobia lantanae Frick	Agromyzidae Diptera	1974	Leaf feeder	Significant damage reported in North Qld. Still dispersing.
Octotoma championi Baly	Hispidae, Coleoptera	1975	Leaf miner	Established in limited areas. Still dispersing.
Uroplata sp.	Hispidae, Coleoptera	1975	Leaf miner	Releases very recent.
Autoplusia illustrata Guen.	Noctuidae, Lepidoptera	1976	Foliage feeder	Release very recent.

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Insects and Fungi Associated with Some Aquatic Weeds in Indonesia

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ABSTRACT

Insect species associated with waterhyacinth (*Eichhornia crassipes* (Mart.) Solms)., molesting salvinia (*Salvinia molesta* (Aubl.) D.S. Mitchell), water lettuce (*Pistia stratiotes* L.), alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb.), water primose (*Ludwigia* spp.) and giant bulrush (*Scirpus grossus* L.f.) in Indonesia were recorded. Most of them are general feeders, and some are pests of cultivated plants. A few of them seems to be specific to water lettuce, primose and giant bulrush, but so far based on laboratory and field survey findings only the leaf feeder, *Proxenus hennia* Swinhoe, seems most promising as a biological control agent for water lettuce. In Java 13 taxa of fungi associated with waterhyacinth were also recorded. They are *Myrothecium roridum* Tode ex Fr., *Alternaria eichhorniae* Nag Raj & Ponnappa, *Rhizoctonia solani* Kuhn, *Curvularia* sp., *Pestalotia* sp. and 8 undetermined taxa. *M. roridum*, *A. eichhorniae* and *R. solani* were most important parasitic fungi of the weed. These fungi appear to have some potential for bio-control of the weed.

INTRODUCTION

According to Soerjani *et al.* (1975) 10 species of aquatic plants have also been incriminated as major aquatic weeds in Southeast Asia. These include waterhyacinth, molesting salvinia, water lettuce, Florida elodea, (*Hydulla verticillata* (L.f.) Royle lotus (*Nelumbo nucifera* Gaertn.), giant bulrush, torpedograss (*Panicum repens* L.), cattail (*Typha angustifolia* L.), monochoria (*Monochoria vaginalis* (Burm.f.) Presl) and water fern (*Salvinia cucullata* Roxb.). Sankaran *et al.* (1967) and Burkhalter *et al.*, mentioned that primose have invaded and disturbed fresh water lakes, canals, ponds and other aquatic habitats.

Efforts with biological control have been made against the first four species in Florida in addition to mechanical and chemical control (Anon. 1973). These programs were initiated in 1966 by the introduction of

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exotic biocontrol agents from South America. In Southeast Asia biocontrol has also been recommended for waterhyacinth, molesting salvinia, water lettuce and Florida elodea (Soerjani *et al.* 1976).

It has been known that specific insects, fungi and other organisms could be used as biocontrol agents against certain species of perennial aquatic weeds. To support research and implementation of biological control, information on taxonomy, biology and ecology of insects, fungi and other organisms, associated with the target weeds, both in their original planned control areas are needed (Zettler and Freeman 1972; Freeman *et al.* 1974; Allen and Mangoendihardjo 1975).

Studies on insects and fungi associated with some important aquatic weeds in Indonesia were initiated in 1973 with an emphasis on waterhyacinth, molesting salvinia, water lettuce, alligator weed, water primose and giant bulrush. Information on insects recorded from these weeds in many part of the world has been given by USAED (U.S. Army Engineering District), Florida (Anon 1973; Allen 1974; Bennett 1975; Rao 1969; Sankaran *et al* 1967) while records of some fungi associated with waterhyacinth were given by Charudattan (1973), Nag Raj and Ponnappa (1970) and Freeman *et al.* (1973).

MATERIALS AND METHODS

Observations on insects associated with the weeds were carried out in Java and South Sulawesi while observations on diseases on waterhyacinth were made at the Curug reservoir and in the Krawang area (West Java), at Rawa Pening (Central Java) and Danau Bureng (East Java). Insects feeding and found on the weeds, plants injured by insects and fungi were collected. Some of the organisms were bred and isolated for identification.

Insect species which are also known as pests of crops were rejected. Further studies were conducted on other species causing appreciable damage to the weeds in the field. The studies include the bionomics, host specificity and damage potential of the species. The methods of studies used are as mentioned by Syed (1976) and Allen and Mangoendihardjo (1975).

Diseased materials with different symptom were collected separately and kept in plastic bags. They were examined under the microscope and isolations were made from affected plants parts. The procedure of isolation and pathogenicity test were made as described by Charudattan (1973). The isolated fungi were subjected to a test of Koch's postulate.

RESULTS AND DISCUSSION

On waterhyacinth an unidentified Hydrophilid, two Noctuids (*Spodoptera litura* F. and *S. mauritania* Sn.), a Symtomid (*Symtomis germana* Feld), 7 species of grasshoppers (Acrididae: *Gensonula punctifrons* Stall., *Oxya japonica* (Thunberg), *O. chinensis* L., *Acrida turita* L., *Attractomorpha psittacina* de Haan, and *Pseudocarsula* sp.) and a Tettigonid (*Conocephalus* sp.), two unidentified Dipterans and an unidentified Aphid (? *Rhophalosiphum nymphae*) were recorded. Among these species *G. punctifrons* appears to be the most common natural enemy of the weed but according to Mangoendihardjo and Syed (1974) its potential is low.

Nymphula responsalis Wlk. (Lepidoptera: Pyralidae) in the most important natural enemy of water fern in Java. The bionomics, host range and potential of this insect were studied in some detail by Subagyo (1975). From the studies it is evident that this stenophagous insect is not very promising as a biocontrol agent for water fern, because of its low damage potential and its parasitization by a pupal parasite (*Tetrastichus* sp.) . An unidentified predacious Coleopteran and a Tabanid associated with roots of the fern and two unidentified Hemipterans on the weed were also recorded in Java. The status of both bugs (Hemipterans) is not clear, but at the Curug reservoir more specimens could be found on plants with abnormally curled form than from healthty plants.

Water lettuce in Java and South Sulawesi is attacked by P. *hennia* Swinhoe (Lepidoptera: Noctuidae), *N. responsalis, S. mauritia,* an unidentified Aphid, a Mesovelid (*Mesovelia* sp. ? *subvittata* (Horv.), and a Cicadelid (*Zygina* sp. (*sensu lato*). Besides these natural enemies a Hydrophilid (*Coelostoma* sp.) and a Tabanid (*Tabanus* sp.) were also associated with roots of the weed. *P. hennia* is the most promising natural enemy. This species was studied by Mangoendihardjo and Syed (1974), Mangoendihardjo and Nasroh (1975) and appears to be specific to water lettuce. Larvae of *P. hennia* were not able to survive on 44 other tests plants belonging to 21 families.

On alligator weed *Psara basalis* Wlk. (Lepidoptera: Pyralidae) is very common in South Sulawesi and Java. Other natural enemies recorded from the weed were a Pyralid (*Hymenia* sp. *recurvalis* F.) a Chrysomelid (*Metriona viridinotata* Boh) and an unidentified Lepidopteran. Preliminary test on host range of *P. basalis* indicated that the species is stenophagous and was able to develop completely on *Ama-*

ranthus sativus a common vegetable crop in Indonesia. In nature it is also attacked by an unidentified larval parasite and a Scarabid. Further studies of other natural enemies are being conducted in the laboratory at BIOTROP.

Three species of lepidopterous stem borers of giant bulrush were recorded viz. 2 species of Pyralids (*Schoenobius ochracellus* Sn. and *Proceras sachariphagus* Wlk.) and a Noctuid (*Sesamia inferens* Wlk.) (Kalshoven 1950). Kalshoven also recorded the weed as the alternate host of *Scotinophara inermis* (Hemiptera: Pentatomidae). An unidentified stem borer, a curculionid (Coleoptera) and an unidentified Flattid (Hemiptera) were also recorded in the Krawang area in 1975. The stem borer (Curculionid) does not seem to be a promising natural enemy because it seems to develop only on the old and flowering plants. The adults were able to survive for six months in the laboratory but the females produced a very small number of eggs. However, this species will be studied further in the future.

Field observations on natural enemies of water primrose in Java and South Sulawesi showed that *Haltica cyanea* (Weber) and *Haltica* sp. (Coleoptera : Chrysomelidae) and *Nanophyes nigritulus* Boh (Coleoptera : Curculionidae) are the most important species feeding on the weed. *H. caerulea* Oliv. occurs in India and was studied by Sankaran *et al.* (1967). The species was tested on 123 species of plants and indicated that *Trapa bicornis* Osbeck proved as alternate host for *H. caerulea.*

In Indonesia *H. cyanea* was recorded from *Ludwigia hyssofolia* and *L. adscendens* and *Haltica* sp. on *L. adscendens* causing appreciable damage to the weeds. *Nanophyes* sp. nr. *nigritulus* was a common fruit borer in India (Rao 1969) and has not been studied in detail. *N. nigritulus* Boh occurring in Indonesia seems to be very promising as a biocontrol agent against water primrose and will be studied in detail.

During the observations, several diseases on waterhyacinth leaves were recorded. The degree of damage caused by these naturally occurring diseases did not appear to be high enough to retard significantly the enormous growth of the weed.

Koch's postulate tests proved that only 13 taxa of fungi were pathogenic. They were *M. roridum* (4 pure cultures), *A. eichhorniae* (2 pure culture), *R. solani* (3 pure cultures), *Curvularia* sp. (1 pure culture), *Pestalotia* sp. (1 pure culture) and 8 unidentified taxa. Only some of them i.e. *M. roridum*, *A. eichhorniae* and *R. solani* showed the same symptoms as in the field and caused appreciable injuries to the leaves of waterhyacinth. Apparently these fungsi were primary parasites and the rest were secondary parasites.

According to Freeman *et al* (1973), *Myrothecium* disease and *Alternaria* leafspot were found on waterhyacinth in India and Florida, whereas *Rhizoctonia* blight was found in Panama, Puerto Rico and India.

Myrothecium disease was the most common fungus infecting waterhyacinth. It was found in all areas observed, causing a certain degree of damage and it appears to have some potential for the biocontrol of the weed. Tulloch (1972) said that *M. roridum* can be considered as a serious plant pathogen, usually causing leaf spots which sometimes may result in shot hole and dieback.

Alternaria leafspot caused by *A. eichhorniae* was found in the Curug reservoir and at Rawa Pening. Nag Raj and Ponnappa (1970) considered that *A. eichhorniae* found in India might have some potential for the control of waterhyacinth, because apparently it has a narrow host range. It is expected that *A. eichhorniae* found in both localities in Java will have a similar potential as the species found in India.

Rhizoctonia blight, caused by *R. solani,* induced severe irregular lesions on the leaves, causing blighting and often death of the plants. This fungus was found in Krawang rice fields, Curug reservoir and Danau Bureng. The frequency with which plants infected by this fungus occurred was very low compared with that of plants infected by *M. roridum* and *A. eichhorniae.* According to Charudattan *et al* (1974), *R. solani* is a broad host-range pathogen and its use as a biocontrol agent of waterhyacinth should be considered carefully.

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Further Researches on Tadpole Shrimps for Biological Weeding

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ABSTRACT

The effect of tadpole shrimps on rice seedlings, especially young seedlings at 2.5-leaf stage and suitable for mechanical transplanting, was investigated. The results showed that there was no damage to young seedlings by tadpole shrimps even in the case of irregular and rough transplanting operations. Introduction of egg-containing soil into paddy fields, which had been flooded, did not result in the occurrence of tadpole shrimps. The effect of the flooding date before the introduction of tadpole shrimps was tested using experimental concrete pots. Although the pots were flooded 3, 6, and 9 days before the introduction of eggs no tadpole shrimps could be observed in these plots. Only when the eggs were introduced at the same time as flooding were a reasonable number of tadpole shrimps observed. It appears that the natural enemies, which had hatched prior to the tadpole shrimps took their toll when the introduction of the eggs was delayed. Actual labor of weeding was estimated in paddy fields where a number of tadpole shrimps occurred and no pesticide was used. Total weeding labor was found to be 20 hr per ha which was significantly less than the average of 100 hr per ha for present weeding systems in Japan, including the use of herbicides.

INTRODUCTION

The outline of the utilization of tadpole shrimps (*Triopus longicaudatus* LeConte, *T. granarius* Lucas and *T. cancriformis* Bosc.) as a biological tool of weed control in transplanted rice fields in Japan was introduced at the 5th Asian-Pacific Weed Science Society Conference (Matsunaka, 1976). Taxonomical position, life cycle, distribution in Japan, weeding mechanism, utility in weeding and problems in the future were discussed.

In this paper, some further subjects such as the effect on young rice seedlings, the effect of flooding date on the occurrence of tadpole shrimps, and the estimation of actual labor of hand-weeding in the paddy fields utilizing tadpole shrimps, will be reported.

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MATERIALS AND METHODS

Effect of tadpole shrimps on rice seedlings: After flooding the concrete pots (50 by 50 cm) on June 3, 1976, the soils with eggs of American tadpole shrimps (*T. longicaudatus*) were added into the water and the contents of the pots puddled. Rice seedlings (cv Nihonmasari) of 2.5-leaf age were transplanted by hand, at 8 hills per concrete pot and 4 seedlings per hill (32 seedlings per pot). The seedlings had been cultivated for mechanical transplanting. Bad transplanting operations, which may sometimes be expected in practice, were simulated by putting the soil part of the seedlings on the surface of the flooded soil. Normally the soil parts, including the roots of the seedlings are inserted into the ground soil by the transplanting machine. Water depth was kept at 3 cm. In the plots without any tadpole shrimps the weeding was done by hand. The number of tillers was counted, 26 days after transplanting. The top parts were harvested, 41 days after transplanting and their dry weight was measured.

Effect of flooding date on the occurrence of tadpole shrimps: The same 50 by 50 cm concrete pots were used. Flooding was done 9, 6, and 3 days before and just on the day of adding of tadpole shrimp eggs. The number of tadpole shrimps was counted 8 days after the introduction of eggs. In this experiment, rice plants were not transplanted.

Weeding labor estimation: A farmer's paddy field, where tadpole shrimps appeared naturally, was used for this experiment. The field had an area of 6 acres and was managed without any pesticides. Forty days after transplanting hand-weeding was done and the manpower labor estimated.

RESULTS AND DISCUSSION

The effect of tadpole shrimps on young seedlings is shown in Table 1. Neither the number of tillers nor the dry weight of the shoot showed any significant difference between the plots with and without tadpole shrimps, although between normal and bad transplanting operations we did find significant differences. No weeds were found in the tadpole shrimp plots and the last column of Table 1 shows that the number of tadpole shrimps was sufficient to control the weeds. From these results, tadpole shrimps do not damage transplanted rice plants even though they may be young (2.5 leaf age) and poorly transplanted. In the case of direct seeding onto flooded land, tadpole shrimps cause severe damage to the emerging rice plants.

The first step in the practical experiments was to introduce eggs of tadpole shrimps into the soil of an experimental paddy field just after puddling, in the 1976 season. However, no tadpole shrimps were observed

Table 1. Effect on young seedlings by tadpole shrimps

Trans-planting	Tadpole shrimps	Number of tillers per hill			Dry weight of top part (g/8 hills)			Number of tadpole shrimps per m^2 (range)
		Mean	S.D.	Difference *	Mean	S.D.	Difference *	
Normal	with	15.0	0.92	a	48.6	6.07	a	68 (40 - 132)
	without	14.6	1.02	a	45.4	3.51	ab	0
Poor	with	16.2	1.30	b	44.9	4.73	ab	100 (28 - 264)
	without	16.0	0.91	b	42.7	3.03	b	0

Eight pots were used to each plots, respectively. Number of tillers was counted on June 30 (26 days after transplantation) and rice plants were harvested for measurement of dry weight on July 15 (41 days after transplantation).

* Not significant in the case of the same letter at 5% level.

in the plots. The reason for their absence appears to be early unexpected flooding as a result of irrigation in the adjacent experimental paddy fields. The effect of the flooding date on the occurrence of tadpole shrimps was therefore, substantiated.

The results are shown in Table 2. It shows that flooding 3 days before the introduction of tadpole shrimp eggs may inhibit the

Table 2. Effect of flooding date on occurrence of tadpole shrimps

	Number of tadpole shrimps per 0.25 m^2 — Flooding date (days before introduction of eggs)			
	9	6	3	0**
	0	1*	0	37
	0	2*	0	56
	0	0	0	30
	0	0	1*	25
Means	0	0.8*	0.3*	37

Four pots were used to each plots, respectively.

* Large scale tadpole shrimps, which hatched from the original soil when flooded.

** September 9, 1976. Number was counted on September 17.

occurrence of shrimps in the same way as flooding 6 or 9 days beforehand did. Although one or two tadpole shrimps were found in some pots flooded 3 or 6 days before the introduction of eggs, they were large and seemed to have hatched from the original soil at the same time as flooding. From this experiment, we may conclude that, for the purpose of normal hatching from eggs in the natural paddy fields, the addition of eggs into the fields should be done at the same time as flooding. The reason seems to be due to the reduction of the natural enemies which had hatched and were dominant already and probably would have a severe effect on the newly hatched tadpole shrimps.

To the limited area (about 10 m²) of the experimental paddy fields, a large number of tadpole shrimps were introduced, but they disappeared 3 to 4 days afterwards. No dead bodies could be found in the plot. The relatively large enemies, birds, frogs and others, all seemed to feed on tadpole shrimps. Here we can say that, when planning to apply the eggs to paddy fields as a bio-pesticide (bio-herbicide), we should do it over a wide area to avoid a local attack by the natural enemies.

In a farmer's field with a large number of tadpole shrimps the management, after transplanting, was done without any pesticides. Weeding was done only by tadpole shrimps and the number of weeds remaining were decreased, so hand-weeding was practiced 40 days after transplantation. Two men took 40 minutes to hand-weed 6 acres of paddy fields. It was calculated that 20 man-hours per ha, were needed and this was significantly less than the 90 to 100 man-hours per ha which is the average for present weeding procedures in Japan including the use of herbicides.

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Some Ecological Impacts of the Introduction of Grass Carp (Ctenopharyngodon idella Val.) for Aquatic Weed Control

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ABSTRACT

The faeces of grass carp (*Ctenopharyngodon idella* Val.) indirectly cause deterioration of water quality such as a decrease in dissolved oxygen (Odum 1971). A mixed culture in equal weight of grass carp and kissing gourami (*Helostoma temmincki* c.v.) reduced the deterioration of water quality. When the plankton feeder constituted only 30% of the total fish population, the deterioration of water quality still occurred. A mixed culture with common carp (*Cyprinus carpio* L.) did not reduce the deterioration of water quality. Another ecological implication of the use of grass carp for biological control of aquatic weeds is its preference for rice plants. The presence of hydrilla (*Hydrilla verticillata* L.f. Royle) significantly reduced the consumption of rice by grass carp while the presence of salvinia (*Salvinia cucullata* Roxb.) and waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) did not decrease the damage to rice.

INTRODUCTION

Grass carp is considered one of the most efficient plant-eating fishes and is being employed both as a biological weed control agent and a source of food in a number of countries (Bailey 1972, Mehta *et al* 1972, Sharma of food in a number of countries (Bailey and Boyle 1972, Mehta and Sharma 1972, Sharma and Kulshresta 1974). This fish consumes an enormous amount of food with estimates running as high as two to three times its body weight per day (Sneed 1971). Its gut is only two or three times the length of the body and consequently the faeces contains about 50% of undigested food. Faecal material and undigested food may act as a fertilizer and cause phytoplankton blooms. The blooms rise to the surface and the oxygen produced by photosynthesis largely escapes into the air. When the bloom dies, oxygen in the water is used up, often stressing or killing the fish (Odum 1971).

The use of grass carp for weed control entails the risk of their escape into natural waterways and possible damage to valuable plants (Bardach *et al* 1972). Studies in Indonesia indicated that grass carp could control dense population of hydrilla, salvinia (*Salvinia molesta* D.S. Mitchell)

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and could retard the growth of waterhyacinth. However, it also causes some damage to rice plants (*Oryza sativa* L.).[2]

The object of this study was to determine if mixing other fish species with grass carp could mitigate the adverse effects of grass carp on water quality. Feeding preference of grass carp for different varieties of rice was also investigated.

MATERIALS AND METHODS

Experiment 1. Ten cylindrical tanks of 1.77 m^3 each were used in this experiment. The tanks were filled with pond water and after one week each tank was stocked with fish (6.7 − 8.6 cm in length and 11.5 − 15.0 g in weight). Three days later sufficient waterhyacinth plants were put in to cover 1/4 of the surface area of each tank. The treatments of this experiment were as follows : (A) control (without fish); (B) 99.5 g of grass carp; (C) 54 g of grass carp and 51 g of common carp; (D) 54.8 g of grass carp and 54.5 g of kissing gourami; (E) 31 g of grass carp and 33 g of kissing gourami and 30.2 g of common carp. Hydrilla, at 200% of the total fish weight was given as daily food supply. Parameters measured included physical factors (temperature, turbidity); chemical factors (pH, CO_2, O_2, alkalinity, N and P), suspended organic matter and biological factors (phyto-and zooplankton). Phyto- and zooplankton samples counted under a microscope.

Experiment 2. This experiment was designed to discover if grass carp showed any food preferences for different rice varieties and if the fish preferred hydrilla to rice.

Sixteen 6 m^2 ponds lined with plastic, eight varieties of rice (C_4 − 63 gb, PB_5, PB_8, Pelita I/1, Pelita II/2, Syntha, Serayu and Ketan Ampera) were used.

As a first step each variety was tested individually. In this experiment 32 stems arranged in 8 clusters and planted in 2 plastic pots were put in the middle of the pond. The depth of water from the surface to the base of the rice stems was maintained at 20 cm. Fish were put into the ponds and the test was continued for three days.

In the second experiment varietal preference was tested. The procedure was similar to the previous test, except that all the eight varieties were planted together in each pond, and each treatment was replicated four times. The preference test was repeated with hydrilla (250 g) added to the ponds to see if it had any effect on the preferences of grass carp for

2 Pheang C.T. 1975. A preliminary study on the Biological Control of Important Aqualitic Weeds in Southeast Asia with Chinese Grass Carp (*Ctenopharyngodon idella* Val.) BIOTROP Int. Report. 12 pp.

Problems and Control of Weeds on Young Tea in Indonesia

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ABSTRACT

The undesirable effects of manual or mechanical weed control on young tea, traditionally applied in Indonesia, could be avoided by using herbicides. Pre-emergence herbicides proved to be very useful in controlling weeds propagated by seeds. The triazine group appeared to be the best for this purpose, without affecting young tea plants. Further investigations and field trials on the application of diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] are still needed to obtain a clear picture of the effect of this herbicide on young tea plants. Postemergence herbicides such as paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) and other contact herbicides are also recommended for use in young tea. A special application technique to avoid plant damage is required. Glyphosate [*N*-(phosphonomethyl) glycine] proved to give good results in controlling many species of weeds and was not harmful to the young tea plants.

INTRODUCTION

The rehabilitation of the tea (*Camellia sinensis* var. *assamica* (Mast.) Steen.) industry in Indonesia was started in 1970 by the government tea estates, and in 1974 by the smallholder and private tea estates. Replanting of abandoned areas and block infilling on a large scale is one of the objectives of the rehabilitation program. It is expected that in the future, the hectarage of young tea will increase steadily.

Based on past experience, special attention must be paid to the upkeep of young tea plants. Weed control plays an important role as the upkeep cost is much higher in young tea compared with that in mature tea. Weeds in young tea are considered to be the most important problem due to the fact that they suppress tea growth and prolong the non-productive period (Sharma 1967, Anon. 1969, Soedarsan *et al* 1975).

Chemical weed control had been used in producing fields since the 1970's, and seems to give effective results. Due to the risk of plant damage and limited data, chemical control is not applied in young tea. Insufficient mechanical weed control in young tea is found on many tea estates as well as in smallholder plantings. Plant damage, loss of top soil to erosion and retardation of growth are usually observed. In a large part of the young

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tea plantings, mechanical weed control is difficult to affect at the right time because the method of weeding is very labour intensive (van Staalduine 1972). There is a need for more labour in the producing fields as well as in the factory, due to the increased production resulting from the rehabilitation programme.

Chemical weed control has been used in young tea in East Africa and South India (Anon. 1969, Sharma 1967). Some preliminary experiments and field trials which have been carried out in the Research Institute for Tea and Cinchona (RITC) — Indonesia, showed that certain herbicides applied correctly give good weed control without affecting the young tea plants[2].

WEED PROBLEMS IN YOUNG TEA

New tea plants are planted in the field at a spacing of 120 cm by 60 cm, leaving a large area of soil surface open to full sunlight. This condition lasts for 2 years and is very favourable for weed growth before the canopy of the tea bushes completely covers the soil. As in other crops, weeds in young tea compete for nutrients, water (in the dry seasons) and occasionally for light (Sharma 1967, Soedarsan *et al* 1975). It is mentioned by Venkataramani (1973), and Soedarsan *et al* (1975) that there is a possibility that toxic exudates of weeds could play an important role in retarding the growth of young tea plants.

Various weeds in tea plantations were identified by Backer and van Slooten (1924). According to Soedarsan *et al* (1974), the weed composition differs from one tea estate to another. Perennial grasses create the greatest problem in tea plantations (Sharma 1967, Anon. 1969). It is due to the fact that these grasses propagate not only by seeds, but often by ground runners and underground parts such as stolons, rhizomes, tubers or bulbs which all make these grasses difficult to eradicate.

Grasses with shallow fibrous roots and soft broadleaf weeds appear to be less troublesome in comparison with the deep rooting perennial grasses. The eradication of deep rooting perennial grasses by mechanical weeding is very difficult because pieces of rhizome left in the soil can sprout and start a new plant. Moreover, insufficient mechanical weeding of grasses, such as alang-alang (*Imperata cylindrica* (L.) Beauv.) and *Panicum repens* L., might stimulate the growth of these weeds.

Soedarsan *et al* (1975) reported, that there are indications that the growth retardation of the young tea plant is related to nutrient uptake

2 Martosupono M, M. Sanusi, K. Suhargiyanto and R. Purnama 1976. Pengujian beberapa herbisida "pra-tumbuh" pada tanaman teh muda. Research Institute for Tea and Cinchona. Unpublished.

of the weed. He also stated that the production of organic matter by weeds should be in some way related to the extent of nutrient uptake.

In an effort to understand and cope with the weed problems in young tea plantations it should be noted that most of the tea plantations in Indonesia are located on steep areas with a relatively high rainfall so soil erosion is an important consideration.

WEED CONTROL IN YOUNG TEA

Most weed control in young tea plantations in Indonesia is carried out mechanically, either by slashing, forking and digging, or by handpulling. To obtain adequate control, this effort must be carried out at least 8 to 10 times per year requiring 100 to 200 man days/ha/year or more for special grasses such as alang-alang (van Staalduine 1972).

On many estates, due to the shortage of labour, weeding operations on large areas of young tea is often carried out too late and with unskilled labour. Most of the areas are in an undesirable weed condition where some woody weeds need to be removed by digging or perhaps by deep soil cultivation. Van Staalduine (1972) described the undesirable effects of mechanical weed control practices, as follows :

1. Late weed removal suppresses growth of young tea, due to competition.
2. Serious damage to the roots of young tea retards the plants growth.
3. Decreasing soil fertility by soil erosion.

Strip weeding has also been done on many tea estates, particularly on the steep slopes in order to control soil erosion. In practice this system is often not performed in a correct manner as in the case of mechanical clean weeding. Insufficient labour and rapid growth of weeds in strip weeding systems, often cause the weeding operations to be carried out after weed damage has occurred.

Mulching with leaves of Guatemala grass *(Tripsacum laxum)* or other materials on young tea could suppress weed growth and control soil erosion. It is not applicable on a large scale due to its high cost. Planting a cover crop between tea rows is more applicable in a large area. Two kinds of cover crops are usually planted in young tea areas, *Tephrosia vogelii* Hook. f. and *Crotalaria anagyroides* H.B.K. A regular pruning should be done to avoid competition to the young tea plants.

CHEMICAL WEED CONTROL AND ITS PROSPECT

In producing fields, as mentioned above, chemical weed control has been widely applied in Indonesia. Even so, further research on this subject still needs to be done due to the fact that continual spraying with the same. herbicide, such as paraquat, from year to year has changed the weed composition and enhanced the growth of dominant weeds which are now resistent to paraquat. The continuous use of only one herbicide over a long period, will create new weed problems.

Very limited data on the use of herbicides in young tea, seem to be the reason that chemical control is not applied widely in Indonesia. In East Africa and South India, the use of certain herbicides to control weeds in young tea has been recommended since 1967 (Sharma 1967, Anon. 1969).

Pre-emergence herbicides, which persist in the soil, could be very useful to prevent growth of various weeds. Triazine herbicides have been shown to be safe for young tea and keep the treated area in an acceptable condition for 2 to 4 months after spraying (Sharma 1967, Anon. 1969). In North Sumatra, several pre-emergence herbicides have been tested in young tea plants. Van Staalduine (1972) reported that simazine (2-chloro-4,6-bis(ethylamino)-*s*-triazine) at 1.5 kg/ha and other triazines at the same rate are safe for young tea plants. Sharma (1967) recommended higher doses of 4 to 6 kg/ha of simazine and 3 to 4 kg/ha of atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) which were effective in controlling broadleaf weeds and shallow rooted grasses without adversely affecting the tea. It is also mentioned that simazine can be sprayed safely in 6-month old young tea plants in the field.

Another pre-emergence herbicide is diuron, which showed good results in controlling weed which propagated generatively. According to van Staalduine (1972) in North Sumatra the use of diuron at to 2.4 kg/ha damaged the young tea plants. It is also recommended by Venkataramani (1973) that even in mature tea, use of diuron should not be more than 0.5 kg/ha per application, and not more than 1 kg/ha/year. The effect of diuron on tea plants differs depending on the type of the soil and the organic matter content. There is also a possibility that the susceptibility of different tea clones to diuron is different. Further experiments with this herbicide are needed.

Paraquat, a contact herbicide which is directly inactivated in the soil, could be very useful in controlling weed growth in young tea. A special technique of spraying must be used to avoid plant damage caused by contact with the herbicide (Anon. 1969). Paraquat kills only the green parts of a plant, so in a high population density of broadleaf weeds and perennial grasses with deep rooting systems, applications need be applied at close intervals (Sharma 1967, Venkataramani 1973).

Dalapon (2,2-dichloropropionic acid) which is effective in controlling alang-alang and perennial grasses, is not recommended on tea less than 2 years old because of it systemic action and persistence in the soil (Anon. 1969).

To eliminate harmful effects of perennial grasses, mechanical weeding by pulling out the underground parts of the weeds and removing these parts from the field is still recommended in combination with chemical (spot) spraying using a contact herbicide. This method of control is expensive but must be done to enhance the growth of the young tea plants so that the canopy of the bushes will cover the soil as soon as possible. It is known that some perennial grasses do not grow well under shade.

A prospective herbicide to control weeds in young tea is glyphosate, a broad spectrum postemergence herbicide. Rahman *et al* (1975) reported that glyphosate has no apparent residual soil activity or pre-emergence effect when sprayed on soil or if it comes in contact with soil indirectly through decomposing weed vegetation. He also found that glyphosate has no visual adverse effects on tea when applied at rates of up to 2.88 kg/ha on the soil or when sprayed directly to the foliage at rates of up to 1.44 kg/ha. From our experiments under normal weed conditions 3 applications of glyphosate at 1 to 2 kg/ha/year gives sufficient weed control in young tea. This herbicide also showed good control of *Saccharum spontaneum* L. which is not controlled by other herbicides and has become a serious problem on several tea estates.

Whatever method or herbicides used, weed control must be a continuous programme with a set schedule of operations. In the case of chemical weed control, incorrect weed control management would not only cost more but would increase or create new weed problems.

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Biological Control of Weeds in Queensland, Australia

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ABSTRACT

The use of biological factors for weed control in Queensland dates from early in the century. Current research is by the Sir Alan Fletcher Research Station of the State Department of Lands, and a Federal body, the Commonwealth Scientific and Industrial Research Organization (CSIRO), maintains a biological control unit in Queensland to investigate weed problems on a national level. Biological control techniques are considered concurrently with other control measures — chemical, mechanical and, particularly property management — and these are developed to integrate with biotic suppression. Three stages are involved in biological control programmes; overseas exploration and assessment of enemies, the determination of host-specificity of candidate species, and the introduction, establishment and evaluation of acceptable organisms; generally 10 years will elapse between initiation of the project and review of its results. Host-specificity cannot be determined absolutely but the margin of risk can be reduced to an acceptable level by cage feeding and oviposition tests, review of published and documented records of pests of economic plants, the host plant and related species, and a judgement made using all information about the candidate and related species; this latter item applies particularly in countries where the fauna and flora are not well known. A minimum quarantine period of one full generation prevents the accidental importation of parasites, predators and extraneous species.

Current projects include :

A. Prickly pears *(Opuntia* spp.*)* Effective control is claimed although some manual dispersal of colonies is necessary.

B. *Lantana camara* L. Twelve insect species have been released since 1956, seven are now established and two leaf-mining beetles are exercising significant control. Further species are to be released.

C. *Xanthium pungens* Wallr. Two stem-borers are ineffective but a new rust fungus gives promise.

D. *Eupatorium adenophorum* Spreng. Effective control by insects and a fungus is claimed.

E. *Baccharis halimifolia* L. Seven insect species have been released with disappointing results. Further releases of these and other species will be made.

F. *Eriocereus martinii* (Lab) Ricc. Optimism is felt about three insect species now established and dispersing.

G. *Parthenium hysterophorus* L. Several promising insect enemies are reported from the Americas. Host-specificity determination will commence shortly.

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INTRODUCTION

Queensland was the site of the spectacularly successful prickly pear *(Opuntia* spp.) campaign in the 1930's (Dodd 1940), and in this State biological control techniques have been popular, both scientifically and socially, since that time.

Following the disbandment of the Commonwealth Prickly Pear Board in 1940, the functions of this body in Queensland were assumed by the Department of Lands and a Biological Section, (subsequently the Sir Alan Fletcher Research Station) was created. Research was broadened to include all aspects of weeds and their control in non-crop (rangeland) situations and the use of biological control techniques became part of a general overall approach towards major weed problems. All aspects of this technique (including overseas investigations) were undertaken and it was possible to consider the potential and results of biological control in conformation with other methods of control including chemical, mechanical, land usage and property management. With some minor exceptions, Queensland was the only Australian State to undertake studies of biological methods of weed control, and the other States relied on investigations undertaken on their behalf by the CSIRO. There has been close collaboration between the Sir Alan Fletcher Research Station and the CSIRO and the areas of interest of these two bodies have overlapped. In recent years the CSIRO has set up a biological control laboratory in Brisbane and investigations have been undertaken in the biological control of weeds of national importance.

BIOLOGICAL CONTROL PROGRAMMES

There has been a tendency for many laymen, and many weed scientists, to regard biological control techniques as either something to attempt when all else fails or as a panacea which will cure all weed ills completely independently of other actions. I would submit that neither of these attitudes is correct and that the use of biological factors should be included for consideration when the initial studies of a weed problem are being made. This method would receive only brief attention in situations where eradication was desirable and feasible, but in general it should be carefully considered where the weed is established widely and would pose a continuing threat. Biological control programmes are long-term but can be undertaken concurrently with the development of other control measures.

A standard pattern has been adopted by the Sir Alan Fletcher Research Station for biological control programmes, and in this three basic stages are recognised; (A) the systematic exploration for and assessment of enemies of the weed, (B) the determination of host-specificity and the introduction of acceptable species and (C) their establishment and evaluation in the field; these three steps can be quite separate, consecutive or even concurrent when several species are involved.

The exploration phase is usually short-term and involves limited field surveys (about six weeks duration) during the main periods of activity of the weed (peak vegetative growth and flowering); the timing and duration of these surveys will depend on its biology and occurrence. Investigations are usually commenced in the areas where the plant is considered to have evolved but may be extended to the same or closely related species in geographically isolated areas. Assessment of potential and host-specificity at this stage is largely speculative and its value depends to a considerable extent on the experience of the investigator. From this report decisions can be made about :

(a) whether further investigations are warranted;
(b) where the investigations should be located;
(c) the order of priority of study to be given to the various candidate species.

The host-specificity of candidate species can never be determined absolutely and in the relatively limited time allotted to an overseas programme (usually 3 years) indications of restriction of feeding are as important as the results of cage tests or official records which may be far from complete or even incorrect when the country being explored is undeveloped. Evidence on which to determine host range is obtained from:

(a) official records of scientific organisations and instrumentalities;
(b) interviews with workers in agricultural or other scientific fields;
(c) published papers on the host-plant and the candidate enemies;
(d) the host-range of closely related species;
(e) field observations on the biology and ecology of the candidate species;
(f) detailed biology studies;
(g) multiple-choice cage tests using a selected list including plants of economic importance, particularly within the same family.

In Australia the final decision on whether a phytophagous or pathogenic species can be introduced is made by the Federal Government Department of Health. All imported species are subjected to a minimum quarantine period of one complete generation to preclude the accidental introduction of parasites, diseases or extraneous species.

Establishment in the field usually is slow as it involves the growth of relatively small colonies through several generations before numbers are sufficient to have any significant effect on the host plant. As a general rule the period from initiation of a project to a review of its results is about 10 years, although in exceptional cases it may be shorter or much longer.

CURRENT PROJECTS

Current biological control projects being undertaken by the Sir Alan Fletcher Research Station include :

A. Prickly pears *(Opuntia* spp.). The prickly pear biological control programme in Australia has been well documented (Dodd 1940 and Mann 1970), and the excellent control achieved by *Cactoblastis cactorum* (Berg) and the cochineal insects *(Dactylopius* spp.) has continued. Of interest is the fact that effective control of two species *O. aurantiaca* Lindley and *O. monacantha* (Haworth) can only be maintained by manual distribution of cultures of *Dactylopius* sp. near *confusus* Cockerell and *D. ceylonicus* Green. It is assumed that poor powers of dispersal have limited the efficiency of these two species, and the populations of the host plant can reach major proportions in their absence.

B. Lantana *(L. camara* L.). Progress in this long-term (Wilson 1960) programme is now encouraging and significant control of the weed has been recorded from several areas of Queensland (Willson 1976). Recent exploration in Central America and South America has revealed a further number of host-specific insect species and of these, three have been forwarded to Queensland from Costa Rica (Sir Alan Fletcher Research Station project) and four from Brazil (CSIRO project); the species shown in Table 1 have been released in the field.

C. Noogoora burr *(Xanthium pungens* Wallr.). The only insect species known to be specific to *Xanthium*, *Euaresta aequalis* Loew, is established in restricted areas but causes no significant control of its host (Wilson 1960). Two stem-boring beetle species, *Mecas saturnina* Le.C. and *Nupserha antennata* Gahan, although shown to be oligophagous within related Compositae, were imported in 1957 (Wilson 1960) and, following further investigations, were released in the field (Haseler 1970). *M. saturnina* has survived at one site but shows little potential as a control factor. *N. antennata* is established widely at several sites and, although large populations are very destructive in mid-summer, the short adult emergence period is not synchronised with the much longer noogoora burr germination and the plant persists as a major weed. Further, rainfall in Queensland is very variable in time and volume and the annual host population fluctuations may be so extreme as to severely limit the long-term efficiency of biological control factors. A "rust" fungus, *Puccinia xanthii* Schw., was recorded from noogoora burr in Queensland for the first time in 1975 (Alcorn 1975) and dispersal is now widespread. Although reservations are held about its host-specificity (Alcorn 1976) this pathogen gives considerable promise as a control factor and major damage is reported to dense stands of the host.

D. Crofton Weed [*Eupatorium adenophorum)* Spreng]. A significant, although not complete degree of biological control of this weed by three factors, a stem-gall fly, *Procecidochares utilis* Stone, a stem-boring beetle *Dihammus argentatus* Auriv. and a-fungus *Cerospora eupatorii* Peck, has been achieved (Haseler 1966). This plant is now only a significant weed in shaded, damp environments or on damp hillsides with a southern aspect. No significant dispersal of the plant has been recorded since 1952.

E. Groundsel bush *(Baccharis halimifolia* L.). Following surveys of insects of *Baccharis* spp. in North and South America (Bennett 1964), and host-specificity investigations in Florida, USA, between 1967 to 1969, six species of insects were introduced into Australia (McFadyen 1973). Of these, three, a foliage-feeding beetle *Trirhabda baccharidis* Weber, a foliage-feeding moth, *Aristotelia* sp,., and a stem-boring moth, *Oidaematophorus balanotes* Meyrick, were released in the field and the former two species are established, although in limited numbers and without significant effect. Further investigations in Brazil during 1973 to 1976 resulted in the selection of a further 7 host-specific insect species for introduction into Australia, and 4, including three foliage feeding beetles *Anacassis fuscata* Klug., *Anacassis phaeopoda* Buzzi and *Metallactus* sp., and a stem-boring beetle, *Megacyllene mellyi* Chev., have been released in southern Queensland. Releases of all species are continuing.

F. Harrisia cactus *(Eriocereus martinii* (Lab.) Ricc). Following reports that several destructive insect species were present on *Eriocereus* spp. in South America (Bennett 1972; Fidalgo and Zimmermann 1972), four host-specific insects were imported into Queensland; three species, *Alcidion cereicola* Fisher; and *Ericereophaga humeridens* O'Brien, both stem-boring beetles, and *Hypogeococcus festeriana* Lizer and Trelles, a mealy bug, are now established. Although populations of all three species are still in a dispersal phase, indications of significant control are already present.

G. Parthenium weed *(Parthenium hysterophorus* L.) *P. hysterophorus* is widespread in North and South America although seldom is it a weed of economic significance (Bennett 1977; McFadyen 1976). A large insect fauna and disease organisms of unknown host-specificity are present in both the Mexico/United States (Bennett 1977) and Brazil/Argentina (McFadyen 1976) regions. A three year programme to investigate the host-range and biological control potential of the insect and other enemies is planned to commence in South America in mid-1977.

Table 1. Species released on *L. camara* in Queensland since 1956.

Species	Family	Date of introd.	Type of damage	Results
Catabena esula Druce	Noctuidae, Lepidoptera	1956	Foliage feeder	Widespread but population low due to native parasites. Ineffective.
Syngamia haemorrhoidalis Guen	Pyraustidae, Lepidoptera	1956	Leaf roller	Population limited due to native parasite attack. Ineffective.
Diastema trigris Guen	Noctuidae, Lepidoptera	1956	Leaf feeder	Colonies lost through disease.
Hypena strigata Fabr.	Noctuidae, Lepidoptera	1964	Leaf feeder	Indistinguishable from a native species. No change in effects of native sp. observed.
Plagiohammus spinipennis Thoms.	Cerambycidae Coleoptera	1966	Stem borer	Field conditions apparently unsuitable.
Octotoma scabripennis Guerin	Hispidae, Coleoptera	1966	Leaf miner	Effective control in some areas of cooler part of State. Still dispersing.
Uroplata girardi Pic.	Hispidae, Coleoptera	1966	Leaf miner	Effective control in several areas of State. Still dispersing.
Leptobyrsa decora Drake	Tingidae, Hemiptera	1969	Foliage feeder	Some damage reported in North Qld. Still dispersing.
Teleonemia elata Drake	Tingidae Hemiptera	1969	Foliage feeder	No field survival reported.
Teleonemia scrupulosa Stal (biotypes)	Tingidae Hemiptera	1969	Foliage feeder	Indistinguishable from a previously introduced species. No change in effects of established sp. observed.
Teleonemia harleyi Froeschner	Tingidae Hemiptera	1969	Foliage feeder	No field survival reported.
Teleonemia prolixa Stal	Tingidae Hemiptera	1972	Foliage feeder	Limited field survival to date.
Phytobia lantanae Frick	Agromyzidae Diptera	1974	Leaf feeder	Significant damage reported in North Qld. Still dispersing.
Octotoma championi Baly	Hispidae, Coleoptera	1975	Leaf miner	Established in limited areas. Still dispersing.
Uroplata sp.	Hispidae, Coleoptera	1975	Leaf miner	Releases very recent.
Autoplusia illustrata Guen.	Noctuidae, Lepidoptera	1976	Foliage feeder	Release very recent.

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Insects and Fungi Associated with Some Aquatic Weeds in Indonesia

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ABSTRACT

Insect species associated with waterhyacinth (*Eichhornia crassipes* (Mart.) Solms), molesting salvinia (*Salvinia molesta* (Aubl.) D.S. Mitchell), water lettuce (*Pistia stratiotes* L.), alligator weed (*Alternanthera philoxeroides* (Mart.) Griseb.), water primose (*Ludwigia* spp.) and giant bulrush (*Scirpus grossus* L.f.) in Indonesia were recorded. Most of them are general feeders, and some are pests of cultivated plants. A few of them seems to be specific to water lettuce, primose and giant bulrush, but so far based on laboratory and field survey findings only the leaf feeder, *Proxenus hennia* Swinhoe, seems most promising as a biological control agent for water lettuce. In Java 13 taxa of fungi associated with waterhyacinth were also recorded. They are *Myrothecium roridum* Tode ex Fr., *Alternaria eichhorniae* Nag Raj & Ponnappa, *Rhizoctonia solani* Kuhn, *Curvularia* sp., *Pestalotia* sp. and 8 undetermined taxa. *M. roridum, A. eichhorniae* and *R. solani* were most important parasitic fungi of the weed. These fungi appear to have some potential for bio-control of the weed.

INTRODUCTION

According to Soerjani *et al.* (1975) 10 species of aquatic plants have also been incriminated as major aquatic weeds in Southeast Asia. These include waterhyacinth, molesting salvinia, water lettuce, Florida elodea, (*Hydulla verticillata* (L.f.) Royle lotus (*Nelumbo nucifera* Gaertn.), giant bulrush, torpedograss (*Panicum repens* L.), cattail (*Typha angustifolia* L.), monochoria (*Monochoria vaginalis* (Burm.f.) Presl) and water fern (*Salvinia cucullata* Roxb.). Sankaran *et al.* (1967) and Burkhalter *et al.*, mentioned that primose have invaded and disturbed fresh water lakes, canals, ponds and other aquatic habitats.

Efforts with biological control have been made against the first four species in Florida in addition to mechanical and chemical control (Anon. 1973). These programs were initiated in 1966 by the introduction of

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exotic biocontrol agents from South America. In Southeast Asia biocontrol has also been recommended for waterhyacinth, molesting salvinia, water lettuce and Florida elodea (Soerjani *et al.* 1976).

It has been known that specific insects, fungi and other organisms could be used as biocontrol agents against certain species of perennial aquatic weeds. To support research and implementation of biological control, information on taxonomy, biology and ecology of insects, fungi and other organisms, associated with the target weeds, both in their original planned control areas are needed (Zettler and Freeman 1972; Freeman *et al.* 1974; Allen and Mangoendihardjo 1975).

Studies on insects and fungi associated with some important aquatic weeds in Indonesia were initiated in 1973 with an emphasis on waterhyacinth, molesting salvinia, water lettuce, alligator weed, water primose and giant bulrush. Information on insects recorded from these weeds in many part of the world has been given by USAED (U.S. Army Engineering District), Florida (Anon 1973; Allen 1974; Bennett 1975; Rao 1969; Sankaran *et al* 1967) while records of some fungi associated with waterhyacinth were given by Charudattan (1973), Nag Raj and Ponnappa (1970) and Freeman *et al.* (1973).

MATERIALS AND METHODS

Observations on insects associated with the weeds were carried out in Java and South Sulawesi while observations on diseases on waterhyacinth were made at the Curug reservoir and in the Krawang area (West Java), at Rawa Pening (Central Java) and Danau Bureng (East Java). Insects feeding and found on the weeds, plants injured by insects and fungi were collected. Some of the organisms were bred and isolated for identification.

Insect species which are also known as pests of crops were rejected. Further studies were conducted on other species causing appreciable damage to the weeds in the field. The studies include the bionomics, host specificity and damage potential of the species. The methods of studies used are as mentioned by Syed (1976) and Allen and Mangoendihardjo (1975).

Diseased materials with different symptom were collected separately and kept in plastic bags. They were examined under the microscope and isolations were made from affected plants parts. The procedure of isolation and pathogenicity test were made as described by Charudattan (1973). The isolated fungi were subjected to a test of Koch's postulate.

RESULTS AND DISCUSSION

On waterhyacinth an unidentified Hydrophilid, two Noctuids (*Spodoptera litura* F. and *S. mauritania* Sn.), a Symtomid (*Symtomis germana* Feld), 7 species of grasshoppers (Acrididae: *Gensonula punctifrons* Stall., *Oxya japonica* (Thunberg), *O. chinensis* L., *Acrida turita* L., *Attractomorpha psittacina* de Haan, and *Pseudocarsula* sp.) and a Tettigonid (*Conocephalus* sp.), two unidentified Dipterans and an unidentified Aphid (? *Rhophalosiphum nymphae*) were recorded. Among these species *G. punctifrons* appears to be the most common natural enemy of the weed but according to Mangoendihardjo and Syed (1974) its potential is low.

Nymphula responsalis Wlk. (Lepidoptera: Pyralidae) in the most important natural enemy of water fern in Java. The bionomics, host range and potential of this insect were studied in some detail by Subagyo (1975). From the studies it is evident that this stenophagous insect is not very promising as a biocontrol agent for water fern, because of its low damage potential and its parasitization by a pupal parasite (*Tetrastichus* sp.) . An unidentified predacious Coleopteran and a Tabanid associated with roots of the fern and two unidentified Hemipterans on the weed were also recorded in Java. The status of both bugs (Hemipterans) is not clear, but at the Curug reservoir more specimens could be found on plants with abnormally curled form than from healthty plants.

Water lettuce in Java and South Sulawesi is attacked by P. *hennia* Swinhoe (Lepidoptera: Noctuidae), *N. responsalis, S. mauritia,* an unidentified Aphid, a Mesovelid (*Mesovelia* sp. ? *subvittata* (Horv.), and a Cicadelid (*Zygina* sp. (*sensu lato*). Besides these natural enemies a Hydrophilid (*Coelostoma* sp.) and a Tabanid (*Tabanus* sp.) were also associated with roots of the weed. *P. hennia* is the most promising natural enemy. This species was studied by Mangoendihardjo and Syed (1974), Mangoendihardjo and Nasroh (1975) and appears to be specific to water lettuce. Larvae of *P. hennia* were not able to survive on 44 other tests plants belonging to 21 families.

On alligator weed *Psara basalis* Wlk. (Lepidoptera: Pyralidae) is very common in South Sulawesi and Java. Other natural enemies recorded from the weed were a Pyralid (*Hymenia* sp. *recurvalis* F.) a Chrysomelid (*Metriona viridinotata* Boh) and an unidentified Lepidopteran. Preliminary test on host range of *P. basalis* indicated that the species is stenophagous and was able to develop completely on *Ama-*

ranthus sativus a common vegetable crop in Indonesia. In nature it is also attacked by an unidentified larval parasite and a Scarabid. Further studies of other natural enemies are being conducted in the laboratory at BIOTROP.

Three species of lepidopterous stem borers of giant bulrush were recorded viz. 2 species of Pyralids (*Schoenobius ochracellus* Sn. and *Proceras sacchariphagus* Wlk.) and a Noctuid (*Sesamia inferens* Wlk.) (Kalshoven 1950). Kalshoven also recorded the weed as the alternate host of *Scotinophara inermis* (Hemiptera: Pentatomidae). An unidentified stem borer, a curculionid (Coleoptera) and an unidentified Flattid (Hemiptera) were also recorded in the Krawang area in 1975. The stem borer (Curculionid) does not seem to be a promising natural enemy because it seems to develop only on the old and flowering plants. The adults were able to survive for six months in the laboratory but the females produced a very small number of eggs. However, this species will be studied further in the future.

Field observations on natural enemies of water primrose in Java and South Sulawesi showed that *Haltica cyanea* (Weber) and *Haltica* sp. (Coleoptera : Chrysomelidae) and *Nanophyes nigritulus* Boh (Coleoptera : Curculionidae) are the most important species feeding on the weed. *H. caerulea* Oliv. occurs in India and was studied by Sankaran *et al.* (1967). The species was tested on 123 species of plants and indicated that *Trapa bicornis* Osbeck proved as alternate host for *H. caerulea.*

In Indonesia *H. cyanea* was recorded from *Ludwigia hyssofolia* and *L. adscendens* and *Haltica* sp. on *L. adscendens* causing appreciable damage to the weeds. *Nanophyes* sp. nr. *nigritulus* was a common fruit borer in India (Rao 1969) and has not been studied in detail. *N. nigritulus* Boh occurring in Indonesia seems to be very promising as a biocontrol agent against water primrose and will be studied in detail.

During the observations, several diseases on waterhyacinth leaves were recorded. The degree of damage caused by these naturally occurring diseases did not appear to be high enough to retard significantly the enormous growth of the weed.

Koch's postulate tests proved that only 13 taxa of fungi were pathogenic. They were *M. roridum* (4 pure cultures), *A. eichhorniae* (2 pure culture), *R. solani* (3 pure cultures), *Curvularia* sp. (1 pure culture), *Pestalotia* sp. (1 pure culture) and 8 unidentified taxa. Only some of them i.e. *M. roridum, A. eichhorniae* and *R. solani* showed the same symptoms as in the field and caused appreciable injuries to the leaves of waterhyacinth. Apparently these fungsi were primary parasites and the rest were secondary parasites.

According to Freeman *et al* (1973), *Myrothecium* disease and *Alternaria* leafspot were found on waterhyacinth in India and Florida, whereas *Rhizoctonia* blight was found in Panama, Puerto Rico and India.

Myrothecium disease was the most common fungus infecting waterhyacinth. It was found in all areas observed, causing a certain degree of damage and it appears to have some potential for the biocontrol of the weed. Tulloch (1972) said that *M. roridum* can be considered as a serious plant pathogen, usually causing leaf spots which sometimes may result in shot hole and dieback.

Alternaria leafspot caused by *A. eichhorniae* was found in the Curug reservoir and at Rawa Pening. Nag Raj and Ponnappa (1970) considered that *A. eichhorniae* found in India might have some potential for the control of waterhyacinth, because apparently it has a narrow host range. It is expected that *A. eichhorniae* found in both localities in Java will have a similar potential as the species found in India.

Rhizoctonia blight, caused by *R. solani,* induced severe irregular lesions on the leaves, causing blighting and often death of the plants. This fungus was found in Krawang rice fields, Curug reservoir and Danau Bureng. The frequency with which plants infected by this fungus occurred was very low compared with that of plants infected by *M. roridum* and *A. eichhorniae.* According to Charudattan *et al* (1974), *R. solani* is a broad host-range pathogen and its use as a biocontrol agent of waterhyacinth should be considered carefully.

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Further Researches on Tadpole Shrimps for Biological Weeding

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ABSTRACT

The effect of tadpole shrimps on rice seedlings, especially young seedlings at 2.5-leaf stage and suitable for mechanical transplanting, was investigated. The results showed that there was no damage to young seedlings by tadpole shrimps even in the case of irregular and rough transplanting operations. Introduction of egg-containing soil into paddy fields, which had been flooded, did not result in the occurrence of tadpole shrimps. The effect of the flooding date before the introduction of tadpole shrimps was tested using experimental concrete pots. Although the pots were flooded 3, 6, and 9 days before the introduction of eggs no tadpole shrimps could be observed in these plots. Only when the eggs were introduced at the same time as flooding were a reasonable number of tadpole shrimps observed. It appears that the natural enemies, which had hatched prior to the tadpole shrimps took their toll when the introduction of the eggs was delayed. Actual labor of weeding was estimated in paddy fields where a number of tadpole shrimps occurred and no pesticide was used. Total weeding labor was found to be 20 hr per ha which was significantly less than the average of 100 hr per ha for present weeding systems in Japan, including the use of herbicides.

INTRODUCTION

The outline of the utilization of tadpole shrimps (*Triopus longicaudatus* LeConte, *T. granarius* Lucas and *T. cancriformis* Bosc.) as a biological tool of weed control in transplanted rice fields in Japan was introduced at the 5th Asian-Pacific Weed Science Society Conference (Matsunaka, 1976). Taxonomical position, life cycle, distribution in Japan, weeding mechanism, utility in weeding and problems in the future were discussed.

In this paper, some further subjects such as the effect on young rice seedlings, the effect of flooding date on the occurrence of tadpole shrimps, and the estimation of actual labor of hand-weeding in the paddy fields utilizing tadpole shrimps, will be reported.

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MATERIALS AND METHODS

Effect of tadpole shrimps on rice seedlings: After flooding the concrete pots (50 by 50 cm) on June 3, 1976, the soils with eggs of American tadpole shrimps (*T. longicaudatus*) were added into the water and the contents of the pots puddled. Rice seedlings (cv Nihonmasari) of 2.5-leaf age were transplanted by hand, at 8 hills per concrete pot and 4 seedlings per hill (32 seedlings per pot). The seedlings had been cultivated for mechanical transplanting. Bad transplanting operations, which may sometimes be expected in practice, were simulated by putting the soil part of the seedlings on the surface of the flooded soil. Normally the soil parts, including the roots of the seedlings are inserted into the ground soil by the transplanting machine. Water depth was kept at 3 cm. In the plots without any tadpole shrimps the weeding was done by hand. The number of tillers was counted, 26 days after transplanting. The top parts were harvested, 41 days after transplanting and their dry weight was measured.

Effect of flooding date on the occurrence of tadpole shrimps: The same 50 by 50 cm concrete pots were used. Flooding was done 9, 6, and 3 days before and just on the day of adding of tadpole shrimp eggs. The number of tadpole shrimps was counted 8 days after the introduction of eggs. In this experiment, rice plants were not transplanted.

Weeding labor estimation: A farmer's paddy field, where tadpole shrimps appeared naturally, was used for this experiment. The field had an area of 6 acres and was managed without any pesticides. Forty days after transplanting hand-weeding was done and the manpower labor estimated.

RESULTS AND DISCUSSION

The effect of tadpole shrimps on young seedlings is shown in Table 1. Neither the number of tillers nor the dry weight of the shoot showed any significant difference between the plots with and without tadpole shrimps, although between normal and bad transplanting operations we did find significant differences. No weeds were found in the tadpole shrimp plots and the last column of Table 1 shows that the number of tadpole shrimps was sufficient to control the weeds. From these results, tadpole shrimps do not damage transplanted rice plants even though they may be young (2.5 leaf age) and poorly transplanted. In the case of direct seeding onto flooded land, tadpole shrimps cause severe damage to the emerging rice plants.

The first step in the practical experiments was to introduce eggs of tadpole shrimps into the soil of an experimental paddy field just after puddling, in the 1976 season. However, no tadpole shrimps were observed

Table 1. Effect on young seedlings by tadpole shrimps

Trans-planting	Tadpole shrimps	Number of tillers per hill			Dry weight of top part (g/8 hills)			Number of tadpole shrimps per m² (range)
		Mean	S.D.	Difference *	Mean	S.D.	Difference *	
Normal	with	15.0	0.92	a	48.6	6.07	a	68 (40 - 132)
	without	14.6	1.02	a	45.4	3.51	ab	0
Poor	with	16.2	1.30	b	44.9	4.73	ab	100 (28 - 264)
	without	16.0	0.91	b	42.7	3.03	b	0

Eight pots were used to each plots, respectively. Number of tillers was counted on June 30 (26 days after transplantation) and rice plants were harvested for measurement of dry weight on July 15 (41 days after transplantation).
* Not significant in the case of the same letter at 5% level.

in the plots. The reason for their absence appears to be early unexpected flooding as a result of irrigation in the adjacent experimental paddy fields. The effect of the flooding date on the occurrence of tadpole shrimps was therefore, substantiated.

The results are shown in Table 2. It shows that flooding 3 days before the introduction of tadpole shrimp eggs may inhibit the

Table 2. Effect of flooding date on occurrence of tadpole shrimps

	Number of tadpole shrimps per 0.25 m² — Flooding date (days before introduction of eggs)			
	9	6	3	0**
	0	1*	0	37
	0	2*	0	56
	0	0	0	30
	0	0	1*	25
Means	0	0.8*	0.3*	37

Four pots were used to each plots, respectively.
* Large scale tadpole shrimps, which hatched from the original soil when flooded.
** September 9, 1976. Number was counted on September 17.

occurrence of shrimps in the same way as flooding 6 or 9 days beforehand did. Although one or two tadpole shrimps were found in some pots flooded 3 or 6 days before the introduction of eggs, they were large and seemed to have hatched from the original soil at the same time as flooding. From this experiment, we may conclude that, for the purpose of normal hatching from eggs in the natural paddy fields, the addition of eggs into the fields should be done at the same time as flooding. The reason seems to be due to the reduction of the natural enemies which had hatched and were dominant already and probably would have a severe effect on the newly hatched tadpole shrimps.

To the limited area (about 10 m^2) of the experimental paddy fields, a large number of tadpole shrimps were introduced, but they disappeared 3 to 4 days afterwards. No dead bodies could be found in the plot. The relatively large enemies, birds, frogs and others, all seemed to feed on tadpole shrimps. Here we can say that, when planning to apply the eggs to paddy fields as a bio-pesticide (bio-herbicide), we should do it over a wide area to avoid a local attack by the natural enemies.

In a farmer's field with a large number of tadpole shrimps the management, after transplanting, was done without any pesticides. Weeding was done only by tadpole shrimps and the number of weeds remaining were decreased, so hand-weeding was practiced 40 days after transplantation. Two men took 40 minutes to hand-weed 6 acres of paddy fields. It was calculated that 20 man-hours per ha, were needed and this was significantly less than the 90 to 100 man-hours per ha which is the average for present weeding procedures in Japan including the use of herbicides.

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Some Ecological Impacts of the Introduction of Grass Carp (Ctenopharyngodon idella Val.) for Aquatic Weed Control

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ABSTRACT

The faeces of grass carp *(Ctenopharyngodon idella* Val.) indirectly cause deterioration of water quality such as a decrease in dissolved oxygen (Odum 1971). A mixed culture in equal weight of grass carp and kissing gourami (*Helostoma temmincki* c.v.) reduced the deterioration of water quality. When the plankton feeder constituted only 30% of the total fish population, the deterioration of water quality still occurred. A mixed culture with common carp *(Cyprinus carpio* L.) did not reduce the deterioration of water quality. Another ecological implication of the use of grass carp for biological control of aquatic weeds is its preference for rice plants. The presence of hydrilla *(Hydrilla verticillata* L.f. Royle) significantly reduced the consumption of rice by grass carp while the presence of salvinia (*Salvinia cucullata* Roxb.) and waterhyacinth *(Eichhornia crassipes* (Mart.) Solms) did not decrease the damage to rice.

INTRODUCTION

Grass carp is considered one of the most efficient plant-eating fishes and is being employed both as a biological weed control agent and a source of food in a number of countries (Bailey 1972, Mehta *et al* 1972, Sharma of food in a number of countries (Bailey and Boyle 1972, Mehta and Sharma 1972, Sharma and Kulshresta 1974). This fish consumes an enormous amount of food with estimates running as high as two to three times its body weight per day (Sneed 1971). Its gut is only two or three times the length of the body and consequently the faeces contains about 50% of undigested food. Faecal material and undigested food may act as a fertilizer and cause phytoplankton blooms. The blooms rise to the surface and the oxygen produced by photosynthesis largely escapes into the air. When the bloom dies, oxygen in the water is used up, often stressing or killing the fish (Odum 1971).

The use of grass carp for weed control entails the risk of their escape into natural waterways and possible damage to valuable plants (Bardach *et al* 1972). Studies in Indonesia indicated that grass carp could control dense population of hydrilla, salvinia *(Salvinia molesta* D.S. Mitchell)

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and could retard the growth of waterhyacinth. However, it also causes some damage to rice plants (*Oryza sativa* L.).[2]

The object of this study was to determine if mixing other fish species with grass carp could mitigate the adverse effects of grass carp on water quality. Feeding preference of grass carp for different varieties of rice was also investigated.

MATERIALS AND METHODS

Experiment 1. Ten cylindrical tanks of 1.77 m^3 each were used in this experiment. The tanks were filled with pond water and after one week each tank was stocked with fish (6.7 – 8.6 cm in length and 11.5 – 15.0 g in weight). Three days later sufficient waterhyacinth plants were put in to cover 1/4 of the surface area of each tank. The treatments of this experiment were as follows : (A) control (without fish); (B) 99.5 g of grass carp; (C) 54 g of grass carp and 51 g of common carp; (D) 54.8 g of grass carp and 54.5 g of kissing gourami; (E) 31 g of grass carp and 33 g of kissing gourami and 30.2 g of common carp. Hydrilla, at 200% of the total fish weight was given as daily food supply. Parameters measured included physical factors (temperature, turbidity); chemical factors (pH, CO_2, O_2, alkalinity, N and P), suspended organic matter and biological factors (phyto-and zooplankton). Phyto- and zooplankton samples counted under a microscope.

Experiment 2. This experiment was designed to discover if grass carp showed any food preferences for different rice varieties and if the fish preferred hydrilla to rice.

Sixteen 6 m^2 ponds lined with plastic, eight varieties of rice (C_4 – 63 gb, PB_5, PB_8, Pelita I/1, Pelita II/2, Syntha, Serayu and Ketan Ampera) were used.

As a first step each variety was tested individually. In this experiment 32 stems arranged in 8 clusters and planted in 2 plastic pots were put in the middle of the pond. The depth of water from the surface to the base of the rice stems was maintained at 20 cm. Fish were put into the ponds and the test was continued for three days.

In the second experiment varietal preference was tested. The procedure was similar to the previous test, except that all the eight varieties were planted together in each pond, and each treatment was replicated four times. The preference test was repeated with hydrilla (250 g) added to the ponds to see if it had any effect on the preferences of grass carp for

2 Pheang C.T. 1975. A preliminary study on the Biological Control of Important Aqualitic Weeds in Southeast Asia with Chinese Grass Carp *(Ctenopharyngodon idella* Val.) BIOTROP Int. Report. 12 pp.

rice. The number of leaves eaten by the fish were counted after 24 hours and the plants were then replaced with a new set of plants. A completely randomized design was used in this experiment.

Experiment 3. This experiment was a continuation of experiment 2. A larger pond (100 m^2 and 60 cm in depth), waterhyacinth, salvinia and older rice plants (4 months old) were used in this experiment. Almost all of the rice varieties were local varieties. They were planted together at the corner of the pond and their stem bases were 20 cm below the water surface. The same observations were made as in experiment 2.

RESULTS AND DISCUSSION

Experiment 1. The ranges of the water temperature and pH in all treatments during the experiment were not different from the control (Table 1).

Table 1. The temperature, pH, alkalinity turbidity of water in each treatment during 42 days.

Treatment	Temperature C	pH	Turbidity (cm)[1]
Control (without fish)	23.5 — 32.2	5.9 — 7.1	90.0
Grass carp only	23.5 — 32.4	5.0 — 6.9	52.8
Grass carp + Common carp	23.8 — 31.8	5.6 — 7.7	59.5
Grass carp + Kissing gourami	23.5 — 32.4	5.6 — 7.1	90.0
Grass carp + Common carp + Kissing gourami	23.5 — 31.4	5.7 — 7.7	70.0

Data was measured by using secchi dish in the last 42 days.

The phytoplankton population increased very quickly in the tanks where only grass carp were present, this might have been caused by an increase in plant nutrients released from grass carp faeces. Logically the increase of the phytoplankton population and consequent increase in photosynthesis should result in an increase in dissolved oxygen and a drop in the CO_2 content in water, but this did not occur. Actually the dissolved oxygen decreased and the CO_2 and alkalinity increased very quickly (Figure 1). This may be due to restricted photosynthetic activity caused by the increased turbidity in water (Table 1). Another factor may have been an increase in the biological oxygen demand (BOD) as a result of the bloom of macro-zooplankton (Figure 2). The increase of CO_2 also indicated an increase of bacteria, fish and macro-zooplankton.

Similar trends were observed in the mixed culture of grass carp and common carp and of grass carp and kissing gourami (when the last mentioned was at 30% of the total weight of fish). However, there was some

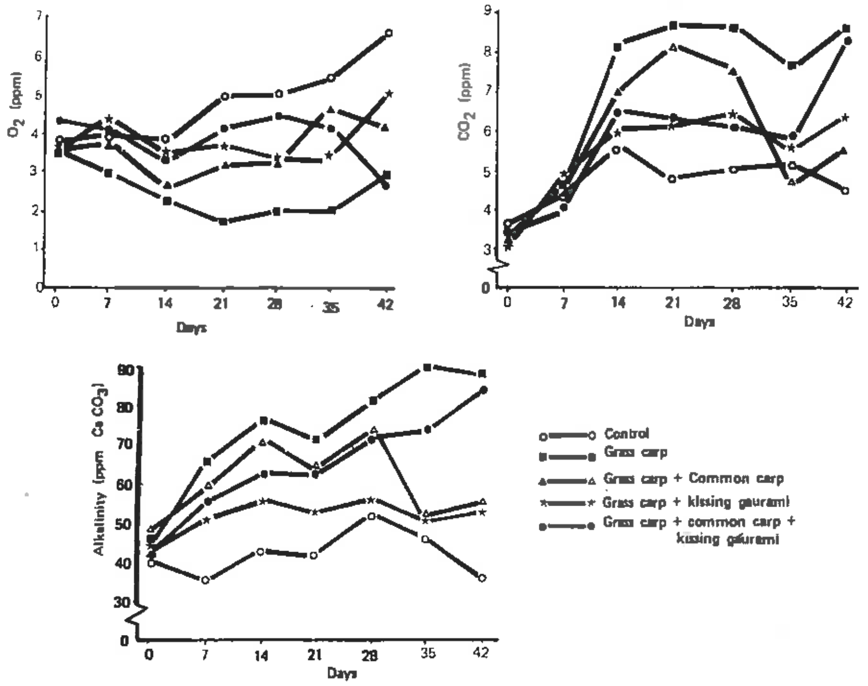

Figure 1. Trend of the dissolved oxygen (O_2), carbon dioxide (CO_2) and alkalinity in each treatment during 42 days.

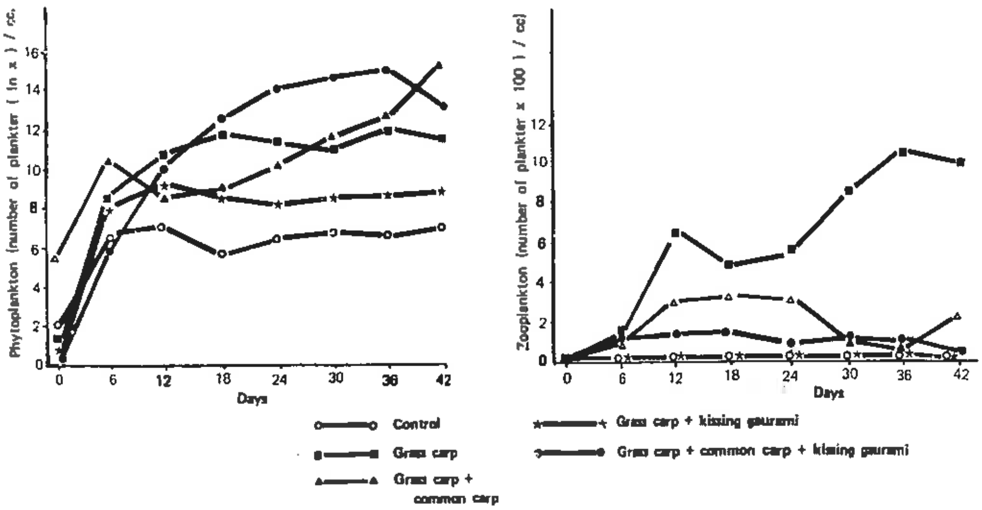

Figure 2. Trend of the phytoplankton and zooplankton populations in each treatment during 42 days.

indication that the presence of kissing gourami as a plankton-feeder, in equal weight with grass carp (50% of the fish weight) reduced the plankton bloom and consequently checked the drop in dissolved oxygen (Figure 1 and 2).

The nitrogen content was almost constant in the control. However, in other treatments it increased by as much as 230% after 28 days (Figure 3). In all treatments the phosphate decreased continuously during the experiment until it could not be detected (Figure 3). Part of the decrease in phosphate might have been caused by its uptake by phytoplankton and part may have been due to its precipitation.

