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FEDERAL HOTEL, KUALA LUMPUR, MALAYSIA

JUNE 7 TO 12, 1971

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CHLORAMBEN FOR WEED CONTROL IN TRANSPLANTED RICE

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Summary

Research trials in five countries have demonstrated that 1.5 to 2.5 kg/ha chloramben is an effective early post-planting treatment in paddy rice. Applications from 2 to 8 days after transplanting have produced very good to excellent grass and broadleaf weed control with safety to the rice. Time between soil preparation and transplanting and chemical treatment should be held to a minimum as delay could allow weeds to become established, making satisfactory chemical control doubtful. Proper water control could be an important factor in this practice. Weed control was better where adequate water levels were maintained after chloramben application. There should be further trials to study water management aspects and formulation mixtures including chloramben plus 2,4-D, liquid, clay granule or urea prill formulations. (New granular formulations are being developed specifically for rice.) The use of chloramben for weed control in transplanted rice appears to be an important new development for a well-known herbicide.

Searching for new herbicides or adapting known materials to control a changing or variable weed population in field crops is a continuous process. The method of use of a chemical for weed control in a crop such as transplanted rice can be entirely different from its use in a dryland crop situation.

Chloramben has long been established as one of the principal herbicides in the major U.S. soya bean-production area. Use of chloramben for pre-emergence grass and broadleaf control on several horticultural crops including dry beans, lima and snap beans, sunflowers and transplanted tomatoes and peppers, has also received wide farmer acceptance. The mode of activity and selectivity of chloramben prompted experimentation with it as a herbicide for transplanted paddy rice. Results have been most encouraging. This report summarizes trials conducted in five countries.

Chloramben activity is almost exclusively pre-emergent, killing both annual grass and broadleaf weeds as they germinate. Maximum herbicidal effects are obtained when chloramben is in the seed zone or in direct contact with the germinating seed of a susceptible weed species. Because chloramben is absorbed mainly by roots, its location in the soil zone below germinating weed seed is considered more effective than when the chemical is above the seed. Some control of grasses is obtained through coleoptile uptake, but this response is variable.

Application to seedling plants of susceptible species or to perennial weeds may result in root and shoot growth inhibition. However, chloramben is considered essentially inactive post-emergence, as true phytotoxic effects are rare. Therefore, application to established or transplanted plants can be made with relative safety.

Highly water soluble (700 ppm at 25° C), chloramben is not deactivated by adsorption to organic matter or clay particles, although for the same degree of weed control more chemical is usually required on clay or heavy soils than on sandy or light soils.

The high solubility of chloramben can influence its field performance. Excessive rainfall may leach the herbicide from soil with a high percolation rate. Also, drawing off the water from a rice paddy may remove any chemical in solution, so water management may play an important part in the performance of chloramben in paddy rice.

Chloramben controls a large number of grass weeds, including barnyard grass (*Echinochloa crus-galli*), probably the principal grass found in rice throughout the world. A wide spectrum of broadleaf weeds is susceptible to chloramben.

Chloramben commercial formulations are the 2 lb/U.S. gal. and 10% attaclay granular. Additional formulations in the following trials were 2% chloramben on urea prill and on attaclay granule, and a 2% chloramben + 0.4% 2,4-D on urea prill and on attaclay granule.

GREENHOUSE AND FIELD TRIALS

Performance of chloramben liquid and 2% attaclay granule formulations was compared with combinations of chloramben plus 2,4-D on attaclay granule and urea prill in several greenhouse trials. One of these was conducted at the Amchem Research Farm in Ambler, Pennsylvania (Koerwer, 1970a), with cut-down 55 gal. drums for test containers. Nova 66 variety rice seedlings at the 5- to 6-leaf stage were transplanted into soil in the drums. Pre-germinated barnyard grass seed was mixed into the surface 2 to 5 cm of soil just prior to the rice transplanting. Chemical treatments were applied four days later. A 5 cm water depth was maintained throughout the trial. Control data taken at the conclusion of the experiment showed that all formulations provided acceptable barnyard grass control, with no injury to the rice (Table 1).

TABLE 1: BARNYARD GRASS CONTROL IN TRANSPLANTED RICE WITH DIFFERENT CHLORAMBEN FORMULATIONS AMBLER, PENNSYLVANIA, 1970

Treatment	*Formulation*	*Rate (kg/ha)*	*% Injury Rice*	*% Control Barnyard Grass*
chloramben + 2,4-D	2% + 0.4% urea prill	1.68 + 0.34	0	83
chloramben + 2,4-D	2% + 0.4% attaclay granule	1.68 + 0.34	0	93
chloramben	2% attaclay granule	1.68	0	83
chloramben	liquid	1.68	0	80
chloramben	2% urea prill	1.68	0	85
control	—	—	0	0

A pot test was also conducted in Japan (Jingo, 1970a). In this trial 5- to 6-leaf stage rice seedlings of Japonica strain were transplanted into 60 × 60 cm concrete pots. The chloramben treatments of 1.5 and 3.0 kg/ha were applied 3 and 7 days after transplanting. Control of barnyard grass (*Echinochloa crus-galli*), *Monochoria vaginalis*, *Eleocharis acicularis*, and other volunteer weeds was rated 35 days after treatment, as was rice injury (see Table 2). Barnyard grass control was excellent from both dates of treatment. The higher rate (3.0 kg/ha) resulted in only fair to good *Monochoria* and *Eleocharis* control. Rice injury was in the form of cupped leaves or rolled flag leaf.

Other greenhouse trials in Japan indicated that the Japonica strain of rice sustained chloramben injury in the form of cupped leaves and/or rolled flagleaf (Jingo, 1969). Injury was not con-

TABLE 2: RESPONSE OF RICE AND WEEDS TO TWO RATES OF CHLORAMBEN APPLIED AT TWO DATES, JAPAN, 1970

Treatment (kg/ha)	*Days after Transplant*	*Barnyard Grass*	Monochoria vaginalis	Eleocharis acicularis	*Rice Injury*
chloramben 1.5	3	95+	0	80+	Medium
chloramben 3.0	3	95+	50+	80+	Much
chloramben 1.5	7	95+	50+	80+	Little
chloramben 3.0	7	95+	50+	80+	Medium

sistent, ranging from practically none (leaf cupping) to serious (tiller retardation). Additional trials indicated that Indica varieties tolerate chloramben better.

In Japan (Jingo, 1970a), field studies during both the early season (14 May transplant) and normal season (6 June transplant) were established with chloramben at 1.5 kg/ha. Observations 35 days after treatment for both seasons showed that chloramben at 1.5 kg/ha gave commercially acceptable control of barnyard grass. There was no observable injury to the rice at this rate of chloramben, but cupped leaves resulted from higher rates.

Although Pennsylvania field trials (Koerwer, 1970b) were far from normal rice production areas, the results do indicate the potential feasibility of using chloramben for weed control in transplanted rice with safety to the crop. The rice was not transplanted but was sown directly into a specially constructed paddy on 10 June; treatments were applied on 30 June when the rice was in the 2- to 2½-leaf stage and barnyard grass producing its first leaf. The paddy was flooded immediately after herbicide treatment, and a 2.5 to 5 cm depth of water was maintained throughout the trial. The urea prill produced 70% barnyard grass control and 80% control of fine-leaf sedge (*Cyperus polystachyos* var. *texensis*) at 2.24 kg/ha chloramben. Attaclay granule chloramben formulation control of both these species was 53%. There was no injury to rice (var. Nova 66).

In two separate trials in the Dominican Republic (Cooke and Zubillaga, 1970), the feasibility of using chloramben on transplanted rice was further demonstrated. The trial results (see Table 3) show that chloramben formulations applied at 1.5 kg/ha with or without 0.3 kg/ha 2,4-D gave very good to excellent grass and broadleaf control at location 1; at locations 2 and 3 weed control was variable. The inconsistency was attributed mainly to changing water levels. Although generally good water cover (5 to 10 cm) was present at the time of chemical application, these levels were not maintained throughout the trial, the soil actually being exposed. The chloramben attaclay granule was an outstanding performer in this trial with 95 to 100% grass and broadleaf control at two of the three locations. The addition of 2,4-D to this formulation did not help weed control. Slight injury to the rice was noted at location 1 where the test variety was Higueyano. This variety is a Dominican Japonica type strain. No rice injury was observed at the other two locations where the variety was IR-5, a new Indica strain.

TABLE 3: RESPONSE OF RICE AND WEEDS TO THREE CHLORAMBEN FORMULATIONS AT THREE LOCATIONS, DOMINICAN REPUBLIC, 1970

Treatment	Formulation	Rate (kg/ha)	% Weed Control — 3 Locations: Grass[1] 1	2	3	Broad-leaves[2] 1	2	3	% Injury Rice 1	2	3
chloramben	urea prill	1.5	95	0	0	80	0	0	5	0	0
chloramben	clay granule	1.5	97	95	0	100	100	60	5	0	0
chloramben	+2,4-D urea	1.5 + 0.3	80	100	70	85	100	50	5	0	0
chloramben	+2,4-D granule	1.5 + 0.3	77	70	0	90	90	0	5	0	0
chloramben	2 lb/gal liquid	1.5	73	80	95	80	100	75	5	0	0

[1] Grass weeds — *Ischaemum rugosum, Eleusine indica, Cynodon dactylon* (seedling).
[2] Broadleaves — Oreja de gato, Hierba Patico.

The second series of trials conducted in the Dominican Republic was established at four locations; results are summarized in Table 4. The varieties under test were Ingles at locations 1 and 3, Higueyano at locations 2 and 4. In this trial no injury to the rice was observed at any location. Control of the weed grasses, primarily seedling Bermuda grass, barnyard grass, *Ischaemum rugosum,* and fine-leaf sedges was outstanding at three or four locations. Water levels were adequately maintained throughout the trials.

Several rice field trials were conducted in Hawaii in 1969-70 and were reported at the 10th British Weed Control Conference (Obien and Plucknett, 1970). The first trial included a 3.36 kg/ha chloramben granule treatment on transplanted rice. The soil in

TABLE 4: WEED CONTROL IN RICE WITH THREE CHLORAMBEN FORMULATIONS; FOUR LOCATIONS, DOMINICAN REPUBLIC, 1970

Treatment	Formulation	Rate (kg/ha)	% Weed Control — 4 Locations: Grass 1	2	3	4	Broadleaves 1	2	3	4
chloramben	2 lb/gal liquid	2	98	95	95	80	95	99	85	80
chloramben	2% clay granule	2	98	98	95	90	90	100	90	95
chloramben + 2,4-D	2% + 0.4% granule	2 + 0.4	99	98	99	95	99	100	95	95

this trial was montmorillonite-kaolinite clay with an organic matter content 8 to 14%, pH 4.9 to 5.5. Chloramben was applied three days after transplanting 2 to 3 IR-8 rice seedlings per hill. Weeds included a fine-leaf sedge (*Cyperus difformis*) and barnyard grass among others. Chloramben treatment did not injure the rice, and produced excellent weed control. Yield of rice from the chloramben plots compared very favourably with that from the hand-weeded controls.

In a second Hawaiian trial, chloramben granular at 2.24, 3.36 and 4.48 kg/ha was applied 2, 8 and 12 days after transplanting rice; 3.36 kg/ha liquid chloramben was also applied two ways two days after transplanting, one application being sprayed on the plot, and the second applied through the irrigation system. The weed population in this trial was somewhat thin and not uniform, with few broadleaf weeds. Chloramben caused negligible injury to the rice at 2.24 or 4.48 kg/ha while giving effective control of the barnyard grass and fine-leaf sedge. There was no measurable difference between the granular chloramben and the 2 lb/gal commercial formulation regarding weed control or safety to rice. Of major interest was the fact that the effective treatment time for weed control after transplanting was not later than 8 days. The 12-day treatment resulted in very poor weed control.

A third trial (Table 5) showed that rice could tolerate chloramben applications of 2.24 to 6.72 kg/ha with tolerance increasing as the age of the rice increased. Treatments were applied 3 and 10 days after the rice was transplanted. Weed control from

TABLE 5: EFFECTS OF DIFFERENT RATES AND TIME OF CHLORAMBEN APPLICATION ON CALORO RICE AND ON WEED CONTROL, WAILUA SUBSTATION, KAUAI, HAWAII, 1970

(Obien and Plucknett, 1970)

			23 Days After Treatment				86 Days After Treatment			
			%	% Weed Control			%	% Weed Control		
Chloramben (kg/ha)	Formulation	DAT	Injury Rice	Grass	Sedge	B/L	Rice Stand	Grass	Sedge	B/L
2.24	granule	3	5	93	77	90	98	96	92	98
3.36	granule	3	10	95	80	100	98	94	93	100
6.72	granule	3	27	100	87	100	100	100	93	100
3.36	liquid	3	10	100	90	97	96	96	95	95
2.24	granule	10	5	60	37	43	33	30	16	13
3.36	granule	10	10	80	37	67	50	56	46	10
6.72	granule	10	10	92	53	88	85	80	70	70
Weeded control		—	0	95	95	90	98	100	100	100
Unweeded control		—	0	0	0	0	18	0	0	0

the application 3 days after transplanting was very good to excellent with 2.24, 3.36 and 6.72 kg/ha chloramben. There was slight to moderate rice injury, increasing as the rate of herbicide increased. At 10 days after transplanting, these same rates injured rice less. However, weed control was also considerably reduced owing to the resistance of the older weed plants. The stand of rice was reduced as weed competition increased.

Trials conducted in the Philippines (Jingo, 1970b) showed that 2.5 to 5 kg/ha of chloramben combined with 0.3 to 0.6 kg/ha of 2,4-D could provide very good to excellent grass and sedge control when applied 3 to 6 days after rice was transplanted (Table 6).

TABLE 6: WEED CONTROL WITH CHLORAMBEN + 2,4-D APPLIED TO LOWLAND RICE AT THREE DATES, PHILIPPINE ISLANDS, 1970

Treatment	Rate (kg/ha)	Treatment Days after Transplanting	% Weed Control
chloramben + 2,4-D	2.5 + 0.3	3	95
chloramben + 2,4-D	3.75 + 0.45	3	98
chloramben + 2,4-D	5.0 + 0.6	3	100
chloramben + 2,4-D	2.5 + 0.3	6	85
chloramben + 2,4-D	3.75 + 1.45	6	98
chloramben + 2,4-D	5.0 + 0.6	6	100
chloramben + 2,4-D	2.5 + 0.3	10	48
chloramben + 2,4-D	3.75 + 0.45	10	70
chloramben + 2,4-D	5.0 + 0.6	10	80
Hand-weeded control			100
Unweeded control			0

Application 10 days after transplanting resulted in very poor grass control at the low rate of 2.5 kg/ha chloramben plus 0.3 kg 2,4-D, although control increased as the rate of herbicide applied increased. In this trial there was no apparent rice injury from the chloramben/2,4-D combination. Grain yields from all rates of application were significantly better than from unweeded plots and were comparable to yields from hand-weeded checks.

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Chloramben (kg/ha)	Formulation	DAT	% Injury Rice	% Weed Control Grass	Sedge	B/L	% Rice Stand	% Weed Control Grass	Sedge	B/L
2.24	granule	3	5	93	77	90	98	96	92	98
3.36	granule	3	10	95	80	100	98	94	93	100
6.72	granule	3	27	100	87	100	100	100	93	100
3.36	liquid	3	10	100	90	97	96	96	95	95
2.24	granule	10	5	60	37	43	33	30	16	13
3.36	granule	10	10	80	37	67	50	56	46	10
6.72	granule	10	10	92	53	88	85	80	70	70
Weeded control		—	0	95	95	90	98	100	100	100
Unweeded control		—	0	0	0	0	18	0	0	0

the application 3 days after transplanting was very good to excellent with 2.24, 3.36 and 6.72 kg/ha chloramben. There was slight to moderate rice injury, increasing as the rate of herbicide increased. At 10 days after transplanting, these same rates injured rice less. However, weed control was also considerably reduced owing to the resistance of the older weed plants. The stand of rice was reduced as weed competition increased.

Trials conducted in the Philippines (Jingo, 1970b) showed that 2.5 to 5 kg/ha of chloramben combined with 0.3 to 0.6 kg/ha of 2,4-D could provide very good to excellent grass and sedge control when applied 3 to 6 days after rice was transplanted (Table 6).

TABLE 6: WEED CONTROL WITH CHLORAMBEN + 2,4-D APPLIED TO LOWLAND RICE AT THREE DATES, PHILIPPINE ISLANDS, 1970

Treatment	Rate (kg/ha)	Treatment Days after Transplanting	% Weed Control
chloramben + 2,4-D	2.5 + 0.3	3	95
chloramben + 2,4-D	3.75 + 0.45	3	98
chloramben + 2,4-D	5.0 + 0.6	3	100
chloramben + 2,4-D	2.5 + 0.3	6	85
chloramben + 2,4-D	3.75 + 1.45	6	98
chloramben + 2,4-D	5.0 + 0.6	6	100
chloramben + 2,4-D	2.5 + 0.3	10	48
chloramben + 2,4-D	3.75 + 0.45	10	70
chloramben + 2,4-D	5.0 + 0.6	10	80
Hand-weeded control			100
Unweeded control			0

Application 10 days after transplanting resulted in very poor grass control at the low rate of 2.5 kg/ha chloramben plus 0.3 kg 2,4-D, although control increased as the rate of herbicide applied increased. In this trial there was no apparent rice injury from the chloramben/2,4-D combination. Grain yields from all rates of application were significantly better than from unweeded plots and were comparable to yields from hand-weeded checks.

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WEED CONTROL IN UPLAND RICE WITH MIXTURES OF PROPANIL AND 2,4-D ESTERS

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INTRODUCTION

In North Sumatra, weeds cause serious losses in production in upland rice. In order to eliminate these losses, changkolling is carried out which is time-consuming and requires as much as up to 318 man-hours per hectare in labour (Soepadyo and Kadnan, 1970). In sparsely populated areas with extensive upland rice plantings, weed control by means of changkol is impossible.

Chemical weed control with propanil gives poor results on grasses like *Leptochloa paniceae*, or sedges and broadleaved weeds. Additions of phenoxy acids to propanil have improved weed control (Anon., 1964).

According to Moomaw *et al.* (1966), the ester and amine forms of 2,4-D are less toxic than the other 2,4-D compounds. Also they are more effective and less susceptible to rain or flooding, and have been shown to require slightly lower rates for the same weed control.

In a previous trial in upland rice (Soepadyo and Kadnan, 1970b), it was shown that a sequential treatment of propanil followed by 2,4-D amine gave lower yields compared with application of the two chemicals as a tank mix.

MATERIALS AND METHODS

The common weeds found were grasses such as *Echinochloa colona*, *Eleusine indica*, *Paspalum conjugatum*, *Cynodon dactylon* and *Digitaria adscendens;* the broadleaves *Cleome aspera*, *Spilanthes acmela*, *Phylanthus niruri*, *Physalis angulata*, *Amaranthus gracilis*, and *Oldenlandya corimbosa;* and the nut sedges *Cyperus rotundus*, *C. compressus* and *C. killinga*.

The herbicides used were "Stam F 34" (35% propanil), "Hedonal butyl glycol ester" (0.48 kg a.e./l) and "Hedonal isopropyl ester" (0.48 kg a.e./l).

The experiment was conducted at the experimental fields of the RISPA in Kampung Baru, Medan, during the period August 1970 to March 1971 on alluvial soil, with pH 5.8 to 6.1.

The experiment was a strip plot design, with 20 treatments (see Table 1) and 3 replications. The rice variety, Arias No. 50, was directly drilled into the soil to a depth of 2 to 3 cm, 3 to 5 seeds to a hole. Plots were separated from one another by small dikes constructed around each plot. Seeds were treated with 0.15% powder DDT formulation. The plot area was $4 \times 4\ m^2$ with plant spacing of 20×25 cm.

TABLE 1: TREATMENTS
(All applications made 20 days after planting)

Plot No.	*Treatment*	*Rate (kg/ha)*
1.	Unweeded	—
2.	2,4-D BE	0.48
3.	2,4-D BE	0.60
4.	2,4-D IPE	0.48
5.	2,4-D IPE	0.60
6.	propanil	2.80
7.	propanil + 2,4-D BE	2.80 + 0.48
8.	propanil + 2,4-D BE	2.80 + 0.60
9.	propanil + 2,4-D IPE	2.80 + 0.48
10.	propanil + 2,4-D IPE	2.80 + 0.60
11.	propanil	3.15
12.	propanil + 2,4-D BE	3.15 + 0.48
13.	propanil + 2,4-D BE	3.15 + 0.60
14.	propanil + 2,4-D IPE	3.15 + 0.48
15.	propanil + 2,4-D IPE	3.15 + 0.60
16.	propanil	3.50
17.	propanil + 2,4-D BE	3.50 + 0.48
18.	propanil + 2,4-D BE	3.50 + 0.60
19.	propanil + 2,4-D IPE	3.50 + 0.48
20.	propanil + 2,4-D IPE	3.50 + 0.60
21.	Hand-weeding (twice) — 21 and 45.	

Fertilizer was given as a basal application of 40 kg N/ha and 50 kg P_2O_5/ha, followed by a second application of 25 kg N/ha at panicle initiation stage. Pest control was carried out by spraying with 0.15% "Dipterex 80" SP at 3-week intervals.

Herbicides were dissolved in 600 l water/ha, to prevent spraying drift of herbicides to neighbouring plots and each plot was screened by plastic sheets to a height of 1 m.

A "Solo" knapsack sprayer with a blue polijet tip nozzle (ICI adaptor, jet orifice = 0.062) was used. To ensure equal spray per plot, the pressure was kept constant at 103 kPa (15 lb/sq.in.) with a pressure gauge, and the walking speed of 4 km/hr controlled with a stop-watch.

Observations on toxicity, tillering, plant height and sampling for the weight of weed were made by stratified sampling on 5 sites of $0.5 \times 0.5\ m^2$.

Numbers of tillers were counted at maximum tillering stage and the plant height was measured at panicle initiation stage. Weed samples and grain yield were collected at harvest time.

RESULTS AND DISCUSSION

Phytotoxicity

Effect on the rice plant is shown in Table 2. Observations were made 7 days and 35 days after spraying. No damage was observed, except treatments with propanil 2.8/2,4-D IPE 0.6 kg/ha; propanil 3.15/2,4-D BE 0.48; propanil 3.5/2,4-D BE 0.48; and propanil 3.5/2,4-D IPE 0.6. Toxicity symptoms were generally indicated by leaf burns. The tips of the leaf turned brown and soon dried up. The extent of the drying up was, however, only up to about half of the leaf length; furthermore, the younger leaves and those that emerged subsequently were all normal, and normal growth was resumed after about two weeks.

Weed Control

The effect of herbicides on the different weeds (grasses, broadleaf weeds and sedges) was observed at 55 days after planting (35 days after spraying) and the dry weight of weeds at harvest is shown in Table 2.

The application of 2,4-D BE and 2,4-D IPE alone showed a rather moderate killing effect on broadleaf weeds and sedges, but no control on grasses. Propanil alone seemed to give rather poor control on grasses, and no control of broadleaf weeds and sedges.

Generally plots treated with mixtures of propanil + 2,4-D BE or IPE, seemed to give good control of grasses, broadleaf weeds and sedges, particularly when applied at 3.5 kg/ha propanil + 0.48 or 0.6 kg/ha 2,4-D IPE.

Dry weight of weeds is weight of fresh weed after air and sun drying till constant weight. The application of 2.8 kg/ha propanil + 0.6 kg/ha 2,4-D BE resulted in significantly lower weed weight per plot compared with the unweeded (control) plots and was not significantly different from other treatments.

The effects of the propanil treatments and its interaction with 2,4-D BE or 2,4-D IPE were not significant.