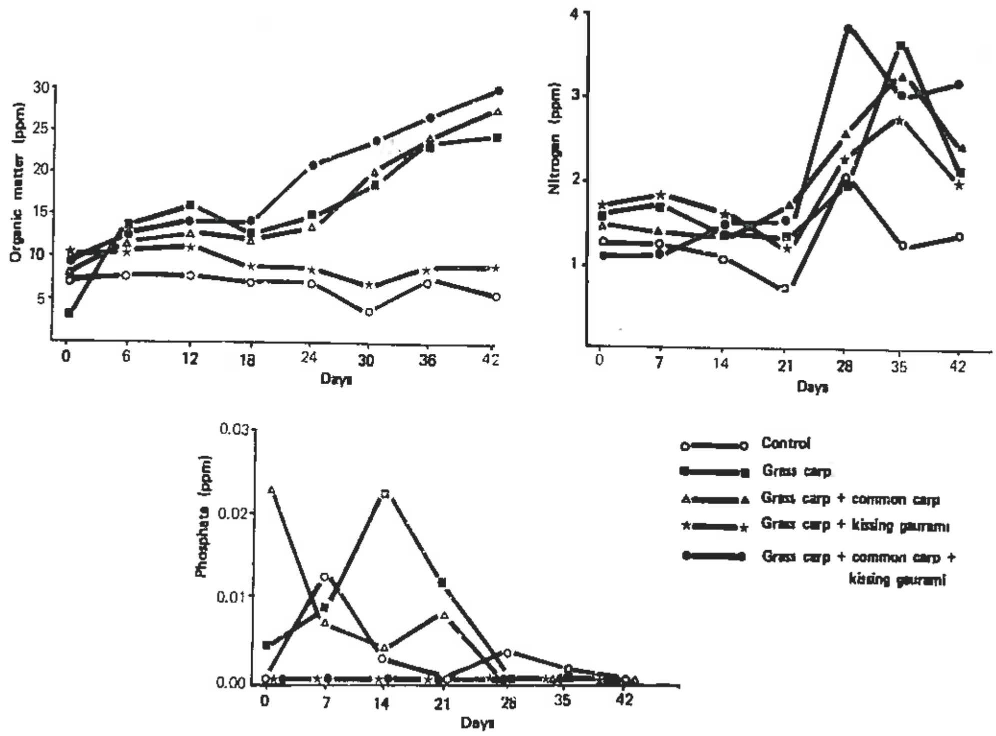

Figure 3. Trend of the organic matter, total nitrogen and phosphate in each treatment during 42 days.

Experiment 2. The result showed that the grass carp could consume all rice varieties and did not show any preference for any one variety (Table 2

Table 2. Number of leaves eaten by grass carp on starvation test.

Rice variety	Heigh (cm)	Number of leaves[1]	Relative damage
Ketan Ampera	38.54	157.0 ± 4.0	94.76 %
C_4 — 63 gb	30.35	149.3 ± 5.7	97.34 %
PB 8	31.33	144.6 ± 5.3	99.31 %
Pelita I/2	29.00	143.6 ± 7.7	98.48 %
Syntha	42.33	135.0 ± 10.5	91.96 %
Pelita I/1	29.33	132.0 ± 7.8	91.72 %
PB 5	30.10	127.0 ± 9.5	94.74 %
Serayu	41.83	125.6 ± 20.8	81.82 %

1 Each value is average of 3 day observations, followed by standard deviation.

Table 3. Number of leaves eaten by grass carp on preference test.

Rice variety	Number of leaves[1]	Relative damage
Pelita I/2	75.58 bc	86.79 %
Pelita I/1	75.24 bc	88.48 %
Serayu	71.08 ab	81.12 %
C_4 — 63 gb	69.16 ab	88.63 %
Ketan Ampera	68.41 ab	82.89 %
PB 8	68.24 ab	82.18 %
PB 5	63.83 ab	80.77 %
Syntha	59.08 a	71.72 %

1 Values followed by the same letter are not significantly different at 5% level as determined by HSD test. Each value is the mean of four replication.

and 3). The addition of hydrilla at about 150% — 250% of the fish weight significantly reduced the number of rice leaves eaten by the fish (Table 4). Pheang[2] reported that grass carp prefer hydrilla to some other aquatic plants and Prowse (1971) reported that in Malacca if foods to which the fish had been trained were put in pond with hydrilla, they refused the other foods until all the hydrilla was eaten.

Table 4. Effect of hydrilla to the number of leaves eaten by grass carp[1]

Rice variety	Without hydrilla	With hydrilla	Different
PB 8	101.50	88.93	11.67
Pelita I/2	98.16	88.83	9.33
Pelita I/1	96.33	95.16	1.17
Syntha	94.66	77.33	17.33
Ketan Ampera	93.00	80.63	12.37
Serayu	92.63	70.16	22.47
PB 5	92.33	74.33	18.00
C_4 — 63 gb	91.00	76.33	14.67
Total	759.61	652.60	107.04
Average[2]	94.40 a	81.57 b	13.38

1 Each value is the mean of three replication.

2 Different letter means significantly different at 5% level as determined by LSD test.

Experiment 3. The number of leaves of each variety damaged in the presence or absence of waterhyacinth and salvinia by grass carp were not significantly different at 5% level (determined by HSD test) (Steel and Torrie 1960). Dwarf plants were damaged to a greater extent then the taller varieties (Table 5). There was a significant negative correlation at 5% level, between height of plant and number of leaves damaged.

The presence of waterhyacinth and salvinia did not reduce leaf damage to rice plants.

Table 5. Number of leaves of nine varieties of rice damage:

No.	Rice varieties	Maximum height of plant (m)	Rice: Without aquatic weed	Rice: With[2] aquatic weed
1.	Serayu	0.75	16 a[1]	19 a
2.	Syntha	1.05	20 ab	18 a
3.	Pelita	0.65	37 c	45 c
4.	PB 8	0.60	44 c	42 c
5.	Pelopor	0.95	18 ab	20 a
6.	Cempo Merah	1.20	14 a	17 a
7.	Ketan Ampera	1.10	12 a	15 a
8.	Dewi Ratih	0.69	32 abc	24 ab
9.	C 4	0.60	58 bc	39 bc
	Total		271 $R_1 = 85$	[3]239 $R_2 = 71.5$[2]

1 Values with the same letter are not significantly different at 5% level as determined by HSD test. Each value is the mean of four replications.

2 Waterhyacinth and salvinia.

3 $R_2 = 71.5 > R.\ 0,05\ (9,9) = 62$ — non significant (determined by Mann- Withney U-Test) (Nasoetion and Barizi 1975).

Correlation :

1. Between height of plant and number of leaves damaged of rice without aquatic weed. $r_1 = -0.82 > r_{0.01} = 0.73$; negative correlation significantly at $P < 0,01$.
2. Between height of plant and number of leaves damaged of rice with aquatic weed. $r_1 = -0.80 > r_{0.01} = 0.73$; negative correlation significantly at $P < 0.01$.

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An Attempt on Biological Control of Eupatorium odoratum L.f. in Sabah, Malaysia

R. A. SYED [1]

ABSTRACT

Biological control of *Eupatorium odoratum*, a serious weed in Southeast Asia, was attempted in Sabah, Malaysia by introducing *Ammalo insulata* (Walk.) (Artiidae) and *Apion brunneonigrum* B.B. (Curculionidae) from Trinidad. The former was temporarily established in one locality while the latter oviposited in nature but later disappeared. It appears that the attempt was a failure.

INTRODUCTION

Eupatorium odoratum L., commonly known as Siam weed in Southeast Asia, is a native of West Indies and continental America from Florida to Paraguay. It was apparently introduced from the West Indies in the ballast of cargo boats into Singapore whence it spread into Malaysia, Burma and other neighbouring countries.

The West Indian Station of the Commonwealth Institute of Biological Control (CIBC) had made a survey for insects associated with *E. odoratum* in Trinidad and had found *Ammalo insulata* (Walk.) and *Apion brunneonigrum* B.B. suitable for introduction into other countries. The Department of Agriculture, Sabah provided funds in 1970 to the CIBC for importation and introduction of these insects into Sabah for the biological control of the weed.

STATUS AND DISTRIBUTION OF *E. ODORATUM* IN SABAH.

E. odoratum is found almost all over Sabah. It is very abundant on the eastern coast near Tawau, Kunak and Sandakan where it has occupied most of the areas cleared from forest and competes with cover crops and young plantation crops, retarding their growth to a considerable extent. On the western coast its distribution is patchy around Kota Kinabalu, Tuaran, Kota Belud and Papar but is abundant in some coconut fields near Beaufort.

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In Sabah the weed flowers from November to January, except on roadsides where the soil is very compact the old stems continue growing and branching from leaf axils. This gives rise to dense bushes of tangled branches which are very difficult to penetrate. These bushes may be up to 10 feet high but at places they have been seen to grow over 20 feet high as semicreepers on trees.

NATURAL ENEMIES OF *E. ODORATUM* IN SABAH.

E. odoratum seems to be quite free from insect enemies in Sabah. The only insect causing some damage all over the State is an aphid *(Aphis spiraecola)* which attacks young shoots and causes leaf curl. *Coptosoma* sp. ? *variegata* H.S. (Plataspidae) is often found on young shoots but it does not appear to cause any significant damage. In addition to these four species of Coridae *(Mictis gallina* Dall., *Homoeocerus serrifer* Westw., *Riptortus pilosus* Thunb. and *Riptortus* sp.), a weevil *(Hypomeces squamosus* (F.)) and a few species of grasshoppers have been recorded on the weed.

SELECTION OF NATURAL ENEMIES FOR IMPORTATION INTO SABAH.

The CIBC West Indian Station had carried out a survey for the natural enemies of *E. odoratum* in Trinidad and South America at the request of and financed by the Nigerian Institute for Oil Palm Research. Preliminary investigations indicated that the Arctiid *Ammalo insulata* (Walk.) (previously identified as *A. arravaca* Jordan) was quite host-specific and capable of causing considerable defoliation, but was controlled by numerous parasite species and a polyhedral virus. It was suggested that if disease and parasite-free stocks were introduced this insect might have the potential to keep *E. odoratum* under continued pressure and thereby reduce its competitiveness with other plants (Cruttwell 1968). This insect was further investigated for host specificity (Bennett and Cruttwell 1973) and it was found that *A. insulata* was unable to complete its development on plants other than *Eupatorium* spp., and that even within the genus *Eupatorium* only two species *E. ivaefolium* and *E. microstemon*, apart from its regular host *E. odoratum*, were suitable for normal development. Additional tests were carried out at the CIBC Indian Station where 85 species of plants representing 42 families were screened. No feeding occurred on 75; and only slight feeding or nibbling was observed on 10 species[2]. These tests further confirmed the conclusion that *A. insulata* is extremely specific to *Eupatorium* spp.

2 T. Sankaran, personal communication.

Young larvae were provided to the entomologist, Agricultural Research Centre, Tuaran, for further screening tests in Sabah. These tests reconfirmed the above-mentioned conclusion.

Another insect, a Curculionid, *Apion brunneonigrum* attacking *E. odoratum* in Trinidad was found promising and investigated in detail (Cruttwell 1973). Adults of this weevil feed on the young leaves and buds of *E. odoratum* and *E. ivaefolium.* During the flowering season of the host the females lay eggs in flower-buds where larvae develop and destroy the flower-buds. Each pupates within the flower-head and on emergence the beetle feeds on flowers and/or on buds and young leaves before dispersing. Adults congregate on flowers again during the following flowering season.

A. brunneonigrum has never been recorded damaging economic plants and its life-history is closely linked with the development of its host. In screening tests it did not feed on leaves or buds of any other plant and it proved very selective in oviposition tests.

For the reasons stated above *A. insulata* and *A. brunneonigrum* were considered safe for importation and trial against *E. odoratum* in Sabah.

IMPORTATION, BREEDING, RELEASES AND RECOVERIES OF *AMMALO INSULATA.*

Importation : In view of the fact that *A. insulata* is attacked by a polyhedral virus in Trinidad, eggs were shipped to the CIBC Indian Station where a disease-free culture was established. The Indian Station shipped *A. insulata* eggs to Sabah in November 1970. A culture was established and releases were made. Later it was felt that the insect might have become weakened due to inbreeding so fresh cultures were obtained from Trinidad again via the Indian Station in July 1972. Details of shipments are presented in the following table.

Table 1. Shipments of *A. insulata* eggs received from the CIBC Indian Station

Date of shipment	Date of receipt	No. of eggs shipped	No. of larvae obtained
18 – 11 – 70	23 – 11 – 70	2,000	100
30 – 11 – 70	7 – 12 – 70	2,500	18
13 – 7 – 72	17 – 7 – 72	1,500	344
15 – 7 – 72	19 – 7 – 72	2,000	372
17 – 7 – 72	22 – 7 – 72	1,000	732
19 – 7 – 72[1]	24 – 7 – 72	1,000	1,000

[1] 200 pupae from which 36 moths emerged were also included in this shipment.

Breeding and Life History : Breeding of *A. insulata* was carried out in an open insectary in cages measuring 45 by 45 by 45 cm. The cages had a wooden floor, one side with sliding glass and three sides and top of nylon mesh. The moths were released in these cages and provided with diluted honey in soaked sponge-piece which was attached to one side of the cage. A small bouquet of *Eupatorium* twigs with their ends dipped in water in a small container were placed in the cage for oviposition. It was observed that if the entire floor of the cage was covered with synthetic sponge soaked in dilute honey, oviposition and hatching were considerably improved.

Eggs were laid on leaves, the sides of the cages and dropped on the floor of the cages. These were collected and put in Petri dishes on leaves of *E. odoratum.* The young larvae were transferred to glass jars containing leaves and when they were 3 — 4 days old these were transferred to cages similar to the breeding cages with a large bouquet of *E. odoratum* leaves. Leaves were replaced with fresh ones as often as required. Pre-pupae and pupae were transferred to glass jars for emergence of adults. Life-history was as follows:

Table 2. Duration (in days) of the various stages of *A. insulata* (temperature 25° to 35°C).

Stage	Duration	Average duration
Egg	4	4
Larva 1st instar	3	3
2nd ,,	3 — 4	3.7
3rd ,,	2 — 3	2.2
4th ,,	2 — 5	3.7
5th ,,	3 — 8	4.7
6th ,,	4 — 6	4.3
Pre-pupa	1 — 2	1.8
Pupa	10 — 12	10.7
Adult	5 — 8	6.7
Total Life Span	39 — 44	42

All males and some females had only five larval instars while most females had six. The female laid up to 186 eggs in the laboratory.

Releases : The criteria of selection of test release sites were, (a) availability of sufficient host plants for larval feeding, (b) accesibility of the release site for recoveries, (c) availability of local help to keep an eye on release sites and (d) varied ecological conditions. For these reasons suitable situations near Tuaran (near Tuaran River and Tuaran Road), Kota

Kinabalu (Petagas and Papar Road), Ulu Dusun (in and near Oil Palm Research Station) and Tawau (in and near BAL estates) were selected. It was planned that if the insect became readily established and increased its population, mass-releases would be made in other areas. Details of releases are given in Table 3.

The first release of 200 larvae at Tuaran was made in a field cages. After a day or two no larvae were found in the cage and therefore subsequantly this method was abandoned. Releasing eggs instead of the larvae was tried to facilitate releases and to avoid possible weakening of stock by keeping them under laboratory conditions and also to avoid disturbing the diurnal feeding rhythm of the larvae (larvae feed at night). From 4200 eggs relased on March 29, only 475 were found on April 1, and from 200 released on April 11, only 14 were recovered on April 12. Ants were seen amongst the remaining eggs and it appeared that they had removed the eggs.

Table 3. Release of *A. insulata* in Sabah

Date	Locality	Number of larvae/ eggs released
Dec. 1970	Tuaran	200 larvae
Feb. 1971	Ulu Dusun	1,500 ,,
Mar. 1971	,,	2,038 ,,
Apr. 1971	Tuaran Road	2,086 ,,
Jul. 1971	Ulu Dusun	408 ,,
Aug. 1971	Tawau	1,683 ,,
Sep. 1971	,,	1,200 ,,
Oct. 1971	,,	800 ,,
Mar. 1972	Tuaran Road	8,320 ,,
Sep. 1972	Tawau	5,627 ,,
Feb. 1973	Papar Road	8,050 ,,
Mar. 1973	Petagas	4,200 eggs.
Apr. 1973	,,	200 ,,
	Total:	36,312

Recoveries : There were no recoveries from Tuaran or from Ulu Dusun where 1500 larvae were released. A fortnight after releasing 2038 larvae at Ulu Dusun in March a batch of hatched eggs and a larva were recovered from near the release site. Neither the released larvae nor any subsequent generation of the larvae released at other sites during 1971 were found. On the Tuaran Road where 8320 larvae were released on March 21, 1972 only 12 larvae were seen on April 8, and none thereafter. At Tawau, where 5627 larvae were released in September 1972, evidence of larval feeding was observed in October but neither larvae nor any other stage was recovered.

On the Papar Road, a week after the release of 8050 larvae (on 20th February, 1973) a number of these were seen hiding in crevices near the roots. About a month later (March 24) 3 hatched egg-batches and 24 larvae were recovered. Four months after the release (on June 27) five damaged spots with *Ammalo* frass and 5 larvae were seen. Six months after the release (on August 28) at night 3 batches of eggs, 8 moths and 12 larvae were seen. Four days later two of the egg batches were found, both had hatched but only one showed evidence of young larval feeding. At this locality, although *Ammalo insulata* had survived for over six months, during which it had passed through 4 — 5 generations, the population did not seem to have increased. Further, it was observed that all the population was restricted to a small patch of *Eupatorium* sp. from where it had not spread. It appeared that natural enemies, most probably ants and other general predators, were keeping the population down.

IMPORTATION, RELEASES AND RECOVERIES OF *APION BRUNNEONIGRUM*

Importation : Since *A. brunneonigrum* oviposits on flowerbuds which are available only from November to January no attempt was made to establish its laboratory culture. In the first shipment which contained some flower-buds for their feeding in transit, 80 eggs were laid during transit. These were transferred to flower-buds on potted plants in the laboratory but failed to develop.

Details of shipments received from the CIBC West Indian Station are given in Table 4.

Table 4. Shipments of *A. brunneonigrum* received from the CIBC West Indian Station

Date of shipment	Date of receipt	No. of adults shipped	No. of live adults received
Dec. 8, 1970	Dec. 14	430	100
Dec. 15, 1970	Dec. 26	250	7
Feb. 16, 1971	Feb. 20	212	200
Dec. 10, 1971	Dec. 14	240	200
Dec. 17, 1971	Dec. 22	128	64
Dec. 24, 1971	Dec. 30	104	69
Feb. 11, 1972	Feb. 23	480	480
Feb. 18, 1972	Feb. 23	220	220
Feb. 21, 1973	Mar. 1	80	70

Releases : Releseas of *Apion* were made at the same localities where *A. insulata* was released. Details of releases are given in Table 5.

Table 5. Release of *A. brunneonigrum* in Sabah.

Date	Locality	Number of adults released
Dec. 10, 1970	Ulu Dusun	70
Feb. 18, 1971	,,	50
Dec. 16, 1971	Tawau	200
Dec. 24, 1971	,,	60
Dec. 30, 1971	Kota Kinabalu	69
Feb. 23, 1972	,,	500

As mentioned by Cruttwell (1973a) the weevils released in December were sexually mature while those released in February were young. This may also be responsible for the higher mortality of weevils in shipments received in December.

The first release of 70 weevils was made in a field cage fixed on a large bush of *Eupatorium* sp. This cage was soon torn by animals etc. and after a fortnight no weevils were seen inside the cage. Under these circumstances subsequent releases were not made in cages.

Recoveries : At Ulu Dusun where 70 adults were released in December 1970, *Apion* was reared from 20 flowers out of 224 collected in February 1971. Isolated weevils were seen in flower-heads during February and March. A year later in the next flowering season of *Eupatorium* no weevils were found.

On the Tuaran Road where 69 gravid females were released in December 1971, 6 adults were seen two months after the release. This again indicated that *Apion* had laid eggs in the field. After the release of 500 adults in February, 20 adults were seen a week later and also three weeks after the release, but none thereafter. It was not recovered from Tawau.

The adults received in the last shipment were tested on rice and sorghum inflorescences, but no feeding was observed.

It appears that gravid females readily laid eggs after release but probably the subsequent generation was unable to find suitable niches to pass the period when no flowers were available. There is also a possibility of the weevil having been established in some situation in or near the forest which we have not been able to find.

SOME OTHER POTENTIAL CANDIDATES FOR BIOLOGICAL CONTROL OF *E. ODORATUM.*

Work had been continued at the CIBC West Indian Station to find and test other species of natural enemies of *Eupatorium*. An Eriophyid mite *Acalitus odoratus* Keifer, heavy attack of which stunts and slows the growth of plant, has been found suitable for introduction into other countries (Cruttwell 1972). A Phycitid bud and stem-borer, ? *Acrobasis* sp., has also been investigated and recommended for introduction (Cruttwell 1973).

Some areas of Central and South America have been surveyed for natural enemies of *Eupatorium* and a number of promosing species have been found (Cruttwell 1969; 1971).

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GOAL — A New Herbicide for Multiple Crops

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ABSTRACT

GOAL, a diphenyl ether herbicide synthesized by Rohm and Haas Company, has been evaluated extensively on a variety of crops in Southeast Asia. GOAL controls many broad-leaf weeds and grasses when used pre-emergence at low rates. It has exhibited excellent control in plantation crops when applied post-emergence in combination with other herbicides. Efficacy is discussed.

INTRODUCTION

The nitrodiphenylether compounds are important for weed control in agronomic and horticultural crops. GOAL, commonly known as oxyflourfen, was first described by Yih and Swithenbank (1975) as very active for weed control in various crops. Major emphasis in the South Asian region was placed on the pre-emergence evaluation of this compound in leguminous crops, cassava, sugarcane and rice. Soil incorporation of GOAL resulted in reduced effectiveness. However, considerable improvement has been observed in direct performance comparisons with nitrofen (2,4-dichlorophenyl-*p*-nitrophenyl ether).

GOAL has also shown good herbicidal activity in controlling established weeds when applied in combination with paraquat (1,1'-dimethyl-4,4'-bipyridinium ion), MSMA (monosodium methanearsonate) and several other herbicides. The various combinations require further field evaluation under tropical conditions before their efficacy can be fully determined.

PHYSIOLOGICAL PROPERTIES

GOAL is adsorbed by clay and organic matter, and its activity is directly related to the organic content of the soil (Decker 1975). The

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greatest herbicidal activity is obtained on light-textured soil with low organic matter. Little or no leaching has been observed which is a great advantage in high rainfall regions.

The mode of action of GOAL has not been clearly defined. However, light is required for the herbicidal activity of GOAL (Fadayomi and Warren 1976). It can best be described as a contact, non-systemic herbicide.

Pre-emergence use. Cassava. Trials conducted in Malaysia indicated that GOAL can be used immediately after planting if the farmer is willing to accept a certain amount of phytotoxity in the initial growth stage. The most promising dosage under Malaysian conditions is 0.42 to 0.50 kg a.i./ha. Initial phytotoxicity symptoms will disappear within 6 weeks.

Large scale field trials were conducted, resulting in good weed control without adverse effects on plant growth and root yield. Where farmers will not tolerate any phytotoxicity, post-emergence applications of GOAL in combination with paraquat or MSMA 8 – 10 weeks after planting have been successful. When GOAL was compared with alachlor, fluorometuron and linuron higher yields of cassava resulted (Table 1).

Table 1. Cassava yields with weed control using various herbicides.

Product	Dosage kg a.i./ha	Cassava yield, metric tons/ha	
		Trial A	Trial B
GOAL	0.25	14.0	8.1
— do —	0.50	14.9	6.1
— do —	1.00	14.2	3.8
— do —	2.00	14.0	—
Alachlor[1]	1.5	16.5	—
Fluorometuron[2]	1.6	—	5.4
Linuron[3]	1.1	12.5	—
Control		12.6	2.5

1 [2-chloro-2',-6'-diethyl-*N*-(methoxymethyl) acetanilide]

2 [1,1-dimethyl-3-(2,a,a-trifluoro-*m*-tolyl) urea]

3 [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea]

Legume cover – plantation crops. Pure legume cover in newly planted rubber and oilpalm plantations can be a great attribute. A good legume cover can return as much as 150 kilos of nitrogen per ha/yr. There are also other advantages, such as reduction of soil erosion, increased yields, more organic matter, sparser ground vegetation in ex-legume plots.

GOAL has been evaluated for 3 years and proved suitable for reducing handweeding in establishing legume covers. A single application of GOAL at 0.42 to 0.50 kg a.i./ha immediately after seeding *Calopogonium caeruleum* Desv., *C. mucunoides* Desv., and *Pueraria phaseoloides* Bth. provides 10 — 15 weeks weed control. A few weeds may germinate, and some supplementary weeding (either manual or chemical) is suggested. Germination and growth of *Centrosema pubescens* has been adversely affected by GOAL. This species should be omitted from the seed mixture.

Depending on the soil type, lower dosages of GOAL (0.125 kg a.i./ha) have been found very effective, especially on sandy soil in North Sumatra.

Orchids. GOAL can be used as a pre-emergence herbicide without adverse effects on *Arachnis* variety Maggie Oei. The dosage recommended is 0.75 — 1.00 kg a.i./ha in 500 — 600 l water, applied after planting.

Peanuts. Farmers are generally interested in weed control for a period not exceeding 4 weeks. Rates of 0.17 to 0.25 kg a.i./ha have been found adequate when applied in approximately 500 l of water/ha immediately after planting. Initial test results are shown in Table 2.

Table 2. Peanut yields using various herbicides.

Product	Dosage kg a.i./ha	Peanut yield kg/ha	
		Trial A	Trial B
GOAL	0.25	2,396	1,112
— do —	0.50	2,367	1,352
Nitrofen	3.00	1,447	1,056
Alachlor	1.70	—	1,051
Control	—	348	738

Rice. GOAL has been widely tested in Japan and selected Asian countries. A 2% granule and a 24% ec are being registered in Japan as an incorporated treatment 3 — 7 days before transplanting. Use of GOAL in fertilizers is also very promising because of its stability and flexible timing of application (first to last puddling) at rates 0.2 to 0.4 kg a.i./ha.

These results have been confirmed in the Dominican Republic. There a 1% granule applied at 25 — 50 kg/ha resulted in better weed control (dicots and grasses) and greatly reduced phytotoxicity (Table 3).

Timing of application as post-transplanting treatment ranges from zero up to 26 days, depending on the application method. These have been as follows:

Single application (1 day), double application (1 and 12 days) triple application (1,12 and 26 days).
Rates have ranged from 0.12 to 0.5 a.i./ha (Table 4). Compared to pre-transplant applications of GOAL 2 ec, propanil (3',4'-dichloropropionani-

Table 3. Phytotoxicity of granular GOAL on rice.

Formulation	Origin	Rate kg ai/ha	Injury index (0 — 10)[1]
GOAL 1-G sand	Costa Rica	0.25	0.1[2]
		0.25 + 0.25	0.6
		0.5	1.0
GOAL 1-G calcium carbonate	Costa Rica	0.25	0.5
		0.25 + 0.25	1.5
		0.5	0.8
GOAL 1-G sand	USA	0.25	0.8
		0.25 + 0.25	1.3
		0.5	0.6
GOAL 1-G clay	USA	0.25	1.0
		0.5	2.5
Control		—	0

1 Evaluation 20 days after first application.

2 Average of 3 replications.

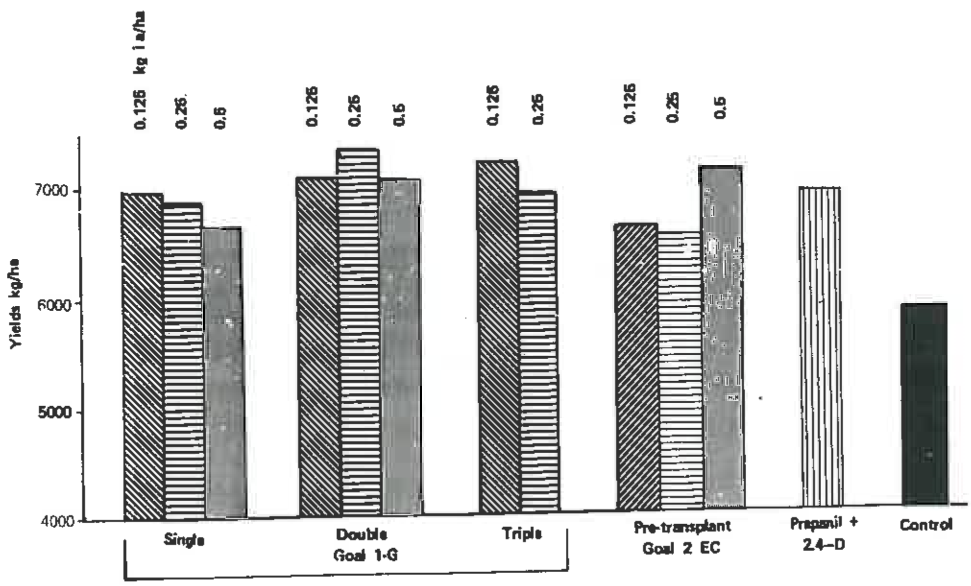

Figure 1. Yields (kg/ha) from single, double and triple applications of Goal 1-G VS. Pre-transplant applications of Goal 2 EC, propanil + 2,4 — D and control.

Table 4. Weed control and field results of different treatments with GOAL 1-G and GOAL 2EC applied in transplanted rice.

Treatment	Rate kg a.i./ha[1]	% Weed Control[2] Broadleaf 26	Broadleaf 54	Broadleaf 86	Grasses 26	Grasses 54	Grasses 86	% Overall Control Pre-harvest	Yields kg/ha 14% moisture	% Yield Increase Over Control
GOAL 1-G	0.125	77	58	48	0	70	52	63	7008	22
	0.25	92	60	53	87	80	78	75	6898	20
	0.5	97	85	62	73	92	85	88	6662	16
GOAL 1-G	0.125 + 0.125	91	73	65	53	78	77	98	8123	24
	0.25 + 0.25	98	93	88	80	98	97	98	7385	28
	0.5 + 0.5	98	97	97	100	95	98	99	7139	24
GOAL 1-G	0.125 + 0.125 + 0.125	94	87	80	73	83	92	88	7249	26
	0.25 + 0.25 + 0.25	98	75	85	60	82	85	91	6969	21
GOAL 2EC	0.125	94	57	65	40	57	52	47	6626	15
	0.25	99	90	63	80	95	83	87	6579	14
	0.5	97	82	72	47	83	87	97	7172	24
GOAL 1—G + propanil	0.125 + 3.5	72	53	50	0	60	52	57	6749	17
propanil + 2, 4-D	3.5 + 0.5	33	47	93	0	55	87	95	6866	19
Control	—	0	0	0	0	0	0	0	5759	—

1 Application, number of days after transplanting; single 1 day; double 1 and 12 days; triple 1, 12 and 26 days.

2 Percent weed control: 26,54 and 86 days after transplanting based on counts of number of weeds per 7 squares of 0.25 by 0.25 cm/plot.

lide), 2,4—D [(2,4 — dichlorophenoxy) acetic acid] and control, GOAL I — G gave better than standard control using a split application at 0.25 kg ai/ha. This treatment gave the highest yields (Figure 1).
Best results, as a surface treatment, have come where applications are made in 1 — 4 cm of water maintained up to 20 days after transplanting. Incorporation is not recommended for GOAL 1 — G has a potential for broad usage in transplanted rice growing areas.

Soybeans. Pre-emergence herbicide trials have been conducted to determine the efficacy of GOAL under different conditions. Some phytotoxicity has been observed in the GOAL plots, however, full recovery to normal growth was observed after a two week period.

Rates of 0.20 — 0.30 kg a.i./ha of GOAL are recommended as a single pre-emergence application in 500 l of water immediately after seeding. In areas where pre-plant incorporated treatments are commonly employed, dosage of 0.42 — 0.50 kg a.i./ha are recommended.

Yield fluctuated considerably, depending on location, disease incidence, soil and other environmental conditions (Table 5).

Table 5. Yield of soybeans with weed contro using various herbicides.

Product	Dosage kg a.i./ha	Soybeans yield, kg a.i./ha		
		Trial A	Trial B	Trial C
GOAL	0.125	1,469	995	—
— do —	0.5	1,150	1,049	1,543
Nitrofen	2.00	1,464	918	—
— do —	3.00	2,307	1,020	1,058
Alachlor	1.70	—	1,060	1,057
Control	—	716	854	774

Sugarcane. Most test work has been with pre-emergence applications. The most promising dosage of GOAL being 0.4 to 0.5 kg a.i./ha. In all trials, phytotoxicity has been observed. However, the crop has recovered within 4 to 6 weeks and newly emerging leaves did not show typical phytotoxicity symptoms. Yield comparisons are not yet completed.

Trials have been intiated to compare different combinations of emergence compounds which warrant further investigation.

Postemergence Use. GOAL, in combination with various postemergence compounds such as diuron [3-(3,4-dichlorophenyl)-1,1-dimethyl urea], MSMA and paraquat can provide effective weed control, especially of germinating weed seeds. Considerable differences have been observed, depending on light intensity, rainfall and weed species.

The most promising combinations in plantation crops in Malaysia are MSMA + GOAL (2.5 + 0.25 — 0.50 kg a.i./ha), and paraquat + GOAL (0.42 + 0.25 — 0.50 kg a.i./ha). Investigations are needed to define optimum dosage.

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The Effect of Molinate SM on Some Perennial Weeds

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ABSTRACT

Molinate SM is a mixed granular herbicide for paddy fields. This granular herbicide contains 8.0% (w/w) molinate [*S*-ethylhexahydro-1*H*-azepine-1-carbothioate], which is effective against graminaceous and cyperaceous weeds, 1.5% (w/w) simetryn [2,4-bis(ethylamino)-6-(methylthio)-*s*-triazine] and 0.8% (w/w) MCPB [4-(4-chloro-*O*-tolyl)butyric acid], both of which are effective against broadleaf weeds. The mixing of these three compounds made it possible to control some perennial weeds, *Scirpus hotarui*, *Cyperus serotinus* and *Sagittaria pygmaea*, when applied until at a rather advanced stage of growth. Good herbicidal effects were shown under leakage conditions of 2 cm/day and at 2 to 8 cm depth of irrigation water at application. In the field test, molinate SM was able to control both annual and some perennial weeds simultaneously without injury to rice, when applied 15 to 25 days after the transplanting.

INTRODUCTION

The rapid increase of perennial weeds in paddy fields in Japan was considered to be caused by the changes of rice cultivation techniques for the sake of saving labor and by repeated uses of the herbicides which could control only annual weeds. Molinate SM (MAMET SM) was developed as a herbicide which could control both annual and perennial weeds simultaneously.

In general, perennial weeds have considerable reserve substances in their tubers, and some weeds, *C. serotinus, S. pygmaea,* have several buds on the tubers. Therefore, they have a strong ability to recover from the effects of herbicides. In order that the herbicidal effect on them could be increased, the application was made at a rather advanced stage of growth when their reserve substances would be exhausted.

The active ingredients of molinate SM, molinate (began to be used in Japan in 1972), simetryn (in 1969), MCPB (in 1961), have been widely used as a compound in many mixed herbicides, among which molinate SM, the mixture of these three compounds, show the greatest herbicidal

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effect on *Echinochloa crus-galli* Beauv. which is the most troublesome annual weed. This characteristic is very useful to control both annual and some perennial weeds simultaneously.

This report described mainly the effect of molinate SM on *S. hotarui*, *C. serotinus* and *S. pygmaea* which are the troublesome perennial weeds in Japan.

MATERIALS AND METHODS

Experiment 1, with 2 replications was conducted to determine the effect of molinate alone, molinate + simetryn and molinate + simetryn + MCPB on the three species of perennial weeds. In this experiment, granules of 8.0% molinate, granules of 1.5% simetryn and granules of 0.8% MCPB were used alone or together. Forty seeds of *S. hotarui* per pot were sown in 1/5000 a pots and irrigated to a depth of 4 cm under no leaching condition. Ten tubers of *C. serotinus* and 6 tubers of *S. pygmaea* per plot in the paddy field were planted in 1 m by 1 m plots and irrigated to a depth of 4 cm under 0.5 cm/day leaching condition. The granules at the rate of 30 kg/ha were applied at various leaf stages. The surviving plants were sampled 40 days after the application, and their numbers counted and their dry weights measured.

Experiment-2 was to determine the influences of leakage. Twenty seeds of *S. hotarui*, 3 tubers of *C. serotinus* and 3 tubers of *S. pygmaea* per pot were planted in 1/5000 a pots irrigated to a depth of 4 cm. Thirty kg/ha of molinate SM were applied at the 4-leaf stage of *S. hotarui*, at the 3-to 4-leaf stage of *C. serotinus* and at the 5-to 6-leaf stage of *S. pygmaea* under 0 cm/day, 2 cm/day and 4 cm/day leaching conditions. The leachings were continued 3 days from the application. The experiment was conducted with 3 replications. The surviving plants were sampled 30 days after the application and their dry weights were measured.

Experiment-3 was to determine the influences of water depth at time of application. The same number of the seeds or tubers were planted as in experiment-2. The 1/5000 a pots were irrigated to a depth of 1 cm, 2 cm, 4 cm and 8 cm. Molinate SM at the rate of 30 kg/ha was applied at various leaf stages. The investigation was carried out in the same way as in experiment-2.

Experiment-4 was conducted in the paddy field using 2 m by 3 m plots, with 2 replications, to confirm the effect on both annual and perennial weeds. The rice plants (cultivar Sinanokogane Japonica) in the 2.5-leaf stage were transplanted on June 21st in 1974, and 30 kg/ha of molinate SM was applied 15, 20 and 25 days after transplanting under a water depth of 3 to 5 cm and under 1 cm/day leakage condition. The surviving weeds and the rice plants were sampled 40 days after application, and their dry weights measured.

RESULTS AND DISCUSSION

The results of experiment 1 are shown in Figure 1. On *S. hotarui* and *C. serotinus*, molinate alone had a strong inhibitory effect, as it stopped their growth completely when applied at their less advanced stage. *S. hotarui* gradually died, which seemed to be caused by the exhaustion of the reserve substances in their seeds. *C. serotinus* did not die, one of the reasons for that was because *C. serotinus* appeared to have much reserve substance in their tubers. Molinate did not show a strong inhibitory effect on *S. hotarui* in the 4-leaf stage and *C. serotinus* in the 4- to 5-leaf stage, since many individuals recorvered.

The addition of simetryn made it possible not only to inhibit growth but to cause their leaves to wither. Molinate + simetryn had much more effect on these plants than molinate alone, but not enough in these stages. The addition of MCPB increased the herbicidal effect, especially in their rather advanced stages. Molinate SM was able to control *S. hotarui* in the 5 to 6 leaf stage and *C. serotinus* in the 4 to 5 leaf stage without subsequent recovery.

The molinate SM effect on *S. hotarui* and *C. serotinus* was mainly due to the inhibitory effect of molinate, simetryn and MCPB acted effectively, especially in their rather advanced stages.

On the other hand, molinate alone had little effect on *S. pygmaea*. It only inhibited growth for a while after the application. The mixture of molinate and simetryn caused leaves to wither due to the activity of simetryn, which was greater at the more advanced growth stage However, it was unable to kill them and they continued to live with only the basal parts of their shoots alive and later they gradually recovered. The effect on *S. pygmaea* was greatly increased by the addition of MCPB to molinate + simetryn, so molinate SM was able to control *S. pygmaea* when applied up to the 5 to 6 leaf-stage. However, application at the less advanced stage failed to inhibit their recovery sufficiently.

S. pygmaea had a strong ability to recover, which is attributed to the tuber with several buds having a large reserve substance. The proper timing of the application of molinate SM to *S. pygmaea* is in the rather advanced stages when their reserve substances would be exhausted. On

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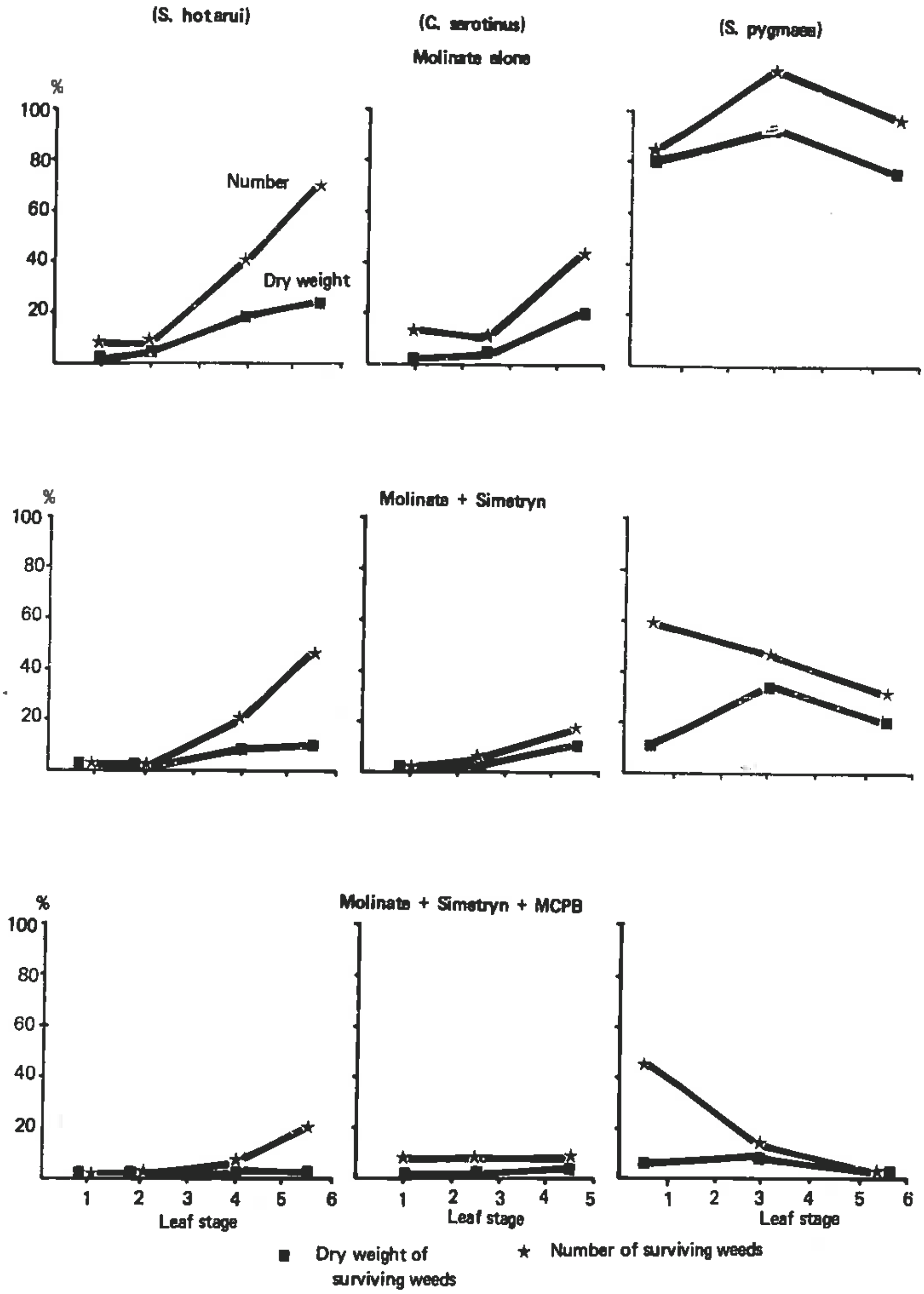

Figure 1. The effects of molinate alone, molinate + simetryn and molinate + simetryn + MCPB on *S. hotarui*, *C. serotinus* and *S. pygmaea*.

the other hand, the recoveries of *C. serotinus*, which has the same kind of ability to recover as *S. pygmaea*, is inhibited under the reducing conditions of paddy fields. *C. serotinus* needs a large amount of oxygen at the germination, so that its recovery is not so remarkable as that of *S. pygmaea* which recovered easily under similar conditions.

The leaching of the water was expected to have considerable influence on the effect of molinate SM, because each compound has a high solubility and they are effective due to the absorption of herbicide by the shoots of weeds. Sandy loam soil was used so that the influences of leaching would appear strongly in this soil. The result showed that 4 cm/day leaching decreased the herbicidal effect, but 2 cm/day leaching caused no decrease (Table 1). This herbicide should not be used under extreme leaching conditions.

Table 1. The influence of leakage on the effect of molinate SM.

Leakage (cm/day)	Dry weight of weed (% of no applied control)		
	S. hotarui	*C. serotinus*	*S. pygmaea*
0	0	0	0
2	2	0	0
4	32	22	40

The influences of the water depth at the time of application was not significant, although there was a little variation from species to species and from stage to stage (Table 2). In general, the effects appeared sooner

Table 2. The influences of the water depth at the application on the effect of molinate SM.

The depth of water (cm)	Dry weight of weeds (% of no applied control)											
	S. hotarui				*C. serotinus*				*S. pygmaea*			
Leaf stage	1	2	4	5-6	1	3	4	5-6	1	3	5	7
1	0	0	0	24	0	0	6	8	0	0	2	15
2	—	—	0	0	—	—	0	11	—	—	2	1
4	0	0	0	0	0	0	0	16	2	4	2	0
8	0	0	4	6	0	0	0	5	6	4	6	0

in the shallow depth than in the deeper depths, but it did not always mean that the effect of the shallow condition was superior to the deeper condition.

The effect of molinate SM on *S. hotarui* and *C. serotinus* was rather stable under the various depths of the water. This stability seemed to be supported largely by the stability of the effect of molinate.

On *S. pygmaea* in the 5 leaf stage or less, the effect was a little better under the shallow depths, since such conditions were not adequate for the growth of *S. pygmaea* ,which is a water plant. Further, those conditions increased the absorption of simetryn by increasing the transpiration.

On the other hand, the effect was inferior under 1 cm of the depth when applied at the most advanced stage of these three species. This can be explained by the decrease of the concentration of the compounds in the plants as the result of the extreme decrease in the relative absorbing area of the plant.

These results showed that molinate SM has a stable effect on these weeds under 2 to 8 cm of the water depth.

The field tests on the simultaneous control of the annual and perennial weeds were conducted in 1972 to 1976, and the results were successful. Table 3 shows the results of the experiment in 1974. Molinate SM was able to control both annual and some perennial weeds simultaneously without injury to the transplanted rice when applied 15 to 25 days after the transplanting.

The remarkable character of molinate SM was the high herbicidal effect on *E. crus-galli*. This herbicide was able to kill this grass when applied up to the 3.5 leaf stage, and the application at their 4 leaf stage showed a strong inhibitory effect. This characteristic is suitable for the control of some perennial weeds like *S. pygmaea* and *Sagittaria trifolia* which could be well controlled by application at a rather advanced stage of growth.

Table 3. The effect of molinate SM on both annual and perennial weeds in the field.

The application time (days after transplanting)	Dry weight of crop and weeds (% of no applied control)									
	Rice	Weed species**								
		E.c	C.d	M.v	E.a	S.h	C.s*	S.p*	S.t	Others
15	98	0	0	2	1	0	4	8	39	0
20	103	2	0	0	3	0	11	10	1	0
25	97	0	0	0	3	0	9	0	0	0

* The tubers of *C. serotinus* and *S. pygmaea* were planted before the transplanting.

** E.c = *Echinochloa crus-galli* Beauv., C.d = *Cyperus difformis* L., M.v = *Monochoria vaginalis* Presl.
E.a = *Eleocharis acicularis*, S.h = *Scirpus hotarui*, C.s = *Cyperus serotinus*, S.p = *Sagittaria pygmaea*,
S.t = *Sagittaria trifolia* and Others were *Lindernia procumbens* Philcox, *Elatine triandra* Schkuhr and *Rotala indica* Rochne.

Factors of Treated Layer Formation of Oxadiazon under Flooded Condition in Paddy Fields.

T. OHYA,[1] T. IKAI, K. HIRAI, K. SUZUKI and Y. KAWAMURA

ABSTRACT

The behaviour of oxadiazon[2], [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-$\Delta^2$1,3,4-oxadiazolin-5-one], and of the treated layer formations under flooded condition in paddy fields, when applied directly as an emulsifiable concentrate without dilution, were investigated. Oxadiazon e.c. applied in the flooded condition spreads quickly on the water surface and then emulsifies. Regardless of application, before or after puddling, the concentration in the water decreased within one or two days. When oxadiazon was applied after puddling, an extremely thin treated layer was formed on the soil surface. In the case of application before puddling, the distribution of oxadiazon was restricted mainly to within 1 to 2 cm depth of the soil surface. For good formation of the thin treated layer the soil had to be mixed with more than 2.5 cm depth water just after application. Such a treated layer corresponded to the layer of fine soil particles which was clearly formed by puddling. No significant differences between, fine and rough soil particles, were obtained with different contents of clay and organic matter. Therefore, it is reasonable to suggest that the higher adsorptive ability of oxadiazon to the treated layer formation was more related to the fine soil particle than to the rough one. New methods for practical application are introduced.

INTRODUCTION

Oxadiazon[2], a selective pre-emergence herbicide, was used in about 600,000 hectares of transplanted rice in Japan in 1976. As the herbicide controls a wide spectrum of weeds with no injury to crop plants (Burgaud *et al* 1969), the herbicide is also being tested for its effectiveness in upland crops in other countries (Felton 1974, Cooke and Simmonds 1970). Kawamura reported that the herbicide contains a high adsorptive ability (Kawamura and Hirai 1975), and that the herbicide forms a treated layer over the soil surface when applied on flooded water (Kawamura 1971). The formation of about a 3 cm treated layer and the maintenance of flooded condition after the

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[2] Ronstar — 12%ec.

oxadiazon treatment are required for effective weed control (Kawamura 1971).

The present work was aimed to study influences of flooded water-depth and soil aggregate size on the formation of a treated layer and to study the sedimentation-ability of oxadiazon with the progress of time after treatment.

MATERIALS AND METHODS

Experiment 1. An experiment was conducted, under field condition, to determine the concentration of oxadiazon in flooded water after certain periods of time after application of the herbicide. Four plots of 10 m^2 were laid out, flooded, and each plot puddled twice.

Oxadiazon treatment at the rate of 5 l/ha was made in two situations of puddling; one, before the last puddling (pre-puddling treatment), and the other, after the last puddling (post-puddling treatment). Each treatment was replicated twice. Both treatments were made at 5 cm flooded condition. Water samples were collected 0.5, 3, 24, 48 and 72 hours after oxadiazon application. Oxadiazon was extracted from each sample by n-hexane and the concentration of the herbicide was determined by gas chromatography using a 1.2 m by 4 mm id glass column packed with 10% SE 30 on 60-80 mesh Chromosorb WAW operating at 200°C. An electron capture detector was used. The carrier gas was nitrogen at 1.2 kg/cm^2 and retention time was 6 minutes.

Experiment 2. This experiment was carried out to determine the concentration of oxadiazon, organic matter (carbon and nitrogen), sand, silt and clay in various depth of oxadiazon treated soil. Surface soil of paddy fields of our laboratory was used. The experiment was conducted in pots. Each pot was filled with 1 kg of soil to a total depth of 4 cm. Just before filling the pot with soil, the soil was thoroughly mixed with 1 or 2 l of water. The mixing operation was done in a 5 l glass flask. Oxadiazon treatment at the rate of 1.2 mg a.i./pot and 3.6 mg a.i./pot was done by two methods, one before mixing and one after mixing. Sampling was done six days after treatment by inserting a thin walled stainless steel pipe 4 cm into the pot. Before sampling standing water was removed from the pot by pipette. The sample was divided into six layers in the following order, 0 to 0.25, 0.25 to 0.50, 0.50 to 0.75, 0.75 to 1.00, 1.00 to 2.50 and 2.50 to 4.00 cm from the surface.

Concentration of oxadiazon was determined from each layer of soil by the same method described in experiment 1. Results obtained are presented in Figure 1.

After determination of the oxadiazon concentration, each layer of soil was tested for its content of organic matter, sand, silt and clay. Results obtained are presented in Table 2.

Experiment 3. This experiment was carried out to study the distribution of oxadiazon in treated layers according to soil aggregate size. The same procedure as that of experiment 2 was followed in this experiment, with the exception that there were two soil aggregate sizes; the aggregate-size as it was in the original soil, and the aggregate size after crushing the original soil aggregates and screening them through a 2 mm sieve. Results obtained are presented in Figure 2.

RESULTS AND DISCUSSION

Oxadiazon is a herbicide having high adsorptive ability to the soil (Kawamura 1971). It is, therefore, expected that oxadiazon, when applied on the flooded and puddled water, becomes adsorbed to the soil and naturally settles over the soil surface by sedimentation and forms a treated layer. Results of the present study substantiated the above expectations. It was observed that the major part of oxadiazon, irrespective of treatment time, settled over the soil surface within one or two days and this was evident by the gradual reduction of oxadiazon concentration in treated-flooded water with the progress of time (Figure 1). In case of pre-puddling treatment it settled very quickly and in case of post-puddling treatment it settled slowly (Figure 1). Settling over the soil surface it formed a treated layer. In case of pre-puddling treatment the treated layer was 1 cm thick and in case of post-puddling treatment the layer was 0.25 cm thick (Table 1). Thickness of the treated layer was not influenced by the dose of the herbicide or depth of flooded water (Table 1). This is in contrast to the previous study (Kawamura *et al* 1972) in which the thickness of treated layer was influenced by the depth of standing-flooded water. This might be due to the difference in total soil depth in the pot and in the mixing operation applied in the studies.

But in the present study, a uniform distribution of oxadiazon throughout the 4 cm soil depth in pots was obtained when the crushed fine soil was used. As the different layers of original soil which had fine and comparatively bigger soil aggregate did not appreciably differ in the contents of organic matter and clay, it was assumed that uniform

Table 1. Distribution of oxadiazon in various depths of treated soil under various conditions (treatment, standing water depth and rate of application).

Treatment	Soil depth from soil surface (cm)	Conc. of oxadiazon (ppm)		
		Water depth (cm) 2.5		4.5
		Application rate (mg/pot) 1.2	3.6	1.2
Pre-puddling	0.00 — 0.25	3.46	9.26	4.96
	0.25 — 0.50	3.98	11.03	4.38
	0.50 — 0.75	4.55	9.43	4.49
	0.75 — 1.00	3.41	9.15	3.24
	1.00 — 2.50	0.95	2.44	0.96
	2.50 — 4.00	0.84	1.58	0.67
Post-puddling	0.00 — 0.25	13.24		
	0.25 — 0.50	3.55		
	0.50 — 0.75	1.52		
	0.75 — 1.00	0.50		
	1.00 — 2.50	0.10		
	2.50 — 4.00	—		

Table 2. Percentage of organic matter and soil particles in various depths of treated soil.

Depth from soil surface (cm)	C (%)	N (%)	Sand (%)	Silt (%)	Clay (%)
0.00 — 0.25	3.6	0.32	9.6	34.5	55.9
0.25 — 0.50	3.5	0.33	14.3	34.4	51.3
0.50 — 0.75	3.4	0.32	17.4	33.4	49.2
0.75 — 1.00	3.4	0.35	19.4	33.3	47.3
1.00 — 2.50	2.9	0.26	25.0	34.8	40.2
2.50 — 4.00	2.7	0.26	32.0	31.3	36.6

distribution of oxadiazon in the finely crushed soil was due to the fineness of the soil aggregate.

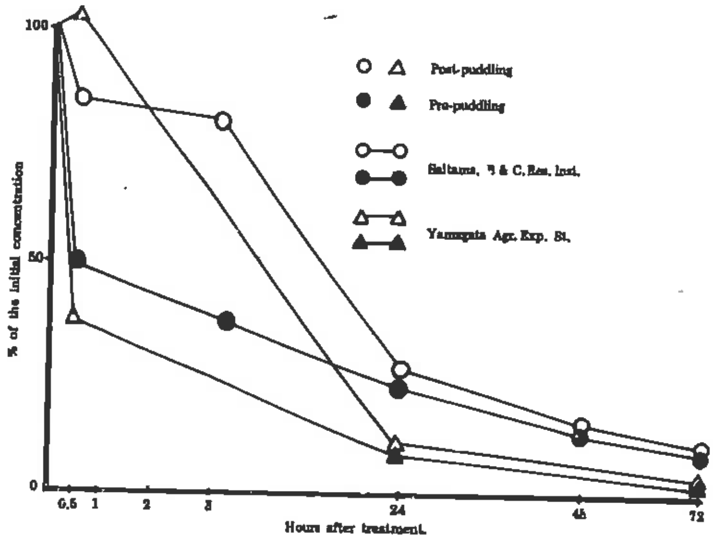

Figure 1. Oxadiazon concentration in flooded water (about 5 cm depth) with the progress of time ofter treatment.

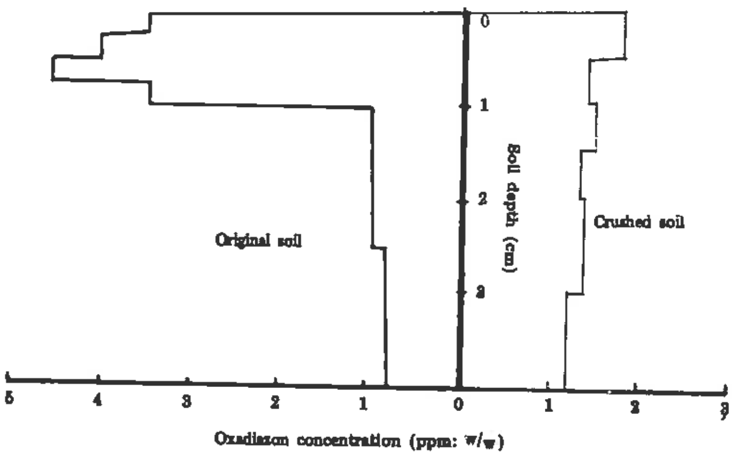

Figure 2. Distribution of oxadiazon in original soil and crushed soil (< 2 mm diameter). Flooded condition: 2.5 cm standing water.

It was, therefore, concluded that oxadiazon applied in a puddled field settles very quickly if the puddled water contains soil where the distribution of oxadiazon in the sedimented soil becomes uniform due to fine soil aggregate and where oxadiazon when applied before last puddling forms a treated surface layer of about 1 cm depth. Due to the fact that the surface layer of about 1 cm of a flooded puddled-rice field in Japan contains more or less fine soil aggregate and that the oxadiazon is uniformly distributed in a fine soil layer, the use of oxadiazon in paddy fields in Japan seems to be promising.

ACKNOWLEDGEMENTS

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Control of Legume Encroachment in Rubber and Oil Palm with the New Plant Growth Regulator Krenite

E. ROCHECOUSTE[1] and C. K. CHAI[2]

ABSTRACT

The new plant growth regulator Krenite (ammonium ethyl carbamoyl phosphonate) for which a generic name has not yet been established was evaluated for the control of legume encroachment in rubber and oil palm plantations. From the results obtained it was shown that Krenite at rates of 0.75 — 1.00 kg a.i./ha provided excellent growth suppression of the leguminous twiners for 8 to 12 weeks depending on their growth vigour at time of spraying. After that interval hand pulling of the twiners, followed by a second application of the chemical, was demonstrated to provide another effective suppression of their encroachment for another 8 to 12 weeks. This suppression in growth, at those rates of application, was found adequate to provide satisfactory ground cover to prevent weed infestation in the treated experimental plots. At the rates of Krenite used, there was no adverse effect on crop growth as evaluated by visual symptoms and by girth and front-length measurements for rubber and oil palm respectively. The data obtained in this investigational work indicate that this approach of integrated control of legume encroachment by a plant growth regulator and manual labour could prove an ideal way of resolving this problem.

INTRODUCTION

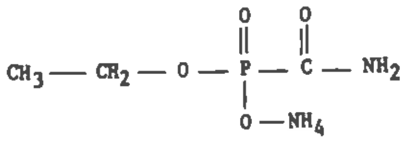
Krenite is a new plant growth regulator and its generic name has not yet been established. Throughout this paper its trade name Krenite will be used to present the experimental results obtained with this chemical on the control of legume encroachment in rubber and oil palm plantations.

Chemical physical and toxicological characteristics. Krenite is available as a water soluble formulation of ammonium ethyl carbamoyl phosphonate containing 480 g a.i./l. It is a non-volatile and non-flammable liquid, and has the following molecular structure :

The chemical has a very low acute and chronic oral toxicity. It is neither an eye nor a skin irritant, and it is not a skin sensitizer. The oral LD_{50} for rats is 10,200 mg/kg. When rats were fed diets containing 1,000 ppm of the chemical for 90 days no clinical and pathological changes attri-

1 Du Pont (Australia) Limited, 168 Walker St, North Sydney

2 Du Pont Far East (Malaysian Branch), Box 2396, Kuala Lumpur, Malaysia.



butable to the compound were detected and there was no adverse effect on the birth of offspring.

Krenite has little toxicity to fish and wildlife. It breaks down rapidly in water. Ammonium ethyl carbamoyl phosphonate is absorbed by the soil organic colloids and is decomposed by soil micro-organisms. As a result no problem of run-off or leaching into surface or sub-surface water can be expected. Its half life in soil is about one week. Its favourable toxicological properties and its negligible impact upon the environment contribute to its safety for use to control legume encroachment in rubber and oil palms.

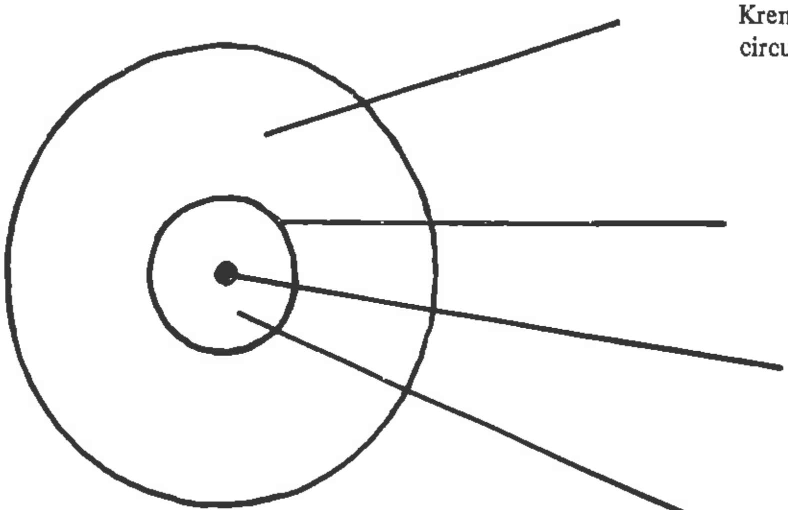
Its mode of action has not yet been well defined. It has been established that it is absorbed by buds, foliage and stems of treated plants but its path of translocation in woody plants has yet to be determined. Applications of the chemical to only one side of a tree affects only those branches receiving the spray. This certainly indicates that the chemical has localised systemic effect and we may conclude that adequate coverage is essential for best results.

Present status of legume encroachment. The following leguminous plants are sown soon after transplanting rubber or oil palm seedlings to protect the soil from weed infestation: *Pueraria phaseoloides* Bth, *Calopogonium caeruleum*, and *Centrosema pubescens* Bth,

In general a mixture of these legumes are sown but owing to the vigorous growth of *P. phaseoloides* Bth. and *C. caeruleum* they often become the dominant species. Hand weeding is resorted to until the cover crop is well established. In general 3 to 4 months after the legumes are sown encroachment on the weed free "circle" or "strip" areas around the plants begins and this is kept in check by hand pulling of the vines about once every 3 to 4 weeks. The objective of the trials presented was to use Krenite as a strip treatment along the rows of rubber plants or as circle treatment outside the drip line in oil palm at rates that will provide enough suppressing effect on the leguminous vegetation without destroying the green cover on the surface of the ground which is necessary to keep weed infestation in check.

MATERIALS AND METHODS

The plant growth regulator Krenite was first tested in an exploratory manner in 1974 — 1975 to determine whether it could suppress legume growth without causing any adverse effect on crop growth. During this earlier work it became evident that rates of application to obtain satisfactory growth suppression would be between 0.50 to 2.00 kg ai/ha. As a result some 10 trials were conducted in Malaysia under a varied set of climatic conditions. The statistical layout for those trials was a randomised block with 4 replications. In rubber plot size consisted of a strip 10.5 m long by 2.4 m wide and there were 3 trees per experimental plot. In oil palm plot size was an outer circular strip of 1 m wide along the drip line as shown hereunder :



There were 5 palms per replicate. The spray was applied after hand pulling of the vines encroaching on the rubber stems and on oil palm fronds.

Krenite was tested at rates 0.50, 0.75, 1.00 and 2.00 kg a.i./ha and a non-ionic surfactant at 0.5% (100% basis) was added to all sprays. Treatment effects were measured thus :

Crop. 1. Visual assessment of phytotoxic symptoms in terms of numerical values or indices related to a rating system.

2. Rubber girth measurements at the standard height of 1.52 m above ground level — 3 trees per replicate.

3. Oil palm length measurement of 1st fully open frond from apex to base — 5 palms per replicate.
4. Legume (i) visual assessment of encroachment based on the number of new shoots invading the treated plots
   (ii) visual evaluation of suppressing effect of the chemical on individual legume species when they occur in almost pure stands on the treated plots.

Of the 10 trials which were laid down only 2 will be presented showing the effect of Krenite 12 weeks after the first spraying and 12 weeks after the second spraying on rubber and two others showing that effect on oil palm.

Legume encroachment trials — rubber. Five trials were conducted in 2 year old rubber plantations. The chemical was applied soon after the encroaching vines pulling operation of the vines was done and the plots were re-sprayed. In those trials Krenite was applied at rates 0.50, 0.75, 1.00 and 2.00 kg a.i./ha. Results obtained are presented in Table 1.

RESULTS

Crop response. Krenite had no adverse effect on crop growth as determined by visual assessment of phytotoxic symptoms and by girth measurements, both at 12 weeks after the 1st spraying and again at a further 12 weeks after the second spraying.

Legume response. From the data presented it would appear that Krenite at 0.50 kg a.i./ha would not provide a satisfactory suppressing effect over a period of 6 to 8 weeks, since at 9 weeks after treatment legume encroachment reached over 50%. The 2.0 kg a.i./ha on the other hand indicates that this rate would be too high for legume suppression. It is excessive and would lead to weed infestation of the treated areas. Krenite at rates of application 0.75 and 1.00 kg a.i./ha gave fairly good suppression of the legumes for about 12 weeks. The 1.0 kg rate provided a better suppressing effect than the 0.75 kg rate.

Legume encroachment trial – oil palm. Four trials were conducted in 2 year old and two in 6 month old oil palm plantings. The chemical was applied soon after hand pulling of the vines encroaching the fronds of the oil palm. About 12 weeks after the 1st spray the vines were hand pulled again and a second spray applied. In those trials Krenite was applied at 0.50, 0.75, 1.00 and 2.00 kg ai/ha. Results obtained are presented in Table 2.

Crop response. Krenite did not affect crop growth as measured by visual assessment of phytotoxic symptoms and by frond length measurements taken, both at 12 weeks after the first spray and again at a further 12 weeks after the second spraying.

Table 1. Suppressing effect of krenite on legume encroachment
Crop : Rubber

Treatments kg a.i./ha	Test: 1 Location: N. Sembilan Crop age: 2 years old No. rainy days : (i) 12 weeks after 1st spray = 25; (ii) 12 weeks after 2nd spray = 54 Total rainfall : (i) 12 weeks after 1st spray = 432 mm; (ii) 12 weeks after 2nd spray = 1005 mm								Test: 2 Location: N. Sembilan Crop age: 2 years old No. rainy days : (i) 12 weeks after 1st spray = 25; (ii) 12 weeks after 2nd spray = 54 Total rainfall : (i) 12 weeks after 1st spray = 432 mm; (ii) 12 weeks after 2nd spray = 1005 mm							
	First spraying				Second spraying				First spraying				Second spraying			
	% encroachment weeks after			Mean girth (cm) 12 weeks after	% encroachment weeks after			Mean girth (cm) 12 weeks after	% encroachment weeks after			Mean girth (cm) 12 weeks after	% encroachment weeks after			Mean girth (cm) 12 weeks after
	6	9	12		6	9	12		6	9	12		6	9	12	
Krenite 0.50	22.5	55.0	77.5	13.57	2.3	71.3	97.5	15.26	33.8	67.5	88.8	12.66	6.5	92.0	98.6	15.71
Krenite 0.75	16.3	55.0	72.5	13.62	1.8	61.3	87.5	16.68	11.3	35.0	50.0	12.97	3.8	53.8	71.3	15.58
Krenite 1.00	10.0	30.0	42.5	13.19	0.0	22.5	65.0	16.53	11.3	20.0	43.8	13.61	1.8	17.0	57.0	17.12
Krenite 2.00	2.5	2.5	2.5	13.35	0.8	7.5	45.0	16.69	3.8	6.3	7.5	14.20	0.0	3.3	25.5	17.52
Untreated control	97.5	100.0	100.0	12.98	77.5	100.0	100.0	15.53	97.5	97.5	100.0	13.13	76.3	100.0	100.0	16.50
LSD (P = 0.05)				NS				NS				NS				NS

Table 2. Suppressing effect of krenite on legume encroachment
Crop : Oil palm

Treatments kg a.i./ha	Test: 3; Location: Kapar, Selangor; Crop age: 2 years old; No. rainy days: (i) 12 weeks after 1st spray = 33, (ii) 12 weeks after 2nd spray = 36; Total rainfall: (i) 12 weeks after 1st spray = 264 mm, (ii) 12 weeks after 2nd spray = 600 mm								Test: 4; Location: Banting; Crop age: 6 months old; No. rainy days: (i) 12 weeks after 1st spray = 34, (ii) 12 weeks after 2nd spray = 24; Total rainfal: (i) 12 weeks after 1st spray = 456 mm, (ii) 12 weeks after 2nd spray = 287 mm							
	First spraying				Second spraying				First spraying				Second spraying			
	% encroachment weeks after			Mean frond length 12 weeks after	% encroachment weeks after			Mean frond length 12 weeks after	% encroachment weeks after			Mean frond length 12 weeks after	% encroachment weeks after			Mean frond length 12 weeks after
	6	9	12	(cm)	6	9	12	(cm)	6	9	12	(cm)	6	9	12	(cm)
Krenite 0.50	21.3	39.0	60.8	313.5	12.7	33.5	50.8	328	26.9	43.9	70.0	135.3	7.7	13.4	34.2	181.4
Krenite 0.75	12.9	25.7	61.6	326.5	10.7	16.0	40.9	338	22.9	35.3	51.5	126.7	5.0	7.9	19.1	171.6
Krenite 1.00	7.9	14.9	29.0	330.5	4.7	7.5	20.9	342	10.9	19.4	23.7	138.6	3.6	6.1	16.1	182.9
Krenite 2.00	5.7	7.7	25.8	336.5	3.9	4.5	14.1	348	4.6	6.8	14.6	136.4	1.4	5.3	13.0	175.3
Untreated control	47.0	54.9	83.3	335.5	28.0	60.0*	58.3	346	85.0**	4.1	52.5	140.0	30.5	43.4	61.2	182.6
LSD (P = 0.05)				NS				NS				NS				NS

* Hand pulling done at 9 weeks
** Hand pulling done at 6 weeks.

Table 3. Effect of krenite on growth of *Pueraria phaseoloides* and *Calopogonium caeruleum*.

Table 3. Effect of krenite on growth of *Pueraria phaseoloides* and *Calopogonium caeruleum*.

Treatments kg a.i./ha	Location: N. Sembilan; Trial Conditions: Refer Test 1						Location: N. Sembilan; Trial Conditions: Refer Test 2											
	Pueraria phaseoloides						*Pueraria phaseoloides*						*Calopogonium caeruleum*					
	Effect on growth weeks after 1st spray			Effect on growth weeks after 2nd spray			Effect on growth weeks after 1st spray			Effect on growth weeks after 2nd spray			Effect on growth weeks after 1st spray			Effect on growth weeks after 2nd spray		
	6	9	12	6	9	12	6	9	12	6	9	12	6	9	12	6	9	12
Krenite 0.50	3.4	3.1	2.5	4.5	3.9	0.8	3.6	2.5	1.8	4.3	3.3	0.5	4.0	3.3	2.6	5.0	3.9	1.3
Krenite 0.75	4.5	3.8	3.1	5.0	4.5	1.5	4.3	3.8	3.6	5.0	4.4	1.8	4.6	4.3	3.6	5.0	4.9	2.3
Krenite 1.00	4.9	4.8	4.2	5.0	5.1	2.8	4.8	5.1	4.0	5.0	4.9	3.0	4.9	5.1	4.5	5.6	5.0	4.6
Krenite 2.00	6.4	6.5	6.5	6.5	5.4	4.5	5.6	5.8	5.8	5.0	6.3	3.5	5.8	5.5	5.8	6.0	6.5	5.0

Scoring system : 0 = No effect

5 = Optimum effect — growth should not be allowed to go any further as encroachment will begin to pose a problem.

10 = Complete suppressing effect leading to bare ground and weed invasion.

Legume response. In those trials the 0.50 kg a.i./ha gave satisfactory growth suppression 12 weeks after application. However it would appear that 0.75 and 1.0 kg a.i./ha rates have given a more consistent check of legume growth with the 1.0 kg rate having the edge on the 0.75 kg rate. Again it would appear that 2.0 kg a.i./ha would not be acceptable, because its effective suppression of legume growth could lead to the treated areas becoming exposed to weed infestation.