TABLE 2: EFFECT OF HERBICIDES ON PHYTOTOXICITY, WEED CONTROL RATING AND DRY WEIGHT OF WEEDS. RISPA, 1970 RAINY SEASON

No.	Treatment (kg/ha)	*Toxicity Rating of Rice Plant** 7 days	35 days	*Weed Control Rating 55 days after Planting†* G	B	S	*Dry Weed Weight at Harvest‡ (g/m²)*
1	Unweeded (control)	1	1	10	10	9	1. 409
2	2,4-D BE 0.48	1	1	9	5	6	2. 371
3	2,4-D BE 0.60	1	1	9	4.5	5	3. 332
4	2,4-D IPE 0.48	1	1	9	5	5	4. 322
5	2,4-D IPE 0.60	1	1	8	4.5	5	6. 307
6	propanil 2.8	1.3	1	7	9	9	5. 304
7	propanil 2.8/2,4-D BE 0.48	1	1	5	4	4	11. 296
8	propanil 2.8/2,4-D BE 0.60	1	1	4	3.5	3.5	16. 294
9	propanil 2.8/2,4-D IPE 0.48	1.3	1	4	3.5	4	7. 290
10	propanil 2.8/2,4-D IPE 0.60	2.3	1	4	3	3.5	10. 272
11	propanil 3.15	1.7	1	7	9	8	8. 268
12	propanil 3.15/2,4-D BE 0.48	2.3	1	4.5	3	3	9. 239
13	propanil 3.15/2,4-D BE 0.60	2	1	4	3.5	3.5	12. 221
14	propanil 3.15/2,4-D IPE 0.48	2	1	4	3	3	13. 221
15	propanil 3.15/2,4-D IPE 0.60	1.7	1	3	3.5	3	17. 220
16	propanil 3.50	2	1	6.5	8.5	8	19. 202
17	propanil 3.50/2,4-D BE 0.48	2.3	1	3.5	4	3	20. 151
18	propanil 3.50/2,4-D BE 0.60	1.3	1	3	3	3	14. 151
19	propanil 3.50/2,4-D IPE 0.48	2	1	2	3.5	3	15. 146
20	propanil 3.50/2,4-D IPE 0.60	2.3	1	2.5	3	3	18. 112
21	Hand-weeding (twice)	1	1	4	3.5	4	239

CV % = 30.79
LSD 5% = 270.98
LSD 1% = 367.21

*Estimates of rice toxicity on a scale of 1 (no toxicity) to 5 (complete kill).
7 days after spraying (= 27 days after planting)
35 days after spraying (= 55 days after planting)
†Estimates of weed control on a scale of 1 (complete control) to 10 (no control).
G = grasses; B = broadleaf weeds; S = sedges.
‡Treatments joined by the same line are not significantly different at the 5% level.

Tillers and Height of Plant

As shown in Table 3, the influence of the herbicides on numbers of tillers at the time of maximum tillering stage gave variations from 4.1 to 6.4 and statistical analysis showed significant differences among treatment means.

The effect of the propanil treatments at several levels and its interaction with numbers of tillers was significant, but there was no interaction with 2,4-D BE or 2,4-D IPE.

Plants treated with propanil 3.5, propanil 3.5/2,4-D BE 0.6, propanil 3.15/2,4-D IPE 0.48 kg/ha had more tillers compared with hand-weeding.

In the same table, the influence of the herbicides on plant height at the time of panicle initiation stage showed that plant height ranged from 98.6 to 133.2 cm; treatment with propanil 2.8/2,4-D BE 0.6 resulted in the growth of the tallest plants while plants in the unweeded (control) plots gave the shortest plant height. There were significant differences among the various treatments.

TABLE 3: EFFECT OF HERBICIDES ON THE GROWTH OF RICE PLANTS AND THE GRAIN YIELD. RISPA, 1970 RAINY SEASON

No.	Treatment (kg/ha)	*No. of tillers/ hill**	*Plant Height† (cm)*	*Grain Yield (14% moisture) (kg/plot)*	*(kg/ha)*
1	Unweeded (control)	16. 6.4	8. 133	8. 4.17	2,609
2	2,4-D BE 0.48	13. 6.3	12. 131	14. 3.95	2,466
3	2,4-D BE 0.60	8. 6.3	10. 131	12. 3.86	2,409
4	2,4-D IPE 0.48	14. 6.1	13. 130	13. 3.60	2,254
5	2,4-D IPE 0.60	6. 5.9	14. 127	11. 3.46	2,162
6	propanil 2.8	7. 5.9	11. 127	10. 3.43	2,147
7	propanil 2.8/2,4-D BE 0.48	18. 5.8	6. 127	15 3.40	2,123
8	propanil 2.8/2,4-D BE 0.60	11. 5.7	15. 125	16. 3.30	2,063
9	propanil 2.8/2,4-D IPE 0.48	15. 5.7	7. 125	17. 3.28	2,052
10	propanil 2.8/2,4-D IPE 0.60	20. 5.6	16. 123	6. 3.20	1,999
11	propanil 3.15	17. 5.4	18. 122	19. 3.01	1,881
12	propanil 3.15/2,4-D BE 0.48	12. 5.3	17. 120	9. 2.98	1,865
13	propanil 3.15/2,4-D BE 0.60	9. 5.0	20. 117	7. 2.97	1,859
14	propanil 3.15/2,4-D IPE 0.48	10. 4.8	9. 117	20. 2.86	1,788
15	propanil 3.15/2,4-D IPE 0.60	19. 4.8	19. 116	18. 2.83	1,768
16	propanil 3.50	2. 4.6	5. 116	2. 2.80	1,749
17	propanil 3.50/2,4-D BE 0.48	4. 4.5	4. 111	5. 2.62	1,638
18	propanil 3.50/2,4-D BE 0.60	3. 4.4	2. 107	4. 2.59	1,617
19	propanil 3.50/2,4-D IPE 0.48	5. 4.4	3. 107	3. 2.54	1,585
20	propanil 3.50/2,4-D IPE 0.60	1. 4.1	1. 99	1. 1.47	917
21	Hand-weeding (twice)	6	127	3.50	2,184
	CV %	13.85	7.77	19.23	
	LSD 5%	1.69	14.92	1.04	
	LSD 1%	2.29	20.22	1.41	

*At maximum tillering stage.
†At panicle initiation stage.
Treatments joined by the same line are not significantly different at the 5% level.

The effect of the propanil treatment and its interaction with 2,4-D BE or 2,4-D IPE was not significant.

Grain Yield

Compared with the unweeded (control) plot, there was a general increase in yield resulting from the treatment either by chemical or by hand-weeding as shown in Table 3. The highest grain yield (4.17 kg/plot = 2,609 kg/ha) was obtained with the herbicide mixture propanil 2.8/2,4-D BE 0.6, and lowest grain yield (1.47 kg/plot = 917 kg/ha) was recorded on the unweeded (control) plot, and both differences were highly significant at 1%.

The effect of the propanil treatments and its interaction with 2,4-D BE or 2,4-D IPE were not significant in this regard.

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WEED CONTROL IN DIRECT-SOWN RICE: STUDIES WITH BENTHIOCARB, RP 17623 AND MBR 76343*

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Studies were conducted to determine the effects of rate, formulation (liquid vs. granule), and time of application of three new herbicides, benthiocarb, RP 17623, and MBR 76343 (an experimental compound) on direct-sown rice. These three compounds were found safe on rice at the rates used. Applications made before the weeds emerged (about 3 days after sowing) or at the early 2-leaf stage (9-10 days) of barnyard grass (*Echinochloa crus-galli*) resulted in adequate control of all weed species. In general, weed control was better with the liquid or emulsifiable formulations than with the granules. The influences of formulation and time of application were more critical with RP 17623 than with "Saturn", particularly at the low rates. For example, granular RP 17623 at rates as low as 0.56 kg/ha was effective as pre-emergence treatment but was poor when applied post-emergence.

TABLE 1: SUMMARY OF MATERIALS AND METHODS USED IN STUDIES WITH THREE HERBICIDES IN DIRECT-SOWN RICE. WAILUA, KAUAI, 1970-71

	Experiment 1 (*Summer 1970*)	*Experiment 2* (*Summer 1970*)	*Experiment 3* (*Spring 1971*)
Rice variety	Caloro	IR8	IR8
Plot size	1.5 × 3 m	2 × 3.8 m	1.8 × 4.0 m
Planting distance	25 × 25 cm (6 rows)	25 × 25 cm (10 rows)	25 × 25 cm (7 rows)
Seeds soaked	19 June	16 Aug.	1 Feb.
Date planted	22 June	18 Aug.	4 Feb.
Date treated	24 June	19, 22, 25, 28 Aug.	8, 13 Feb.
Date rated	3, 22 July; 12 Oct.	17 Sep.	17, 25 Feb.; 30 Mar.
Date harvested	No grain yield data taken		7 June

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TABLE 2: EFFECTS OF THREE HERBICIDES ON DIRECT-SOWN RICE (CALORO) AND CONTROL OF WEEDS. WAILUA, KAUAI, SUMMER 1970

Treatment[1] (kg/ha)	Time of Rating (DAS)[2]	Effect on Rice (%) Stand Reduction	Effect on Rice (%) Growth Reduction	Weed Control (%)[3] Grass	Weed Control (%)[3] Sedge	Weed Control (%)[3] Broadleaf
benthiocarb (EC) 2.24	11	5	0	90[4]		
	30	5	0	95	90	95
	112	5	0	95	90	95
benthiocarb (EC) 4.48 ...	11	15	0	90[4]		
	30	5	0	90	100	90
	112	0	0	95	100	100
RP 17623 (EC) 1.12 ..	11	0	0	90[4]	90	95
	30	10	0	95	90	95
	112	0	0	100	100	100
MBR 76343 (WP) 2.24 ...	11	5	50[5]	95[4]		
	30	5	30[5]	90	95	75
	112	5	0	95	100	95
MBR 76343 (WP) 4.48	11	10	80[5]	100[4]		
	30	20	50[5]	95	95	90
	112	0	0	100	100	100

[1] EC = emulsifiable concentrate; WP = wettable powder.
[2] DAS = days after sowing.
[3] Grass was entirely *Echinochloa crus-galli*, sedges were mainly *Cyperus difformis* and few *Scirpus juncoides*, and the broadleaf weeds were few and included *Jussiaea suffruticosa*, *Ammania coccinea*, and *Dopatrium junceaum*.
[4] Include all three weed groups, grasses, sedges, and broadleaf.
[5] Rice seedlings were "whitish" and very chlorotic at the lower portion of the leaves, but plants showed good signs of recovering.

TABLE 3: INFLUENCES OF TIME OF APPLICATION ON THE EFFECTS OF THREE HERBICIDES ON DIRECT-SOWN RICE AND BARNYARD GRASS. WAILUA, KAUAI, SUMMER 1970

Treatment[1] (kg/ha)	Time of Application (DAS)[2]	Stand Reduction of Rice (%)	Barnyard Grass Control (%)
benthiocarb (G) 2.24 ...	1	0	93
	4	0	99
	7	0	98
	10	0	100
RP 17623 (G) 1.12	1	13	100
	4	2	98
	7	1	97
	10	3	90
MBR 76343 (WP) 2.24	1	3	99
	4	0	99
	7	0	92
	10	0	92

[1] G = granular; WP = wettable powder.
[2] DAS = days after sowing. Data were taken 30 DAS.

TABLE 4: EFFECTS OF THREE HERBICIDES ON DIRECT-SOWN RICE AND BARNYARD GRASS. WAILUA, KAUAI, SPRING 1971

Treatment[1] (kg/ha)	Time of Application (DAS)	Item Rated[2]	Rice 13	Rice 20	Rice 50	Barnyard Grass 13	Barnyard Grass 20	Barnyard Grass 50
			Time of Rating (DAS)[3]					
benthiocarb (EC) 3.36 ...	4	SR	0	0	0	95	100	100
		GR	0	0	0	90	100	100
(G) 3.36 ...	4	SR	0	0	0	83	96	98
		GR	2	0	0	37	73	53
(G) 6.72 ...	4	SR	0	0	0	93	100	100
		GR	0	0	0	87	100	100
(EC) 3.36 ..	9	SR	0	0	0	40	100	99
		GR	0	7	0	50	100	87
(G) 3.36 ...	9	SR	0	0	0	20	95	98
		GR	0	5	0	27	93	50
RP 17623 (EC) 1.12	4	SR	0	5	0	95	100	100
		GR	27	21	5	77	100	100
(G) 0.56 ...	4	SR	0	0	0	80	87	88
		GR	0	2	0	30	23	0
(G) 1.12	4	SR	0	2	0	82	95	93
		GR	7	13	0	30	43	23
(EC) 1.12	9	SR	0	0	0	40	85	93
		GR	27	20	0	88	82	50
(G) 1.12 ...	9	SR	0	0	0	30	43	72
		GR	0	2	5	20	37	0
MBR 76343 (WP) 3.36 ...	4	SR	0	0	0	100	99	100
		GR	33	20	3	100	93	100
Control (weedy)	—	—	—	—	—	—	—	—

[1] EC = emulsifiable concentrate; G = granular; WP = wettable powder.
[2] SR = stand reduction or control (%); GR = growth reduction.
[3] DAS = days after sowing. At 4 DAS, barnyard grass seeds were at the "breaking" stage, about 20% had emerged from the soil; at 9 DAS, the grass seedlings were at the early 2- to 3-leaf stage. There was excellent control of sedges in all treatments.

THE USE OF 2,4-D IMPREGNATED UREA FERTILIZER GRANULES AND RELATED PHENOXY HERBICIDES FOR PRE-EMERGENCE WEED CONTROL IN TRANSPLANTED RICE[1]

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Three experiments were conducted, two in 1970 and one in 1971, to explore the possible use of three rates of a granular formulation of 2,4-D impregnated urea fertilizer (2,4-D + urea) for pre-emergence weed control in transplanted rice. The activity of 2,4-D + urea was compared with granular trifluralin + 2,4-D (2,4-D + trifluralin); TCE-styrene + 2,4-D (M 3493); and three standard compounds, 2,4-D amine, 2,4-D IPE, and MCPA amine. All compounds used, when applied before the weeds emerged, were effective against most weed species in flooded rice, including barnyard grass (*Echinochloa crus-galli*), and sedges (*e.g., Cyperus difformis*). Recovery of rice seedlings was apparently improved in plots treated with granular 2,4-D + urea, but application of urea fertilizer soon after treatment with 2,4-D IPE spray seemed to increase injury to rice. A rate of 1.03 kg/ha 2,4-D, either granular or liquid spray, appeared to be the optimum dosage. Good water management was essential for best activity; this was very critical during the first 10 days for low rates (0.74 kg/ha) of granular herbicides. Erratic or poor weed control resulted when water level was uneven and below 2 cm in depth. Applying herbicide and fertilizer granules could have several advantages: (a) more rapid adoption of herbicides by farmers now using nitrogen fertilizers, (b) more even distribution, and (c) savings in time and labour.

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TABLE 1: SUMMARY OF MATERIALS AND METHODS IN HERBICIDE EXPERIMENTS ON 2,4-D IN TRANSPLANTED RICE. KAUAI, 1970-71

	Experiment 1 *Spring 1970*	*Experiment 2* *Summer 1970*	*Experiment 3* *Spring 1971*
Rice variety	IR8	Caloro[1]	IR8
Plot size	1.8 × 3 m	1.5 × 3 m	1.8 × 3.3 m
Planting distance ...	25 × 25 cm (7 rows)	25 × 25 cm (6 rows)	25 × 25 cm (7 rows)
Date planted	13 Mar.	30 Jun.	5 Feb.
Date treated	16 Mar.	6 Jul.	8 Feb.
Date rated[2]	3 April (21 DAT)	25 Jul. (25 DAT), 14 Oct. (112 DAT)	18, 25, Feb., 30 Mar., (13, 20, 50 DAT)
Date harvested	14 Jul.	14 Oct.	7 Jun.
	Grain yield data taken	No grain yield data	Grain yield data taken
Fertilizer[3]	Urea 100.8 kg N/ha applied at 10 days after treatment; 60 kg N/ha at 50 days	Same as in Experiment 1	Urea at 100.8 kg N/ha at 20 days after treatment. Tillering stage: 25-50-50 kg/ha of NPK. Panicle initiation: 25 kg N/ha.

[1] Caloro matures earlier than IR8 during the summer months.
[2] DAT = days after transplanting.
[3] Applied to all plots in which urea was not a component of the basic treatment. All experiments were conducted in different fields previously planted to rice treated with 60 kg N/ha.

TABLE 2: EFFECTS OF 2,4-D IMPREGNATED UREA FERTILIZER AND RELATED HERBICIDES ON GROWTH, WEED CONTROL, AND GRAIN YIELD OF RICE (IR8)[1]. WAILUA, KAUAI. SPRING, 1970

Treatment (kg/ha)	Effect on Weeds: Barnyard Grass Tillers No. per 625 cm²	Barnyard Grass Tillers per Plant	Barnyard Grass Height (cm)	Weed Control (%) Barnyard Grass	Weed Control (%) Sedge	Weed Control (%) Broad-leaf	Effect on Rice: No. of Tillers per Hill	Growth Reduction[2] (%)	Grain Yield[2] (kg/ha)
2,4-D + urea (G) 0.74	nil	—	—	95	100	100	7.5	11.6 ab	8,170 a
1.03	nil	—	—	93	100	100	6.6	8.3 ab	7,840 a
1.52	nil	—	—	94	100	100	7.1	15.0 a	8,350 a
2,4-D IPE (EC) 0.74	nil	—	—	94	100	100	7.9	6.6 b	8,410 a
2,4-D 0.8 + trifluralin (G) 0.6	nil	—	—	91	100	95	8.9	6.6 b	8,300 a
M 3493:									
2,4-D 0.56 + TCE-styrene 0.84	nil	—	—	85	98	83	7.5	5.0 b	8,110 a
Check (unweeded)	7.20	2.7	22.2	0	0	0	8.2	0 c	5,980 b
Statistical significance				NS			NS	$P = 0.05$	$P = 0.01$

[1] Data on tillers, height, and growth reduction of barnyard grass and rice were taken at 21 DAT; percentage weed control was recorded at 35 DAT. Number of tillers of rice was based on the mean of 5 hills per plot. Grain yield of rice was at 14% moisture.

[2] Values with different letters are different at the indicated levels of significance.

TABLE 3: EFFECTS OF 2,4-D IMPREGNATED UREA FERTILIZER AND RELATED HERBICIDES ON RICE (CALORO) AND BARNYARD GRASS. WAILUA, KAUAI, SUMMER, 1970

Treatment[1] (kg/ha)	Item Rated[2]	Time of rating (DAT)[3] Rice 25	Rice 112	Barnyard Grass 25	Barnyard Grass 112
2,4-D + urea (G) 0.74	SR	0	35	70	60
	GR	10	—	—	—
1.03	SR	10	15	80	90
	GR	20	—	—	—
1.52	SR	10	5	90	95
	GR	30	—	—	—
2.08	SR	20	25	95	65
	GR	40	—	—	—
2,4-D IPE (EC) 0.74	SR	0	7	90	93
	GR	10	—	—	—
1.03	SR	10	35	85	57
	GR	20	—	—	—
1.03[4]	SR	15	30	80	60
	GR	20	—	—	—
2,4-D amine (EC) 1.03	SR	0	15	85	75
	GR	10	—	—	—
1.03[4]	SR	0	10	85	83
	GR	10	—	—	—
MCPA amine (EC) 1.03	SR	0	0	90	98
	GR	10	—	—	—
1.52	SR	5	10	90	78
	GR	20	—	—	—
2,4-D + trifluralin (G) 0.9 0.67	SR	10	17	80	75
	GR	15	—	—	—
M 3493 (G) 0.56	SR	5	7	90	93
	GR	10	—	—	—
1.12	SR	20	7	90	93
	GR	30	—	—	—
Check (unweeded)	SR	0	43	0	0
	GR	50	—	—	—

[1] G = granular; EC = emulsifiable concentrate.

[2] SR = stand reduction or control (%); GR = growth reduction (%).

[3] DAT = days after transplanting rice seedlings.

[4] Applied through "irrigation water".

TABLE 4: EFFECTS OF 2,4-D IMPREGNATED UREA FERTILIZER AND RELATED HERBICIDES ON RICE (IR8) AND BARNYARD GRASS. WAILUA, KAUAI, SPRING, 1971

Treatment[1] (kg/ha)	Item Rated[2]	Time of Rating (DAT)[3] Rice 13	20	50	Barnyard Grass 13	20	50
2,4-D + urea (G) 0.74	SR	0	0	0	60	85	78
	GR	0	0	10	60	80	35
1.03	SR	0	0	0	83	90	88
	GR	0	0	3	77	80	45
1.52	SR	0	0	0	92	96	94
	GR	13	3	5	88	90	53
2,4-D IPE (EC) 0.74[4] ..	SR	0	0	0	70	83	72
	GR	27	7	13	70	77	27
0.74[5]	SR	0	0	0	77	88	88
	GR	10	3	0	77	87	57
1.03[5]	SR	0	0	0	85	90	90
	GR	10	3	0	80	88	50
2,4-D amine (EC) 1.03[5]	SR	0	0	0	92	97	96
	GR	13	3	8	90	93	77
MCPA amine (EC) 1.03[5]	SR	0	0	0	88	94	92
	GR	13	3	10	85	92	53
2,4-D + trifluralin (G) 0.9[5] 0.67	SR	0	0	0	93	95	93
	GR	7	0	3	93	90	70
M 3493 (G) 0.56[5]	SR	0	0	0	88	93	95
	GR	3	2	0	72	77	55

[1] G = granular; EC = emulsifiable concentrate.
[2] SR = stand reduction or control (%); GR = growth reduction (%).
[3] DAT = days after planting.
[4] Urea at 100.8 kg/ha was applied following herbicide treatment.
[5] Urea at 100.8 kg/ha was applied after the rice plants had recovered (20 DAT).

GERMINATION, GROWTH RATE, AND CONTROL OF THE PERENNIAL SEDGE, *SCIRPUS MARITIMUS*, IN TROPICAL RICE

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Summary

The perennial sedge, *Scirpus maritimus*, is capable of becoming a persistent weed in lowland rice fields. Solitary culms are produced from underground tubers or rhizomes and emerge from the soil about 5 days after the last harrowing. Each plant produces new rhizomes and tubers which in turn give rise to new plants. Infested fields cause lodging of the rice plants and reduce grain yield. Herbicides commonly used for controlling annual grasses and broadleaved weeds are not effective against *S. maritimus* at the recommended rates. In the greenhouse, each plant developed an average of 10 rhizomatous sprouts and 7 new tubers, and attained a height of 60 cm in 5 weeks. While 5 cm of water did not affect the germination of tubers placed just below the surface of the soil, it markedly reduced the germination of tubers placed 3 cm below the soil. Tubers placed deeper than 3 cm did not germinate even with 3 cm of standing water. In field tests, a number of herbicides were tested during 1970-71 in transplanted rice. Herbicides found effective against the weed were OCS 21799, mecoprop, butachlor and PP 493. The effectiveness of butachlor was markedly increased when combined with mecoprop or PP 493. The combination of mecoprop and butachlor (at 1.0 + 3.0 kg/ha) gave effective control of *S. maritimus* during the entire growing period of rice, when applied 4 days after transplanting (*i.e.*, at or before the emergence of *S. maritimus*).

INTRODUCTION

The common weeds in tropical rice generally consist of annual grasses and broadleaved weeds. They can be effectively controlled in transplanted rice at a relatively low cost by application of 2,4-D just after transplanting (De Datta and Lacsina, 1969). Other herbicides commercially available for weed control are butachlor, TCE-styrene/2,4-D IPE, and trifluralin/2,4-D IPE. Promising results have also been obtained in 1970 trials at IRRI with benthiocarb and NTN 5006/2,4-D IPE (Lacsina, 1971). In direct-sown, flooded rice, benthiocarb, butachlor, and NTN 5006/MCPA ethyl esters have also been successfully used for the control of annual weeds (De Datta and Bernasor, 1971; Lacsina, 1971).

When the problem of annual weeds becomes less serious, perennial grasses and sedges take over as the major weed problems. These perennial weeds are more difficult to control, particularly when they have become established. Many of them build up large food reserves in underground rhizomes and tubers and multiply rapidly from these vegetative organs. If top growth is destroyed chemically or mechanically, fresh growth takes place from well-protected underground vegetative buds.

Scirpus maritimus is one such perennial sedge. It propagates and multiplies mainly from a network of tubers and rhizomes produced below the soil surface. Mature tubers are 1.0 to 1.5 cm in size, globose, hard, thick, lignose, covered with chestnut-brown to blackish thin scales, and interconnected by thin, wiry rhizomes (for details refer to Koyama, 1958). Young tubers are creamy-white and succulent. They develop at the end of creeping, fleshy rhizomes and may in turn produce further fleshy rhizomes. Solitary erect culms may develop from a mature or young tuber, or directly from a fleshy rhizome. Thus, the weed is capable of multiplying rapidly in the field.

The culms emerge above the soil surface about 5 days after the last harrowing. The weed grows at about 10 cm/wk and soon is taller than the rice plant. At 60 to 70 days after transplanting, just before the rice has headed, the weed may lodge, affecting grain yield.

The tubers become desiccated when the soil dries. If desiccated tubers are exposed to the surface, they float off when the field is flooded. However, enough tubers remain in the soil to re-infest the field. Pulling the plants by hand does not give satisfactory control since the tubers remain in the soil and produce a new growth. Water management and the depth of the tuber in the soil appear to affect tuber germination.

In transplanted rice fields, *S. maritimus* can multiply rapidly, thereby affecting the growth and grain yield of rice. A number of fields on the IRRI farm are infested in varying degrees by *S. maritimus*. Natural stands of 500 plants/m^2 have been observed in some of the fields. Extensive *S. maritimus* infestation has also been observed in the Albay Province, and about 4000 ha are reportedly infested in the Cagayan Valley, Philippines. Seaman and Kittipong (1968) listed *Scirpus* spp. as a common weed found in transplanted rice in Thailand.

Herbicides that so far have been used for controlling annual weeds in transplanted rice do not give satisfactory control of *S. maritimus*. Certain chemicals like fluorodifen may provide initial control of the culms but regrowth is very rapid. Some degree of control of *S. maritimus* and related species in rice has been reported from an application of 4 to 6 kg/ha of propanil (Evsikov, 1967; Mukhopadhyay and Bag, 1967). In Italy, fenoprop at 0.8 to 1.2 kg/ha is commonly applied 25 to 35 days after transplanting for the control of *Scirpus* spp. (Y. Jingo, pers. comm.; P. N. Pande, pers. comm.). A combination of amitrole and 2,4-D applied at the active growth stage of the weed, but at least 5 weeks before the transplanting of rice, is suggested for effective control (Y. Jingo, pers. comm.). Under upland conditions, MSMA has been reported to control *Scirpus* spp. (Hull, 1968), while in irrigation and drainage channels a mixture of dalapon Na (80%) and fenoprop ester (59%) is said to control the weed (Capolupo, 1969).

To gain a better understanding of the germination and growth of *Scirpus maritimus*, greenhouse experiments were conducted at IRRI in 1970 and 1971 to observe the germination behaviour of tubers, the growth rate of culms, and the development of new rhizomes and tubers of this perennial weed. Water depth and tuber placement were also observed for their possible influence on the germination of tubers.

Field experiments also were conducted in the dry and wet seasons of 1970 and in the dry season of 1971 to test selected herbicide treatments for controlling *S. maritimus*.

MATERIALS AND METHODS

Greenhouse Study

In each experiment 20 mature tubers, freshly collected from the field, were placed uniformly in each pot. All observations on the growth rate of culms, rhizomes, and tubers were based on three replications. The same procedure was used to study the effects of water management and depth of tuber placement on tuber germination. Observations on germination of tubers, as influenced by three water levels and four depths of tuber placement, were recorded after 30 days.

Field Experiments

Three field experiments were laid out during 1970-71 to test selected herbicide treatments for the control of *S. maritimus*. In each experiment, a simple randomized block design was used with three replications. Herbicides were applied to plots irrigated to a depth of 2 to 3 cm. A natural stand of *S. maritimus* was used for evaluation. Annual weeds were effectively controlled in all the treated plots. Throughout the study, weed control, therefore, refers to *S. maritimus* only.

May Planting

Dapog seedlings of IR22 were transplanted on 12 May, 1970 at 25 × 25 cm spacing. Seven herbicide treatments were made 4 days after transplanting.

October Planting

Wet-bed seedlings of IR8 were transplanted on 2 October, 1970 at 20 × 20 cm spacing. Acid and K-salt formulations of PP 493, either alone or in combination with OCS 21799 and mecoprop, were included in the trial. Nine herbicide treatments were made 4 days after transplanting.

December Planting

Wet-bed seedlings of IR8 were transplanted on 4 December, 1970 at 20 × 20 cm spacing in a field that had been severely infested by *S. maritimus*. Choice of treatments was based mainly on observations from the 1970 experiments and screening trials. Since PP 493, mecoprop, OCS 21799, and butachlor had shown a certain degree of effectiveness against *S. maritimus*, these were used alone or in combination. In the mecoprop + butachlor combination the amount of mecoprop was reduced to 1.0 kg from 3.0 kg/ha in an attempt to reduce toxicity without decreasing the effectiveness against *S. maritimus*. The herbicides were applied 4 days after transplanting.

RESULTS

GREENHOUSE STUDY

The culms of *S. maritimus* grew rapidly after they emerged from the soil and they always remained well above the rice crop, forcing the latter to lodge at the heading stage. Development of new rhizomes and tubers was slow during the first 2 weeks. In about 5 weeks the plant developed 10 or more new rhizomatous sprouts and about seven new tubers, and it attained a height of about 60 cm. The results of greenhouse studies on the rate of

TABLE 1: GROWTH RATE OF CULMS, RHIZOMES AND TUBERS IN *S. MARITIMUS*

Days after Emergence	*Culm Height (cm)*	*No. New Sprouts/ Mother Tuber*	*No. New Tubers/ Mother Tuber*
2	13	0	0
8	27	2	0
15	40	4	2
23	49	5	3
28	56	6	4
34	61	11	7

growth of culms and development of rhizomes and tubers are presented in Table 1.

The results of the greenhouse study of the effects of water levels above the soil surface and of the depth of tuber placement in the soil on tuber germination are presented in Table 2. While 5 cm of water did not affect the germination of tubers placed just below the surface of the soil, it markedly reduced the germination of tubers placed 3 cm below the soil. Tubers placed deeper than 3 cm did not germinate even with 3 cm standing water. A similar effect has been observed in water management experiments in the field.

TABLE 2: INFLUENCE OF SOIL AND WATER DEPTH ON THE GERMINATION PERCENTAGE OF *S. MARITIMUS*

Soil depth (cm)	*Germination (%) Water depth (cm)* 0	3	5
0	53	70	57
3	43	20	3
6	30	0	0
12	23	0	0

FIELD EXPERIMENTS

May Planting

Compared with the untreated control, the treated plots showed significant reduction in *S. maritimus* stand and a consequent increase in grain yield. The difference in grain yield among herbicide treatments was not significant (Table 3). Grain yield in general was low. The highest yield was 3.6 t/ha from plots treated with 3.0 kg/ha of butachlor. Low grain yield was due to either the toxic effect of herbicides or to weed competition, or both.

TABLE 3: CONTROL OF *S. MARITIMUS* IN TRANSPLANTED IR22 RICE WITH HERBICIDES APPLIED 4 DAYS AFTER TRANSPLANTING. MAY PLANTING

Treatment[1] *(kg/ha)*	*Weed Count*[2] *(No./m²)*	*Toxicity Rating*[3]	*Grain Yield*[4] *(t/ha)*
butachlor 2.0	68.5	0.0	2.3 ab
butachlor 3.0	40.0	2.7	3.6 a
butachlor 2.0/2,4-D BE 1.0	15.0	2.0	3.3 a
butachlor 3.0/2,4-D BE 1.5	21.5	3.3	2.6 ab
butachlor 2.0/2,4-D BE 1.0 fb butachlor 1.0/2,4-D BE 0.5	33.5	1.7	3.3 a
benthiocarb 2.8/simetryn 0.6	0.0	9.7	0.0 c
2,4-D IPE 1.6	65.0	1.3	1.9 b
Untreated control	218.5	0.0	1.0 c
LSD (0.05)	72.0	1.3	

[1] "fb" = applied 2 weeks after the first application.
[2] Based on two samples, 0.1 m² each, taken 37 days after transplanting.
[3] 0 = no visual toxicity to rice; 10 = complete kill. Rated 14 days after transplanting.
[4] Average of three replications. Any two means followed by the same letter are not significantly different at the 5% level.

TABLE 4: CONTROL OF *SCIRPUS MARITIMUS* IN TRANSPLANTED IR8 RICE WITH HERBICIDES APPLIED 4 DAYS AFTER TRANSPLANTING. OCTOBER PLANTING

Treatment (kg/ha)	*Weed Count*[1] *(No./m²)*	*Toxicity Rating*[2]	*Grain Yield*[3] *(t/ha)*
PP 493 acid 0.75	18.5	1.7	2.3 ab
PP 439 K-salt 0.75	35.0	1.3	2.4 ab
PP 493 acid 0.25/mecoprop 1.5	8.5	2.0	2.3 ab
PP 493 K-salt 0.25/mecoprop 1.5	33.5	1.3	2.3 ab
PP 493 acid 0.25/OCS 21799 2.0	1.5	2.0	2.6 ab
PP 493 K-salt 0.25/OCS 21799 2.0	6.5	2.3	2.4 ab
mecoprop 1.5/OCS 21799 2.0	1.5	3.0	3.0 a
mecoprop 3.0/butachlor 3.0	1.5	3.3	2.7 ab
NTN 5006 2.0/2,4-D 0.4	20.0	0.3	2.1 b
Untreated control	88.5	0.0	1.9 b
LSD (0.05)	41.5	1.5	

[1] Based on two samples of 0.1 m² each, taken 35 days after transplanting.
[2] 0 = no visual toxicity to rice; 10 = complete kill. Rated 19 days after transplanting.
[3] Average of three replications. Any two means followed by the same letter are not significantly different at the 5% level.

Benthiocarb/simetryn ("Saturn S") (2.8 kg/ha) gave effective control of *S. maritimus* but also killed rice. A combination of butachlor and 2,4-D BE gave more effective control of the weed than butachlor alone. Additional application of butachlor/2,4,D BE (1.0/0.5 kg/ha), 2 weeks after the first (2.0/1.0 kg/ha), did not improve the effectiveness of the treatment.

October Planting

The treated plots showed a significant reduction in weed stand compared with the untreated control. *Scirpus maritimus* infestation was relatively low in all plots, even 1 month after transplanting. OCS 21799/mecoprop (2.0/1.5 kg/ha), butachlor/mecoprop (3.0/3.0 kg/ha) gave the most effective control of the weed.

The crop was affected by a typhoon and by blast. The grain yield was low irrespective of treatment and degree of weed control. The highest yield was 3.0 t/ha from the OCS 21799/mecoprop combination, as compared with 1.9 t/ha from the untreated control. The difference was significant (Table 4).

TABLE 5: CONTROL OF *S. MARITIMUS* IN TRANSPLANTED RICE WITH HERBICIDES APPLIED 4 DAYS AFTER TRANSPLANTING. DECEMBER PLANTING

Treatment (kg/ha)	*Weed Count*[1] *(No./m²)*	*Toxicity Rating*[2]	*Grain Yield*[3] *(t/ha)*
butachlor 3.0	26.5 abc	1.3	2.3 e
mecoprop 3.0	15.0 ab	1.7	3.4 bcde
PP 493 acid 1.5	143.5 de	6.7	3.7 bcd
OCS 21799 2.0	15.0 ab	2.0	4.9 a
mecoprop 1.0/butachlor 3.0	5.0 a	0.3	4.2 ab
PP 493 acid 0.5/butachlor 3.0	18.5 ab	3.3	3.9 abc
PP 493 acid 0.25/OCS 21799 2.0	21.5 ab	4.7	3.8 abcd
PP 493 acid 0.5/OCS 21799 1.0	65.0 cd	5.0	2.7 de
mecoprop 1.0/OCS 21799 2.0	46.5 bcd	1.3	2.8 cde
PP 493 acid 0.5/mecoprop 1.0	90.0 d	2.3	2.3 e
Untreated control	361.5 e	0.7	0.9 f
LSD (0.05)		1.7	

[1] Based on two samples of 0.1 m² each. Taken 32 days after transplanting. ANOV based on values transformed to log $(x + 1)$. Any two means followed by the same letter are not significantly different at the 5% level.
[2] 0 = no visual toxicity to rice; 10 = complete kill. Rated 14 days after transplanting.
[3] Average of three replications. Any two means followed by the same letter are not significantly different at the 5% level.

December Planting

Excellent weed control was observed during the first 6 weeks from application of mecoprop/butachlor (1.0/3.0 kg), OCS 21799 (2.0 kg), mecoprop (3.0 kg), PP 493 acid/OCS 21799 (0.25/2.0 kg), or PP 493 acid/butachlor (0.5/3.0 kg) (Table 5). Beyond this period, fresh weed growth appeared in all but the plots treated with mecoprop/butachlor (1.0/3.0 kg/ha), which remained weed-free until harvest. The highest grain yield, 4.9 t/ha, was obtained from OCS 21799 (2.0 kg), followed by 4.2 tonnes from mecoprop/butachlor (1.0/3.0 kg). The difference was not significant, however. Low grain yields from the untreated control and other unsuccessful treatments were mainly due to severe lodging of rice before heading.

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RECENT PROGRESS OF CHEMICAL WEED CONTROL PROGRAMME FOR TRANSPLANTED RICE IN TAIWAN

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INTRODUCTION

Rice in Taiwan is still grown largely by the method of transplanting. In 1970, the total planted area of rice reached 776 139 ha, producing 2 462 643 tonnes of brown rice (PDAF, 1971a). Although hand-weeding remains the most common practice of controlling weeds in transplanted rice fields, chemical weed control is becoming increasingly popular among rice farmers in Taiwan. This interest has been stimulated partly by the soaring cost of labour, and partly by the successful release of various herbicides for commercial use in recent years. A considerable amount of work has been done on chemical weed control in transplanted rice during the past two years. Several promising new granular herbicides have been identified. Effects of varietal type and crop season on the performance of granular formulation of isopropyl ester of 2,4-D have been evaluated. Rice fields controlled with herbicides have been greatly increased. This paper presents the highlights of chemical weed control experiments and extension works conducted by various experiment stations and government agencies in 1969 and 1970.

PROMISING NEW GRANULAR HERBICIDES

Among new granular herbicides screened for transplanted rice during the past two years, the performance of butachlor and benthiocarb appeared particularly encouraging (PDAF, 1971b). Both herbicides were evaluated for two crop seasons at three locations representing northern, central, and southern parts of Taiwan. Nitrofen, the most widely used herbicide for transplanted rice in Taiwan (Chang, 1969a), was included as a standard check for making a comparison.

BUTACHLOR

The performance of butachlor in the first crop of 1970 is shown in Table 1. It was observed that butachlor applied 5 days after transplanting at rates of 1.0 to 2.5 kg/ha provided good control

TABLE 1: EFFECT OF GRANULAR BUTACHLOR APPLIED 5 DAYS AFTER TRANSPLANTING ON TRANSPLANTED JAPONICA RICE AT THREE DISTRICT AGRICULTURAL IMPROVEMENT STATIONS IN TAIWAN, FIRST (DRY SEASON) CROP, 1970

Treatment (kg/ha)	Weed Control[1] (weeds/m²)			Rice Toxicity[2]			Grain Yield[3] (t/ha)		
	Hsinchu	Taichung	Kao-hsiung	Hsinchu	Taichung	Kao-hsiung	Hsinchu	Taichung	Kao-hsiung
butachlor 1.0 ...	14	11		–	–	–	4.3 a	5.9 a	
butachlor 1.5 ...	10	8	8	–	–	–	4.3 a	5.7 a	6.1 a
butachlor 2.0 ...	4	4	5	+	+	++	4.0 a	5.7 a	5.9 a
butachlor 2.5 ...			4			++			5.9 a
nitrofen 2.0 ...	8	5	9	–	–	–	4.0 a	5.6 a	6.2 a
Hand-weeding ...	19	134	27	–	–	–	4.1 a	5.8 a	6.3 a
Untreated ...	169	601	84	–	–	–	3.3 a	4.4 a	5.6 a

[1] Counted at 20 days after transplanting.
[2] –, not toxic to rice; +, toxic to rice.
[3] Rice varieties used were Hsinchu 56, Taichung 178, and Kaohsiung 137, respectively, for Hsinchu, Taichung, and Kaohsiung stations.

of weeds comparable to that of nitrofen, although weed control effect improved with the increase in the rate of application. Experimental results of the Chiayi Agricultural Experiment Station (CAES) from both 1970 crops also indicated that 1.0 kg/ha of butachlor applied 4 days after transplanting, resulted in excellent control of weeds (Chang, 1971). In another experiment, also conducted at CAES in the first crop of 1971, practically no difference was detected in the weed control effect of butachlor applied 6 days after transplanting at the rates of 1.0 and 3.0 kg/ha. However, when butachlor was applied 16 days after transplanting or at the 2- to 3-leaf stage of weeds, weeds such as *Monochoria vaginalis* were not adequately controlled in the treatments below 2.0 kg/ha. Butachlor generally provides excellent control of annual grasses such as *Echinochloa crus-galli,* and sedges such as *Cyperus difformis.* Furthermore, the growth of *Marsilea quadrifolia,* a noxious weed of transplanted rice not controlled by most commercial herbicides, can also be considerably suppressed by butachlor.

Table 1 shows that butachlor was toxic to rice when the application rates exceeded 2.0 kg/ha. This phytotoxicity was manifested largely by the yellowing of rice leaves and stunted growth of seedlings. The symptoms became evident about one week after application, but most rice plants generally recovered within one or two weeks. Moderate rice injury was also observed 20 days after the application of the experiment conducted at the National Taiwan University in the second crop of 1969 when butachlor was applied at a rate as high as 3.0 kg/ha (Chang *et al.,* 1970). In the experiment conducted at CAES in the first crop of 1971, it was noted that butachlor rarely caused any phytotoxicity to rice in the post-emergence application.

It was also indicated in Table 1 that butachlor applied at 1.0 kg/ha gave the highest grain yield, and rice production tended to decrease with the increase of application rates. However, differences in grain yield among application rates of butachlor failed to reach a significant level in all three locations. There were also no significant differences in rice production either between butachlor treatments and the standard herbicide, nitrofen, or between butachlor and hand-weeding. It appears, therefore, that pre-emergence application of granular butachlor at rates of 1.0 to 1.5 kg/ha can be recommended for commercial use in This treatment may produce reasonably high grain yield by transplanted rice under the conditions prevailing in Taiwan.

TABLE 2: PERFORMANCE OF GRANULAR BENTHIOCARB FOR TRANSPLANTED RICE AS AFFECTED BY RATE AND TIME OF APPLICATION AT THREE LOCATIONS IN TAIWAN, FIRST (DRY-SEASON) CROP, 1970

Treatment (kg/ha)	Time DAT[1]	Weed Control[2] (weeds/m²)			Rice Toxicity[3]			Grain Yield[4] (t/ha)		
		Hsinchu	Taichung	Kao-hsiung	Hsinchu	Taichung	Kao-hsiung	Hsinchu	Taichung	Kao-hsiung
benthiocarb 3.0	7	14.1	198.3	25.6	–	–	–	5.0 bc	5.6 a	6.6 a
benthiocarb 4.0	7	1.0	55.3	11.9	+	–	+	5.0 bc	5.6 a	6.2 a
benthiocarb 3.0	10	12.3	158.1	38.9	–	–	–	5.1 abc	5.8 a	6.2 a
benthiocarb 4.0	10	2.5	56.2	12.0	+	–	+	5.2 ab	5.8 a	6.2 a
nitrofen 2.0	7	2.4	4.9	8.7	–	–	–	5.4 a	5.6 a	6.2 a
Hand-weeding		38.6	134.1	26.8	–	–	–	5.2 ab	5.8 a	6.3 a
Untreated		177.3	600.5	84.2	–	–	–	4.8 c	4.4 b	5.6 a

[1] Days after transplanting.
[2] Counted at 20 days after transplanting.
[3] –, not toxic to rice; +, toxic to rice.
[4] Rice varieties used were Hsinchu 56, Taichung 178, and Kaohsiung 137, respectively, for Hsinchu, Taichung, and Kaohsiung stations.

providing adequate control of weeds without causing any visible injury to rice plants.

Benthiocarb

The influence of rate and time of application on the performance of granular benthiocarb in transplanted rice is presented in Table 2. The weed control effect of benthiocarb was apparently not affected by the time of application. Practically the same control of weeds was obtained when benthiocarb was applied either before weeds emerged (7 days after transplanting) or at the 1- to 2-leaf stage of weeds (10 days after transplanting). However, in the experiment conducted at CAES in both crops of 1970, pre-emergence application of benthiocarb gave consistently better control of weeds than post-emergence application (Chang, 1971). The weed control effect of benthiocarb was considerably affected by the rate of application. An application of 4.0 kg/ha generally resulted in better control of weeds than a rate of 3.0 kg/ha. In the experiment also conducted at CAES in the first crop of 1971, it was observed that weeds, particularly broadleaves, were not adequately controlled at rates below 1.5 kg/ha. Like granular butachlor, benthiocarb provides excellent control of *Echinochloa crus-galli* and *Cyperus difformis*. *Eleocharis acicularis*, another hazardous weed of transplanted rice, can also be controlled with benthiocarb.

Rice plants were slightly injured when the rate of benthiocarb exceeded 4.0 kg/ha, excepted at Taichung station where rice plants were not injured (Table 2). Chlorosis and stunting of seedlings became evident about 8 days after the application, but most symptoms of phytotoxicity disappeared within 3 to 4 days. No phytotoxicity to rice was detected in the experiment conducted in both crops of 1970 at CAES when granular benthiocarb was applied at 3.0 kg/ha (Chang, 1971).

There were no significant differences in grain yields between applications of benthiocarb at 7 and 10 days after transplanting or at rates of 3.0 and 4.0 kg/ha (Table 2). There were also no significant differences in grain yields between benthiocarb treatments and hand-weeding. All benthiocarb treatments out-yielded the standard herbicide, nitrofen, except at Hsinchu station where early application of benthiocarb gave significantly lower grain yield than nitrofen. Because of its excellent performance, granular benthiocarb has already been recommended for commercial use in transplanted rice in Taiwan. The recommended method of application is to apply granular benthiocarb at 3.0 kg/ha 7 to 10 and 5 to 7 days after transplanting in the first and second crops, respectively. As the weed control effect of benthiocarb at 2.0 kg/ha was found to differ very slightly from that of 3.0 kg/ha in the experiment conducted at CAES in the first crop of 1971, a slight reduction in the current recommended rate of 3.0 kg/ha appears likely.

EFFECTS OF VARIETAL TYPE AND CROP SEASON ON THE PERFORMANCE OF 2,4-D IPE

In Taiwan, two different groups of rice (Indica and Japonica types) are commonly grown in two different crop seasons, the first and second crops. Since the two varieties differ greatly in both morphological and physiological characters, they may respond quite differently to the application of herbicides. Similarly, the performance of herbicides in the first crop, which is generally cool and dry, is likely to differ from that in the warm and wet second crop season. An understanding of the role played by varietal type and crop season on the performance of herbicides appears necessary if they are to be evaluated correctly.

Granular formulation of 2,4-D isopropyl ester (IPE) was found to provide good control of weeds with remarkably mild rice toxicity when it was first tested in Taiwan (Chang, 1969b). Particular attention has been paid to the performance of this herbicide in transplanted rice because it is probably the only herbicide commercially available at a price within the reach of the average rice farmer. For this reason, the performance of 2,4-D IPE or herbicides combined with 2,4-D IPE in transplanted rice, as affected by varietal types and crop seasons, was evaluated at the Chiayi Agricultural Experiment Station in 1970.