Effect of Krenite on Pueraria and Calopogonium. In general the terminal portion of the young shoots are the most affected parts. Morphogenetic effects produced were characterised by a marked check in their development. The axillary buds become arrested in their growth and the young shoots become distorted with the production of malformed leaves. Depending on rate of application the effect becomes more pronounced and at the 2.0 kg a.i. rate the sprayed shoots just dry up and regrowth occurred from buds well inside the canopy which were apparently not sprayed. The general pattern of effect recalls a hormonal type of response. When a specific legume species was dominant at the experimental site its response to Krenite was recorded.

Table 3 gives the typical effect of Krenite on *P. phaseoloides* and *C. caeruleum* in Tests 1 and 2. Legume encroachment was evaluated by a scoring system whereby a reading of 5.0 on the scale is an indication that the plot has to be re-sprayed or submitted to the hand pulling operation. From the data presented it would appear that Krenite at rates 0.75 to 1.0 kg ai per acre provides adequate growth suppression for 12 weeks without running the risk of bare ground exposure which would lead to weed infestation.

DISCUSSION

Experimental work conducted with the plant growth regulator Krenite showed that this chemical could effectively control legume encroachment in rubber and oil palm without causing any adverse effect on the growth of these crops. Of the rates tested the 0.75 and 1.00 kg a.i./ha would appear to give satisfactory growth suppression over a period of 10 – 12 weeks. This technique, supplemented by hand pulling when the Krenite effect wears off, would provide a new approach to solving the problem by the integration of the two systems. From the experiments conducted in legume encroachment with this chemical it was demonstrated that the rate of applications was critical since it must be within the range of exercising an acceptable growth suppressing effect which would leave enough green cover to prevent weed infestation.

Although data on only *P. phaseoloides* and *C. caeruleum* have been submitted similar observations were also made on *C. pubescens*. It is interesting to note that *Mikania cordata* B.L. Robinson which occurred at some of the trial sites was also stopped in its growth thus extending the benefits that would be derived from the use of this plant growth regulator.

From investigational work carried out so far they are good indications that Krenite has a localized systemic effect and that good coverage of the treated plants appear to be essential for satisfactory results. It is suggested that the use of low volume application with misting machine to reduce droplet size and provide a better distribution pattern on the dense legume cover might result in an effective control of legume growth at lower rates of application.

Benthiocarb-Prometryn Mixture for Upland Crops

K. JIKIHARA and I. KIMURA [1]

ABSTRACT

Herbicidal activity of a combination product, containing benthiocarb [*S*-(4-chlorobenzyl)-*N*,*N*-diethylthiolcarbamate] and prometryn [2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine, (trade name "Valor"), was evaluated under upland conditions, using emulsifiable concentrate (50% + 5%) and granules (8% + 0.8%). In field tests conducted in Kikugawa in 1975, both formulations showed excellent herbicidal activity without any injury to the main crops (rice, corn, peanut, soybean and cotton) when applied as a pre-emergence application at 8 l and 50 kg/ha respectively. In the greenhouse, the influence of soil moisture on herbicidal activity and persistence in soil was investigated. The herbicidal activity was higher under wet soil condition than under dry soil condition, and also higher as emulsifiable concentrate than granules. Simulated rainfall after application enchanced the activity under dry soil condition. Persistence in soil was longer for granules than it was for emulsifiable concentrates. It was also more persistent in dry soil than in wet soil. Bioassay of its volatility in a petridish indicated that the loss of active ingredients from soil surface was less when granules were used than when emulsifiable concentrates were used.

INTRODUCTION

Benthiocarb-prometryn mixture, a selective pre-emergence herbicide for many upland crops such as corn, upland rice, cotton, soybean and peanut, has excellent herbicidal activity on a large number of annual weeds; gramineous, cyperaceous and broadleaf weeds.

In Japan, an emulsifiable concentrate of benthiocarb-prometryn (BP.ec), containing 50% benthiocarb and 5% prometryn has been registered and is being used in upland rice, dry seeded lowland rice and soybean fields at 6 to 8 l/ha. Registration applications have been submitted for additional crops such as wheat, peanut, kidneybean and corn.

In recent years, the granular formulation of herbicides which do not require water in application appeal to many of upland farmers who are

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short of a water supply. Granular formulation of benthiocarb-prometryn (BP.G) containing 8% benthiocarb and 0.8% prometryn has been evaluated officially since 1975 for application in upland rice, soybean, peanut, sweet potato, konnyaku (*Amorphophalus konjac* Koch) and ornamental trees. Promising results have been obtained not only by pre-emergence applications, but also by posttransplanting or post-intertillage applications.

The authors studied in the previous paper the factors affecting the respective herbicidal activity of benthiocarb and prometryn (Jikihara *et al.* 1973). They reported that herbicidal activity of both chemicals decreased as soil moisture content decreased, but high herbicidal activity was obtained by shallow incorporation of these chemicals into soil under dry soil conditions.

Mori and Edo (1976) studied the herbicidal activity of several upland herbicides, including the benthiocarb-prometryn mixture , using fine granule and emulsifiable concentrate under various soil conditions (Mori and Edo 1976). They reported that the fine-granular formulation of benthiocarb-prometryn mixture showed higher herbicidal activity than emulsifiable concentrate under dry soil condition because granules sifted down into deeper soil layers through gaps among the coarse clumps of soil, killing the weeds which emerged beneath the clumps.

In the course of evaluating BP.G, the authors noticed a higher activity of BP.G than of BP.ec under dry soil conditions when rainfall was delayed. The authors, therefore, studied the influence of soil moisture, after application, on the herbicidal activity of BP.G in comparison with BP.ec to clarify its herbicidal characteristics.

MATERIALS AND METHODS

BP.G prepared by coating 48 to 53 mesh pumice sand with 8% benthiocarb and 0.8% prometryn, was broadcasted. BP.ec as a commercial formulation, containing 50% benthiocarb and 5% prometryn, was sprayed in a volume of 1000 l water/ha. Experiments were replicated three times.

Field evaluation. Field experiments were conducted in 1975 on sandy clay loam soil field in Kikugawa — maximum water holding capacity (max WHC) 54%; organic matter (om) 3.8%; clay 17%. In each plot (4 by 5 m), seeds of corn, rice, cotton, soybean and peanut were sown at 2.5 cm depth. BP.G and BP.ec were applied at 4.0 + 0.4 and 6.0 + 0.6 kg a.i./ha. Trifluralin (α.α,α,-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) was applied as 2,5% G and 44.5% ec and alachlor [2-chloro-2,6-diethyl-*N*-(methoxymethyl) acetanilide] 43% ec as a commercial formulation at 1.0 and 2.0 kg a.i./ha, both as pre-emergence treatments. Herbicidal effects were investigated 30 days after application by visual assesment.

Influence of duration of dry soil condition on herbicidal activity. Experiments were conducted in the greenhouse on a sandy clay loam soil bed (max WHC 52%; om 5.3%; clay 17%). In each plot (2 by 1 m), seeds of barnyardgrass (*Echinochloa crus-galli* Beauv.) crabgrass (*Digitaria adscendens* Henr.) and smartweed (*Polygonum blumei* Meisn.) were broadcasted and incorporated 4 cm depth into dry soil (1.5% of max WHC). BP.G and BP.ec were applied as pre-emergence treatment at 3.0 + 0.3 and 4.0 +0.4 kg a.i./ha. Then, simulated rainfall of 20 mm for 4 hours was given either 0, 10 or 20 days after application. After simulated rainfall, each plot was maintained between 85 - 100% of field water capacity by irrigation. Herbicidal activity was investigated 20 days after rainfall by counting the number of weeds.

Influence of soil moisture on herbicidal activity. Barnyardgrass seeds were sown at 1 cm depth in pots filled with 6 mesh of sandy clay loam soil of the same nature as in the preceding experiment. Soil moisture content of each pot was set at 15 to 18, 40 to 43, 64 to 67 and 89 to 92% of max WHC respectively by immersing the bottom of the pots into a fixed volume of water. BP.G and BP.ec were applied at 2.0 + 0.2 and 4.0 + 0.4 kg a.i./ha on the soil surface. The soil moisture content of each pot was maintained at the set level throughout the experiment. Herbicidal activity was investigated 20 days after treatment by measuring the fresh weight of barnyardgrass.

Influence of soil moisture on persistence in soil. Persistence in soil was assayed with barnyardgrass under dry (15 to 18% of max WHC) and wet (64 to 67% of max WHC) soil conditions. Two groups of pots, dry and wet, were prepared in the same manner as above mentioned, treated with BP.G and BP.ec at 2.0 + 0.2 and 4.0 + 0.4 kg a.i./ha, then seeded with barnyardgrass 0, 7, 14, 21 and 28 days after treatment respectively. After seeding, soil moisture was maintained between 85 - 100% of max WHC by supplying water from the bottom of pots. Fresh weight of barnyardgrass was measured 15 days after seeding.

Table 1. Effects of BP.G and BP.ec on several upland weeds and crops.

Herbicide	Rate (kg a.i./ha)	Rate of herbicidal effectiveness *						Rate of crop injury *				
		Bnd	Crb	Smt	Pig	Lam	Sed	Corn	Rice	Soybean	Cotton	Peanut
BP. 8.8%G	4.0 + 0.4	10	10	9	9	9	10	0	0	0	0	0
	6.0 + 0.6	10	10	10	10	10	10	0	0	0	0	0
BP. 55%ec	4.0 + 0.4	10	10	9	10	9	10	0	0	0	0	0
	6.0 + 0.6	10	10	10	10	10	10	0	0	0	0	0
Trifluralin 44.5%ec	1.0	8	9	4	5	5	0	0	2	0	0	0
	2.0	10	10	9	10	10	5	4	5	0	0	0
Trifluralin 2.5%G	1.0	9	10	6	7	7	0	2	3	0	0	0
	2.0	10	10	10	10	10	6	7	6	0	0	0
Alachlor 43%ec	1.0	10	10	6	5	4	8	0	9	0	0	0
	2.0	10	10	9	10	9	10	0	10	0	0	0
Control (Average number of weeds/m^2)		125	180	74	40	56	156					

* Rating system: 0 = no effect to 10 = complete death.

Bnd = Barnyardgrass (*Echinochloa crus-galli* Beauv.)
Smt = Smartweed (*Polygonum blumei* Meisn.)
Lam = Lambsquater (*Chenopodium album* L.)
Crb = Crabgrass (*Digitaria adscendens* Henr.)
Pig = Pigweed (*Amaranthus retroflexus* L.)
Sed = Rice flatsedge (*Cyperus iria* L.)

Influence of soil moisture on volatility. Fifteen cm diameter petridishes were filled with 150 g air-dried soil of the same nature and soil moisture was set at 2, 20, 40 and 60% of max WHC respectively for each petridish. BP.G and BP.ec were applied at 2.0 + 0.2 kg a.i./ha on the soil surface of each petridish. Then 3 cm diameter petridishes containing 2 ml water and 15 seeds of barnyardgrass were placed in the center of 15 cm diameter petridishes, which were covered with glass. The covered dishes were kept in an incubator at 25°C for 48 hours, then kept in laboratory room for 5 days without a glass cover. Volatility was compared by measuring the shoot length of barnyardgrass.

RESULTS AND DISCUSSION

Field evaluation. Herbicidal effects of BP.G and BP.ec in several upland-crop fields were investigated comparing with trifluralin 2.5% G, 44.5% ec and alachlor 43% ec (Table 1). In this experiment, treatments were made under dry soil condition and there was 16 mm rainfall 3 days after treatment and high soil moisture was maintained by consecutive rainfall. Both BP.G and BP.ec showed excellent herbicidal activity against barnyardgrass, henry crabgrass, smartweed, redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarter (*Chenopodium album* L.) and rice-flatsedge without any injury to corn, rice, cotton, soybean and peanut at 4.0 + 0.4 and 6.0 + 0.6 kg a.i./ha. There was no difference between BP.G and BP.ec in herbicidal effects and selectivity.

Influence of duration of dry soil condition on herbicidal activity. In the bed-test in the greenhouse, herbicidal activity of BP.G and BP.ec was compared in relation to various times of rainfall after application under dry soil condition (Table 2). Both formulations showed excellent herbicidal activity with a simulated rainfall given soon after application, however, BP.G was slightly inferior to BP.ec. Herbicidal activity of both formulations decreased as the rainfall was delayed. The degree of decrease was higher in BP.ec than in BP.G. With a simulated rainfall 10 or 20 days after application, BP.G showed higher activity than BP.ec. These results suggest that the persistence of BP.G in soil is longer than that of BP.ec, under dry soil condition.

Influence of soil moisture on herbicidal activity. In the greenhouse, herbicidal activity of BP.G was compared with that of BP.ec under soil

Table 2. Influence of duration of dry soil condition on the herbicidal activity of BP.G and BP.ec.

Herbicide	Rate (kg ai/ha)	Average number of weeds/m²								
		Duration of dry soil condition, days after application								
		0 days			10 days			20 days		
		Bnd	Crb	Smt	Bnd	Crb	Smt	Bnd	Crb	Smt
BP.8.8%G	3.0 + 0.3	8.2	3.7	8.0	11.6	7.8	10.4	12.4	13.4	16.0
	4.0 + 0.4	0.0	0.0	0.0	2.1	0.3	3.1	6.6	0.7	8.7
BP. 55%ec	3.0 + 0.3	0.0	0.0	2.3	13.2	12.9	9.5	23.2	31.3	19.7
	4.0 + 0.4	0.0	0.0	0.0	4.8	0.4	0.8	13.9	17.5	6.6
Control		183.2	108.8	76.1	124.3	113.7	57.2	87.1	108.0	48.3

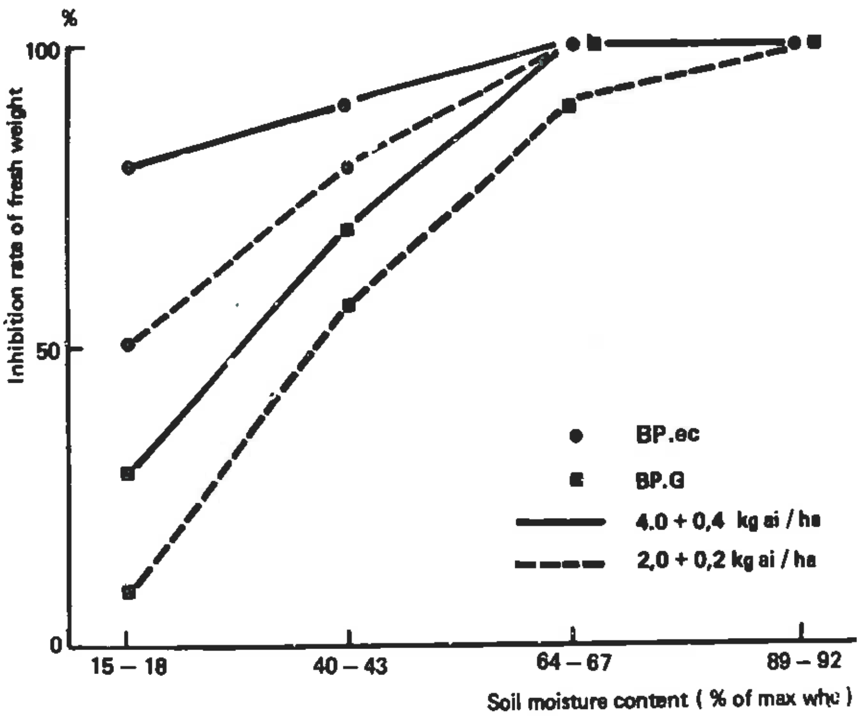

Figure 1. Influence of soil moisture on herbicidal activity of BP.G and BP.ec to barnyardgrass.

with various water contents (Figure 1). Herbicidal activity of both formulations decreased as soil moisture decreased. The degree of decrease was higher in BP.G than in BP.ec. In dry soil, active ingredients available for weeds to absorb are less. This can be explained by the fact that in the case of BP.ec, the active ingredients are adsorbed more tightly by dry soil and in the case of BP.G, active ingredients remain unreleased in carrier granules unavailable for the weeds to absorb.

Influence of soil moisture on persistence in soil. Persistence of BP.G and BP.ec under dry and wet soil conditions was investigated by means of bioassay (Figure 2). Persistence was longer in dry soil than in wet soil and also longer in BP.G than in BP.ec, irrespective of soil moisture. These results indicate that the decomposition or volatilization of active ingredients is less under dry soil condition than wet soil condition, and also less in BP.G than BP.ec.

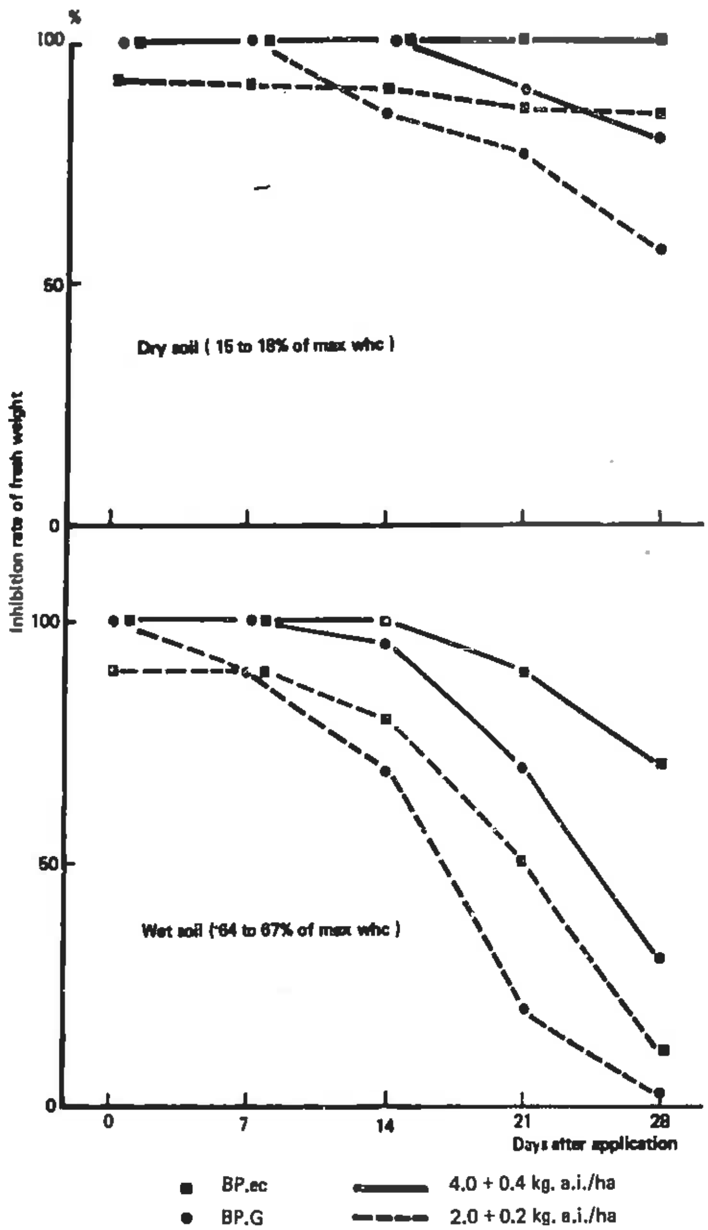

Figure 2. Influence of moisture on persistence in soil of BP.G and BP.ec.

Influence of soil moisture on volatility. Volatilization from soil surface in both formulations was investigated in relation to soil moisture (Figure 3). Volatility was higher under wet soil conditions than under dry soil condition, and also higher in BP.ec than in BP.G. This means that elusion from soil and volatilization of active ingredients are accelerated in the presence of water.

To summarize, BP.G as well as BP.ec showed excellent herbicidal activity without any injury to the main crops under upland conditions with proper soil moisture. Although BP.G, like BP.ec, is less active under dry soil condition, it can exhibit high herbicidal activity if soil moisture reaches high levels due to rainfall after treatment. Persistence of both formulations is definitely longer under dry soil condition than under wet soil condition and longer in BP.G than in BP.ec. BP.G shows

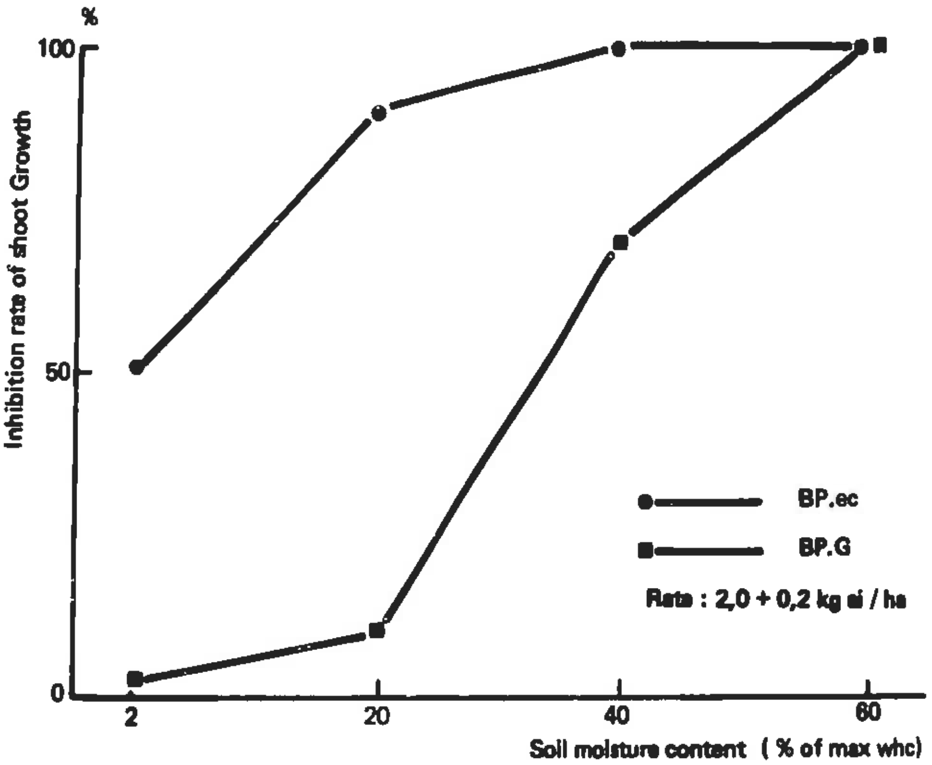

Figure 3. Influence of soil moisture on volatility of BP.G and BP.ec.

herbicidal activity than BP.ec when rainfall after application is considerably delayed. One of the main reasons for this persistence is considered to be the smaller loss of active ingredients in BP.G than in BP.ec by volatilization because the active ingredients of BP.G remain unreleased on carrier granules under dry soil condition.

From these experimental results, BP.G is considered to be applicable in upland crop fields (corn, upland rice, soybean, peanut and cotton) where cultivation is dependent on rainfall.

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The Effects of Buthidazole and New Diphenyl Ether on Chromolaena odorata (L.) R.M. King and H. Robinson

K WARGA DALEM and A. SOEDARSAN [1]

ABSTRACT

Second to *Imperata cylindrica* (L.) Beauv., *Chromolaena odorata* (L.) R.M. King and H. Robinson is considered as the most noxious weed species in most plantation crops in Indonesia. To develop a better chemical control method the efficacy of buthidazole (3,5-(1,1-dimethylethyl)-1,3,4 thiadizole-2-yl-4-hydroxy-1-methyl-2-imidazolidinone) and new diphenyl ether (RH-2915) (2-chloro-1-(3'-ethoxy-4'- nitro-phenoxy)-4-trifluoromethyl benzene) on this weed are studied under greenhouse condition. Root treatment of *C. odorata* with buthidazole resulted in desiccation of the stem and the leaves, whereas leaf treatment did not show such effect. In contradiction to buthidazole, leaf treatment with RH-2915 induced desiccation of the leaves, whereas root treatment had only a slight effect which appeared after about seven days. The symptoms after root treatment of buthidazole appeared after three to four days, while desiccation of the leaves after leaf treatment with RH-2915 was observed after two days. The visual symptoms indicate that RH-2915 applied to the leaves was neither translocated to the upper nor the lower part of the plant, but translocation of buthidazole was only observed when it was applied to the roots.

INTRODUCTION

C. odorata is a weed species commonly found in Indonesia (Bennet and Rao 1968). The vegetative and generative reproduction capacity is very high and the seeds are distributed by wind. Seed germination is induced by sunlight and the plant grows preferably in open fields (Ivens 1974, Soerohaldoko 1975).

C. odorata is considered as a noxious weed in most plantation e.g. rubber (RRIM 1967, Holm and Herberger 1970, Ivens 1972; 1974. Soerjani *et al* 1976), oil palm (Ivens 1974, Soerjani *et al* 1976), cocoa (Ivens 1974, Komolafe 1976) and coffee (Komolafe 1976). In the rubber plantation *C. odorata* can become one of the dominant weed species after the eradication of *I. cylindrica* (RRIM 1957). Due to its vigorous growth, the growth of the rubber trees may be depressed (RRIM 1967).

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Chemical control with picloram (4-amino-3,5,6-trichloropicolinic acid), 2,4-D[(2,4-dichlorophenoxy) acetic acid] and paraquat (1,1'-dimethyl-4,4'-bipyridilium ion) was already recommended (Ivens 1974, Madrid 1974, Risdiono 1975). Buthidazole and RH-2915 are new products of Velsicol Agricultural Chemical and Rohm & Haas Co, respectively.

Few works have been published on buthidazole behaviour in plants. It is absorbed by root and recommended for controlling weeds in plantation crops (Velsicol Dev. Bull 1976).

RH-2915 is developed for weed control in a wide variety of crops including orchards and tropical plantation crops. It controls a wide spectrum of annual broadleaf weed and grass species either as a pre-emergence or contact herbicide. The mode of action is not throughly known yet. At this time the product can be described as a non-systemic, contact action herbicide (Decker 1976).

This study was conducted to determine the efficacy of the new herbicide for the control of *C. odorata.*

MATERIALS AND METHODS

The trial was conducted in the greenhouse of the Research Institute for Estate Crops, Bogor, Indonesia. It was laid out in a randomized block design with 7 treatments and 3 replications.

Cuttings of *C. odorata* were arranged in an aluminium container containing moist sand as growth medium. After five weeks, the plants were transplanted to flasks containing Hoagland solution and three weeks later they were treated with buthidazole and RH-2915.

Buthidazole and RH-2915 were applied to the leaves as well as to the liquid medium at the rates of 0, 1, 2, 4, 8 ppm a.i. and 0, 0.1, 0.2, 0.4, 0.8 ppm a.i. respectively. Records on visual symptoms were made and one week after the treatment the dry weights of the plants were determined.

RESULTS AND DISCUSSION

Desiccation of the stem and the leaves was observed three to four days after buthidazole treatment of the root. This symptoms did not appear on the leaf treated plants. The results indicate that buthidazole was translocated acropetally. It was also observed that the dry weight of the plants correlates with the buthidazole applied (Figure 1). The dry weight of the root treated plants differs significantly from that of the leaf treated ones (Table 1).

In contradiction to buthidazole, leaf treatment of *C. odorata* with

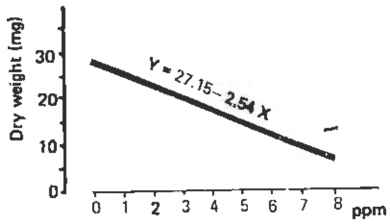

Figure 1: The dry weight of *C.odorata* in relation to the dose rate of buthidazole,

Table 1 : Dry weight of *C. odorata* between treatment

Root	19,53
Leaf	64,67
Difference	45,14 ++

++ highly significant.

RH-2915 induced desiccation of the leaves, whereas root treatment had only a slight effect that appeared after seven days. The observed symptoms indicate that RH-2915 has the character of a contact herbicide. The results of RH-2915 are in agreement with the other reports in fluorodifen (2,4'-dinitro-4-trifluoromethyl-diphenyl ether), (Easton 1969, Walter et al/1970). The dry weights of the RH-2915 root treated plants and the leaf treated plants were similar.

ACKNOWLEDGEMENTS

The authors wish to thank the Velsicol Agricultural Chemical and Rohm & Haas Co. for the herbicides used in the experiments. Thanks are also due to Mr. M. Sudradjat of Padjadjaran University who kindly analysed the data, and Dr. S. Wardojo, Head of Entomological and Plant Pathological Section, RIEC, for his critisms and comments on the manuscript.

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Sulglycapin a New Herbicide with a Wide Range of Efficacy in Rice

B. H. MENCK and J. C. VAN DE WEERD[1]

ABSTRACT

The strength of this new substance with its tentative common name, sulglycapin [methylsulfamic acid 2-(hexahydro-1 *H*-azepin-1-yl)-2-oxoethyl ester], lies in its effectiveness in controlling Gramineae. Important Cyperaceae and several broadleaved weeds are also within its control spectrum. This control spectrum includes *Alisma* spp., *Cyperus difformis, Cyperus serotinus, Echinochloa* spp., *Eleocharis* spp., *Leptochloa filiformis, Monochoria vaginalis, Rotala indica, Scirpus hotarui, Scirpus juncoides* and *Scirpus mucronatus.* In transplanted rice in Japan the granular combination product of sulglycapin + simetryn (2,4-bis(ethylamino)-6-(methylthio)-s-triazine) + MCPB (4-[4-chloro-*o*-tolyl)oxy]butyric acid) showed its herbicidal properties best as a so-called "middle stage herbicide". In wettable powder (w.p.) or granular form, this product worked very effectively in the direct-sown paddy rice regions of the United States of America and the Mediterranean when used as a post-emergence herbicide at the one-to threeleaf stage of *Echinochloa crus-galli.* A very effective herbicide spectrum was obtained by using sulglycapin and bentazon [3-isoprophyl-1*H*-2,1,3-benzothiadiazin-4-(3*H*)-one 2,2-dioxide] in a combination treatment.

INTRODUCTION

Chemical weed control is an absolute necessity for ensuring good yields in intensive paddy rice cultivation. The greatest worldwide problem is posed by grasses, in particular by *Echinochloa crus-galli.*

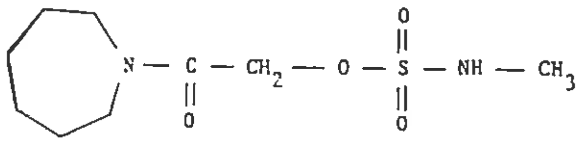
Herbicides such as benthiocarb [*S*-(4-chlorobenzyl)-*N,N*-diethylthiolcarbamate], butachlor [*N*-(butoxymethyl)-2-chloro-2',6'-diethylacetanilide], molinate (*S*-ethyl hexahydro-1*H*-azepine-1-carbothioate), and propanil (3',4' dichloropropionanilide) are all quite effective against *E. crus-galli.* In some rice-growing regions, however, they have some disadvantages as regards rice selectivity, spectrum of activity and water management. Some of these drawbacks can be avoided by using sulglycapin.

MATERIALS AND METHODS

Chemical name: methylsulfamic acid 2-(hexahydro-1*H*-azepin-1-yl) 2-oxoethyl ester.

1 BASF Agricultural Research Station, Limburgerhof, Germany F. R.

Structural formula :



Tentative common name: sulglycapin.
Formulations: BAS-461 00H (65% wp) and BAS-461 01H (9% granular) are available.

Numerous trials were conducted during the years 1974 to 1976 in transplanted (by hand and mechanically) paddy rice in Japan and Taiwan and in direct-sown (in part pre-germinated seeds) paddy rice in Italy, Portugal, Spain and the USA. These trials demonstrate the activity of sulglycapin in the important rice cultivation regions.

The applications were made 1 to 3 days before sowing, pre-emergence (1 to 3 days after sowing (DAS) or 4 days after transplanting (DAT)) and post-emergence (3 to 15 DAS or 15 to 25 DAT). The granular was applied by hand and the wettable powder by knapsack sprayer. Application was either on the water surface or on the soil surface. Afterwards, the water level in the plots was kept at 0, 5 or 10 cm. It was kept constant for six days and then later raised to 10 cm. The same conditions prevailed when the granular and the w.p. were applied.

All the trials were made with three or four randomized block replications. The effect of sulglycapin on the weeds and on the rice (rice varieties: cv Nihonbare, Koshihikari, Honenwase, Kaohsiung No. 52, Kaohsiung No. 139, Chainong No. 242, Tainan No. 6, Taipei No. 309, Bahia, Girona, Italpatna, Le Belle, La Bonnet) was assessed using a 0 — 10 system (0 = 0 % effectiveness, 10 = 100% effectiveness).

RESULTS AND DISCUSSION

Weed spectrum. In addition to *E. crus-galli*, *C. difformis*, *Eleocharis acicularis*, *M. vaginalis*, *R. indica*, *S. hotarui* and *S. juncoides* were controlled in transplanted paddy rice in Japan and Taiwan (Table 1). The granular combinations of sulglycapin with bentazon, MCPB, simetryn, KUE 2079 [3-(3-chloro-4-chloro-difluoro-methylthiophenyl)-1,1-dimethyl urea] and oxadiazon [2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one] broadened the control spectrum. These combinations were used 15 to 25 days after transplanting (Table 2).

In direct-sown paddy rice in Italy, Spain, Portugal and the USA, the wettable powder at 2.6 — 2.9 kg ai/ha and the granular at 3.2 — 3.6

Table 1. The effect of sulglycapin after 35 to 50 days in transplanted paddy rice (Japan, Taiwan) when applied at the 1- to 3-leaf stage of *E. crus-galli*.

Weed	% herbicidal effectiveness			
	Sulglycapin 65% wp kg a.i./ha		Sulglycapin 6% G* kg a.i./ha	
	1.5	2.0	2.0	2.5
Cyperus difformis	90	97	90	94
Cyperus serotinus	65	75	70	75
Echinochloa crus-galli	90	95	92	95
Elatine triandra	—	37	65	70
Eleocharis acicularis	80	90	85	90
Lindernia pixydaria	—	55	60	90
Monochoria vaginalis	80	90	85	85
Polygonum hydropiper	30	30	45	55
Rotala indica	85	90	93	97
Sagittaria pygmea	50	60	40	50
Sagittaria trifolia	50	55	45	50
Scirpus hotarui	75	95	90	93
Scirpus juncoides	80	90	85	90

* G = granular.

kg a.i./ha were also highly effective against *Alisma* spp., *Brachiaria platyphylla*, *Commelina communis*, *Leptochloa fascicularis*, *S. mucronatus* and *Typha* spp. (Table 3).

Application schedule. The optimal time for application in transplanted paddy rice is while the *E. crus-galli* is in the 1- to 3-leaf stage (Figure 1).

The initial and lasting effect is satisfactory to very good (90 to 100% effectiveness) if the direct-sown rice is treated with sulglycapin when the majority of the grasses are already present and the rest will soon emerge. This takes place in direct-sown paddy rice when the crop is at the 1- to 4-leaf stage. That corresponds to about the 1- to 3 leaf stage of the *E. crus-galli*. The effectiveness of sulglycapin is decreased and its residual activity does not last long enough if the grasses germinate over an extended period of time.

Table 2. Granular combinations of sulglycapin and various rice herbicides for broadening the range of effectiveness. Assessment made 35 days after application.

Product	Application rate kg a.i./ha	% herbicidal effectiveness against :									
		Cyperus difformis	*Cyperus serotinus*	*Echinochloa crus-galli*	*Elatine triandra*	*Eleocharis acicularis*	*Gratiola japonica*	*Lindernia pixydaria*	*Monochoria vaginalis*	*Sagittaria pygmea*	*Scirpus hotarui*
sulglycapin	1.8	98	50	95	30	93	50	50	70	40	90
	2.7	98	50	97	52	95	80	85	90	50	95
+bentazon	1.8 + 2.0	98	70	96	95	94	98	98	93	35	97
	2.7 + 2.0	98	75	97	—	95	—	98	98	55	94
+bentazon+MCPB	1.8 + 2.0 + 0.33	98	85	95	92	94	80	98	95	70	96
	2.7 + 2.0 + 0.33	98	85	97	96	96	97	98	98	70	96
+bentazon+simetryn	1.8 + 2.0 + 0.45	98	70	97	95	95	97	98	95	60	95
	2.7 + 2.0 + 0.45	98	80	96	92	96	95	98	97	75	96
+simetryn+MCPB	1.8 + 0.45 + 0.22	98	60	95	90	95	92	98	90	72	93
	2.7 + 0.45 + 0.22	98	60	97	90	96	92	98	97	75	96
+KUE 2079+MCPB	1.8 + 0.6 + 0.33	97	60	96	97	95	—	98	90	75	95
	2.7 + 0.6 + 0.33	98	75	97	97	95	—	98	98	80	97
+oxadiazon+MCPB	1.8 + 0.21 + 0.24	98	60	98	90	93	—	98	98	—	90
molinate+simetryn +MCPB	2.4 + 0.45 + 0.24	94	75	94	65	94	75	96	75	45	90
benthiocarb +simetryn + MCPB	3.0 + 0.45 + 0.24	98	60	90	85	97	85	97	87	50	85

Table 3. The effect of sulglycapin after 35 to 50 days in direct-sown paddy rice (Mediterranean areas, USA) when applied at the 1- to 3-leaf stage of *E. crus-galli.*

	% herbicidal effectiveness			
	Sulglycapin 65% wp kg a.i./ha		Sulglycapin 6% G* kg a.i./ha	
	2.6	2.9	3.2	3.6
Alisma spp.	80	90	90	95
Ammannia coccinea	50	65	50	60
Brachiaria platyphylla	85	90	90	95
Butomus umbellatus	20	40	0	10
Commelina communis	95	97	—	—
Cyperus difformis	90	95	95	95
Echinocloa crus-galli	95	97	95	97
Echinochloa colonum	94	97	—	—
Leptochloa fascicularis	90	95	—	—
Scirpus maritimus	20	50	40	40
Scirpus mucronatus	93	97	95	97
Typha spp.	85	90	90	95

* G = granular.

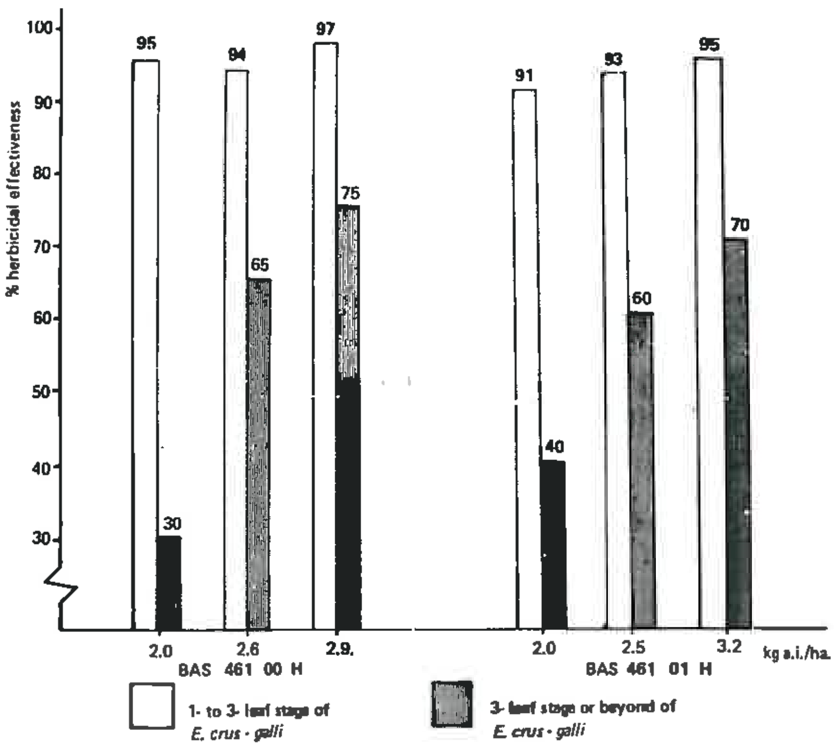


Figure 1. The effect of sulglycapia after 35 — 50 days at various stages of development of *E. crus-galli.*

Tolerance. The influence of sulglycapin on the rice depends on the stage of development (Figures 2 and 3) at the time of treatment and on water management shortly before and after application. Transplanted rice is less sensitive than direct-sown rice under the same conditions of treatment.

With the granular formulation, sulglycapin is selective in rice when the water level is 5 cm at the time of treatment, or when the plots are drained one day before application and reflooded one to two days afterwards, and the rice has formed three to four leaves.

If the rice is in the 1- to 3-leaf stage at the time of application, the sulglycapin may check growth and cause the rice leaves to turn a deep green. The lower the water level at the time of treatment, and for several days after the treatment, the more pronounced the set-back will be.

When the herbicide is applied at the recommended rates during the late 3- to 4-leaf stage of the sown rice, the effects on the crop are barely observable, regardless of water management.

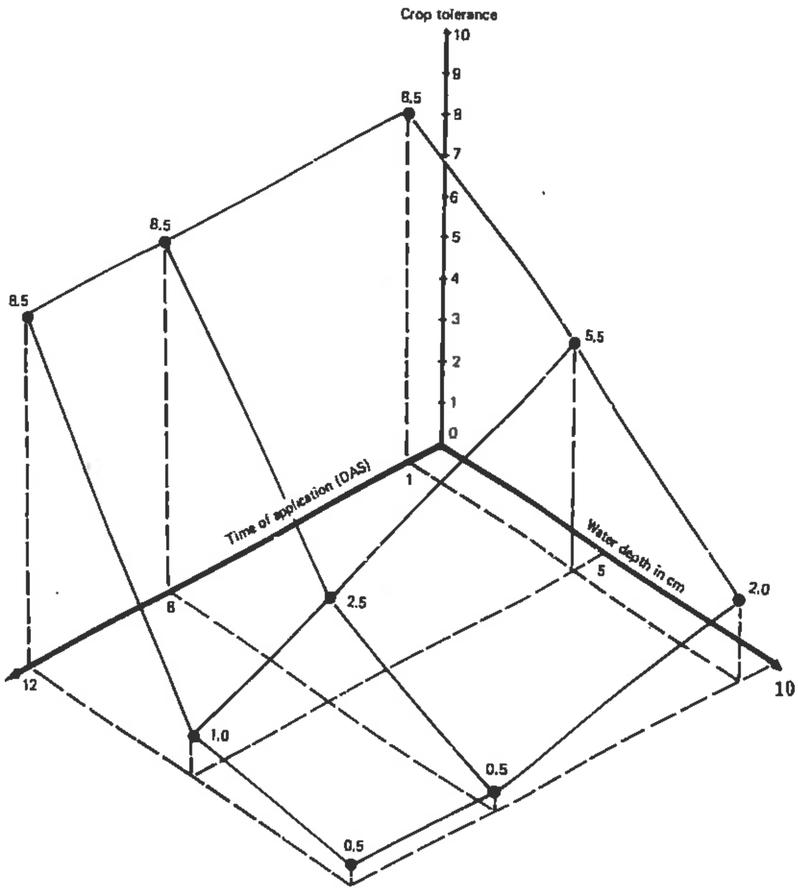


Figure 2. The dependence of crop tolerance on the water level after treatment with BAS-461 01H and on the time of application (days after sowing, DAS)

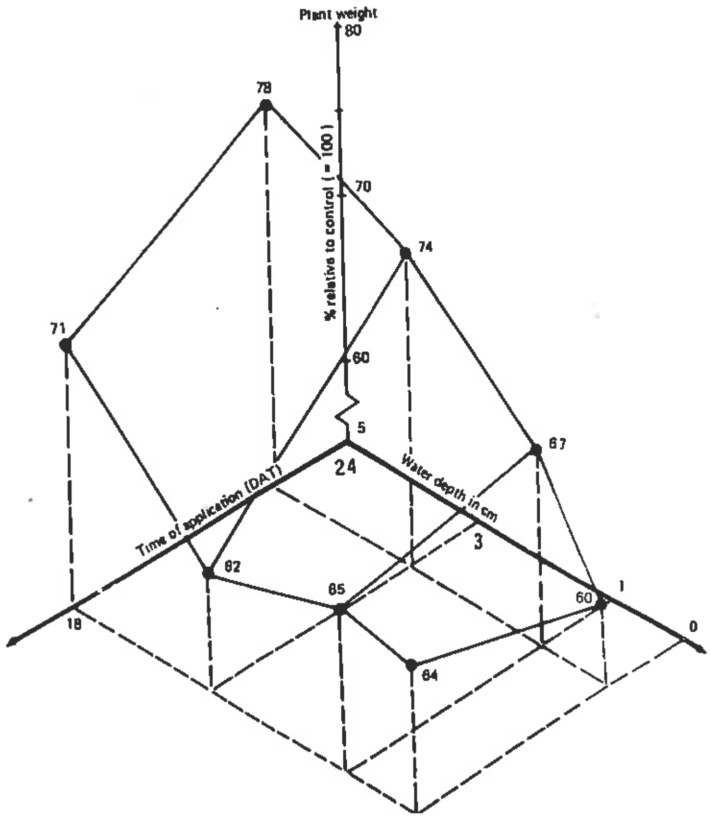


Figure 3. The dependence of crop tolerance on the water level after treatment with BAS 461 01H + simetryn + MCPB and on the time of application (days after transplanting, DAT).

Yields. Even with the slight damage that can arise due to unfavorable water conditions, the yields (Table 4) of the treated plots are not significantly different than those of weed-free plots. On the average, yields of the treated plots were at least 40% above the yields of the weed infested, untreated control plots.

Sulglycapin is a grass herbicide for use in transplanted and direct-sown paddy rice. The strength of the new active ingredient lies in its dependable control of Gramineae, important Cyperaceae and several broadleaf weeds.

Using carbon 14 as a radio active tracer it could be shown that sulglycapin was taken up primarily by the roots and then transported to the upper shoots. When sulglycapin is taken up by the leaves, there is little transport to other untreated leaf and shoot parts (Retzlaff and Hamm 1976).

Leaching trials are being made at this time to study the activity of sulglycapin in different soil types.

Table 4. Yields achieved using sulglycapin alone and in combination with simetryn + MCPB; applied at the 1- to 3-leaf stage of *E. crus-galli.*

Product	Application rate kg ai/ha	Yield relative to that of untreated control (= 100)		
		Japan	Taiwan	Europe
Sulglycapin 85% wp	2.9			134
Sulglycapin 6% G*	2.0			
	3.2		134	143
Sulglycapin 6% G + simetryn + MCPB	1.8 + 0.45 + 0.22	148	131	
	3.2 + 0.45 + 0.22	145		
Butachlor	1.5			
Molinate	3.75 — 4.1		133	134
Molinate+simetryn+MCPB	2.4 + 0.45 + 0.24	142		
Benthiocarb+simetryn+MCPB	3.0 + 0.45 + 0.24	146		

* G = granule.

In Japanese transplanted rice, sulglycapin in combination with simetryn and MCPB showed its herbicidal activity best as a "middle stage herbicide" (Table 2). This effect could not be achieved with molinate or benthiocarb in similar combinations.

As with other herbicides, for controlling Gramineae in Mediterranean rice-growing areas, a late postemergence treatment against insensitive weeds must be made, despite sulglycapin's broad activity spectrum. Sulglycapin and bentazon can be used as a combination treatment to provide an effective herbicide spectrum in direct-sown rice.

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High Selectivity of the New Herbicide SL-501 for Non-Cereal Crops

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ABSTRACT

This is the first report about the evaluation of SL-501 developed by Ishihara Sangyo Kaisha, Ltd. SL-501 is a new systemic herbicide which successfully controls almost all grasses, regardless whether annual or perennial. In various treatments, such as pre-emergence, post-emergence, and soil-incorporated applications there is almost no phytotoxicity on broad-leaf crops, with only one exception for cruciferous crops using a postemergence application. The average rates required for the complete kill of annual and perennial grasses were in the range of 0.5 to 1 kg a.i./ha and 2 kg a.i./ha or more, respectively.

INTRODUCTION

In the course of a greenhouse screening program for evaluating herbicidal activity of various substituted pyridyloxy-phenoxy-alkanoic acid derivatives, a new compound was found to be an excellent systemic herbicide (coded SL-501). A large number of well established selective pre-emergence grass killers have been commonly used in all of the major broad-leaf crops. However, few are used safely as a foliage application on these broad-leaf crops because of their narrow selectivity. SL-501 is characterized by its high herbicidal activity and its considerable selectivity by foliage application. It also gives sufficiently good control of not only annual but also troublesome perennial grasses by all application methods without causing phytotoxic injuries to a wide range of broad-leaf crops.

MATERIALS AND METHODS

Experiment 1. Twenty five species of plants were topically sprayed when they were in the 3- to 4-leaf stage of growth. Only johnsongrass

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(*Sorghum halepense*) was treated at two growth stages (2- to 3- and 5- to 7-leaf stages). SL-501 was applied at 0.5, 1, 2, and 4 kg a.i./ha with surfactant at 0.5% v/v in 600 l of water. The phytotoxicity was evaluated 4 weeks after the treatment on a scale of 0 (no phytotoxicity) to 10 (complete kill).

Experiment 2. In the pre-emergence tests, seeds of 16 species were sown approximately 1 cm deep in rows across plastic flats, which were sprayed immediately after sowing and watered from the bottom.

Experiment 3. SL-501 was soil-incorporated at 0.5, 1, 2, and 4 kg a.i./ha before sowing. Seeds and rhyzome fragments were placed in the soil at 3 cm deep and the flats were watered from the bottom.

Experiment 4. Field trials were carried out on soybeans, both by pre- and post-emergence treatments, at 0.5, 1, 2, and 4 kg a.i./ha with 2 replicated plots. The size of each plot was 2 m by 2.5 m long. The assessments were similar to those in the previous experiments.

RESULTS AND DISCUSSION

Table 1 presents the response of plants to SL-501 when it was applied at post-emergence. All grasses were highly susceptible to SL-501, the response rates varying according to annual and perennial species. SL-501 was slow in acting and in some cases it took several weeks or more to achieve complete kill of perennial grasses. There were no visible symptoms

Table 1. Response of crops and weeds to SL-501 in post-emergence treatment. (Greenhouse test)

Weeds and crops	Stage	kg a.i./ha				
		0.5	1.0	2.0	4.0	6.0
Weeds:						
Alopecurus aequalis Sobol var. *amurensis* Ohwi.	3—4 L	10	10	10	10	10
Agropyron repens (L.) Beauv.	6	6	8	10	10	10
Avena fatua L.	3—4	9	10	10	10	10
Cynodon dactylon (L.) Pers.	7	9	10	10	10	10
Digitaria adscendens Henr.	3—4	10	10	10	10	10
Echinochloa crus-galli Beauv.	3—4	10	10	10	10	10
Setaria viridis (L.) Beauv.	3—4	10	10	10	10	10
Sorghum halepense (L.) Pers.	6—7	8	10	10	10	10

Table 1. (Continued).

Weeds and crops	Stages	Dosages, kg a.i./ha				
		0.5	1.0	2.0	4.0	6.0
Amaranthus retroflexus L.	3—4	1	1	1	1	2
Chenopodium album L.	3—4	1	1	1	1	1
Convolvulus japonica Thunb.	7	1	1	1	1	1
Cypperus microiria Steud.	7	1	1	1	1	1
Cyperus rotundus L.	4	1	1	1	1	1
Medicago denticulata Willd.	3—4	1	1	1	1	1
Polygonum nodosum Pers.	3—4	1	1	1	1	1
Rumex obtusifolius L.	4	1	1	1	1	1
Crops:						
Barley	3—4	7	10	10	10	10
Corn	"	10	10	10	10	10
Oat	"	10	10	10	10	10
Rice	"	10	10	10	10	10
Wheat	"	7	10	10	10	10
Beet	"	1	1	1	1	2
Cotton	"	1	1	2	4	5
Peanut	"	1	1	1	1	1
Rape	"	1	2	4	5	5
Soybean	"	1	1	1	1	1
Sunflower	"	1	1	1	1	1

Assessments
Weeds; 1—10 where 1 = no effect and 10 = complete kill.
Crops : 1—10 where 1 = no damage and 10 = complete death.

for the first 5 to 6 days after spraying. After this period, during which the growth appeared to be arrested, susceptible plants became wilted in appearance and some discoloration to a reddish brown was evident on the lower leaves. The simultaneous necrosis which resulted in the plants final death was observed on the clums near the soil surface. Very susceptible grasses in young stages were killed by the severe burning of the whole plant before the decay of the clums occured. The dosage of

1 kg a.i./ha or less provided complete control of all the annual grasses tested, but the higher rate of 2 kg a.i./ha was required against such perennial grasses as johnsongrass, bermudagrass (*Cynodon dactylon*), and quackgrass (*Agropyron repens*). The susceptibility of these grasses was in the order of johnsongrass > bermudagrass > quackgrass. As for johnsongrass, it became clear that the controlling activity of SL-501 was closely related to its growth stages as shown in Table 2. When treated

Table 2. Post-emergence effects of SL-501 on johnsongrass in different growth stages. (Greenhouse test).

Growth stages		Dosages, kg a.i./ha			
		1.0	2.0	3.0	4.0
2 - 3 leaf	Top kill	10	10	10	10
	Regrowth	4	6	7	9
5 - 7 leaf	Top kill	10	10	10	10
	Regrowth	10	10	10	10

at 5- to 7-leaf stage, the regrowth from the rhizomes was sufficiently inhibited at 1 kg a.i./ha, whereas at 2 to 3 leaf stage, even the higher rate of 3 kg a.i./ha was insufficient for an acceptable control of the regrowth. This suggests that the timing of the application is quite important for the control of johnsongrass in practical use.

SL-501 showed no herbicidal activity against broad-leaf weeds. Most of the broad-leaf crops showed considerable tolerance to the highest rate of 6 kg a.i./ha. Among the broad-leaf crops tested, rape was the most susceptible to SL-501. Cotton was also somewhat affected at 2 kg a.i./ha with some slight necrosis and wilting on the leaves contacted directly with by the chemical. However, these injuries did not extend to the newly developed leaves or inhibit subsequent growth.

Fine selectivity was also obtained by pre-emergence treatment without a deterioration of its herbicidal activity. Only one exception was found regarding johnsongrass, against which 4 kg a.i./ha or more was required for complete kill, whereas by post-emergence treatment, 1 kg a.i./ha was sufficient to achieve a similar result (shown in Table 3 and Table 2).

Table 3. Response of crops and weeds to SL-501 in pre-emergence treatment (Greenhouse test).

Weeds and crops	kg a.i./ha			
	0.5	1.0	2.0	4.0
Weeds:				
Alopecurus aequalis Sobol var. *amurensis* Ohwi.	7	10	10	10
Avena fatua L.	8	10	10	10
Digitaria adscendens Henr.	7	10	10	10
Setaria viridis (L.) Beauv.	7	10	10	10
Sorghum halepense (L.) Pers.	1	3	7	8
Amaranthus retroflexus L.	1	1	1	1
Convolvulus japonica Thunb.	1	1	1	1
Cyperus microiria Steud.	1	1	1	1
Polygonum nodosum Pers.	1	1	1	1
Medicago denticulata Willd.	1	1	1	1
(Crops)				
Beet	1	1	1	1
Cotton	1	1	1	1
Rape	1	1	1	2
Soybean	1	1	1	1
Sunflower	1	1	1	1
Wheat	4	8	10	10

Table 4 presents the herbicidal activity by soil-incorporation. A large difference of activity between pre-emergence and soil-incorporated treatment was found only for johnsongrass. The rate of 1 kg a.i./ha by soil-incorporation showed the same effect at 4 kg a.i./ha by pre-emergence. This herbicidal activity against johnsongrass by soil-incorporation might have been achieved due to greater contact of rhizomes with the

Table 4. Response of crops and weeds to SL-501 in soil-incorporated treatment. (Greenhouse test).

Weeds and crops	kg a.i./ha			
	0.5	1.0	2.0	4.0
Weeds:				
Alopecurus aequalis Sobol var. *amurensis* Ohwi.	9	10	10	10
Avena fatua L.	10	10	10	10
Digitaria adscendens Henr.	10	10	10	10
Setaria viridis (L.) Beauv.	10	10	10	10
Sorghum halepense (L.) Pers.	6	10	10	10
Amaranthus retroflexus L.	1	1	1	1
Convolvulus japonica Thunb.	1	1	1	1
Cyperus microiria Steud.	1	1	1	1
Polygonum nodosum Pers.	1	1	1	1
Medicago denticulata Willd.	1	1	1	1
Crops:				
Beet	1	1	1	1
Cotton	1	1	1	1
Rape	1	1	1	3
Soybean	1	1	1	1
Sunflower	1	1	1	1
Wheat	6	8	10	10

chemical through the treated soil layers, whereas for preemergence treatment only a very thin soil layer existed because of the watering from the bottom. Twelve weeks later, all the rhizomes were taken up from the soil. It was found that they were completely killed in the plots treated at 1 kg a.i./ha and root growth was severely inhibited in all plots.

In Table 5 assessments of the field trials at 3 months after treatment are shown. SL-501 provided complete control of all annual grasses at 0.5 kg a.i./ha without subsequent emergence for 3 months, that was, until the end of the field test period. Against johnsongrass and bermudagrass, however, the higher rate of 2 kg a.i./ha was necessary to achieve perfect control. No phytotoxic symptoms were observed on soybeans, even at the highest rate of 4 kg a.i./ha. There was no herbicidal effect on broad-leaf weeds.

Table 5. Field trials in soybeans in pre and postemergence treatment.

Crops and weeds	Preemergence				Postemergence				
	kg a.i./ha				Stage (leaf)	kg a.i./ha			
	0.5	1.0	2.0	4.0		0.5	1.0	2.0	4.0
Soybean	1	1	1	1	2 L	1	1	1	1
Digitaria adscendens Henr.	9	10	10	10	4	10	10	10	10
Echinochloa crus-galli Beauv.	10	10	10	10	5	10	10	10	10
Setaria viridis (L.) Beauv.	8	10	10	10	4	10	10	10	10
Agropyron repens (L.) Beauv.	2	5	7	7	6	6	8	10	10
Cynodon dactylon (L.) Pers.	2	4	5	7	—	6	7	10	10
Amaranthus retroflexus L.	1	1	1	1	5	1	1	1	1
Chenopodium album L.	1	1	1	1	6	1	1	1	1
Convolvulus japonica Thunb.	1	1	1	1	7	1	1	1	1

Results from greenhouse tests and field trials revealed that SL-501 could afford considerable flexibility in timing of application for a wider species selectivity of broad-leaf crops. For some tolerant perennial grasses further investigations must be conducted with regard to the treating methods. In view of the extreme tolerance of broad-leaf weeds to SL-501, it is also necessary to consider developing it for other crops by mixing it with other well established selective broad-leaf weed killers.

Mode of Action and Selectivity Mechanism of Herbicide

S. MATSUNAKA [1]

ABSTRACT

The mode of action and the selectivity mechanism of herbicides was reviewed using data mainly from the field of rice culture. The mode of action was classified into 6 categories; inhibition of photosynthesis, contribution of light, inhibition of ATP formation in respiration, disturbance of auxin action, inhibition of protien synthesis, and miscellaneous. Inhibition of photosynthesis has two sub-groups; inhibition of electron transport in photosystems and formation of chlorosis. The primary site of action to which light contributes is mediated by yellow pigment(s). This sub-group of herbicides causing chlorosis has low acute toxicity to mammals. The other sub-group, including paraquat (1,1' dimethyl-4,4'-bipyridinium ion), results in the formation of active oxygen. Selectivity mechanisms of herbicides in agricultural use are identified as physical separation, difference in absorption and translocation, and biochemical processes. The last one consists of differences in the primary site of action, activation and inactivation. Inactivation mechanisms by tolerant crop plants such as hydrolysis, *N*-dealkylation and conjugation are explained using practical examples.

INTRODUCTION

Herbicides are pesticides which kill or damage weeds. There are many examples of different modes of action of herbicides from those of insecticides or fungicides. The important primary site of action of herbicides on weeds is different than in the case of insecticides on insects or fungicides on pathogenic microorganisms. Herbicides for agricultural use should have selectivity between crop plants and weeds.

In order to utilize herbicides effectively and safely, both the mode of action and the selectivity mechanism should be understood by the user or at least by extension workers. For the purpose of synthesis of new herbicides this information may also be useful.

There is much literature on this subject (Ashton and Crafts 1973, Corbett 1974, Kearney and Kaufman 1975, Matsunaka 1976a, Moreland 1977). In this paper the mode of action and selectivity mechanism of herbicides will be reviewed using data mainly from the field of rice culture.

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MODE OF ACTION OF HERBICIDES

It is very important to clarify where the site of the primary action is located. We should carefully observe the herbicidal process in weeds under practical conditions to determine the site. If a herbicide has a strong inhibitory activity to the Hill reaction, it can be called a photosynthetic inhibitor only if the following criteria are fulfilled. The main modes of action of herbicides may be classified as shown in Table 1.

Table 1. Mode of action of herbicides

Type of mode of action	Herbicides
1. Inhibition of photosynthesis	
(1) Inhibition of electron transport in photosystem II.	diuron, linuron, simazine, simetryn, bromacil, bentazon
(2) Formation of chlorosis	amitrole, dichlormate, methoxyphenone, SW-751
2. Contribution of light	
(1) Mediated by yellow pigments	nitrofen, CNP, chlomethoxynil, bifenox, fluorodifen, oxadiazon
(2) Active oxygen formation	paraquat, diquat
3. Inhibition of ATP formation in respiration	PCP, DNOC, ioxynil, TPCL
4. Disturbance of auxin action	2,4-D, MCPA
5. Inhibition of protein synthesis	
(1) Inhibition of protein synthesis	benthiocarb, EPTC, butachlor
(2) Inhibition of mitosis	chloropropham, trifluralin, methylpiperophos, S-32
6. Miscellaneous	

Inhibition of photosynthesis. Photosynthesis is the most important process in plants, including weeds. Inhibition of photosynthesis causes a shortage of carbohydrates and results in starvation of weeds. If the primary action of a herbicide is the inhibition of photosynthesis of weeds, the following four criteria may be fulfilled :

(a) Slow herbicidal action owing to the starvation of weeds.
(b) Inhibition of the Hill reaction, CO_2-fixation, O_2-exhaustion, or increase of dry weight.

(c) Recovery from the herbicidal effect by the supply of sugars.
(d) No difference from untreated weeds in darkness.

Inhibition of photosynthesis may be caused mainly in two ways, the inhibition of the Hill reaction (electron transport in photosystem) and the formation of chlorosis.

The electron flow in the photosystems during the initial steps of photosynthesis is shown in Figure 1. The inhibition of the electron

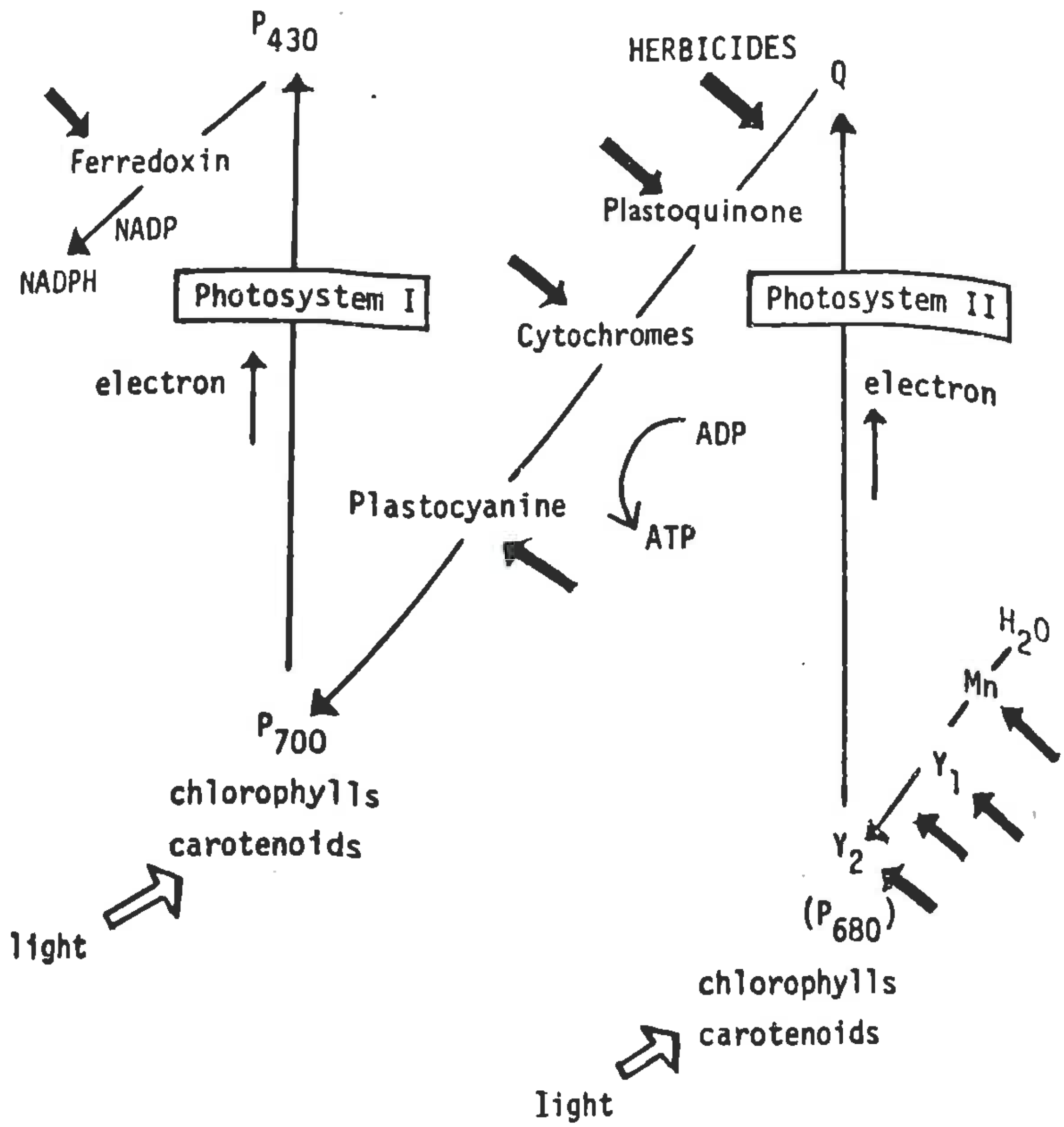

Figure 1. Electron transport system in photosynthesis and acting site of inhibitors (Kato, 1973) Thickset arrows show the acting sites of inhibitors.

flow between Q (supposed quencher) and plastoquinone by a herbicide, causes the inhibition of the Hill reaction, mainly composed of photosystem II, and inhibits the formation of ATP and NADPH which are utilized for CO_2-fixation. At least nine points, as respective inhibitors, were proposed as the inhibitory points of the electron transport systems from the degradation of water to the reduction of NADP (Kato 1973). Moreland and Hilton (Moreland 1977) separated herbicidal inhibitors of the photochemically induced reaction into five classes, (a) electron transport inhibitors, (b) uncouplers, (c) energy transport inhibitors, (d) inhibitory uncouplers, and (e) electron acceptors.

However, almost all main herbicides in practical use that inhibit photosynthesis of weeds, as the primary action, attack the election transport at a point between Q and plastoquinone. Only perfluidone [1,1,1trifluoro-*N*-2-methyl-4-(phenylphonyl)phenylmethane sulphonamide] is identified as a pure uncoupler at pH 8.0.

A selective herbicide in rice culture, bentazon [3-isopropyl-l*H*-2,1,3-benzothiadiazin-4-(3*H*)-one-2,2 dioxide] shows two herbicidal properties. Generally the herbicidal effect develops slowly, only after translocation of the herbicide has occurred, but when the weeds were contacted directly with relatively high concentrations of the herbicide, the effect appears rather rapid. The slow herbicidal effect appears to be an important mode of action of bentazon when applied on weeds under flooded rice field conditions. The slow effect was found to be caused by inhibition of photosynthesis, as supported by the following experimental results: (a) Inhibition of the Hill reaction, (b) inhibition of photosynthetic CO_2-fixation in susceptible weeds, (c) the herbicidal effects appeared much slower when it was applied as a flooded-water treatment and (d) bentazon injury was prevented by endogenously and exogenously supplied carbohydrates (Mine & Matsunaka, 1975).

Inhibition of chlorophyll synthesis or of chloroplast formation causes chlorosis and reflects the inhibition of photosynthesis.

The most famous herbicide of this group is amitrole (3-amino-1,2,4-triazole). Its mode of action was investigated in details. Bartels *et al* (1967) found that plastids from amitrole treated plants, grown in the light, are quite abnormal in appearance, contain few 70s ribosomes, and have reduced amounts of fraction I protein and plastid DNA. The inhibition of nucleic acid metabolism were suggested as the mode of action.

The next example is dichlormate (sirmate; 3,4-dichlorobenzyl-*N*-methylcarbamate). Bartels and Pegelow (1968), by ultrastructural studies, showed that the chloroplasts lacked normal grana-fret membranes and chloroplast ribosomes. In contrast, the cytoplasmic ribosomes and endoplasmic reticulum were abundantly present. Organelles, other than chloroplasts, were morphogenically normal.

The following three herbicides used for weeding in rice culture cause chlorosis in weeds. They are U-18 [ethyl-*N*-(2,4,5-trichlorophenyl carbamate], methoxyphenone (3,3'-dimethyl-4-methoxybenzophenone), and SW-751 [4-(2,4-dichlorobenzoyl)-1,3-dimethyl-pyrazol-5-yl p-toluenesulfonate]. In the case of U-18, the author showed that, using microscopic observation, this herbicide had almost no effect on the number of plastid, but the development and growth of proplastid and chlorophyll formation were inhibited by U-18 (Takamura and Matsunaka, 1972). Selectivity of these herbicides in transplanted rice culture should be recognized.

Contribution of light. Herbicides of this group show herbicidal activity only under the light condition. They can not fulfill the above-mentioned criteria of photosynthetic inhibitors. This groups may be classified into two sub-group :

(a) Mechanism mediated by yellow pigment(s)

(b) Active oxygen formation

The first sub-group was introduced, at the First Conference of this society (Matsunaka 1969), by describing nitrofen (NIP, 2,4-dichlorophenyl-p-nitrophenyl ether) and CNP (2,4,6-trichlorophenyl-4'-nitrophenyl ether) as examples. They are active only in the light and kill weeds just after their emergence from the soils. Another experiment showed that yellow mutants, without chlorophylls, were killed by these chemicals but this was not the case for white mutants (Matsunaka 1976). These results indicate that the mode of action of these herbicides are not due to inhibition of photosynthesis, but mediated by yellow pigments, probably xanthophylls.

Diphenyl ether herbicides, having ortho substituents on the benzene ring opposite that containing the nitro group, have such a mode of action. For examples are nitrofen, CNP, fluorodifen (*p*-nitrophenyl α, α, α-trifluoro-2-nitro-*p*-tolyl ether), chlomethoxynil (2,4-dichlorophenyl 3'-methoxy-4'-nitrophenyl ether), bifenox [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate], CFNP (2,4-dichloro-6-fluorophenyl p-nitrophenyl ether) and others. HE-314 (3-methylphenyl-p-nitrophenyl ether) or DMNP (HE-306; 3,5-dimethyl-phenyl-p-nitrophenyl ether) do not have such mode of action, because they have no ortho-substituent(s) although they are diphenyl ether compounds.

On the other hand, three other compounds having quite different structures from the diphenyl ethers show almost the same mode of action as nitrofen or CNP. They are oxadiazon (oxadiazolinone, 17623 RP, or G-315; 2-*tert.*-butyl-3-(2,4-dichloro-5-isopropyloxyphenyl)-1,3,4-oxadiazoline-2-one), phenopylate (2,4-dichlorophenyl pyrrolidinylcarboxylate), and MK-129 (*N-p*-chlorobenzyloxyphenyl Δ'-tetrahydrophtalimide). Compounds of this group also have other common characteristics. All are found to be useful herbicides when applied just before or after transplanting rice seedling. They produced brown spots on rice leaf sheath if they were applied in excessive amounts. From the standpoint of acute oral toxicity in mammals, all of them have a very low toxicity (Table 2).

These results suggest the possibility of finding new herbicides with other chemical structures which show the same mode of action and are useful and safe.

Biochemical details of the mode of action of these compounds have not been clarified.

Another sub-group is the bypyridynium herbicides. Typical examples of this sub-group are diquat [6,7-dihydrodipyrido (1,2- α:2',1'-*c*)],pyrazine diium ion and paraquat. Paraquat, methylviologen, has a long history as a biochemical reagent as an indicator of redox potential. One electron,

Table 2. Acute toxicity of diphenylether herbicides and other with same mode of action.

Herbicides	Acure toxicity LD_{50} (mg/kg weight)	
	Rat	Mouse
nitrofen	3,580	—
chlomethoxynil	—	33,000
fluorodifen	—	13,215
CNP	10,800	11,800
CFNP	2,890	6,770
oxadiazon	—	4,600
phenopylate	2,050	2,200
MK-129	—	6,500

at a low redox potential, can reduce paraquat to a free radical. When paraquat is applied to weed leaves, the excited electrons, produced by photosystem I, reduce the herbicide producing its free radical. It is then easily re-oxidized by atmospheric oxygen. During this oxidation, active oxygen similar to the superoxide radical (O_2^-) and others are produced. When the amount of active oxygen exceeds the detoxification activity of scavengers such as superoxyde dismutase, the weeds will be damaged.