Rice varieties, Taichung native 1 and Chianung 242, were used to represent two contrasting varietal types. The former is a short culm, heavy tillering variety, and the latter a tall culm, light tillering Japonica one. The first or dry season crop was transplanted on 21 February, 1970, and the second crop on 27 July, 1970. Herbicide treatments included five granular herbicides, namely, single applications of 2,4-D IPE and 2,4-D ethyl ester (EE), butachlor combined with 2,4-D butyl ester (BE), EPTC combined with 2,4-D IPE, and TCE-styrene in combination with 2,4-D IPE. All herbicides were applied 4 days after transplanting.

WEED CONTROL

The weed control effect of granular 2,4-D herbicides as affected by varietal types and crop seasons is given in Table 3. Adequate control of weeds was apparently available for all herbicide treatments. It was observed that the control of weeds was not affected by varietal types when it was rated at 19 days after transplanting. However, when rice plants had developed to the panicle initiation stage, each herbicide consistently provided better control of weeds for Indica variety than for Japonica. The main reason for the herbicidal effect varying with varietal types at the late growing stage of rice may be largely associated with the tillering ability of the rice varieties. Heavy tillering Indica rice, Taichung native 1, appeared to leave smaller space for weed growth when compared with poor tillering Japonica rice, Chianung 242. Table 3 also indicates that the initial weed control of the various treatments was not affected by crop season, except EPTC/2,4-D IPE which appeared to provide better initial control of weeds in the dry season crop. It was observed that weed control by 2,4-D IPE, 2,4-D EE, and TCE-styrene/2,4,-D IPE was better in the wet season crop when rating was made at the panicle initiation stage. This may be largely attributed to the higher toxicity of these herbicides to rice plants in the dry season crop, which resulted in more open space for the growth of weeds by killing or suppressing the growth of rice plants.

TABLE 3: INFLUENCE OF VARIETAL TYPE AND CROP SEASON ON THE CONTROL OF WEEDS FOR GRANULAR 2,4-D HERBICIDES APPLIED AT 4 DAYS AFTER TRANSPLANTING, CAES, 1970

	19 DAT[1]		*PIS*[2]			
	1st	*2nd*	*1st Crop*		*2nd Crop*	
Treatment (kg/ha)	*Crop*	*Crop*	*TN 1*[3]	*Ch 242*[4]	*TN 1*	*Ch 242*
2,4-D IPE 0.8	1.3	1.3	1.6	2.2	1.0	1.4
2,4-D EE 0.8	1.1	1.2	1.7	2.6	1.0	1.6
butachlor 1.0/2,4-D BE 0.5	1.2	1.1	1.4	1.7	1.0	1.3
EPTC 0.75/2,4-D IPE 0.5 ..	1.4	2.3	2.2	2.4	1.5	2.4
TCE-styrene 0.75/2,4-D IPE 0.5	1.2	1.4	1.9	2.2	1.0	1.3
Untreated control	5.0	5.0	5.0	5.0	5.0	5.0

[1] Days after transplanting.
[2] Panicle initiation stage.
[3] Taichung native 1.
[4] Chianung 242.

Rice Toxicity

Rice toxicity ratings made at 19 days after transplanting and at panicle initiation stage are shown in Table 4. Severe rice toxicity was observed in the treatments of 2,4-D IPE, 2,4-D EE, and TCE-styrene/2,4-D IPE, while rice plants were only slightly injured by the application of butachlor/2,4-D BE and EPTC/2,4-D IPE. The phytotoxicity of herbicides was manifested in the yellowing of leaves, stunted growth of rice plants, reduction in the number of tillers, development of onion leaves, and even the complete kill of rice plants. Toxicity ratings of Taichung native 1 made 19 days after transplanting were slightly higher than those of Chianung 242, indicating that young rice plants of Indica variety were more sensitive to the phytotoxicity of granular 2,4-D herbicides. However, Chianung 242 appeared to suffer heavier toxicity than Taichung native 1 when rated at the panicle initiation stage, showing that the Indica variety was capable of more rapid recovery from injuries caused by herbicides than the Japonica variety. It was of interest to note that phytotoxicity of granular 2,4-D herbicides was more pronounced in the first crop than in the second. Granular 2,4-D IPE, 2,4-D EE, and TCE-styrene/2,4-D IPE were highly toxic to rice in the first crop, but they showed remarkably mild rice toxicity in the second. Since temperature during the early stage of rice growth in 1970 was considerably lower than that of the second, it appears likely that high toxicity of granular 2,4-D herbicides may be associated with low temperature.

TABLE 4: INFLUENCE OF VARIETAL TYPE AND CROP SEASON ON THE RICE TOXICITY OF GRANULAR 2,4-D HERBICIDES APPLIED 4 DAYS AFTER TRANSPLANTING, CAES 1970

	19 DAT				*PIS*			
	1st Crop		*2nd Crop*		*1st Crop*		*2nd Crop*	
Treatment (kg/ha)	*TN 1*	*Ch 242*	*TN 1*	*Ch 242*	*TN 1*	*Ch 242*	*TN 1*	*Ch 242*
2,4-D IPE 0.8	2.7	2.3	1.5	1.6	1.5	2.0	1.0	1.0
2,4-D EE 0.8	2.7	2.5	1.7	1.8	1.6	2.0	1.0	1.3
butachlor 1.0/2,4-D BE 0.5	1.4	1.6	1.2	1.4	1.4	1.9	1.0	1.0
EPTC 0.75/2,4-D IPE 0.5	1.5	1.6	1.0	1.4	1.3	1.8	1.0	1.0
TCE-styrene 0.75/2,4-D IPE 0.5	2.3	2.3	1.7	1.7	1.8	2.5	1.0	1.3
Untreated control	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Grain Yield

Grain yields and panicles per hill of Taichung native 1 and Chianung 242 in the first and second crops of 1970 are shown in Table 5. Japonica type rice variety, Chianung 242, was found to suffer greater reduction of yield than Indica type variety, Taichung native 1, indicating that the profuse tillering Indica variety was more tolerant to chemical injury than the weak tillering Japonica variety. It appears, therefore, that chemical weed control can be more safely practised in paddy fields growing Indica varieties. It was also noted that the first crop of rice suffered much more loss of yield from the applications of herbicides than the second crop. Since rice toxicity of granular herbicides was heavier in the first crop, difference in the degree of yield reduction associated with crop seasons could be ascribed to the effect of chemical injury. The analysis of yield variance also revealed that difference in grain yield among granular 2,4-D herbicides was significant in the first, but failed to reach a significant level in the second. The decrease in grain yield was caused largely by the reduction in the number of panicles per hill (Table 5). The results of this experiment seem to indicate that granular 2,4-D IPE, 2,4-D EE, butachlor/2,4-D BE, EPTC/2,4-D IPE, and TCE-styrene/2,4-D IPE can be recommended for use in transplanted rice only in the warm second crop. These herbicides should give adequate weed control without causing any serious injury to rice.

ACREAGE AND COST OF CHEMICAL WEED CONTROL IN TRANSPLANTED RICE

It was estimated that nearly 11 225 and 15 838 ha of transplanted rice in Taiwan were controlled exclusively with herbicides in 1969 and 1970, respectively (Table 6). In 1968, the acreage of chemical weed control in transplanted rice was reported to reach only 3597 ha (Chang, 1969a), showing a rapid extension of chemical weed control practice during the past two years. However, rice fields controlled with herbicides constituted only 2% of the total transplanted rice in 1970, that is, almost 98% of rice fields still use traditional hand-weeding. To help rice farmers understand chemical weed control practice in transplanted rice, a large-scale demonstration programme was initiated in 1967 by the Provincial Department of Agriculture and Forestry (PDAF). In 1970, a total of 16 demonstration plots with a total area of 160 ha were set up at 8 prefectures around the island (PDAF, 1971a).

TABLE 5: INFLUENCE OF VARIETAL TYPE AND CROP SEASONS ON THE GRAIN YIELDS AND PANICLES PER HILL OF TRANSPLANTED RICE APPLIED WITH GRANULAR 2,4-D HERBICIDES, CAES, 1970

Treatment (kg/ha)	Grain Yield (t/ha) 1st Crop TN 1	1st Crop Ch 242	2nd Crop TN 1	2nd Crop Ch 242	No. of Panicles/hill 1st Crop TN 1	1st Crop Ch 242	2nd Crop TN 1	2nd Crop Ch 242
2,4-D IPE 0.8	5.2 a	4.9 ab	4.8 a	4.6 a	13.4 b	11.0 ab	16.5 a	10.2 a
2,4-D EE 0.8	5.8 a	4.5 b	4.9 a	4.4 a	13.7 b	10.1 ab	15.3 a	9.7 a
butachlor 1.0/2,4-D BE 0.5	5.8 a	5.5 ab	5.1 a	4.7 a	16.4 a	12.4 a	17.7 a	10.5 a
EPTC 0.75/2,4-D IPE 0.5	5.4 a	5.1 ab	4.9 a	4.6 a	14.4 b	10.2 ab	15.3 a	9.1 a
TCE-styrene 0.75/2,4-D IPE 0.5	6.0 a	5.0 ab	4.7 a	4.5 a	15.0 ab	9.6 b	14.9 a	9.2 a
Untreated control	6.2 a	5.8 a	4.9 a	4.1 a	15.9 a	10.7 ab	15.4 a	9.4 a

TABLE 6: ACREAGE AND COST OF CHEMICAL WEED CONTROL FOR TRANSPLANTED RICE IN TAIWAN, 1969-70

	Herbicide Nitrofen	PCP	2,4-D	Propanil	Ebiden	Total or Average	% Total Planted Area of Hand-weeding
Acreage (ha), 1969:							
First crop	4,519.6	316.5	196.0	—	10.0	5,042.1	1.48
Second crop	5,373.1	268.0	507.0	20.0	10.0	6,183.1	1.42
Total	9,892.7	584.5	703.0	20.0	20.0	11,225.2	1.45
%	88.1	5.2	6.3	0.2	0.2	100.0	
Acreage (ha), 1970:							
First crop	6,403.5	626.3	80.0	—	166.1	7,275.9	2.14
Second crop	7,487.2	380.2	165.4	80.0	449.6	8,562.4	2.02
Total	13,890.7	1,006.5	245.4	80.0	615.7	15,838.3	2.07
%	87.7	6.4	1.6	0.5	3.9	100.0	
Cost (US$/ha):							
Chemical (A)	19.1	13.4	8.0	26.0	20.8	17.5	
Hand (B) First crop						31.2	
Second crop						28.2	
A — B First	—12.1	—17.8	—23.2	—5.2	—10.4	—13.7	—43.91
Second	— 9.1	—14.8	—20.2	—3.2	— 7.4	—10.7	—37.94

Currently, 8 herbicides are officially recommended for use in transplanted rice. They are 12% "Glenbar EC", 50% "DBN WP", 7.7% "Nitrofen G", 25% "PCP G", 14.6% "Pamcon G", 14.6% "Ebiden G", 21.2% 'DIC-4103 G", and 8.7% "Mo-401 G" (PDAF, 1970). Among these recommended herbicides, granular nitrofen, pentachlorophenol, and "Ebiden" have been commercially accepted, especially the granular nitrofen which was used on nearly 88% of the transplanted rice fields controlled with herbicides in 1970 (Table 6). However, the importance of granular nitrofen for transplanted rice in Taiwan is likely to decline in the future when more effective and/or cheaper new herbicides become commercially available. While either the granular or liquid form of herbicides can be used for transplanted rice, farmers in Taiwan prefer to use granular herbicides because they can be handled more easily.

In recent years, the cost of hand-weeding in transplanted rice has been continuously increasing, while that of chemical weed control is gradually decreasing. In 1967, costs of hand-weeding were estimated to be US$25.00 and $18.75/ha for the first and second crops, respectively, while chemical weed control cost US$22.50/ha by using granular nitrofen (Chang, 1967). Current figures indicate that hand-weeding costs about US$31.2 and $28.2/ha in the first and second crops, respectively, whereas chemical weed control with granular nitrofen costs US$19.1/ha, showing that cost of hand-weeding has increased 25% and 50%, respectively, in the first and second crops, while that of chemical weed control has decreased 15% during the past four years. It is also noted that current costs of chemical weed control are almost 43.91% and 37.94% lower than those of hand-weeding in the first and second crops, respectively. As labour costs in Taiwan are likely to increase, more farmers are expected to replace hand-weeding with herbicides in their rice fields. The increase in the acreage of chemical weed control can be accelerated if the price of herbicides can be substantially reduced to a level within the reach of the average farmer.

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A REVIEW OF WEED CONTROL RESEARCH IN JAVA'S SUGARCANE

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Summary

Weed control is important to ensure high cane sugar production in Java. At present hand-weeding accounts for about 10 to 20% of the labour requirements for cane production but there is increasing difficulty in maintaining good weed control with hand labour. Chemical weed control to replace hand-weeding is a possible solution. Some trial results showed that weed control for several weeds can be achieved by herbicide application in milling cane fields using pentachlorophenol in oil-water emulsion, paraquat, or a mixture of TCA + 2,4-D amine salt sprayed as pre-planting application; mixtures of atrazine or ametryn + 2,4-D amine, sprayed as early post-planting application; mixtures of ametryn or dalapon + 2,4-D amine salt, sprayed as late post-planting application. However, there were some harmful effects to the cane, especially after the late post-planting applications, resulting in a reduction of cane yield and sucrose content. On railroad tracks, weed control for 7 to 9 months could be obtained by spraying with a mixture of bromacil and 2,4-D. Herbicides for weed control in cane fields are not yet recommended, owing to high cane susceptibility. Apparently, cultural practices and conditions in Java are significant, and some are discussed.

INTRODUCTION

In the cultivation of sugarcane in Java the Reynoso system is used, sugarcane being planted on land rented from the farmers. Much labour is used in this particular method of cultivation. Usually 800 to 900 man-days are needed per hectare for all operations from planting to harvesting, about 75 to 180 man-days being used for hand-weeding.

Weeding in the sugarcane is carried out before each cultivation operation, such as planting, replacing dead cane seedlings, fertilization, filling-in the plant furrows. Repeated hand-weeding is necessary to maintain weed-free conditions. Weeding is done from 3 to 15 times, depending upon weed conditions, type of soil, cultivation method and climatic conditions.

HAND-WEEDING IN CANE FIELDS

Weeds growing in the furrows and on the ridges (inter-rows) are pulled out by hand, or more often cut off with sickles or other tools. Usually 10 to 40 women or men labourers are needed

to hand-weed one hectare in a single day. Nowadays, weed control by this means is no longer easily carried out. Some estates even reported that hand-weeding alone was insufficient for weed control in their cane fields. The trouble is caused among others by:

(1) The decrease of working capacity and poorer weeding performances. The energy of a worker engaged in weeding is today far below that of the same worker 15 years ago. In addition just cutting off the aerial part of weeds gives a weed-free condition for only 3 to 5 days. Correct weeding — *i.e.*, pulling out all parts of the weed — controls weed regrowth for 2 weeks. Because of poor weed control performance, more weeding rounds are needed to keep the cane field clean.

(2) Hand-workers are not always available, especially during the planting and harvesting seasons of rice and other crops, or during the first months of the cane planting season. This is because higher wages are paid for work on the other crops, and because more workers are needed in planting the cane, so that weeding operations are often neglected until planting is completed.

(3) Bad management and poor control of the staff result in less than perfect weeding performance.

These hand-weeding problems are encountered by nearly all sugar estates in Java. To solve them:

(1) Workers must be imported from other areas, or

(2) Weeding must be regulated to be done before or after the planting or harvesting seasons of rice and other crops, or

(3) Soil cultivation has to be repeated to avoid weed infestation, or

(4) People must be attracted to work in the cane fields by raising the weeding costs or wage rates.

However, all these means do not seem sufficient to solve the ever-increasing problems of weed control in Java. Another approach is chemical weed control.

CHEMICAL WEED CONTROL RESEARCH

Investigations of chemical weed control to replace hand-weeding were started after World War 2. A series of weed control trials were carried out in cane and on the railroads of several sugar estates after 1948 (Duyverman, 1957). In 1958 all trials were abruptly stopped when Dutch planters left Indonesia as a result of the political dispute between Indonesia and the Netherlands.

Research began again in 1965. It is carried out and sponsored by the Sugar Experiment Station of Pasuruan with the purpose of finding a herbicide or herbicide mixture which will be able to control weeds and will not be toxic to sugarcane in Java.

Within these research activities, there are three different subjects — *i.e.*, weed control in milling cane, in seed nurseries, and on railroad tracks. Trial results on these three subjects will be discussed hereunder.

Milling Cane Fields

The planting season for sugarcane in Java starts in the late wet season (May-June) and lasts until the early dry season (July-August). As soon as the harvested rice fields are made available to the sugar estates by the farmers (owners), they are prepared directly for sugarcane planting. In general, one month later, after the soil has been prepared, the cane is planted. During this period, after soil preparation — *i.e.*, digging drainage ditches and making planting furrows — and before actual planting, weeds are growing on the furrows and on the sides of the ridges. Usually one or two hand-weeding rounds will be needed to control weeds before planting, while three to six weeding rounds are still needed to suppress weed growth until the cane closes in.

Herbicide application trials are of three kinds — pre-planting spraying; early post-planting spraying; and late post-planting spraying.

Pre-planting Spraying Trials

These trials were of two kinds: spraying the harvested rice fields before digging ditches and furrows, and spraying after this operation.

Before digging ditches and furrows, the harvested rice fields were sprayed with a mixture of TCA at 20 kg/ha + 2,4-D triethanol amine salt at 2 to 3 kg/ha, at Sumberhardjo sugar estate (Duyverman, 1957). This application was performed ± 20 days before the cane was planted. By this application weed growth was suppressed for 8 weeks and could make unnecessary 4 or 5 hand-weeding rounds before and after planting. It also resulted in increased sugar production of 6.5 qt/ha (Duyverman, 1957). For better results, the sprayed land needed to be worked out and planted as soon as possible (Ruinard, 1960). This kind of herbicide application was tried only on the Sumberhardjo sugar estate.

In other sugar estates, land for planting sugarcane is delivered rather late and not all at once, since the rice crops are not harvested at the same time. These estates are forced to prepare the soil for sugarcane planting an area at a time. This partial land delivery occurs more frequently nowadays and it is doubtful how effective this type of herbicide application is in these circumstances.

A pre-planting application of herbicides carried out, after the soil has been prepared, 2 weeks before planting would be sound. In this case pentachlorophenol at 3 to 4 kg/ha in water-oil emulsion or paraquat at 0.4 to 0.6 kg/ha can be used. This application burns out the aerial parts of all the weeds and can suppress the weed regrowth for 3 to 4 weeks after application or 1 to 2 weeks after planting (Anon., 1969; Kuntohartono and Tarmani, 1967). This kind of pre-planting spraying is effective for a shorter period, but it is more practical than the other method.

Early Post-planting Spraying

Several weeks after planting, owing to intensive care of the cane by irrigation, nitrogen fertilization and shallow cultivation of the furrows, the weeds grow vigorously. In this period hand-weeding is also carried out.

To suppress weed growth in the first weeks after planting, numerous trials using translocated and residual herbicides have been carried out. Up to now, the best results have been shown by mixtures of triazines and 2,4-D. Atrazine at 1 to 2 kg/ha + 2,4-D amine salt at 0.5 to 1.0 kg/ha was best in areas where *Cyperus rotundus* dominated the weed composition, while a mixture of ametryn at 1 to 1.5 kg/ha + 2,4-D amine salt at 0.5 to 1.0 kg/ha, proved to be sufficient for controlling a mixed stand of grasses and broadleaf weeds.

These two mixtures can control weeds for 4 to 5 weeks after application. Higher dosages can suppress the weed longer, but cane germination and growth are then affected.

The most practical and least hazardous time of application of the herbicides in respect to cane germination and growth is 3 to 7 days after planting. This time of application is particularly important when sprouting seed cane is used as plant material.

Late Post-planting Spraying

This is carried out 5 to 6 weeks after the early post-planting application. It is intended to control weed growth until the cane closes in.

At the time of application, the weeds have just begun to regrow in the inter-rows and among the cane shoots. The herbicides to be used must have a foliage action or must be active upon roots and foliage together. Trials using different kinds of herbicides or herbicide mixtures, sprayed over the cane as a broadcast application, have not given satisfactory results. Up to the present, there is no well-known herbicide mixture that can control the weeds until the cane closes in without affecting the cane growth.

Herbicide mixtures tried were: dalapon 1.7 kg/ha + 2,4-D amine salt 1 kg/ha, and ametryn or atrazine 1.0 to 1.5 kg/ha + 2,4-D amine salt 0.5 to 1.0 kg/ha. These mixtures were able to suppress weed growth for 2 to 3 weeks and 5 weeks, respectively.

Nearly always, the cane crop has fewer shoots and lower cane stalks, with or without phytotoxicity symptoms, and cane yield and sucrose content are reduced.

Efforts are still being made at Pasuruan to find some other herbicide that is less toxic to the cane, and can be applied in a less hazardous way.

SEED CANE NURSERIES

Sugarcane for seed purpose is planted in seed cane nurseries 7 to 8 months before the planting season. About 60 to 75% of planting materials derived from these nurseries are planted in areas which comprise ± 11% of the total cane acreage of each sugar estate.

The weed problem in cane nurseries is always more serious than in the milling cane, as the nurseries are planted in the early wet season (November-December). This coincides with the critical labour demand period of the rice planting season.

Weed control trials in seed cane nurseries have been carried out at Pasuruan and Djatiroto sugar estates since 1968, and until recently there was no satisfactory herbicide treatment. Some of the problems are:

(1) The cane is more susceptible to residual herbicide application in the wet season than in the dry season.

(2) Herbicide effectiveness is very low in dosages which do not affect the cane. This is probably a result of the heavy rainfall during the planting season.

(3) The hard-to-kill weeds, *Cyperus rotundus*, *Cynodon dactylon*, *Polytrias amaura*, *Panicum repens* and others, grow vigorously and dominate the weed composition.

Several preliminary trials gave the following results:

One or more pre-planting spraying applications were needed to obtain a weed-free condition during planting. Generally there is a heavy weed infestation before planting as a result of the 3 to 4 weeks fallow period. Pentachlorophenol at 3 to 4 kg/ha in water-oil emulsion or paraquat at 0.4 to 0.6 kg/ha sprayed 2 weeks before planting, burns out the aerial parts of weeds and delays regrowth for only 2 to 3 weeks after application.

As for the early post-planting spraying application, no treatment was found which could suppress weed regrowth sufficiently and not affect cane germination and growth. Even the less toxic herbicides, such as atrazine, 2,3,6-TBA + 2,4-D, and dicamba, still caused severe cane damage.

Dalapon at 3.4 kg/ha + 2,4-D ester formulation at 1 kg/ha sprayed as a late post-planting application checked weed growth for 2 or 3 weeks without affecting the cane, provided it was not sprayed more than 2 times in one season, with a 3- to 4-week interval between each application.

Trials to find a desirable herbicide or herbicide mixture and its application are still being carried out with the aim of obtaining several highly selective, foliage-acting herbicides. In addition, trials with repeated sprayings of herbicides at reduced rates are also being carried out with the aim of reducing the phytotoxic effect.

RAILROAD TRACKS

In most sugar estates, lorries are used for cane transportation from the fields to the mills. The average length of railroad tracks in each estate is 60 to 90 km.

Formerly weeding on railroad tracks was intensive, 6 to 8 weeding operations being done each year. At present, weeding is done only once to three times yearly before the milling season. Consequently, heavy weed infestations still exist for a longer period, particularly during the wet season. This results in high costs and ineffective weeding.

Trials of total weed control on railroads indicate that sodium chlorate at 60 kg/ha or 2,4-D sodium salt at 4 kg/ha (1 ha railroad is equal to 5 km by 2 m width of railroad track), sprayed 8 times a year is cheaper than hand-weeding the same number of times (Wiljes, 1954). The results of other trials at Sumberhardjo sugar estate using a mixture of TCA 20 kg/ha + 2,4-D amine salt 4 kg/ha sprayed 6 times a year, showed a decrease in weeding costs of 30 to 50% as compared with hand-weeding (Duyverman, 1957).

A new series of trials using recent soil sterilants showed that a mixture of bromacil 12.8 kg/ha + 2,4-D amine salt 6 kg/ha could control weed growth for 7 to 9 months. This promising herbicide mixture gave better results when sprayed in the late wet season — *i.e.*, before the milling season. More trials have been carried out in several sugar estates this year using bromacil herbicide in combination with others, in an attempt to obtain more effective mixtures (Kuntohartono and Tarmani, 1967).

FIELD APPLICATIONS OF HERBICIDES

All the herbicides mentioned above are dissolved in irrigation water at 400 and 600 l/ha in cane field and railroad trials, respectively. Usually a pneumatic knapsack sprayer is employed.

In cane fields and cane nurseries, one spray-man using this sprayer with a teejet nozzle 8004, can cover 0.3 to 0.4 ha a day. When spraying in cane fields already planted, a spray-man must walk slowly in the plant furrows and avoid treading on the young emerging cane shoots. Some difficulties in spraying have been met at the late post-planting application, because it is not possible to walk on the thin and high soil piles of the ridges.

For spraying the soil before ditches and furrows are dug, a portable power pump, connected with a boom spray 8.5 m long with 12 nozzles of Lyunet 1.6/3.4 by a 12 m rubber hose was tried out at Sumberhardjo sugar estate (Ruinard, 1960). This apparatus, operated by three men, could spray 2.5 to 3.0 ha per day.

During railroad application trials at Sumberhardjo, a small lorry pulled by a small steam locomotive was used. The lorry was supplied with a spray boom which consisted of 6 nozzles, a small air compressor for pressure, and a herbicide solution tank of 3000 litres capacity. Using this apparatus, 25 km (= 5 ha of railroad) could be sprayed in a day (Duyverman, 1957).

Further field application trials to increase the spraying capacity of the spray-men have not been carried out. Trials are now concentrated on designing the lance and placement of nozzles to avoid excessive spray contact with the cane.

CULTURAL PRACTICE PROBLEMS IN RELATION TO HERBICIDE USAGE

The use of herbicides in cane fields to replace hand-weeding has not so far been recommended, because recent data show it evidently affects sugarcane and reduces its yield. This occurred mainly after the late post-planting application, and was also the experience of previous workers (Duyverman, 1957).

Apparently, cultural practices and conditions in Java influence the susceptibility of sugarcane to herbicides. The following are some specific cultural conditions and practices that probably affect the selectivity of the herbicides used.

Kind of seed cane and planting method: Plant material of sprouting seed cane (rayungan) is planted vertically or at an angle with the soil surface. Only that part of the cane internode just below the sprouted bud is buried at 3 to 5 cm depth. A week after planting, the cane seedlings are entering the "root transition stage" (Rochecouste, 1967). The shoot roots grow and are concentrated beneath the soil surface for several weeks afterwards, while the sprouting buds usually have 4 or 5 unrolled leaves at planting. Trial results proved that sugarcane seedlings older than one week are susceptible to leaf and soil acting herbicides.

Spraying difficulties without touching the cane leaves: Sugarcane is planted in narrow and deep furrows. Cane furrows in Java generally measure 40 cm wide × 25 to 30 cm deep × 500 to 1000 cm long. Weeds usually grow at the bottom and on the sides of the furrows, and on the lower half of the ridges between the furrows. It is very difficult to spray the weed foliage without touching the cane foliage, using the usual lance and single nozzle. Attempts to design a directed spray lance and to find a highly selective herbicide are badly needed.

Tillering stage coinciding with the late post-planting application: Part of the tillering stage of the cane varieties coincides with the late post-planting application. Young cane tillers are usually exposed to herbicide application 6 to 15 weeks after planting. A relatively high dosage of the herbicide can be lethal to young emerging cane tillers.

Herbicide concentration around the cane stools: In some areas, intensive soil cultivation and filling in of the furrows are carried out during the first half of the tillering stage. Some herbicide applications, followed by such cultivation, can increase phytotoxic effects, because the herbicide-containing soil after the filling-in becomes concentrated around the cane stools. Factors such as these, not yet understood, are believed to be responsible for the incidence of various phytotoxic effects observed in the field.

As a consequence, herbicides must be used at sufficiently low dosages to prevent cane injury, or other new herbicides must be found which are more selective than those tried so far. Experimental work is continuing to achieve these objectives.

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DEVELOPMENT OF WEED CONTROL IN HAWAIIAN SUGARCANE FIELDS

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BRIEF HISTORY

Sugarcane was apparently brought to the Hawaii Islands by the early settlers. When Captain Cook discovered the islands in 1778, he noted "several plantations of sugarcane" growing. It was not a commercial crop until some time later. After several attempts, the first permanent plantation was established on the island of Kauai in 1837. From this small beginning the Hawaii sugar industry developed rapidly through mechanical improvements and the use of modern technology.

LABOUR NEEDS

As the industry grew, the need for farm labour grew. Since there were not enough local polynesians to fill their needs, the sugar plantations started importing labour, first some Chinese from Hong Kong in 1852. Japanese immigration started in 1868, Portuguese labourers first arrived in 1878, and German immigration followed them in 1881. With utilization of new and improved techniques, more land, previously considered worthless, came under cultivation after the turn of the century. In 1906, Filipino labourers were introduced.

UNIONIZATION OF WORKERS

To improve their working conditions and secure increased pay, the sugarcane workers found it advantageous to join a labour union. Through the efforts of this organization, the sugar workers have become the highest paid in any sugar-growing area. In 1969, the average daily wage of non-supervisory employees in the Hawaiian sugar industry was $23.26, with fringe benefits which include medical care, paid vacations and holidays, pensions and insurance, valued at another $8.74 a day, or a total of $32.00.

The sugar companies, in order to survive in the face of increasing labour costs, were forced to search out ways of economy by way of mechanization and chemical power to reduce manpower.

EXPERIMENT STATION

The Hawaiian Sugar Planters' Association was established in 1895, replacing the Planters' Labor and Supply Company which had been in existence since 1882.

The Association is a non-profit, agricultural organization of sugar companies and individuals united for the purpose of maintenance, advancement and protection of the sugar industry in Hawaii, the support of a scientific experiment station, and the development of agriculture in general.

Major achievements of the Hawaiian sugar industry can be attributed to the excellent work being done by this organization.

SUGAR PRODUCTION

The development of mechanical improvements, more efficient methods of fertilization, weed control, irrigation and water use, harvesting, transporting and milling of cane, have all contributed to the Hawaii plantations producing bigger yields on smaller acreages than anywhere else in the world.

The sugar acreage harvested in Hawaii produced an average yield of 240 tonnes of cane per hectare in 1969. Because cane is a two-year crop in Hawaii, halving this gives a comparison of 120 tonnes per hectare with the 64 tonnes average in Louisiana, the 72 tonnes yield for Florida, and the 69 tonne yield for Puerto Rico.

The industry average is nearly 27 tonnes of sugar per hectare with some areas producing as high as 37 tonnes per hectare.

CHEMICAL WEED CONTROL

With rising costs of manpower, the plantations have turned to chemicals for control of weeds during the first 4 to 6 months, or until the cane "closes in". Sodium arsenite was first used in 1913 and was the primary herbicide used until 1944. Sodium chlorate was tried, but proved too much of a fire hazard. In 1938, Dr E. E. Hance developed a series of oil-water emulsions plus sodium pentachlorphenate. This proved to be so effective for directed spraying that the sugar plantations built large mixing plants to prepare the CADE, as it was called, for the spray gangs. In 1945, 2,4-D entered the picture, monuron in 1951 and diuron in 1953.

Because of inherent qualities, each herbicide is weak against certain weed species. The arsensics and 2,4-D were excellent against broadleaves, but failed to control grasses. TCA became available in 1948 to help fight the grass problem. Dalapon, a more effective grass killer than TCA, came into general use in 1953. Atrazine entered the field in 1961 and proved selectively safe to the sugarcane, plus giving excellent control of broadleaves that were escaping from other treatments. With expanding use of atrazine, it soon became apparent that this product also had its weakness in not giving adequate control of crabgrasses, *Digitaria* species. Ametryn was introduced in 1964 and has proven excellent for contact and residual control of many broadleaved and grass weeds including crabgrass. The most recent registration was terbacil in 1968.

Atrazine remains the safest and preferred residual herbicide for broadleaf control. Ametryn is added for grass control in the irrigated or drier areas. Diuron continues to give longer residual control of weeds, especially grasses, in the wet areas or non-irrigated fields. When approved by federal agencies, it is planned to market GS 14254 ("Sumitol") for pre-emergence control of grass and other weeds in non-irrigated fields. Many tests have shown this product to be superior to ametryn and diuron for pre-emergence grass and broadleaf control in the wet areas.

MODES OF ACTION

Triazines, substituted ureas and uracils such as ametryn, diuron and terbacil enter plants through both roots and foliar tissue and are translocated upward in the xylem tissue. Upon entering the leaves, these compounds exert a toxic effect by blocking one or more of the oxidative reductions in photosynthesis and thus inhibit the fixation of carbon dioxide and liberation of oxygen.

Phenoxy acids, such as 2,4-D, fenoprop and 2,3,5-T, are absorbed by roots and foliar tissue and, apparently, modified by a number of biochemical processes involving interactions with enzyme systems. Lethal action may be shown as cell proliferation, respiratory inhibition, or formation of toxic material.

Halogenated aliphatic acids, such as dalapon and TCA, are absorbed by foliage and roots and are translocated both in the phloem and xylem tissue. They remain unchanged in plants for weeds and exert a chronic inhibitory effect on grass shoots. Dalapon was found to degrade proteins to amino acids in both susceptible and resistant species. Selectivity of dalapon may be due to the ability of tolerant plants to detoxify some breakdown products of proteins such as ammonia.

Bipyridylium quarternary salts, such as paraquat and diquat, are absorbed by leaves and stems and exert a direct contact effect on plant foliage within a few minutes after exposure. Toxic action is exerted through the production of peroxide free radicals which degrade proteins in the cell protoplasm.

Herbicide Selectivity

Herbicides are plant killers and can only be used in certain crops that show some degree of tolerance to them. Sugarcane proved tolerant to the arsenicals, but these compounds were banned owing to heavy build-up of arsenic in the soil. 2,4-D, while an excellent compound for broadleaf control, does not control grasses. Diuron proved to be a good residual herbicide but was weak against fireweed (*Erechtites hieracifolia*) and Flora's paintbrush (*Emilia sonchifolia*). Atrazine effectively controlled fireweed and Flora's paintbrush, but failed to control the *Digitaria* species. Ageratum (*Ageratum conyzoides*) survives in sugarcane fields treated pre-emergence with ametryn.

Each herbicide has its strong and weak points. The sugar plantation weed men select the compounds to fit the conditions of a given area, such as weed species to be controlled, soil conditions, and sugarcane variety. Dalapon, an excellent post-emergence grass killer, is used selectively to kill grasses in sugarcane fields, but must be carefully applied to keep the spray off the cane, especially the growing tips.

Hawaiian top soil will normally tie up 80%, or more, of the diuron, allowing its use without injury to the cane. However, if the field is ploughed and subsoil is brought to the surface, the plantations have found diuron is not sufficiently deactivated by this subsoil and the cane is injured. Atrazine can be safely used in these newly ploughed fields. Sugarcane is able to take ametryn in through the roots and de-toxify it (true selectivity) when it is applied to the soil around the cane. This is also true for diuron and atrazine. If ametryn is applied to the foliage of sugarcane, certain varieties, such as 53-263 (Hawaiian), 57-5174 (Hawaiian) or P.R. 1048 (Puerto Rican) will show a temporary chlorosis on the older leaves. This is much more pronounced if ametryn is applied over sensitive varieties during water stress conditions.

Sugarcane is much more tolerant to applications of atrazine. Sugarcane, like corn, is able to metabolize atrazine quite rapidly and it is the safest herbicide now registered for weed control in sugarcane. Rates as high as 13.44 kg/ha, as a pre-emergence application, have proven safe and highly effective in controlling weeds, including many grass species and the difficult to control Aiea morning glory (*Ipomoea triloba*). Sugarcane will tolerate these rates of atrazine when it is applied over the cane.

Field Use of Herbicides

With increasing costs of manpower and the difficulty of getting labourers to carry back-pack sprayers, the sugar plantations are turning more and more to spray rigs and aircraft or helicopters for their weed control application. Ground spray rigs can only be used in non-irrigated fields. Irrigation flumes prohibit their use in irrigated fields.

Residual herbicides, such as diuron, atrazine, ametryn and terbacil, are standards for comparing any new candidate herbicide for weed control in Hawaiian sugarcane fields. These products are used singly or in combination, depending on field conditions, for residual control of broadleaves and grasses. Contact or systemic materials, such as 2,4-D, dalapon and/or TCA may be added where needed. Surfactants (surface-active agents) may be added to the spray mix to aid in spreading the herbicides over the weeds to be killed.

Sugarcane is grown on 97,000 ha with plantations on four of the islands, employing 11,000 people. Of these, approximately 400 have the responsibility of weed control, or one man for each 240 ha of sugarcane — quite a saving in manpower.

Herbicides and Rates Used

The residual herbicides, ametryn, atrazine or diuron, are applied at the rate of 4.48 kg/ha pre-emergence and again post-emergence. Post-emergence applications are normally at a lower rate of a residual compound and may be combined with a contact herbicide. These materials are applied in 80 l of water per hectare if applied by airplane or in 340 to 570 l/ha if applied by ground rig or back-pack sprayed. One to three post-emergence applications are made, depending on field conditions and degree of weed control obtained until the cane "closes in". Terbacil is normally applied at 1.12 kg/ha and in combination with ametryn, atrazine or diuron. Dalapon is used at 2.24 to 5.60 kg/ha and 2,4-D is applied at 2.24 kg/ha, provided there are no susceptible crops or home gardens near by.

Sugarcane weed control is rated "out of control" and in need of another herbicide application when the field is more than 20% re-infested with weeds. The interval between sprays may vary from a few to 8 weeks or more depending on soil, weather, weed populations and herbicides used.

COMPARISON BETWEEN 2,4-D SODIUM AND DIMETHYL AMINE SALTS FOR WEED CONTROL IN SUGARCANE

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Summary

Sodium and dimethyl amine salt formulations of 2,4-D were compared for their efficacy of weed control and effects on sugarcane. Each formulation was used either alone at 4.8 kg/ha or in mixture (at 0.8, 1.6 and 3.2 kg/ha) with 1.6 kg/ha of diuron or atrazine. Two crops of sugarcane planted in spring and autumn were treated pre-emergence and post-emergence. Since the weed population in the two crops was entirely of gramineous species (*Digitaria sanguinalis, Dactylotanium aegyptiacum,* and *Cynodon dactylon*), the post-emergence applications had little effect, resulting in significant reduction of the growth and yield of sugarcane by competition from re-emerged weeds. Pre-emergence application achieved fairly good control and caused no adverse effect to cane plants. The mixtures resulted in higher yields of sugarcane than 2,4-D used alone. No significant difference was observed between the two forms of 2,4-D as sole herbicide, because of the dominant gramineous weeds. In mixture with either diuron or atrazine used pre-emergence, weed control with the sodium form of 2,4-D was approximately twice as efficient as the dimethyl amine form. The synergistic activity of the herbicidal combination in pre-emergence application is shown by almost the same degree of weed control obtained with both atrazine 3.2 kg/ha used alone and 2,4-D plus atrazine each at 1.6 kg/ha. The cost of the latter is much less than the former, however.

INTRODUCTION

The sodium salt of 2,4-D, a water-soluble powder containing 80% active ingredient, has been the herbicide most widely used in sugarcane in Taiwan, not only alone but also in mixture with soil sterilants such as the substituted ureas or triazines used for pre-emergence weed control in cane. The mixtures were found to have longer residual activity and to control a wider spectrum of weed species. More important, the cost of treatment could be reduced by replacing some of the high-priced soil sterilants with the cheaper 2,4-D sodium to obtain the same (sometimes higher) efficacy of weed control.

In horticultural crops the sodium salt of 2,4-D has been largely replaced by the more effective amine or ester forms. In a plantation crop such as sugarcane that requires a fairly long growing

season and wider planting space, weed response may not be the same as in a short-season horticultural crop. Experiments were therefore conducted to compare dimethylamine and sodium salts of 2,4-D for efficacy of weed control and possible effect on sugarcane.

MATERIALS AND METHODS

Two sugarcane crops planted in the dry and cool month of April, 1968 (spring-planting cane) and in the wet and warmer September of the same year (autumn-planting cane) were tested with the herbicides. The liquid form containing 35.1% dimethyl amine salt of 2,4-D and the water-soluble powder wih 80% sodium salt of 2,4-D were used either solely or as components wih diuron or atrazine (80% and 50% wettable powder, respectively) in mixtures. They were sprayed broadcast pre-emergence or overall post-emergence. The field layout was a randomized complete block design for each cane variety and each herbicidal treatment was replicated four times.

RESULTS AND DISCUSSION

EFFICACY OF WEED CONTROL

After spraying herbicides, weed regrowth in plots was rated at various intervals using a scale of 0 to 10 (0 = totally clean plots, 10 = full weed cover). Harvested weights of weeds according to species were also recorded prior to breaking field ridges (for banking up the cane rows later to facilitate drainage during the rainy season). The results of weed control in the two crops of sugarcane are given in Tables 1 and 2.

As the weed populations of the two crops consisted mostly of gramineous species, both salts of 2,4-D were significantly more effective when used pre-emergence than post-emergence. Both forms of 2,4-D sprayed pre-emergence gave more than one month of fairly good control at the rate of 4.8 kg/ha which was three times higher than general field practice. Emerged weeds were little affected when treatment was about 3 weeks after planting cane, even at the same high rate of 4.8 kg/ha.

The amine salt gave slightly better control of germinating weed seeds perhaps because of its complete water solubility (Klingman, 1963); also there was no loss through leaching because of the prevailing dry season after spraying. The amine salt applied post-emergence was also more effective than the sodium salt in controlling the broadleaved species as evidenced by the later

TABLE 1. WEED CONTROL EFFICACY OF THE SODIUM AND DIMETHYL AMINE SALTS OF 2,4-D APPLIED TO A SPRING-PLANTED CANE (VARIETY F156), 1968-9

(Cane planted 4 April, 1968. Pre- and post-emergence applications of herbicides 6 April and 23 April, 1968)

Treatment (kg/ha)	Pre- or Post-Emergence	Date Weed Cover Observed* 4 Apr.	30 Apr.	6 May	14 May	24 May	5 Jun.	Weeds Harvested (5 Jun.) (kg/plot)	(%)
1. 2,4-D amine 4.8	pre	0	0.3	0.5	1.6	2.9	7.3	26.9	35.0
2. 2,4-D amine 4.8	post	0.5	5.1	5.6	7.4	8.6	10.0	62.9	81.9
3. 2,4-D Na 4.8	pre	0.1	1.0	1.0	3.2	5.0	9.4	39.0	50.8
4. 2,4-D Na 4.8	post	0.6	5.9	6.4	7.8	8.7	10.0	59.6	77.6
5. diuron 1.6/2,4-D amine 3.2	pre	0	0.4	0.4	1.0	2.0	4.5	13.2	17.2
6. diuron 1.6/2,4-D amine 1.6	pre	0	0.6	0.6	2.1	3.9	7.6	35.1	45.7
7. diuron 1.6/2,4-D amine 0.8	pre	0	0.7	0.7	2.5	4.0	7.8	43.2	56.3
8. diuron 1.6/2,4-D amine 1.6	post	0.5	7.1	7.9	7.8	9.2	10.0	77.3	100.7
9. diuron 1.6/2,4-D Na 1.6	pre	0	0.6	0.6	2.1	3.1	7.0	26.4	34.4
10. diuron 1.6/2,4-D Na 1.6	post	0.3	4.6	6.1	7.8	8.6	9.6	66.5	86.6
11. atrazine 1.6/2,4-D amine 3.2	pre	0	0.4	0.4	1.3	2.2	6.9	23.9	31.1
12. atrazine 1.6/2,4-D amine 1.6	pre	0	0.7	0.7	2.3	3.6	9.0	56.5	73.6
13. atrazine 1.6/2,4-D amine 0.8	pre	0	0.8	0.8	3.3	4.1	8.5	41.9	54.6
14. atrazine 1.6/2,4-D amine 1.6	post	0.4	5.6	5.9	8.4	8.9	10.0	57.9	75.4
15. atrazine 1.6/2,4-D Na 1.6	pre	0	0.7	0.7	2.3	3.3	8.1	31.5	41.0
16. atrazine 1.6/2,4-D Na 1.6	post	0.5	6.7	7.4	7.9	9.0	10.0	65.0	84.6
Hand-weeding		0.4	6.9	7.9	8.4	9.6	10.0	76.8	100.0
F test								2.70**	
LSD (0.05)								23.03	
(0.01)								30.76	

*Weed species re-emerged: *Digitaria sanguinalis* (90%), *Lactyloctenium aegyptiacum* (6%), *Amaranthus viridis* (1%), *Amaranthus spinosus* (1%), *Eleusine indica*, *Portulaca oleracea*, etc Most of the broadleaved species appeared in the check plots.

appearance of such weeds only in the pre-emergence and hand-weeded plots. The complete solubility of the amine form allowing more of 2,4-D to be absorbed by the broadleaves could be the reason. The mixtures showed far better results than 2,4-D used alone.

Pre-emergence treatments of both salts of 2,4-D in mixture with diuron or atrazine were markedly superior to the post-emergence applications, indicating tolerance of the gramineous species to herbicides sprayed after they had begun to establish. However, in mixture with 1.6 kg/ha of diuron or atrazine 3.2 kg/ha of the amine salt was needed to obtain the same degree of control as 1.6 kg/ha of the sodium salt. In other words, the sodium mixture was about twice as effective as the amine mixture. Possibly there is some antagonistic activity between the mixture components that deserves further investigation.

It can be concluded that selection of the amine or sodium form of 2,4-D should be based upon the weed species to be controlled. When the weed population consists mostly of gramineous species, both salts are equally effective for pre-emergence treatment. When broadleaved species are dominant, however, the amine form should be preferred and used as a post-emergence spray. When mixtures are used, those containing the sodium salt of 2,4-D should be used pre-emergence for reliable results. It can be seen from Table 2 the pre-emergence treatments of atrazine alone at 3.2 kg/ha and atrazine plus 2,4-D (sodium or amine) achieved almost the same weed control results. This further indicates the synergistic activity between the two herbicides demonstrated by Peng (1966).

EFFECTS OF HERBICIDES ON THE GROWTH AND YIELD OF SUGARCANE

Periodic measurements of cane growth[1] and final yields in cane and sugar for both crops were used to assess the effects of herbicides on cane plants. The yields in cane and sugar following different treatments on the two crops are summarized in Tables 3 and 4.