It may be easily understood that these processes are inhibited in the dark, the absence of oxygen, or by the co-existence of Hill reaction inhibitors. Application of these herbicides has a close relationship with sunshine and the combined application of them with another herbicide the Hill reaction.

Hagimoto and Watanabe (1967) recommended a sunset application, if rain is not expected. After sufficient absorption of the herbicide during the night, the sunshine the next day will fully accelerate the activity of paraquat. From the standpoint of the efficacy of bipyridynium herbicides, the combined application with Hill reaction inhibitors will decrease the rapid herbicidal activity of the bipyridynium.

Inhibition of ATP formation in respiration. In the case of herbicides it is difficult to find inhibitors of the electron transport system in respiration. The only exceptions are azide compounds.

As inhibitors of ATP formation, both uncouplers and energy transfer inhibitors, substituted phenol herbicides may be recognized. They are PCP (pentachlorophenol), DNOC (4,6-dinitro-*o*-cresol) and DNBP (dinoseb; 4,6-dinitro-*O*-*sec*-butyl phenol). The mode of action of PCP was reported by the author (Matsunaka 1965). Although ioxynil (4-hydroxy-3,5-diodobenzonitrile) and bromoxynil (3,5-dibromo-4-hydroxy benzonitrile) are classified as nitriles, they could be uncouplers in the oxidative phosphorylation.

This site of action is common among aerobic organisms. Inhibitors of oxidative phosphorylation can act on higher plants, animals, and even on microorganisms where they act as a fungicide. The herbicides of this group relate to the toxicity to mammals and fish in an important manner. The herbicides described have a high acute toxicity LD_{50} to to rats and mice. The LD_{50} is less than 250 mg/kg weight.

Disturbance of auxin action. 2,4-D [(2,4-dichlorophenoxy)acetic acid] or MCPA ([(4-chloro-o-tolyl)oxy]acetic acid) are typical hormonal herbicides. Normal physiological activity of auxins has not been clarified by biochemical studies. Herbicidal actions of these compounds seems to be the result of over stimulation of normal activity. The mode of action of hormonal herbicides may be stated as the disturbance of auxin action, which contributes to RNA biosynthesis by the interaction with DNA.

Inhibition of protein synthesis. Many herbicides cause inhibition of growth, resulting in malformations in weeds. This abnormal growth may result in death of the weed. Ichizen *et al.* (1972) classified these herbicides into three groups, depending upon characteristics of malformations that in barnyardgrass *(Echinochloa crus-galli* Beauv.) when treated with the following herbicides :

(a) Benthiocarb [*S*-(4-chlorobenzyl)*N*,*N*-diethylthiolcarbamate], EPTC (*S*-ethyl dipropylthiocarbamate), Diallate [*S*-(2,3-dichloroallyl) diisoprpylthiocarbamate], butachlor [*N*-(butoxymethyl)-2-

chloro-2',6'-diethylacetanilide] and CDAA (*N,N*-diallyl-2-chloroacetamide),

(b) Chloropropham (isopropyl-*m*-chlorocarbanilate), chlorbufam (1-methylprop-ynyl 3-chloro phenyl carbamate), trifluralin (α, α, α,-trifluoro-2,6-dinitro-*N-N*-dipropyl-*p*-toluidine) and DMPA [*o*-(2,4-dichlorophenyl)-*o*-(methylisopropylphosphoramidothicate] and

(c) Diphenamid (*N, N*-dimethyl-2.2-diphenyl acetamide), diphenatrile (diphenyl acetonitrile) and asulam (methyl sulfanilyl carbamate).

Kimura *et al.*(1971) found that either benthiocarb or EPTC inhibited the α-amylase synthesis induced by gibberellin in rice and barnyardgrass endosperms. The elongation test of lamina-joints of excised rice leaves with indoleacetic acid showed the possibility of inhibition of protein synthesis by benthiocarb through the competition at the auxin-acting site.

Thiocarbamate herbicides have also been shown to inhibit the synthesis of unsaturated fatty acids. The recovery of this inhibition by the practical antidotes of EPTC, 1,8-naphthalic anhydride or R-25788 (*N,N*-diallyl-2,2-dichloroacetamide) has been reported by Wilkinson and Smith (1975).

Chloropropham and others of sub-group (b) were demonstrated to be mitotic poisons and to inhibit cell division. There was no spindle formation. Trifluralin, pronamide [propyzamide; *N*-(1,1-dimethyl-2-propyl)-3,5-dichlorobenzamide] and other thionophosphoroamidate herbicides show the same mode of action.

SELECTIVITY MECHANISM

Practical herbicides for agricultural use kill the weeds but co-existing crop plants should not be damaged by them. Here selectivity between crop plants and weeds is required.

The first example of the selectivity mechanism is explained as the difference between locations of susceptible points of crop plants and herbicides, in other words, physical separation.

Difference in absorption and translocation of herbicides between crop plants and weeds may be the second example of the selectivity mechanism. This appears to be a physiological selectivity.

The third selectivity mechanism may be biochemical, consisting of a difference in primary sites of action and in the activation or inactivation mechanism of the herbicides. It is difficult to find an example of the difference in primary sites of action, because almost all primary sites of action should be fundamental in killing plants and will be common to both crop plants and weeds.

An activation mechanism was explained, in the case of MCPB (4-[(4-chloro-*o*-tolyl)oxy] butyric acid) and 2,4-DB (4-(2,4-dichlorophenoxy) butyric acid), as the so-called β-oxidation process.

Mainly inactivation mechanism in the tolerant crop plants will be explained in this paper. The main inactivation mechanisms are hydrolysis, *N*-dealkylation and conjugation.

Hydrolysis. The best known example of hydrolysis, of an amide herbicide, is that of propanil (3',4'-dichloropropionanilide) by rice plants. Details were reported at the 2nd Conference of this society (Matsunaka 1969a). The product of this hydrolysis is 3,4-dichloroaniline, which has almost no activity as an inhibitior of the Hill reaction (I_{50} = 4 x 10^{-2}M). Matsunaka (1974) provided direct evidence to show that the hydrolyzing enzyme, aryl acylamidase, contribute to the selectivity of rice plants to propanil by using artificial mutants of rice plants which were susceptible to propanil in that they lacked the proper enzyme. It was shown that the process was controlled genetically.

The rice enzyme acylamidase is inhibited by organophosphates or by carmabate insecticides which have inhibitory activity on acetycholine esterase. These facts reflect the limitation of practical use of insecticides with propanil. These insecticides cause damage on rice plants, when sprayed just before or after propanil application.

Swep (methyl-*N*-(3,4-dichlorophenyl)-carbamate) is also widely used in Japan for weeding in rice culture, and it has a somewhat similar chemical structure although the herbicide is classified as a carbamate. In vitro experiment showed that the rice aryl acylamidase does not hydrolyze swep. However, the propanil susceptible rice mutant is also susceptible to swep. The residue of swep in the top portions of soil-treated rice plants increased to 22 ppm in the mutant, but in normal rice plants the maximum value was only 7 ppm and decreasing 2 days after the application. Swep seems to be hydrolyzed to some extent in the intact rice plants, and the degradation mechanism is assumed to be the same as the case of propanil. This may contribute to the tolerance of the rice plant to this herbicide. The application of insecticides just before or after the swep application causes the same injury as with propanil on the intact rice plants.

The chlorinated *s*-triazine herbicides, simazine [2-chloro-4,6-bis (ethylamino)-*s*-triazine], atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*S*-triazine], propazine [2-chloro-4,6-bis(isopropylamino)-*S*-triazine], and others, can be inactivated by a tolerant plant such as maize *(Zea mays* L.). One of the inactivation process was found to be the non-enzymatic reaction by a special component in corn plants, 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one or its 2-glucoside. This process is a kind of hydrolysis, by which simazine is converted to hydroxysimazine, which is inactive as a herbicide. This non-enzymatic inactivation mechanism contributed to the development of calcium polysulfide as the antidote for simazine in soils (Castelfranco and Deutsch 1962).

N-dealkylation. *N*-dealkylation is usually the inactivation mechanism of herbicides and it related to the selectivity mechanisms of tolerant plants to herbicides. This process is found in the metabolism of phenylurea and *s*-triazine herbicides. In cotton plants, diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] is *N*-demethylated by two demethylation steps and cleavage of the C-N bond to form 3,4-dichloroaniline. Similar mechanisms were also found in other plants or for other phenylureas herbicides such as monuron [3-*p*-dichlorophenyl)-1,1-dimethyl urea-], fluometuron [1,1-dimethyl-3-(α, α, α-trifluoro-*m*-tolyl)urea], chloroxuron (3-[*p*-(*p*-chlorophenoxy)phenyl]-1,1-dimethyl urea), linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methyl urea], and chlorbromuron [3-(4-bromo-3-chlorophenyl)-1-melthoxy-l-methyl urea].

Tolerant plants have a high activity of *N*-dealkylation, while susceptible ones have a low activity. The degree of inactivation is correlated with the recovery rates of photosynthetic inhibition by the herbicide. The *N*-dealkylation mechanisms may be mediated by a microsomal mixed-function oxygenase system. It may be inhibited by several *N*-methyl carbamate insectivides but not by SKF-525, a noted inhibitor of the system in animal tissue (Frear *et al.* 1969).

An *s*-triazine herbicide, atrazine, is also *N*-dealkylated in peas and cotton plants. This process contributes to the moderate tolerance of these plants. Other *s*-triazine herbicides may be *N*-dealkylated in the same way as atrazine.

Conjugation. Higher plants, as compared with animals, have lower activities in the excretion of used or unfavorable metabolites. Here, conjungation with other metabolites or polymerization *per se*, followed by precipitation at inactive sites in the cell, is important, and contributed to the tolerance to herbicides.

Conjugation of pesticides in plant tissues can be classified in four groups, depending upon the conjugation partners: (a) sugars, especially glucose, (b) amino acids, (c) peptides, and (d) high molecular weight compounds. When glucose is the partner it may be divided into two conjugation forms: glucoside and glucose ester. The former form of conjugation can taken place through two different routes: i.e. conjugation with amino or hydroxyl radicals of herbicides.

A good example of the first case is the conjugation of the amino radical of chloramben (3-amino-2,5-dichlorobenzoic acid), a herbicide used in soybean culture. This reaction is catalyzed by arylamine *N*-glucosyl-transferase (Frear 1968) which is specific for uridine diphosphate-5'-glucose (DPG). The heterocyclic amine herbicide, pyrazone (5-amino-4-chloro-2-phenyl-3(2*H*)-pyridazinone) also forms *N*-glucosylpurazone in red beets (Ries *et al.* 1968).

The second case is bentazon [3-isopropyl-1*H*-2,1,3-benzothiadiazin-4-(3*H*)-one 2,2-dioxide]. This herbicide is a selective herbicide for weed control in rice and soybeans. Many graminaceous plants such as rice, corn and others are resistant. The tolerant mechanism was found to be hydroxylation at the 6 position of bentazon and conjugation with glucose, forming 6-bentazon-O- β -glucopyranoside (Mine *et al.* 1975).

In the case of peptides, conjugation of atrazine with glutathione is best known. The enzyme responsible for catalyzing this reaction, a glutathione *S*-transferase, is located primarily in the shoots of tolerant plants (Shimabukuro *et al.* 1970). Corn and sorghum plants have high activities of the glutathion-*S*-transferase in their shoots, but have low activities in their roots. This enzyme was partially purified and its properties surveyed (Frear and Swanson 1970). Lamoureux *et al.* (1971) reported that propachlor (2-chloro-*N*-isopropylacetanilide) conjugated with glutathione or -glutamycysteine in corn, sorghum, sugar cane, and barley.

In the case of high molecular components in plants, conjugation of swep with lignin, and of 2.4-D with protein are known to occur.

Conjugation of herbicides should also be considered from the standpoint of this terminal type bond and its relationship to residue problems.

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Herbicide Antidotes — A New Concept in Weed Control

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ABSTRACT

EPTC (*S*-ethyl dipropylthiocarbamate) will provide effective weed control in many crops, but at normal recommended use rates it is not sufficiently selective to maize. A combination of EPTC with R-25788 (*N,N*-diallyl-2, 2-dichloroacetamide) in a 12:1 ratio greatly increases the selectivity of EPTC to maize without affecting the persistence or spectrum of weed control. R-25788 can be also combined with butylate (*S*-ethyl diisobutylthiocarbamate) to increase further the selectivity of this maize herbicide.

INTRODUCTION

The commercial acceptance of the value of herbicide antidotes in preventing herbicide injury has been firmly established in some developed countries. Prior to the discovery of chemical antidotes the search for effective methods of preventing herbicide injury to susceptible crops was concentrated on the use of physical means such as activated charcoal barriers, and the differential placement of herbicides and germinating seeds in the soil. The widespread acceptance in certain countries of the use of trifluralin (α, α, α-trifluoro-2,6-dinitro-*N,N*-dipropill-*p*-toluidine) and triallate [*S*-(2,3,3-trichlorallyl)diisopropylthiocarbamate] herbicides in wheat is an example of the successful development of the latter method of preventing herbicide injury.

This presentation describes the successful utilization of a chemical antidote to protect maize from injury associated with the use of some thiocarbamate herbicides.

In the Asian Pacific region the thiocarbamate herbicides EPTC and butylate in combination with R-25788 antidote are registered for weed control in New Zealand maize.

PROTECTION OF MAIZE BY R-25788

The need for pre-emergent weed control in maize is self-evident. EPTC is a nonpersistent preplant incorporated thiocarbamate herbicide that will provide effective weed control (Matthews 1974). However, its use in maize has been limited because its margin of safety with regard to crop selectivity is too narrow. EPTC can cause injury to maize at

[1] Stauffer Chemical Company, 15 Scotts Road, Singapore.

rates as low as 2 kg/ha. This usually occurs under soil or climatic conditions that retard the germination and early growth of maize.

Recently it was shown[2] that R-25788, a dichloroacetamide type chemical, will protect maize against injury from thiocarbamate herbicides. This discovery permits the safe use of EPTC in maize at rates that were previously unacceptable because of crop injury. When the antidote is combined with EPTC, in the required ratio of 12:1, R-25788 has prevented such injury at rates of EPTC up to 12 kg/ha.[3]

In the US approval has been granted for use of the EPTC: R-25788 combination in a 12:1 ratio at a rate of 6.7 kg a.i./ha EPTC.

This rate will provide control of such important weeds as shattercane *(Sorghum bicolor)*, johnsongrass *(S. halepense* Pers.*)*, bermudagrass *(Cynodon dactylon* Pers.*)*, nutsedge *(Cyperus rotundus* L.*)* and couchgrass *(Agropyron repens)*. In addition the combination will permit normal maize yields (Table 1).

Table 1. Effects of EPTC and R-25788 on maize yields[1].

Treatment	Yield in kg/plot
Control (unweeded)	19.0
EPTC, 6.7 kg/ha	43.6
EPTC, 6.7 kg/ha + R-25788, 0.56 kg/ha	98.6
Handweeded control	96.5

1 Raines and Fletchell, 1973.

Greenhouse tests have shown that about 1 part of antidote is needed per 100 parts of EPTC to protect corn plants (Pallos *et al.* 1975). The commercial product contains 1 part antidote for 12 parts EPTC, clearly much more antidote than is needed in the greenhouse. Thus the product has a built-in safety factor in order to achieve reliable performance under variable field conditions.

PERSISTENCE OF R-25788

The microbial degradation of R-25788 in the soil has been shown to be equivalent to EPTC. The combination of EPTC + R-25788 does not alter the residual life of EPTC.

2 Stauffer Chemical Company 1972. Belgium Patent 782, 120.

3 Appleby, A. 1971. Oregon State University, Weed control Research, Antidote Studies.

ACTION OF R-25788

Basic biochemical studies showed that the protection offered by R-25788 did not result from decreased uptake of EPTC by maize roots (Chang *et al.* 1974, Gray 1975). Root or shoot uptake of the antidote provided protection in the meristematic region of the shoot where thiocarbamate injury is manifested.

It has been shown that corn seedlings injected with [^{14}C]EPTC contain detectable amounts of the corresponding sulfoxide when analyzed 8 hr after treatment (Casida *et al.* 1975). It was proposed that the thiocarbamate sulfoxides are the active herbicidal compounds formed by the plant on metabolism of the thiocarbamate. This is supported by *in vitro* studies which showed that thiocarbamate sulfoxides will carbamoylate coenzyme A and glutathione (Lay *et al.* 1975). It is postulated that this biochemical action *in vivo* could result in mortality of plant seedlings.

More recent studies have shown that the presence of R-25788 in maize seedlings causes an increase in glutathione content and glutathione *S*-transferase activity which allows rapid detoxification of the thiocarbamate sulfoxide (Lay and Casida 1976).

TRIALS WITH THIOCARBAMATE-R-25788 COMBINATION IN THE ASIAN-PACIFIC REGION

Field trials in New Zealand have been carried out by the Ministry of Agriculture and Fisheries and by the technical staff of N. Cropper and Company, Ltd. The combinations used were EPTC + R-25788 and butylate + R-25788, each with and without the addition of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine]. Table 2 shows data obtained by Porter and Cornwal (1974)[4] in Gisbourne.

In Australia EPTC + R-25788 has been tested in sweet corn (Golden Jubilee) by ICI Australia Ltd. and in maize (XL 361 and XL 45) by Agrisearch Services Pty. Ltd.[5] (1975) under sprinkler and flood irrigated conditions.

Data presented in Table 3 was obtained at Mudgee NSW by Agrisearch Services Pty. Ltd. in the summer of 1974 — 1975. Weeds occurring were lovegrass *(Eragrostis cilianensis* Vignolo-Lutati*)*, thornapple *(Datura ferox* L.*)* and jimson weed *(D. stramonium* L.*)*, black nightshade *(Solanum nigrum* L.*)*, puncturevine *(Tribulus terrestris)*, common purslane

4 Porter, J. and M. Cornwall 1974. Internal Report. Neil Cropper and Co., Limited. Auckland

5 Agrisearch Services Pty. Ltd. Evaluation of Eradicane for weed control in maize 1974/1975. Trial report submitted to Stauffer Chemical Co. (Aust.) Pty. Ltd. July 1975.

Table 2. Weed control and yields in New Zealand maize obtained by thiocarbamate R-25778 combinations.

Treatments and rates[1]	Crop vigor[2]	Weed control[3]		Yield in mt/ha
		25 DAA	50 DAA	
EPTC + R-25788, 4.04 kg/ha	3.0	8.6	2.0	3.47
EPTC + R-25788, 6.06 kg/ha	4.0	9.1	6.0	6.09
EPTC + R-25788, 4.04 kg/ha + atrazine, 1.6 kg/ha	4.0	9.7	9.5	8.71
Butylate + R-25788, 6.06 kg/ha	2.5	7.5	2.5	3.90
Butylate + R-25788, 4.04 kg/ha + atrazine, 1.6 kg/ha	4.0	8.8	6.0	7.47
Control (unweeded)	0.5	5.0	0.5	1.70

1 EPTC: R-25788 ratio 12:1; butylate:R-25788 ratio 24:1

2 50 days after application; 0 = poor vigor, 4 - full vigor

3 DAA = days after application· 0 = no control, 10 = complete control.

Table 3. Weed control and yields in sprinkler irrigated XL 361 maize obtained by EPTC — R-25788 combination.

Treatment	Mean % ground 41 DAT	cover 65 DAT	(all weeds)[1] 93 DAT	Mean yield t/ha
EPTC — R-25788, 2.2 kg a.i./ha	2.42 b	3.78 b	4.31 c	9.3 ab
EPTC — R-25788, 4.5 kg a.i./ha	1.34 a	1.54 a	2.08 ab	9.3 ab
EPTC — R-25788, 6.5 kg a.i./ha	0.84 a	1.14 a	0.93 ab	8.5 b
EPTC — R-25788 + atrazine 4.0 + 1 kg a.i./ha	0.71 a	1.04 a	1.06 ab	9.3 ab
EPTC — R-25788 + atrazine 4.0 + 1.8 kg a.i./ha	0.84 a	0.78 a	0.71 a	9.1 ab
Atrazine 2.0 kg a.i./ha	1.47 a	1.94 a	2.79 bc	10.1 a
Untreated control	86.3 c	97.5 c	100. d	5.8 c

1 Data for all treatments except control transformed $\sqrt{x + ½}$ before statistical analysis.
DAT = Days after treatment and planting.
Numbers followed by the same letter are not significantly different at the 5% level.

(Portulaca oleracea L.*)*, common lambsquarters *(Chenopodium album* L.*)*, barnyard grass *(Echinochloa crus-galli* Beauv.*)* and crabgrass *(Digitaria adscendens* Henr.*)*. The result in Tables 2 and 3 show that combinations of EPTC + R-25788 or butylate + R-25788 are highly effective herbicides. Their activities can be further enhanced by the addition of atrazine at a rate which will prolong weed control but minimize carry-over effect onto succeeding crops.

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Ametryn Leaf Absorption of Different Susceptible Cane Varieties [1]

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ABSTRACT

Varied ametryn [2-(ethylamino)-4-(isoproylamino)-6-(methylthio)-s-triazine] uptake by susceptible cane plants (variety Ps 30) caused different degrees of cane toxicity. Absorption through the roots or leaves alone, caused no, or slight, cane injury, while ametryn uptake through both roots and leaves caused the most severe cane damage. To prevent cane toxicity following ametryne application to fields planted with susceptible cane varieties, application should be made at the earliest possible time so as to avoid spraying the cane foliage. The leaf absorption model of ametryn to cane leaves in the greenhouse and air conditioned room is exponential in nature, and no apparent environmental influence is exerted on the mechanism of ametryn absorption. The amount absorbed follows the degree of cane varietal susceptibility toward ametryn, whereas more tolerant varieties absorb more ametryn into their leaves.

INTRODUCTION

Differences in susceptibility of different sugar cane varieties towards various herbicides have been reported (Nolla 1950, Rochecouste 1962, Millholon and Matherne 1968). There is differential susceptibility towards ametryn for five most widely cultivated cane varieties and their ancestors grown in Indonesia.[5]

Triazine herbicides enter the plant through the roots and the leaf. The leaf entrance is more important for ametryne and other methylthio-s-triazine herbicides (Fryer and Evans 1970). Absoprtion through leaf and roots simultaneously, causes more damage to the plants (Thompsons and Slife 1969, Parochetti 1974). A similar case apparently occurs with ametryn applications to sprouting seed cane in the field.

Although we are not aware of other reports concerned with the relationship between herbicide absorption and plant susceptibility, there

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1 Part of a thesis submitted by the senior author in partial fulfillment of requirements for the Doctorate degree. Bogor Agric. Univ. October 1976.

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5 Kuntohartono, T. 1976. Ametryn selectivity towards some Indonesian cane varieties. Doctor dissertation at Bogor Agric Univ.

is at least to a limited extent, an indication that it might occur with the methylthio-*s*-triazine. Cotton absorbed the least prometryn [2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine] compared to soybean or peanuts and is the least susceptible (Singh *et al.* 1972).

Due to the increasing use of ametryn in the sugar plantations in Java in recent years, it was necessary to study the mechanism of herbicide uptake and the related toxicity resulting from different susceptible cane varieties. Spraying in the field could thus be adjusted to avoid herbicide toxicity if susceptible varieties are grown.

MATERIALS AND METHODS

Ametryn uptake and toxicity. This experiment was carried out to study cane toxicity following ametryn uptake through different entrances. Cane cuttings and sprouting seedcane of Ps 30 (susceptible) and Ps 41 (tolerant) varieties were planted in pots, then treated with ametryn at the rate of 4.0 kg/ha as follows: (a) An ametryn-talc mixture was incorporated in 10 cm of the upper soil layer and then cane cuttings were planted. (b) The same as (a), but planted with sprouting seedcane. (c) Ametryn water solution was sprayed on the soil surface 35 days after planting the cuttings. (d) The same as (c), but planted with sprouting seedcane. (e) Ametryn was sprayed on the foliage and on the soil 35 days after planting the cuttings. (f) The same as (e), but one day after planting sprouting seedcane. (i) Check, no ametryn application but planted with cuttings. (j) Check, planted with sprouting seedcane. All treatments were replicated six times (pots) and watered every day. The cane stools were harvested 180 days after planting. The aerial parts were separated from the roots, and weighed separately. The data obtained were compared according to Duncan multiple range test (Steel and Torrie 1960). This experiment was carried out between 23 January and 23 July 1975.

Ametryn foliage uptake. This experiment was conducted to study ametryn absorption by cane leaves of Ps 30 and Ps 41 varieties. Forty μl of ametryn-water solution at 2 x10^{-3} M were transferred with a pipette to a ring lanolin on the surface of leaf number +3 (Kuijper 1918). A non-ionic surfactant X-114 (octyl phenoxy polythoxy ethanol) was added to enhance the leaf wetting. After a predetermined period of time, the leaf section was washed with 5 ml of 50% ethanol. Ametryn concentration in the ethanol solution was determined spectrophotometrically at the wavelength of 223 μm. The amount of ametryn absorbed during a given period of time was determined by subtracting the unabsorbed concentration found in the leaf washings from the total concentration applied. The experiment was carried out in the greenhouse and in an air conditioned room lighted with two fluorescent lamps of 40 watts each.

Foliar uptake of different susceptible cane varieties: This experiment was carried out to support the previous experiment and to compare ametryn leaf absorption of six cane varieties which belong to six different susceptibility groups. To the leaf number +3 of six cane varieties (Ps 18, Ps 22, Ps 23, POJ 3067, Ps 30 and Ps 41), 1 μl of ^{14}-C-ametryn (0.02 y Ci) in waterethanol solution was applied by a pipette. After the predetermined absorption time, the treated leaves were excised and washed for 30 seconds by shaking in scintillation counting vials containing Bray scintillator. The treated leaves were removed from the counting vials and the residual radioactivity in each vial was determined using a liquid

Table 1. The effect of various methods and times of ametryn application to cane fresh weight (g) at 180 days after planting.

Treatments	Ps 30		Ps 41	
	Shoots	roots	Shoots	roots
a. Soil + ametryn (cuttings)	2161.3^{ab}	497.9^{d}	2239.5	668.3
b. Soil + ametryn (sprouting seedcanes/rayungan)	2372.3^{a}	523.5^{d}	2098.8	702.0
c. Ametryn sprayed on the soil (35 days after cutting is planted)	1839.8^{bc}	325.6^{def}	2099.9	871.6
d. The same as C. (35 days after planting rayungan)	1975.4^{ab}	352.9^{de}	2082.0	747.6
e. Ametryn sprayed on the cane (35 days after planting the cuttings)	1679.2^{bc}	501.6^{d}	2332.8	591.4
f. The same as e (1 day after planting rayungan)	2105.2^{ab}	457.0^{de}	2086.9	650.4
g. Ametryn sprayed on the soil and cane (35 days after planting cuttings)	1153.7^{c}	286.0^{ef}	2258.2	433.7
h. The same as g (35 days after planting rayungan)	1242.4^{c}	153.9^{f}	2100.3	603.5
i. Check (cuttings)	2000.6^{ab}	370.7^{de}	2310.1	664.1
j. Check (rayungan)	2051.1^{ab}	359.1^{de}	1904.9	654.8
F-test	4.41**	2.44**	NS	NS.

NS means non significant at $p > 0.05$.

scintillation counter. The amount of ^{14}C-ametryn absorbed during a given period of time was determined by subtracting the unabsorbed radioactivity found in the leaf washings from the total amount applied. Four leaves of each cane variety were treated. The experiment was carried out on 5 May 1976.

RESULTS AND DISCUSSION

Ametryn uptake and toxicity. Various methods of ametryn application at different times affected the growth of the susceptible cane variety Ps 30 while no growth reduction occurred to the tolerant variety Ps 41 (Table 1). The aerial parts of Ps 30 suffered more from ametryn application than the roots. Ametryn absorption occurred mainly through cane set-roots (treatment a and b), shoot roots (c and d), through sprouting seedcane leaves (f) and through young developing foliage at 35 days after planting (e), but did not significant reduce the fresh plant weight. Uptake through the foliage and roots simultaneously at 35 days after planting (g and h) resulted in severe toxicity and significant fresh plant weight reduction. These data also indicate ametryn uptake through the foliage caused more damage to the cane than uptake through the roots.

Ametryn foliage uptake. Spectrophotometric determination of ametryn concentration in the leaf washings provides us with a picture of ametryn absorbed by the foliage (Table 2). These data show us that under both conditions the Ps 41 leaf absorbed more ametryn than the leaf of Ps 30. The calculated regression equations of ametryn absorption at different periods of time were found to be exponential in nature. The equations

Table 2. Ametryn leaf absorption (%) of Ps 30 and Ps 41 (average of four replication)

Time (hours)	Ametryn absorbed (%)					
	Green house			Air-conditioned room		
	Ps.30	Ps 41	t-test	Ps 30	Ps 41	t-test
1	—	—	—	29.7	21.7	1.32
2	22.1	19.7	0.45	31.8	31.5	0.03
4	15.1	25.7	1.72	38.0	32.7	0.63
8	37.1	43.6	1.41	38.1	40.1	0.41
12	36.8	47.2	2.73*	44.6	51.2	1.52
24	47.3	54.1	1.63	42.5	57.5	4.91**

* and ** means significantly different in $P < 0.05$ and $P < 0.01$, respectively.

in the greenhouse give $Y = 21.28 (X^{0.22})$ for Ps 30 and $Y = 22.42 (X^{0.25})$ for Ps 41. In the airconditioned room $Y = 33.25 (X^{0.07})$ and $Y = 28.48 (X^{0.17})$, where Y is the ametryn absorption (in arcsin square percentage) and X is the absorption time (in hours). The correlation coefficients for Ps 30 are 0.8340 (greenhouse) and 0.9388 (air-conditioned room), while those for Ps 41 are 0.9725 (greenhouse) and 0.9792 (air-conditioned room). The ametryn absorption curves are shown in Figures 1 and 2.

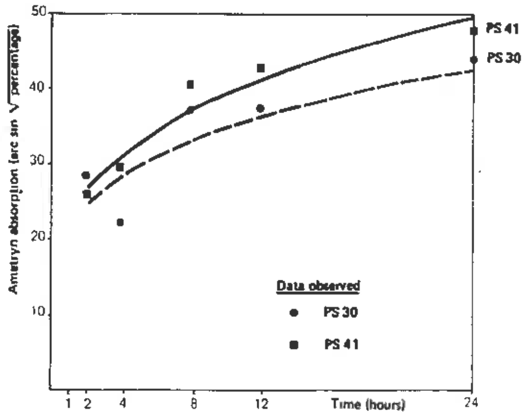

Figure 1. Ametryn leaf absorption in the green house.

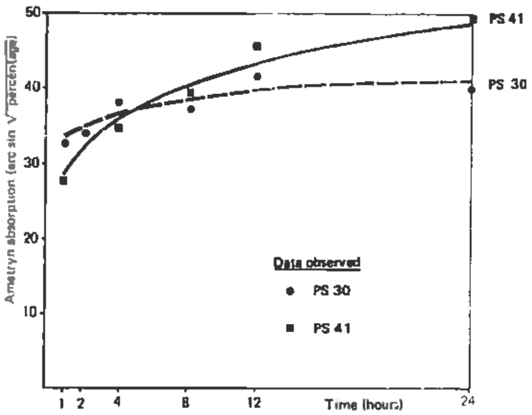

Figure 2. Ametryn leaf absorption in air conditioned room.

Foliar uptake of different susceptible cane varieties. Determination of the radioactivity of the leaf washing provides us with the percentage of ^{14}C-ametryn absorbed by the cane leaves (Table 3). The absorption data of the first 4 hours does not express any relationship of varietal suscep-

Table 3. Ametryn leaf absorption (%) of six different susceptible cane varieties (average of four replication).

Time (hours)	ametryn^{14} absorbed (%)					
	Ps 18***	Ps 23	Ps 22	POJ 3067	Ps 30	Ps 41
1	44.7	—	16.3	36.7	27.5	31.9
2	16.4	24.6	48.1	23.5	35.1	21.9
4	39.5	40.9	46.7	32.0	25.5	26.5
8	37.7	—	42.2	53.0	42.3	47.7
24	46.0	53.5	55.0	51.0	59.9	64.0

*** The most susceptible cane variety; followed successively by the less susceptible ones.

tibility. The absorption data for 8 and 24 hours indicate that there seems to be a connection between ametryn leaf absorption and varietal susceptibility. Except for POJ 3067, higher ametryn leaf absorption occurred in less susceptible cane varieties.

These experiments show that in either method of application, later ametryn applications tend to cause more severe cane toxicity. To prevent cane damage, following ametryn application in field, ametryn should be sprayed before or soon after planting to avoid application to the foliage.

Since the absorption curves for Ps 30 and Pas 41 leaves are similar for the greenhouse and air-conditioned room, we inferred therefore that ametryn absorption was not influenced by different environmental conditions. The fate of ametryn absorbed in the leaf tissues probably controlled the rate of intake.

In tolerant or resistant cane varieties, the ametryn absorbed undergoes metabolic degradation within the leaf tissues.[5] The ametryn content remains fairly low and thus permits more intake into the leaf tissues. In susceptible varieties, slight ametryn degradation occurs in the leaf tissues, resulting in high ametryn concentrations which in turn inhibit further intake.

ACKNOWLEDGEMENTS

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Photosynthesis of and the Effect of Photosynthetic Inhibitors on Waterhyacinth [Eichhornia Crassipes (Mart.) Solms]

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ABSTRACT

Gas exchange in waterhycinth (*Eichhornia crassipes* (Mart.) Solms) was measured using an infrared gas analyzer at a constant CO_2 concentration of 400 ppm, 25°C and relative humidity of 70%. At 36 klux the CO_2 exchange rate was about 15 mg $CO_2/dm^2/h$, and was not saturated yet. Carbondioxide compensation point was 60 ppm. Foliar and root application of cyanatryn [2-{(6-ethylamino-4-methylthio-*s*-triazin-2-yl)amino}-2-methylpropionitrile] at 1 — 2 kg a.i./ha under 25% and 50% sunlight intensities killed the plants in 2 weeks, under 100% sunlight intensity the plants were killed in 1 week. Exposure of plants for 2 hours through root application of 1 kg a.i./ha of cyanatryn did not kill the plants although foliar application did.

INTRODUCTION

The photosynthetic rate of waterhyacinth was reported to be low (18 mg $CO_2/dm^2/h$) (Chen *et al.* 1970), but despite this low photosynthetic rate it can grow very fast (Evans 1963, Bock 1969, Widyanto and Soerjani 1974, Widyanto 1976), to become a hazard to navigation (Grantz 1972, Timmer and Weldon 1967), to choke the irrigation channels, to increase water losses through evapotranspiration (Brezny *et al.* 1973, Ohsawa and Risdiono 1976), to be conducive to mosquito breeding (Wilson 1967) and reduce water storage capacity (Little 1966). It is considered one of the most serious aquatic weeds in Mekong area (Ganstad *et al.* 1972) and rated as the worst aquatic weed in Southeast Asia (Soerjani *et al* 1975).

This rapidity of growth was thought due to the efficient use of photosynthate for stolon production[3] and later for leaf production (Widyanto 1976).

Since photosynthesis is the biochemical process responsible for the fixation of CO_2 which ultimately forms the material for growth and devel-

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opment, it is of interest to know the effect of cyanatryn, a photosynthetic inhibitor on this plant.

MATERIALS AND METHODS

The photosynthetic rate of waterhyacinth was measured in term of the rate of CO_2 exchange using a URAS infra red gas analyzer. This measurement was conducted at the Institute for Useful Plant Research, Division of Vegetable Research, Berlin, Federal Republic of Germany, in October 1976. Waterhyacinth plants were taken from Sudan, grown in Stuttgart and later flown to Berlin where they were grown in a controlled environment at 25°C for 48 h before measurement.

Eight plants were grown in plastic containers with 500 ml of 1/4 strength Hoagland solution. The plants were placed inside a growth chamber measuring 1 by 1 by 1.2 m, kept at a constant temperature of 25°C with relative humidity of 70%. Light was provided by 9 mercury lamps capable of delivering up to 36 klux. The concentration of CO_2 was kept constant at 400 ppm by a dosimeter. Leaf area was measured using an automatic leaf area meter. For comparison tomato plants (*Lycopersicon esculentum* Mill.) were also measured in the same manner.

Trials on the effect of cyanatryn on waterhyacinth were done in pot experiments. Pots of 5 l capacity lined with plastic bags were filled with 4 l of 1/4 strength of Hoagland solution. Waterhyacinth plants were grown in the plastic pots for 7 days before treatment to acclimatize them. Foliar application of herbicide were carried out using Killasprayer with a pressure of 20 psi, a T-jet fan type nozzle giving 1 meter spray swath width from 45 cm above the ground and calibrated at 100 ml/10 seconds. The spraying were done upon a quadrat of 2 m^2 with the treated pots randomly placed inside the quadrat.

The first experiment was done with treatments consisting of 3 levels of light intensities (25%, 50% and 100% sunlight intensity), 3 levels of cyanatryn (0, 1 and 2 kg a.i./ha), and 2 methods of application (foliar and root applications). These treatments were arranged factorially and randomized completely with 2 replications.

The second experiment was done with treatments consisting of 3 levels of cyanatryn (0, 1 and 2 kg a.i./ha), 3 different times of washing or replacing the culture solution after treatment (2, 4 hr and no washing) with 2 methods of application (foliage and root). The treatments were arranged factorially and randomized completely with 2 replications.

In both experiments the phototoxicity was recorded at 1, 3, 5, 7 and 14 days after treatment as percentage of damage. At 14 days after treatment the plants were harvested, dried at 80°C for 48 h, weighed and the results were analyzed statistically.

RESULTS AND DISCUSSION

The CO_2 exchange rate varied with light intensity (Figure 1). The curve for waterhyacinth differed slightly from that for tomato. The photosynthetic rate of tomato plant reached saturation at 36 klux, while that of waterhyacinth has not reached saturation at that light intensity. The carbon dioxide exchange rate of waterhyacinth at a constant CO_2 concentration of 400 ppm, 25°C and relative humidity of 70% under 36 klux was 15.52 mg $CO_2/dm^2/h$, with a CO_2 compensation point of 60 ppm. This is similar to that of C_3 plants such as sugar beet (Downton and Treguna 1968). Chen *et al.* (1970) implicated waterhyacinth to be C_3 plant. The curve of waterhyacinth which was not saturated yet at 36 klux, however, contrasts the usual behaviour of C_3 plants which will be saturated by a light intensity around 30 klux. This photosynthetic behaviour of waterhyacinth may explain partly why it grows very fast in spite of a low photosynthetic rate. Living in open water it can take full advantage of available sunlight.

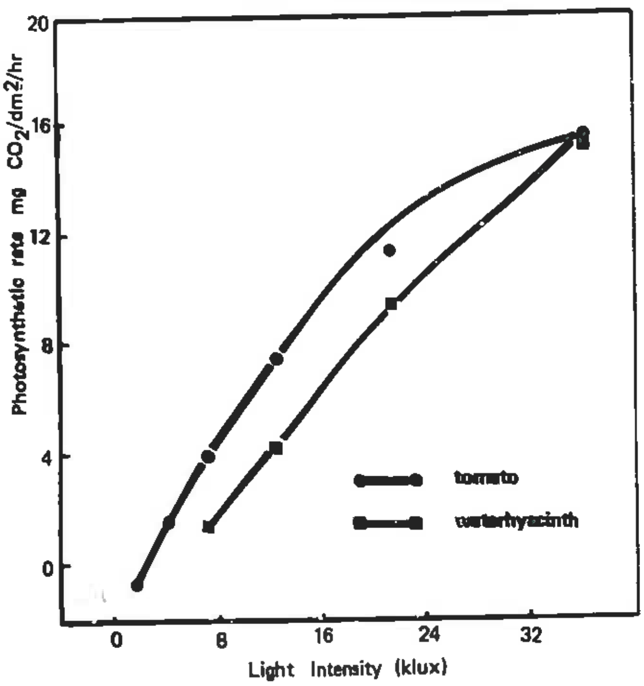

Figure 1. The relationship between photo synthetic rate of waterhyacinth and tomato plant and light intensity.

Under 25% sunlight intensity all treatments killed the plants after 2 weeks. Under 50% sunlight intensity only treatment at higher dosage (2 kg/ha) and foliarly applied that killed the plants faster, i.e. after one week. Under 100% sunlight intensity, foliar application at lower rate (1 kg/ha) killed the plants after one week. (Table 1)

Table 1. Time (days) where waterhyacinth plants killed completely by treatments of cyanatryn.

Application	Rate (kg a.i./ha)	Light intensity 25%	50%	100%
Root	0	1	—	—
	1	14	14	14
	2	14	14	7
Foliar	0	—	—	—
	1	14	14	7
	2	14	7	7

1: No. damage until the end of observation.

Dry matter measurement indicated that the application of 1 and 2 kg a.i./ha of cyanatryn reduced more dry matter under full sunlight than under 25% of 50% sunlight intensities (Figure 2). At 2 kg a.i./ha of cyanatryn, dry matter was reduced to the same extent by foliar and root applications, but at 1 kg a.i./ha of cyanatryn the foliar application reduced dry matter more than root application (Table 2). Cyanatryn can apparently

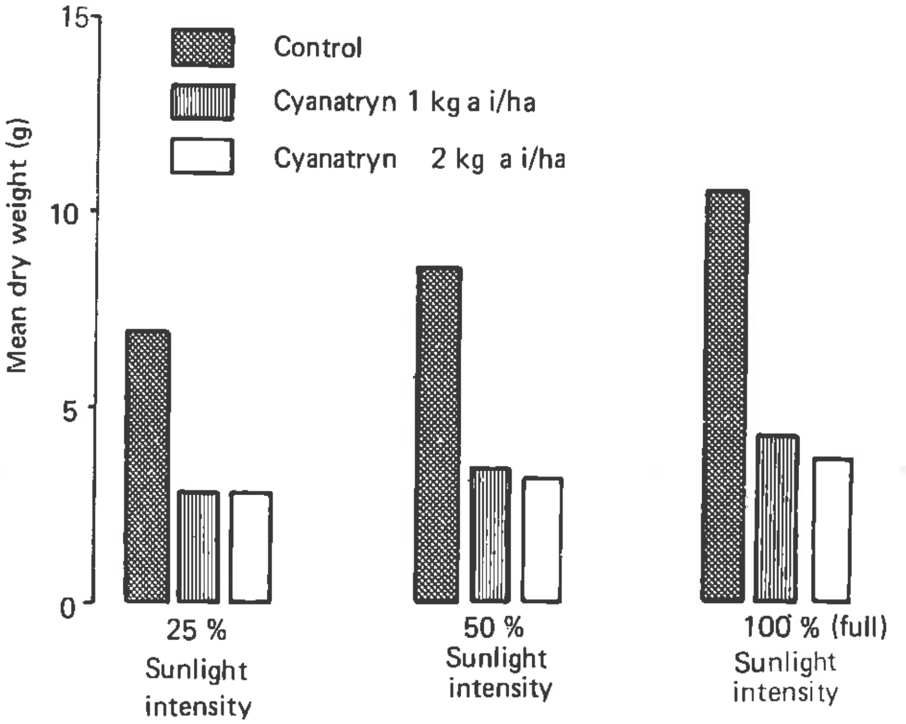

Figure 2. Mean dry weight (g) of waterhyacinth plant harvested 14 days after treatment with cyanatryn at 1 and 2 kg a.i./ha at different light intensities.

be absorbed through foliage and root, but foliar application seems to be more efficient. The differences in the efficiency may be attributed to non-physiological factors such as the dilution of herbicide concentration when it was injected to the culture solution and the relatively smaller area of root than that of foliage.

Table 2. Mean dry weight (g) of waterhyacinth plants harvested 14 days after treatment with cyanatryn at 1 and 2 kg a.i./ha through root and foliar application.

Mode of application	Rate of cyanatryn 0	1 (kg a.i./ha)	2
Root	8.81	4.28	3.12
Foliar	9.05	2.84	2.99

HSD. 05 : 1.1

Foliar application of cyanatryn at 1 kg a.i./ha even when followed by washing the treated foliages 2 — 4 h after treatment, killed the plants. The root application of cyanatryn at 1 kg a.i./ha and the culture solution was replaced 2 — 4 h after treatment the plant recovered and was still alive 14 days after treatment. Root application of cyanatryn followed by replacement of culture solution 2 — 4 h after treatment may kill the plant if applied at higher rate (2 kg a.i./ha) (Figure 3).

Dry matter measurement indicated that changing the culture solution and washing the treated foliage had no effect on dry matter when cyantryn was applied at 2 kg a.i./ha. At 1 kg a.i./ha of cyanatryn, however, changing the culture solution or washing the treated foliages 2 h after

Table 3. Mean dry weight (g) of waterhyacinth plants harvested 14 days after the treatments of washing treated leaves and replacing the culture solution in root application.

Rate of cyanatryn (kg a.i./ha)	Period of washing of treated leaves or replacement of culture solution 2 h	4 h	No washing or replacing
0	9.70	10.26	10.07
1	5.30	4.14	3.95
2	3.89	3.57	3.43

HSD. 05 : 0.75

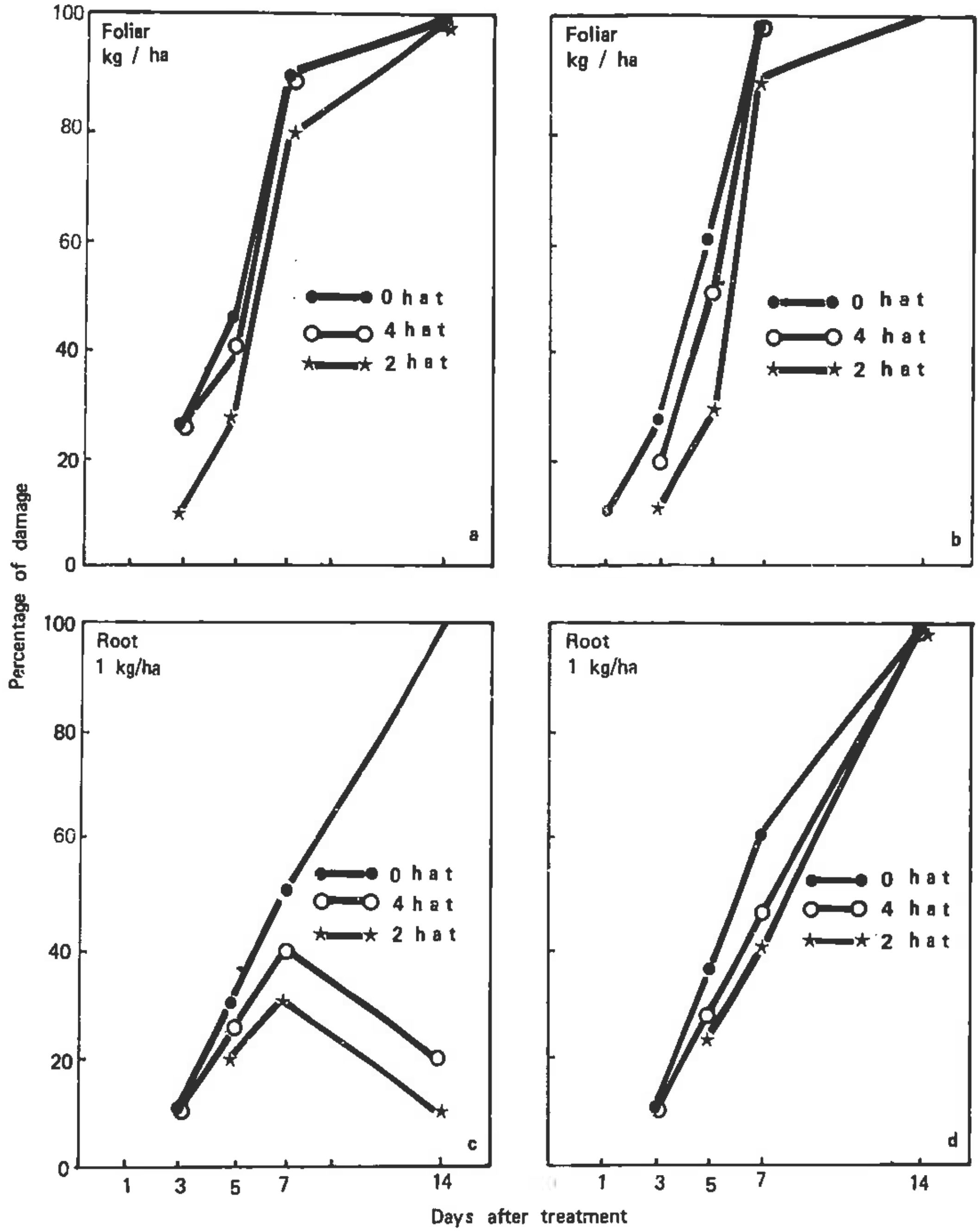

Figure 3. Percentage of damage of waterhyacinth plant treated with cyanatryn at different rate, mode of application and time (h a t = hour after treatment;
a = foliar application at 1 kg/ha;
b = foliar application at 2 kg/ha;
c = root application at 1 kg/ha;
d = root application at 2 kg/ha).

treatment gave a higher dry matter than that after 4 h (Table 3). These dry matter measurements support the visual observations shown in Figure 2.

The absorption of cyanatryn molecule by waterhyacinth seems to be very fast. Exposure of plants to 2 kg a.i./ha for 2 h was enough to kill the plant. This may have practical implication suggesting that cyanatryn may be used even during the rainy season. Rain 2 hours after spraying would not reduce the phytotoxicity of the herbicide when applied at the rate of at least 2 kg a.i./ha. Root application requires larger dose for each ha of infested area.

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The Effect of Glyphosate and Ametryn on the Root Tip Mitosis of Waterhyacinth [Eichhornia crassipes (Mart.) Solms]

F. GOLTENBOTH [1]

ABSTRACT

A gradual decrease in the percentage of waterhyacinth cells undergoing mitosis occured as the concentration of glyphosate [*N*-(phosphonomethyl) glycine] and ametryn [2-(ethylamino)-4-isopropylamino)-6-(methylthio)-*s*-triazine] was increased. Complete inhibition of mitosis was observed with 50 ppm of ametryn and glyphosate after 24 hours of treatment and with 10 ppm of ametryn after 48 hours of treatment. No abnormalities of the chromatin and chromosomes could be observed after ametryn treatment and less than 1% of the cells treated with glyphosate for 96 hours at concentrations of 0.4 ppm and 1.6 ppm showed abnormalities such as stickiness of chromosomes and fragmentation. Both herbicides are able to prevent interphase cells entering mitosis and ametryn disturbs and blocks the formation of metaphase much more effectively than glyphosate.

INTRODUCTION

The programs of medica industries have greatly promoted the production and research in the branch of agricultural chemicals. A large variety of herbicides has become important in the control of waterhyacinth. From a biological standpoint it is highly desirable to elucidate fundamentally at the cellular level the effect of the various herbicides on the cytomorphological structures of target and non-target organisms.

Boyle and Evans (1974) reported the mutagenic effect of glyphosate and ethaphon on meiotic chromosomes in rye. Dharurkar and Dnyansagar (1974) observed various types of mitotic abnormalities induced by different herbicides in the meristematic root tip cells of waterhycinth. A perusal of available literature indicates that no information exists on the action of glyphosate and ametryn on root tips of waterhyacinth undergoing mitosis. The present paper deals with the effect of these herbicides on root tip mitosis in waterhyacinth.

MATERIALS AND METHODS

Roots of four young waterhyacinths from Rawa Pening Lake were used for each experiment. Solutions of glyphosate and ametryn were pre-

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pared with filtered original water from Rawa Pening Lake, at concentrations of 0.4 ppm, 1.6 ppm, 10 ppm and 50 ppm.

The roots of waterhyacinth were exposed to each concentration of herbicide after measurement of leaf number and size and total plant weight. In addition data on the percentage of destruction of the leaves at the various concentrations were collected in a pre-survey. Control plants remained in filtered original water from Rawa Pening Lake. The root tips in each concentration were collected after 24, 48, 72 and 96 h and subsequently fixed in a mixture of 3 parts 96% isopropanol and 1 part concentrated acetic acid for 1 h. After removal of the root tip cover under the stereo-microscope, the 2 – 3 mm long root tips were stained with orcein-acetic acid overnight (12 h). The mixture was composed of 1 g orcein dissolved in 100 ml 50% acetic acid. The differentiation of the stained root tips was carried out by incubating for 1 h in 50% acetic acid at 60°C. After squash preparation of the single root tips in 50% acetic acid, removal of the cover glass was carried out by placing the microscope slides into fixing solution until the cover glass floated away. The preparations were transferred for 2 min into 96% isopropanol and subsequently into 100% isopropanol for at least 2 min. The preparations were mounted with euparal (Chroma, Stuttgart, Germany). The mitotic indices were obtained by dividing the total number of cells undergoing mitosis by the total number of cells observed. More than 100 squash preparations for each herbicide treatment were examined.

RESULTS AND DISCUSSION

An average of five leaves per plant were counted for the plants used in the experiments with ametryn and glyphosate. The average total leaf size was 122,58 cm^2 (ametryn) and 122,90 cm^2 (glyphosate), the average total weight/plant was 20,45 g (ametryn) and 20,95 g (glyphosate). (Table 1).

The treatment of the plants with the various concentrations of ametryn and glyphosate showed a different effect concerning the destruction of the leaves. While the destruction after treatment with ametryn started at the leaf tip with a quick spread of the blackish spots over the entire leaf, the treatment with glyphosate resulted in a progressive wilting of the leaves. As expected an increase in the concentration of the herbicide solution resulted in an increase of destruction (Figure 1).

As shown by Widyanto *et al.* (1975) both herbicides are effective as control agents for waterhyacinths. Uptake via roots is shown as much more effective than spraying the leaves. Besides this it was found that low concentrations such as 0.4 ppm and 1.6 ppm only retarded growth. These results correspond well with our results. Therefore it is necessary to use

Table 1. Leaf area, number of leaves and total weight of the waterhyacinth plant used in the experiments with ametryn and glyphosate.

Herbicides	Concentration (ppm)	Leaf area* (cm^2)	Number of leaves*	Total weight* (g)
A	0.6	121.59 ± 13.26	4.7 ± 0.5	20.75 ± 1.71
	1.6	119.62 ± 12.84	5.5 ± 0.5	19.25 ± 1.5
	10.0	114.81 ± 6.63	5 ± 0	21.75 ± 0.96
	50.0	128.43 ± 4.71	4.7 ± 0.5	21.0 ± 0.82
B	0.4	128.43 ± 5.26	5 ± 0	20.75 ± 0.5
	1.6	115.64 ± 3.88	5.2 ± 0.5	21.5 ± 1.7
	10.0	115.79 ± 12.92	4.7 ± 0.5	22.7 ± 1.7
	50.0	126.61 ± 8.62	5 ± 0	20.25 ± 2.99

* The average of 3 replications

A = Ametryn
B = Glyphosate

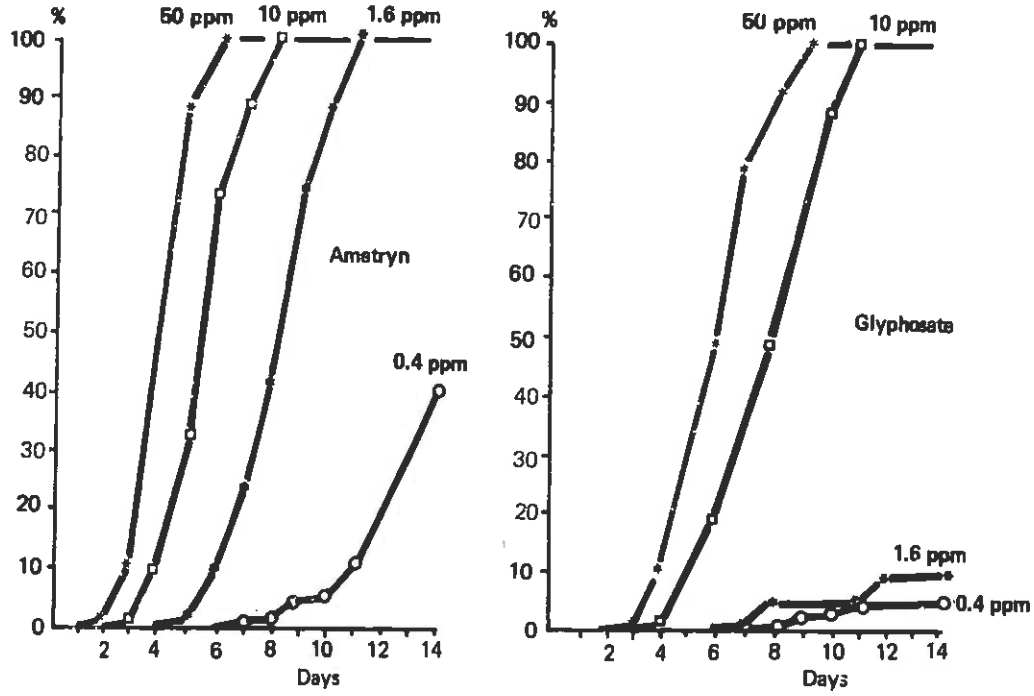

Figure 1. Percentage of leaf destruction within two weeks by glyphosate (G) and ametryn (A) at various concentrations.

concentrations above the 1.6 ppm if waterhyacinth is to be eradicated in a reasonable time. On the other hand, it is well known that at higher doses especially glyphosate causes a large variety of damage to organisms like *Agrostis tenuis*, *Anthoxanthum odoratum*, *Poa* sp. and *Festuca* sp. (Williams 1974).

The phytotoxicity of glyphosate, at rates adequate for weed control, to non-target organisms like young apple trees is shown by Rom *et al.* (1975). This phytotoxicity is stressed by the results of Sprankle *et al.* (1975) which show that glyphosate totally reduces all photosynthetic activity in *Agropyron repens* at higher concentrations.

Glyphosate therefore must be considered as a toxic substance for all chlorophyll bearing organisms in an ecosystem, if used in concentrations effective for waterhyacinth control; hence the effect of this herbicide on the mitotic activity of meristematic cells is of considerable interest,

Within the root tip cells of waterhyacinth all stages of mitosis were found in the experiments of 24 h root exposure to 0.4 ppm and 1.6 ppm in both herbicidesolutions. At the concentration of 50 ppm, in both herbicides, no mitotic activity could be observed after 24 h treatment. While at 10 ppm of ametryn concentration the mitotic activity was almost totally stopped after 24 h treatment, in the equivalent glyphosate solution the effect was not so striking. As shown in Table 2, increase in concentration of both substances generally resulted in a gradual decrease in the percentage of cells undergoing mitosis. At 0.4 ppm of ametryn concentration 7.27 ± 0.69% of the cells were engaged in mitosis, at 0.4 ppm of glyphosate concentration the percentage was 7.85 ± 18%. In the case of ametryn this is 1.22% below the mitotic index of the control and for glyphosate only 0.43%. That means no significant difference in relation to the control.

Tabel 2. Mitotic indices of root tip cells from waterhyacinth treated with various concentrations of ametryn and glyphosate.

Herbicides	Concentration (ppm)	Control	Time (hr) 24	48	72	96
A*	0.0	8.50 ± 1.83*	—	—	—	—
	0.4	—	7.27 ± 0.69*	5.27 ± 0.73	1.37 ± 0.16	0.40 ± 0.05
	1.6	—	2.43 ± 0.25	1.94 ± 0.70	1.00 ± 8.34	0.65 ± 0.06
	10.0	—	0.87 ± 0.12	0.00	0.00	0.00
	50.0	—	0.00	0.00	0.00	0.00
B**	0.0	8.28 ± 1.7**	—	—	—	—
	0.4	—	7.85 ± 0.18	6.52 ± 0.32	5.63 ± 1.09	4.35 ± 0.41
	1.6	—	6.25 ± 1.88	5.22 ± 0.69	4.27 ± 0.26	2.01 ± 0.48
	10.0	—	5.47 ± 1.92	3.92 ± 0.58	1.41 ± 0.18	0.80 ± 0.04
	50.0	—	0.00	0.00	0.00	0.00

* The average of 2 replications.
** The average of 3 replications.
— No measurement.

A = Ametryn
B = Glyphosate

The percentage of 7.27 ± 0.69 (ametryn) and 7.85 ± 0.18 (glyphosate) decreased to 0.87 ± 0.12% (ametryn) and 5.47 ± 1.92% respectively at a concentration of 10 ppm. Prolongation of root treatment resulted in general and gradual decrease of the mitotic indices (Figure 2). For ametryn a complete inhibition of mitosis was reached after 24 h with concentrations of 10 ppm and within 96 h nearly a totally inhibition was reached even with a concentration of 0.4 ppm. For glyphosate even at 10 ppm complete inhibition of mitotic activity was not reached in 96 h. At the concentrations of 0.4 ppm and 1.6 ppm even after 96 h. of treatment the percentage of cells engaged in mitosis was 4.35 ± 0.41% and 2.01 ± 0.48% respectively.

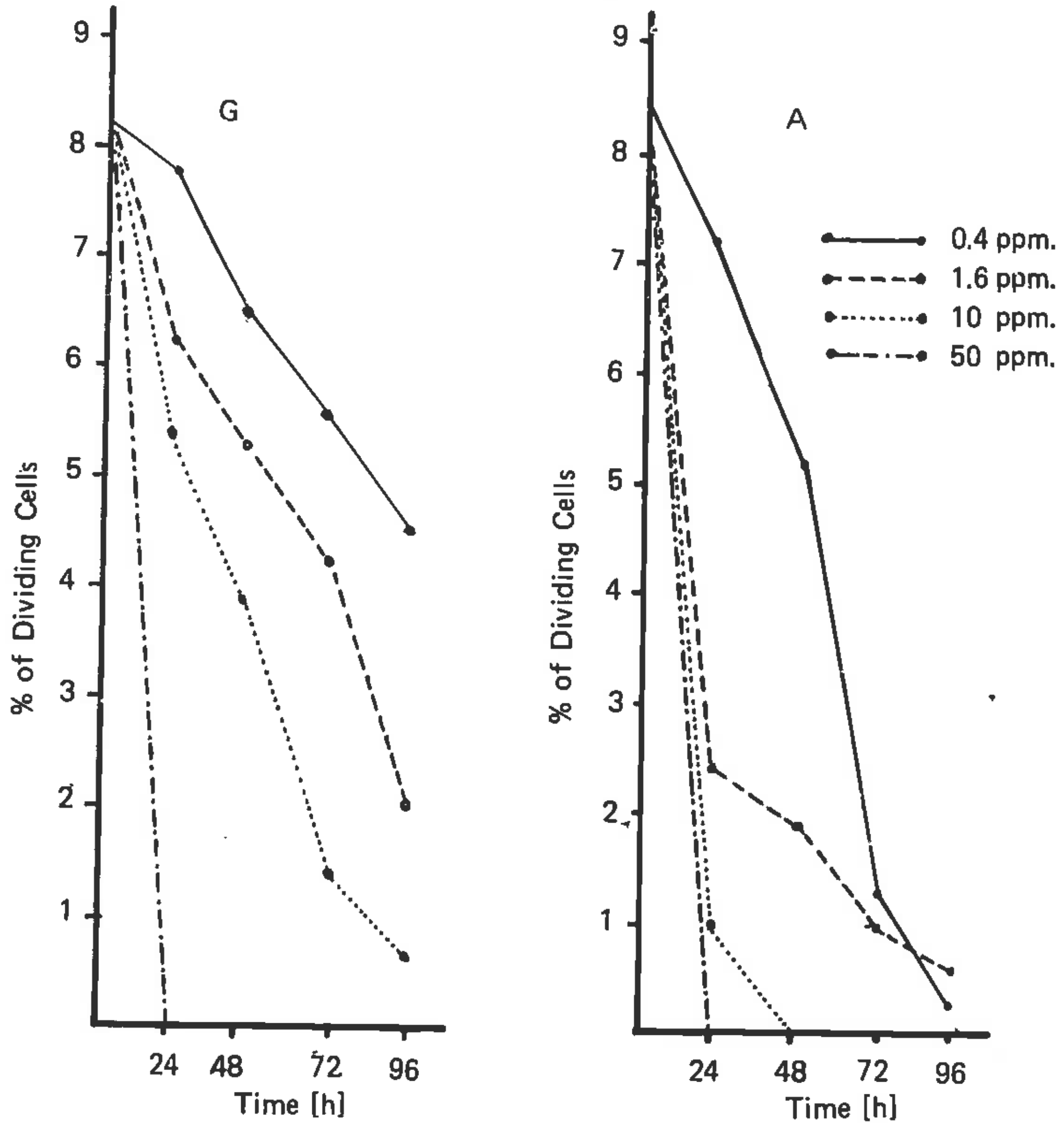

Figure 2. **Decrease in the percentage of deviding root tip cells after treatment with various concentrations of glyphosate (G) and ametryn (A).**

Abnormalities such as bridge-building in anaphase, precoccious movement of chromosomes, abnormal shape of nuclei, multinucleolated condition, clumping of meristematic cells as reported by Dharurkar and Dnyansagar. (1974) after treatment of waterhyacinth with silvex [2,4,5-inchloropropionic acid] and sodium-pentachlorophenate, could not be observed in our experiments. Only stickiness of chromosomes and fragmentation of metaphase chromosomes could be observed after treatment of the plants with 0.4 ppm and 1.6 ppm for 96 h with glyphosate in less than 1% of the cells undergoing mitosis.

The results show that glyphosate is only of value for the control of waterhyacinth at concentrations higher than 1.6 ppm, while ametryn causes significant damage and reduction of mitotically active cells even at lower concentrations. These results correspond well with the results of Widyanto *et al.* (1975) which show on the basis of spraying that ametryn at concentrations of 0.4 ppm and 1.6 ppm is much more effective than glyphosate at the same concentrations. Further our results show a much quicker decrease in mitotic activity by ametryn than by glyphosate.

Similar to the results of Mallah and Dawood (1956) in their experiments with sodium arsenite treated root tip cells of *Vicia narbonensis* and the investigations of Sawamura (1964) on the effect of 2,4-D on

Table 3. Percentage of mitotic phases in relation to interphase at the various concentrations of glyphosate.

Concentration (ppm)	Time (hr)	Interphase (%)	Prophase (%)	Metaphase (%)	Anaphase (%)	Telophase (%)
0.4	24	100	5.2	2.3	0.4	0.2
	48	100	3.8	1.6	0.9	0.6
	72	100	3.4	1.2	0.7	0.5
	96	100	1.9	1.0	0.8	0.7
1.6	24	100	3.7	1.5	0.8	0.3
	48	100	2.7	1.6	0.7	0.4
	72	100	2.8	1.05	0.1	0.4
	96	100	0.9	0.5	0.2	0.3
10	24	100	2.6	1.5	0.2	0.7
	48	100	2.0	1.2	0.3	0.5
	72	100	0.4	0.6	0.1	0.1
	96	100	0.5	0.2	0.0	0.1
50	24	100	0.0	0.0	0.0	0.0
Control		100	4.6	2.3	1.5	0.8

staminal hair cells of *Tradescantia reflexa*, inhibition of the mitotic activity could be observed, but in our experiments much higher concentrations had to be used. Such a delay in the reaction of the root tip cells on herbicide treatment is also reported for the herbicides silvex, acrolein and sodium-pentachlorophenate by Dharurkar *et al.* (1974) in his experiments with waterhyacinth. If the occurrence of the different stages of mitosis is set in relation to the amount of interphase cells at the various concentrations of glyphosate and ametryn (Tables 3 and 4) it is possible to show a slight stimulation of the mitotic activity at 0.4 ppm in the first 24 h of treatment.

Table 4. Percentage of mitotic phases in relation to interphase at the various concentrations of ametryn.

Concentration (ppm)	Time (hr)	Interphase (%)	Prophase (%)	Metaphase (%)	Anaphase (%)	Telophase (%)
0.4	24	100	4.0	2.1	0.8	0.2
	48	100	3.2	1.6	0.4	0.1
	72	100	0.9	0.2	0.1	0.0
	96	100	0.4	0.0	0.0	0.0
1.6	24	100	0.9	0.5	0.7	0.2
	48	100	1.1	0.2	0.3	0.2
	72	100	0.7	0.1	0.1	0.1
	96	100	0.3	0.0	0.1	0.1
10	24	100	0.5	0.2	0.04	0.04
	48	100	0.0	0.0	0.0	0.0
50	24	100	0.0	0.0	0.0	0.0
Control		100	3.9	3.2	1.4	1.0

The percentage of prophase stages increase from 4.6% (control) to 5.2% in 0.4 ppm of glyphosate. With increasing length of treatment the percentage of prophase cells decrease to 1.9% in glyphosate and 0.4% in ametryn. This effect can also be shown if the concentration itself is increased. At 1.6 ppm a sharp decrease from 4.6% (control) to 0.9% in 96 h can be observed in glyphosate, in ametryn from 3.9% (control) to 0.9% in 24 hours. While 10 ppm and 50 ppm solutions of ametryn block mitotic activity in 24 h, glyphosate of 10 ppm has not this significant effect. (Figure 3).