All the post-emergence treatments resulted in significant reduction of cane growth (both in length and tillering) owing to poor control of weeds and possible toxicity to cane seedlings. The growth reduction was not recovered in the spring-planted crop which had a growing season of only 12 months and statistically significant reduction in yield resulted. In the autumn-planted

TABLE 2: WEED CONTROL EFFICACY OF THE SODIUM AND DIMETHYL AMINE SALTS OF 2,4-D APPLIED TO AUTUMN-PLANTED CANE (VARIETIES N:Co 310 AND F 156), 1969-70

(Cane planted 9 September, 1968. Pre- and post-emergence applications 14 September and 27 September, 1968)

Variety and Treatment (kg/ha)	Pre- or Post Emergence	Date Weed Cover Observed* 3-22 Sep.	1 Oct.	23 Oct.	13 Nov.
N:Co 310:					
1. 2,4-D amine 4.8	pre	1.3	1.9	6.4	7.0
2. 2,4-D Na 4.8	pre	2.6	4.1	6.8	7.4
3. 2,4-D amine 4.8	post	7.5	8.2	8.9	9.1
4. 2,4-D Na 4.8	post	5.6	7.0	8.1	8.4
5. atrazine 1.6/2,4-D amine 1.6	pre	0.8	1.3	3.6	4.1
6. atrazine 1.6/2,4-D Na 1.6	pre	1.2	1.5	4.1	4.8
7. atrazine 3.2	pre	1.6	2.1	4.8	5.1
Hand-weeding		2.1	8.4	9.5	10.0
F 156:					
1. 2,4-D amine 4.8	pre	0.9	1.2	5.6	6.1
2. 2,4-D Na 4.8	pre	1.3	1.7	6.2	7.0
3. 2,4-D amine 4.8	post	4.9	5.9	8.1	8.1
4. 2,4-D Na 4.8	post	5.6	6.5	8.0	8.8
5. atrazine 1.6/2,4-D amine 1.6	pre	1.3	1.6	5.4	6.5
6. atrazine 1.6/2,4-D Na 1.6	pre	0.9	1.1	4.6	5.1
7. atrazine 3.2	pre	1.7	2.1	4.6	5.5
Hand-weeding	pre	5.0	2.0	9.4	10.0

*Re-emerged weed species as noted in Table 1.

TABLE 3: YIELDS OF SUGARCANE (VARIETY F 156) OF SPRING-PLANTED CROP TREATED BY HERBICIDES, 1968-69

Treatment No.*	Yields (t/ha) Cane	Sugar
1	37.68	5.23
2	29.57	3.92
3	36.78	4.83
4	33.52	4.47
5	39.49	5.38
6	35.25	4.95
7	34.27	4.23
8	26.63	3.52
9	39.84	5.45
10	27.12	3.49
11	39.89	5.49
12	38.76	5.19
13	36.24	4.89
14	25.62	3.29
15	36.46	4.95
16	30.37	4.04
Hand-weeding	26.62	3.45
F test	2.66**	3.03**
LSD (0.05)	1.74	0.31
(0.06)	2.32	0.42

*See Table 1.

TABLE 4: YIELDS OF SUGARCANE (VARIETIES N:Co 310 AND F 156) OF AUTUMN-PLANTED CROP TREATED BY HERBICIDES, 1969-70

Variety and Treatment No.*	Yields (t/ha) Cane	Sugar
F 156:		
1	127.80	12.74
2	125.10	12.45
3	102.40	12.11
4	110.95	11.49
5	121.48	13.05
6	119.66	11.23
7	124.20	12.20
Hand-weeding	114.15	13.21
N:Co 310:		
1	112.50	14.34
2	113.04	13.90
3	107.64	11.58
4	103.54	12.15
5	115.34	14.14
6	103.23	12.98
7	111.08	13.78
Hand-weeding	113.48	12.20

*See Table 1. *F* test for both varieties is non-significant.

crop, the growth reduction lasted for about 8 months and all plants resumed normal growing when temperature and rainfall began to increase in May through August (rainy season) of the second year. The yield in cane and sugar measured at harvest after about 15 months of cane growing did not show any significant difference between the different treatments as shown in Table 4.

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WEED CONTROL IN GROUNDNUTS, SOYA BEANS AND MAIZE

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INTRODUCTION

Adequate weed control can mean the difference between the success and failure of a crop where weed growth is rapid and vigorous. For instance, soya beans were found to suffer a crop reduction of 60% owing to weed competition (Ellery and Slife, 1968). The degree of competition would, of course, vary with the species of weeds occurring.

In West Malaya, earlier investigations into the cultivation of annuals and biennials as catch crops in rubber showed that hand-weeding constitutes a considerable proportion of the costs of production (Chandapillai and Yeow, 1969; Pushparajah and Wang, 1969; Tan and Templeton, 1969). Many workers have found that some herbicides could successfully control weeds in some short-term crops (Watson, 1969; Wong, 1969). In this way a large amount of time and labour required for hand-weeding could be saved.

The object of the present investigation was first to find out the period of time after sowing within which groundnuts, soya beans and maize were most susceptible to weed competition. This would indicate the minimum period of control that any herbicide should render in order to be implemented successfully. A large range of chemicals is available for use in various crops, but, as their activities in the temperate zones are unlikely to be identical in the tropics, testing under local conditions must be carried out. The selection of these chemicals for testing was based on their availability, either in test quantities or on a commercial scale locally. Their effectiveness in controlling weeds and the tolerance of the crops to them were observed.

METHOD

The experiment was located on a sandy loam soil (colluvium of Serdang series soil) which had previously been used for vegetable cultivation and then left vacant for a few years. The soil data are given in Table 1. The weeds present in the area were observed to be reasonably uniform. The land was ploughed once

TABLE 1: SOIL DATA

	Expressed on Oven-dry Soil						
	Depth (cm)	*Coarse Sand (%)*	*Fine Sand (%)*	*Silt (%)*	*Clay (%)*	*pH*	*C Org. (%)*
Maize plots	0-15	22.5	59.2	5.2	7.4	6.1	1.40
	15-30	22.0	59.1	8.8	7.2	5.7	1.25
Groundnut plots	0-15	23.0	59.9	7.9	6.0	6.0	1.48
	15-30	25.4	58.2	8.3	5.8	5.6	1.13
Soya bean plots	0-15	33.7	48.3	8.8	6.0	5.9	1.43
	15-30	36.2	46.4	8.4	6.4	5.4	1.33

TABLE 2: HERBICIDES AND APPLICATION RATES (a.i.)

chloramben at 2.4 and 3 kg/ha
atrazine at 1 and 2 kg/ha
Bas 2901 H at 2.5 and 4 kg/ha
"Dynap" at 8.4 and 11.2 l/ha
alachlor at 0.9 and 1.5 kg/ha
alachlor 1/atrazine 1 kg/ha
alachlor 1.5/atrazine 1 kg/ha
alachlor 1/linuron 1 kg/ha
nitralin at 0.75 and 1 kg/ha
simazine at 1 and 2 kg/ha
disul at 2.25 and 3.15 kg/ha
methabenzthiazuron at 1.4 and 2.1 kg/ha
Hand-weeded the whole season.
No weeding

TABLE 3: OPERATIONAL DETAILS

	Groundnuts	*Soya Beans*	*Maize*
Variety	Menglembu (inoculated with Rhyzobium red)	NK 3 (inoculated with R. green)	Metro
Plot size	20 m² (4.4 × 4.5 m)	20 m² (4.4 × 4.5 m)	20 m² (4.4 × 4.5 m)
Planting distance	33 × 36 cm 13 rows of 37 points	66 × 10 cm 7 rows of 42 points	66 × 30 cm 7 rows of 14 points
Seeds per point	1	3	2
Block	4	4	4
Date of planting	7-8/10/69	13-14/10/69	6/10/69
Date of spraying	9/10/69	15/10/69	7/10/69
Spray volume	500 l/ha	500 l/ha	500 l/ha
Dates of weed observation (a)	6/11/69	6/11/69	6/11/69
(b)	26/1/70	26/1/70	26/1/70

and then harrowed ten days later. During harrowing magnesium limestone at the rate of 1700 kg/ha and double superphosphate at the rate of 220 kg/ha were incorporated. A fortnight later, a second harrowing was done and a basal application of 110 kg/ha of ammonium sulphate was incorporated. In the maize plots, a further 220 kg/ha ammonium sulphate was broadcast at 4 weeks after planting.

Plots of 20 m² with 40 cm wide inter-row space between the plots were marked out. The trials on groundnuts, soya beans and maize were of a randomized block design with 4 replicates per treatment. The herbicidal applications were made at 500 l/ha solution by a fanjet nozzle from a knapsack sprayer as soon as possible after planting. The chemicals and rates applied are given in Table 2, and some operational details are presented in Table 3. The necessary pest control measures against insects and snails were carried out. Thinning out at the third week was done where more than one seed per point had been planted.

The trial also included progressive rounds of hand-weeding at intervals of two weeks from planting. A treatment without any weeding after planting and one with continuous hand-weeding for the entire growing season were used as controls.

Observations of weed density were made at 4 weeks after planting and at harvest when crop yields were recorded.

RESULTS

Table 4 shows the weeds that were present before the cultivation of the land and also those that regenerated during the growth of the crops in the unweeded plots. The major regeneration consisted of grass weeds, mainly *Eleusine indica* and some *Digitaria longiflora:* broadleaved weeds, mainly *Borreria latifolia,* and some *Croton hirtus;* and *Cyperus* species.

GROUNDNUTS

The unweeded control gave the poorest yield. Weeding at two and four weeks after sowing was the best treatment, increasing the yield by 173% over the control. However, no significant yield differences were observed between the different rounds of hand weeding, even though the weed densities at harvest varied considerably from treatment to treatment.

All chemical treatments resulted in better yields than the unweeded control. Highest yield was found in the hand-weeded treatment. Weed regeneration was very rapid and, at harvest,

TABLE 4: CHANGES IN DISTRIBUTION OF WEEDS ON CULTIVATION OF SOIL

	Prior to Cultivation	*4 wk after Planting*	*12 wk after Cultivation*
Eleusine indica	2	23	49
Axonopus compressus	1	—	—
Paspalum conjugatum	7	—	—
Digitaria longiflora	2	6	7
Digitaria sanguinalis	2	—	—
Tricholena rosea	1	—	—
Imperata cylindrica	9	—	—
Cyperus spp.	5	18	12
Borreria latifolia	28	15	13
Mikania cordata	14	—	—
Croton hirtus	1	3	6
Ageratum conyzoides	2	—	1
Stachytarpheta indica	6	—	—
Others	14	—	—

most of the plots had high weed densities. Of the chemicals tested, "Dynap", chloramben, alachlor/linuron and nitralin seemed to be promising.

Soya Beans

The unweeded control gave the lowest yield compared with the other hand-weeded treatments. The highest yield was obtained by hand-weeding throughout the growing season which increased the yield by 92% compared with the unweeded control. No statistical differences were observed between all the treatments with hand-weeding subsequent to sowing. Weed regeneration was not so rapid after a weeding round at two weeks after sowing and, in these plots, they appeared only after one month from sowing.

On comparison with the yields of the chemical treatments, hand-weeding resulted in the highest yield. Differences between the yields from hand-weeding and treatments with several herbicides, however, were not statistically significant. Weed regeneration was rapid after treatment with chemicals and at harvest 75 to 95% weed cover was observed. Treatments where more weeds were observed at one month after sowing tended to give lower yields. Among the more promising chemicals were chloramben, "Dynap", alachlor, alachlor/linuron and methabenzthiazuron. Disul seemed to affect the yield adversely.

Maize

Weeding at two and four weeks after sowing resulted in the highest yield, giving an increase of 28% over the unweeded control. All weeded treatments were superior in yield to the unweeded control. Weed regeneration was very rapid in all cases.

All the chemical treatments resulted in better yields than the unweeded control.

It must be noted that the variations within treatments in the maize plots were very great, and no statistical analysis could be carried out for the yield data. The general tendencies observed, however, followed that in groundnuts and soya beans.

EFFECTIVENESS OF HERBICIDES

The effectiveness of the various herbicides used in controlling the three groups of weeds are summarized in Table 5.

TABLE 5: EFFECTIVENESS OF HERBICIDES

	At 4 wk			*At Harvest*		
	Grass	*Cyperus*	*Broad-leaf*	*Grass*	*Cyperus*	*Broad-leaf*
alachlor	++	++	—	+	+	—
methabenzthiazuron	++	+	++	+	—	—
"Dynap"	++	++	+	+	++	—
nitralin	++	—	—	+	—	—
disul	+	+	+	+	+	—
chloramben	++	+	+	+	+	—
alachlor/linuron	++	++	+	++	++	—
simazine	++	+	++	+	—	—
atrazine	++	++	++	—	—	+
alachlor/atrazine	++	++	++	+	—	—
Bas 2901 H	++	++	+	+	—	—

— no effect
+ partial control
++ good control

CONCLUSIONS

From the results, it appears that, if a weed-free condition can be maintained for about a month, whether by mechanical or chemical means, subsequent weed regeneration does not have much effect on the yield of groundnuts, soya beans and maize. A number of chemicals tested were effective in controlling weeds and increasing yields.

ACKNOWLEDGEMENT

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HERBICIDES FOR THE CONTROL OF GRASSES IN MAIZE IN NEW ZEALAND

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Summary

Atrazine and cyprazine were investigated alone and in combination with propachlor and chloramben for the control of grass and broadleaf weeds in maize grown on two soil types in the North Island of New Zealand. For post-emergence weed control, 1.12 to 2.24 kg/ha of cyprazine alone was equivalent in effectiveness to 2.24 to 4.48 kg of atrazine, although the effectiveness of atrazine was enhanced by formulating in emulsifiable oil. The ability of both chemicals to control grass weeds, particularly in soils with high organic matter, was increased with the addition of 4.48 kg/ha of propachlor or 4.48 kg/ha of chloramben. This is believed to be due to the pre-emergent activity of these additive herbicides. The trials demonstrated the need to apply chemicals at a very early stage of weed seedling development.

INTRODUCTION

The central North Island regions of New Zealand, namely, South Auckland, Waikato and Bay of Plenty, are ideally suited to maize growing, enjoying, as they do, sunny summers, moderate day temperatures, cool nights, regular rainfall and fertile soils. In the past, these regions have been used primarily for dairying or fat lamb production.

Recently, however, because of uncertain markets for New Zealand dairy products, the introduction of dairy beef and the increasing demand for maize for poultry, pigs, corn starch and greenfeed, considerably increased maize acreages in these regions have resulted.

Grain yield of over 490 bushels per hectare were obtained on some farms this year. Unfortunately, weed growth occurs with equally dramatic vigour, causing serious reduction in yield by reducing the plant population, the number of cobs formed and kernels "set" (Cumberland *et al.*, 1970; Mitchell, 1970). In first-year crops, the main weeds are broadleaf — *Amaranthus retroflexus, Polygonum persicaria, Chenopodium album* and *Solanum nigrum* — and these are generally successfully controlled with 1.12 to 2.24 kg of atrazine plus non-ionic surfactant, band applied followed by inter-row cultivation (Cumberland *et al.*, 1970;

Mitchell, 1970; McPhail, 1968). Where grass weeds are present
up to 4.48 kg of atrazine may be used, often with the addition
of a non-phytotoxic oil, without encountering problems from
residues (McPhail, 1968). However, the pre-emergent residual
activity of atrazine is often insufficient to provide adequate control
of grass weeds — particularly on soils high in organic matter
or with a large clod structure (McPhail, 1968; Spycher, 1969).
Consequently, when maize is grown for two or more years con-
secutively on the same area, the grass weeds tolerant to atrazine
can become a serious problem. These species include *Panicum
capillare, Digitaria sanguinalis, Eleusine indica* and *Setaria glauca*
(Spycher, 1969); although their incidence varies according to
the region and soil type (Woon, 1970; Cumberland *et al.*, 1970).
To obtain better control of these weed grasses an additional
selective herbicide with pre-emergent activity is required. Trials
conducted in the 1969-70 season indicated that propachlor and
chloramben exhibited suitable herbicidal activity as well as
acceptable selectivity towards maize (Woon, 1970; Mitchell,
1970). A new triazine — cyprazine (S6115) — also evaluated in
these trials appeared to have greater pre- and post-emergent
activity than atrazine (Woon, 1970). The two trials presented
in this paper evaluated propachlor and chloramben in combina-
tion with atrazine, cyprazine and an emulsifiable formulation of
atrazine in oil for the control of grass and broadleaf weeds in
maize.

MATERIALS AND METHODS

The treatments were applied to 10 m² plots using an Oxford
Precision Sprayer, applying chemical at 207 kPa and 340 l/ha at
5 km/h through seven 730308 teejet nozzles spaced at 38 cm
along the boom. Non-ionic surfactant (0.5%) was used in all
treatments. The treatments were sprayed overall across the rows,
each plot covering 6 rows, 10-12 plants wide (*i.e.*, 90 × 23 cm
planting). Each trial was replicated 3 times and the chemicals
applied at both early and late post-emergence of the weeds. Early
applications were made 10 and 14 days after planting; late appli-
cations 18 and 22 days after planting. Trial 1 was conducted on a
peat loam with 70% organic matter. The soil type in Trial 2 was a
clay loam. Rainfall preceding and following treatment was
recorded.

During the first 2 months following application of the treat-
ments, each trial was rated 3 or 4 times for grass and broadleaf

weed control. At harvest, 6 months after planting, the cobs from
6 plants from each of 5 rows within each plot were collected and
weighed. The cobs were then stripped and the grain yield ex-
pressed in bushels per hectare at 15.5% moisture content. Grain
yields were analysed using Duncan's multiple F and range test
(Duncan, 1955).

TRIAL 1

(Cambridge. Rukuhia peat loam. Planted 23 October 1970.)

Early application (treated 2 November 1970)

Treatments were applied to maize seedlings in active growth
2.5 to 5 cm in height. Weather at the time of application was
warm and humid; 227 mm of rain had fallen in the 2 days prior
to treatment. Broadleaf weeds were in the cotyledon stage and
consisted of *Solanum nigrum* 10%, *Polygonum persicaria* 5%,
Amaranthus retroflexus 5%. Grass weeds showing one true leaf
but not completely emerged were *Panicum capillare* 60%, *Digi-
taria sanguinalis* 10% and *Echinochloa crus-galli* (not emerged).
In the week following treatments 6 mm of rain fell.

Late application (treated 10 November 1970)

The maize when this treatment was applied was 10 to 12.5 cm
in height. Both broadleaf and grass weeds had advanced to the
2- to 3-leaf stage. Eleven days after treatment, 24 mm of rain fell.

TRIAL 2

(Pokeno. Bombay clay loam. Planted 26 October 1970.)

Early application (treated 9 November 1970)

Treatments were applied during fine, warm weather to maize
seedlings 5 to 7.5 cm in height with 2 true leaves. Rainfall 1 week
prior to treatment was 5 mm. Broadleaf weeds possessed 1 to 2
true leaves and consisted of *Amaranthus retroflexus* 15%,
Solanum nigrum 10% and *Polygonum persicaria* 10%. The grass
weeds *Panicum capillare* 50%, *Echinochloa crus-galli* 10% and
Digitaria sanguinalis 5% were just emerging with 1 true leaf. No
rain fell until 12 days after treatment.

TABLE 1: TRIAL 1

The effect of early and late post-emergence application of herbicides on the control of *Panicum capillare, Digitaria sanguinalis* and *Echinochloa crus-galli* in maize

Treatment (kg/ha)	Days after Treatment[1] 17		31		46		67		Yield (bu/ha)		No. of Cobs from 30 Plants	
	Early[2]	Late[3]	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Control	0.4	0.3	0	0.3	0	0	0	0	7 aA	2 aA	14.3 a	6 a
atrazine 2.24	1.2	—	1.1	—	0.2	—	0	—	42 aAB	—	23.0 abc	—
atrazine 4.48	2.2	1.8	1.7	1.4	1.9	0.8	0.1	0.4	39 aAB	32 abAB	23.0 abc	16.3 b
atrazine 2.24/ propachlor 4.48	3.9	2.4	3.3	2.5	2.7	1.7	2.0	0.8	96 bB	42 abAB	28.7 c	23.0 bc
atrazine 2.24/ chloramben 4.48	4.6	2.9	4.2	2.8	3.9	2.7	3.0	1.8	106 bB	69 bB	29.7 c	25.7 c
cyprazine 1.12	2.5	—	1.4	—	0.8	—	0.2	—	37 aAB	—	16.3 ab	—
cyprazine 2.24	3.3	3.6	2.1	2.6	1.4	1.8	0.4	0.8	25 aA	42 abAB	17.7 ab	23.7 bc
cyprazine 1.12 (2.24)/ propachlor 4.48 (4.48)[4]	4.5	4.3	3.7	3.7	3.4	3.0	2.4	1.5	106 bB	72 bB	28.7 c	25.3 bc
cyprazine 1.12 (2.24)/ chloramben 2.24 (4.48)[4]	4.6	4.0	4.0	3.7	3.7	3.3	2.9	2.1	106 bB	64 bAB	29.3 c	24.0 c
atrazine EC 4.48		2.8		1.9		0.8		0.1		17 aAB		19.0 bc
atrazine EC 2.24/ propachlor 4.48		3.9		3.4		2.6		1.0		62 bAB		24.3 bc
atrazine EC 2.24/ chloramben 4.48		4.0		3.5		3.2		1.8		69 bB		26.0 c

[1] Ratings mean of 6 values. Coefficient of variation of yield figures: 38.2%. Grass weed control rating: 0 — no control, 1 — poor, 2 — unacceptable, 3 — marginal, 4 — good, 5 — excellent.
[2] Early application — 10 days after planting.
[3] Late application — 18 days after planting.
[4] Late application rate in parentheses.

Late application (treated 17 November 1970)

The maize by this time was growing very actively in fine sunny conditions and was 12.5 to 17.5 cm in height. The weeds were at the 4- to 6-leaf stage. In the first 4 days following treatment 44 mm of rain fell.

All herbicide treatments in both trials provided excellent broadleaf weed control. The results and discussion are therefore confined to the control of grass weeds.

RESULTS

The results of Trial 1 are shown in Table 1. A dense infestation, primarily of *Panicum capillare,* in this trial resulted in a considerable depression in grain yield in the controls. This was caused by both a reduction in cob numbers and in the weight of grain per cob. Little improvement in weed control was achieved from either of the triazines, atrazine or cyprazine, when used alone. Post-emergent activity of atrazine was increased marginally by formulating in oil (atrazine EC) but there was no resultant increase in yield.

The addition of 4.48 kg of either propachlor or chloramben to atrazine, cyprazine or atrazine EC, significantly increased the control of grass weeds and grain yield. The mixtures not only possessed greater post-emergent activity than the triazines alone, but apparently the propachlor and chloramben also possessed pre-emergent activity. This prevented later germination of, and therefore severe competition from, the weed grasses during the critical vegetative and early reproductive stages of the crop.

There was a distinct improvement in grass weed control by applying the chemicals early, the advantages being more apparent from the mixtures than from the triazines alone. With respect to the cyprazine mixtures, twice the quantity of cyprazine was required for the late application to produce a level of weed control similar to the early application. Yields of grain from the mixtures applied early were considerably higher.

The results from Trial 2 are shown in Table 2. Yields were considerably higher than in Trial 1 and weed infestation was not sufficiently severe to prevent cob formation. Despite this, all treatments produced a significant grain yield increase over control. There was little difference between early and late application of the chemicals in weed control or grain yield, possibly because of the lack of rain following the early application.

TABLE 2: TRIAL 2

The effect of early and late post-emergence application of herbicides on the control of *Panicum capillare* and *Digitaria sanguinalis* in maize

Treatment (kg/ha)	*Days after Treatment*[1] 8		24		39	*Yield (bu/ha)*		*No. of Cobs from 30 Plants Early and Late*
	Early[2]	*Late*[3]	*Early*	*Late*	*Early*	*Early*	*Late*	
Control	0	0	0	0	0	178 a	165 a	30
atrazine 4.48	1.8	1.6	0.8	1.3	0.8	269 bc	264 b	30
atrazine EC 4.48	2.4	3.3	1.8	2.4	1.1	289 bc	281 b	30
atrazine 2.24/propachlor 4.48	3.1	2.1	2.6	0.6	1.8	264 bc	269 b	30
atrazine 2.24/chloramben 4.48	2.6	2.2	2.9	2.1	2.7	262 b	287 bc	30
cyprazine 1.12	2.9	2.3	1.4	1.2	0.8	267 bc	287 b	30
cyprazine 2.24	3.6	3.7	3.3	2.9	2.6	304 c	287 b	30
cyprazine 4.48	4.1	4.7	4.4	4.6	4.2	304 c	284 b	30
cyprazine 2.24/propachlor 4.48	4.4	3.9	4.4	2.8	3.9	279 bc	284 b	30
cyprazine 2.24/chloramben 4.48	4.4	3.9	4.7	4.4	4.2	279 bc	274 b	30

[1] Ratings mean of 6 values. Coefficient of variation of yield figures: 7.85%. Grass weed control rating: 0 — no control, 1 — poor, 2 — unacceptable, 3 — marginal, 4 — good, 5 — excellent.