Both herbicides interfere obviously with the metabolism responsible for the entrance of a cell into mitosis. With increasing concentrations and

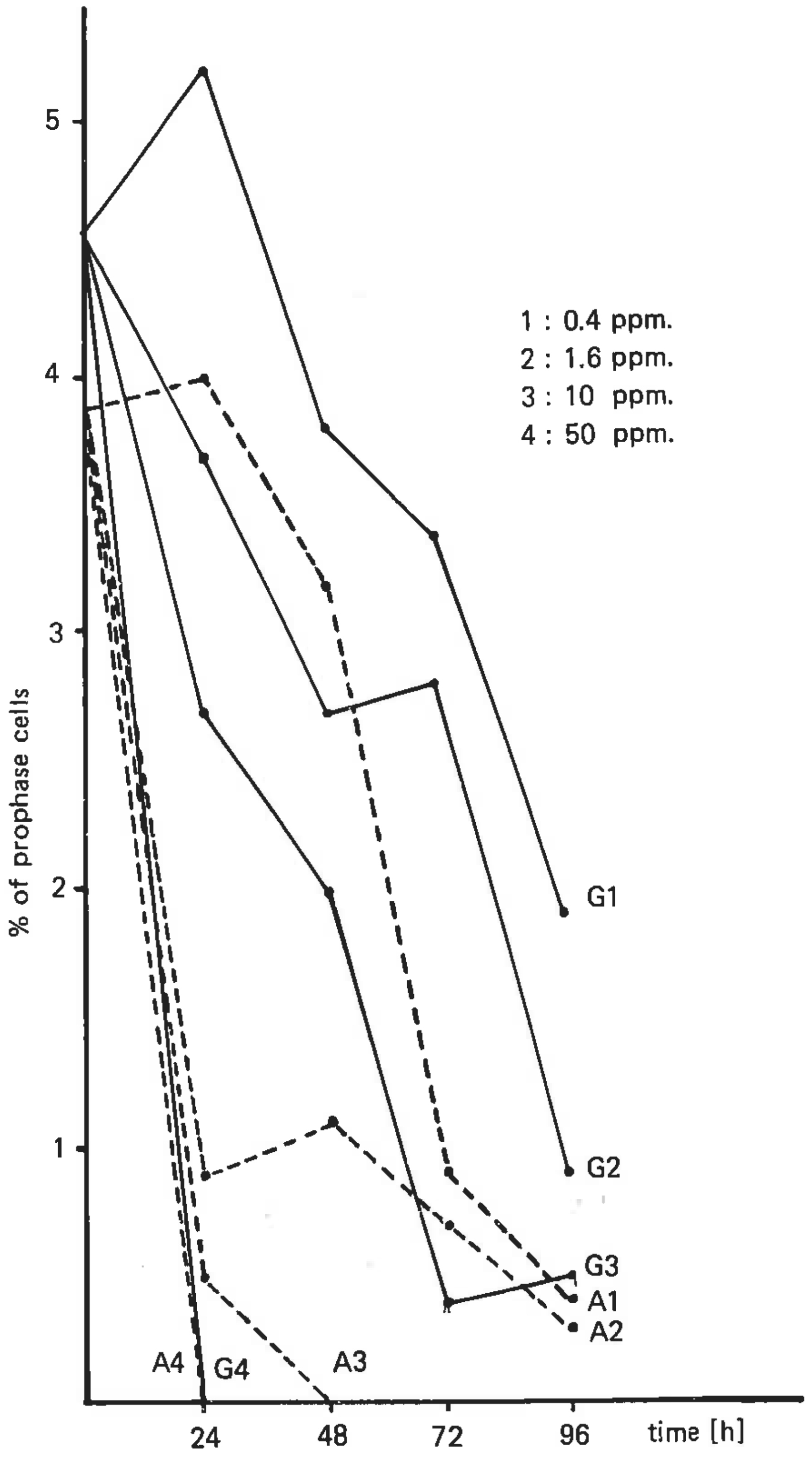

Figure 3. Comparison between the decrease of the percentage of prophase cells after treatment with various concentrations of glyphosate (G) and ametryn (A).

length of treatment the effect becomes more significant. If a cell has already started mitosis, glyphosate at 0.4 ppm concentration has only a slight effect on the formation of the metaphase stage and therefore probably on the spindle formation and chromosome constriction. This is

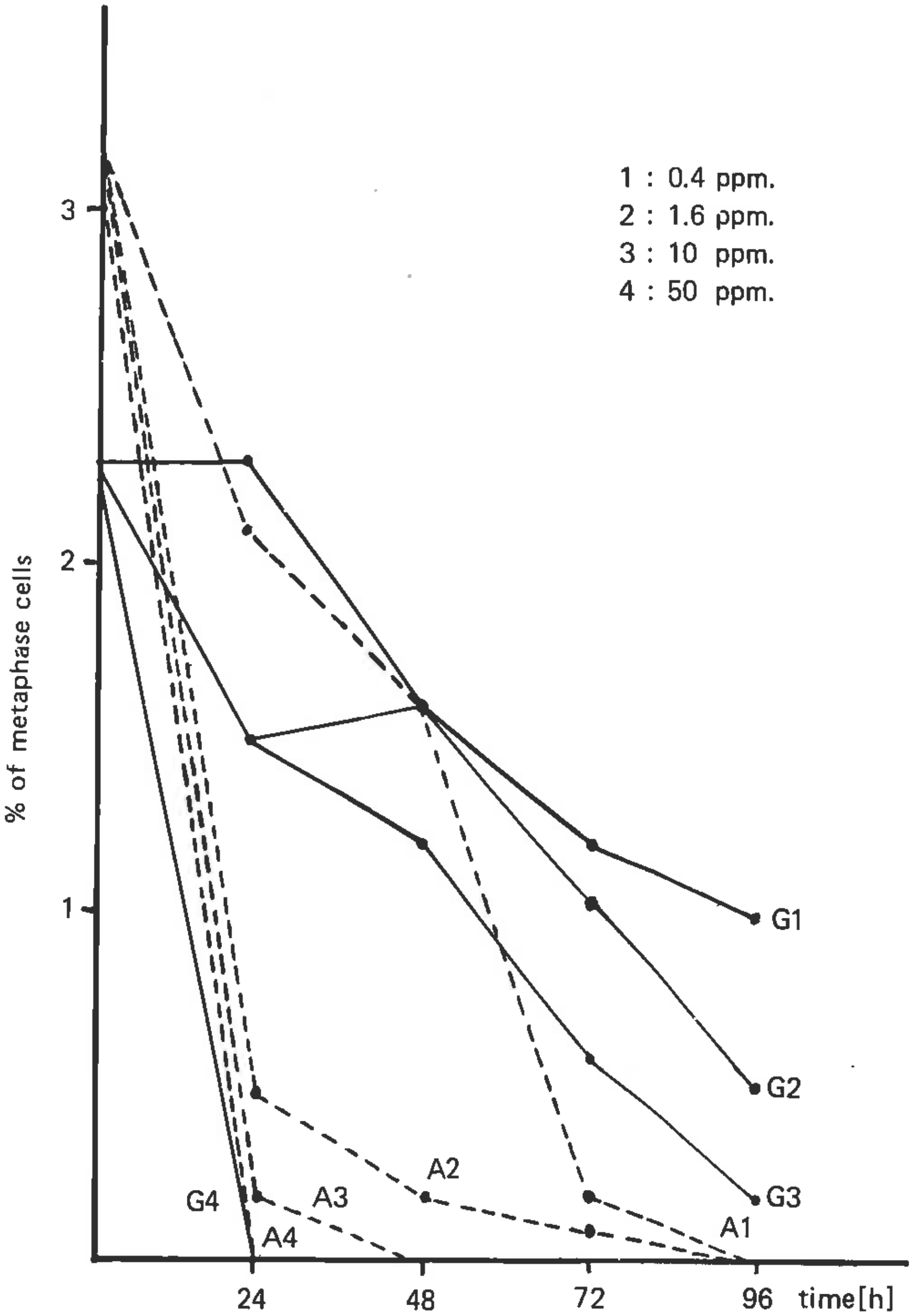

Figure 4. Comparison between the decrease of the percentage of metaphase cells after treatment with various concentrations of glyphosate (G) and ametryn (A).

shown by the fact that there is no difference to observe between control (2,3%) and the percentage of metaphase cells at this concentration in the first 24 h of treatment (Figure 4). The prophase cells pass to metaphase without being disturbed too much. That glyphosate influences the formation of the spindle and therefore the construction of microtubuli is indicated by the decrease of metaphase stages to 1% in 96 h to treatment. In

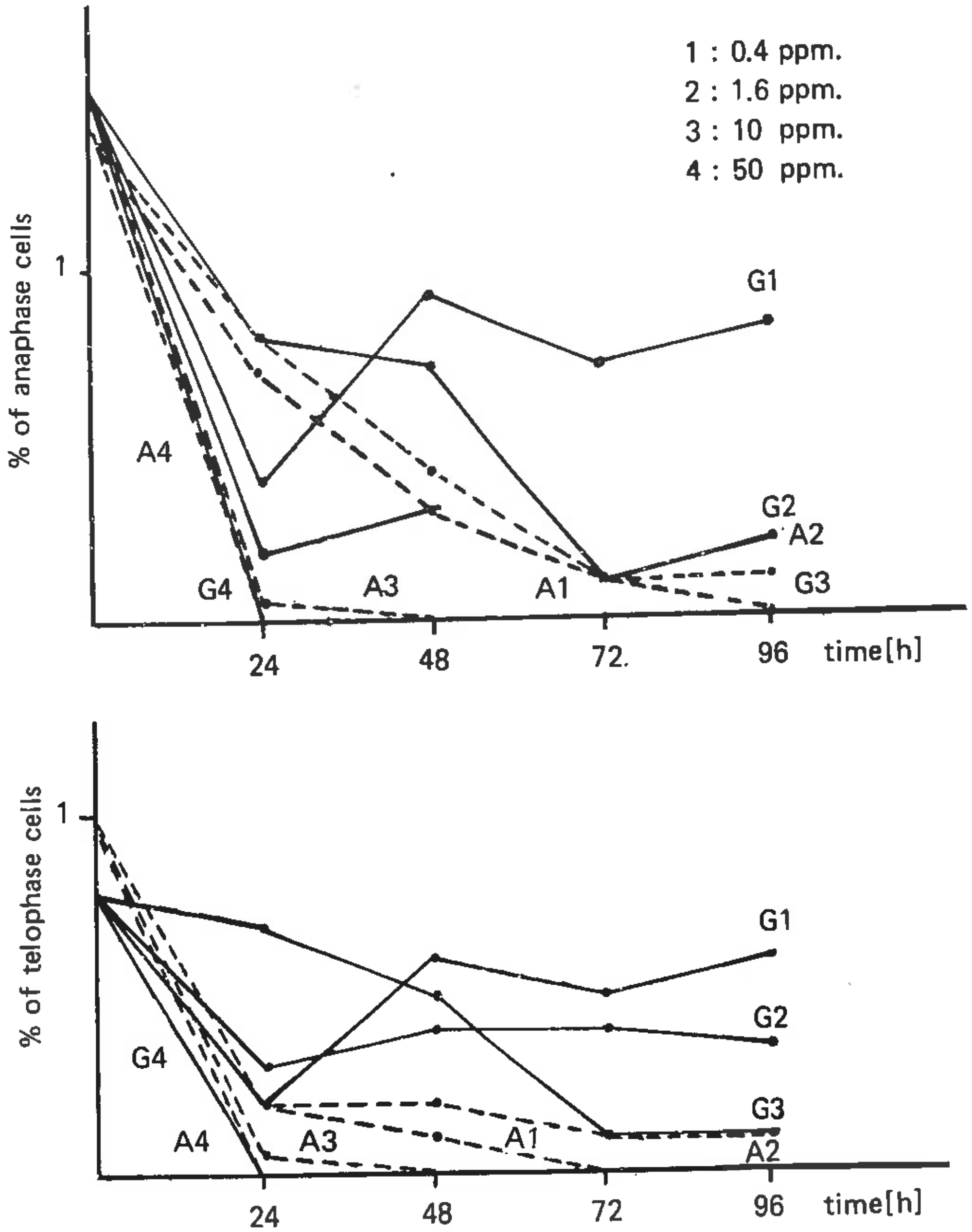

Figure 5. Comparison between the decrease of the percentage of anaphase and telophase cells after treatment with various concentrations of glyphosate (G) and ametryn (A).

contrast to the effect of glyphosate, 0.4 ppm of ametryn shows a more serious effect on the metaphase formation. This is indicated by the decrease from 3.2% (control) to 0% in 96 h of treatment. These results are stressed by the percentage of ana-and telophase stages found in this investigations (Figure 5).

As a total view it can be stated that ametryn shows a greater toxicity to the formation of metaphase cells than glyphosate.

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Action of Light on Herbicide Toxicity to Germination [1]

S. C. Datta and R. Basu [2]

ABSTRACT

The influence of two commonly used herbicides, 2,4-D ((2,4-dichlorophenoxy acetic acid) and 2,4,5-T ((2,4,5-trichlorophenoxy acetic acid), as modified by light and darkness, on the germination of *Abutilon indicum* (L.) Sw. seeds were studied. Higher concentrations (100 and 1,000 ppm) of herbicides induced complete suppression or slight inhibition, while lower concentrations (1 and 10 ppm) were stimulatory. The inhibitory action was conspicuous in the dark rather than in the light, being more so with 2,4,5-T than with 2,4-D. In the 2,4,5-T series, such activity was noted in all portions of the visible spectrum except in the red. This was also evident in the green and red regions in the 2,4-D. However, the combination of lower concentrations of 2,4-D with green or red light and of 2,4,5-T with white or blue light showed promotive effects.

INTRODUCTION

Herbicides have been known to inhibit the germination of weed seeds in agricultural crops (Mayer and Poljakoff-Mayber 1975). However, the response of germination seeds to herbicides are distinct from those of established plants (Crafts 1961, Bingham 1968, Lewis *et al.* 1969).

Various types of herbicides allow the establishment of seedlings before exerting a lethal effect and death of seedlings may be preceded by malformation of shoots or roots (Friesen *et al* 1964). Little attention has been paid to such basic aspects as the influence of various environmental factors on herbicide behaviour with germination (Datta and Dunn 1959, Bakale and Dnyansagar 1971).

The present treatise deals with the effects of 2,4-D and 2,4,5-T on the seed germination of *A. indicum*, a very common and troublesome weed in high uncultivated lands of West Bengal. The aim was to determine the effects of these two herbicides at different concentrations and under darkness as well as different portions of the visible light spectrum.

MATERIALS AND METHODS

Fruits of *A. indicum* were collected from the experimental garden of the Botany Department, University College of Science, Ballygunge, in October 1974. The dispersal units of each individual fruit were at

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first separated and the pericarp of each unit removed to set the seeds free. The seeds, thus obtained, were stored in brown paper containers at room conditions (24 – 32°C). Since the seeds were found to possess very low germinability due to the impermeability of the tests, they were scarified with conc. H_2SO_4 for 2 hr and followed by a thorough washing in water. Germination tests were conducted by scattering acid-scarified seeds in petridishes upon 1 circle of Whatman No. 1 filter paper, moistened with 4 ml of water or test solutions. Aqueous solutions of the herbicides were prepared and diluted to give 1, 10, 100 and 1,000 ppm of active ingredient. The pH of the solutions was adjusted to 7.0. The dishes were placed in a germinator maintained at 25 ± 1°C. While some of the dishes were covered with a piece of black nylon cloth, most of them were exposed to light from a fluorescent lamp. In the latter case, the dishes were wrapped with a double layer of coloured cellophane in order to obtain the different light qualities, such as white, blue, green, yellow and red. Four replicates were arranged per treatment.

RESULTS AND DISCUSSION

In general, germination was higher in the dark than in the light and this was more so with 2,4,5-T than with 2,4-D (Table 1). There was a reduction in the percentage of germination with increasing concentration of the two herbicides. In the 2,4,5-T series, such a progressive decline was noticed in all portions of the visible light spectrum except the red band. This kind of trend was also evident in the green and red regions in the 2,4-D series.

In both the herbicides, there was little or no germination at 1,000 ppm. Compared to treated white light, germination was higher in blue and lower in other regions with 100 ppm of 2,4-D as well as higher in all regions with the same concentration of 2,4,5-T. With 1 ppm of 2,4-D, germination was maximum only in red light. With 1 ppm of 2,4,5-T, germination was highest in blue light and lower in other types of light.

In comparison with untreated white light, germination improved considerably with lower concentrations (1 and 10 ppm) of both the herbicides. However, there was a difference between the effect of herbicides as modified by yellow light. In this case, there was inhibition in the lower concentrations of 2,4-D and stimulation in the same concentrations of 2,4,5-T. A difference was induced by the two lower concentrations, stimulation being greater at 1 ppm than at 10 ppm. However, this statement seems to hold good for the green and red parts of the spectrum under the influence of 2,4-D as well as for white and blue parts under the influence of 2,4,5-T.

Table 1. Herbicidal action on the germination of *A. indicum* as modified by light.

Conc. of herbicide (ppm)	Darkness	Percentage germination				
		Light				
		White	Blue	Green	Yellow	Red
2,4–D						
1000	0	0	1.0 ± 1.2	0	0	0
100	0	17.0 ± 5.8	37.0 ± 4.5	5.0 ± 2.5	9.0 ± 4.1	1.0 ± 0.3
10	79.0 ± 4.5	81.0 ± 4.8	66.0 ± 8.3	45.0 ± 6.5	30.0 ± 5.9	56.0 ± 3.3
1	90.0 ± 4.1	65.0 ± 8.2	65.0 ± 8.2	59.0 ± 9.8	28.0 ± 8.9	94.0 ± 0.3
2,4,5–T						
1000	3.0 ± 2.5	1.0 ± 1.2	0	0	14.0 ± 6.8	5.0 ± 2.5
100	30.0 ± 0.5	2.0 ± 1.6	41.0 ± 12.3	18.0 ± 5.6	31.0 ± 12.8	11.0 ± 13.5
10	93.0 ± 5.8	40.0 ± 16.3	64.0 ± 8.3	71.0 ± 8.2	49.0 ± 2.9	83.0 ± 10.3
1	72.0 ± 11.5	72.0 ± 11.5	95.0 ± 4.0	71.0 ± 8.2	51.0 ± 7.3	65.0 ± 7.3
Control	84.0 ± 9.8	33.0 ± 14.8	27.0 ± 9.0	40.0 ± 13.3	33.0 ± 7.8	21.0 ± 9.0

'Y

The combined herbicide-light effect was measured by germination variations from those of the control. Any value above the control is indicative of stimulation and below the control that of inhibition. In the present study, both 2,4-D and 2,4,5-T stimulated seed germination of *A. indicum* at lower concentrations as well as partly or completely inhibited the process at higher concentrations.

It has been generally found that herbicides affect the growth of plants more in light than in darkness (Leopold 1964). This does not follow in the case of germination of *A. indicum* where herbicides tend to be more potent in the dark than in the light. Moreover, 2,4,5-T was observed to be more effective than 2,4-D. This proves that the toxicity of the herbicides depends on the structural configuration of the chemical.

A difference in herbicidal activity, as modifed by spectral sensitivity, was evident in *A. indicum.* It was noted that there was germination inhibition in the 2,4-D series under the influence of both green and red light. Such activity was also noticed in the 2,4,5-T series under the impact of all portions of the visual spectrum except the red. Interestingly enough, a combination of lower concentrations of 2,4-D with either green or red light resulted in promotion of seed germination. Similarly, an interaction of lower concentrations of 2,4,5-T with either white or blue light exerted a promotive effect on germination.

The general pattern of reduction in germination percentage in different parts of the light spectrum was not similar to the pattern of reduction in dry-weight yield for photosynthesis (*cf.* Datta and Dunn 1959). This suggests that the effect of these herbicides on germination may be operative through a process not related to photosynthesis but through some other mechanisms in metabolism.

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Photodecomposition and Some Behavior of Herbicide Butachlor in Soils [1]

YUH-LIN CHEN AND CHIEN-CHIN CHEN [2]

ABSTRACT

Photodecomposition of the herbicide, butachlor [*N*-(Butoxymethyl)-2-chloro 2',6'-diethylacetanilide], as a thin film on glass under UV light was very fast. The half life was found to be about 1.5 h under experimental conditions. The decomposition reaction followed first order kinetics. At least 7 decomposition products were observed by thin layer chromatography (TLC) and GLC. The main degradation pathways involved debutoxymethylation, dechlorination followed by hydroxylation, *O*-dealkylation and polymerization. Among the photodecomposed products, 2-chloro-2',6'-diethylacetanilide was identified by means of TLC, GLC, IR Spectrophotometry, Mass Spectrophotometry NMR spectrophotometry with comparison to authentic sample. Four components with molecular (mol) sp of 218, 219 ($C_{13}H_{17}NO_2$), 223 ($C_{12}H_{14}NOCl$) and 293 ($C_{17}H_{27}NO_3$) were determined by GC-MS. Two of them were assigned as 2-hydroxy-2',6'-diethyl-*N*-(butoxymethyl)acetanilide (mol wt 293) and *N*-2',6'-diethyl phenyl-2,3-dihydrooxazole-4-one (mol wt 219) respectively from the evidence of IR and mass spectra. The degradation of butachlor in soil under flooded conditions varied with the incubation period and type of soil. The degradation was more rapid in soils containing large amounts of sp. 2-Chloro-2'6'-diethylacetanilide was also identified as a degradation product in soil. Soil fungus, *Fusarium oxysporum* Schlecht, effectively degraded butachlor. At 50 ppm concentration, half life was found to be approximately 5 days.

INTRODUCTION

Butachlor is a pre-emergence herbicide which has been officially recommended in Taiwan in the form of 5% granule and 58.8% e.c. for the control of weeds in transplanted rice in paddy fields since 1971. Five per cent granule and 58.8% e.c. of butachlor have also been recommended for the control of weeds in direct seeded rice in wet fields and spinach fields since 1973. This herbicide is still one of the most important and popular ones used in rice fields in this country.

In order to study the environmental degradation and dissipation of this herbicide, after its application in the field, and to seek further,

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data on the safe and correct use, experiments have been carried out on the photodecomposition under sunlight or UV irradiation as a thin film on glass. The behavior of the herbicide in soils, including degradation by the soil microorganism *Fusarium oxysporum* were investigated.

MATERIALS AND METHODS

Technical butachlor of 87.5% purity was used to prepare the pure compound[3]. Pure compound was prepared by silica gel column chromatography, followed by preparative TLC of the hexane eluate. It was then developed with a mixture of benzene:chloroform:acetic acid (3:3:0.05). The band around a R_f value 0.7 was scraped out from the plates and extracted with methanol.

2-Chloro-2',6'-diethylacetanilide was synthesized from butachlor by treating with hydrochloric acid. The product was recrystallized from a mixture of acetone and water (mp 134 −135°C). The mp of this compound was reported to be 134 −134.5°C (Tiedje and Hagedorn 1975). 2,6-Diethylaniline, bp 125 − 129°C (22 mmHg), is a commercial product.[4] 2',6'-Diethylacetanilide was prepared from 2,6-diethylaniline hydrochloride and acetic anhydride. The mp of this compound was somewhat higher (140 − 140.5°C) than that recorded in the literature (130 −131°C) (Tiedje and Hagedorn 1975), but the results of IR and mass spectra supported the structure.

Soils used for the experiments were collected from the upland field of Shan-Hua (Soil A) of Tainan Prefecture, paddy fields of Chung-Lih (Soil B) of Tauyuan Prefecture and Shin-Zuan (Soil C) of Taipei Prefecture respectively (Table 1).

Table 1. Some physico-chemical properties of the soils.

Soil	pH (H_2O)	CEC (me/100 g)	Organic matter %	C/N ratio	Texture	Location
A	6.2	12.90	2.48	13.20	Silty loam	Shan-Hua
B	5.2	4.71	0.60	6.38	Sandy clay loam	Chung-Lih
C	5.3	9.70	1.80	10.20	Silty clay loam	Shin-Zuan

The soil microorganism, *Fusarium oxysporum*, was provided from the Applied Microbiology Laboratory, Department of Agricultural Chemistry of this university.

3 Product of Monsanto Co., St. Louis, Mo., USA.

4 Tokyo Chemical Industry Co., Tokyo, Japan.

ECD GLC was performed with Shimadzu Gas Ghromatograph Model GC-5A type. TCD GLC was used for the isolation and collection of each peak for the purpose of IR determination and GC-MS analysis. IR was performed with Perkin-Elmer Model 457 Grating Infrared Spectrophotometer. NMR was carried out with Hitachi Perkin-Elmer Model R-20B High Resolution NMR Spectrometer. GC-MS was performed with Hitachi 063-RMS-4 GC-Mass Spectrometer.

TLC was carried out with silica gel F_{254} precoated plate, a product of E. Merck, Germany, with thickness of 0.25 mm. Preparative TLC plates were prepared in the laboratory from silica gel with thickness of 0.75 mm.

Each 10 ml of acetone solution of pure butachlor, at 1,000 ppm concentration, was placed in a petridish (dia 90 mm). The solvent was evaporated at room temperature and the uniform thin film was exposed to a UV lamp (254 nm) for 2, 4, 8, 12, 16, 24 and 48 hr respectively. It was then washed out with acetone and concentrated to an appropriate vol. for the further experiments.

Soil samples were air dried and passed through a 2 mm sieve. Each 40 g of 3 soil samples were placed in a Erlenmeyer flask with 100 ppm of pure butachlor under the flooded condition. The flasks were kept at 30° C for 5, 10, 20 and 40 days and analyzed for the remaining herbicide by GLC.

Culture medium consisted of K_2HPO_4 0.8 g, KH_2PO_4 0.2 g, $MgSO_4$ $7H_2O$ 0.2 g, $CaSO_4$ 0.1 g, $(NH_4)_2SO_4$ 5.0 g, glucose 0.1 g per 1 l at a pH 6.0 and a concentration of 50 ppm butachlor. One disc (ca 2.6 mg in dried wt) of the soil microbe *F. oxysporum*, was added to each flask containing 100 ml of culture medium. It was then incubated at 23°C on a rotary shaker for 2, 4, 6 and 12 days.

RESULTS AND DISCUSSION

Butachlor was photodecomposed as a thin film on glass and analyzed by TLC. The first photodecomposed product appeared after an exposure of 2 h. The products increased as the period of exposure was prolonged. When the photodecomposed products (24 h) were analyzed by two-dimensional TLC with the solvent system hexane: isopropyl ether (2:3) as first development and benzene: chloroform: acetic acid (3:2:0.05) as second development, at least 7 spots were observed on the chromatogram. The location of the spots was detected under UV lamp at 254 nm. One of the spot with R_f value 0.35 (Compound II) agreed with the location of 2-chloro-2'6'-diethylacetanilide. The other spot with R_f value 0.41 (Compound IV) gave a fluorescence under UV lamp at 366 nm, coincided with one of the photodecomposed product of 2-chloro-2'6'-diethylacetanilide. The result suggested that the product with R_f value 0.41 seemed to be a photodecomposed product of 2-chloro-2',6'-diethylacetanilide. The product with a dark orange red color remained at the origin (Compound VIII) increased proportionally as exposure was prolonged. It appeared to be a polymerized final component of the photodecomposed product. No spots corresponding to 2,6-diethylaniline or 2,6-diethylacetanilide were observed.

The quantitative analysis by GLC showed that the photodecomposition of butachlor was very fast, about 60% decomposed after an exposure of 2 h and above 95% after 24 h (Figure 1). The reaction seemed to follow a first order kinetics, the half life is approximately 1.5 h. Total organic

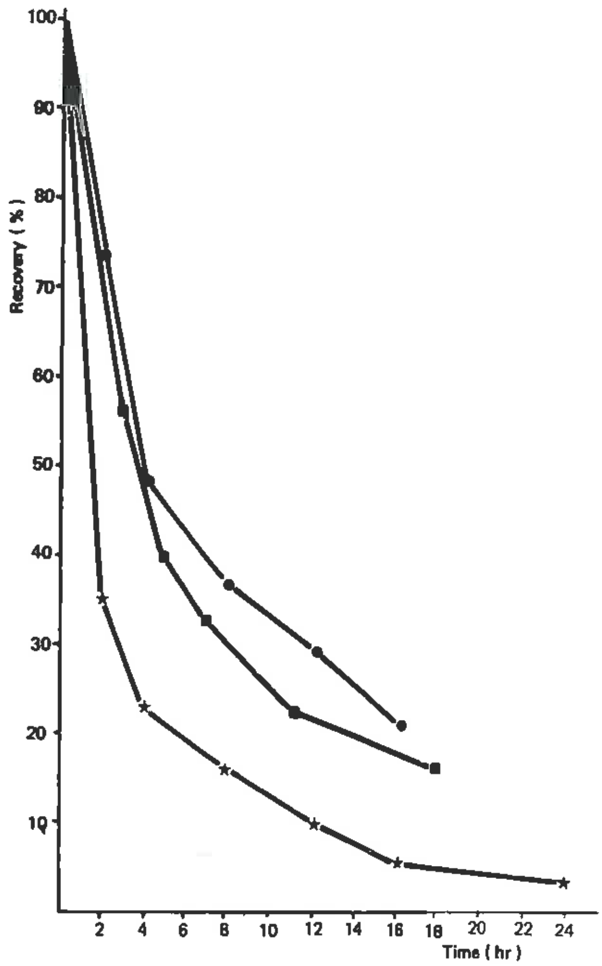

Figure 1. Change of butachlor (*), total chlorine (●) and 2-chloro-2' 6 -diethylacetanilide (■) after photodecomposition for different time to UV lamp.

Cl was determined by Volhard method during the photodecomposition. A significant loss of Cl was observed in the initial 4 h, but the rate slowed down later (Figure 1). The result indicated that dechlorination is involved in the course of photodecomposition. 2-Chloro-2'-6'-diethylacetanilide was also photodecomposed and analyzed quantitatively. This compound also degraded rapidly in the initial several hours. Again, the reaction followed a first order kinetics, the half life was found to be about 4 h (Figure 1).

Photodecomposed products (24 h) were spotted in a band on the preparative TLC plates, developed, scraped out from the plates extracted with methanol and concentrated to a small vol. The major products were analyzed by GLC with TCD as a detector, 5% OV-17 as a liquid phase Figure 2). Mass spectra were measured for each peak with GC-MS.

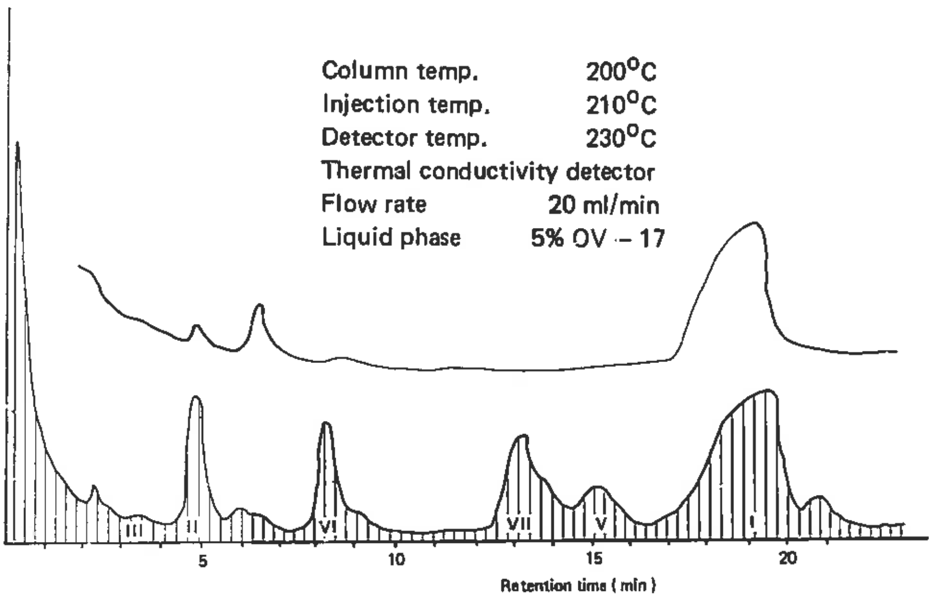

Figure 2. Gas chromatogram of photodecomposed products from butachlor exposed for 24 h (lower line) and incubated in soil A for 20 days (upper line).

Compound II (retention time 5.0 min) was found to be 2-chloro-2', 6'-diethylacetanilide. It was identified by TLC, GLC, IR, mass and NMR analyses with authentic compound. Compound III (retention time 3.5 min) was abserved but the structure could not be established because of the lack of a standard. This product gave the following mass spectra, m/e (% base peak) $M^{+}+2$ 225(16), M^{+} 223(40), 208(12), 174(100), 160(74), 146(49) and 132(28). On the basis of the mass spectra which showed the presence of Cl, N, a mol ion of 223, a single methyl group (208) and a chloroacetyl moiety (146), the compound was suggested to have an empirical formula of $C_{12}H_{14}NOCl$. Compound V (retention time 15.0 min) had the mass spectra, m/e M^{+} 293(7), 275(5), 236(10), 219(40), 206(18), 188(60), 176(77), 160(54), 148(38), 134(22) and 57(100). It did not contain Cl. Since the mass spectra had M^{+}-H_2O (275) peak, it seemed to have an OH group. From the mass fragmentation pattern, the compound was postulated to be 2-hydroxy-2'6'-diethyl-*N*-(butoxymethyl) acetanilide. Compound VI (retention time 8.4 min) had the following spectra, m/e M^+ 219(53), 204(25), 190(31), 178(100), 161(84), 148(68) and 134(32), IR absorptions at 1690 and 1080 cm^{-1}. On the basis of the mass spectra, the compound seemed to have N remaining and Cl eliminated. IR showed a tertiary amide (1690 cm^{-1}) and an ether linkage (1080 cm^{-1}). From the mass fragmentation pattern, Compound VI was assigned as *N*-2',6'-diethylphenyl-2,3-dihydrooxazol-4-one. It seemed to be formed from *O*-dealkylation, dechlorination followed by cyclization of butachlor or through the formation of Compound V. Compound VII (retention time 13.3 min) had the mass spectra, m/e M^+ 218(30), 202(62), 186(70), 174 (95), 160(48), 146(83), 130(36) and 57(100). The mass spectra showed the compound did not contain Cl. No further information could be obtained for this compound. From the above data, a partial pathway involved in the photodecomposition of butachlor is proposed (Figure 3).

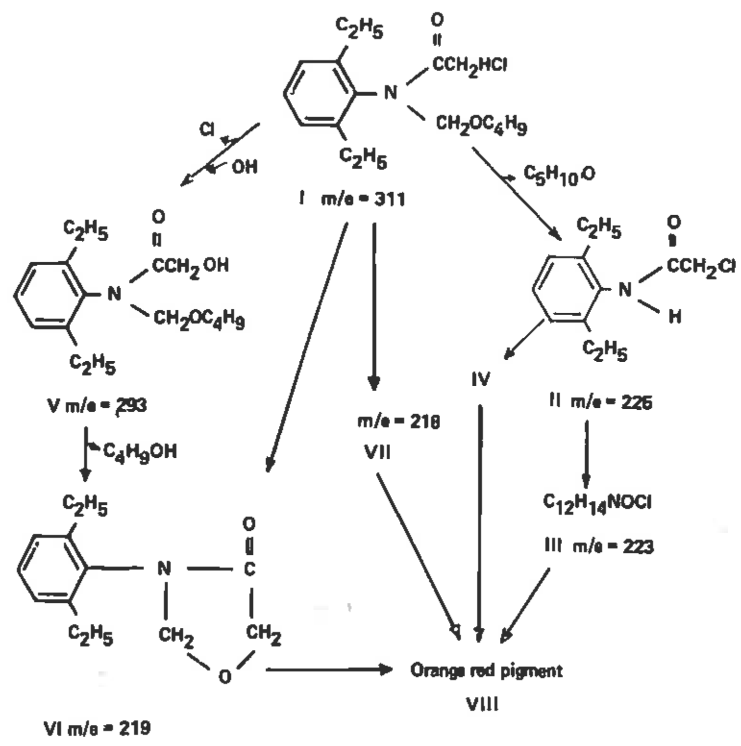

Figure 3. Partial pathways involved in photodecomposition of butachlor.

Three different soil samples were treated with 100 ppm of butachlor and analyzed by GLC. The recovery of butachlor in soils was found to be 89% for Soil A, 91.8% for Soil B and 87.5% for Soil C. When butachlor was incubated with autoclaved Soil A for 40 days, the recovery was also found to be about 89%, indicated that the absorption of this herbicide was not increased by the prolonged period. Under flooded condition, soil samples were treated with 100 ppm of butachlor, incubated at 30°C for 5, 10, 20 and 40 days, and the remaining butachlor determined by GLC (figure 4).

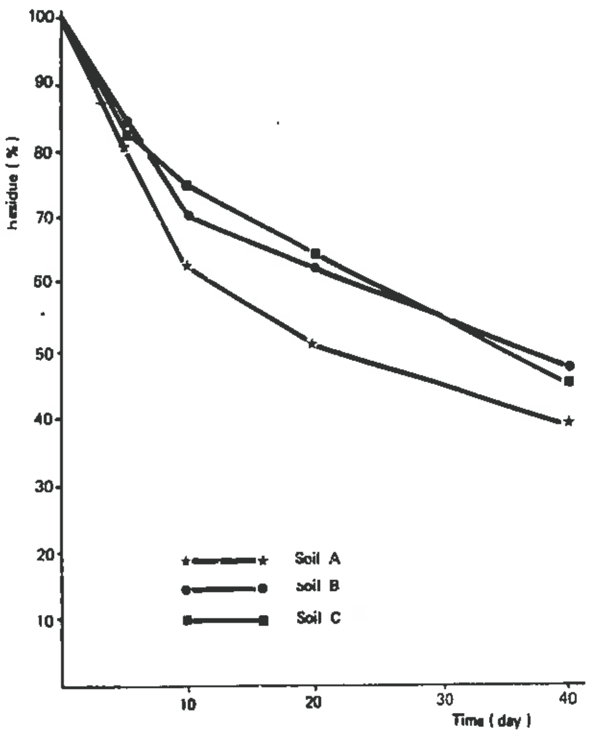

Figure 4. Degradation of butachlor in various soils under flooded condition.

The decomposition of butachlor in soils was different for each type of soil. Soil om may play an important role for peristence of butachlor in soils. The larger amount of om in Soil A compared to Soil B seemed to be responsible for the faster decomposition in Soil A than in Soil B. The results did not agree with the data obtained by Beestman and Deming (1974) due to the quite different conditions and circumstances. They demonstrated that faster dissipation of butachlor with Ray silt soil (1% om) than with Wabash silty clay soil (3% om) under field conditions. However, Parochetti (1973) studied soil om effect on activity of related acetanilide herbicides, alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl) acetanilide] and propachlor (2-chloro-*N*-isopropylacetanilide), and found no statistical difference with different om levels.

2—Chloro-2'6'-diethylacetanilide (Compound II) was also detected by GLC analysis from the soil treated with butachlor (Figure 2). The same compound was found by Hargrove and Merkle (1971) to be a degradation product of alachlor.

The degradation of butachlor by a soil fungus, *F. oxysporum*, showed that this microbe effectively degraded butachlor. At 50 ppm concentration, the half life was found to be about 5 days (Table 2). No further

Table 2. Degradation of butachlor by *Fusarium oxysporum*.

Incubation period * (day)	Butachlor remaining (ppm)	(%)	Final biomass ** (mg/flask)
0	50.00	100.00	2.6
2	49.25	98.50	9.4
4	28.91	57.82	159.8
6	7.40	14.80	337.8
12	3.43	6.86	492.8

* Average temperature 23°C.
** Means of three replication.

investigation was made about the isolation and identification of the degradation products. Recently, Tiedje and Hagedorn (1975) reported that degradation of alachlor by a common soil fungus, *Chaetomium globosum*, produced 4 metabolites which were identified as 2-chloro-2',6'-diethylacetanilide, 2,6-diethyl-*N*-(methoxymethyl)aniline, 2,6-diethylaniline and 1-chloroacetyl-2,3-dihydro-7-ethylindole. Six other soil fungi were unable to effectively degrade alachlor. Beestman and Deming (1974) also concluded that microbial decomposition is a major avenue of dissipation of 3 commercial α-chloroacetanilide herbicides, propachlor, alachlor and butachlor from soils. Kaufman and Blake (1973) reported that the soil fungus, *F. oxysporum*, effectively degraded alachlor and propachlor. The major route of degradation involved dechlorination but no aniline metabolite was obtained.

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Influence of Selected Soil Properties on the Phytotoxicity of Soil-Applied Herbicides [1]

A. RAHMAN, B. E. MANSON and B. BURNEY [2]

ABSTRACT

Glasshouse experiments were conducted to determine the influence of soil properties other than organic matter (om) on the initial and residual activity of two soil-applied herbicides, atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] and trifluralin (α, α, α-trifluoro-2,6-dinitro-*N*, *N*-dipropyl-*p*-toluidine). Seven different soils containing om levels between 11.1 and 11.6% but varying widely in their parent material, texture, and other physico-chemical properties were used. Concentrations of both herbicides causing 50% growth reduction compared with the control (GR_{50}) were determined using oats (*Avena sativa* L. c.v. Mapua) as an indicator species. Results showed that GR_{50} values of both herbicides were correlated positively with clay and cation exchange capacity (CEC) and negatively with the sand content of the soil, although these relationships were not very strong. The residual activity remaining in the soil after about 6 weeks from the GR_{50} value of the herbicide did not vary appreciably between soils. However, the residual toxicity from any given concentration of either chemical was negatively correlated with the GR_{50} value and tended to be higher in soils containing lower clay content or CEC.

INTRODUCTION

The activity of soil-applied herbicides depends to a great extent upon several soil properties. Excellent reviews on soil-herbicide relationships have been published (Bailey and White 1970, Osgerby 1973, Upchurch 1972, Weber and Weed 1974). In numerous studies the influence of soil organic matter (om) on herbicide behavior was the factor of most significance. However, other factors such as soil texture, cation exchange capacity (CEC), exchangeable bases, pH, moisture equivalent etc have also been reported to influence the adsorption and effectiveness of most herbicides. Identification of their importance has been difficult in most studies because of high correlation between om and other soil properties and also due to the high degree of correlation between om and herbicide phytotoxicity. Differences in soil properties would also be expected to affect the persistence of soil-applied herbicides due to the differences in the adsorptive capacity of the soils.

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New Zealand, for its size, has an unusually wide range of soils. A number of soils contain a high proportion of allophane clays, most of which are derived from volcanic materials. The only work on the soil-herbicide relationship in this country has been reported by Rahman (1976) who found strong relationship between soil om and herbicide activity using soils of different om levels from the same soil type. The present study utilised soils varying widely in parent material, texture and many other properties but containing comparable om levels with the object of determining the influence of soil properties other than om on the initial and residual activity of soil-applied herbicides.

MATERIALS AND METHODS

Bulk samples from the top 10 cm of 7 different soils were collected, air-dried and passed through a 5-mm screen. These soils were selected to provide a broad range of parent materials, texture, and other physico-chemical properties whilst retaining comparable om levels (Table 1). Organic carbon in the soils was determined by the Walkley-Black method as modified by Smith and Weldon (1940). Mechanical analyses were performed by the pipette method by pretreating soil samples with H_2O_2 and sodium hexametaphosphate and dispersing for 10 min ultrasonically. Other properties were determined by the Ruakura Soil Testing Laboratory using procedures described earlier (Rahman 1977).

A series of concentrations between 0.25 and 0.70 ppmw of oven-dry soil of atrazine and between 0.25 and 3.0 ppmw of trifluralin was used for all the 7 soils. The rates were selected to produce a complete response curve, from no injury to complete kill. Oats were used as the bioassay species. Plastic pots 15 cm in diameter were filled with air-dry soil to 70% capacity and weighed amounts of treated soil were added to provide a top layer in each pot to a depth of 5 cm. Ten seeds were planted at a depth of 2 cm and were thinned to 8 plants per pot after emergence. A randomized block design with 4 replications was used.

The experiments were conducted in a glasshouse maintained between 20°C and 27°C, with no artificial light. At the start of each experiment the soil was watered to field capacity and maintained thereafter between 75 and 100% field capacity. Herbicide response was evaluated after about 5 weeks by harvesting top growth and obtaining dry matter weight. These data were used to determine the amount of herbicide required to

Table 1. Some physico-chemical properties of the soils.

Soil type	Organic matter (%)	Sand (%)	Silt (%)	Clay (%)	CEC (me/100 g)	pH	Total N (%)	Total P (%)	Bulk density (g/ml)	Field capacity (%)	Exchangeable bases (me/100 g) Ca	Mg	K	Na
Hauraki clay	11.1	17.6	23.4	52.4	29.6	5.3	0.44	0.10	0.58	41.9	8.5	1.60	1.07	0.43
Hamilton silt loam	11.2	31.9	28.5	33.1	37.5	5.6	0.43	0.15	0.73	40.1	9.5	1.55	1.22	0.26
Ohaupo silt loam	11.6	32.6	31.4	30.0	42.6	5.5	0.51	0.17	0.68	44.3	9.2	0.74	0.50	0.24
Waitoa silt loam	11.3	47.4	26.4	20.1	29.0	5.4	0.43	0.12	0.65	39.1	9.2	1.11	0.55	0.15
Horotiu sandy loam	11.2	59.1	18.8	15.3	25.2	5.6	0.33	0.14	0.70	41.6	8.3	0.57	0.25	0.18
Taupo sandy silt	11.5	65.7	20.6	7.7	24.6	5.5	0.49	0.14	0.55	53.6	3.1	0.44	0.90	0.15
Paengaroa sand	11.1	70.2	15.4	7.2	18.8	5.6	0.36	0.13	0.73	43.1	5.8	0.65	0.27	0.13

produce a 50% growth reduction compared with the control (GR_{50}). These GR_{50} values were used in all summary and correlation work presented here.

At the conclusion of each experiment the pots were allowed to dry for 2 days and then the upper 2 cm of soil was removed. The pots were reseeded with oats, the soil was replaced and the process repeated to find out the residual activity of atrazine and trifluralin remaining in the soil.

RESULTS AND DISCUSSION

The 7 soils used in this study varied widely in their texture (sand and clay), CEC, exchangeable bases, total N and P and to a small extent in bulk density and field capacity. The pH of the soils had a very narrow range and they were all acidic (Table 1). Further the soils were developed from distinctly different parent materials. The Hauraki soil is developed from estuarine sediment, and contains mainly halloysite and kaolinitic materials. The Hamilton soil is strongly weathered and contains mainly kaolinite and halloysite clays while the Ohaupo soil is relatively weakly weathered and contains some allophane clay. Waitoa silt loam is a gleyed soil containing mainly halloysitic materials and the Horotiu soil is developed mainly from water sorted volcanic ejacta containing predominantly allophane clays. The Taupo and Paengaroa soils are developed from recent volcanic materials and possess 100% allophane clay.

Initial phytotoxicity of herbicides. The concentration of herbicides required for the GR_{50} value varied between 0.39 and 0.55 ppmw for atrazine and between 0.65 and 1.17 ppmw for trifluralin depending upon the soil type (Table 2). Relationships between herbicide phytotoxicity and soil factors were evaluated by comparing simple and multiple correlation coefficients. The GR_{50} values were correlated positively with the clay content and CEC of the soil and negatively with the amount of sand in the soil (Table 3). Multiple regression analyses were attempted to see if more of the variations in herbicide phytotoxicity could be explained by any of the combinations. However, the inclusion of CEC with either clay or sand gave only slightly higher correlation coefficient values (R^2) compared to the simple correlation coefficients (r^2) for both herbicides (Table 3). Trifluralin appeared to be slightly more sensitive on a *pro rata* basis to changes in soil constituents, but this effect was not significant.

Table 2. Initial and residual activity of atrazine and trifluralin in the seven soils.

Soil type	GR_{50} value (ppmw)		Residual activity — dm % of control (= 100)			
			Atrazine		Trifluralin	
	Atrazine	Trifluralin	From GR_{50}	From 0.5 ppmw	From GR_{50}	From 1.0 ppmw
Hauraki clay	0.51	1.04	98	94	81	81
Hamilton silt loam	0.55	0.92	102	103	72*	75*
Ohaupo silt loam	0.50	1.17	91	91	77*	86
Waitoa silt loam	0.44	0.73	108	77*	74*	56*
Horotiu sandy loam	0.42	0.65	89	76*	75*	49*
Taupo sandy silt	0.39	0.70	91	69*	72*	56*
Paengaroa sand	0.44	0.76	96	83	77*	63*

* Significantly different from their respective controls ($P<0.05$).

Table 3. Regressions* of GR_{50} (ppmw) on soil characteristics.

	Clay		CEC		Sand
Atrazine					
b**	.00506 ± .00160		.00284 ± .00094		—.00245 ± .00069
r^2	.574		.646		.716
R^2		.742		.736	
Trifluralin					
b**	.01880 ± .00685		.00904 ± .00284		—.00800 ± .00266
r^2	.677		.584		.645
R^2		.731		.719	

* All the b, r^2 and R^2 values in this table are significant at 5% level of probability.
** Mean GR_{50} value for atrazine — 0.464 ppmw and for trifluralin — 0.946 ppmw.

Although the phytotoxicity of both atrazine and trifluralin decreased with increasing clay and CEC or decreasing sand content of the soil, the correlation values were low and never exceeded the 5% level of significance (Table 3). This contrasts with r values of 0.97 and 0.98 (both significant at 0.1%) between soil om and the phytotoxicity of atrazine and trifluralin respectively, which were obtained by Rahman (1976) using Horotiu sandy loam soil, one of the soils included in the present study. This observation is in agreement with Hollist and Foy (1971), Lavy (1968), Segraves *et al.* (1973) and Talbert and Fletchall (1965) who also reported much higher degree of correlation of atrazine and trifluralin's activity with om compared to the clay or sand content of the soil.

The type of clay mineral has been shown to influence the adsorption of both atrazine and trifluralin as the soils containing high surface area, expanding lattice type clays are more adsorptive than those containing non expanding clays with low surface area (Harrison *et al.* 1976, Hollist and Foy 1971, Weber 1970). Two of the soils used in this study (Taupo and Paengaroa) contain 100% allophane clays while the Horotiu sandy loam has substantial quantity of allophane as its clay component. The allophanic material has a very high surface area — values as high as 400 m^2/g have been reported in New Zealand (Birrell 1964) while some Japanese workers have reported values of up to 600 m^2/g (Wada and Harward 1974). However, the soils containing allophane clays had a relatively lower clay content than the ones containing none or small amounts of allophane. It is difficult therefore, to compare the effect of the type of clay on a *pro rata* basis from the results obtained in this study. Further, it has been established that in the case of trifluralin, the surface area is not a reliable index to measure the potential of an adsorbent to reduce phytotoxicity (Hollist and Foy 1971).

None of the soil properties besides clay, sand and CEC showed any consistent relationship with herbicide phytotoxicity. Also when combined with any of the above three constituents, none of the soil factors resulted in an overall R^2 bigger than 0.65. Bulk density due to its direct relationship with actual amount of om in the soil could be expected to have some effect on the GR_{50} values. Similarly, pH is known to be related to the phytotoxicity and adsorption of atrazine (Weber 1970). However, differences in both these properties were very small between the soils and this probably was the reason for poor correlations with the herbicide phytotoxicity.

Residual phytotoxicity of herbicides. The bioassay data for persistence of herbicides at the termination of experiments indicated that trifluralin had much more residual activity than atrazine. The concentration of active atrazine remaining in the soil from the GR_{50} rates was not phytotoxic to the following crop while that of trifluralin resulted in significant reductions in oats yield in all but one soil (Table 2). This residual activity from the GR_{50} rate was not related to any soil property and was similar in all the 7 soils. However, the residual activity remaining from any given concentration of either herbicide was less in soils containing greater amounts of clay or CEC or low sand content. Thus the soils having a higher GR_{50} showed smaller residual activity of both herbicides as determined by the dm wt (Table 2). This does not necessarily suggest smaller amounts of herbicide residues since more herbicide would be required to produce a similar growth reduction in soils exhibiting high GR_{50} values due to their large adsorptive capacity compared with soils having low GR_{50} values. This point has been discussed in detail by Rahman *et al.* (1976).

Results of this study confirm the findings of some other workers in demonstrating that the clay, CEC and sand content of the soil influenced both the initial and residual activity of atrazine and trifluralin. However, none of these soil properties were related as highly to herbicide activity as the om content of the soil, determined in a previous study (Rahman 1976). The next step would be to examine the interaction between om and other soil properties with regard to the effect on herbicide performance. Field trials are in progress at present with a number of soil types, each at 3 to 4 om levels, in different parts of the country to study this problem.

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Determinants for Initial Phytoactivities of Herbicides in Rice Paddy Soils [1]

S. J. DAMANIK, Y. YAMASUE and K. UEKI [2]

ABSTRACT

Initial phytoactivities of 3 herbicides on barnyardgrass *Echinochloa crus-galli* Beauv. var. *oryzicola* Ohwi) were determined by using 11 soils with different characteristics and a soil with designated pH, clay or om content at several levels. The herbicides used were simetryn [2,4-bis(ethylamino)-6-(methylthio)-*s*-triazine], MCP-Na ([(4-chloro-*O*-tolyl)]oxy sodium acetate) and benthiocarb [*S*-(4-chlorobenzyl)-*N,N*-diethylthiolcarbamate]. They were incorporated into 300 g of the air-dried soils at 7 levels of ranging from 0 to 6.4 ppmw for simetryn and MCP-Na, and 0 to 32.0 ppmw for benthiocarb. Plant responses in height and fresh weight were bioassayed 2 weeks after incorporation in a phytotron. The phytoactivities of simetryn varied in soils depending on the pH, clay and om content. Decreased acitivity was observed as the clay or om content increased. When soils different in pH were used, simetryn showed the minimum activity near its pKa. The reverse is the case with the Na salt of acidic MCP. Decreased activity of MCP-Na was observed as the om and clay content increased. No significant difference in phytoactivity of benthiocarb was shown when the pH and clay content were changed between the range from 3.75 to 7.65 and from 5 to 20% in weight, respectively. Decreased activity of benthiocarb was evident when the om content increased in the soil. It was suggested by the results obtained that adsorption of herbicides onto clay minerals and/or om was an important determinant for the initial phytoactivities of simetryn, MCP-Na and benthiocarb when applies to rice paddy soil.

INTRODUCTION

Simetryn, MCP-Na and benthiocarb are the herbicides extensively used in rice paddy fields. It is often reported that performance of these herbicides varied from soil to soil. The variation in the initial phytoactivities of herbicides with soils is caused by differences of the soil capacity to inactivate the herbicides (Day *et al.* 1968, Harris and Sheets 1965). A number of studies have been conducted to relate soil properties to the phytoactivities of herbicides (Day *et al.* 1968, Harris and Sheets 1965, Obien *et al.* 1966, Upchurch *et al.* 1966) These studies show that soil om was the most important factor influencing the phytoactivities of soil-applied herbicides. Other researchers (Sheets 1962, Weber *et al.* 1968, Weber

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1 This study was conducted at the Weed Science Laboratory, The Faculty of Agriculture, Kyoto University.

2 Graduate student, Research Associate and Professor, respectively, Weed Science Laboratory, The Faculty of Agriculture, Kyoto University, Kyoto 606, Japan.

et al. 1974) found that clay minerals also affected phytoactivity in soils. Soil pH may directly or indirectly influence phytoactivity of herbicide by affecting the adsorption and degradation of herbicides (Corbin and Upchurch 1967, Kuwatsuka *et al.* 1975).

The objectives of the experiments were to determine initial phytoactivity of simetryn, MCP-Na and benthiocarb in various soils of rice paddy fields and to relate the phytoactivities of the herbicides to pH, om and clay contents of soils.

MATERIALS AND METHODS

Experiment 1. Simulated soils with several levels of om, clay and soil pH were used to determine influences of soil om, clay content and pH on the herbicides phytoactivity. The simulated soils having an om content ranging from 1.0 to 15.0% were prepared by using Takatsuki soil, washed sand and manure. The physicochemical properties of Takatsuki soil and washed sand are shown in Table 1. Organic matter and pH of the manure used were 78.82% and 6.8, respectively. Appropriate amounts of the manure or washed sand was added to Takatsuki soil to obtain 1.0, 2.5, 5.0, 10., and 15.0% om contents. Clay content of the simulated soil ranged from 11.85 to 13.74%, and pH from 6.21 to 6.95.

Tawara and Sasaki soils were used to prepare simulated soils with 4 levels of clay content. Physico-chemical properties of the mixture of the above 2 soils were 34.75% om, 34.65% clay, 21.35% silt, 44.50% sand and pH at 5.1. Appropriate amounts of sand was added to the mixture to obtain 5.0, 10.0, 15.0, and 20.0% clay content. After the clay content was simulated, om content of the simulated soils ranged from 0.66 to 2.73, and pH from 4.85 to 5.01.

Adjustment of pH was done in Takatsuki soil to obtain 5 levels of pH in the soil. Two weeks before transplanting pH of the soils was adjusted by titrating the soil with HCl or base mixture containing 60% $Ca(OH)_2$ and $Mg(OH)_2$. This mixture was required because soils titrated only with $Ca(OH)_2$ were toxic to plants (Corbin and Upchurch 1967). The soils were thoroughly mixed and remoistened after the HCl or base misture was added, and every 24 hours the pH of the soils was measured until a constant pH level was obtained. The soil pH values recorded prior to transplanting, 7 and 14 days after transplanting of the assay plant were 3.8 ± 0.2, 4.4 ± 0.1, 5.5 ± 0.2, 6.6 ± 0.2 and 7.7 ± 0.1.

One thousand and two hundred grams of simulated soil were treated with herbicides at constant concentration, 4.0, 5.0 and 6.0 ppmw respectively. They were thoroughly incorporated by a mixer in a plastic bucket, and transferred to 4 replicated 8 by 8 by 10 cm plastic cups. The assay plant used was barnyardgrass which was germinated in a Petri dish

Table 1. Physico-chemical properties of soils.

Soil source	Soil type[1]	Nitrogen (%)	Carbon (%)	pH	Organic matter (%)	Clay (%)	Silt (%)	Sand (%)
Kyoto University	SL	0.16	2.53	5.7	3.1	14.2	11.9	73.9
Takatsuki	SL	0.12	1.43	6.3	2.9	14.1	19.9	66.0
Kameoka	SCL	0.10	1.50	6.0	2.6	16.8	19.1	64.1
Ejiri	SL	0.18	2.42	7.6	1.8	3.1	18.1	78.8
Chitose	CL	0.25	3.34	5.5	5.8	16.7	26.5	56.8
Takahara	SL	0.51	14.03	7.6	13.8	1.5	25.9	72.6
Noma	SL	0.15	2.42	4.6	3.2	13.0	12.2	74.8
Tawara	LiC	0.10	1.84	4.7	5.0	30.0	31.1	38.9
Thukahata	LiC	0.13	2.38	5.0	5.3	26.4	24.5	49.1
Sasaki	LiC	0.14	2.37	5.1	4.5	39.3	11.6	49.1
Sand	S	0.01	0.00	7.2	0.01	0.3	0.5	99.2

1 SL = Loamy sand, SCL = Sandy clay loam, CL = Clay loam, LiC = Light clay, S = Sand.

in growth chamber for 48 h at 27°C. Transplanting of 10 plants per cup was done immediately after the incorporation of the herbicides into the soils. Seven days after planting, plants were thinned to 4 plants a cup to increase the degree of uniformity. Throughout the period of the experiment, sufficient water was added up to a depth of 5 mm above the soil surface to make the soil mimic the conditions in a paddy field. Two weeks after transplanting, plants were cut off at the soil surface for determination of fresh weight and height. The experiment was done in a phytotron as a fully randomized block design (RBD) with 4 replications.

Experiment 2. The phytoactivity of simetryn, MCP-Na and benthiocarb were determined in 11 soil samples which were collected from rice paddy fields of Kyoto Prefecture, Japan. The soils were pulverized, air-dried and passed through a 4 mm mesh-screen. A part of each soil was used for the analyses on particle distribution, pH and om content (Table 1). Particle distribution was performed by the pipetting method (Day 1965). The pH of the soils was determined on water saturated soil pastes using a pH meter. Organic matter content was determined by combustion at 500 C for 24 h. Bioassay was performed in a similar manner to that in Experiment 1. Herbicide treatments were made at a series of concentrations of 0.0, 0.2, 0.4, 0.8, 1.6, 3.2 and 6.4. ppmw for simetryn and MCP-Na and 0.0, 1.0, 2.0, 4.0, 8.0, 16.0 and 32.0 ppmw for benthiocarb.

RESULTS AND DISCUSSION

Experiment 1. Influence of pH, om and clay content of the simulated soils on the phytoactivity of simetryn, MCP-Na and benthiocarb are shown in Figure 1.

Simetryn. The phytoactivity of simetryn decreased as pH of the soil increased from 3.8 to 4.4, then increased when pH was further increased from 4.4 to 7.7. The highest phytoactivity was observed at pH 7.7, while the lowest was at pH 4.4, a value which appeared to be close to the pKa value of this basic herbicide. This finding was in agreement with the previous investigations on prometone [2,4-bis(isopropylamino)6-methoxy-*s*-triazine] (Corbin *et al.* 1971), prometryn [2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine], and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] (Best *et al.* 1975). Weber (1966) reported that the amount of *s*-triazine adsorbed by montmorillonite clay increased as the pH of soil decreased until an adsorption max was reached, and the maximum adsorption occurred in the vicinity of its pKa value. Therefore, the lowest phytoactivity at pH 4.40 may be due to the highest adsorption by the soil colloids. Highly significant difference of activity of simetryn were observed when soil om and clay content increased from 1.0 to 15.0% and from 5.0 to 20.0%, respectively. With increasing the om and clay contents

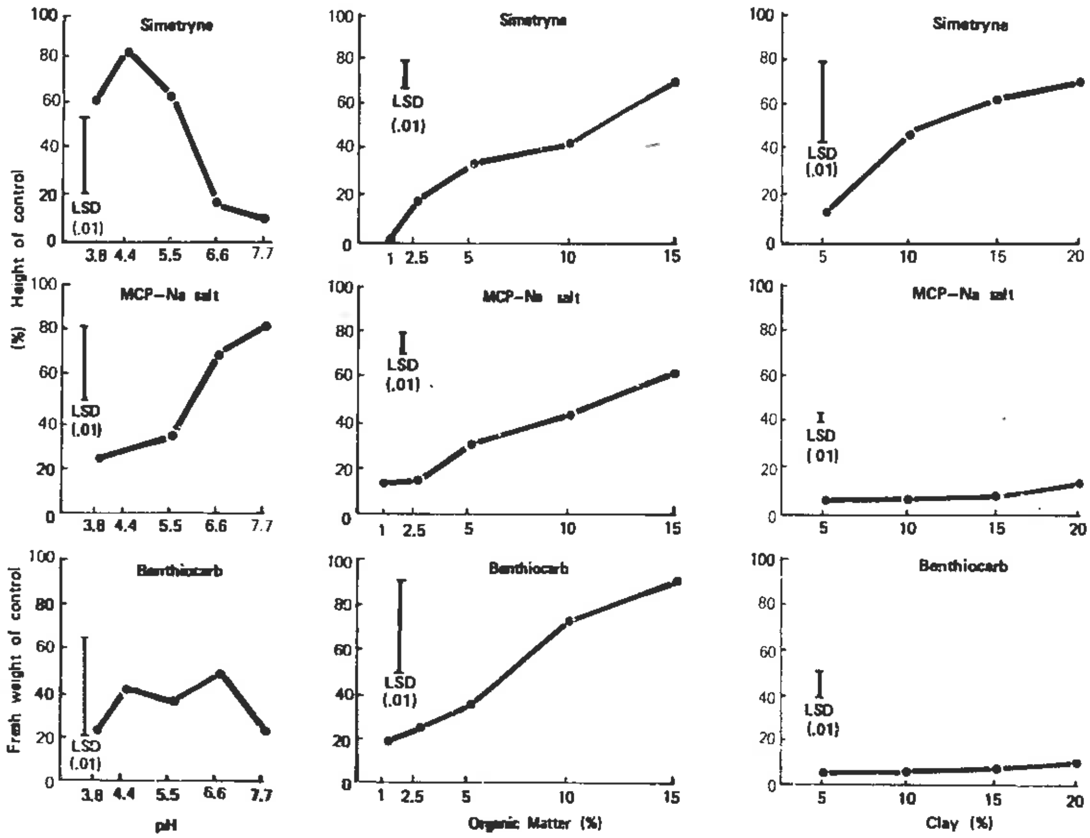

Figure 1. Influence of pH, organic matter and clay contents of phytoactivities of simetryn, MCP — Na, salt and benthiocarb in the soils.

the activity decreased. Talberg and Fletchall (1965) reported that increased amounts of om and-or clay content in soil generally associated with increased adsoption of *s*-triazine. The differential phytoactivity of simetryn observed in this experiment appeared largely due to adsorption onto the clay minerals and organic colloids, depending upon pH of the soils.

MCP-Na. The maximum activity of MCP-Na occurred at pH 4.40, and the least activity at pH 7.65 of the soil. A decrease in pH below 4.40 did not additionally increase the phytoactivity. The data reported herein is in complete contrast to the phytoactivity of 2,4-D [(2,4-dichlorophenoxy) acetic acid], reported by Corbin *et al.* (1971). They found the phytoactivity of 2,4-D increased as pH increased from 4.3 to 7.5. The om content of soil significantly affected the phytoactivity of MCP-Na. Its phytoactivity decreased when the soil om content increased. However, the effect of the clay content was not evident and there was little significant change in the phytoactivity of this acidic herbicide when the content increased from 5.0 to 20.0%. Weber (1971) reported that acidic herbicide were adsorbed by organic and clay colloids, depending on pH of soil.

Benthiocarb. Phytoactivity of benthiocarb was not significantly affected by soil pH, although there was a little fluctuation of the activities with the soils used. Activity of this herbicide markedly increased when soil om increased from 1.0 to 15.0%. Similar finding was reported by Koren *et al.* (1968) on the phytoactivity of some thiocarbamate herbicides. Adsorption studies by Koren *et al.* (1969) showed a correlation between the rates of adsorption and amounts of om in the soils and such a correlation was not found between the rates of adsorption and amounts of clay in soils. This experiment also showed that no significant difference of activity was observed even when the clay content was altered from 5.0 to 20.0%.

Experiment 2. The initial activities of simetryn, MCP-Na and benthiocarb in 11 soils are shown as % of growth in height or fresh weight of treated plants compared to non-treated plants (Figures 2, 3 and 4).

Simetryn. The herbicide was the most toxic to barnyardgrass in sand and the least toxic in Thukahata light clay soil (Figure 2). Regarding the phytoactivity of this herbicide, the soils used in this experiment can be divided into two groups: Sands, Ejiri, Takatsuki, Kyoto Univ., Kameoka, and

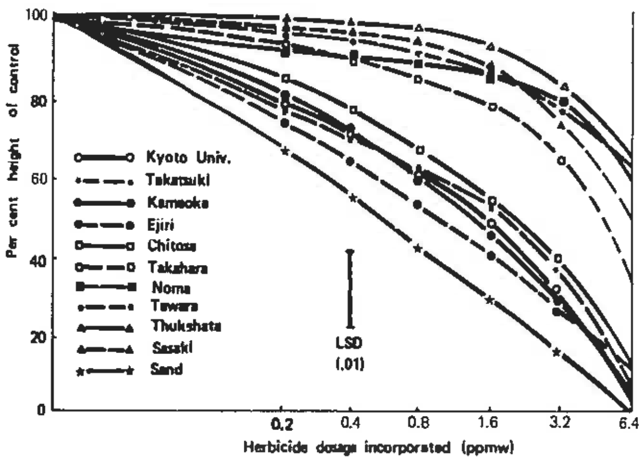

Figure 2. Herbicide activities to barnyardgrass of simetryn, incorporated in to various soils.

Chotose soils, where high activity of simetryn occurred and Takahara, Noma, Tawar, Sasaki and Thukahata soils, where low activities of simetryn occurred. The former soils possessed lower om or clay content compared to the latter soils. These data support the results obtained in Experiment 1 where the initial activity of simetryn was high in soils low in om and clay content and low in soils high in om and clay content. Excluding Takahara volcanic soil, the activity of simetryn was reduced in soils with pH ranging from 4.6 to 5.1 while not in those soils with pH ranging from 5.5 to 7.6. Those data reported herein also supported the results obtained in Experiment 1.

Experiment 1. MCP-Na. This herbicide was the most toxic in sands and the least toxic in Takahara volcanic soil. The phytoactivity of MCP-Na in the other soils was intermediate between these two extremes (Figure 3). More MCP-Na was required, in soils with high om and/or clay content, to produce the same degree of toxicity compared to soils with low om and/or clay content. Except for Takahara and Ejiri soils, the results obtained were in complete contrast to the results obtained in the Experiment 1

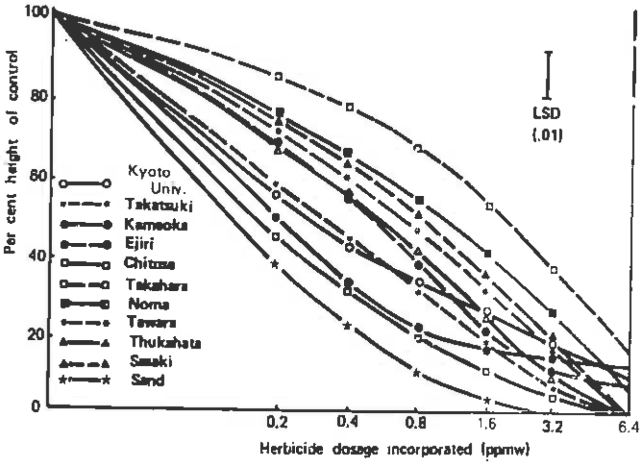

Figure 3. Herbicide activities to barnyardgrass of MCP—Na salt, incorporated into various soils.

where in soils with a pH ranging from 4.6 to 5.1, the activities were lower compared to the soils with a pH above 5.1. This result suggests that pH is not the major factor in determining the phytoactivity of MCP-Na in a soil and the toxicity is associated with other factors such as om and clay minerals.

Benthiocarb. The highest activity was obtained in sands followed by Takatsuki, Ejiri, Kyoto Univ., Kameoka, Noma, Chitose, Sasaki, Takahara, Thukahata and Tawara soils (Figure 4). That is, the activities of benthiocarb were lower in soils with high om and/or clay content. A similar finding was reported by Danielson *et al.* (1961) on activities of some thiocarbamates in soils at several levels of om. However, Experiment 1 showed that no significant difference of phytoactivity was observed even when the clay content changed form 5.0 to 20.0%. From the results obtained, it is suggested that adsorption of this non-ionic herbicide by soil om is the most important factor in determining the phytoactivity of benthiocarb.

From the results obtained in Experiments 1 and 2, it could be suggested that phytoactivity of simetryn and MCP-Na were influenced by pH, om and clay content of soils while the phytoacitivity of benthiocarb was

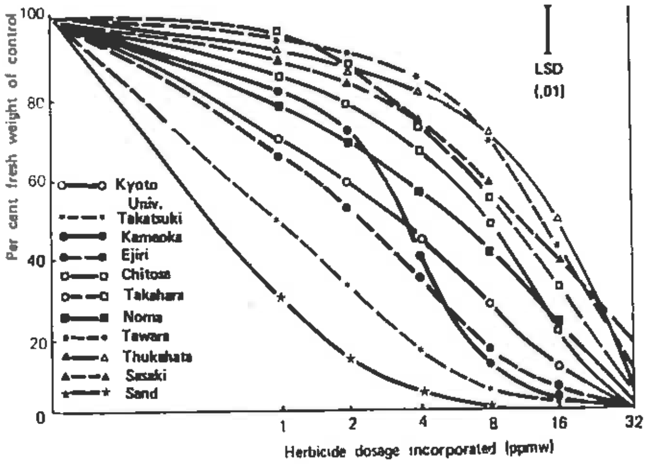

Figure 4. Herbicide activities to barnyardgrass of benthiocarb, incorporated into various soils.

determined by om content. However, detailed studies will be required for further investigation of the determinants for initial phytoactivity of these herbicides in rice paddy fields.

ACKNOWLEDGEMENTS

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Disappearence of Benthiocarb Herbicide in Irrigation Water [1]

Y. YUSA [2] and K. ISHIKAWA [3]

ABSTRACT

Changes in benthiocarb [S-(4-chlorobenzyl)N,N-diethylthiocarbamate] concentration in the paddy field water in 1973 and in the irrigation systems in 1974 and 1975, before and after application of benthiocarb herbicide, were investigated. The concentration in the paddy' field water, where two-fold of the practical dose of benthiocarb herbicide was applied, reached about 1.5 ppm immediately after the application, decreasing relatively slowly there-after and reduced to half within 5 days. In the irrigation systems, practically no benthiocarb was detected before the application of bentiocarb herbicide, but the concentration in water showed a rapid increase with the application of the herbicide. In creek and plain areas, the concentration in water reached about 40 ppb during the period of max application of the herbicide, and decreased thereafter at a fairly constant rate; the concentration reduced to half within 6 to 9 days after the max concentration was recorded. After 2 months it fell to the initial level before the application. In water near the summit of the mountain, however, benthiocarb was not detected throughout the investigations. In the downstreams of that applied area, only a small amount of benthiocarb was detected correspondingly with the period of applicaiton.

INTRODUCTION

The benthiocarb herbicide, Saturn, is now widely used in Japan and many other countries. The amount used is also increasing year by year. Six thousand tons of the technical material was produced during 1976, and its formulations were applied in about 60% of the whole paddy fields in Japan.

Recently, a large number of studies have been conducted on the behavior of some herbicides in the environment. Most of these studies, however, were carried out in the laboratory in order to clarify the role of each factor of the behavior. Besides the laboratory experiments, field studies on the behavior of herbicides in the practical environment are of equal importance. Fate and behavior of benthiocarb herbicide in the soil

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environment and plants have been studied (Ishikawa *et al.* 1976a). Fate of benthiocarb in the practical paddy field (Ishikawa *et al.* 1976b) and water environments (Yusa *et al.* 1976 and Suzuki *et al.* 1977) have also been studied. The present paper summarized the results of authors' recent studies on disappearence of benthiocarb in irrigation water.

MATERIALS AND METHODS

Disappearence in paddy field (Ishikawa *et al.* 1976a). This field test was conducted at a paddy field of the Life Science Research Institute, Kumiai Chemical Industry Co., Ltd. A granular formulation of benthiocarb containing 10% benthiocarb was applied to the paddy field at a dose of 6 kg a.i./ha 4 days after transplanting rice. Paddy field water, rice plant and soil of the field were sampled and analyzed every designated day.

Changes in creek and river water (Yusa *et al.* 1976). Disappearence of benthiocarb in creek and river water in Saga and Kanzaki Districts, Saga Prefecture in the west-south of Japan was investigated during the period from March, 1974 to November, 1975. In the districts, besides the customary irrigation system of using flumes commonly employed in Japan, an irrigation system of pumping up water from the creek in the low district along the sea is also being practised. In the mountain area and the plain area, the investigations were carried out from March through November, 1975, at 3 or 4 selected monitoring station and water was sampled at regular intervals, once a week from May to June, and once in every 2 or 3 months during the rest of the period. In the creek area, the investigations were carried out from March to November, 1974. More than 10 monitoring stations were selected and water was sampled once a week from June to August, and once in every 2 or 3 months during the rest of the period.

RESULTS AND DISCUSSION

Disappearence in paddy field (Ishikawa *et al.* 1976b). Benthiocarb is applied mainly on the water surface of paddy fields in granular formulations. Benthiocarb applied dissolves in water from granules. It is adsorbed mostly by soil and only partly absorbed by rice plants. Benthiocarb dissolved in water, however, disappears by various factors such as photodegradation, degradation by microorganisms, volatilization and so on (Ishikawa *et al.* 1976a). The disappearence of benthiocarb in water, soil and rice plant in the paddy field, treated with two fold dose (6 kg a.i./ha) of benthiocarb in granular form, was investigated (Fig. 1).