[2] Early application — 14 days after planting.

[3] Late application — 22 days after planting.

Cyprazine was considerably more active than atrazine in post-emergent weed control although, as in Trial 1, the activity of the latter was enhanced when formulated in oil.

The addition of propachlor was more effective and gave more persistent grass weed control when added to cyprazine than when added to atrazine. Furthermore, mixtures containing chloramben surpassed, in each case, the weed control obtained with the mixtures containing propachlor, particularly in their residual activity.

DISCUSSION

The results from the trials presented confirm the reports of Spycher (1969) of the "relative resistance of deep-rooted rhizomatous grasses and *Panicum* spp. to atrazine"; and the limited improvement in the post-emergent activity of atrazine when applied as an oil formulation. The results also demonstrate the potential usefulness of cyprazine for weed control in maize. This chemical appears equally selective to maize as atrazine (Woon, 1970; Cumberland *et al.*, 1970) but appears to be considerably more herbicidally active. However, on soils high in organic matter (Trial 1) cyprazine did not possess sufficient pre-emergent activity to control grass weeds emerging after treatment.

Propachlor and chloramben both demonstrated sufficient pre-emergent activity to provide, in combination with atrazine or cyprazine, acceptable control of *Digitaria sanguinalis, Panicum capillare* and *Echinochloa crus-galli*. The ideal ratio of triazine : propachlor or chloramben appears to be 1 : 2.

In these trials, particularly Trial 1, there appeared to be significant advantages in applying these chemicals immediately weeds develop their first true leaf. The addition of propachlor or chloramben to provide residual pre-emergent grass weed control reduces the reliance on the triazine herbicides for post-emergent activity, in which role they are frequently effective only when applied to true seedling grasses.

CONCLUSIONS

The new triazine cyprazine appears to be up to twice as active as atrazine when used for controlling weeds in maize, although the post-emergent activity of atrazine may be enhanced by formulating it in oil. Cyprazine appears equally selective to maize as atrazine (Woon, 1970), provides similar control of broadleaf weeds, but provides better control of grass weeds when applied very early post-emergence. Like atrazine, however, its pre-emergent activity appears to be reduced on soils high in organic matter.

The inclusion of propachlor or chloramben to either atrazine or cyprazine, at the ratio of 2 : 1, confers upon the mixtures sufficient post- and pre-emergent properties to enable them to be used to release maize seedlings from the severe grass infestations likely to be encountered when the triazines are used alone. No data are yet available to assess whether cyprazine stimulates maize growth to the extent attributable to atrazine.

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PRONAMIDE

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Summary

Pronamide is a selective herbicide that has demonstrated excellent control of many broadleaf weeds and grasses. Its use in lettuce, alfalfa (lucerne), clover and related small-seeded legumes and in Bermudagrass turf is in initial commercial stages. It is offered primarily as a 50% wettable powder and application rates range from 0.84 to 2.24 kg a.i./ha. Toxicity studies have been conducted on rats, dogs, fish and birds. Such studies show the compound is of moderately low toxicity: LD_{50} to male rats 8,350 mg/kg; dogs > 10,000 mg/kg. In the soil it is eventually cyclized to a compound not herbicidally active and this in turn is hydrolysed to other nonactive compounds.

Pronamide is a new selective herbicide being developed by Rohm and Haas Company, Philadelphia, Pa., and its overseas affiliates under the proprietary name "Kerb". Its chemical nature is illustrated in Fig. 1. Some of the physical properties of the technical grade are: Melting point, 154 to 156° C; vapour pressure, 8.5×10^{-5} Torr. at 25° C; water solubility, 15 ppm at 25° C.

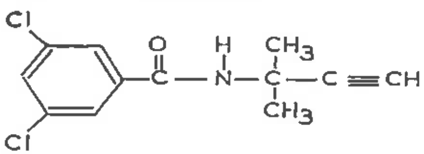

Fig. 1: Chemical structure of pronamide.

Toxicological studies have shown pronamide to be among the least toxic of pesticide chemicals. Its use as proposed should not result in hazards to humans or wildlife. Acute toxicity is as follows:

Acute oral LD_{50} (technical "Kerb"):	
Male rats	8 350 mg/kg
Female rats	5 620 mg/kg
Mongrel dogs	10 000 mg/kg
75% formulation:	
Japanese quail	8 870 mg/kg
Mallard ducks	14 000 mg/kg

LC_{50} (75% formulation):	
Goldfish	350 ppm
Rainbow trout	72 ppm

The product has been offered for evaluation as a 50% wettable powder and in granular formulations.

Pronamide has broad effectiveness against various broadleaf weeds and is especially effective for control of many grasses. It may be applied pre-emergence or post-emergence in various crop situations but most generally it is applied pre-emergence to the weeds. The excellent performance of this herbicide against susceptible weed species has created much interest in its possibilities and early commercialization.

Application of pronamide pre-emergence produces root inhibition of sensitive species and abnormal shoot development. Weeds succumb either before or soon after emergence from the soil. Post-emergence activity is slow. The first symptoms usually are retarded growth and subsequent chlorosis and death. The process generally takes several weeks. The sensitivity of various weeds in pre-emergence application is shown in Table 1.

TABLE 1: SENSITIVITY OF WEEDS TO PRONAMIDE AT RATES OF 1.12 TO 3.36 kg/ha

	S = Sensitive	*R = Resistant*
Amaranthaceae (pigweed)	S	
Caryophyllaceae (chickweeds)	S	
Chenopodiaceae (goosefoot, lambsquarters)	S	
Compositae (thistles, ragweed, groundsel, dandelion)		R
Cruciferae (mustards)	S	
Cyperaceae (sedges)		R
Euphorbiaceae (spurge)	S	
Gramineae:		
Grasses including wild oat, quackgrass	S	
Kikuyu grass, Johnsongrass		R
Labiatae (mint, henbit)	S	
Leguminosae (legumes)		R
Malvaceae (mallow)	S	
Oxalidaceae (woodsorrel)		R
Polygonaceae (buckwheat, smartweed, curly dock)	S	
Solanaceae (nightshade)	S	
Urticaceae (nettles)	S	

Crops tolerant to pronamide when applied pre-emergence at rates up to 2.24 kg/ha are:

Artichoke	Peas
Chicory	Peanuts
Cotton	Romaine
Endive	Safflower
Escarole	Snap Bean
Lentils	Southern Pea
Lettuce	Soybean
Lima Beans	Squash

Crops tolerant to post-emergence applications include those tolerant to pre-emergence use plus the following:

Alfalfa	Stone Fruits
Apples	Strawberries
Blueberries	Sweet Potatoes
Caneberries	Trefoil
Clovers	Vetch
Cranberries	Bermudagrass turf
Grapes	Centipede turf
Lespedeza	St. Augustine turf
Pears	Zoysia turf
Perennial ornamentals	

At present pronamide is in commercial development on Bermudagrass turf, lettuce and alfalfa and related legumes. Its use on these and the various other crops tolerant to it is being investigated in detail in important producing areas throughout the world.

In the soil pronamide eventually undergoes chemical rearrangement to compounds not herbicidal. The rate of this chemical change is dependent on soil composition and temperature. At 5° C it may remain in the soil for several months. At 25° C in an average silt loam soil it may disappear in a few weeks. This property makes it well suited for autumn applications to control sensitive winter annuals and perennial grasses such as quackgrass. High organic soils will severely reduce the activity of pronamide in pre-emergent applications. Application pre-emergence on loam soils in areas of moderate rainfall and cool temperatures is considered the optimum condition, but excellent results can also be obtained in most other soils and in warm temperatures if the material is properly incorporated into the

(a)

(b)

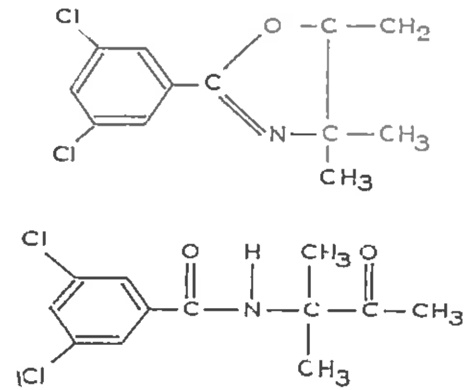

Fig. 2: Initial soil metabolites. (a) 2-(3,5-dichlorophenyl)-4,4-dimethyl-5-methyleneoxazoline. (b) 3,5-dichloro-N-(1,1-dimethylacetonyl) benzamide.

soil. Where furrow irrigation is practised, pronamide should be lightly incorporated into the soil before the crop is planted but incorporation is not necessary in all pre-emergence uses.

Its decomposition has been studied in the Rohm and Haas laboratories in soil, plants and animals utilizing ^{14}C-labelled pronamide, labelled in the carboxyl carbon. In the soil it is eventually cyclized to a compound not herbicidally active and this in turn is hydrolyzed to another inactive compound. These are illustrated in Fig. 2.

STUDIES IN THE CONTROL OF SUSUKI (*MISCANTHUS SINENSIS*) WITH DALAPON

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INTRODUCTION

More than 80% of the forests in Japan are on ground sloping more than 15 degrees. As a consequence, all forestry operations have to be carried out on steep slopes. Brush cutting is one of the operations conducted under these severe conditions. This involves cutting weeds, grasses and bushes at regular intervals for several years to eliminate competition from unwanted plants until the young planted trees are large enough to compete successfully. Brush cutting accounts for a high percentage of the total labour used in forest management in Japan, as shown by the following figures:

Operation	*% of Total Labour Used*
Brush cutting	45.3
Pruning	17.9
Soil preparation	15.4
Transplanting	10.4
Miscellaneous	11.0

In recent years, chemicals have been actively introduced in brush control to reduce labour costs and to overcome the shortage of labour; heavy industry has been absorbing labour from forestry areas.

The major brush and grass weeds found in forests where release cutting is necessary are species of *Pleioblastus*, *Pueraria*, *Cheilantes* and *Miscanthus*. Control of *Pleioblatus* is with sodium chlorate, *Pueraria* with phenoxy herbicides, and *Cheilanthes* with ammonium sulphamate.

For susuki (*Miscanthus sinensis*) a spot treatment of sodium chlorate was formerly recommended. This treatment had limited value because of the short period of control; soon after treatment, germination started again giving growth up to 30 cm. It is difficult to completely destroy deep-rooted rhizomatous weeds like susuki with sodium chlorate.

The effect of dalapon against annual grasses and some perennial weeds has been widely reported (Buchholtz and Peterson, 1957; Carder, 1967; Hodgeson, 1958). Further, dalapon has been reported as effective against susuki (Kawana *et al.*, 1966). However, dalapon had always been applied by spraying an aqueous solution, which offers difficulties in practice because of the need for water supply and difficulty in transporting water to the treatment area, as well as injury to trees owing to drift of the herbicide. For these reasons, treatment with dalapon has not been practised.

After some trials, treatment with micro-granular dalapon, a solid formulation, gave successful control of susuki in planted forests. This formulation of dalapon is now officially registered and has been used in Japan.

MATERIALS

Miscanthus species are graminaceous weeds, widely distributed throughout Japan, not only in forests, but also in open country, on embankments, and in orchards. Three species, *M. sinensis*, *M. floridulus* and *M. condensatus*, are commonly found. All are rhizomatous weeds, and from an ecological viewpoint exhibit much the same behaviour.

Susuki has a dense root system which forms an almost solid mat in the upper few centimetres of soil. This mat of roots absorbs available moisture and nutrient from the soil at the expense of tree seedlings which are normally planted in late March or early April. Elimination of such competitive pest grasses, therefore, is absolutely necessary to ensure adequate moisture and nutrients in the soil for tree seedlings.

In early spring, susuki emerges from its rhizomes and, after the tillering of buds, grows rapidly from spring to summer, reaching a height of 1.5 to 2 m.

Invasion and growth of *Miscanthus* species in planted forests is normally through germination from seed and growth of rhizomes. An observation of how *Miscanthus* species invades and multiplies in forests was reported by Ogata as follows:

> "In a natural broadleaved forest (17 hectares), surrounded by fields where *Miscanthus* species is dominant, all basic plants in the first year were annual grasses. *Miscanthus* species did not occur as a weed, although seed of *Miscanthus* species started its invasion. In the second year, the population of *Miscanthus* species reached a level of about 20-30%. In the third year, the level of infestation reached 50-70%, approximately 4,000 stubbles per hectare averaging 15 tillering per stubble. After this stage, the increase of stubbles by tillering becomes more vigorous than invasion by seed. In the fourth year, the population of *Miscanthus* species reaches a 100% level."

The solid formulations of dalapon used in this experiment contain 20% active ingredient. The products were formulated as follows:

Dust. Technical dalapon, containing 85% active ingredient, was blended with inert carrier and sifted to produce particles of 150-250 mesh (Tyler standard). The diameter of the particles ranged from 0.06 mm to 0.1 mm.

Micro-granule. Technical dalapon was kneaded with an inert carrier with an appropriate quantity of water. The product was dried and pelletized. The pellets were crushed and sifted to produce micro-granules of 48-150 mesh in particle size. The diameter of the particles ranged from 0.1 to 0.5 mm.

Granule. Technical dalapon was kneaded with inert carrier and an appropriate quantity of water. It was then dried and granulized through a sieve of adequate size. The granular size ranged from 12 to 32 mesh. The diameter of the particles ranged from 1.4 mm to 0.5 mm.

After formulation, these solid products were analysed to assay the concentration of active ingredient.

METHODS

EXPERIMENT 1

Herbicidal activity was determined by spot treatment using various formulations of dalapon against susuki. Test plots were arranged in a plantation of Japanese cypress (*Chamaecyparis obtusa*) which were 1 to 1.5 m high in their fifth year after transplanting. The area was in a mountainous region.

Dalapon was applied to susuki bushes which had grown to a 600 to 900 cm² basal width (20 bushes per each plot). Foliar treatments by dust and micro-granules were by manual application. Granules were manually applied to the base of the bushes. Treatments were made on 13 April, 22 April, 15 May and 19 June according to heights of susuki (30 cm to 1.5 m). Dosage rates were 2, 4, 6 and 8 g active ingredient per bush.

Observations were made at various times after application, and height of grass, and number of tillers of all treated bushes were determined. The rate of regrowth was recorded in the spring of the following year.

An evaluation of activity was determined from the amount of growth inhibition of the grass, and the number of tillers killed according to the following formulae:

Rate of growth inhibition =

$$\frac{\text{Height of grass at time of observation}}{\text{Height of grass at time of treatment}} \times 100$$

Rate of tillers killed =

$$100 - \frac{\text{No. of tillers at time of observation}}{\text{No. of tillers at time of treatment}} \times 100$$

The results are shown in Fig. 1.

As shown in Fig. 1, 60% of the tillers of susuki had sprouted within 1 month (by the end of April), the rate of increase then declining. The height of the grass increased vigorously until the

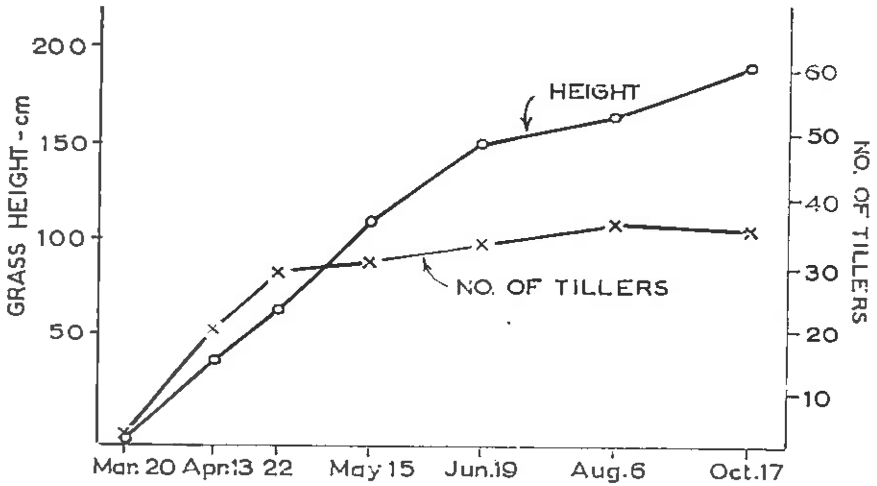

Fig. 1: Growth pattern of susuki indicated by grass height and number of tillers.

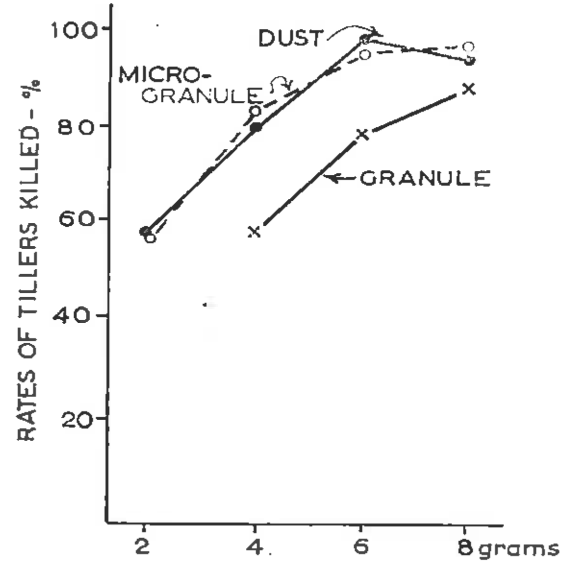

Fig. 2: Effects of different formulations of dalapon against susuki according to rates, treated on 22 April and observed on 17 October.

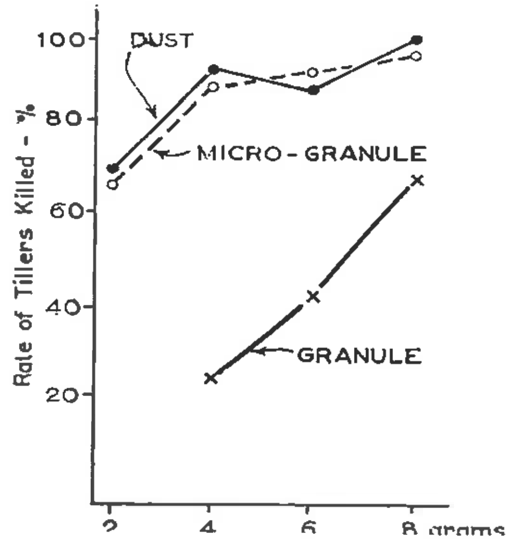

Fig. 3: Effects of different formulations of dalapon against susuki according to rates, treated on 15 May and observed on 17 October.

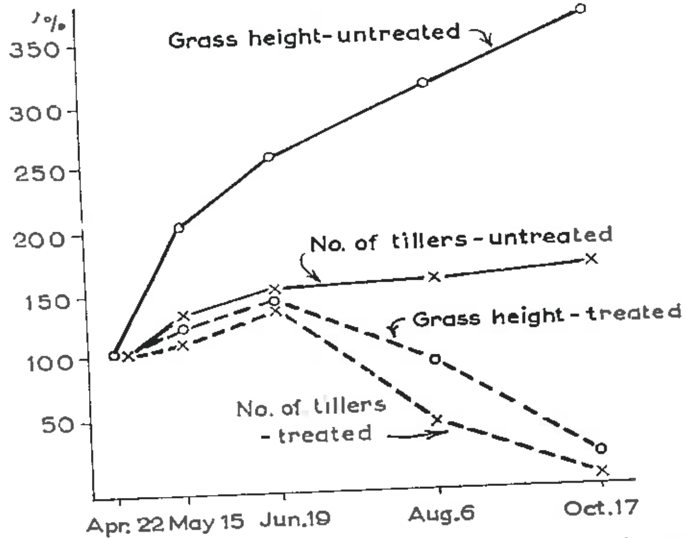

Fig. 4: Effects of micro-granule dalapon against susuki in comparison with untreated plots (by percentages based on time of application) treated on 22 April and observed on 17 October.

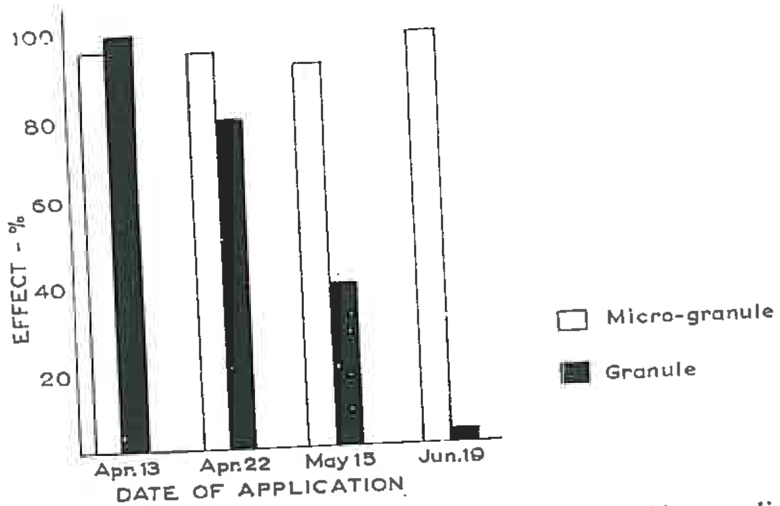

Fig. 5: Effect of micro-granule dalapon against susuki according to different times of application at same dosage, 6 g per bush, observed on 17 October.

middle of June, the rate of growth then decreasing although growth continued until the middle of October. The results and conclusions are as follows:

Dosage and Herbicidal Effects

Figure 2 gives results from the plots treated on 22 April (grass height of 50 to 60 cm) and observed on 17 October. The dalapon micro-granule and dust showed the same response curve — *i.e.*, slightly reduced but nevertheless satisfactory control at the rate of 4 g per bush. Control of more than 90% was achieved at the rate of 6 g per bush. Granular dalapon was less effective than the other two formulations, but showed more than 90% control at an application rate of 8 g per bush.

Figure 3 shows results from plots treated on 15 May (grass height of 100 to 110 cm) and observed on 17 October. The micro-granules and dust again showed the same response curve; more than 90% control was achieved at the rate of 6 g per bush. In comparison with these two formulations, the granular dalapon was far less effective when applied at this stage of growth.

From the results of these two treatments, it is thought that the relationship between particle size and efficacy is important. The dust and micro-granules achieved similar control because the herbicide adhered to the foliar and stem parts of the plant sufficiently to allow proper absorption and translocation of the dalapon by the plant.

Change of Growth with Time after Treatment

Figure 4 shows the changes of grass height and numbers of tillers of susuki treated with micro-granules at a rate of 6 g per bush on 22 April. The grass height was observed to increase slowly for 2 months after treatment, although its rate was only 50% in comparison with untreated plots. After 2 months, the rate of increase in grass height rapidly decreased as the tillers began to die. The number of tillers was observed to increase at a slow rate for 2 months after application and then decrease rapidly. This rapid decrease results in the destruction of nearly all tillers of susuki when treated with micro-granular dalapon.