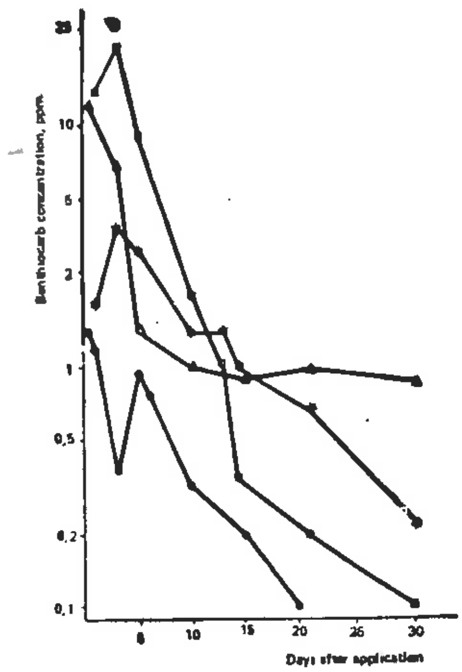

Fig. 1. Changes of benthiocarb concentration in soil (▲), water (●), foliage (■) and root (✱) of rice plant in paddy field treated with Saturn granules (a.i. 6 kg/ha)

The concentration in water reached about 1.5 ppm immediately after the application, decreased to half within about a week, and to < 0.1 ppm after 30 days. As shown in Fig. 1, benthiocarb in soil decreased rapidly. Benthiocarb in soil was degraded mostly by soil microorganisms (Yamada 1973, Nakamura *et al.* 1977a), and finally even the benzene ring of the benthiocarb molecule was decomposed into carbon dioxide (Nakamura *et al.* 1977a). Besides, benthiocarb was rapidly degraded under the aerobic condition of the soil (Nakamura *et al.* 1977a). Consequently, the rapid decrease of benthiocarb in soil is thought to be caused by microbial degradation.

Rice plants began to absorb benthiocarb immediately after the application. Benthiocarb reached max concentration after 3 days, and the concentration decreased rapidly thereafter. The decrease of benthiocarb concentration in rice plants is considered to be attributable to metabolic degradation by the plants (Nakamura *et al.* 1974 and 1977b).

Benthiocarb in water is degraded by sunlight as well. When irradiated with sunlight, benthiocarb in the aqueous solution was degraded to <10% in 2 days (Ishikawa *et al.* 1977b). Since there are changes of such photodegradation, a part of the above decrease of benthiocarb in water perhaps involves photodegradation as well.

The volatilization of benthiocarb from the aqueous solution correlated proportionally with vaporization of water (Ishikawa *et al.* 1977a). However, when soil was added to aqueous solution, volatilization rate of benthiocarb slowed down. The volatilization of benthiocarb from the practical paddy field, therefore, is considered to be relatively small.

Changes in creek and river water (Yusa *et al.* 1976). After being applied on the surface of paddy field water, benthiocarb is degraded, for the most part, in water and soil and only a small part flows out into other downstream paddy fields. This movement of benthiocarb is caused by that of water, such as runoff of water from the paddy field. And finally it moves into flumes, rivers or creeks.

The mountain area: Throughout the investigations, benthiocarb was not detected in water near the source of the river. In water among the valleys, where benthiocarb herbicide was applied to paddy fields, traces of benthiocarb were detected corresponding to the period under application of benthiocarb herbicide, but were practically undetectable except for a short period after the application. In downstream monitoring stations, the application time of the herbicide became delayed, and the time of application coincided with that of detection at each monitoring station.

The max concentration detected in the mountain area was 2 ppb. The monitoring station, where the max concentration was detected, is located at the end of the mountain area and borders on the beginning of the plain. It is the same station as A in Fig. 2.

The plain area: The results of the investigations on changes in benthiocarb concentration at the monitoring stations, A and B, by sampling water which irrigated the paddy fields of about 150 ha are shown in Fig. 2. No benthiocarb was detected in water at both stations before the application of benthiocarb herbicide, and the concentration of benthiocarb increased with the start of the application. The concentration increased remarkably at station A, recording the highest value of 49 ppb at the time of max application of the herbicide, and decreased thereafter at a constant rate, to almost half in 6.4 days.

The creek area: Since the max value and the rate of the decrease of benthiocarb concentration were found to be more or less similar at nearly all monitoring stations within the creek area investigated, change in benthiocarb concentration near the center of the area is shown in Fig. 3.

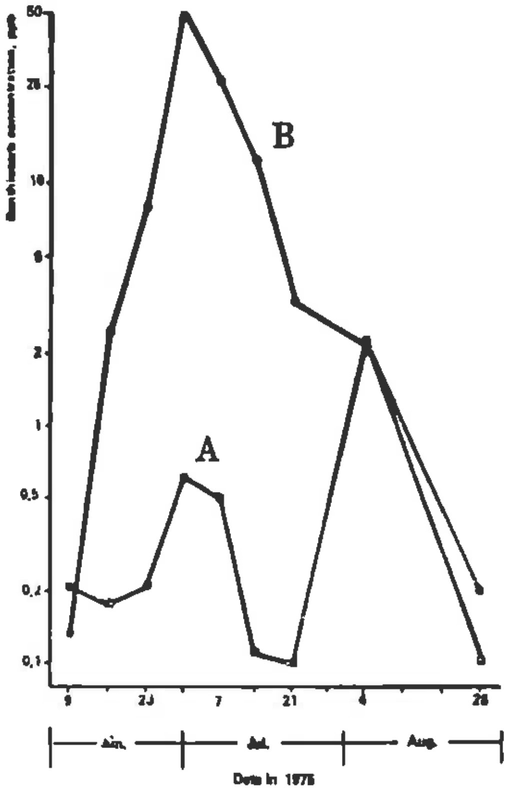

Fig. 2. Changes of benthiocarb concentration in irrigation water sampled at the stations before (A) and after (B) irrigation to paddy field.

Creek water throughout the year revealed the presence of benthiocarb. From February to May prior to the application of benthiocarb herbicide, the concentration in water was very low, recording 0.1 to 0.2 ppb. It showed increases with the commencement of June, the time of application, recording the highest value of 41 ppb at the time of max application at each station. The concentration decreased slowly since then, and after 2 months, in September reverted to the initial level before the application. The concentration decreased to half in 8.8 days.

As stated above, benthiocarb concentration in river water, and the rate of decrease differed among the creek, plain and mountain areas. In the creek and plain areas, benthiocarb concentration in water reached about 40 ppb at the time of max application, decreasing thereafter at a relatively constant rate. In the mountain area, however, the concentration in river water was generally low with the highest value of 2 ppb, and decreased rapidly. This difference was found to be related with the vol. of running water and amount of benthiocarb herbicide applied. In the mountain river, the flow rate was high and the amount of benthio-

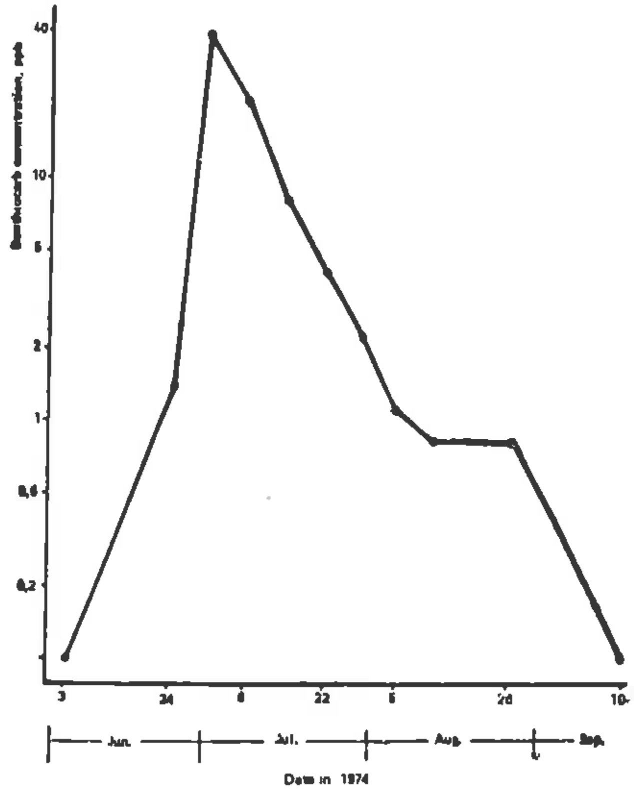

Fig. 3. Changes of benthiocarb concentration in creek water.

carb dissolved in water was considerably small. In the plain and creek areas a larger amount of the herbicide was used concentratedly in a short period of time, causing an increase in the concentration of benthiocarb. Because of slow flow of irrigation water in these areas, the concentration showed correspondingly slow changes.

The decrease of benthiocarb in water in the creek and plain areas is considered to be attributable to the fact that benthiocarb was carried away downstream from the stations investigated. Volatilization, degradation by microorganisms, absorption by plants and photodegradation are also taken as responsible factors for the decrease.

When applied in paddy fields, benthiocarb herbicide is mostly degraded in the fields. From the fact that the concentration of benthiocarb in the outgoing water is relatively higher than that in incoming water and that the increase in concentration coincides with the time of application, a small amount of benthiocarb is carried away by water from the paddy fields. Thus, the highest concentration in creek and river water was 49 ppb, decreasing rapidly thereafter.

There remains much to be reported on the influence of benthiocarb on the aquatic organisms. For instance, it was reported that benthiocarb gave no adverse effects to carp which degraded benthiocarb rapidly (Shinohara *et al.* 1973). More studies on the influence on other aquatic organisms are in progress. With the completion of these studies, the investigation summarized in this paper is expected to serve better for evaluating the influence of benthiocarb in the environment.

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Herbicidal Activity of Diuron: Persistance of Diuron in Soil at Varying Depths and its Redistribution after Deep and Shallow Cultivation [1]

L. K. VASWANI [2] AND V. KUMAR [3]

ABSTRACT

Diuron residue determination was carried out on soil from varying depths and at different intervals during a crop growth period of 220 days. When pre and post-emergence doses of diuron varying between 0.5 to 2.5 kg/ha were applied to cotton, it persisted up to 30 cm depth after 220 days of its application. However, the surface layer recorded higher residues as compared with 7.5, 15 and 30 cm depth with a few exceptions. Un-intercultivated plots recorded more residues than intercultivated ones. The preparatory tillage for succeeding crops with tractor drawn plough resulted in more uniform mixing of residues as compared to bullock drawn plough. It can be concluded that mobility of diuron is high (30 cm) and it is persistent when applied at recommended dose (1.0 kg/ha) and above, under the conditions of Haryana. Hence, in cotton diuron can control weeds over a greater length of time when used at rates recommended for selective weed control. However, long term residue problems need further investigation. Intercultivation (hoeing) before post-emergence application can be used as a means of reducing its persistance together with rapid degradation of diuron applied pre-emergence. Deep ploughing can bring diuron below the lethal level by uniform mixing and dilution of herbicide residues.

INTRODUCTION

Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea) has found wide acceptance both as a selective herbicide and soil sterilant over an extensive range of crop-weed and agro-climatic conditions. The residue carry-over from one year to another may be adequate to injure susceptible crops grown in rotation. Some earlier studies show that residues from annual applications of diuron at 1 to 2 lb per acre to the same soil did not accumulate fast enough to damage subsequent cotton crops (Arley *et al.* 1965, Dalton *et al.* 1966 and Van Rijn 1967) but sensitive cereals were often injured 6 to 12 months after application. Schweizer *et al.* (1966) reported

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[3] Haryana Agricultural University, Hissar, Haryana, (India).

greater accumulation of diuron when used as directed sprays at Lay-by when compared to pre-emergence applications.

The movement of a herbicide by leaching may determine its effectiveness as a herbicide, may explain selectivity, or may account for its removal from the soil. In addition to the protection offered by depth, crop tolerance to the herbicide is very desirable. Under field conditions at the rates of 1 to 2 kg/ha the accumulation of diuron in top soil layer has been reported (Weldon and Timmons 1961, Dawson *et al.* 1968, and Marriage *et al.* 1975). Liu (1974) determined leaching of diuron, applied at 4 kg/ha in field lysimeters of Vega Alta Clay Soil (highly leached with friable brown heavy clay top soil). Diuron in low concentration has been found to leach to a maximum depth of 36".

To examine the problem, a detailed study was conducted to determine the residue carry-over from one year of diuron application at varying depths and its redistribution following deep and shallow cultivations after harvest of cotton.

MATERIALS AND METHODS

The experiments were conducted in a double split-plot design in the Kharif and rabi seasons of 1975 — 1976 in sandy loam soil at the Research Farm of Haryana Agricultural University, Hissar.

The soil characteristics were determined according to the Standard methods recommended by the U.S. Salinity Laboratory, Riverside, California (USDA Handbook No. 60).

Table 1. Analytical value of soil at different depths

Soil property	Depth from soil surface (cm)			
	0 – 5	5 – 10	10 – 20	20 – 30
Silt content (%)	17.80	17.65	17.30	16.65
Clay content (%)	16.00	15.74	15.28	15.20
Organic Carbon (%)	0.16	0.16	0.14	0.14
pH (1:2.5 Soil water ratio)	8.2	8.2	8.2	8.2

The main plot treatments consisted of (i) Un-intercultivated (Io) (ii) Intercultivated (I_1). Sub-plot treatments were three dosages of diuron as the pre-emergence at (i) 0.5 kg/ha (ii) 1.0 kg/ha (iii) 1.5 kg/ha. Sub-

sub plot treatments consisted of three dosage of diuron as directed post-emergence at 0, 0.5 & 1.0 kg/ha 50 days after planting cotton.

Soil samples were collected from herbicide treated plots at four different depths 0 (0 to 2.5), 7.5 (5 to 10), 15 (12.5 to 17.5) and 30 (27.5 to 32.5) cm after 35, 75, 120 and 220 (at harvest) days of planting. Although each treatment was sampled from four replications, a composite sample was used for each depth and each treatment for the purpose of analysis. The samples were stored in a deep-freeze until analysis was done. The method given by Katz (1966) for determination of diuron in surface water was used with few modifications for diuron determination in soil.

Following the harvest of cotton the plots which were intercultivated during Kharif season were given two deep cross ploughings followed by harrowing with a tractor drawn disc harrow and finally planked. While other plots, which were not intercultivated in the previous season, were given two ploughings with a bullock drawn mould board plough, harrowed and finally planked. After pre-planting tillage operations and re-establishment of gross and sub-plots, soil samples were taken from the four depths to assess the redistribution of diuron residues.

RESULTS AND DISCUSSION

Diuron residues at varying depths and intervals are depicted in Figure 1.

Diuron residues were detected only in surface layers (0 — 2.5 cm) after 35 days. From the date of pre-emergence application of diuron only 22.1 mm rainfall was recorded up to 35 days which was not sufficient to leach diuron below 1″ depth. During this period soil as well as atmospheric temperatures (max 40 to 49°C, min 22 to 29°C) were quite high and bright sunshine was received. The decline in initial concentration can be attributed to photo and thermal-decomposition. Under laboratory conditions diuron showed a loss of 18 and 32% at 1 ppm when incubated with soil for 45 days at 30 and 45°C respectively. A loss of 30% was recorded when exposed to sunlight at 1 ppm for 45 days in pots under field conditions (Vaswani 1976)[4]

Intercultivation followed by post-emergence application of diuron made marked alteration in its distribution at varying depths. Within 35 — 75 days period additional 156.8 mm rainfall was received which resulted in leaching of diuron to 30 cm depth. At this depth diuron content varied between 0.042 to 0.088 ppm for different treatments. Similar results from Hissar on leaching of diuron under field conditions were reported by

4 Vaswani, L.K. 1976. Environmental factors affecting the herbicidal activity of diuron. Ph.D. thesis, H. A. U., Hissar.

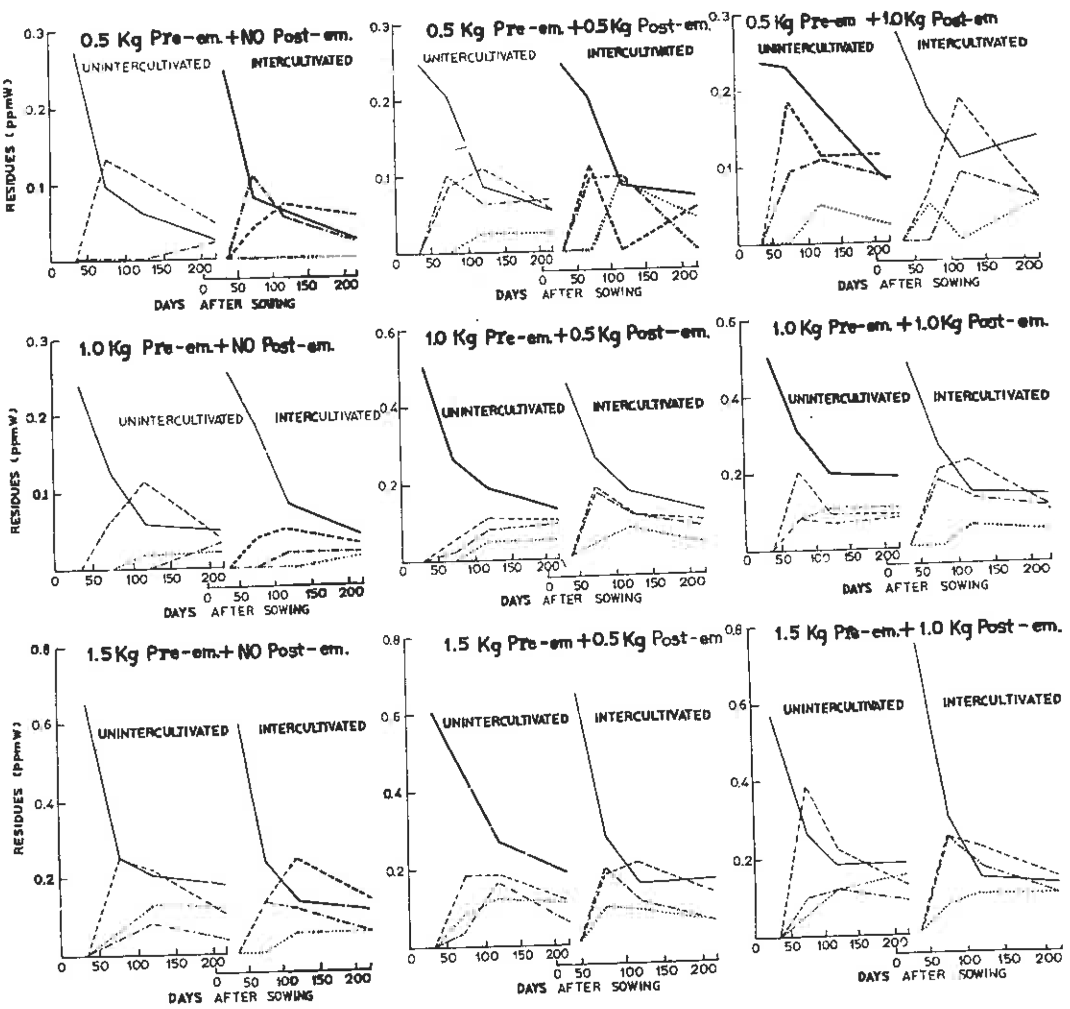

Figure 1. The persistance of diuron in the field at varying depths (———) 0 cm depth, (- - - -) 7.5 cm, depth, (—·—) 15 cm depth, (............) 30 cm depth.

Chauhan[5] (1975) when applied at 2.0 kg/ha for control of Johnson grass (*Sorghum halepense* (L.) Pers). He reported that phytotoxic concentrations of diuron leached up to 30 cm to cause severe injury to wheat. Soil column studies under laboratory conditions showed that 225 and 450 mm water leached diuron to 30 cm when soil from the same field was used (Vaswani[4] 1976). The leaching of diuron in field soil can be attributed to low adsorptive capacity (K = 1.0, Q = 357) of the soil (Vaswani[4] 1976). The loss between 35 to 75 days was most rapid from surface layer (0 to 2.5 cm). This can be due to leaching of diuron in lower layers and possibly rapid decomposition by micro-organisms which have adapted themselves to degrade diuron after a 'lag phase' (Roslycky 1971).

5 Chauhan, H.V.S. 1975. Ecology and control of Johnson grass. Ph. D. thesis, H.A.U., Hissar.

Leaching with supplemental irrigation, 246.2 mm additional rainfall up to harvest and decomposition brought further decrease in diuron residue level gradually. The residues in the surface layer were high as compared to 7.5 cm depth at high rates (above recommended i.e. 1 kg/ha) of herbicide application and vice-versa. The results are supported by leaching studies with soil columns by the author which show that at equal application rates, more chemical moves to lower layers due to increased solubility. After 75 days rate of dissipation was slower. This can be due to reduction in population of diuron decomposing microbes as concentration of diuron

Table 2. Redistribution of diuron residues at different depths following shallow and deep ploughings.

Treatments*	Residues (ppm W)			
	0 Cm.	7.5 Cm.	15.0 Cm.	30.0 Cm.
I_0 + 0.5 + 0.0	0.000	0.044	0.028	0.000
I_0 + 0.5 + 0.5	0.056	0.040	0.068	0.032
I_0 + 0.5 + 1.0	0.075	0.088	0.074	0.000
I_0 + 1.0 + 0.0	0.069	0.089	0.070	0.000
I_0 + 1.0 + 0.5	0.089	0.110	0.090	0.040
I_0 + 1.0 + 1.0	0.125	0.137	0.090	0.110
I_0 + 1.5 + 0.0	0.090	0.108	0.100	0.090
I_0 + 1.5 + 0.5	0.137	0.070	0.096	0.100
I_0 + 1.5 + 1.0	0.131	0.125	0.095	0.120
I_1 + 0.5 + 0.0	0.000	0.050	0.042	0.000
I_1 + 0.5 + 0.5	0.040	0.050	0.026	0.000
I_1 + 0.5 + 1.0	0.075	0.025	0.053	0.041
I_1 + 1.0 + 0.0	0.096	0.075	0.026	0.022
I_1 + 1.0 + 0.5	0.096	0.093	0.083	0.041
I_1 + 1.0 + 1.0	0.110	0.055	0.088	0.024
I_1 + 1.5 + 0.0	0.100	0.117	0.096	0.050
I_1 + 1.5 + 0.5	0.132	0.098	0.062	0.069
I_1 + 1.5 + 1.0	0.120	0.135	0.088	0.062

* I_0 represents un-intercultivated treatments followed by shallow cultivation.

I_1 represents intercultivated ones followed by deep cultivation.

The first values are for diuron (kg/ha) pre-emergence treatment rates and second for diuron post-emergence rates.

decreased (Roslycky 1971). After 120 days a temporary increase in diuron residues was recorded for 15 and 30 cm with further leaching due to irrigation. However, at harvest, range of residues was 0.026 to 0.192, 0.050 to 0.143, 0 to 0.100 and 0 to 0.155 ppm at 0, 7.5, 15 and 30 cm depths respectively.

Increasing the pre- and post-emergence dosages, higher residues were recorded. Intercultivated plots showed less residues compared to un-intercultivated plots. It can be attributed to rapid decomposition of the herbicide from upper soil layers due to better contact of post-emergence spray and mixing of pre-emergence applied diuron at the time of hoeing. This is the layer having highest biological activity which is conducive to rapid decomposition of herbicides.

Deep and shallow ploughings resulted in alteration in localization of residues at different depths. The range of residues at surface reduced to 0 to 0.132 ppm from 0.026 to 0.192 ppm after two deep or shallow ploughings under the respective treatments. Similarly the range changed at all depths. Two shallow ploughings with a bullock drawn mould board plough resulted in a shift of residues from surface to 7.5 cm while for deep ploughing with tractor drawn plough the major shift was towards 15 cm depth (Table 2). A more or less uniform distribution of residues was observed by deep as well as shallow ploughings up to 15 cm depth but a little shift in residues at 30 cm was observed. Mixing up and dilution of herbicide has been reported by Arley *et al.* (1965) and Dalton *et al.* (1966) with cultivation or preparatory tillage.

ACKNOWLEDGEMENT

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An Ethnobotanical Observation on Alang-alang (Imperata cylindrica (L.) Beauv.) in Bali

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ABSTRACT

The utilization of alang-alang (*Imperata cylindrica* (L.) Beauv.) in Bali is described against the Balinese cultural background. Alang-alang rhizome is employed in folk medicine against stomach disorders as well as in preparing a kind of refreshing drink. The culm and leaves of this plant are valuable economically because they are widely used as building material for houses and temples. From ethnobotanical point of view alang-alang represents an important plant due to its significant role in many Balinese traditional ceremonies and religious rituals.

INTRODUCTION

As in many other parts of Indonesia, in Bali the alang-alang or cogon grass (*Imperata cylindrica* (L.) Beauv.) can be found flourishing in many large tracts of land. But here the similarity ends, because a closer look will reveal that in some areas these healthy alang-alang fields are kept purposely. In many parts of Bali one will occasionally find sizable pieces of arable land, covered by the luxuriant growth of this generally considered most troublesome weed, maintained because of their economic value in providing thatching and other housing material. Therefore, not all Balinese will agree with the notion that alang-alang should always be labelled as a noxious weed. In fact this ubiquitous plant will be looked upon with friendly and respectful eyes because it plays a significant role in the many religious rituals of these culturally rich and tradition conscious people. Besides for spiritual purposes the Balinese also utilize alang-alang to bring solace to bodily discomfiture, ranging from thirst to stomach disorder.

In the following, an account will be given of the various uses extracted by the present day Balinese from alang-alang.

ALANG-ALANG AS THE SOURCE OF FOOD AND MEDICINE

In looking for the usefulness of any plant species, the first thing that comes up to the human mind will be its value as a food source. From

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the records of Indonesian food plants accumulated by our Institute, so far only the Balinese are known to be making use of alang-alang as a source of food, namely by using this plant as the main ingredient in making a certain kind of drink. For this purpose fresh rhizomes are cleaned and squeezed with water, and the extract obtained is then mixed up with tamarind and sugar. It is taken as a refreshing drink and function like "rujak" — an Indonesian concoction made up of several raw fruits, vinegar, salt, chilli pepper and palm sugar of fish sauce.

As has been reviewed by Soerjani (1970) the knowledge and the practice of using alang-alang rhizome for medicine are not confined to the Balinese. In this enchanted island alang-alang is mostly utilized in curing stomach disorders. In this respect a herb medicine called "wisade" is prepared by mixing fresh rhizomes of alang-alang with rhizomes of *Curcuma domestica* Val. (Zingiberaceae) and the leaves of *Piper betle* L. (Piperaceae). The mixture is pounded in a mortar, extracted with water and then a little honey is added and administered to the patient concerned by drinking a potion.

ALANG-ALANG AS HOUSING MATERIAL

The use of alang-alang for thatching purposes is a long established practice in many tropical areas where this plant grows (Soerjani 1970). If in these areas alang-alang leaves are gathered from the wild by those who need them, in Bali people frequently set aside a piece of land for growing them, because it is quite profitable to grow alang-alang (Heyne 1927, Coster 1932). A bundle of dried alang-alang leaves with a diameter of approximately 50 cm costs Rp 100 — Rp 200 in 1976. Depending on the growth and vigour of the plant this bundle may represent the yield of 2 — 4 square metres of land, and it is enough to make 2 runs of thatching each 3 m long. One can buy this ready-to-use thatching for Rp 125 — Rp 150 for each run. A simple calculation will reveal that should there be enough demand for roofing material it will be more profitable to grow alang-alang than rice.

In Bali a run of thatch is prepared in the following manner. A 3 meter long stick made of split bamboo or betel stem is prepared and to this are tied up approximately 100 small bundles of alang-alang about 3 cm diameter each. In order to ensure that these small bundles are of the same size, they measure them by putting these bundles into the hollow of a piece of bamboo culm. By arranging the distance between adjacent sticks, different thickness of thatching can be obtained, and this determines the durability of the roof, which varies from 3 to 15 years.

The frequency of the use of alang-alang as thatching material is determined by the ability of the local people to prepare the roof. Consequently in the western part of Bali which is partly populated by the Javanese and Madurese, alang-alang is very much less used than in Bangli area in the south central Bali, for example.

Besides for houses, one may also find alang-alang roof on temples and less frequently as cover on mud fences. For the latter rice straw is much preferred.

ALANG-ALANG IN BALINESE RELIGIOUS RITUALS

The most important role played by alang-alang in Bali probably lies in its use as "sedmingmang", the sacrificial agent for dispersing sacred water in many ceremonies officiated by Balinese priests. In saying their prayers the Balinese use 3 alang-alang leaves if there is no water available. Alang-alang also appears as an offering in certain ceremonies. Even during the "ngaben" or cremation ceremony, the Balinese use alang-alang rope on the coffin.

"Cicih lalang" is an old Balinese saying for indicating a phenomenon similar to the simultaneous and quick appearance of alang-alang flowers, such as in the case of quick flowering rice.

DISCUSSION

How much we wish that we could subtitle this paper with a provocative line something like "the Balinese solution to the alang-alang problem". As it is the economic and other uses of alang-alang in Bali are not sufficiently extensive to assist in decreasing, let alone in suppressing the menace of this species as an agricultural weed. The use of alang-alang does not seem to cause any genetic erosion, because the "domestication" of alang-alang thus far does not produce any sign of weakening in the aggressiveness of cultivated biotypes seen flourishing in Bali, as one may expect from the process of domestication of wild taxa into cultivation.

Be that as it may it seems to us that it is in Bali more than anywhere else where alang-alang is still used conscientiously on a scale economically justifiable to set aside and maintain an arable land full of alang-alang. Perhaps this consideration and the now popular movement to go back to nature may be used as a lever to promote this trend in other areas.

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The Role of Weeds in Sown Meadows in Japan

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ABSTRACT

Sown meadows in Japan consist of sown grasses and legumes. These sown species have been mostly introduced into Japan from the temperate or the cool temperate zones of Europe. Thus, inadequate management usually leads to infestation by weeds and growth of the sown species are depressed markedly. Here we define any plant other than the sown species as a weed. In this report, we discuss changes in yield of sown species under different cutting treatments. We divided the weed species into two large groups according to their growth form, life span and response to cutting, e.g. one is the group of "tall-growing weeds" and the other is "short-growing weeds". Weeds, belonging to the "tall-growing weeds" group are harmful to sown species and we have to control them before they seriously cover the sown species. The "short-growing weeds", on the other hand, under proper management shares the habitat without competing with the sown species. We point out in this paper that based on the existing floristic composition and the quantity of the weeds in grassland, it is possible to judge whether the condition of a meadow is poor, fair or excellent. We emphasize the use of weeds as a biological indicator of grassland condition.

INTRODUCTION

Sown meadows composed of grasses and legumes must be well managed in order to maintain them in a good condition for a long time. For this purpose, the optimum cutting frequency and suitable fertilization may be most important. However, sown meadows which have deteriorated for various causes can be found.

Forage species such as orchard grass (*Dactylis glomerata* L.), meadow fescue (*Festuca pratensis*), perennial ryegrass (*Lolium perenne* L.), ladino clover (*Trifolium repens* L.) and red clover (*Trifolium pratense* L.) were widely introduced into Japan from Europe about 100 years ago. These species grow well in the northern half of Japan where the climate is similar to that of middle and northern Europe. However, unsuitable management often causes the infestation with many weed species. In the southwestern part of Japan, the depression of growth of forage species during the summer leads to an infestation of weeds (Kawanabe 1968).

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The definition of "weeds" in meadows is given from two different standpoints. One is defined according to the degree of livestock preference (Numata 1962) or digestibility (Spedding 1971). The other is defined as plants other than sown forage species (Sakai, *et al.* 1975). The latter can only be adopted for sown meadows and so is employed in this report. Weeds competing against sown forage species are called "pests".

Although weeds invading sown meadows decrease the forage yield, their invading mechanism and means of "pest" control have not been studied much in Japan. Changes of biomass of forages and representative weed species are classified according to (1) the type of response to cutting and (2) the degree of competition with forage species. Such a classification of weeds may be used for judging the condition and trend of sown meadows.

MATERIALS AND METHODS

The survey was carried out at a sown meadow of Tohoku University located at northeastern part of Honshu from 1973 to 1975. It is a hillock area, 200 m above sea level. The annual average temperature is 10.7°C and the annual precipitation is 2,335 mm with heavy snow fall.

The sown meadow * used for this survey was established in 1971. In the meadow, experimental plots with different cutting treatments were set up in 1973. The plot layout was 4 by 4 Latin square. Cutting treatments were 0 (no cutting), 2, 4 and 8 times a year. The cutting height was 4 cm above the ground. Sufficient amounts of nutrient salts were supplied to each plot. To measure the vegetation, twelve 1 m^2 quadrats were randomly distributed in each plot. The height and coverage of all species in the quadrats were measured at an interval of 4 weeks during the growing season from 1973 to 1975. After these measurements the aboveground parts in cutting treatment plots were clipped and weighed at every cutting occasion.

RESULTS AND DISCUSSION

The influence of cutting frequency on the yield of forage. Farmers desire to maintain a relatively high and stabilized yield of forage for a long period of time. Fig. 1 shows the relationship between yearly accumulated biomass, calculated, of forage and cutting frequency.

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* The mixed sowing of orchard grass, meadow fescue, perennial ryegrass, ladino clover and red clover was used.

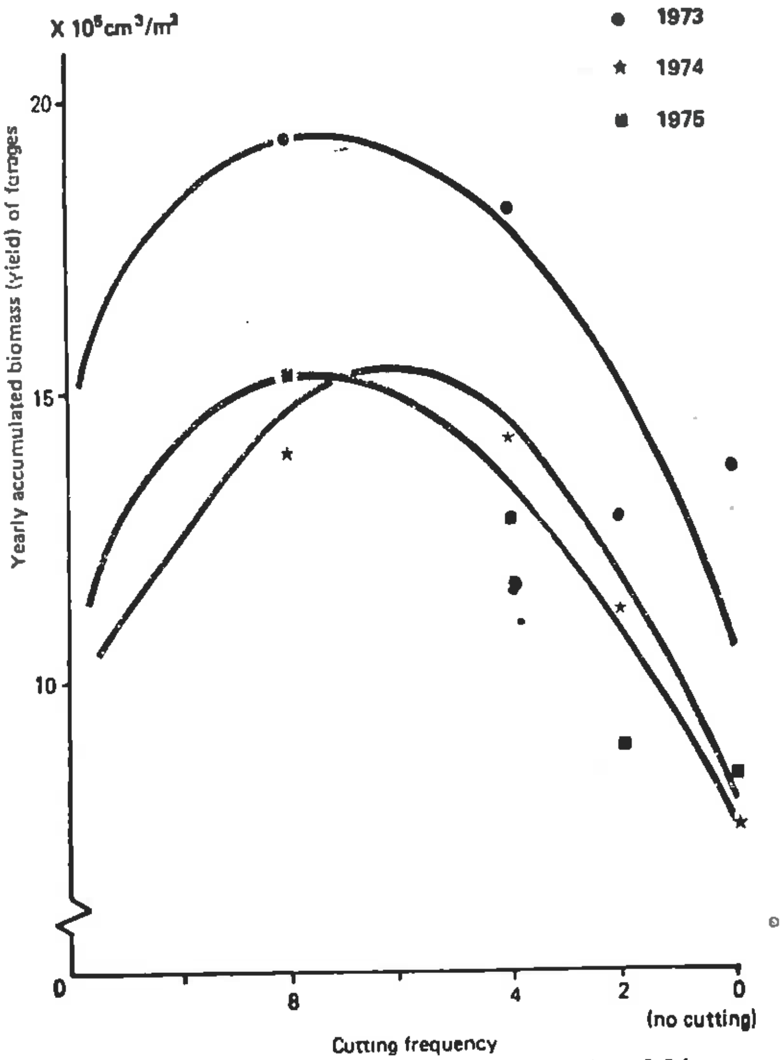

Figure 1. The tendency of yearly accumulated biomass (yield) of forage species under the different cutting treatments.

It shows the tendency of yield of forages under different cutting treatments from 1973 to 1975. To measure the dry weight of forage is impossible in the control plots. Therefore, the yield was estimated with multiplied values of height and coverage. The biomass of weeds was also estimated in the same manner. The actual dry weight is parallel to the calculated value based on the height and coverage as an estimate of forage yield.

In general, the higher the cutting frequency, the higher the yield (yearly accumulated biomass) of forages as shown in Figure 1. However, when the cutting frequency becomes more than 8 times a year, its rate will go down, suppressing the regeneration of forages.

The maximum biomass during a year in no cutting plot was less than the yearly accumulated biomass in all cutting plots as in Numata's experiment (1976). Secondary succession in the no cutting plots rapidly progressed to the vegetation of abandoned semi-natural grasslands (Numata 1961). At first *Erigeron annuus* became dominant and then *Artemisia vulgaris* L. predominated. Weed species such as *Erigeron, Artemisia* and *Rumex* gradually suppressed the growth of forage.

In sown meadows mixed with orchard grass, ladino clover, etc. in Northeast District of Honshu the optimum cutting frequency is from 4 to 8 times per year with sufficient supply of nutrient salts. If farmers cut a sown meadow more frequently, the sown meadow may be stabilized as a pasture under appropriate grazing.

Responses of weeds to cutting and their growth forms in sown meadows. From the synecological standpoint, Numata and Yoda (1957) attempted to establish the criteria to diagnose the condition and trend of sown grasslands. Measurements were made on floristic composition, the relation between the number of individuals and the order of species, types of distribution of the individuals and life form spectra in sown grasslands in relation to weeds. Numata (1965) proposed the criteria for ecological judgements of semi-natural grasslands in Japan. In USA, the evaluations of conditions and trends of range (Arnold 1955) and prairie (Tomanek and Albertson 1957) were attempted based on the potential height and response to cutting as shown in Table 1.

Table 1. The classification of weeds based on the type of response to cutting and the growth form.

Tall-growing weeds			Short-growing weeds	
Erigeron type	*Artemisia* type	Rumex type	Short-growing annual type	Short-growing perenial type
Erigeron annuus *E. canadensis* *E. philadelphicus* etc.	*Artemisia vulgaris* L. *Sonchus asper* Hill. etc.	*Rumex obtusifolius* L. *Polygonum cuspidatum* etc.	*Cerastium glomeratum* Thuill. *Sagina japonica* *Stellaria media* Vill. *Stellaria alsine* Grimm. etc.	*Plantago asiatica* *Mazus miquelii* *Oxalis corniculata* L. *Taraxacum officinale* Wiggers etc.

To judge the trend of sown meadows, weed species were classified based on the potential height and response to cutting as shown in Table 1.

Weeds were first classified into two groups according to the plant height. One is the group of tall-growing weeds higher than the sown species and the other is the group of short-growing weeds lower than the sown species. The former is often in competition with sown species. The latter grows in harmony with sown species under a proper cutting condition. Under a frequent cutting condition, short-growing weeds invade in large quantities because of depressing the regrowth of sown species. Under an infrequent or no cutting condition, sown species completely cover the ground and shut out short-growing weeds (Nemoto and Kanda 1976)

Tall-growing weeds higher than 40 cm are pests in sown meadows. Yearly changes of biomass of tall-growing weeds under different cutting treatments are shown in Figure 2. Tall-growing weeds are classified into three types on the response to cutting. Weed species of the *Erigeron* type decrease or disappear under infrequent or not cutting and survive under an optimum cutting. Weed species of the *Artemisia* type occupy a large part of a sown meadow under infrequent or no cutting. Weed species of the *Rumex* type are not influenced by different cutting frequencies. When this type of weed is established in a sown meadow, its control by cutting may be very difficult.

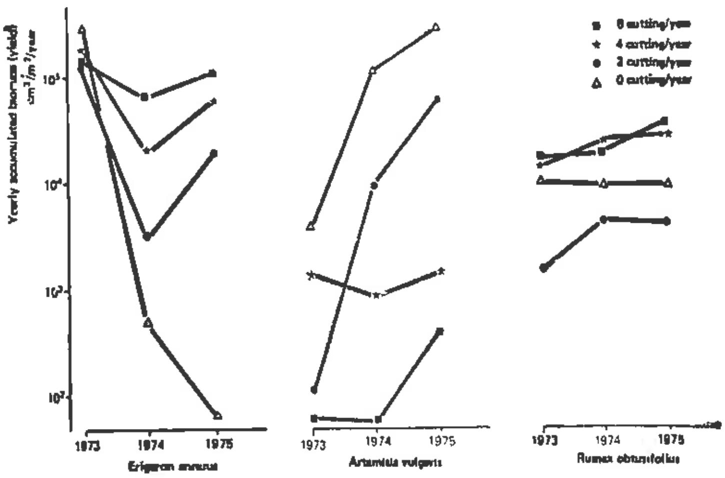

Figure 2. Yearly changes of biomass of tallgrowing weeds under different cutting treatments.

Short-growing weeds growing in a sown meadow are much lower than the height of forage grasses and are of the same height as or lower than sown legumes. This type of weed is not damaged by the cutting height of 4 - 10 cm above the ground. The biomass of weeds if this type is closely related to the space which is not covered with forage or tall-growing weeds. The number of perennial short-growing weeds in a sown meadow increases with age except in over cutting meadows. Short-growing weeds are divided into two groups according to the difference of the life span. One is the short-growing annual type, the biomass of which decreases year by year, particularly with treatments of few or no cutting frequency. Yearly changes of the biomass of short-growing annual type weeds with different cutting treatments are shown in Figure 3.

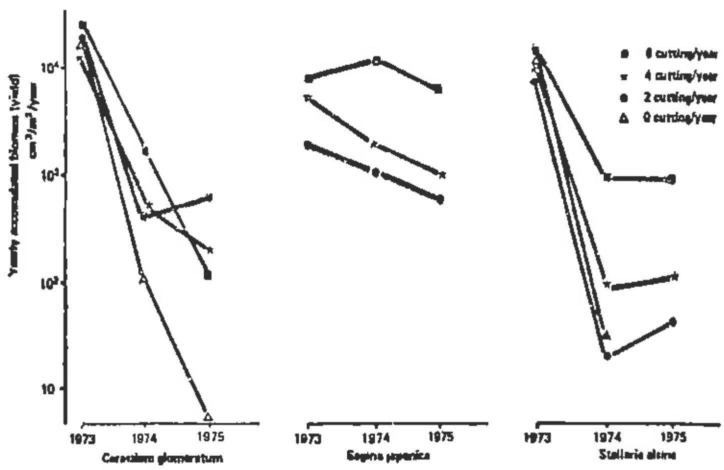

Figure 3. Yearly changes of biomass of shortgrowing annual weeds under different cutting treatments.

Another is the short-growing perennial type, the biomass of which increases year by year, but no cutting treatments shut out this type as in the short-growing annual type (Figure 4).

The evaluation of trend of sown meadows by weed communities-Method for judging the optimum cutting frequency in a sown meadow. Three typical trends of floristic composition and quantity of weeds in sown meadows under various kinds of cutting treatments are shown in Figure 5. Using Figure 5, the optimum cutting frequency may be determined.

(1) The age of meadow stands is determined by the ratio of annual to perrenial species on short-growing or the whole weed species (Sakai *et al.* 1975). It is also determined quantitatively by the degree of succession

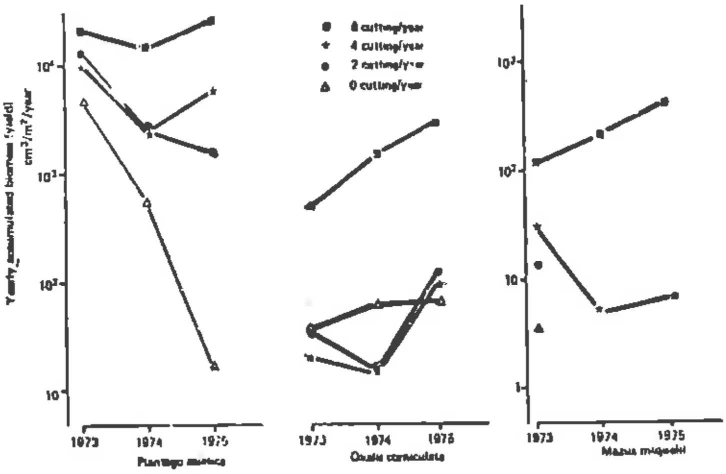

Figure 4. Yearly changes of biomass of shortgrowing perennial weeds under different cuttingtreatments.

(Numata 1970; 1976). (2) Based on the amount of each weed species and ratio of tall-growing weeds to short-growing weeds, types are recognized as follows: (I) Optimum cutting type, (II) Frequent cutting type, and (III) Infrequent or no cutting type. Then,

(I): Almost the same yield as that of the current year may be expected in the following years.

(II) : The sown meadow may have deteriorated and when the cutting frequency is decreased, it will recover.

(III): The sown meadow may have deteriorated because of progression of succession. It will recover with more frequent cutting.

Tall-growing weeds belonging to the *Artemisia* type will be eliminated from sown meadows with frequent cutting, however it is very difficult to control the *Rumex* type weeds even with frequent cutting. Elimination of tall-growing weeds may increase the yield of forages under proper fertilization.

ACKNOWLEDGEMENT

The authors are particularly indebted to professor Dr. H. Sakai, Experimental Farm, Tohoku University for his kind help in conducting our experiments.

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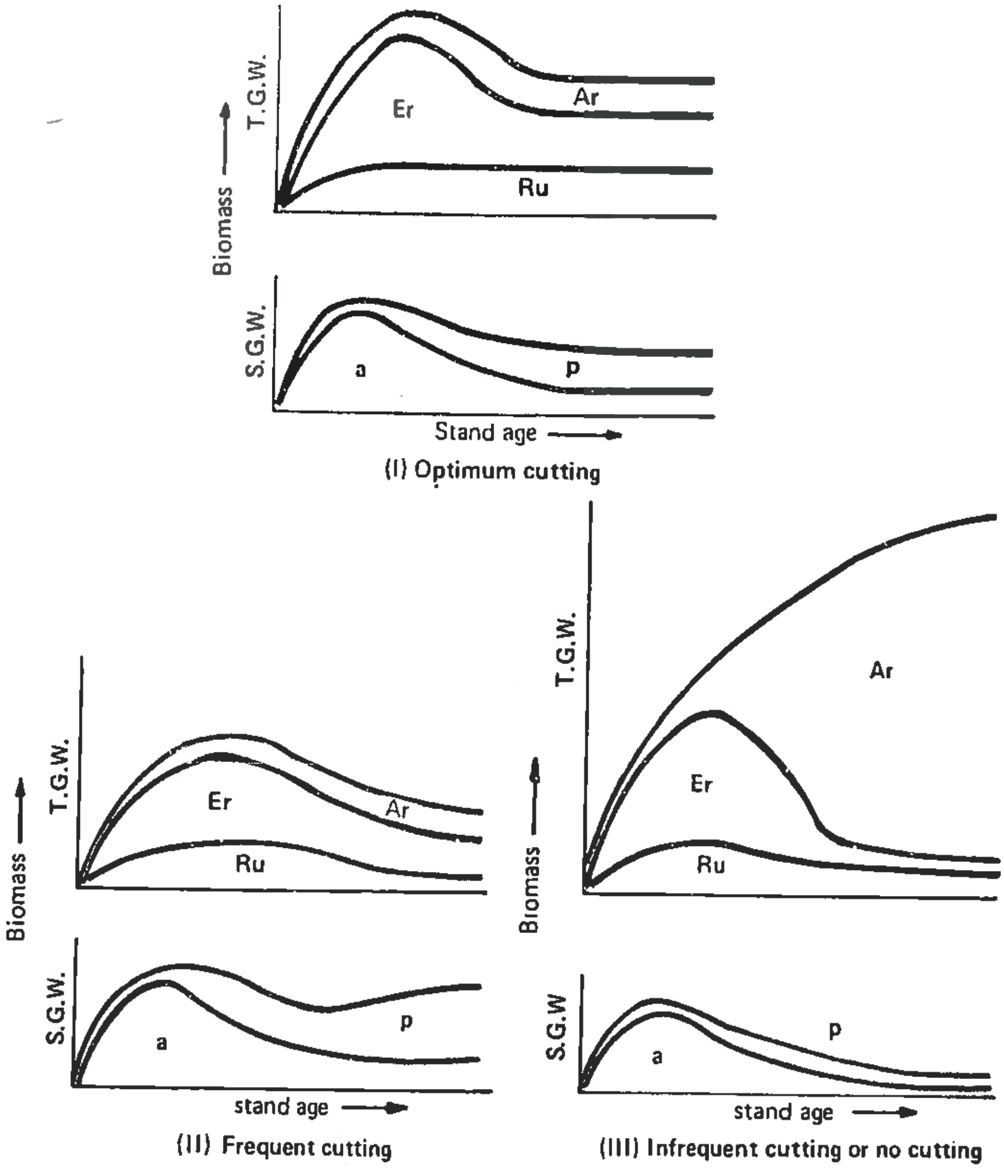

Figure 5. Diagrammatic representations of the trend of floristic composition and quantity of weeds in sown meadows under various strength of cutting. T.G.W.: tall-growing weeds, S.G.W.: short-growing weeds, Ar: *Artemisia* type, Er:*Erigeron* type, Ru: *Rumex* type, p: perennial type, a: annual type.

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Waterhyacinth [Eichhornia crassipes (Mart.) Solms] in Broiler Rations

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ABSTRACT

An experiment was conducted to study the utilization of waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) as a source of forage in a broiler ration. Ground dried waterhyacinth was incorporated at levels of 2.5%, 5.0% and 7.5% of total ration and water spinach (*Ipomoea aquatica* Forsk.) at 5.0% level was used as control. Water spinach resulted in a better average weekly gain compared to waterhyacinth at 5.0% and 7.5% levels. Feed efficiency was not significantly different. Level of waterhyacinth did not affect either weekly gain or feed conversion.

INTRODUCTION

Considerable research has been done on the utilization of waterhyacinth as animal feed for cattle (Chatterjee and Abdul Hye 1938, Stephens *et al.* 1973, Soewardi 1974), sheep (Loosli *et al.* 1954), and pigs (Choy and Devaraj 1958, Burkill 1966, Sharma 1971). However, research on utilization of this prolific plant in poultry rations is very limited, if any. The present study was intended to assess the effect on weight gain and feed efficiency of waterhyacinth in broiler rations.

MATERIALS AND METHODS

One hundred and forty four one-week old chicks of Starbro Sheaver strain were randomly assigned to 4 treatments in a completely randomized design (Steel and Torrie 1960). Six replicate groups of 6 chicks were used in each treatment. The four treatments were 2.5%, 5.0% and 7.5% levels of ground dried waterhyacinth in the diets with 5.0% level of water spinach in the fourth diet as control.

Fresh waterhyacinth and water spinach were both chopped, oven dried and then ground before being mixed in the diets at the respective levels. Composite samples of the plants and basal diet were taken for proximate analyses and their calcium and phosphorus contents which were determined by AOAC (1970) prosedures. The chemical composition is

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shown in Table 1. Rations and water were supplied *ad libitum* to the chicks which were weighed at weekly intervals up to eight weeks old.

Table 1. Chemical composition of each treatment*.

Item	Ration of Water spinach at 5.0%	Waterhyacinth at 2.5%	Water-hyacinth at 5.0%	Water-hyacinth at 7.5%
	%			
Crude protein	24.18 (23.19)	23.79 (22.14)	23.13 (22.16)	23.10 (21.93)
Crude fibre	4.25 (4.50)	4.20 (5.03)	4.65 (5.05)	5.23 (5.38)
Ether extracts	6.01 (6.21)	6.13 (6.43)	5.62 (6.10)	5.00 (6.06)
N-free extracts	57.78 (59.27)	58.25 (59.57)	58.72 (59.71)	58.44 (59.08)
Ash	7.78 (6.82)	7.63 (6.83)	7.88 (6.98)	8.23 (7.55)
Ca	1.825(1.380)	1.890(1.405)	1.915(1.545)	1.970(1.555)
P	0.895(0.685)	0.935(0.910)	0.925(0.870)	0.900(0.835)
K	1.130(1.130)	1.050(1.030)	1.180(1.215)	1.180(1.215)
Na	0.210(0.135)	0.150(0.080)	0.165(0.110)	0.190(0.110)
Mg	0.260(0.260)	0.270(0.260)	0.280(0.310)	0.330(0.345)
Fe	0.06 (0.05)	0.04 (0.03)	0.04 (0.04)	0.05 (0.04)
	ppm			
Cu	10.0 (10.0)	6.0 (8.0)	6.0 (8.0)	6.0 (8.0)
Mn	20.0 (25.0)	30.0 (25.0)	45.0 (35.0)	50.0 (35.0)
Zn	46.5 (50.0)	42.0 (45.0)	44.5 (48.5)	45.0 (49.5)

* Composition is expressed on dry matter basis.
Figure outside bracket is for starter ration and figure inside bracket is for grower ration.

RESULTS AND DISCUSSIONS

Chemical composition of waterhyacinth and water spinach in comparison with that of alfalfa *(Medicago sativa* L.*)*, presented in Table 2, showed that waterhyacinth is lower in protein content but not much different in crude fibre content. Waterhyacinth is especially rich in Ca, Mn and both waterhyacinth and water spinach are richer in K compared to alfalfa. Water spinach contains more Zn than the other roughages. Although there are wide variations in inorganic element content, the highest levels are still below the toxic levels as described by the National Research Council (1971). This is supported further by the rates of growth of the chicks in all treatments which are very close to the standard growth stated by NRC (1971) as shown in Figure 1.

According to the National Academy of Science (1976) if an animal gets more than 10% to 20% aquatic plants in its diet a mineral inbalance may result. However, this depend on the mineral content of the plant which

Table 2. Chemical composition of waterhyacinth, water spinach and alfalfa.

Item	Waterhyacinth		Water spinach	Alfalfa [a]
	%			
Protein	13.03		22.10	24.22
Crude fibre	20.16		16.60	19.91
Ca	3.09	2.20[b]	1.95	0.56
P	0.45	0.40	0.38	0.30
K	4.04	0.20	4.62	2.70
Na	0.05	0.61	0.48	0.12
Mg	0.42	0.80	0.31	0.37
Fe	0.03	0.03	0.03	0.05
	ppm			
Cu	3.23	27.30	6.17	11.95
Mn	554.66	180.10	82.33	39.83
Zn	21.00	11.15	72.04	21.53

a NRC (1971).
b Stephens *et al.* (1973).

Table 3. Average weekly gain, dry matter intake and feed conversion*.

Weekly data	Ration of			
	Water-spinach (5.0%)	Water-hyacinth (2.5%)	Water-hyacinth (5.0%)	Water-hyacinth (7.5%)
Weight gain (g)	217.9[a]	209.6[ab]	204.9[b]	201.3[b]
Dry matter intake (g)	439.3	434.0	434.3	428.0
Feed conversion	2.2	2.3	2.3	2.3

* Values with different superscripts on the same horizontal line were either significantly ($P<0.05$) or highly significant ($P<0.01$) different.

depend on the dissolved minerals in the waterways. This also explains the difference between the inorganic element contents obtained in the present experiment and those obtained by Stephens *et al.* (1973).

Data on weight gain, dry matter intake and feed conversion are presented in Table 3. The ration with water spinach at 5.0% level produced a higher average of weekly gain than the ration with waterhyacinth at 5.0% level ($P < 0.05$) and waterhyacinth at 7.5% level ($P < 0.01$); other differences are not significantly different. It was unlikely that the protein

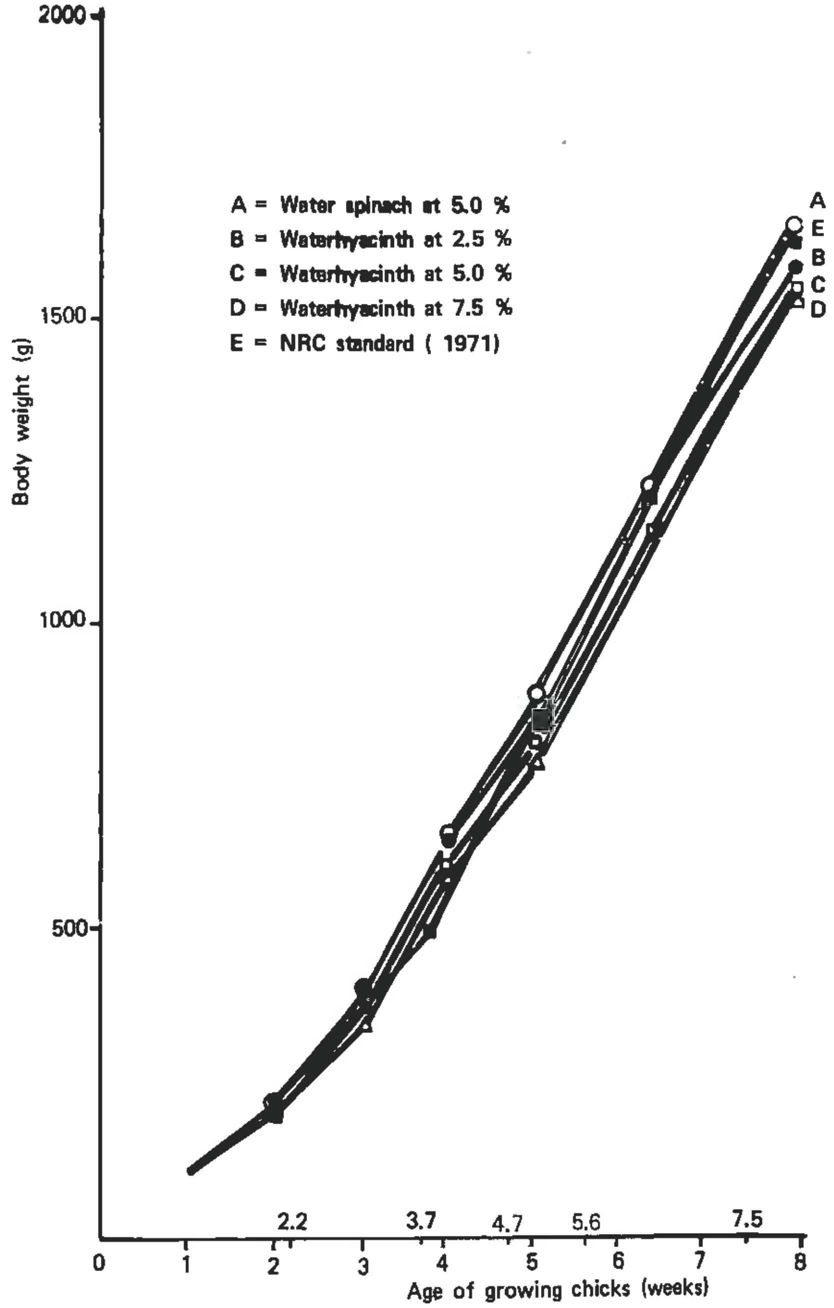

Figure 1. Relation between body weight and age.

and crude fibre content were the reasons for the ration with water spinach being superior to that waterhyacinth above 5.0% level (see Table 3). There is no way to explain this phenomenon since dry matter consumption and feed conversion were not significantly different between treatment means.

From the economic point of view the utilization of waterhyacinth has an advantage over water spinach since in many countries (NAS 1976) this latter plant is widely used as a vegetable and there is a serious competition for direct human consumption.

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A Study on the Control and Possible Utilization of Parthenium hysterophorus L.

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ABSTRACT

In the course of the last twenty five years, the neotropical weed *Parthenium hysterophorus* L. has become widely established in tropical and sub-tropical India. Its first pre-emergence control with atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino-s-triazine], chlorbromuron [3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea] and monuron [3-(p-chlorophenyl)-1,1-dimethylurea] and postemergence control with cacodylate (hydroxydimethylarsine oxide, sodium salt), bromoxynil (3,5-dibromo-4-hydroxybenzonitrile), metribuzin [4-amino-6-tert-butyl-3-(methylthio)-*as*-triazin-5(4H) one] and methazole [2-(3,4-dichlorophenyl-4-methyl-1,2,4-oxidiazolidine-3,5-dione] were reported from this laboratory. Further, the ecology, chemistry and constituents of the weed were isolated, characterised and intensively studied. The weed contains about 4.8% of KCl on dw basis. It could be a possible source for extraction of muriate of potash. The allelogen parthenin was found to possess phytocidal and germination inhibiting properties. A saponin extracted from *Parthenium* sp. when applied at appropriate doses has been observed to promote germination, leaf area and grain yields in maize, cowpea, peanut, wheat, barley, chickpea and Melilotus. The possible implications of the mechanism of action are discussed and the experimental data on chickpea and barley are presented. The current work underway on physiological and biochemical effects of the saponin is mentioned.

INTRODUCTION

Parthenium hysterophorus L. a plant of neotropical regions, imported to India as a contaminant of grain materials was reported for the first time by Rao (1965). The weed is a human and livestock health hazard. It is now established throughout tropical and sub-tropical India. In their report Dutta *et al.* (1976) communicated for the first time its pre-emergence control with atrazine, chlorbromuron and monuron and postemergence with cacodylate. The adverse side effect of 2,4-D [(2,4-dichlorophenoxy) acetic acid] for the control of the weed in the context of existing cropping patterns and safety of the other herbicides was discussed. The postemergence control with 2,4-D was reported earlier by Chandras and Vartak (1970). Further Dutta and Verma (1977) reported the control of this weed with bromoxynil, metribuzin and methazole. Autecological

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studies on *Parthenium* sp. carried out in this laboratory were communicated by Gupta *et al.* (1977). The weed was noticed to cause allelopathic suppression of other species in the vicinity of its gregarious stands. Patil *et al.* (1976) from this laboratory reported the isolation of the sesquiterpene parthenin which was identified as the allelogen. Besides parthenin, β-sitoterol, campesterol, stigmasterol, β-D-glucosides of β-sitosterol, myricyl alcohol, hexacosanol, phenolic acid, an unidentified sterol and a saponin were isolated and identified by cochromatography and IR spectra. The saponin on acid hydrolysis yielded a neutral and an acid sapogenin in addition to glucose and sugar components. The acid sapogenin was identified as oleanolic acid. The weed contained 4.8% of KCl on dw basis. It is, therefore a potassium accumulator from the soil. In the context of the heavy import of potassic fertilisers to India, the ashing of the weed for recovery of muriate of potash appears to be an interesting possibility. The allelogen parthenin was found to possess barley (*Hordeum vulgare*) and oats (*Avena sativa* L.) at 150 ppm. In guar (*Cyamopsis tetragonoloba* Taub.) and egyptian clover (*Trifolium alexandrium* L.) the germination was either inhibited or delayed at 350 ppm. The germination of the weeds *Vicia sativa* L., *Cassia tora* L., *C. occidentalis* L. was highly inhibited at 250 ppm.

MATERIALS AND METHODS

Seed-soak treatment of aqueous saponin in the range of 150 ppm to 500 ppm were tried on maize, cowpea, peanut — in *kharif* (July-October) season and wheat, barley, chickpea, Melilotus — in *rabi* (October-March) season. Germination studies were carried out on moist filter papers in petridishes at 30°C and 100% R.H. in dark for 48 hr. To eliminate the interaction of endogenous gibberellins the seedlings were next subjected to red light treatment at 30°C for 48 hr in the germination chamber. Thereafter they were grown under the ambient laboratory conditions. On the sixth day, the seedlings were transferred to pot cultures under natural conditions with 9 : 1 well pulverised soil and decomposed farmyard manure. In the field, the seedlings were transplanted to plots 1 : 2 m with 10 by 25 cm spacing and replicated twice. No additional fertilizer was applied. The chlorophyll content of the leaves were estimated from 10 mg pooled samples of equal age in 5 ml of 80% ethanol at 665 mμ according to the method of Kende (1964). The optical densities were determined with a Baush and Lomb 'Spectronic 70' Spectrophotometer.

The leaf area were determined with a 'Licor' electronic portable area meter. Other observations were by visual records (Tables 1 and 2).

Table 1. Responses of chickpea (*Cicer arietinum* L.) to saponin seed-soak treatment

Initiated on Nov. 29, 1976 = 0 day	3	4	6	4	6	Days 16
Treatments	% of germination	Axial root length in (mm) Shoot length in (mm) Before red light	After red light	Shoot length in (mm) Before red light	After red light	Shoot length
S_{150}	80	25.80±12.3	38.6±12.3	25.8± 1.9	57.2±13.0	92±38
S_{250}	95	28.60±10.9	50.7±14.0	34.0±14.6	79.4±38.8	101±23
S_{350}	85	32.5 ±18.0	62.2±28.3	31.9±14.0	80.2±32.0	102±23
Check (tap water seed-soak)	78	23.8 ±11.3	42.5± 6.0	23.8±11.3	31.1± 1.7	62±13

S = Saponin.

Table 2. Responses of barley (*Hordium vulgare* L.) to saponin seed-soak treatment.

Nov. 29, 1976 = 0 day	3	4	6	4	6	Days 18
Treatments	% of germination	Axial root length in (mm) Before red light	After red light	Shoot length in (mm) Before red light	After red light	Shoot leng (cm)
S_{150}	69	29.0±5.1	47.5±14.0	6.2±2.3	75.7±20.0	125±27
S_{250}	92	19.4±6.0	25.9± 4.2	12.6±4.5	121.7±40.0	190±18
S_{350}	88	33.7±7.0	93.3±28.0	9.7±1.3	155.7±41.0	182± 2
Check (tap water seed-soak)	65	23.8±5.1	39.9±13.0	8.3±2.4	135 ±43.0	165±12

S = Saponin.

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	Days						
6	16	42	36	61	57	86	106
n fter light	Shoot length	No. of branches	Chlorophyll content 10 mg in 5 ml = 80% EtOH O D	Leaf area cm²	Date to anthesis	Fruit set /10 plants	Grain yield /10 plants g
±13.0	92±38	3.8±1.0	0.260	4.9±1.0	72	73	42.120
±38.8	101±23	11.3±3.1	0.956	5.8±1.2	67	100	43.0
±32.0	102±23	9.2±3.0	1.097	4.9±1.2	71	75	30.153
± 1.7	62±13	8.8±2.4	0.699	3.8±1.0	70	88	32.140

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	Days					
6	18	36	75		88	106
h ıfter l light	Shoot lenght (cm)	No. of tillers	Leaf area cm²	Days to anthesis	Fruit set means /10 plants	Grain yield /10 hills g
5.7±20.0	125±27	3.2± 1.3	34.2±1.6	71	18	95.0
1.7±40.0	190±18	4.2± 1.6	59.2±1.2	67	25	179.5
5.7±41.0	182± 2	3.6± 1.0	35.5±2.0	66	21	152.9
5 ±43.0	165±12	2.8±13.0	28.6±1.2	77	17	129.5

RESULTS AND DISCUSSION

Typical responses to saponin soak treatment of seeds for a graminaceous crop viz. barley (*Hordeum vulgare*) and a legume crop viz. chickpea (*Cicer arietinum*) are presented in Tables 1 and 2. In general, germination, seminal root and shoot growth, number of tillers or branches, chlorophyll content of leaves in chickpea, leaf area, fruit set and grain yields were promoted by saponin treatment. Saponin treatment had no effects on days to anthesis. In chickpea, the best results were obtained for germination, leaf area, fruit-set and grain yield at 250 ppm. Comparable results were obtained in barley at 350 ppm.

It was evident that the saponin derived from *Parthenium* sp. had a lasting promotive effect in chickpea and barley for 106 days till harvest. From this laboratory we have already reported similar results on promotion of germination, growth and grain yields in maize, cowpea, and peanut (Patil *et al.* 1977). Seed-soak treatment of saponin at appropriate dosage levels appears to have an interesting potential as manipulative technology for exploitation in agricultural productivity in responsive crops. Heftmann (1965) has cited instances where saponin at low doses promoted germination while high doses inhibit it, in some cases the seed treatments had a persistant effect on subsequent plant growth. In general, saponin are detergents which cause depolarisation of electrical membranes, reduce surface tension of water, disrupt Van der Waal forces, cause separation of protein complexes, digitonin (a saponin) cause blood cells to lose their selective ion-permeability (Netter 1969). Schuphan (1969) reported that saponin are inhibitory to plant growth. The contradictory reports in the literature is perhaps due to dosage levels, modes of application and special characterists of the compound at the molecular level.

Investigation are underway in our laboratory to study the reactions (positive, negative or synergistic) of the saponin with IAA, GA, Cytokinins, ABA, m-inositol (in aseptic organ culture), membrane permeability through differential transport of ions to the active site, activation of adenine pool and DNA synthesis with appropriate radio-isotope, control environmental and other biochemical instrumentation facilities.

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Weed Control Systems Development Methodology in Northeast Brazil [1]

H. H. FISHER [2]

ABSTRACT

Concern has been expressed recently over two possible effects of introducing technological change in agriculture : (1) non-equitable distribution of welfare gains and, (2) introduction of socially inefficient technologies. Observing that weeds cause serious losses in food crops, many developing nations wish to leap from the hoe to herbicides. However, chemical weed control closely resembles mechanization in that both are potentially laborsaving. Compared with the hoe, a backpack sprayer can reduce weeding labor requirements 20 fold in annual crops. Premature adoption of herbicides in low-wage, labor abundant economies can displace agricultural workers, leaving them limited alternative employment opportunities. It might be concluded that where labor constraints exist during peak weed control periods and land is not limiting, the introduction of modern weed control techniques could allow crop area expansion or cropping intensification, thereby expanding labor utilization. However, correct evaluation of each situation must be based on social opportunity costs of labor and capital rather than subsidy-distorted market prices. Two case studies shown below were conducted by Oregon State University (OSU), the Brazilian Enterprise for Agricultural Research (EMBRAPA) and the United States Agency for International Development (USAID): (1) the sugarcane, hired-labor, plantation economy of the humid, coastal area of Pernambuco State and, (2) the diversified. small "family farm" agriculture of that state's semi-arid Agreste region. Project objectives of these studies of the dualistic agriculture structure, typical of many less developed nations, were: (1) to develop effective and economical weed control systems for small and medium-sized producers of food crops in the Agreste, (2) to evaluate the socio-economic impacts of the systems on the farm and associated labor pool and, (3) to estimate efficiency trade offs to achieve other societal goals such as greater rural employment and more even income distribution. Development of these systems was based on adequate on-site field research and careful analyses of the prevailing agronomic, socio-economic and political situations. In the sugarcane case study it was estimated, from linear programming models, that if herbicides and labor were available at social or free market prices, employment would be reduced by 0 to 27% under integrated (mechanical and chemical methods) short run conditions, and 0 to 70% under pure chemical long run conditions as compared to manual weed control methods depending upon the seasonal wage increases. Corresponding labor earnings reductions would be 0 to 26% and 0 to 68%, respectively. At current government subsidy-distorted prices, corresponding reductions would be 45 to 57% and 71 to 91% for employment and 43 to 53% and 64 to 84% for earnings, considering both short and

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[1] This study was conducted in the state of Pernambuco, Northeast Brazil within the period June 1973 — June 1976.

[2] Weed control specialist, International Plant Protection Center (IPPC), Oregon State University, Corvallis, Oregon 97331/USA.

long run conditions, respectively. In the diversified agriculture region hoeing was the most effective and economical weed control method under existing cropping patterns, climate and socio-economic conditions. In crops where herbicides or mechanical cultivation appeared economically more viable, human and capital constraints and infrastructural deficiencies restricted their use. Project experience indicates that new technology distributional changes can best be studied on large-scale agricultural enterprises where such innovations are adopted first. In addition to assisting the small farmer, meaningful efforts can be channeled toward those who are often the poorest of the third world, the landless agricultural workers on plantations. Also, focusing only on weed control is not sufficient. There are often many more serious problems. Besides a dearth of general agricultural technology the small Agreste farmers suffered from: a lack of extension assistance, little agricultural credit, regressive land taxes, crippling government restrictions on small land parcel exchange, a shortage of land, extremely unpredictable weather and, under/unemployment, in addition to the weed problem.

INTRODUCTION

Developing effective and economical weed control systems for small food producers in developing nations requires an indepth comprehension of the existing agronomic,socio-economic and political situations; a multidisciplinary approach and a close working relationship with the farmer.

Interest in cropping systems and conducting research with the small farmer have increased significantly during the past five years. Several international agricultural research centers, as well as regional and national institutions, have initiated research programs along these lines.

Reasons for this include: (1) increasing awareness that agricultural research results are generally ignored by small farmers, (2) a better understanding of the small producer and his production system in order to identify appropriate intermediate technology, (3) a concern that small farmers in the tropics have been bypassed or overlooked in traditional agricultural research and development programs coupled with the realization that very little is known about him, his household, or his management problems, (4) an increased awareness that world food needs can best be met by intensifying production on existing lands, some of which are marginal and will not receive all the inputs that high yielding varieties may require, (5) the fact that small farmers around the world produce more food per unit area of land than larger producers, and (6) an increased awareness of the need for an overall management approach to pest control within the dynamic crop environment.

The small farmer should be an integral part of cropping systems research. Studies should be conducted with him, on his farm and under his management. In this manner practical weed control systems, employing various methods, singly or in combination, can be developed. His yields will be increased and his living standard will be improved.

Much time and labor are often needed for weeding. Mechanization and herbicides, unlike most "Green Revolution" inputs, are strongly labor-saving. For example, the leap from the hoe to herbicides was found to reduce labor requirements about 20-fold in annual food crops from 25 man-days/ha to 1.2 man-days/ha in Northeast Brazil (Scolari and Young 1976). Premature adoption of chemical weed control in low-wage, labor-abundant economies can displace agricultural workers; leaving them few alternative employment possibilities. Thus, a multi-disciplinary approach, focusing on all consequences of introducing more sophisticated weed control technologies, is essential.

The purpose of this paper is to present the methodology or approach employed in achieving these three project objectives within the framework of Northeast Brazil's dualistic agriculture. The development and evaluation of weed control systems within the ecosystem of the Agreste small food producer was a site-specific research effort. The crop-area specificity of the plantation sugarcane economy survey is also evident. However, the distinct, two-part agriculture, i.e. the family, food crop farm as opposed to the export commodity plantation, is ubiquitous among the world's developing nations. It is hoped, therefore, that the Northeast Brazil experience will have world-wide usefulness wherever similar ecological and socio-economic conditions exist.

MATERIALS AND METHODS

A variety of weed control methods were used in the Agreste agronomic field experiments. Hoeing was carried out with the heavy-handled, wide-bladed hoe typical of the region. Animal traction cultivation was realized with the 5-sweep, adjustable row width cultivator purchaseable at the local farm stores. Mechanical cultivation, soil incorporation of volatile herbicides and some land preparation was accomplished with a walk-behind, diesel-powered tiller equipped with rotovator. Herbicides, available locally or orderable from larger cities, were applied broadcast with a one-wheeled, compressed air plot sprayer equipped with adjustable boom utilizing Tee Jet nozzles. Where only the crop row was treated, herbicides were banded with a one-nozzle, belt-supported, plot sprayer using CO_2 gas as propellant. This latter sprayer, equipped with a 4-nozzle boom, was also used in broadcast situations.

For the socio-economic surveys of farms and their associated labor pools, questionnaires were designed and pretested with a limited number of farmers. Then improved questionnaires covering each farmer's household, agriculture and off-farm employment opportunities were developed.

Agronomic and socio-economic data were collected in the two study zones through literature review, agronomic experiments, and farm surveys. Enterprise and total farm budgets were prepared for the important crops and weed control alternatives. Mathematical models oriented to both farm and regional decision making were developed. Different weed control systems and policies were investigated to determine their effect on the decision parameters of economic efficiency, employment, and income distribution.

A growing need exists to evaluate distributional as well as efficiency consequences of adopting new agricultural technology. The project developed a theoretical framework for evaluating short-term benefits and costs (welfare implications) of adopting herbicides within the study regions. Two basic reasons for adopting new technology are: (1) technological breakthroughs or exogenous market forces that make the new technique more efficient, that is, allow expanded output at a given cost when all inputs are at their social prices[3] (efficiency-enhancing developments, Table 1), (2) factor price distortions, or other forms of government intervention, that can make a new technique privately profitable,

Table 1. A theoretical classification of welfare changes due to technical change in agriculture.

Cause	Efficiency changes	Distributional changes
Efficiency-enhancing developments	I (Gains)	II (Gains or losses)
Market distortions	III (Losses)	IV (Gains or losses)

Source: OSU/EMBRAPA/USAID Weed Research Project. Recife, Pernambuco, Brazil.

but not socially efficient when evaluated at the true social values of the utilized resources (market distortions, Table 1). Government policies which lower the capital/labor price ratio include several types of subsidies for capital inputs, exemption from levies and taxes and restrictive labor legislation. Efficiency changes reflect society's resource cost to produce a given output. Distributional changes refer to the spreading of welfare benefits and costs among different groups in society.

Through linear programming models and partial budgeting the project was able to predict the diffusion of modern weed control technologies and measure changes in rural labor employment and earning and differences in economic efficiency of various weed control systems within the two study regions.

3 Social prices prevail under free market conditions in the absence of price distortions caused by government intervention or other forces.

The agricultural, socio-economic and political situations in any research area must be thoroughly understood before the choice of an appropriate weed control technology can be made (Young and Miller 1976). This situation was explored initially in 71 interviews with Agreste farmers; mostly small and mediumsized producers, and their families. Some large farmers were also included since they commonly employ agricultural workers. Additional surveys and literature searches were carried out as needed. From this information six basic types of agro-socio-economic field experiments were then designed and executed to study the following areas of interest: (1) Economic trade off between labor (numbers of hoeings) and capital (rates of herbicides), (2) herbicide selectivity for monocrop and intercrop systems, (3) interaction between manual (number of hoeings) and cultural (crop spacing/density and fertilizer level) methods, (4) integration of various control methods (hoes, cultivators, herbicides) in relation to labor availability during the year, (5) comparison of cultural, manual, mechanical, chemical and integrated methods, and (6) preplant tillage methods for removal of weed flushes.

These experiments were carried out during two crop years under both traditional (hoe-cleared, no fertilizer) and modern (mechanical tillage, with fertilizer) land preparation, in monoculture and intercrop situations, and in most instances, on small farmers' properties and under their management.

By seeking first to understand the Northeast Brazilian Agreste farmer, his household and each of his complex cropping systems it was possible to design research that bettered his weed control practices. Improvements were small, but substantial, thus increasing crop production and improving the farmer's life by using a technology, an intermediate technology, that he understood, helped develop, and could afford.

RESULTS AND DISCUSSION

The plantation sugarcane case study was undertaken since it concentrated on a commodity very vulnerable to rapid technological change in weed control with its accompanying socio-economic repercussions. In Northeast Brazil the sharp division between wealthy plantation owners and poor, generally landless agricultural workers causes potential benefits and losses of herbicide adoption to belong to clearly distinguishable groups.

Although only about 10 to 15% of the sugarcane area is presently herbicide-treated, current favorable government policy indicates that eventual profitable adoption of chemical weed control will occur in the entire zone. This will happen as skilled manpower, technical and economic constraints are overcome. With both labor and herbicides available at government altered private prices, herbicide use is now profitable in at least 89% of the sugarcane region even without seasonal labor cost increases (Table 2).

Table 2. Percent of total sugarcane area adopting chemical weed control under different situations. Pernambuco State, Northeast Brazil 1976.

Situation	Integrated systems Seasonal wage increase (%) 0	 50	 100	Pure chemical systems Seasonal wage increase (%) 0	 50	 100
Herbicides unavailable, labor available at its social price	0	0	0	0	0	0
Both herbicides and labor available at their social prices	0	9	39	0	39	76
Both labor and herbicides available at their private prices	89	100	100	100	100	100

Source: OSU/EMBRAPA/USAID Weed Research Project. Recife, Pernambuco, Brazil.

If the government did not provide incentives to plantation owners and labor and herbicides were available at social prices and a realistic seasonal wage increase of 50% were assumed, then it would be predicted that only 9 to 39% of the zone would eventually adopt herbicides over the short and long run, respectively (Table 2).

Aside from distributional effects, there are also changes in labor employment and earnings with adoption of more sophisticated weed control methods. At private prices employment and earnings of agricultural workers drop from 45 to 91% and 43 to 84% compared to manual methods, considering both short and long runs as well as integrated and pure chemical systems (Table 3). At social prices corresponding losses are 27 to 70% to employment and 26 to 68% to earnings (Table 4).

Government intervention can allow up to a 25% savings in weed control costs (over social costs) to the plantation owner, but with an accompanying, severel distributional impact. As much as 16.21 cruzeiros can be lost to agricultural workers for every cruzeiro gained by the plantation.

Agronomic and socio-economic research conducted within the Caruaru County Agreste region provided the following information.

Table 3 : Percent change in weed control employment and labor earnings due to availability of herbicides at private (distorted) prices rather than social (corrected) prices under various assumptions. Pernambuco State, Northeast Brazil 1976.

Item	Short run Integrated systems Seasonal wage increase (%)			Long run Pure chemical systems Seasonal wage increase (%)		
	0	50	100	0	50	100
Employment	-57	-56	-45	-91	-86	-71
Labor earnings	-52	-53	-43	-84	-79	-64

Source: OSU/EMBRAPA/USAID Weed Research Project. Recife, Pernambuco, Brazil.

Table 4 : Percent change in weed control employment and labor earnings due to availability of herbicides at social prices under various assumptions. Pernambuco State, Northeast Brazil 1976.

Item	Short run Integrated systems Seasonal wage increase (%)			Long run Pure chemical systems Seasonal wage increase (%)		
	0	50	100	0	50	100
Employment	0	-8	-27	0	-39	-70
Labor earnings	0	-8	-26	0	-37	-68

Source: OSU/EMBRAPA/USAID Weed Research Project. Recife, Pernambuco, Brazil, 1976.

Caruaru county farm survey

The data from a 71-farm, stratified, random sample survey conducted during late 1974 was analyzed in detail during early 1975. In late 1975 the project conducted a follow-up survey (focusing on long-run crop yield variability) that included 29 of the 1974 interviewees, plus 14 additional selected farmers.

Some findings of these surveys were :

(1) Small farmers and tenants were the primary producers of several local varieties each of the basic food crops, maize *(Zea mays* L.), dry beans *(Phaseolus vulgaris* L.) and cassava *(Manihot esculenta* Crantz), that the project was concerned with. Large farmers emphasized livestock

enterprises, forage and fodder crops, and some perennial cottons *(Gossypium* spp.)

(2) Hired labor used on medium or large farms was primarily drawn from the vast number of very small farmer and tenant households. Many of these small farmers/hired workers also found employment in the non-farm sector, or in home industries. Two-thirds of all owners of farms larger than 50 ha did not reside on their farms, but nearly all small farmers were resident operators.

(3) Families of the very small farmer/worker, with properties to two hectares, suffered substantially poorer diets, lower school attendance rates, and more reduced income levels than farmers with slightly larger properties. Many had travelled to areas outside the country to seek employment in the past and some continue to do so; as far as four to five days' journey to southern Brazil industry and construction jobs.

(4) Ant poison was the only modern input employed by a majority of sampled farmers; chemical fertilizer was used on only one farm. About one quarter of the farms 2 ha had used some animal or tractor power, usually rented, for land preparation.

(5) Crop yields per hectare were consistently low and did not vary significantly by farm size.

(6) Weed control was carried out exclusively by hoeing on 100% of the sample farms. Rare instances within the country of the use of animal traction cultivation in cassava, and herbicides in vegetables were noted outside of the survey. Not one of these exceptions occurred in the survey random sample indicating the dominance of traditional weed control practices in the area. Rationality of this choice is supported by the results of repeated project experiments on the efficacy of hoeing for local crops, as well as the economics of herbicide use in popular combination of intercropped maize and beans.

(7) Farmers in the survey sample hoed local crops well within the early critical period of weed competition and hoed more frequently than was minimally necessary to prevent crop yield reductions (Table 5). These findings contradict frequent observations in other regions, especially Africa, that small farmers either hoe too late or not enough (Druijff and Kerkhove 1970). Undoubtedly the availability of labor and the severity of the weed problem are key factors.

Field research

The first year (1974) experimentation was initiated to determine what effect weeds had on maize (var 'Azteca') and beans (var 'Costa Rica')

Table 5. Number and timing of weedings in intercropped maize and beans[a] and in monoculture cassava, Caruaru Municipio, Agreste, Pernambuco, Brazil 1974.

Crop and farm size (ha)	Average number of weedings	Average days after planting	
		to first weeding	to second weeding
Intercropped maize and beans			
0 — 1.99	2.3	17.0	47.0
2 — 4.99	2.2	16.5	55.2
5 — 19.99	2.2	19.1	44.3
20 — 49.99	2.1	17.1	36.6
50+	2.3	19.7	42.2
All	2.2	18.0	44.8
Monoculture cassava			
0 — 1.99	5.0	31.5	85.0
2 — 4.99	7.6	28.7	62.0
5 — 19.99	3.7	30.2	83.3
20 — 49.99	3.5	—	—
50+	—	—	—
All	5.4	29.9	74.0

Source: OSU/EMBRAPA/USAID Weed Research Project Farm Survey, 1974.

[a] Intercropped maize and beans contained, on the average, three crops. These included maize, at least one variety of beans (common dry, lima (*P. lunatus*), or cowpeas (*Vigna unguiculata* Walp.)), and sometimes perennial cotton, fodder cactus (*Opuntia* sp.,) and/or castor beans (*Ricinus communis* L.).

both as monocrops and intercropped and to ascertain the relative efficiency of the various weed control systems, along with their relationship to other cultural practices such as plant spacing and density and fertilizer application. In 1975 agronomic research was designed to confirm the previous year's findings and to examine facets not studied previously, such as effect of pre-seeding tillage (weed flush removal) on crop weed populations. All field experiments, except the three herbicide selectivity trials, were conducted using traditional methods for the regions (manual seedbed preparation without the addition of fertilizer).

In 1975, field research was carried out on dry beans, grain sorghum (*Sorghum bicolor* var 'icapau' and cassaya (var 'crovela'), all as sole crops and maize intercropped with dry beans.

Information obtained from these two years of field research follows. There were no significant yield differences between manual weeding and properly executed alternative methods in beans, maize and sorghum field trials (Table 6). Since chemical and mechanical methods are more costly, using both private and social prices, manual methods were determined to be the most efficient for small farms. Other constraints to the use of herbicides by most Agreste small and medium farmers are: a very low level of education among the rural population, insufficient personal capital or easily accessible credit for the purchase of application equipment and chemicals, and high risk due to rainfall variability, high incidence of disease and insect damage, and an unstable market which all combine to discourage substantial financial outlays for modern inputs.

Table 6: The relative efficacy[a] of alternative weed control systems in selected field experiments, Caruaru municipio, Agreste Pernambuco, Brazil 1974 — 1975.

System	Crop		
	Beans	Maize	Sorghum
		Index of Yield	
No weed control	0.29	0.61	0.57
One hoeing	1.00	1.00	1.00
Two hoeings	1.01	—	1.03
Herbicide	0.99	0.84	0.95
Herbicide plus hoeing	1.05	0.88	—

Source: OSU/EMBRAPA/USAID Weed Research Project. Unpublished results of 1974 and 1975 field experiments. Recife, Pernambuco, Brazil.

[a] Relative efficacy is measured in terms of crop yield achieved by a given weed control system. For comparison, yield achieved with one hoeing was used as a base with an index of 1.00.

In addition, climatic considerations, especially the shortness of the growing season due to moisture limitations and the highly unpredictable weather, generally preclude in the Agreste the possibility of multicropping, overlap cropping or other intensive practices conducive to herbicide use and precise timing of weed control during periods when labor demands are high.

In summary then, it was found that well--timed manual weed control (hoeing) was a generally effective and economical technique under the prevailing soil, water, crop and socio-economic conditions.

Chemical and mechanical controi methods appeared to be more promising economically for cassava and sugarcane. Sugarcane in Northeast Brazil is generally grown on larger farms where the chemical and labor price structure induces growers to switch to herbicides. Cassava, on the other hand, is primarily produced on small acreages. Survey results indicate that manual weed control methods are used exclusively in the production of cassva due to various constraints.

One of the project goals has been to seek world-wide applicability of research results. Several considerations potentially transferable from Northeast Brazil to other regions of the world possessing simiiar climatic, agronomic and socio-economic conditions are :

(1) In areas of general labor abundance and small farms with land shortages that predominantly grow food crops and that are operated by personnel with limited capital and little training, manual weed control methods are likely to be the most economical and efficient. Even serious price distortions in favor of modern inputs — including chemicals — are insufficient to force a switch to herbicides. Areas where this relationship generally prevails are: the majority of Africa, Central America, most of northern South America, and most of Asia.

Less labor-intensive weed control methods may be applicable in certain labor shortage periods, even with food crops. Timeliness of weeding is always critical; when labor demands for weeding conflict with other farm activities or employment, weed may be left uncontrolled resulting in yield reductions. Chemical or mechanical weeding could be an economical alternative under these conditions. Costs of herbicides suggest that a combination of herbicide and hand weeding would also be promising.

(2) Plantations and large commercial farms are not restricted to manual methods of weed control. Higher labor costs, more abundant credit and capital, and generally more favorable government policies in the forms of subsidies and support prices encourage shifting to more advanced weed control methods.

Government intervention in factor markets is not neutral with regard to technology utilization. Price distortions can cause shifts in technology and subsquently in factor useage. This is not universally true, of course. In the Agreste, the least cost methods of weed control in food crops, using either distorted private prices or undistorted social prices, are identical.

However, for the sugar plantations of Northeast Brazil the least cost weed control method is consistently chemical when private prices are used and manual when social prices are used. The only inputs for which the private and social costs vary are herbicides and labor.

(3) Manual weed control methods are generally impractical for small grains such as wheat, barley and rice[4] which are not easily hand weeded. Chemical control methods on these crops may be feasible, in spite of the severe economic and educational limitations previously mentioned.

(4) In situations where land itself is not limiting, the major factor determining how many hectares a farmer will plant is his ability to clear the land (before planting) and to keep the crop weeded. Therefore, greater ability to control weeds could result in an appreciably greater area of land being planted, an important consideration in an era of increasing pressure on food production.

(5) Periods of adverse weather often delay manual weeding resulting in yield losses. While most herbicides are not weatherproof, they can be applied rapidly and thereby deter weed growth during periods when manual or mechanical weeding is impossible. Weather can, however, cause problems if highly unpredictable, such as being subject to downpours.

(6) The need for quick turn-around time in multiple systems may require the use of chemicals to maintain clean fields since labor, faced with a variety of cultural tasks, often has a high opportunity cost and is needed elsewhere.

(7) Proper seedbed preparations that remove "weed flushes" prior to planting are important. Chemical, mechanical, or manual methods may be employed, however mechanical methods have a complimentary effect of increasing water infiltration rates in dry areas such as Northeast Brazil. Chemical methods, on the other hand, have an advantage of not bringing more weed seeds to the surface where they can germinate, or of causing physical damage to crop roots as a hoe blade may.

(8) When the question of appropriate weed control technology is considered from a regional viewpoint (where employment and income distribution as well as economic efficiency are involved), alternative government policies regarding weed control also have important effects on other regional objectives. Government policy may greatly favor the large farm owner, but at the expense of agricultural workers.

(9) The welfare of small farmers cannot be improved significantly by only focusing on a single problem, such as weed control which must be seen as part of a much larger and more complex system. Institutional barriers such as credit shortages, lack of extension assistance, regressive land taxes and crippling restrictions on exchange of small land parcels are interwoven with factors such as adverse climate and a general lack of agro-

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4 Although these three crops were not studied in Northeast Brazil, the project has had considerable experience with them in other countries.

nomic technology. The entire system must be analyzed and the interactions and major constraints understood and quantified before major improvement will be forthcoming.

(10) Large and small farms and the landless rural labor force in the areas studied are limited through seasonal migration. This interrelation and the potential for technologic displacement, has often been overlooked by research oriented only to small farmers. In many situations research and policies concerned with preserving or improving small farmer seasonal plantation employment may have greater bearing on welfare than any marginal improvements in farm management or technology addressed toward their own small farm operation.

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Ecological Effect of Some Herbicides and the Systems Concept of Weed Management

I. N. OKA [1]

ABSTRACT

The ever increasing pest problems since the introduction of modern agricultural technology into developing countries need urgent solution. Weeds are also among those pests which are very significant in reducing crop yields. Chemical weed control is gradually gaining acceptance today because of its effectiveness. Also because of increased wages of laborers hired in some areas of agriculture to do the weeding by hand. However, some herbicides were documented having certain environmental impact, for example they increased insects and diseases, and were detrimental to some beneficial and non-target species. Hence, there is a need for sound ecological basis for weed control. Its aim should be to maintain the desired yield, economically, but at the same time with a minimum unwanted side effect. In this respect judicious and more efficient use of the herbicides should be emphasized. The more so due to the energy crisis causing increased prices of the agricultural chemicals. To achieve this goal the systems concept of weed management would be most appropriate. It may consist of (1) resource reduction, (2) integration and (3) cost/benefit analysis.

INTRODUCTION

In developing countries food shortages still have to be overcome. Indonesia, for example, with 130 million people in 1977, will have to feed about 250 million people by year 2000 (Djojohadikusumo 1976).

Introduction of modern agricultural technology is undoubtedly the only way to meet the challenge. Weed problems are one of the many constraints in modern crop production. Studies indicated that proper weed control in tropical rice increased the yield very significantly. Control of weeds by chemical means gains more and more acceptance today (NAS 1971). However, aside from its benefits, some ecological consequences were also documented (Pimentel 1971). This paper is a review and discussion on the significance of weeds and the ecological impact of some herbicides on the environment.

The systems concept of weed management (Pimentel 1974) is proposed to fulfill the need for high yields, and to maintain a healthy environment.

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SIGNIFICANCE OF WEEDS

Weeds are unwanted plants for various reasons. In cropland weeds compete successfully with the main crops, resulting in reduced yields and lower quality of produce. Losses caused by weeds exceed the losses from any other category of agricultural pests (NAS 1971). There are more than 30, 000 species of weeds throughout the world. About 1800 of them are economically very important. Losses from weeds are greatest in the tropics. Weeds cause a 30% drop in yields of corn in tropical countries. In India, weeds reduce production of food crops from 30 to 100% (Matsunaga 1967). Half or more of the total effort of farming may be devoted to weeding. Proper weeding increases the yield of rice by 45% (NAS 1971). Some weeds are poisonous to livestock. Other weeds may serve as source of inoculum for certain plant pathogens or may be alternate hosts for insect pests of our crops (Emden 1970). Russian thistle, for example, is an important host of the migrating beet leafhopper that transmits curly top virus (NAS 1971). In the Caribbean several weeds harbor the sugarcane froghopper. In Sumatra, *Eupatorium adenophorum* Spreng is a host of tobacco pseudomosaic virus (Kasasian 1971). Water weeds may interfere with irrigation systems.

Under certain situations, however, weeds may become beneficial. They reduce soil erosion on abandoned land, provide food for cattle and wild life, or are used for drugs or delicacies (NAS 1971). They also may give shelter to certain species of predators and parasites of harmful insects. For example, the presence of weeds among brussel sprouts provide a suitable habitat for some arthropod predators of the small cabbage white, *Pieris rapae* (Dempster 1969). *Harpalus rufipes*, an insect predator, is particularly dependent on ground cover. In weed free corn fields more corn plants become infected with corn stunt disease (mycoplasma) as compared to plots infested with weeds *Bracharia platyphylla* (Pitre and Boyd 1970). Some weeds, such as *Tagetes* and *Polygonum* secrete substance that control parasitic nematodes. *Polygonum hydropiper* L. for example inhibits nematode infestation of wheat seedlings (Sukul 1970).

HERBICIDAL CONTROL OF WEEDS

To protect the crop man has practiced various weed control methods such as prevention, biological, managerial, physical, and herbicidal control (NAS 1971). The use of herbicides have been increasing in many parts of the world for the past 30 years. For example, in the United States 63% of peanut acreages, 59% of potato, 57% of corn, 52% of rice, and 52% of cotton acreages receive herbicide treatments (USDA 1968; 1970a, Pimentel 1973). In the tropics, herbicide use is also increasing rapidly on food and other crops (Kasasian 1971).

In 1963 — 1964 crop season in India about 2.5 million ha received herbicide treatments (Pesticide Assoc. India 1968). In tropical Asia 2,4-D (2,4-dichlorophenoxy acetic acid) and MCPA [(4-chloro-o-tolyl)oxy] acetic acid) are used more widely in rice fields to effectively control both broad-leaved weeds and grasses when applied before the weeds emerge (De Datta and Lacsina 1972). In the Philippines both chemicals save farmers about one-fourth to one half the cost of hiring labor to weed by hand (De Data *et al* 1968). About 50% of the 3000 tons of herbicide used in India was 2,4-D (Pesticide Assoc. India, 1968). Particularly for estate agriculture, rising wage rates is one of the reasons for the gradual replacement of conventional hand weeding with herbicides.

ECOLOGICAL EFFECT OF HERBICIDES

Interactions among herbicides, weeds, insects and plant pathogens are extremely complex (Zweep 1970, Emden 1970, Katan and Eshel 1973). For example, herbicide treatment may result in an increase or decrease of certain pests depending on the following mechanisms (Zweep 1970, Katan and Eshel 1973):

1. direct stimulation or toxic effects of the herbicide on pests;
2. indirect effect of herbicides on the treated plants, i.e, host susceptibility/resistance and the consequences of these effect on the attack of the pests;
3. effect on the relationship between pests and other microorganisms.

The discovery that certain herbicides have a synergistic effect on the action of certain organophosphorus insecticides (Lichtenstein *et al* 1973, Liang and Lichtenstein 1974) adds to the complexity of the problem.

Thus the use of herbicides to control weeds seems to be a mixed blessing, because herbicides have also been found to have detrimental effect on certain components of the life system. Pimentel (1971) gave a comprehensive review on the effect of herbicides on non-target species. For example, certain concentrations of 2,4-D caused death of reindeer, caused reindeer to abort their young, resulted in death of silver salmon, blue gills, tadpoles, and several species of arthopods, annelids and other vertebrates, and markedly reduced egg production of chickens. A mixture of sodium salt of 2,4-D and superphosphate applied as serial sprays resulted in distress and 20% mortality in field honey bees, (Palmer-Jones 1964), but the adverse effect of the herbicide can not be detected 12 or 16 days after treatment. 2,4,5-T (2,4,5-trichlorphenoxy acetic acid), silvex [2-(2,4,5-trichlorophenoxy) propionic acid], 2,4-DB [4-(2,4-dichlorophenoxy) butyric acid], EPTC (S-ethyl dipropylthiocarbamate), chloramben (3-amino-2,5-dichlorobenzoic acid) and dalapon (2,2-dichloropropionic acid) also severely reduced or eliminated brood production of the insect at concentrations of 100, 500 and 1000 ppm (Morton and Moffett 1972).

In a number of instances 2,4-D has also been found to increase insect and plant disease problems. For example, Ishii and Hirano (1963) and Hirano (1964) demonstrated that when the Asiatic rice borer, *Chilo suppressalis* was fed on rice plants treated with 2,4-D, it grew significantly larger (45%) than the same species fed on untreated rice. Adams and Drew (1965) reported that both *Rhopalosiphum padi* and *Microsiphum avenae* on 2,4-D treated oats were 39% more abundant than those reared on untreated oats. Laboratory experiments showed that corn plants treated with 2,4-D at 5, 20 and 80 ppm concentrations significantly increased the reproduction of corn leaf aphids, *Rhopalosiphum maidis* (Oka and Pimentel 1974). Field experiments also showed that corn plants grown on fields treated with 2,4-D at a rate of 0.14 kg and 0.55 kg/ha had significantly more aphids compared to the nontreated plots. The percentage of corn plants infested by the corn borer larvae, *Ostrinia nubilalis* was significantly higher on plots treated with 2,4-D at a rate of 0.14 and 0.55 kg/ha as compared to the untreated plots. Laboratory tests showed that mean weight of corn borer pupae obtained from larvae reared on corn treated with 5, 20, and 80 ppm 2,4-D were significantly heavier compared to the nontreated plants. Corn plants treated with 20, 40, 100 and 200 ppm 2,4-D had significantly more lesions of Southern Leaf Blight, *Helminthosporium maydis* pathogen (greater than 1 cm in length) than plants treated with 10 ppm of 2,4-D (Oka and Pimentel 1976). *Nicotiana tabacum* L. ("Samsun NN") hypersensitive of TMV, after treatment with 2,4-D at concentrations of 4.5 x 10^{-4} and 4.5 x 10^{-3} M, showed an increase of TMV lesion diameter of 2.27 mm and 2.71 mm respectively compared to untreated plants which had 1.51 mm lesions (Simon and Ross 1965). Cheo (1969) also found that tobacco treated with 2,4-D increased both susceptibility to TMV infection and TMV biosynthesis even though 2,4-D inhibits TMV *in vitro*. Cotton, which is highly resistant to TMV infection, if treated with 2,4-D resulted in increased replication capacity of the virus. Cheo (1971) suggested that 2,4-D can act in two ways, either by stimulating TMV biosynthesis through a higher rate of RNA turnover or by the production of ethylene which is known to repress metabolic resistance.

Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] was reported to cause breakdown of resistance of a resistant maize variety (Pa_{54}x Pa_{11}) to maize dwarf virus (MacKenzie *et al.* 1964). Application of atrazine at dosages ranging from 0.5 to 2 ppm resulted in about 50% reduction of the following bottom organism: waterbugs, mayfly nymphs, horsefly larvae, common midges, mosquitoes, phantom midges, biting midges, caddice fly larvae, aquatic worms and leeches. On the other hand, damselfly nymphs and water beetles doubled their number after application of the herbicide (Pimentel 1971). Chlorpropham (isopropyl *m*-chlorocarbanilate) when applied at sublethal dosages (1 lb/acre = 0.893 kg/ha) to weed species *Eupatorium maculatum* and *Impatiens biflora* increased the nitrate content of these weeds by 62% and 30% respectively. Increased nitrate content of these plants poisoned livestock if consumed in large amount (Frank and Grigsby 1957). Trifluralin (a,a,a-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine) applied at about 1.11 kg/ha to seedlings of cotton showed 69% infection of *Rhizoctonia solani* as compared to 30% in the untreated plots (Pinkard and Standifer 1966).

The few examples mentioned demonstrate the complexity and risk of using herbicides on the components of the life system.

We do not negate the benefit of using herbicide, but rather suggest that with some herbicides there may be increased risks of insect and disease attack. Hence, there is need for a sound ecological basis for weed control. The objective should be to maintain high yield and at the same time exert the least damaging effect on the function of the life system, man and environment. In this regard the systems concept of weed management will be most appropriate (NAS 1971).

THE SYSTEMS CONCEPT OF WEED CONTROL

The systems concept is flexible, dynamic and subject to constant appraisal and modification. In practice it comprises of various control methods such as ecological, cultural, mechanical, biological and herbicidal in one unified system. The economics of any combination of control methods used should also be considered. The goal of the concept is to create an environment that should be as detrimental to the weeds as possible but least damaging to the agroecosystem and man. The systems concept of weed control may consist of the following (Pimentel 1974):

1. resource reduction,
2. integration of suitable control methods,
3. cost/benefit analysis.

RESOURCE REDUCTION

This consists of any measure and ecological manipulation that will reduce weed infestation. Measures such as law enforcements i.e. seed certification, plant quarantines and laws covering eradication, programs, will prevent the spread of weed seeds. Ecological manipulations may include various management practices such as tillage, crop rotations, burning, flooding, and draining. Biological control of weeds is one of the activities needs more emphasis. Thirty species of weeds have been controlled biologically, in many countries, giving partial to complete control (NAS 1971).

Chemical weed control has become an essential part of modern agricultural technology. However, in view of its possible unwanted side effects, herbicides should be carefully judged, not only for its effectivenees, but also with respect to time and methods of application. In addition, in view of the energy crisis more efficient use of herbicides is needed. The amount of energy necessary to produce and apply a herbicide in the field is quite high. Pimentel (1976) estimated that a total of about 33,000 kcal are utilized per application of 1 lb of pesticide/acre. Therefore, use when necessary and spot treatment of herbicides may be most appropriate.

INTEGRATION

Depending on the weed species and kinds of crop plants we are dealing with, we may be able to integrate the existing weed control practices into a unified program. For example, some grass weeds and broadleaved weeds in rice fields may be effectively controlled by employing appropriate soil tillage methods before planting, continuous submergence of the rice field in early growth stage of the rice plants, weeding once or twice either by hand pulling or using some mechanical apparatus. Planting legumes between rice seasons may to a certain extent reduce weed problems in rice.

In the United States most weed control today is still accomplished by tillage, mechanical and cultural methods (NAS 1971). Bioenvironmental control remain the prime means of weed control in the US, despite the rapid increase in herbicide use for weed control (Pimentel 1976).

COST/BENEFIT ANALYSIS

Any combination of existing weed control methods may be analysed on the basis of their cost/benefit ratio. Those combinations which give the most appropriate ratio of cost/benefit for the farmers would be most economical under certain situation.

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Weed Management Studies in Pigeonpea (Cajanus Cajan L.) based intercropping

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ABSTRACT

The paper summarizes the results obtained through various field trials on different pigeonpea *(Cajanus cajan* L.)-based intercropping systems for two years at the International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India. It was observed that intercropping pigeonpea with various other crops reduced weed growth to an extent of 75%. The crop-weed balance in intercrop system was influenced by many factors like crop species and variety, plant population, crop geometry, soil types and herbicides. Among the various intercrops maize *(Zea mays* L.), cowpea *(Vigna cylindrica* Skeels) and pearl millet *(Pennisetum typhoides)* showed initial weed-smothering effect while groundnut *(Arachis hypogaea* L.) was effective at later stages of the crop growth. Weed growth in compact type of pigeonpea (HY3A) was substantially higher than that observed in spreading type (ST1). Within the intercrop system row arrangement pattern did not influence the weed infestation but the increase in population pressure resulted in considerable decrease in weed dry matter weights. Among the different herbicides evaluated in various systems, alachlor [2-chloro-2', 6'-diethyl-*N*-(methoxymethyl) acetanilide] at 1 kg/ha in maize + pigeonpea system caused initial toxicity to pigeonpea while prometryn [2,4-bis(isopropylamino)-6-(methylthio)-s-triazine],terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-s-(triazine), and ametryn [2-(ethylamino)-4-(isopropylamino)-6-(methylthio)-s-trazine]proved promising in sorghum + pigeonpea system. Further studies with these herbicides are underway. The studies on intercropping revealed that the biological and cultural factors like suitable crop species, crop varieties, plant population, nature of crop in the system and supplemental use of suitable herbicides should form the major part of the integrated weed management system.

INTRODUCTION

Mixed cropping[2] or intercropping[3] are an age-old traditional practice of many farmers in the semi-arid tropics (SAT).In view of the complexities of problems involved in dealing with crop mixtures in both mixed cropping and intercropping, research on crop mixtures has been minimal when compared to sole-cropping research. However, a greater insight in under-

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2 Mixed cropping — two or more crops are grown simultaneously in the same area with no row arrangement.

3 Intercropping — two or more crops are grown simultaneously in the same area in alternate rows or in other geometrical patterns.

standing of the technical, socio-economic, and physical factors associated with crop mixtures (Norman 1974), has revealed that under the prevailing conditions of low resource base, less capital investment, and aberrant weather situation in SAT, intercropping or mixed cropping have greater yield potential, stability in production and advantages in pest-, disease-, and weed-management aspects (Aiyer 1949, Andrews 1972, Rao and Shetty 1977). Intercropping has shown a yield advantage up to 60% over sole crops (Bantilan and Harwood 1973, Munro 1960 and Norman 1970), not only in low levels of technology but also (contrary to the belief of many) at high levels of inputs like improved varieties, fertilizers, and management (Andrews 1972, IRRI Annual Reports 1972, 1973, 1974; Krantz *et al*, 1976). Pigeonpea, one of the important crops in SAT areas, is characterized by slow growth for about 8 to 10 weeks and rapid growth thereafter, to cover as much as 1 to 1.5. m row width. This is especially true in the case of mid to late maturing and spreading varieties which require 180 to 220 days for maturity. This situation provides an excellent opportunity to grow one or two short-duration cereals or pulses between the wide rows of pigeonpea without affecting the growth of the other (Saxena 1973, Rao *et al* 1977). Unless such intensive cropping is practiced with pigeonpea, not only are resources wasted, but the vacant interrow space creates more weed problems.

In the sphere of weed management, little is known about many crops grown individually, let alone intercropping involving these crops. An attempt at ICRISAT Center to determine the effect of some biological factors such as crop species, crop variety and plant density, on the incidence of weeds and crop-weed balance has been reported by Rao and Shetty (1977). A major objective was the determination of how different intercropping systems, using pigeonpea as the main crop, affect the incidence of weeds, and to identify principles which will lead to better management of weeds. Studies were also initiated to assess yield losses due to weeds in established intercropping systems and to determine the critical period of crop-weed competition. Yield trials were also conducted to screen effectiveness of herbicides in selected intercropping systems.

MATERIALS AND METHODS

A series of field experiments on intercropping were conducted at ICRISAT Center during the 1975 – 1976 and the 1976 – 1977 seasons. Observations of weed infestation in many other agronomic field trials involving intercropping were recorded. A description of the ICRISAT Center trials is given below.

Influence of some pigeonpea-based intercropping systems on weed infestation. Two field trials were conducted (during 1975 and 1976) to study the influence of various intercropping systems on the incidence of weeds and the trends in weed infestation.

The experiments were conducted in Randomised Block Design (RBD) with three and four replications. Optimum agronomic inputs were provided for all crops involved in the systems (pigeonpea, sorghum, maize, millet, mungbean, cowpea, and groundnut).

Weed observations (counts and dry weights) were taken frequently to determine the trends in weed infestation.

Evaluation of pigeonpea genotypes with and without intercrop (1975). In this trial, the performance of four pigeonpea genotypes — two of long duration (ICRISAT 7065 and ICRISAT 7086) and two of medium duration (STI and HY3A); in each group one spreading (STI and ICRISAT 7065) and the other compact (HY3A and ICRISAT 7086) — were evaluated in sole form and with sorghum as an intercrop. In intercropping, the planting pattern of pigeonpea to sorghum was 1 : 1 at 75 cm and 1 : 3 at 150 cm row spacing of pigeonpeas (thus all rows were spaced at 37.5 cm). The pigeonpea population growing alone and intercropped was 30,000 plants/ha, while that of sorghum was 100,000/ha. The trial was conducted in factorial RBD replicated four times. Weed observations were taken.

The influence of population pressure in intercropping (1976). In this trial, response of contrasting pigeonpea varieties (compact HY3A and spreading ICRISAT-1) to population pressure (30, 60 and 90 thousand plant units/ha) in sole planting and with sorghum as intercrop at different relative proportions (100 P, 50 : 50, 33 : 66, 25 : 75, and 100 S) was studied. The experiment was conducted in split-plot design with combinations of varieties and densities in main plots and relative proportions in sub-plots repeated four times. Basic row width was 45 cm. In intercropping, three plants of sorghum replaced one plant of pigeonpea in different proportions, the equality being based on the optimum plant population for these crops in sole form. Weed observation were taken.

Critical period of crop-weed competition in sorghum + pigeonpea intercrop system (1975). The objectives of the trial were (i) to determine the nature and extent of weed problems in sorghum + pigeonpea intercrop, and (ii) to determine the most critical period of crop-weed competition in the system. The crops were kept weedfree for certain periods of time by repeated hand weeding, and then compared with the crop (i) that was kept weed free till harvest, (ii) weedy check, and (iii) that which received hand weedings at 4 and 8 weeks after sowing. The trial was condcuted in RBD replicated four times. The intercrop was planted in alternate rows in 50S:50P proportions.

Chemical weed control in intercropping systems. Based on observations of the preliminary herbicide screening trials (Shetty 1977), large-scale replicated field trials were conducted to evaluate the efficacy of some selected herbicides on intercropping systems in an effort to select suitable herbicides safe to the system as a whole. Initial emphasis was on sorghum + pigeonpea and maize + pigeonpea systems.

Two replicated field trials were conducted (1975 – 1976 and 1976 – 1977) to evaluate the effective chemicals on sorghum + pigeonpea system (50S:50P proportion). Only pre-emergence herbicides were included, and the application was made with a high-volume knap-sack sprayer.

A large-scale operational trial was also conducted to determine the efficacy of alachlor (1 kg/ha) in maize and pigeonpea system. Observations were mainly confined to pigeonpea growth.

RESULTS AND DISCUSSION

The most critical period of crop-weed competition is during the early part (4 to 6 weeks) of crop growth (Kasasian and Seeyave, 1969). The crop should be protected from weed competition during this initial stage. Recent work (Bantilan *et al.* 1974) has indicated that crop-weed balance[4] can be manipulated through intercropping. Intercropping of quick-growing short-duration crops with long-duration slow-growing crops may offer such protection. Pigeonpea, a long-duration crop that grows very slowly at first, is a very poor competitor with weeds.

Intercropping of pigeonpea with sorghum reduced weed growth (Table 1). In pure pigeonpea, weed growth was high (200.5 g/m^2) when compared to the intercropped combination (41.0 g/m^2). Also, while the pure pigeonpea required a third weeding, the intercrop treatments did not require further weeding. Data (Tables 1, 2, 3, 4, 5) illustrate that 50 to 75% reduction in weed infestation was achieved through intercropping pigeonpea with crops like sorghum, millet, cowpea, mungbean, and groundnuts. It was noticed that in all intercropping systems the competitive character of the system was derived mostly from the various intercrops, and very little was contributed by pigeonpea.

In intercropping, the total canopy at any times is higher than in sole cropping and ground cover is obtained quickly due to simultaneous growing of two or more crops. Weed growth is influenced by the crop canopy and the amount of light intensity reaching the ground. The larger canopy obtained through intercropping intercepts much of the incident light (reducing downward transmission of light) and competes more effectively for other inputs, creating an environment unfavourable for weed growth.

4 Crop-weed balance: The result of crop-weed competition which is the realization of crop yield as well as yield of the species comprising the weed community (Bantilan *et al* 1974).

The spreading type of crop species, due to their high initial leaf area index, intercept more light than do the compact types, thus possessing more weed suppressing ability. The enchanced competitive ability of intercropping is also due to high plant population pressure provided by the component species together. Crops like pigeonpea, which require 80 to 90 days to develop reasonable spread, benefit from intercropping with short and fast

Table 1. Effect of compact vs spreading pigeonpea genotypes growing on vertisols with and without sorghum intercrop upon weed infestation at 60-day stage one initial hand weeding, ICRISAT center 1975.

Row spacing	Pigeonpea type				Mean
	Spreading		Compact		
	Sole	Intercrop	Sole	Intercrop	
	Dry weight of weeds (g/m^2)				
75 cm	156	40	228	36	115.0
150 cm	178	40	240	48	126.5
Mean	167	40	234	42	
Sole vs intercrop	200.5	41			
Spreading vs compact	103		138		

Weed dry-weights are means of two varieties for each plant type and two replicates; data not analyzed statistically.

Table 2. Effect of intercropping of pigeonpea (HY2) growing on vertisols with cereals and legumes on the growth of weeds 6 weeks following planting ICRISAT center 1975.

S. No.	Crop Combination	Dry weight of weeds (g/m^2)
1	Pigeonpea + Sorghum (CSH5)	92
2	Pigeonpea + Pearlmillet (HB3)	97
3	Pigeonpea + Cowpea (C152)	60
4	Pigeonpea + Field bean	87
5	Pigeonpea + Sorghum (Mixture)	93
6	Pigeonpea sole	196
7	Sorghum sole	96

Table 3. Relative weed-suppressing ability (in percentage) of crops in pure stands

Crop	Day after planting	
	44	68
Setaria	73	73
Pearl millet	82	88
Maize	76	92
Sorghum	69	81
Castor	57	51
Pigeonpea	23	54
Cowpea	78	88
Groundnut	74	62

Weed-suppressing ability :

$$\frac{\text{Dry wt. of weeds from fallow} - \text{Dry wt. weeds from cropped plot}}{\text{Dry wt. of weeds from fallow}} \times 100$$

developing crops which tend to shift the balance of crop-weed competition to the advantage of crop during the early critical period of competition. The wider row spacings (1 to 1.5 m) required for pigeonpea cultivars, if not intercropped, provide ideal conditions for weeds to grow and multiply. The productive advantages of intercropping systems (Willey and Osiru, 1972, Rao 1974, Bantilan and Harwood 1973[5], Krantz *et al.* 1976, Rao and Shetty 1977) in conjunction with their utility as an inexpensive weed management system make them highly renumerative over sole crops.

Bantilan *et al.* (1974) described various physical, biological, and cultural factors affecting crop-weed balance in a crop season. Rao and Shetty (1977) further demonstrated that within an intercropping system the crop-weed balance is again dependent upon various factors such as crop type, genotype, and plant density. A further discussion on some of these factors which can be manipulated in such a way as to minimize weed problems is presented below:

Effect of different crop combinations. Weed dry matter weights as influenced by various pigeonpea-based intercropping systems, along with

[5] Bantilan, R.T. and R.R. Harwood 1973. Weed management in intensive cropping systems. Paper presented at IRRI, Saturday seminar, July 28, 1973.

Table 4. Influence of different intercrops growing on alfisols on weed growth after an initial hand weeding (25 days), ICRISAT center 1976 — 1977.

	Intercrop Yield		Pigeonpea Yield		Total return	Weed dry matter		
						At hand weeding (25 days)	After inter crop harvest (90 days)	At pigeonpea harvest (180 days)
	(q/ha)	(Rs/ha)	(q/ha)	(Rs/ha)	(Rs)	(q/ha)	(q/ha)	(q/ha)
Pigeonpea + Groundnut	10.7	2140	4.5	450	2590	3.5	5.0	6.1
Pigeonpea + Maize	27.8	2224	3.9	390	2614	3.8	3.4	3.8
Pigeonpea + Sorghum	27.5	2063	4.0	400	2463	3.1	2.9	2.8
Pigeonpea + Millet	4.8	360	4.2	420	780	2.8	6.3	6.2
Pigeonpea + Cowpea	10.6	1590	5.4	540	2130	2.5	4.9	6.8
Pigeonpea + Mungbean	5.7	855	4.5	450	1305	2.0	1.5	8.9
Pigeonpea alone	—	—	6.2	620	620	6.1	6.6	17.6

1 q (quintal) = 100 kg.

Table 5. Influence of different intercrops growing on vertisols on weed growth after an initial handweeding (25 days), ICRISAT center 1976 — 1977.

Treatments	Intercrop yield		Pigeonpea yield		Total return	At hand weeding (25 days)	After inter crop harvest (90 days)	At pigeonpea harvest (180 days)
	(q/ha)	(Rs/ha)	(q/ha)	(Rs/ha)	(Rs)	(q/ha)	(q/ha)	(q/ha)
Pigeonpea + Groundnut	11.9	2380	1.4	140	2520	5.2	5.4	16.9
Pigeonpea + Maize	27.4	2192	1.4	140	2332	5.4	5.1	17.9
Pigeonpea + Sorghum	32.5	2438	1.2	120	2558	4.7	5.5	12.5
Pigeonpea + Millet	15.6	1170	1.1	110	1280	4.3	7.4	22.7
Pigeonpea + Cowpea	6.2	930	1.6	160	1090	3.2	4.5	11.9
Pigeonpea + Mungbean	2.3	345	1.4	140	485	2.9	5.6	20.5
Pigeonpea alone	—	—	1.9	190	190	8.2	9.7	23.2

(CSH 5) intercropped with pigeonpea (T-21) on vertisols affected by different Six

Table 6. Grain yield of sorghum (CSH-5) intercropped with pigeonpea (T-21) on vertisols affected by different weed-management treatments, ICRISAT center 1975.

Treatments	Sorghum yield (q/ha)	Pigeonpea yield (q/ha)	Grain yield of sorghum (as % of weed-free sorghum)	Weed counts/m^2 (one week before sorghum harvest)	Weed dry-matter at sorghum harvest (q/ha)
1. Weed-free up to 2 weeks after sowing	21.3	2.8	74	20	11.3
2. Weed-free up to 4 WAS	22.3	3.1	78	18	4.3
3. Weed-free up to 6 WAS	25.1	2.2	88	10	1.0
4. Weed-free up to 8 WAS	27.2	3.0	95	12	0.98
5. Two hand weedings 4,8 WAS	22.9	1.1	80	10	1.2
6. Weed-free	27.8	2.1	100	0	0.0
7. Weedy check	10.4	2.1	35	31	15.4
L.S.D. at 5%	2.75	N.S.			

Table 7. Efficacy of different pre-emergence herbicides in sorghum (CSH-5) and pigeonpea (HY3A) intercropped on alfisols, ICRISAT center 1976 — 1977.

Treatments	Rate (kg/ha)	Sorghum yield (q/ha)	Grain yield of sorghum (% of weed-free)	P. pea yield (q/ha)	P. pea (% of weed-free)	Sorghum + p. pea (Rs/ha)	Weed dry matter	
							At sorghum harvest (q/ha)	At p. pea harvest (q/ha)
dinitramine	0.5	14.0	39	2.9	85	1340	14.5	8.4
devrinol	1.0	18.7	52	2.7	79	1672.50	13.5	13.1
prometryn	1.5	27.9	78	3.2	94	2412.50	5.1	8.1
terbutryn	1.5	29.1	81	2.7	79	2452.50	5.7	11.4
ametryn	1.5	30.9	86	3.1	91	2627.50	6.9	7.2
destun	1.5	8.1	23	1.9	56	792.50	23.2	17.9
fluochloralin	1.5	10.0	28	3.6	106	1110	17.1	11.4
atrazine	1.5	25.0	70	—	—	1875	27.2	11.6
alachlor	2.0	18.6	52	1.8	53	1575	11.2	12:7
Weed-free	—	35.9	100	3.4	100	3032.50	—	—
Weedy check	—	11.9	33	1.6	47	1052.50	36.5	22.0
L.S.D. 0.05.		6.6		1.4				

Table 8. Efficacy of different pre-emergence herbicides in sorghum (CSH-5) and pigeonpea (HY3A) intercropped on vertisols, ICRISAT center 1976 — 1977.

Treatments	Rate (kg/ha)	Sorghum yield (q/ha)	Grain yield (% of weed-free)	P. pea yield (q/ha)	P. pea (% of weed-free)	Sorghum + p. pea (Rs/ha)	Weed dry matter	
							At sorghum harvest (q/ha)	At p. pea harvest (q/ha)
dinitramine	0.5	14.0	84	0.7	140	1120	12.7	9.3
devrinol	1.0	11.3	68	0.5	100	897.50	12.4	13.4
prometryn	1.5	3.9	24	0.6	120	352.50	4.2	0.5
terbutryn	1.5	13.2	80	0.5	100	1040	2.9	14.3
ametryn	1.5	3.7	22	0.4	80	317.50	5.4	6.3
destun	1.5	4.3	26	0.4	80	322.90	22.5	19.7
fluochloralin	1.5	15.1	91	0.4	80	1172.50	10.8	27.6
atrazine	1.5	4.3	26	—	—	322.50	6.1	15.0
alachlor	2.0	9.6	58	0.7	140	790	19.0	22.2
Weed-free	—	16.6	100	0.5	100	1295	—	—
Weedy check	—	4.3	26	0.6	120	382.50	39.9	29.9

yields and gross returns, are presented in Table 2, 3, 4 and 5. Weed infestation was about the same in the early part of the season, but late season weeds yielded 2.4 times more weed weights in the vertisols (black soils) when compared to alfisols (red soils) (Table 4, 5). Even by the first general hand weeding at 25 days, the effect of intercrop systems on weed growth, in contrast to sole pigeonpea, was perceptible in that weed weight was about 2 to 5 q/ha in intercrops, whereas it was 6 to 8 q/ha in sole pigeonpea. By the time of intercrop harvest, the differential effects of various systems on weed was quite evident on either soil type. Intercropping of cowpea and maize with pigeonpea suppressed weed growth to a greater extent, (followed by mung, sorghum, and groundnut) than sole pigeonpeas. However, intercrop systems differed in their weed-smothering effect in that some of them showed low weed intensity throughout the growing period, whereas in others weeds reappeared after the intercrop harvest. Pearl millet growth was poor due to downy mildew and the data for it do not truly represent the system. Though cowpea efficiently suppressed weeds due to its quick growth and ground cover in early stages, weeds reappeared after the early harvest and produced by the end of the season one-third the growth measured in the sole-crop system. A similar trend was also noticed in mung and pearl millet systems. Groundnut, though associated with pigeonpea for a longer time (90 days), could not prevent weed growth in later periods. This may perhaps be due to initial slow growth of the crop, favoring early establishment of weeds. Systems with maize and sorghum as intercrops, on the other hand, recorded less weed growth, not only up to intercrop harvest, but also until the final harvest of pigeonpea. Similar observations were noted in other trials as reported by Rao and Shetty (1977).

Crops differ in their relative growth rates, spreading habit, height, canopy structure, and duration. They accordingly vary in their weed-smothering ability. Quick growing and fast-covering cowpea and tall and fast-developing maize smothered weeds more efficiently than did other crops. Pearl millet, by its tillering and vigorous growth, had a similar weed suppressing effect. Sorghum increased its competitive effect progressively and from flag-leaf stage (50 days) onwards kept down weeds for the rest of the season, as did maize. Mung was equally good on vertisols when there was no moisture stress. In systems where intercrops (millet, mung, cowpea) were harvested early, there was considerable time before closure of the pigeonpea canopy in the rows, and a fresh crop of weeds resulted. On the other hand, tall and vigorous crops (maize and sorghum) suppressed the weeds up to their harvest time. Subsequent weed growth was less. However, because of better moisture conditions in vertisols, specific weeds such as *Phyllanthus niruri* L., *Phyllanthus maderaspatensis* L., *Corchorus sp.*, and *Hibiscus panduriformis* Burm. F. came up after intercrop harvest to record high weed growth during the later part of the season. In low-growing crops like groundnut and mung, tall and hardy weeds like *Celosia argentea* L., *Digitaria sanguinalis* Back., and *Acanthospermum hispidum* L. overtook the crops at later stages.

Yields of pigeonpea on either soil type was not significantly different among various intercrop systems and sole pigeonpea. A slight depression in yields in intercropping situation was apparent, especially in alfisols. Intercrop systems with maize and sorghum, because of their high yields, and groundnut (due to its high premium value) recorded the maximum return on either soil. The gross return from the former three systems on vertisols was 11 to 12 times and those on alfisols 4 times the return from pigeonpea growing alone. To what extent the reduction in weed growth obtained by various intercrop systems reduced the expenditure necessary for weed control could not be ascertained from the current data. Reduction in weed growth alone was not the only cause for the advantages of intercropping observed in all systems. However, if reduced weed growth can be considered a criteria of an efficient system, it can be said that intercropping pigeonpea with any other suitable species is an improved practice of weed management, as well as efficient utilization of available resources.

The cost of the high weed population observed in sole pigeonpea must be considered to be overlapping into subsequent seasons because of the quantities of seeds coming from such populations.

Dry weights of weeds from various intercrop systems on vertisols in 1975 are presented in Table 2. Weed growth in sole pigeonpea was two to three times that observed in intercrop systems and sole sorghum. Again the data suggest that the reduced weed growth in the intercropping systems was primarily due to the presence of fast and spreading intercrops like cowpea or vigorous and competitive intercrops like sorghum and pearl millet.

Effect of plant density. Increase in plant-population pressure produced a significant reduction in weed infestation (Figure 1). This was true in sole as well as the intercropping system. There was a linear decrease in weed dry weights up to 90,000 plants/ha in pigeonpea growing alone and pigeonpea intercropped with sorghum. When the population density was increased from 30 to 60 thousand plants/ha in sole pigeonpea, the reduction in weed growth was 36%. An increase to 90,000 plants/ha achieved 61% weed control. In case of sole sorghum, higher levels than the lowest population level of 90,000/ha (equivalent to 30,000 P/ha) did not produce an additional advantage in suppressed weed growth. Sorghum being very competitive, its presence in the pigeonpea intercropping system helped to reduce weeds by 73%. The three different relative proportions of pigeonpea to sorghum in intercropping (50:50, 33:66 and 25:75) did not result in significantly differing weed infestation problems.

High plant density would enable the crop to cover ground quickly and consequently inhibit the growth of weeds. However, increasing plant

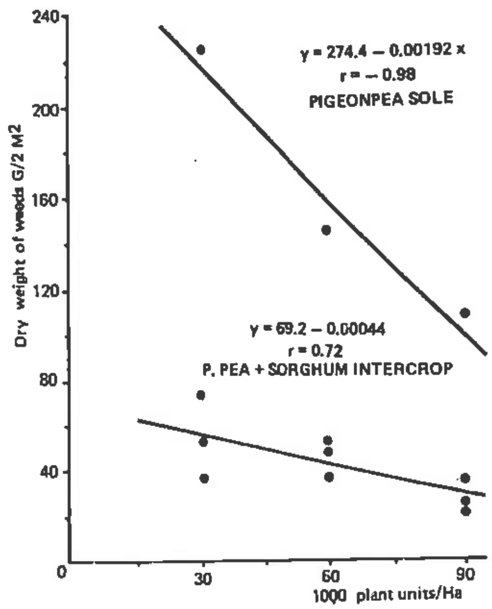

Figure 1. Effect of population pressure on weed growth.

density beyond a certain level may not be of additional advantage, as the total canopy would level off at some value because of interplant competition and death of most of the lower branches. It is important to consider to what extent high populations that suppressed weed growth are necessary for yields. Yield data from the present experiment for pigeonpea indicated that the optimum stand would be anything within 30 to 60 thousand plants/ha when growing alone and no less than 60,000 in an intercrop situation. Earlier work (Anon 1976) has shown that in pigeonpea, being an indeterminate and spreading type, yield remains fairly uniform over a great population range, and 40,000 plants/ha could be the minimum required for high yields. Hence, in such crops as pigeonpea, to help the crop encounter the interference of weeds better and shift the balance of crop-weed competition early in the season to favor the crop, it would be advantageous to use higher levels of population than the minimum required for optimum yields. Especially in intercrop systems, high total populations are required for better intercropping advantages which would also help to check weeds efficiently.

Effect of genotypes. Weed growth in the compact genotype of pigeonpea (HY3A) was 37% higher than in the spreading variety (STI) in the 1975 trial (Table 1). However, in the 1976 trial the advantage of spreading genotype was not apparent, primarily due to the use of a different variety (ICRISAT-1). ICRISAT-1 had not spread much by the time of weed observation. Moreover, growing conditions in 1975 were much better than those in 1976, which experienced a prolonged dry spell from early September onwards. Just like any fast-spreading crop species, genotypes which close the canopy rapidly are more successful in competing against weeds.

Weed management in intercropping. Even though intercropping can be a potential biological tool for the suppression of weeds, the system by itself does not completely avoid weeds. It is evident that the smothering effect of the intercrop system did not increase in additive proportion of the individual sole-crop abilities, mainly due to interspecies competition and also due to poor contribution by the main crop, pigeonpea. Intercropping may greatly help in interrow weed suppression, but little in intrarow weed suppression. Therefore, research should continue to evaluate direct methods of weed control, even in intercropping. This has special significance in that the crops involved in a system differ significantly in growth characteristics.

Critical period of crop-weed competition. In the experiment conducted to determine the critical period of crop-weed competition in sorghum + pigeonpea, pigeonpea (due to excess rain late in the season) was completely damaged. A meaningful pigeonpea yield could not be obtained. However, initially there was an excellent plant stand of both sorghum and pigeonpea and a fairly good yield of sorghum was obtained (Table 6). The preliminary observations indicated that the critical period of crop-weed competition in sorghum + pigeonpea intercrop (alternate rows) falls around 4 to 7 weeks after sowing. The yield loss due to weeds in the intercrop was only 32% indicating the minimum weed infestation in the experimental field. There was a gradual increase in grain yields of sorghum as the duration of the weed-free environment lengthened. Weed dry-matter weighed during sorghum harvest indicates the trend of lesser weed dry-matter values for the better weed-management treatments.

The critical period of crop-weed competition in sole sorghum is the initial 4 to 5 weeks of crop growth (Shetty 1976). But in sorghum + pigeonpea intercropping, the period tends to be extended further, indicating that the system should be kept weed-free for at least 7 weeks after sowing to obtain higher yields. This is understandable in that slow-growing and poorly competitive pigeonpea plants occupy about 50% of the plot area (which otherwise would have been occupied by sorghum in sole cropping) in intercropping, giving a niche favorable for better weed growth. Therefore, though total weed growth is less in intercropping, the weeding operations may have to be extended in order to obtain optimum yields of the crops involved.

Chemical weed control. Hitherto, herbicide-oriented weed research was mainly confined to sole cropping. The selectivity of herbicides is more critical when used on an intercrop system involving two or more crop. For example, sorghum + pigeonpea is a popular intercropping system in many areas. Herbicides for this system should not be injurious to either sorghum (a monocot) or pigeonpea (a dicot). Two herbicidal trial are reported in Tables 7 and 8. In general, triazine herbicides appeared to be more promising than the other herbicides tested. It is known that triazines perform well on sorghum, but atrazine was severely phytotoxic on pigeonpea. However, ametryn appeared very safe on both the crops, as did terbutryn and prometryn. In red soils prometryn, ametryn and terbutryn were the most effective chemicals on sorghum + pigeonpea intercrop system. Further testing of these triazines is underway. Among other herbicides, performance of the fluochloralin (1) [*N*-(2-chloroethyl)-2,6-dinitro-N-propyl-4-(trifluoromethyl analine] (2 kg/ha) was excellent with pigeonpea, but was slightly toxic to sorghum. The efficacy of fluchloralin at lower rates need to be further tested, especially on sorghum.

Alachlor was known to be a potential herbicide for both maize and pigeonpea (Kasasian 1971). Suprisingly enough, it was observed that alachlor caused initial stunting of pigeonpea. The retarded growth of pigeonpea continued up to 4 months after treatment (Figure 2). However, the crop recovered later in the season and the growth was almost equal to that of the untreated crop. Alachlor gave excellent control of weeds intially, but its initial effect on pigeonpea needs further investigation. Perhaps a

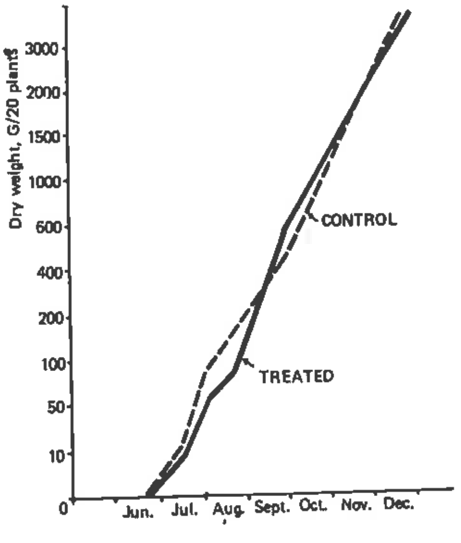

Figure 2. Pigeon pea growth as influenced by alachlor. ICRISAT-1976-1977.

change in the depth of planting of pigeonpea may help avoid the toxic effect of alachlor.

The studies revealed that intercropping systems involving pigeonpea and other crop species, when compared with pigeonpea growing alone, reduced weed growth to varying degres up to 75%. Crop-weed balance was influenced by many factors, including species, variety, population, crop geometry, soil type and herbicides. Maize, cowpea and pearl millet produced weed-smothering effects early in growth and groundnut was effective at later stages. Compact pigeonpea was less effective in suppressing weed growth than was spreading pigeonpea. Initial toxicity of alachlor to pigeonpea disappeared as the plant matured. Prometryn, terbutryn, and ametryn were effective herbicides for sorghum pigeonpea system.

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Practical Training in Weed Control in the South Pacific

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ABSTRACT

In the Pacific, weeds and their propagation in annual and perennial crops, in natural and artificial pastures, and in flower and vegetable gardens, create for the territories, huge problems which are difficult to solve. Advanced agricultural techniques, with diversified cultural methods, the rational use of herbicides, and some biological control have succeeded in controlling weeds in temperate and hot temperate countries. but it is not always the case in tropical countries. Weed control is even more difficult in the Pacific Islands despite commendable and continuing efforts on the part of the research and extension services. This is due essentially to climatic conditions, the wide variety of crops, lack of information, and the difficult of setting up suitably located demonstration fields where the results can be discussed with farmers, stock breeders and technicians. Fortunately all agricultural colleges and practical agricultural schools in the Pacific area include weed science and weed control in their curricula. Agronomic research stations, often situated very close to the agricultural schools, carry out applied research and field trials in cooperation with lecturers and students. There is, however, a gap between agronomic research as such and agricultural extension workers who are working in close contact with farmers. The South Pacific Commission periodically organizes practical training course on weeds and weed control, with the help of consultants, members of the Asian-Pacific Weed Science Society. These courses are intended for agriculturalist, agricultural extension officers and farmers. The emphasis is on practical work in the field. The main objectives are to familiarize participants with a number of generally accepted basic principles in weed control in small farms.

INTRODUCTION

In the Pacific, weeds and their propagation in annual and perennial crops, in natural and artificial pastures, and in flower and vegetable gardens, create for the territories huge problems which are difficult to solve. Advanced agricultural techniques, with diversified cultural methods, the rational use of herbicides, and some biological control have succeeded in controlling weeds in temperate and hot temperate countries, but it is not always the case in tropical countries. Weed control is even more difficult in the Pacific Islands despite commendable and continuing efforts on the part of the research and extension services.

This is due essentially to climatic conditions, the wide variety of crops, lack of information, and the difficulty of setting up suitably located demonstration fields where the results can be discussed with farmers, stock breeders and technicians. In addition, despite continual improvement

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in sea and air transport facilities between the Pacific Islands and the neighbouring continents, island farmers still experience considerable difficulty in obtaining supplies of the products needed for agricultural development.

The existence of weeds that have an inhibiting effect on island agriculture has long been recognized. While it is impossible, in this short paper, to give an exhaustive account of what has been done and written about the subject over the years in the various Pacific Islands, it is worth pointing out that as far back as the 1840's, the following species of weeds were recorded in Fiji by Asa Gray in his "Botany of the United States Exploring Expedition, 1838 – 1842" : *Canavalia obtusifolia* Auct. non D.C., *Cardamine sarmentosa* Forst., *Hydrocotyle asiatica* Linn., *Portulaca quadrifolia* Linn., *Rubus moluccanus* L., *Sesuvium portulacastrum* (L.) L., *Sida linifolia* L., *Sida rhombifolia* L., *Triumfetta procumbens* Forst., *Urena lobata* L., *Waltheria americana* L.

Reports of the Fiji Department of Agriculture in the years 1910 to 1914, listed the most common and most noxious weeds. Further investigations were conducted before, and more especially after, World War II. In Bulletin No. 31 of the Department of Agriculture, Mr. T.L. Mune and Mr. J.W. Parham described in careful detail the declared noxious weeds of Fiji.

Each territory has its own specific problems as regards crop protection and weed control, and in recent times the whole of rural Oceania has become aware of these problems. Everyone now realizes that their solution depends on a thorough knowledge of the physiology of the noxious plants, on the development of reliable control techniques, and on continuous and increasingly appropriate training of agricultural extension workers and farmers.

AGRICULTURAL EDUCATION

The curriculum of every agricultural teaching institution in the Pacific includes theoretical and practical courses on weed science and weed control. The level of these courses naturally varies with the type of institution considered. It is higher at the colleges, such as the Fiji College of Agriculture, the Regional College of Tropical Agriculture (Western Samoa), the Vudal Agricultural College (Papua New Guinea), than at the agricultural schools, such as the Ecole Pratique d'Agriculture d'Opunohu (French Polynesia), the Popondetta Agricultural School (Papua New Guinea), and the Ponape Agriculture and Trade School (Trust Territory of the Pacific Islands).

To illustrate the very high level of the courses provided at the colleges, we have quoted below the weed science syllabus of the Fiji College of Agriculture and of the South Pacific Regional College of Tropical Agriculture:

(i) **Fiji College of Agriculture.**

Unit I : (1) Introduction — Why control the weed?, (2) Weeds in Fiji, (3) Historical Review to 1945, (4) Work of the Department of Agriculture.

Unit II : (1) Classification, growth, life cycle, methods of reproduction, (2) Distribution of weeds in Fiji, (3) "Declared noxious weeds" of Fiji, (4) Legislation relating to the noxious weeds.

Unit III : (1) Methods of Control — A classification, (2) Biological control of weeds.

Unit IV : (1) What are agricultural chemicals, (2) The need for pesticides, (3) Classification of herbicides, (4) The activity and selective toxicity of herbicides, (5) Formulations, active ingredient statement, (6) Persistence of herbicides, (7) Toxicity of herbicides.

Unit V : The application of herbicides.

Unit VI : Spraying equipment.

Unit VII : (1) Weed control in major crops, (2) Weed control in outside crops, (3) Common technical terms.

Unit VIII: Pesticides: (1) A code of conduct, (2) Role of Government, (3) Role of manufacturers, (4) Role of distributors, (5) Role of agricultural users, (6) Role of gardeners, (7) Role of conservationists.

(ii) **South Pacific Regional College of Tropical Agriculture.**

(a) **Theory**

First Year : Weed identification and collection.

Second Year : Principles of weed control.

Third Year : Herbicides — The use of chemicals, effects of competition, general control principles-cover crops and green manuring.

(b) **Practical Work**

First Year : Collection and identification of approximately 25 weeds.

Second Year : Students' own problems in their field plots.

Third Year : Demonstration of weed effect and successful/unsuccessful controls as these become available.

Obviously the agricultural schools, which do not have the same admission requirements nor the same objectives as the colleges, concentrate mainly on giving practical training in the field. At the Ponape Agriculture and Trade School for instance, students are taught practical methods for controlling the weeds most commonly found in the island's major crops.

Part I : **Non-chemical means of weed control.** (1) Mulch, (2) Mechanical control, (3) Hand and hoe in very small plots.

Part II : **Chemical control.** (1) Fence rows (paraquat or diquat), (2) Bananas (paraquat and diuron), (3) Corn.

Part III : **Weed identification of the most common weeds in Ponape,** *Echinochloa colonum* L., *Paspalum orbiculare* Forst., *Eleusine indica* (L.) Gaertn., *Euphorbia hirta* L., *Stachytarpheta jamaicensis* (L.) Vahl, *Polanisia viscosa* (L.) DC.

AGRICULTURAL RESEARCH

Agricultural research and experiment stations engaged in laboratory testing and field trials with a view to weed control exist in many Pacific islands. Often, moreover, agricultural research seems to have preceded training, and agricultural schools and colleges are in many cases located very close to a research station. A great deal of "cross-fertilization" occurs between the stations and the educational institutes, which are constantly exchanging information and personnel; reciprocal assistance in the setting-up of trials, the organization of field training for students, the development of land and the sharing of equipment, is highly beneficial to both. Results of trials undertaken appear in the regular reports of experiment stations and department of agriculture, or are published in special bulletins that are promptly and widely circulated. For example, the results of trials conducted in French Polynesia on the control of nutsedge *(Cyperus rotundus* L.) and on chemical eradication of weed in vegetable crops were disseminated in January 1977, shortly after completion of the trials.

AGRICULTURAL EXTENSION

The agricultural extension officer's job is to introduce any new technique developed into the rural community and to get farmers to shed old attitudes and to adopt unfamiliar patterns of working. To accomplish this, the agricultural extension officer must be thoroughly familiar with the community in which he is operating, fit into it completely, and "speak its language" in every sense of the term, i.e. using not only the same words but the same mental structures, the same frame of reference. He must be able to anticipate and understand the reactions his suggestions will give rise to, keep an open mind, accept discussion, and back up his arguments with sound and reliable information. In the field of weed control, where it is a matter of using chemical products the farmer has never heard of before and, most importantly, of using them rationally and to the best advantage, the extension officer does not always have complete confidence in his own suggestions. He must be cautious and flexible, never forgetting — in the case we are discussing — that the action of chemical weed killers is extremely rapid and liable to vary with prevailing natural conditions, in particular the soil, the climate, and the type of plant to be protected or eradicated.

Failure, by agricultural extension officers, to achieve expected results in a rural community, is often blamed on inadequate training. Before making such a sweeping statement, let us contrive to conjure up a discussion such as might take place between an agriculturalist (who has no doubts whatsoever about the effectiveness of his methods in an experimental situation) and an extension worker (who operates in the field) concerning application of weedicide in a village crop at the request of its owner.

In many Pacific islands there is an evident communication gap between research and extension activities, or at best problems in transferring the knowledge acquired to the actual farming community. Reliable agricultural extension practices and procedures have been formulated and are being applied, but unfortunately they do not always prove as effective as one would wish.

THE ROLE OF THE SOUTH PACIFIC COMMISSION

(i) **Practical training courses.** In order to overcome some of the abovementioned difficulties, the South Pacific Commission periodically organized practical training courses for agricultural extension officers and island farmers. These courses are at sub-regional level, which is to say that they are attended by participants from either the English speaking or the French speaking territories in the Commission's sphere of action and conducted in one language only. The South Pacific Commission pays the cost of travel to and from the site of the course of one participant from each of the territories concerned, as well as per diem allowances at authorized ports of call and on location for the duration of the course. Governments and territorial administrations are invited to nominate participants — as many as they wish, but bearing in mind that expenses of one only will be paid by the South Pacific Commission. A practical course on weed control is usually attended by about twenty trainees: agricultural officers, extension workers, and farmers who already have substantial experience in this field.

To conduct this specialized training, the South Pacific Commission calls upon scientists and agricultural experts with high qualifications and thorough experience of rural areas. Up to now these consultants have been members of the Asian-Pacific Weed Science Society. Each course lasts for 10 to 12 working days and includes both lecturers (60% of the time available), and practical work (40%) — much of wich takes place in the field; weed identification, application of major herbicides, calibration of spraying equipment, use of equipment, etc.

A draft report on the theoretical and practical work covered during the 2 week training period is handed to every participant on the last day of the course. This is regarded as a very necessary practice, for it provides trainees with a document they can refer to as soon as they return to their professional duties, and if hurried preparation occasionally does result in typing errors and loose style, these detract very little from its intrinsic value.

This type of course, for adults already engaged in agricultural activities — whether they be government officers, extension workers, or simply "innovative" and experienced farmers — is highly rated in the South Pacific, because it in fact constitutes a combined training and refresher course. The choice of lecturers and consultants from among APWSS members is in itself a guarantee of quality.

(ii) Clearing-house services. The South Pacific Commission regularly disseminates technical information in French and English on those aspects of weed control that are likely to be of interest to all or part of the South Pacific area. This is done by means of Information Circulars, which are speedily and widely distributed, and through Information Documents and Technical Documents, which are generally of a higher technical level but distribution of which is rather more restricted. An agricultural extension handbook "Weed Control in the South Pacific" prepared in close cooperation with the Asian Pacific Weed Science Society, was published in 1973. The many requests still being received for this booklet are clear evidence of its value and usefulness.

ACKNOWLEDGEMENT

The South Pacific Commission is indebted to the Ministry of Agriculture, Fisheris and Forest of Fiji, the South Pacific Regional College of Tropical Agriculture at Alapua, Western Samoa and the Ponape Agriculture and Trade School, Trust Territory of the Pacific Islands, for the information they so kindly provided.

Ecology Education and Research in India in Relation to Weed Problems

R. S. AMBASHT [1]

ABSTRACT

Ecological education in India for a long time was mainly confined to a very small part of botany courses at B.Sc. and M.Sc. levels. Up to about 1955 most of the university teaching was restricted to *hydrophytes* and *xerophytes* at B.Sc. and to elementary vegetational and floristic studies at M.Sc. level. Banaras Hindu University (B.H.U.), Bombay and Saugor Universities and the Forest Research Institute at Dehra Dun were the main centres of teaching and research in ecology. From 1955 to 1965 ecology teaching and research expanded very quickly at the B.H.U. and the course content was gradually increased. Weeds were a handy choice for autecological research and the importance of this subject spread to other universities who expanded the content of their ecology courses. During the 1965 to 1975 decade there has been a tremendous all round expansion in the teaching of ecology in India. Ecological research on weeds in most cases is confined to the study of the biology of weed species in relation to influence of habitat and climate.

Weeds are undesirable plants that interfere with the good growth of desired plant species or adversely influence human interest at a particular place. They have usually high competitive ability and grow vigorously in situations. Weed control studies have been a subject matter of agriculturists mainly because of persistent occurrence of weeds in crop fields and fresh-water bodies. Ecologists also have been interested in weeds in order to understand the influence of environmental factor on the various phases of their life-cycle; the mechanism of perennation and re-appearance in certain habitats in a particular season; the weakest phase in life-cycle when they could be easily vulnerable to control measures, as also of their role in the ecosystem functioning, etc.

Ecology education in India for a long time was mainly confined to a very small part of botany courses at B.Sc. and M.Sc. levels. Up to about the year 1955 in most of the universities ecology teaching was restricted to *hydrophytes* and *xerophytes* at B.Sc. and to elementary vegetational and floristic studies at M.Sc. levels. Banaras Hindu University (BHU), Bombay and Saugor Universities and the Forest Research Institute at Dehra Dun were the main centres of specialised teaching and research in ecology, but doctoral theses were few and far between.

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During the next decade from 1955 to 1965 ecology teaching and research expanded very fast at the BHU. The course content in this subject was gradually increased. Autecology including ecological life-cycle, population differentiation, competition; synecology including community organisation and development, succession, climax, vegetation and floristics of India, climatic, biotic and edaphic factors and their role plants and plant communities including adaptations, etc were included in an elementary form at B.Sc., and with the critical details of the above and some additional topics like applied ecology and phytogeography, were taught at M.Sc. level. Weeds became a handy choice in autecological researches for reasons of their applied significance, easy availability and short period of their life cycle. With gradual realisation of the importance of this subject many more universities expanded their course contents of ecology.

During the 1965-1975 decade there has been a tremendous all round expansion in the teaching of ecology in this country. The ecosystem concept was introduced as a core of all ecological studies in which the emphasis on weeds was also given as a integral component of interacting and interdependent ecological systems. A number of regional and All India summer institutes and schools were organised at the BHU where college and university teachers drawn from different regions were given lectures, laboratory and field courses in modern ecology by the author of this paper and a few other colleagues. These teachers on return to their own institutions are proving assets in modernising and expanding ecology courses elsewhere. Banaras Hindu University Botany Department had introduced a number of advanced courses under semester systems of which one course of full paper and practicals was on weeds alone.

During the last few years, ecology has been introduced in schools and intermediate or pre-university stages mainly through the efforts of "Kendriya Vidyalaya Sangathan" which runs hundreds of central schools throughout the country, and the Boards of Education of various states. The preliminary concept of interrelationships among organisms and environment as well as awakening about one's surroundings are taught at primary school stage, whereas by class IX and X stage of school education students are taught the fundamentals of biological levels of organisations, populations, community, ecosystem, biosphere and such applied aspects as "ecological crisis", conservation of natural resources, etc. Science, being a compulsory subject up to Class X to all students, the present day young boys coming out of school, whether they choose further science as a career or not, are better equipped to visualise the weed problem in totally *vis a vis* the economics of energy and material input in crop fields or freshwaters, which the weeds steal sway or which goes in the weed control measures together with the side effect of the efforts on the functioning of the system.

Ecological researches on weeds in most cases are confined to the study of biology of weed species in relation to the influences of habitat and climatic features specially on the seed germination and growth stages.

At the Banaras Hindu University, Kaul (1959)[2] found that the populations of *Xanthium strumarium* - a short day annual weed of the family Compositae, is differentiated on the basis of different critical photoperiods for flowering. Further, germination of the two seeds in each fruit very often germinated at certain time intervals. These resulted into occurrence of more than one population extending from early monsoon to post monsoon seasons. He further found that, if the continuity of long night dark phase was interrupted by flash light even for a few minutes, it stopped flowering and consequently there was no seed or fruit setting. Thus this weed could be eliminated in restricted areas by mere exposure to flash light for a few minutes in night in the preflowering period. But hooked seeds of this species are easily disseminated sticking on the coat of grazing animals.

Some of the important weeds studied for their autecology in the botany department, BHU are: *X. strumarium* and *Croton sparciflorus* (Kaul 1959)[2], *Argemone mexicana* (Rugmini 1960)[3], *Euphorbia hirta*, *E. thymifolia*, *Setaria glauca*, *Peristrophe bicalyculata*, (Ramakrishnan 1960)[4], *Alhagi camelorum* (Ambasht 1958; 1963), *Euphorbia dracunculoides* and *Asphodelus tenuifolius* (Tripathi 1965)[5], *Bacopa monnieri* (Sah 1965)[6], *Boerhaavia diffusa* and *Gomphrena celosioides* (Srivastava 1966)[7], *Solanum nigrum* and *S. surattense* (Singh 1966)[8], *Trichodesma*

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[2] Kaul, V.N. 1959. Physiologico-ecological studies of *Xanthium strumarium* Linn. and *Croton sparsiflorus* Morong. Ph.D. thesis, Banaras Hindu University.

[3] Rugmini, C.R. 1960. Investigations in the autecology of weeds. Ph.D. thesis, Banaras Hindu University.

[4] Ramakrishnan, P.S. 1960. Contributions to the ecological flora of Varanasi District. Ph.D. thesis, Banaras Hindu University.

[5] Tripathi, R.S. 1965. An ecological study of weeds infesting wheat and gram crops of Varanasi. Ph.D. thesis, Banaras Hindu University.

[6] Sah, J.D. 1965. Studies in the growth and ecology of *Bacopa monnieri* (L) Penn. A medicinal herb. Ph.D. thesis, Banaras Hindu University.

[7] Srivastava, A. 1966. Ecology of *Boerhaavia diffusa* Linn. and *Gomphrena celosioides* Mart. Ph.D. thesis, Banaras Hindu University.

[8] Singh, Manjula, 1966. Geographical distribution and ecology of medicinal plants-*Solanum surattense* and *S. nigrum*. Ph.D. thesis, Banaras Hindu University.

amplexicaula (Shanker 1967)[9], *Tribulus terrestris* (Pathak 1967)[10], *Biophytum sensitivum* (Shetty 1967)[11], *Rauvolfia tetraphylla* and *R. serpentina* (Biswas 1967)[12], *Eichhornia crassipes* and *Spirodela polyrrhiza* (Das 1967)[13], *Anagalis arvensis* (Pandey 1968)[14], *Eclipta prostrata* L. (Gupta 1969)[15], *Achyranthes aspera* and *A. bidentata* (Ratra 1970)[16], *Desmodium triflorum* DC. (Rao 1971)[17], *Alysicarpus monilifer* (Maurya and Ambasht 1973), *Salvia plebeja* (Jha 1971)[13], *Melilotus indica* (Lavania 1972)[19], *Nepeta ruderalis* (Lalman 1973)[20], *Rumex dentatus* (Gupta 1974)[21], *Chrozophora rottleri* A. Yuss. ex Spreng and *Scoparia dulcis* L. (Lal 1976)[22] etc.

Tripathi (1964)[5] has made competition studies for aboveground and belowground space between *A. tenuifolius* or *E. dracunculoides* weed with gram *(Cicer arietinum)* crop. He finds that if gram crop is sown a

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9 Shanker, V. 1967. Ecology of *Trichodesma amplexicaule* Roth. Ph.D. thesis, Banaras Hindu University.

10 Pathak, P.S. 1967. Ecology of *Tribulus terrestris* Linn. A medicinal plant. Ph.D. thesis, Banaras Hindu University.

11 Shetty, M.S. 1967. Ecology of *Biophytum sensitivum* (L) DC-A medicinal plant. Ph.D. thesis, Banaras Hindu University.

12 Biswas, R. 1967. Ecology of medicinal plants *Rauvolfia tetraphylla* L. and *Rauvolfia serpentina* Benth Exturz. Ph.D. thesis, Banaras Hindu University.

13 Das, R.R. 1967. Growth and distribution of *Eichhornia crassipes* (Schum) (Mart) Salms and *Spirodela polyrrhiza* (L.) Schleid. Ph.D. thesis, Banaras Hindu University.

14 Pandey, S.B. 1968. Ecological observations on *Anagalis arvensis* L. with special emphasis on seed germination. Ph.D. thesis, Banaras Hindu University.

15 Gupta, P.L. 1969. Autecology of *Eclipta prostrata* a medicinal plant. Ph.D. thesis, Banaras Hindu University.

16 Ratra, P.S. 1970. Ecology of medicinal plants. *Achyranthes aspera* Linn and *Achyranthes bidentata* Bl. Ph.D. thesis, Banaras Hindu University.

17 Rao, A. 1971. The role of *Desmodium triflorum* in the production and nitrogen economy of grasslands at Varanasi. Ph.D. thesis, Banaras Hindu University.

18 Jha, S.N. 1971. Autecological studies of *Salvia plebeja* R. Br. Ph.D. thesis, Banaras Hindu University.

19 Lavania, G.S. 1972. Ecology of *Melilotus indica* (L) Ph.D. thesis, Banaras Hindu University.

20 Lalman, 1973. Ecology of two winter annuals *Nepeta ruderalis* Buch. Han. and *Salvia plebeja* R.Br. from Varanasi. Ph.D. thesis, Banaras Hindu University.

21 Gupta, S.K. 1974. Ecology of *Rumex* species *(R. dentatus* Linn. and *R. nepalensis* Spreng.) Ph.D. thesis, Banaras Hindu University.

22 Lal, B. 1976. Ecology of two medicinal plants *Chrozophora rottleri* and *Scoparia dulcis*, Ph.D. thesis, Banaras Hindu University.

little in advance then in presence of its seedlings weed seedlings do not come up well and the weed problem is largely solved. S.B. Panday (1968)[14] has earlier shown that in the weed *A. arvensis* the seed germination is greatly regulated by red light. In the seed coat this mechanism is inbuilt to determine the dormancy period and the time of seed germination. The seed coat develops red pigment (Anthocyanin) at the appropriate season when light passing through the coat becomes red and induces the embryo to germinate. In *A. monilifer* a leguminous weed, Maurya and Ambasht (1973) have discovered dimorphism in seed. Brown smooth seeds which are slightly larger but produced in lesser number show higher germination percentage than the yellow mottled seeds. These differ in their germination periods, thus the dimorphism serves as a means of better survival in a disturbed edaphic environment.

Ramakrishnan (1960)[4] has found that in many of the herbaceous plants there are ecological races correlated to climatic, biotic or edaphic factors. *P. bicalyculata*, an Acanthaceae weed common on waste lands and fallow fields is found to grow in nitrogen rich soil in shade but in open sun it is successful in nitrogen poor soils also. This is again found to be regulated primarily by selective seed germination. Soil calcium is found to be the edaphic factor regulating the occurrence of two ecotypes of *E. thymifolia:* The green form and the red·form. Ramakrishnan has further elaborated and extended his work on *E. thymifolia* and *Cynodon dactylon* at Chandigarh. At the Banaras Hindu University, under a PL 480 research project on the ecology of ten noxious weeds common to the Gangetic plains of India and U.S.A. have been studies for five years (1964 – 1969) by Misra *et al.* (1969)[23] and his research students. These ten noxious weeds are: *Chenopodium album, Cyperus rotundus, E. crassipes, A. arvensis, Spirodela polyrrhiza, Portulaca oleracea, Cassia tora., E. indica, Amaranthus spinosus and Eleocharis palustris.* Under this research scheme K.P. Singh has demonstrated the occurrence of two ecotypes in *P. oleracea* on the basis of microclimate and habitat features into obovate leaf and narrowly obovate leaf forms.

Besides the Banaras Hindu University there are now some other universities where researches on weed ecology is being done. Gorakhpur University, Punjab University, Vikram University, Saugor University, Saurashtra University, BITS Pilani, Kashmir University, etc are notable as new centres of ecology.

Although most of the autecological investigations on weeds have been done to study their ecological life cycle, mechanism of perennation

[23] Misra *et al.* 1969. Final technical report on a PL 1480 research Project on "Ecology of Ten Noxious Weeds Common to Gangetic Plains, India and U.S.A." Banaras Hindu University.

and persistent appearance in certain habitats, yet they often provide information on the weakest phase in the life cycle when weeds could be vulnerable to easy control treatments.

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BIOTROP Training Courses in Weed Science

T. O. ROBSON [1]

ABSTRACT

Since its inception in 1968 BIOTROP's Tropical Pest Biology Program has held 4 six week intensive courses in weed science and 7 six month research training courses. The 6 week courses have been attended by a total of 140 and the 6 month courses by a total of 12 graduates in biology and agriculture. Further opportunities are being provided in the program for the second five year Development Plan which comes into effect from July 1978.

INTRODUCTION

The South East Asian Ministers of Education Organization (SEAMEO) has its Regional Center for Tropical Biology (BIOTROP) at Bogor in Indonesia. The objectives of BIOTROP are to provide facilities for regional research and training in specialized fields within the spheres of tropical forest biology, tropical aquatic biology and tropical pest biology. Its role in weed science has been clearly presented at previous conferences by Soerjani (1971; 1973).

Since its inception in 1968, the Tropical Pest Biology Program at BIOTROP has provided a series of training courses in weed science. These have taken two forms:

a. Six-week intensive courses

b. Six-month training in research techniques.

These weed science courses are directed towards young scientists who are or will be in a position either to disseminate the up to date information they obtain to students and farmers; or to develop their own interests in weed research and the adaptation of modern techniques to local problems.

Those attending the courses have all been graduates in biology or agriculture and most of them have been involved in teaching at universities or colleges. A few have been employed at official research institutes and a few in the research and development programs of commer-

[1] Seconded to BIOTROP, Box 17, Bogor, Indonesia, from Weed Research Organization, Oxford, England.

cial firms. The participants are nominated by the Ministry of Education of their respective countries on receipt of the details of the course from BIOTROP.

Courses held. Up until July 1977 there have been 4 six-week courses and 7 six-month courses in weed science. In each of the six-week courses SEAMEO has sponsored, through the Ministries of Education, 16 official participants and these have been joined by a varying number of "observers" paid for by other sponsors such as commercial firms. In each of the six-month courses not more than 8 officially sponsored participants have been accepted. So far a total of 140 people from the eight member countries of SEAMEO have attended the six-week courses and 42 have attended the six-month research training. Details are given in Tables 1 and 2.

Three six-week courses have been held at Bogor and one at Los Banos in the Philippines. Three of the courses have covered the whole field of weed science — from weed taxonomy and biology to weed control — while the other held in December 1972 specialised on the identification and listing of weeds. A summary of curricula of the general Weed Science courses is given below to illustrate their scope.

1. Introduction to weeds, weed management and pest management.
2. Crop and weed relationships and assessment of crop losses.
3. Weed biology.
4. Collection, taxonomy and weed surveys.
5. Weed control methods:

   a. Preventive measures
   b. Direct physical methods
   c. Cultural & ecological methods
   d. Biological methods
   e. Chemical methods (including herbicide characteristics, formulations, behaviour, use, residues and registration)
   f. Utilization of weeds.
   g. Integrated control.

6. Weed control in major food crops, horticulture, plantation crops, grasslands and pastures, forestry and water.
7. Impact of weed control on the environment (residue analysis, bioassay techniques, effect on soil microbes, etc).

Table 1. Number of participants in BIOTROP Short Term Training Courses in Weed Science.

No.	Year	Dates	Venue	Number of participants per Country								Total parti cipants	Obser-vers	Total
				Ind.	Khmer	Laos	Mal.	Phil.	Sing.	Thai.	Viet.			
1.	1972	April-May	Bogor	3	—	—	2	3	2	3	1	14	30	44
2.	1972	Nov.-Dec.	Bogor	4	2	2	2	2	2	4	1	19	14	33
3.	1974	May-June	Bogor	3	2	1	2	4	1	2	2	17	25	42
4.	1976	April-May	Los Baños	5	—	—	3	4	—	4	—	16	5	21
Total				15	4	3	9	13	5	13	4	66	74	140

Table 2. Number of participants in BIOTROP Long Term Training Courses in Weed Science.

No.	Year	Dates	Venue	Number of participants per country								Total parti-cipants
				Ind.	Khmer	Laos	Mal.	Phil.	Sing.	Thai.	Viet.	
1.	1971/72	Sept.-May	Bogor	2	—	—	—	1	—	2	1	6
2.	1972	April-Dec.	Bogor	1	—	—	—	1	—	1	1	4
3.	1972/73	Nov.-April	Bogor	2	1	2	—	—	—	—	—	5
4.	1974	Jan.-June	Bogor	2	1	1	1	1	—	1	1	8
5.	1974/75	Aug.-Febr.	Bogor	2	1	1	—	1	—	2	—	7
6.	1975/76	Oct.-April	Bogor	2	—	—	—	2	—	2	—	6
7.	1976/77	Aug.-Febr.	Bogor	3	—	—	—	—	—	3	—	6
Total				14	3	4	1	6	—	11	3	42

Although the course is aimed at graduates much emphasis is placed on the practical side and participants have the opportunity of observing and in some cases actively participating in weed control practices in the field. In this way it is hoped they are not only brought up to date with modern techniques but are also reminded that the purpose of weed science is to solve practical weed problems. It is a deliberate policy to balance the theory with practical sessions to emphasize this point.

During the six-month research training period each participant, after a short introductory course of lectures, is assigned to a research project within the BIOTROP weed science program and completes a series of experimental or monitoring studies. These culminate in the preparation of a scientific report and the oral presentation of results at a colloquim. The research topics selected vary considerably from the more highly academic studies of herbicide behaviour to the utilization of weeds. In some cases this research has been accepted by the participants' university as part fulfilment of an M.Sc. or other higher degree.

In addition to these specific courses, lectures in weed science have been given to participants in the Pesticide Ecology courses of which one short term and two long term have been held.

Generally the courses seem to have been well received and considered useful. There have, however, been a number of criticisms. The most important of these is that the level of the short-term courses is either too high or too elementary depending upon the background of the participant. With the present system of selecting participants, it is difficult to avoid some lack of uniformity in background knowledge, interest and experience. As a result it has sometimes been difficult for the organizers and lecturers to adjust the level, to suit everybody. If an improvement can be made then it is in the selection of the participants most suited to the course. This will require both the thoughtful selection by the Ministries of Education concerned and also a clear and detailed description of the course and qualifications required in the notification sent out by BIOTROP solicitating nominations.

Despite occasional difficulties of this nature all participants have gained knowledge from these weed science courses and, especially since BIOTROP accomodation has been available at Tajur, about 5 km from Bogor, have also enjoyed the opportunity of meeting and getting to know the participants from the other SEAMEO member countries.

Future courses. BIOTROP is due to begin its second 5 year Development Period in July 1978 and plans for this are now being finalized. The number of training courses offered is to be reduced but there will still be five short-term specialist-courses lasting 6 weeks and five long-term research training periods of 10 months each. The latter have been extended because experience has shown that 6 months is inadequate for many research projects.

Only one of the short-term courses (in 1980) has been specifically allocated to weed science but that on pest ecology and pest management in 1979 will include the management of weeds.

Of the long-term training periods again only one is specified for weed science but there will be three covering pest ecology and pest management which will also offer opportunities to weed scientists to study integrated weed management. It is expected therefore that BIOTROP will continue to play an important role in the post graduate training in weed science of young scientists in the SEAMEO member countries.

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Status Report on a Decade of Weed Science at Jhansi and Perspectives for the Future

T. R. DUTTA [1]

ABSTRACT

The weed scientist is faced with great challenges in the Indian sub-continent which has a rich flora, varied agroclimatic regions, soil types, wide spectrum of crops and cropping systems ranging from subsistance to mechanised farming. A Division of Weed Ecology & Control was added to the India Grassland and Fodder Research Institute, which was under establishment at Jhansi in 1967. It was envisaged that this Division would initiate integrated research in weed science for the entire country. Despite constraints of a newly developing Institute, the Division has since carried out work on botanical aspects of weeds, physiological studies with herbicides, evaluation of about 150 new herbicides over a wide range of weeds, crops, soils and climate, assessment of herbicide residues, establishment of tolerance limits, synthesis of analogues, studies on herbicide toxicity, quality aspects of agricultural products as a result of herbicides usage, herbicides as antitranspirants and bioregulators, economic exploitation of weeds etc. The Division also devised or standardised control methods for some special noxious weeds eg *Typha* sp., *Cyperus rotundus*, *Parthenium* sp., *Eupatorium* sp., *Eichhornia* sp., submerged aquatic weeds *viz Potamogeton* sp., brush control and training personnel on weed control technology. As a result of demonstrations carried out among actual users by the Institute and other agencies, a steep rise in annual herbicide consumption in the country is noticed. Besides studies on various aspects of weeds and their control, the Division is currently engaged in studies on the economic exploitation of weeds, physiological effects on other crops and weeds of constituents obtained from certain weeds particularly *Parthenium* sp. and *Rivea* sp. Suitable weed control technology for various crop production systems including, peasant farmer, dryland farming, dairy farming and high input farming have been developed. Future projections of studies include compatibility of herbicides with other agrochemicals, enhancement of herbicide reaction with adjuvants, effects of herbicides on soil fertility, use of herbicides in the context of stress physiology and bio-regulants, identification of weeds at their juvenile stages of growth, and deeper insights on the mechanism of action of herbicides. Modern laboratory facilities including, biochemical, environmental, physiological, instrumentation facilities have recently become available. An uptodate list of publications from the Division is given.

A rich flora, a wide spectrum of crops grown in subsistance to mechanised farming, a variety of soil and climate make the India subcontinent one of the greatest challenges for the weed scientist. Weed research in India on modern lines was attempted on a sporadic basis at various centres scattered all over the country. Chakravarti (1963) gave an excellent review

1 Division of Weed Ecology and Control, Indian grassland and Fodder Research Institute, Jhansi, UP, 284003, India.

of the earlier work. Aspects of the current work on weeds and their control in the country is reflected in the proceedings of the Weed Science Conference/Workshop which was held in Hyderabad, 1977. The Govt. of India was aware of the enormous national losses that were caused to productivity by weed competition and the highly effective technology that was then developing in some overseas countries. In this context it was decided to carry out intensive, integrated research on the problems of weeds and their control to bring the benefits of modern weed control technology to Indian farmers. A Division of Weed Ecology and Control was added to the Indian Grassland and Fodder Research Institute, Jhansi which was under establishment in 1967 to lay a foundation for integrated weed research in the country. Pioneering attempts were made by this Division at integrated weed research which *inter alia* included investigations on the (i) botanical aspects on weeds (ii) physiological studies on herbicides, (iii) development of suitable techniques for weed control by chemical and other methods both under arable and noncrop lands, (iv) assessments of herbicide residues, establishment of tolerance limits, monitoring toxicity and quality aspects of agricultural produce as a result of herbicide usage. Devising methods for the control of some special noxious weeds eg *Typha* sp., *Cyperus* sp., *rotundus*, *Parthenium* sp., *Eupatorium* sp., *Eichhornia* sp., submerged aquatic weeds *viz. Potamogeton* sp., etc brush control in natural grasslands etc (v) training of extension personnel, famers, scientists in weed control technology.

In weed botany, investigations were carried out on autecology, survey, mapping, invasion and competition. In plant physiology, about 150 new herbicides and their analogues available on the world market, were evaluated for their selectivity over a wide range of crops, weeds, soils and climate. Besides, some herbicides were studied at sub-lethal doses for their effects and exploitation as anti-transpirants, regulators for growth, seed-setting and increasing protein content of fodders. In chemistry, biochemistry and physiology, problems of quality, residues and synthesis of new herbicide analogues were attempted. Some active constituents of weeds were isolated, purified and examined for their potentials as herbicides, germination and growth promoting and inhibiting agents. In agronomy, field trials both in the experimental farm and among farmers were undertaken and the feedbacks have been analysed before their inclusion in the outreach programme. Training in modern weed control technology has been imparted from the level of illiterate peasant farmers to post-doctoral scholars.

As a result of these efforts by the ICFRI, Jhansi and other agencies, herbicide recomendations are becoming acceptable to farmers. There exists definite consciousness among them wherever the profitable use of herbicides has been demonstrated. The consumption of herbicides in the country has increased from 5 tonnes in 1965 to nearly 1000 tonnes in 1975. The demand for herbicides is still increasing. About twenty herbicides have been licensed for manufacture in the country.

The current lines of work in the Division include exploitation of weed constituents obtained particularly from *Parthenium* sp. and *Rivea* sp. as growth promoters in crops. Suitable weed control technology for the various crop production systems including the peasant farmer, dryland farmer, dairy farmer and specialised high-input farming have been developed and released. Future projections of theDivision include, interaction of herbicides with other agrochemicals, enchancement of herbicide reactions with adjuvants and synergists, effects of herbicides on soil fertility, evaluation of minimum and zero tillage, herbicide use in the context of physiological stress and bio-regulation, identification of weeds at their juvenile growth, weeds as sources of industrial raw materials and deeper insights on mechanism of herbicides. Laboratory facilities such as control environment chamber, IR gas analyser, UV-vis-IR Spectrophotometers, ultracentrifuge, column, TLC, gas, paper chromatography, log sprayers, electronic leaf area meters, spectro-radiometers, have recently become available

LITERATURE CITED

Chakravarti, S.C. 1963. Weed control in India — review. Indian Agric. 7 : 23 — 58.

Rules of the Asian-Pacific Weed Science Society (Inc.)

1. Name

The name of the Society shall be the Asian-Pacific Weed Science Society (Incorporated) hereinafter called the Society.

2. Objectives

The objectives of the Society shall be to promote weed science, in particular in the Asian and Pacific regions, by pooling and exchanging information on all aspects of weed science.

3. Membership

There shall be five classes of membership.

(i) Ordinary members
(ii) Sustaining members
(iii) Honorary members
(iv) Associate members
(v) Affiliated national or region societies.

4. Mode in which Persons become Members

(i) *Ordinary members*: Any person or organizations interested in the objectives of the Society may become a member.

(ii) *Sustaining members*: Proprietary companies interested in the objectives of the Society may become sustaining members by biennial financial contributions to the Society.

(iii) *Honorary members*: Any member who has given outstanding service to the Society may be elected as an honorary member at any biennial or special general meeting.

(iv) *Associate members*

(v) *Affiliated societies* — national or regional societies may affiliate with APWSS for purpose of kindred interests, communication, coordination of activities, etc; by letter of intent or request to APWSS.

5. Mode in which Persons cease to be Members

(i) Any member of the Society may resign by giving notice in writing to the Secretary.

(ii) Any member whose subscription is more than four years in arrears shall be removed from membership and may be readmitted on payment of such arrears or an amount decided by the Executive.

6. **Officers of the Society**

The Officers of the Society shall be:

(i) President
(ii) Vice-President
(iii) Secretary (Permanent position)
(iv) Honorary Treasurer (Permanent position)

and shall be elected at the biennial general meeting. Officers shall hold office until three months after termination of the biennial general meeting next following their election. Newly appointed officers shall take office at the same time.

7. **Executive Committee:**

The Executive Committee shall consist of:

(i) The President
(ii) Vice-President
(iii) Secretary
(iv) Honorary Treasurer
(v) Immediate Past President
(vi) Six other members

The Executive Committee shall have power to appoint new members to fill any casual vacancy and shall have power to co-opt not more than three other members.

8. **Election of Executive Committee**

The members of the Executive Committee shall be elected at the biennial general meeting in the same manner and at the same time as other officers.

9. **Powers of the Executive Committee**

The Executive Committee shall have all the powers of the Society provided that these powers do not conflict with the rules.

10. **Delegation of Powers by Executive Committee**

The Executive Committee may delegate its powers and duties to subcommittees consisting of such member or members as it may resolve and may grant to any such subcommittee the power to co-opt other persons, whether members or not.

11. **Executive Committee Quorum**

At any meeting of the Executive Committee four shall form a quorum.

12. Patron of the Society

A patron shall be selected from the country in which the President is resident.

13. Biennial General Meeting

(i) A biennial general meeting shall be held every two years at the biennial conference or at a time or place decided by the Executive Committee.

(ii) If not to be held at the biennial conference, at least three months' notice shall be given to all financial members of the time and place of biennial general meeting.

(iii) At each biennial general meeting an audited balance sheet and income and expenditure account shall be presented.

(iv) At each biennial general meeting a biennial report shall be presented.

(v) At the biennial meeting (or any special general meeting) a quorum shall consist of 15 members.

14. Voting

Only ordinary and honorary members are entitled to vote. At all meetings voting shall be on the voices or by a show of hands at the discretion of the Chairman provided that if any member shall so demand voting shall be by ballot. The Chairman shall have a deliberative and casting vote. Except where otherwise stated, a simple majority shall be sufficient to carry a motion.

15. Special General Meeting

A special general meeting may be held at any time by resolution of the Executive Committee or on receipt by the Secretary of a requisition signed by at least 20 members specifying the purpose for which the meeting is to be called. At least three months' notice shall be given to all financial members of the time and place of such meeting.

16. Funds

All funds of the Society shall be paid to the Honorary Treasurer, who shall keep correct accounts showing the details of the Society's financial affairs and shall disburse monies of the Society under the authority of the Executive Committee.

17. Bank Accounts

The Society's bank account shall be operated by the Secretary, Honorary Treasurer and any two other members of the Society or other persons appointed by the Executive Committee for that purpose. Cheques and withdrawal warrants shall be signed by any two of the signatories.

18. Financial Year

The financial year of the Society shall end on April 30 in each year, or such other date that may be decided from time to time by the Executive Committee.

19. Auditor

At each biennial general meeting an Honorary Auditor shall be elected.

20. Subscriptions

The biennial subscription which is due at the beginning of the financial year and which shall include all privileges including a copy of the *Proceedings* of that year, shall be $4.00 or such other sum as may be decided from time to time at any biennial or special meeting. The fee for associate members would be half that for ordinary members. Non-members may be admitted to conferences on a daily fee which may be decided by the Executive Committee.

21. Common Seal

The common seal shall be kept in the custody of the Secretary and shall be affixed to documents only by the direction of the Executive Committee, in the presence of the Secretary and any one member of the Executive Committee.

22. Alterations of Rules

The rules of the Society may be altered, rescinded, or added to at any general meeting provided that two-thirds of the members present vote accordingly, and provided that at least three months' notice of intention is sent by post to members.

23. Power to Borrow Funds

The Society shall have power to borrow money.

24. Distribution of Assets

In the event of the winding up of the Society the funds and the property of the Society shall be distributed to any other body or organization having the same or similar objectives as those of the Society or to such charitable organizations or such charitable purposes as shall be decided by members at the general meeting.

25. Official Language

The official language of the Society shall be English.

26. Currency

The currency shall be U.S.A. dollars.

(July 11th, 1977)

Report of the Sixth APWSS Conference

* The Sixth APWSS Conference

The sixth Conference of the APWSS was held from 11 to 17 July 1977 at the Hotel Indonesia-Sheraton, Jakarta. This conference was organized by the Asian Pacific Weed Science Society in cooperation with the Weed Science Society of Indonesia and the Department of Agriculture of the Republic of Indonesia.

Supports were also received from the Departments of Education and Culture, Public Works and Energy and various institutions, organizations, e.g. BIOTROP, plantations, research institutes and agrochemical companies.

The conference was attended by 314 participants coming from 22 countries, namely Australia, Fiji, France, India, Indonesia, Japan, Korea, Malaysia. The Netherlands, New Caledonia, New Zealand, Pakistan, the Philippines, Singapore, Sri Lanka, Switzerland, Taiwan (ROC), Tanzania, Thailand, UK, USA, West Germany.

A one-day fieldtrip to Bogor and its vicinity, was organized on 14 July 1977. Several institutions engaged in weed science were visited, e.g. Research Institute for Agriculture, Research Institute for Estate Crops, BIOTROP, the Gunung Mas Tea Plantation of PTP XII, and the Cibodas Mountain Botanical Garden.

Ninety one papers were presented at the Conference. The Proceedings were published with the assistance of the Weed Science Society of Indonesia. They can be obtained through P.T. ICHTIAR Bookstore, Jalan Majapahit 4, Jakkarta, Indonesia or the Asian Pacific Weed Science Society c/o Dr. R.K. Nishimoto, Dept. of Horticulture, Univ. of Hawaii, 3190 Maile Way Rm. 102, Honolulu, Hawaii 96822, U.S.A.

* Workshop on Weed Control in Scale Farms

At the same time a workshop on Weed Control in Small Scale Farms was held in cooperation with BIOTROP from 15 to 16 July 1977. Fourteen invited papers were presented in this workshop. Discussion was held in five working groups as follow:

1. *Socio-economic aspects of weed control in small farms* (Chaired by P. Mootoka).

2. *Pest management in weed control in small farms* (Chaired by L.C. Burril).
3. *Weed control in small scale rice and food crops* (Chaired by M.R. Vega).
4. *Weed control in small scale perennial and vegetable crops* (Chaired by C. Parker).
5. *Research and education in weed control in small scale farms* (Chaired by P.W. Michael).

The workshop concluded and recommended that:

1. Research to determine economical weed control practices must be site-specific;
2. Interdiciplinary approach in weed management be advocated;
3. Emphasis of weed control should be on preventive measures;
4. Biology of weed at various conditions should be studied to predict the probable infestation, the development of new rice varieties should also pay attention to weed;
5. Herbicides for vegetables should be aimed at the safe use, early post-emergence treatments with short residual life in soil, while in plantations, should be detected to economic and efficient policy towards good crop production.

The papers of the Workshop will be published by BIOTROP.

* **The Fourth WSSI Conference**

The Sixth APWSS Conference was proceeded by the fourth Conference and biennial meeting of the Weed Science Society of Indonesia at the same place on the 9th July 1977.

* **APWSS Business Meeting**

The Executive Committee held a meeting on the afternoon of 10 July 1977 to prepare the agenda of the biennial meeting and to evaluate the preparation of the Sixth APWSS Conference as reported by the Chairmen of the Organizing Committee Mr. O. Adiwinata and Prof. Dr. Haryono Semangun.

The fifth biennial meeting was held on 13 July 1977. The discussions and decisions made at the meeting can be summarized as follow:

1. Standing Committee reports 1975-77:

a. *Membership Committee* — Dr. Roy K. Nishimoto
We have 162 individual members, and 7 sustaining members for the period 1975-77.

b. *Newsletter* — Dr. Philip Motooka, Editor
The newsletter is now issued in January, May and September of each year. Three has been a lack of news to date, and members are encouraged to send in their news items to the Editor.

c. *Education and Training* — Dr. B.L. Mercado
The members of the Committee are Dr. P. Motooka of U.S.A. and Dr. Ueki of Japan. Dr. Ueki surveyed weed science education in Korea and Japan. A survey was also made of texbooks in weed science; there is one in Japan but none for other parts of Asia. There are few non-formal courses in weed science. Courses in weed science do not include weed management and integrated pest management yet.

d. *Compilation of Registered Herbicides* — Dr. S.R. Obien.
Dr. Obien has compiled, with the help of industry and other groups, an extensive draft of an Asian Pacific Herbicide Recommendations 1976-77. This very complete work will be completed and made available to members and interested parties. Dr. Obien is to be congratulated for this prodigious effort.

e. *Nomenclature and Standardization* — Dr. Peter W. Michael
This Committee was assigned three responsibilities, namely:

— common names of weeds (important works to be continued)

— common names of herbicides and related chemicals (to be included in Dr. Obien's Committee work)

— standard experimentation.

It was decided by the Executive Committee that a new Committee on Research Standardization and Methodology would be formed, under the leadership of Dr. Herbert Fisher of IPPC. Dr. Matsunaka and Prof. Ueki were suggested as members of this Committee.

2. **The seventh Conference 1979:**
   The seventh Conference of the APWSS will be held in *Sydney, Australia,* 26-30 November 1979 in conjunction with the Council of Australian Weed Science Societies (CAWSS) and the theme of the Conference will be "Weed Management in Crops and Non-crop situations".

3. **The Eight Conference 1981.**
   It was expected that the site of the eight conference will be *India,* however, no confirmation could be made at this business meeting.

4. **Election of officers 1977-79.**
   The Executive Committee of APWSS 1977-79 are as follow:

President	P.W. Michael (Australia)
Vice-President	H.R. Arakeri (India)
Secretary	D.L. Plucknett (USA)
Treasurer	R.K. Nishimoto (USA)
Past-President	M. Soerjani (Indonesia)
Executive Members	S.V.R. Shetty (India)
	Ojo Adiwinata (Indonesia)
	S. Matsunaka (Japan)
	M.H. Lambert (Pacific Area)
	S. Obien (Philippines)
	R. Jesinger (Singapore)
	Abu Baker (co-opted, Malaysia)
	L. Burrill (Co-opted, USA)

5. **Honorary membership**
   Dr. Marcos R. Vega, the first President of APWSS (1967-77) was elected as the new honorary member of the society.

* Pending to the resolution of a conference site for 1981 permanent secretary, D.L. Plucknett was elected acting vice-president and secretary by the biennial meeting on 13th July 1977. At a latter date, after an approach to the Indian Weed Science Society and the Government of India made by President P.W. Michael, H.R. Arakeri replaced D.L. Plucknett as vice-president for 1977-79.

* **Other Matters**

During the period 1972-79 there have been 424 names once or more than once registered as members of APWSS. Their names are listed elsewhere in this Proceedings. During the Jakarta 1977 conference, 107 new members were accepted and welcomed. The membership fees collected, amounting to US $ 1,232 was sent to the treasurer of the society.

The summary of the budget of the conference was as follow:

a. Conference expenditure (O.C.)	US $ 16,815
b. Workshop on Small Farm's expenditure (BIOTRCP)	US $ 17,648
c. Proceedings, reprints, postages (O.C.)	US $ 19,510 *

The Executive Committee of APWSS (1975-1977) on behalf of the Organizing and Steering Committee of the conference, as well as the Editorial Committee would like to express their utmost appreciation to all, in particular to the Government of the Republic of Indonesia (including various institutions and agnecies), the Weed Science Society of Indonesia, the agro-chemical companies and all participants, etc. who in one way or another showed their interest and assisted the organization of the conference, without which it would not be a successful one.

Jakarta, July 1977

Mohamad Soerjani
President APWSS (1975-77),
Chairman, Steering and Editorial
Committee of the Sixth
APWSS Conference

* of which US $ 8,800 (at the new rate 1 US $ eq. to Rp. 625,—) is not paid yet, but will be covered by selling the Proceedings to non-members.

Mr. Ojo Adiwinata, Chairman of the OC of the 6th APWSS Conference reporting the preparation of the meeting.

Dr. Haryono Semangun, the President of the WSSI delivering his welcoming address.

His Excellency the Minister of Agriculture of the Republic of Indonesia Dr. Thoyib Hadiwijaya addressed and declared open the Sixth APWSS Conference.

Dr. Ishemat Soerianegara, the Director of BIOTROP declared the closing of the Workshop on weed control in Small Scale Farm sponsored by BIOTROP at the end of the Sixth APWSS Conference, July 16, 1977.

Don Plucknett, Secretary of the Executive Committee reading the minutes during the business meeting on July 13, 1977.

Members of APWSS attending the business meeting.

Peter W. Michael inaugurating Marcos Vega as an honorary member of the APWSS on the closing ceremony of the Sixth APWSS Conference on the July 16, 1977.

Marcos Vega, the First President of APWSS (1967 - 69) delivering his address as one in a series of addresses by the past Presidents on the occasion of the tenth Anniversary of the society.

Kenji Noda, the Fifth President of the APWSS (1973-75).

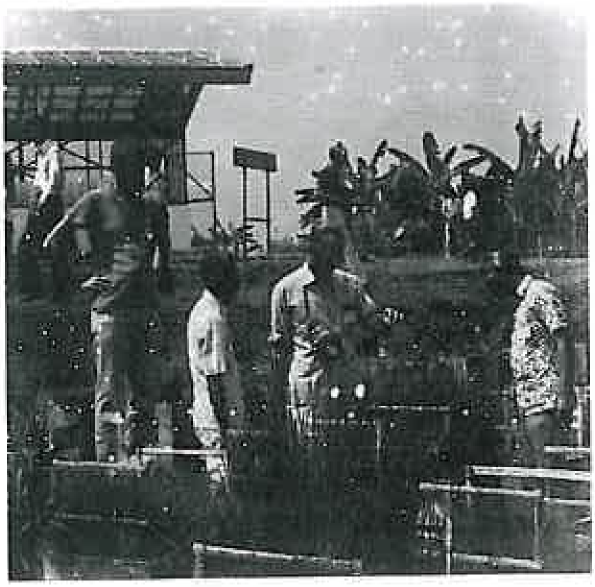
Les Mathews, the Third President of the APWSS (1971-73).

Mohamad Soerjani the Sixth President of the APWSS (1975-77).

Peter W. Michael the Seventh President of the APWSS (1977-79).

Chris Parker, chaired one of the working group sessions of the workshop on weed control in Small Scale Farms, assisted by Aslok K. Seth and Juliana N. Manuel.

Some of Participants of one of the Working groups of the Workshop on weed control in Small Scale Farms.



A visit at BIOTROP's Experimental site, July 14, 1977.

Fieldtrip to a rubber plantation nearby Bogor, West Java, July 14, 1977.

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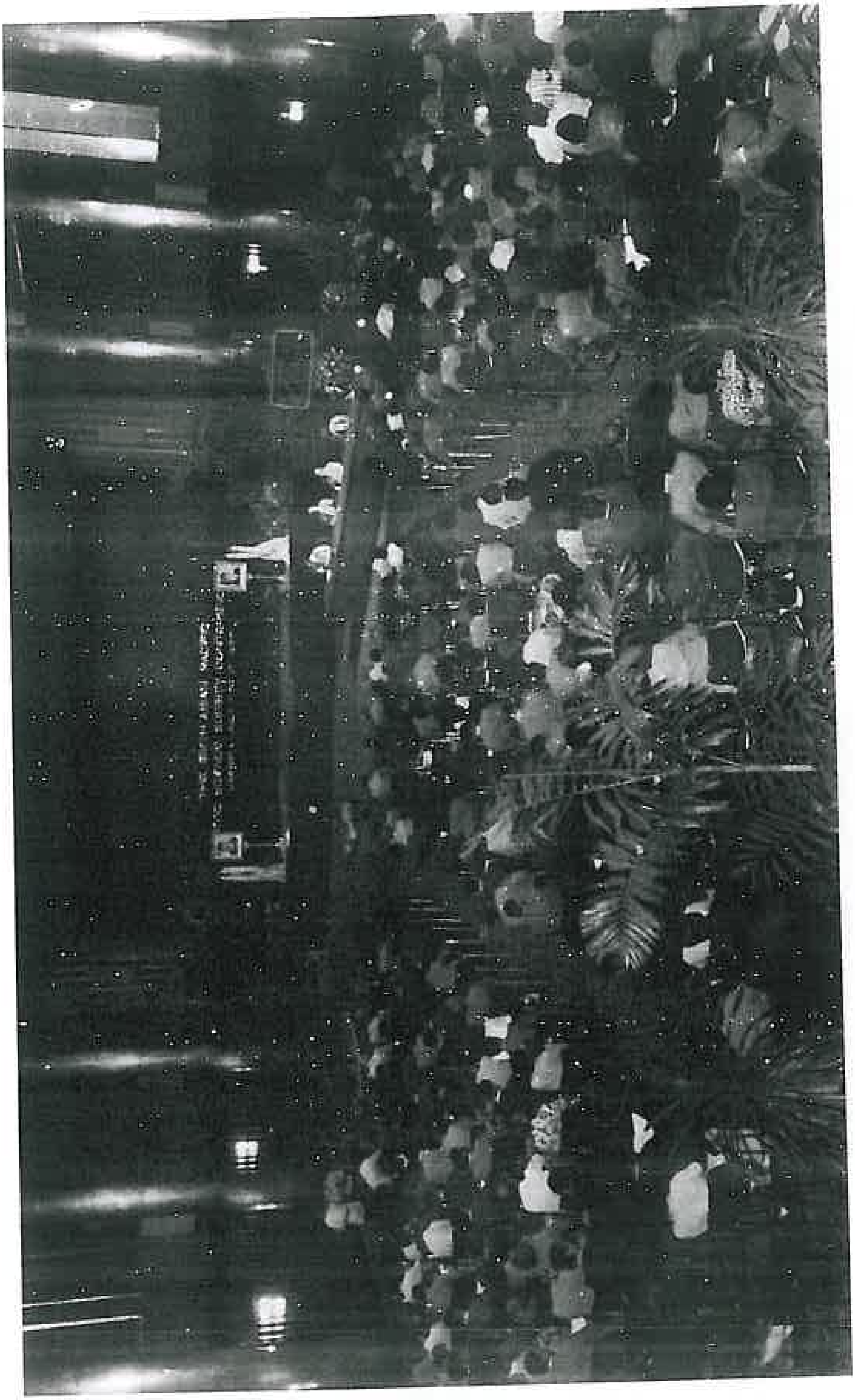
Some of the Participants during the closing ceremony.

The dancers completed the entertainment by singing a farewell song.

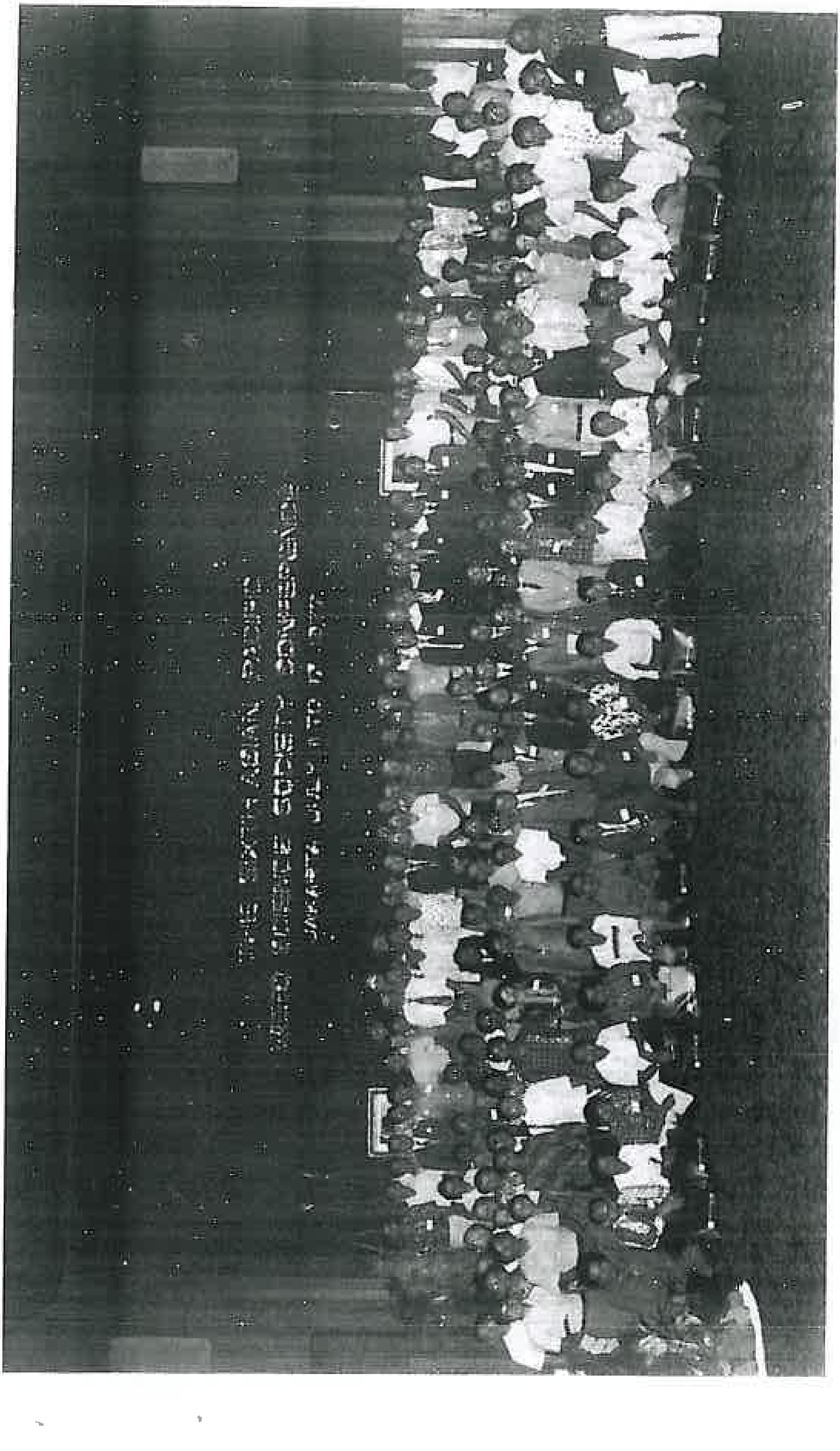
The "Kuda Lumping" dance, performed during the cultural evening on July 16, 1977.

Members at the registration desk.

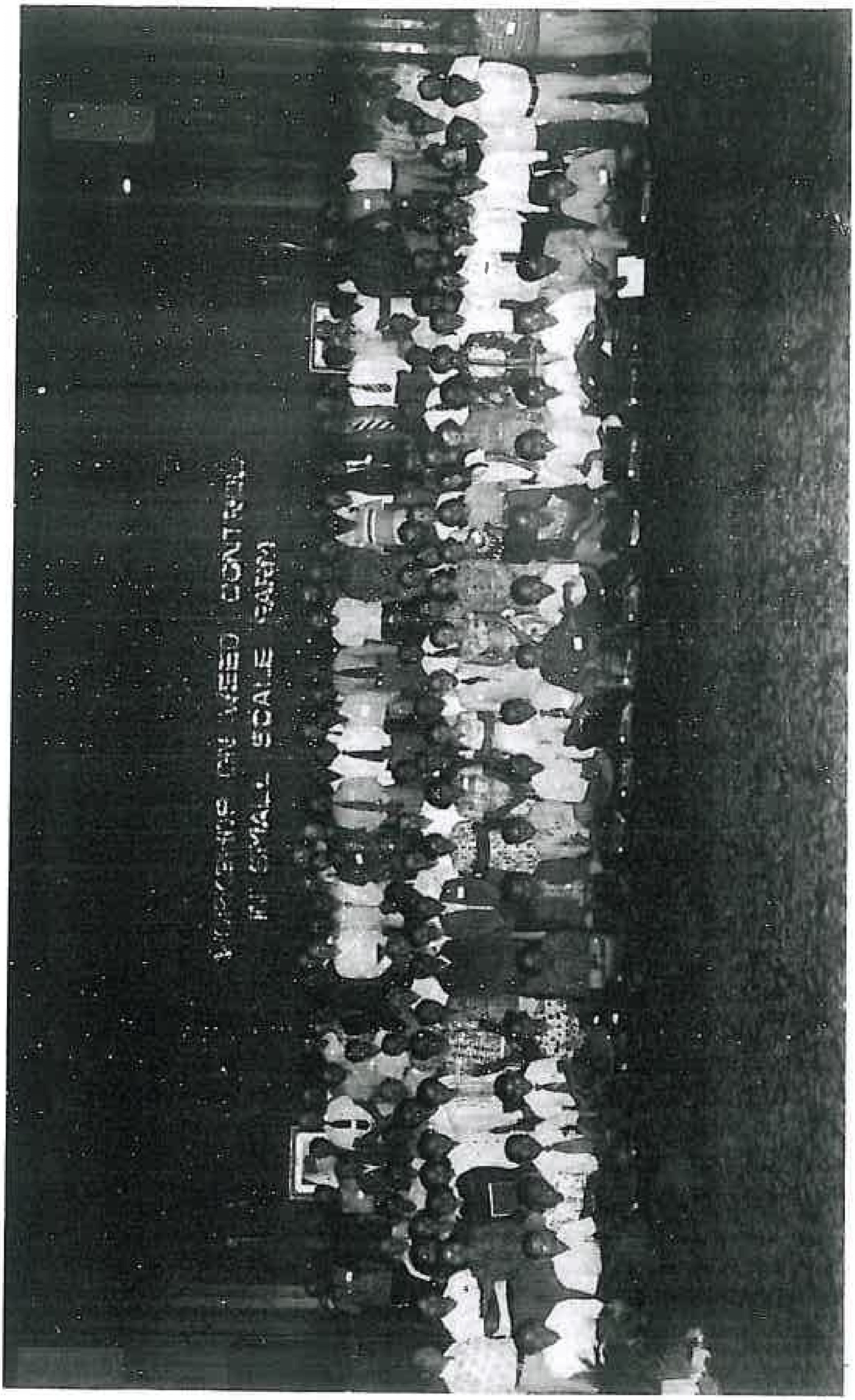


The opening session of the 6th APWSS Conference, July 11, 1977.

The opening session of the 6th APWSS Conference, July 11, 1977.



The Participants on the 6th APWSS Conference, Jakarta July 11 - 17, 1977.



The Participants of the workshop on Weed Control in Small Scale Farm, Jakarta July 15, 1977.

List of Participants
Of The Sixth APWSS Conference
Jakarta, Indonesia
11 — 16 July, 1977

1. **Australia**

1. 1. Allen, P.L., Elanco, 44 McHendrick Ave., Mildura, Victoria 3500.
2. 2. Arvier, A.C., Dept. of Primary Industries, Indocropily, Queensland 4068.
3. 3. Barnett, I.L., Stauffer, 6 Grand Ave., Parramatta, NSW 2150.
4. 4. Cates, A.H., Peterson Co., P.O. Box 332, Mascot, NSW 2020.
5. 5. Davis, R.C., DuPont, 49-55 Falcon Street, Grows Nest 2065.
6. 6. Haseler, W.H., The Allen Flitcher Res. Sta., P.O. Box 36, Sherwood, Queensland 4075.
7. 7. Hood, M.J., 45 William Street, Orange, NSW.
8. 8. Lowe, L.B., Elanco, Wharf Road, West Ryde, NSW 2114.
9. 9. Michael, P.W., Dept. of Agronomy, Sydney University, NSW 2006.
10. 10. Pike, B.R., 18 Nairock Road, Woodside 34.
11. 11. Post, H.A., 4 Cyprian Street, Mosman.
12. 12. Reeves, T.G., Rutherglen Res. Sta., Dept. of Agriculture, Rutherglen, Victoria.
13. 13. Reily, D.L., P.O. Box 59, Bankstown, NSW 2076.
14. 14. Rochecouste, E., 45 Churchill Road, Killara, NSW 2071.
15. 15. Smith, L., Hawkesbury Agr. College, Hawkesbury.
16. 16. Winston, E.C., Boots, P.O. Box 120, Carlingford 2118, Sydney.

2. **Fiji**

17. 1. Karan, B., Dept. of Agriculture, Suva.

3. **India**

18. 1. Ambasht, R.S., Banaras Hindu University, Varanasi.
19. 2. Obien, S.R., ICRISAT, Hyderabad.
20. 3. Shetty, S.V.R., ICRISAT, Hyderabad.

4. Indonesia

21. 1. Adam, N., Satyawacana Christian University, Jl. Diponegoro 56, Salatiga.
22. 2. Adiwinata, O., PTP XII, Jl. Cikapundung Barat 1, Bandung.
23. 3. Agustina, Liliek, Brawijaya University, Malang.
24. 4. Angudi, S., DOW Pacific Chem., Nusantara Bldg. F/17, Jl. Thamrin 57, Jakarta.
25. 5. Ardjasa, W.S., Central Res. Inst. for Agric., Jl. Merdeka 99, Bogor.
26. 6. Arief, A., DOW Pacific Chem., Nusantara Bldg. F/17, Jl. Thamrin 57, Jakarta.
27. 7. Arief, A., Pertamina, Jl. Juanda 13, Jakarta.
28. 8. Azalu, FX. K., Agricon, Jl. Siliwangi 68, Bogor.
29. 9. Aziz, H., Res. Inst. for Industrial Crops, Jl. Cimanggu 1, Bogor.
30. 10. Bahar, F., Maros Res. Inst. for Agric., Ujung Pandang.
31. 11. Bangun, E., C.V. Masyarakat, Jl. Veteran I/29, Jakarta.
32. 12. Barnes, D.E., Indagro, Jl. Tanjung 31, P.O. Box 3314, Jakarta.
33. 13. Bekti, M., Res. Inst. for Horticulture, Pasar Minggu, Jakarta.
34. 14. Benyamin, B., Ciba-Geigy, 58 Five Pillar, Jakarta.
35. 15. Birowo, A.T., Bureau of Agricultural Planning, Dept. of Agriculture, Jakarta.
36. 16. Brata, C., BASF, Jl. Lodan Raya 2, Jakarta.
37. 17. Budihardja, I., Indagro, Jl. Tanjung 31, Jakarta.
38. 18. Burhan, A.H., BIOTROP, P.O. Box 17, Bogor.
39. 19. Butar-Butar, L.H., PTP V, Sei Karang, Medan.
40. 20. Butar-Butar, N., PNP VI, Pabatu, Tebingtinggi.
41. 21. Chaerani, Faiza, BIOTROP, P.O. Box 17, Bogor.
42. 22. Chozin, M.A., Fac. of Agriculture, Bogor Agricultural University, Bogor.
43. 23. Darana, S., Padjadjaran University, Bandung.
44. 24. Darmadi, T., Bayer, Jl. Cikini Raya 97, Jakarta.
45. 25. Darmaputra, Okky S., BIOTROP, P.O. Box 17, Bogor.
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48. 28. Dirdjonegoro, Sri S., BIOTROP, P.O. Box 17, Bogor.

49. 29. Djaenudin, Y., PTP XIII, Jl. Juanda 107, Bandung.
50. 30. Djalil, A., Rolimex, Jl. Juanda III/31Q, Jakarta.
51. 31. Djalil, A., Dept. of Biology, Indonesia University, Jakarta.
52. 32. Djamin, A., PNP VI, Pabatu, Tebingtinggi.
53. 33. Djatmiko, W., Plantation Institute, Jl. Sala 40A, Yogyakarta.
54. 34. Djohan, E.F., Bayer, Jl. Cikini Raya 97, Jakarta.
55. 35. Everaarts, A.P., Res. Inst. for Horticulture, Pasar Minggu, Jakarta.
56. 36. Gelissen, A., Brawijaya University, Malang.
57. 37. Göltenboth, F., Satyawacana Christian University, Salatiga.
58. 38. Gunawan, Marihat Res. Sta., P.O. Box 37, Pematang Siantar.
59. 39. Hadioetomo, Ign. J., Kalatham, P.O. Box 39, Bogor.
60. 40. Hakim, M., PNP X, Kedaton, Tanjung Karang, Lampung.
61. 41. Hamzah, P., Plant Quarantine Dept., Jl. Salemba 16, Jakarta.
62. 42. Hanafiah, A.R., Fac. of Agriculture, Sriwijaya University, Palembang.
63. 43. Harahap, H., PTP V, Sei Karang, Medan.
64. 44. Harahap, N.H., ICI Pestisida Indonesia, J. Fakhruddin 3, Jakarta.
65. 45. Hardjodiningrat, R.M.P.S., PNP VI, Pabatu, Tebingtinggi.
66. 46. Hardjosoesilo, G., Indagro, Jl. Tanjung 31, Jakarta.
67. 47. Heroetadji, H., Fac. of Agriculture, Brawijaya University, Malang.
68. 48. Hunt, J.L., International Timber Corp., P.O. Box 33, Balikpapan.,
69. 49. Joedodibroto, Roechyati, Cellulose Res. Inst., Bandung.
70. 50. Kartana, Y., BIOTROP, P.O. Box 17 Bogor.
71. 51. Kartasasmita, S., Agrocarb, Jl. Kebon Sirih 72, Jakarta.
72. 52. Kartiarso, Fac. of Animal Husbandry, Bogor Agricultural University, Bogor.
73. 53. Kartono, G., Res. Inst. for Industrial Crops, Jl. Industri Timur 36, Malang.
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75. 55. Koesoemanegara, C.I., Wonderful Chem., Jl. Dipati Ukur, Bandung.
76. 56. Koop, F.P., ICI Pestisida Indonesia, Jl. Fakhruddin 3, Jakarta.

77\. 57. Kooy, K., Pameti Karaya, Sumba.

78\. 58. Kuntohartono, T., Res. Inst. for Sugarcane, Jl. Pahlawan 25, Pasuruan.

79\. 59. Lamid, Z., Central Res. Inst. for Agric., Jl. Merdeka 99, Bogor.

80\. 60. Louis, Indagro, Jl. Tanjung 31, Jakarta.

81\. 61. Lowry, R., International Timber Corp., P.O. Box 37, Balikpapan.

82\. 62. Lubis, Y.R., Marihat Res. Sta., P.O. Box 37, Pematang Siantar.

83\. 63. Lumunow, J.K., Dit. Jen. Koperasi, Jakarta.

84\. 64. Lumy, W.F., PNP VI, Pabatu, Tebingtinggi.

85\. 65. Madkar, O.R., Fac. of Agriculture, Padjadjaran University, Bandung.

86\. 66. Malassa, J.L., DuPont, Sahid Jaya Ht., Jl. Sudirman 86, Jakarta.

87\. 67. Mangundihardjo, S., BIOTROP, P.O. Box 17, Bogor.

88\. 68. Mangunsukarjo, S., RISPA, P.O. Box 104, Medan.

89\. 69. Manik, B.I., C.V. Masyarakat, Jl. Veteran I/29, Jakarta.

90\. 70. Manwan, I., Maros Res. Inst. for Agric., P.O. Box 173, Ujung Pandang.

91\. 71. Martosupono, M., Res. Inst. for Tea and Cinchona, P.O. Box 148, Bandung.

92\. 72. Metaleda, B., Cenderawasih University, Manokwari.

93\. 73. Muchsin, I., Fac. of Fisheries, Bogor Agricultural University, Bogor.

94\. 74. Mursalim, H., Pertamina, Jl. Juanda 13, Jakarta.

95\. 75. Mustari, P.T. Pusri, Jl. S. Parman, Jakarta.

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Author Index

Weed Index

Herbicide Index

Common, Abbreviated, and Chemical Names of Herbicides

Acrolein	2-propenal
ACTRIL-DS	mixture of ioxynil octanate and 2,4-D isooctyl ester
Alachlor	2-chloro-2',-6'-diethyl-*N*-(methoxymethyl) acetanilide
Ametryn	2-ethylamino-4-(isopropylamino)-6-methylthio)-*s* triazine
Amitrole	3-amino-*s*-triazole
Asulam	methyl-(4-aminobenzenesulphonyl) carbamate
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine
Barban	4-chloro-2-butynyl *m*-chlorocarbanilate
Bentazon	3-isopropyl-1 *N*-2,2,3-benzothiadiazin-4-(3*H*)-one 2,2,-dioxide
Benthiocarb	*S*-(4-chlorobenzyl)-*N*,*N*-diethylthiolcarbamate
Bifenox	methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate
Bromacil	5-bromo-3-*sec*-butyl-6-methyluracil
Bromofenoxim	3,5-dibromo-2-hydroxybenzaldehyde 2,4-dinitrophenyl oxime
Bromoxynil	3,5-dibromo-4-hydroxybenzonitrile
Butachlor	*N*-(butoxymethyl)-2-chloro-2',6'-diethylacetanilide
Buthidazole	3,5-(1,1,dimethylethyl)-1,3,4 thiadizole-2-yl-4-hydroxy-1-methyl-2-imidazolidinone
Butylate	*S*-ethyl diisobutylthiocarbamate
CDAA	*N*,*N*-diallyl-2-chloroacetamide
CFNP	2,4-dichloro-6-fluorophenyl *p*-nitrophenyl ether
CNP	4-nitrophenyl 2,4,6-trichlorophenyl ether
Cacodylate	hydroxydimethylarsine oxide (sodium salt)
Chlometoxynil	2,4-dichlorophenyl-3-methoxy-4-nitrophenyl ether
Chloramben	3-amino-2,5-dichlorobenzonic acid
Chlorbromuron	3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methyl urea

* TRADE NAMES.

Chloropropham	isopropyl *m*-chlorocarbanilate
Chloroxuron	3-[P(*P*-chlorophenoxy)phenyl]-1,1-dimethyl-urea
Chlortoluron	*N*-(chloro-3-methyl-4-phenyl)-*N*,*N*-dimethyl-urea
Cyanatryn	2-(ethylamino-6-methylthio-*s*-triazin-2-yl) amino-2-methylpropionitrile
Cyanazine	2-(4-chloro-6-(ethylamino)-*s*-triazin-2-yl-amino)-2-methylpropionitrile
2,2-DPA	dalapon sodium salt of 2,2-dichloropropionic acid
2,4-D	2,4-dichlorophenoxy acetic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid
2,4-D IPE	4-(2,4-dichlorophenoxy)isopropyl ester
DMNP	HE-306; 3,5-dimethyl-pphenyl-*p*-nitrophenyl ether
DMPA	*O*-(2,4-dichlorophenyl)*O'*-methyl *N*-isopropyl-phosphoroamidotrioate
DNBP	dinoseb; 4,6-dinitro-*O*-*sec*-butyl phenol
DNOC	2-methyl-4,6-dinitrophenol
Dalapon	*see* 2,2-DPA
DESTUN	*see* perfluidon
DEVRINOL	*see* naprophamide
Diallate	*S*-2,3-dichloroallyl-*N*,*N*-isoprophyl(thiocarbamate)
Dicamba	3,6-dichloro-2-methoxybenzoic acid
Dichlobenil	2,6-dichlorobenzonitril
Dichlormate	sirmate; 3,4-dichlorobenzyl-*N*-methylcarbamate
Dimethametryn	2-methylthio-4-ethylamino-6-(2,1-dimethylpropylamino)-*s*-triazine
Dinitramine	N^4,N^4-diethyl α,α,α-trifluoro-3,5-dinitrotoluene-2,4-diamine
Dinoterb	TOLKAN* = dinitro-2,4-tertiobutyl-6-phenol
Diphenamid	*N*,*N*-dimethyl-2,2-diphenilacetamide
Diphenatrile	diphenyl acetonitrile
Diphenylether	*see* oxyfluorfen
Diquat	6,7dihydrodipyrido(1,2-α:2'1'-*c*)pyrazinediium ion

Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
EPTC	*S*-ethyl dipropylthiocarbamate
Endothall	7-oxabicyclo(2,2,1)heptane-2,3-dicarboxylic acid
Fluometuron	1,1-dimethyl-3-(α,α,α-trifluoro-*m*-tolyl) urea
Fluorchloralin	*N*-(2-chloroethyl)-2,6 dinitro-*N*-prophyl-4-(trifluoromethyl) analine
Fluorodifen	2,4'-dinitro-4-trifluoromethyl-diphenyl ether
CA_3 = gibberelic acid	3:10:13-trihydroxy-4-methyl-16-methylene-s,9-gibb-1-ene-4-6-dicarboxylic acid 4-10 lactone (*growth regulator*)
Glyphosate	(*N*-phosphonomethyl) glycine
GOAL	*see* oxyfluorfen
HE-314	3-methylphenyl-p-nitrophenyl ether
Hexazinone = VELPAR*	3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione
Hoe 23408	2-(1-(2',4'-dichlorophenoxy)phenoxy-methyl propionate
Ioxynil	4-hydroxy-3,5-diiodobenzonitrile
Isoproturon	*N*-(isopropyl-4-phenyl)-*N'*,*N'*,-dimethylurea
K-233	1-(α,α-dimethylbenzyl)-3-(p-tolyl) urea
K-1441	3-methyl-1-(α,α,dimethyl)-3 phenylurea
Krenite	ammonium ethyl carbamoyl phosphonate
KUE 2079	3-(3-chloro-4-chloro-difluoro-methylthiophenyl)-1,1-dimethylurea
Lallicide	*see* sodium arsenite
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
MAMET SM*	*see* molinate
MCPA	(4-chloro-*o*-tolyl)oxy acetic acid
MCPB	4-(4-chloro-*o*-tolyl)butyric acid
MCPCA	2-methyl-4-chlorophenoxyaceto-*o*-chloroanalide
MCP-Na	sodium salt of MCPA

* TRADE NAMES.

MK-129	*N-p*-chlorobenzyloxyphenlyΔ'-tetrahydrophtalimide
MSMA	monosodium methane arsenate
Mecoprop	2-(4-chloro-*o*-tolyl)oxy propionic acid
Methabenzthiazuron	1-benzthiazol-2-yl-1,3-dimethylurea
Methazole	2,3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione
Methoxyphenone	3,3'-dimethyl-4-methoxybenzophenone
Metolachlor	2-chloro-*N*(2-ethylphenyl)-*N*-(2-methoxy-1-methylethy) acetamide
Metoxuron	*N*-(chloro-3-methoxy-4-phenyl)-*N'*,*N'*-dimethylurea
Metribuzin	4-aminc-6-*tert*-butyl-3-(methylthio)-as-triazin-5-(4H)-one
Molinate	*S*-ethylhexahydro-1H-azepine-1-carbothioate
NA	1,8-naphthalic arhydride (*protectant*)
Napropamide	2(*a* naphthoxyl)--*N*,*N*-diethyl propionamide
Nitrofen	2,4-dichlorophenyl-*p*-nitrophenyl ether
Oxadiazon	2-*tert*-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)Δ^2 1,3,4-oxadiazolin-5-one
Oxyfluorfen	RH-2915 = diphenylether = 2-chloro-1-(3 ethoxy-4-nitrophenoxy)-4-.(trifluoromethyl) benzene
PCP	pentachlorophenol
Paraquat	1,1'-dimethyl-4,4'-bipyridinium ion = 1,1'-dimethyl-4,4'-bipyridinium dichloride
Perfluidone	1,1,1-trifluoro-*N*-(2-methyl-4-(phenylsulfonyl) phenyl methanesulfonamide
Phenopylate	2,4-dichlorophenyl pyrrolidinylcarboxylate
Picloram	4-amino-3,5,6-trichloropicolinic acid
Piperophos	*S*-(2-methyl-1,1-piperyl-carbonylmethyl)-*O*,*O*-di-n-propyl-thiophosphate
Prometone	2,4-bis(isopropylamino)-6-methoxy-5-triazine
Prometryn	2,4-bis(isopropylamino)-6-(methylthio)-*s*-triazine
Pronamide	propyzamine; *N*-(1,1-dimethyl-2-propyl)-3,5-dichlorobenzamide
Propachlor	2-chloro-*N*-isopropylacetanilide
Propanil	3',4'-dichloropropionanilide

Propazine	2-chloro-4,6-bis(isopropylamino)-*S*-triazine
Pyrazone	5-amino-4-chloro-2-phenyl-3(2*H*)-pyridazinone
R-25788	*N,N*-diallyl-2,2-dichloro-acetamide
RH-2915	*see* oxyfluorfen
SL-501	substituted pyridyloxy-phenoxy-alkanoic acid derivates
SW-751	4-(2,4-dichlorobenzoyl)-1,3-dimethyl-pyrazol-5-yl p-toluenesulfonate
Simazine	2-chloro-4,6-bis(ethylamino)-*s*-triazine
Silvex	2-(2,4,5-trichlorophenoxy) propionic acid
Simetryn	2-methylthio-4,6-bis(ethylamino)-*s*-triazine
Sodium arsenite	$NaAsO_2$ = lallicide
Sodium chlorate	$NaClO_3$
Sodium hydroxide	
Sulglycapin	methylsulfamic acid 2-(hexahydro-1 *H*-azepin-1-yl)-2-oxoethyl ester
Swep	methyl *N*(3,4-dichlorophenyl)carbamate
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid
TCA	trichloroacetic acid
Terbacil	3-*tert*-butyl-5-chloro-6-methyl uracil
Terbutryn	2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine
TOLKAN	
Triallate	5-(2,3,3-trichlorallyl)diisopropylthiocarbamate
Trifluraline	α,α,α,-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine
U-18	ethyl-*N*-(2,4,5-trichlorophenyl)carbamate
U_{46} KV-T-FLUID*	*see* 2,4-D
VELPAR*	*see* hexazinone