Time of Application

Figure 5 shows the results of the treatment of dalapon granules and micro-granules at a rate of 6 g per bush. Micro-granular dalapon was highly effective in controlling susuki at various stages

TABLE 1: EFFECT OF MICRO-GRANULE DALAPON AGAINST SUSUKI

Treatment (kg/ha)	Date of Treatment	Top Kill in late Autumn (%)	Regrowth in spring of following Year (%)	Phytotoxicity (%) Autumn (late)	Phytotoxicity (%) Spring (following yr)
dalapon 20	Apr. 15	100	5	3	0
dalapon 30	Apr. 15	100	5	7	0
sodium chlorate 100	Apr. 15	100	35	2	0
dalapon 20	May 27	100	5	4	0
sodium chlorate 100	May 27	65	45	3	0
dalapon 20	Jul. 6	100	10	11	0

TABLE 2: PERCENTAGE CONTROL OF COMMON REED WITH DALAPON. (APPLIED JUNE 1970)

Treatment (kg/ha)	Estimated Control Months 1	3	6
dalapon micro-granule:			
40	60	80	100
60	60	90	100
80	70	90	100
dalapon aqueous solution:			
40	80	100	100
60	90	100	100

TABLE 3: PERCENTAGE CONTROL OF COMMON REED WITH DALAPON. (APPLIED SEPTEMBER 1969)

Treatment (kg/ha)	Estimated Control Months 2	7
dalapon micro-granule:		
40	90	100
60	100	100
sodium chlorate:		
300	90	*
600	100	*

*Most of reed had regrown.

of growth between 30 and 150 cm in height (achieving more than 90% control). Granular dalapon was effective at the stage of 30 cm height, and its effectiveness decreased as growth of susuki continued.

Phytotoxicity to Planted Trees

Except where there was direct contact, no phytotoxicity due to dust dalapon drift was noted. Phytotoxicity was not observed on trees where micro-granule or granular dalapon was used in these experiments.

EXPERIMENT 2

Solid formulations of dalapon were evaluated in practical forest management.

In southwestern Japan, the most serious competition to replanting is from perennial grass, primarily susuki, which grows actively in May and June.

The studies were located on a gentle, westerly slope in Kyushu, western Japan, at an elevation of approximately 600 m above sea level. The site was occupied by a dense stand of perennial grass, mainly susuki. The trees were *Cryptomeria japonica* which were transplanted 3 years before.

The plot size was 50 m long and extended down the slope for 40 m (2000 m^2). The density of susuki was about 15,000 bushes per hectare. Each bush was about 30 cm in diameter.

The following treatments were made: 1st treatment, 15 April; 2nd treatment, 27 May; 3rd treatment, 6 July.

The susuki was approximately 50 cm high in April, 120 cm in May, and 2 m in July.

Spraying was with a dust sprayer and the results of spraying were assessed by visual observation at various times after treatment (see Table 1). From the results, it is concluded that:

(1) In practical, large-scale experiments, the micro-granule formulation of dalapon showed excellent efficacy in controlling susuki without serious phytotoxicity to the trees.

(2) The observations in late autumn showed slight phytotoxicity to *Cryptomeria japonica.* Injury was a partial burn-type necrosis of the foliar parts. Randomly selected seedlings were observed for one year, and the phytotoxicity did not affect their growth.

EXPERIMENT 3

Solid formulations of dalapon were evaluated for their control of common reed (*Phragmites communis*), a perennial rhizomatous grass similar to *Miscanthus sinensis* in that it grows vigorously along the waterline and on the banks of waterways. Dense growth of this reed reduces the free water area, and interferes with flow of water. Mechanical mowing is usually used for control.

Control of reeds with aqueous solutions of dalapon has been reported in some countries. In this experiment, dalapon was applied as a micro-granule.

The experimental area contained natural infestations of common reed on the waterline of Onga river, in the southern part of Japan. Plot size was 20 m long by 20 m wide, extending from the water's edge up the bank. Treatments were randomized and duplicated. The micro-granule dalapon was sprayed with dust sprayer, while the liquid formulations were sprayed with a knapsack sprayer. The response and results of the treatments were assessed by visual observation, compared with control plots at various times following application. The first series of treatments were applied in September 1969 and the second in June 1970. Common reed was 2.0 to 2.5 m high in the early sprout stage when first treated. In the second treatment the grass height was 1.5 to 2.0 m and growing vigorously. The results are shown in Tables 2 and 3.

The early summer foliage treatments of the solid formulation of dalapon were as effective in controlling common reed as the aqueous treatments.

ACKNOWLEDGEMENTS

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THE USES OF THE BIPYRIDYL HERBICIDES IN TROPICAL CROPS IN QUEENSLAND

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INTRODUCTION

In common with most warmer parts of the world, tropical Queensland grows a number of economically important crops on a row cultivation system. In coastal areas especially, under the normal summer and autumn influence of moisture-laden trade winds, orographic rainfall ensures lush growth equally of weeds and crops.

Hereunder are the names of some of the more common weeds of tropical crops in northern and central Queensland:

WEEDS OF HORTICULTURE

Bidens pilosa
Brachiaria miliiformis
Cenchrus echinatus
Cynodon dactylon
Cyperus rotundus
Digitaria ciliaris
Digitaria didactyla
Echinochloa crus-galli
Eleusine indica
Eragrostis tenuifolia
Galinsoga parviflora
Lantana camara
Paspalum dilatatum
Passiflora suberosa
Pennisteum clandestinum
Tagetes minuta

WEEDS OF SUGARCANE

Ageratum conyzoides
Ageratum houstonianum
Bidens pilosa
Brachiaria miliiformis
Brachiaria mutica
Cenchrus echinatus
Crassocephalum crepidioides
Crotalaria goreensis
Crotalaria usaramoensis
Cucumis metuliferus
Cucumis sativus
Cyperus esculentus
Cyperus rotundus
Digitaria ciliaris
Echinochloa crus-galli
Eleusine indica
Hyptis suaveolens
Ipomoea purpurea
Ipomoea quamoclit
Luffa aegyptiaca
Mimosa invisa
Mimosa pudica
Momordica charantia
Nicandra physalodes
Panicum maximum
Passiflora alba
Passiflora foetida
Phragmites communis
Sorghum verticilliflorum
Tagetes minuta
Themeda quadrivalvis
Urena lobata

WEEDS OF PASTURES

Ageratum conyzoides	*Panicum maximum*
Ageratum houstonianum	*Paspalum conjugatum*
Axonopus affinis	*Paspalum paniculatum*
Hyptis capitata	*Pennisetum alopecuroides*
Imperata cylindrica var. *major*	*Pteridium esculentum*
Mimosa invisa	*Tagetes minuta*
Mimosa pudica	*Urena lobata*

A broad distinction should be made between the taller horticultural crops — *e.g.*, papaws, mangoes, bananas and citrus, which are similar in spacing and layout to rubber and cocoa — and smaller bushy crops — *e.g.*, beans and tomatoes, grown in narrow rows, with a comparatively short distance between individual plants (15 to 45 cm). Common to all crops are interspaces wide enough for a man to walk, or even mechanical spray equipment to operate. In tall crops in which there is adequate room to move under the canopy of foliage, or between the plant rows without damaging low-hanging branches, wheeled equipment may be used to advantage. With crops grown on steep ground, or on narrow row spacings, allowing only foot traffic, modifications may be called for — *e.g.*, knapsack misting machines, or hand-held dribble bars.

WEED CONTROL IN HORTICULTURAL CROPS

In these crops there is obvious scope for the scorching action of paraquat to control weed growth in the interspaces. With crops that are old enough to possess brown bark or stems that are tolerant of paraquat, weeds within the plant rows may also be controlled. Modified spray techniques include tree-line spraying and individual "ring weeding". In some situations, mechanical inter-row cultivation may be required in some crops for a period — *e.g.*, "hilling" for the first few months after planting in poorly drained situations. Not until disturbance of the soil ceases is any purpose served by spraying with paraquat, as this herbicide is effective on green plant tissue only — its biological properties are inactivated immediately upon contacting the soil.

In some circumstances, prolonged suppression of weed seedlings is required. In such cases, residual herbicides to which the crop in question is tolerant may be recommended — *e.g.*, fluometuron, simazine, and diuron, notwithstanding the doubtful economics of adding these soil-active treatments in low value

crops such as bananas. Extensive articles covering these features in detail include papers on weeds in bananas by Cull (1965), in strawberries by Ward (1967), in papaws by Agnew (1968), and in citrus by Mungomery (1969).

To avoid possible damage, especially to low branches or green stems, special equipment may be required — *e.g.*, dribble bars and flat fan "floodjets". Misting machines, larger dribble bars, and conventional spray equipment operated from a tractor unit may be used in wider row spacings. Boomless jets may also have a place, but, as they are less precise in delivery, they are generally not favoured for weed control use in plantation crops, least of all among sensitive species.

WEED CONTROL IN SUGARCANE

Paraquat has a use in sugarcane in Queensland as a directed spray for controlling blue top and other established weeds in the crop, as well as on headlands. This use as a herbicide has been well summarized by Myatt (1967), Tilley (1968), and Christie *et al.* (1971), with a pattern of performance similar to that in overseas sugar-producing countries described by Robson and Proctor (1963), Gosnell and Thompson (1965), and Peng and Sze (1969). Nearer harvest, paraquat is used occasionally in Queensland (especially in wetter northern areas) for desiccation of both crop foliage and lush weed growth. The spraying of lush foliage of both cane and weeds some 5 to 7 days before the expected date of cutting creates better conditions for pre-harvest burning. It is seldom necessary to treat entire blocks, as desiccation of weeds and cane foliage around the perimeter, as described by Arvier (1970), is usually sufficient to improve the efficiency of burning. It is in this peripheral zone of vigorous cane growth and associated weeds that cane fires are lit, and preliminary desiccation enables fires to start properly and burn effectively. Cleaner burning means less trash harvested, hence fewer penalties at the mill.

In those sugarcane growing districts of the world where two-year crops are common, the suppression of flowering ("arrowing") by spraying with low doses of diquat is commercially important. Variety N.Co.310 is particularly prone to flower each winter and at present it is the most popular variety in Queensland. Trials conducted over three seasons, reported by Arvier (1968, 1969) and Leverington *et al.* (1971), have shown that variety N.Co.310 can be prevented from arrowing by rates as low as 35 g diquat ion per hectare, when applied by aircraft in 112 l/ha of water. The last few days of February and the first two weeks of March appears to be the ideal time in Queensland, undoubtedly corresponding with the early part of September in the northern hemisphere, as recorded by Tanimoto and Nickell (1965). No significant changes have occurred in the commercial cane sugar content of the treated crop, although a slight early retardation in growth has been recorded. The effects of this check disappeared when the treated cane was allowed to grow on for a total of eight months or more following treatment. In sugarcane crops of North Queensland, the problem of arrowing is less commercially significant than in other parts of the State, partly because N.Co.310 is not widely grown north of the Tropic of Capricorn, and partly because sugarcane in Queensland is seldom grown beyond twelve months from planting or ratooning.

WEEDS OF SOWN PASTURES

In North Queensland, investigations into the use of paraquat for manipulation of pastures have been undertaken by Saint-Smith (1964) and Bailey (pers. comm.). Much of the impetus has come from the dairy pasture subsidy scheme on the Atherton Tableland, and the progressive development of King Ranch (Aust.) Pty. Ltd near Tully. Figures compiled by the Department of Primary Industries show that Queensland currently has some 1.8 million hectares of "effective sown pastures", including some 18,500 ha of grass species, plus some 1,400 ha of legumes, destined for seed production.

Sown pastures in North Queensland can be roughly divided into three main types: (a) dry lowland pastures, dominated by Townsville stylo (*Stylosanthes humilis*) and siratro (*Phaseolus atropurpureus*); (b) wet lowland pastures, containing the grasses pangola (*Digitaria decumbens*) and guinea (*Panicum maximum*), and the legumes *Desmodium uncinatum, D. intortum* and *Stylosanthes gracilis:* (c) wet highland pastures, composed mainly of *Setaria* spp. and the legumes *Glycine javanica* together with *Desmodium* spp. as at lower altitudes.

In much of North Queensland, intense summer rainfall coupled with high temperatures combine to provide conditions which give this region a reputation for being "weedy". Admittedly, vigorous established stands of pasture plants normally contain few weeds because of the active competition, but newly sown pastures can be very weedy. This is due to several different causes — *e.g.*,

inadequate seedbed preparation, insufficient fertilizer, poor quality of seed, and unfavourable weather after planting.

The practices of slashing or mowing will often give sown species an advantage over weeds. Intelligent grazing management may also encourage the pasture species to tiller more freely, often to set seed, and to increase in density, thereby combating weeds. The intelligent use of herbicides supplements these conventional techniques. Of the herbicides available, 2,4-DB has selective properties of value, but, where rapid action is required without any residual problems in the soil, diquat may often be used with advantage for broadleaved weeds (*e.g., Ageratum*) and paraquat for grass weeds (*e.g.,* guinea grass). Care must naturally be taken to avoid injuring susceptible pasture plants — *Desmodium* species, for example, are particularly sensitive to diquat.

The harvesting of seed from pasture species, especially in "wet" areas, has been recognized as economically important for several years, and the Queensland Department of Primary Industries estimated the State production in 1970 of all species at just over 1,000 tonnes. The use of diquat as a "chemical frost" to aid in harvesting clean pasture seed was a natural consequence of "crop salvage" in wet wheat harvest, and was advocated by Arvier (1966) to meet the problems of harvesting bulky green material, and the associated difficulties of obtaining yields of clean, bright seed. A desiccated crop reduces the burden on elevators and other moving parts of harvesting machinery, and loss of seed carried over in trash is negligible. Rates of diquat as low as 0.3 kg/ha give adequate desiccation in about a week. There are no undesirable residues on the plant parts, owing to degradation by ultra-violet light, and no residues in the soil owing to immediate inactivation by clay minerals.

CONCLUSION

The bipyridyl desiccants, paraquat and diquat, find scope for use in many crops of economic importance in tropical Queensland. In bananas, papaws, and other plantation crops, paraquat is the production of choice for weed control in the inter-row spaces. Spray applications are often made through specially adapted equipment — *e.g.,* dribble bars and floodjets — to avoid damage to low-hanging foliage.

In sugarcane crops in North Queensland, paraquat is used early to control weeds in young plants and ratoon cane, during mid-season to check weed growth on headlands, and prior to harvest to dry out lush growth to facilitate effective burning prior to cutting. Diquat has been shown to be capable of suppressing arrowing in the same manner as in Hawaii, Mexico and certain other countries growing two-year crops. The one-year crops in Queensland do not yet appear in need of this type of treatment.

In tropical pastures, there is scope for the use of both bypyridyls. If used carefully, paraquat can control many grass weeds without inflicting lasting damage on the pasture plants. For some dicotyledonous weed species, diquat may be preferred, but in pasture swards containing a high proportion of legumes, meticulous care must be taken to avoid spray drift on to these sensitive plants. Where pasture species are grown for harvesting of seed, the desiccant action of diquat can be used to advantage upon mature plants, giving seed yields which are complete and clean, and of low moisture content. Problems of pollution are minimal, owing to rapid inactivation of diquat residues by ultraviolet light on foliage, as well as by clay minerals in the soil.

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CHEMICAL WEED CONTROL IN COTTON

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INTRODUCTION

The control of weeds is essential for the profitable production of quality cotton. Attempts are frequently made to assess a monetary value of crop losses attributed to weeds, and the resulting figures are always astronomical in size. Losses may range from a small reduction in yield to the complete loss of the cotton crop. In some cotton-producing areas, severe weed infestations have made it necessary to abandon fields from further production of cotton until the weeds have been eradicated. This may take several years depending upon the methods used.

For the purpose of review some of the ways in which weed infestations in cotton are responsible for yield reductions, and subsequently lower profits, will be pointed out. Such a review, although rather academic, will help to an understanding of why an effective weed control programme must begin weeks and even months before planting the crop, and extend through the harvest season.

There are many ways in which weeds adversely affect cotton yields. They compete with cotton for soil moisture, nutrients, and sunlight. Competition by weeds for these essentials of plant growth may result in crop losses of varying magnitude, depending upon the density of the weed population and the supply of soil moisture, nutrients, and sunlight.

The control of cotton insects and diseases is also more difficult if weeds are not adequately controlled. First of all, heavy weed populations in cotton fields interfere with the efficient operation of spray equipment, the result being poor coverage of cotton plants with the pesticide sprays. Secondly, weeds serve as host plants for insects, diseases, and nematodes and, therefore, the likelihood of harmful infestations of these pests in the cotton crop and subsequent crops will be greatly enhanced.

Weeds also interfere with harvesting operations whether by hand or with mechanical harvesting equipment. Harvesting is significantly slower in weedy cotton fields and in areas where hand harvesting is practised, but, where labour is in short supply, labourers may even refuse to harvest weed-infested cotton fields. With mechanical harvesters, picking time is increased and picker efficiency is greatly reduced if weeds are prevalent. Proper adjustment and efficient operation of mechanical cotton harvesters is almost impossible in cotton fields heavily infested with weeds.

It is also well established that the quality of the harvested product is frequently reduced as a result of weed infestations. Quality loss may occur in several ways. Fibre length and strength may be decreased as a result of insufficient soil moisture if weeds are allowed to compete for limited moisture supplies. Quality may also be lower because of green leaf stain and trash in the harvested product. This is particularly true when mechanical harvesting is attempted in cotton fields with a high population of weeds.

A good weed control programme not only increases the profitability of the cotton crop, but there are other tangible benefits to the grower. Crops grown in rotation with cotton where effective weed control practices have been used will have fewer weed problems and, therefore, production costs will likely be lower.

Last, but not least, an effective weed control programme enhances the image of the cotton grower in the eyes of his friends and neighbours.

An effective and economical weed control programme for cotton may often include a combination of weed control practices using hand tools, various mechanical tillage implements, and chemicals. The relative proportion of these practices that will be used will be dictated by climatic conditions, availability of labour and mechanical equipment, availability of modern herbicide technology, and the nature of local production practices.

CHEMICAL WEED CONTROL IN COTTON

The remaining portion of this paper will be devoted largely to reviewing some of the chemical weed control practices that may be used in developing an effective weed control programme in cotton. It is only natural that most of the information presented will be that which has proven successful in the United States cotton-growing areas; however, with some modifications and adjustments the same practices should have merit wherever cotton is grown.

Never before has the cotton grower had a greater arsenal of weapons available for his use in doing battle against weed pests which so often rob him of his profits.

Because of the research efforts of government agencies and commercial companies during the past 25 years, herbicides are now available to control nearly all weeds which compete with cotton prior to and during the entire growing season.

Cotton herbicides are generally classified according to the time of their use with respect to the stage of growth of the cotton plants. In this presentation they will be classified as pre-plant, pre-plant incorporated, pre-emergent, and post-emergent herbicides.

PRE-PLANT HERBICIDES

Pre-plant herbicides are generally used before planting time to control those weeds and grasses that have emerged since the land was prepared. The time between land preparation and planting may be from several weeks to several months, depending upon local practices. Herbicides are a natural for controlling pre-season weeds in cotton fields and one or more applications may be necessary during this period to keep the land free from weeds.

In areas of limited soil moisture, the use of mechanical tillage to control weeds may result in the loss of moisture needed for getting the crop started; whereas, in wet seasons, mechanical tillage may not be possible and excessive weed growth may be the result. Under either condition, however, pre-plant herbicides may be used successfully in minimizing weed infestation.

A number of herbicides are now available which may be used to control grasses and weeds growing on land which will later be planted to cotton.

A group of herbicides developed by the Ansul Company almost ten years ago is now considered an essential part of nearly every chemical weed control programme in use today. These are the organic arsenicals, which are unique in that they are very safe to the user, to the cotton plants, and at the same time are effective in controlling a broad spectrum of weeds and grasses.

The organic arsenicals which are useful as pre-plant contact herbicides before planting time may be classified into three categories:

(1) The methanearsonates, monosodium methanearsonate (MSMA) and disodium methanearsonate (DSMA).
(2) Dimethyl arsenic acid or cacodylic acid.
(3) A mixture of MSMA and cacodylic acid formulated in a special ratio which is synergistic in its action against certain weed species.

Probably never in the history of chemical weed control in cotton has the grower had a better family of herbicides than the organic arsenicals for use in controlling weeds prior to planting his crop.

The methanearsonates are particularly effective in controlling such troublesome weeds as Johnsongrass (*Sorghum halepense*), purple nutsedge (*Cyperus rotundus*), yellow nutsedge (*Cyperus esculentus*), purslane (*Portulaca oleracea*), crabgrass (*Digitaria sanguinalis*), pigweed (*Amaranthus* spp.), and many other weeds and grasses.

The MSMA/cacodylic acid mixture is unique in that it possesses most of the advantages of the methanearsonates as grass-killers while, at the same time, it effectively controls many broadleaf weeds that are not controlled by the methanearsonates alone.

Cacodylic acid, at recommended rates, generally acts as a desiccant and is used effectively to control annual weeds and grasses.

All of the organic arsenicals may be safely used to control weeds before planting time without fear that harmful residues will prevent cottonseed germination and affect the stand of cotton. Long-term studies by the Ansul Company have shown that the organic arsenicals are readily tied up on contact with the soil and that, when used as recommended, herbicide residues in crops are not a problem.

Unfortunately no one herbicide will control all weeds and this is true of the organic arsenicals. However, this group of herbicides can be formulated with other herbicides to increase their activity and broaden the spectrum of weeds controlled.

The methanearsonates have been mixed with a number of herbicides such as dinoseb, fluometuron, prometryn, diuron and noruron.

Another herbicide that has been used as a pre-plant herbicide as a spot treatment for Johnsongrass and bermudagrass (*Cynodon dactylon*) is dalapon.

Whatever the pre-plant weed problem might be, there is more than likely a herbicide or a combination of herbicides that will provide the necessary control.

Pre-plant Incorporated Herbicides

Another group of herbicides that are an important part of a chemical weed control programme in cotton are the pre-plant incorporated herbicides. Generally referred to as dinitroanilines, these herbicides are generally applied to the soil just prior to planting and are incorporated (or mixed) with the upper 5 to 8 cm of soil before planting the crop. Their application may also be made from 6 to 8 weeks before planting. When pre-plant incorporated herbicides are used, the cotton seeds are planted in the lower part of the treated zone, disturbing the treated soil as little as possible.

The dinitroanilines are effective on many annual grasses as well as a number of annual broadleaf weeds. They kill weed seeds as they germinate; however, the cotton seeds germinate and, if growing conditions are favourable, the cotton root quickly grows through the herbicide-treated soil and a good stand of cotton emerges. These herbicides, in general, are not effective as contact herbicides.

The dinitroanilines first found widespread use in the mid-1960s. Trifluralin and nitralin are examples of this group of herbicides.

Another herbicide in this group, to be marketed within the next year is chlornidine, which, while controlling essentially the same spectrum of weeds as the other dinitroanilines, appears to offer some added advantages. Tests at Ansul's Development Center in Texas have indicated that soil incorporation may be delayed up to 72 hours without significant loss of activity. Chlornidine also appears to be less toxic to cotton seedlings than the other herbicides of this group. This is a distinct advantage especially under less than optimum soil moisture and temperature conditions. Another distinct advantage is that herbicide carry-over beyond the cotton growing season appears to be less, thus having little detrimental effect on succeeding crops.

The pre-plant incorporated herbicides have been very effective and are an important weapon to have in the arsenal against weeds. However, with their continued use over a period of years, many weeds species have been completely eliminated, and as these species have been removed from competition, the ecology has changed and resistant species have become a problem. Other herbicides must therefore be used to control the resistant species which appear. To accomplish this, post-emergence herbicides are generally used as companion herbicides. The post-emergent herbicides will be discussed in detail later.

Pre-emergent Herbicides

Pre-emergent herbicides may be used in place of pre-plant incorporated herbicides. They are generally applied after the cotton is planted but before the cotton and weed seeds emerge. They are sprayed on the soil surface and do not require incorporation.

Some effective herbicides in this category are prometryn, fluometuron, diuron, chlorthal, and noruron. There may be others which are used to a lesser extent.

Although there are some differences in the spectrum of weeds controlled, these pre-emergence herbicides control a broad spectrum of weeds and grasses. On the other hand, their continued use likewise removes the competition of certain species and changes the ecology to the point where resistant species become a problem.

Therefore to maintain an effective season-long weed control programme, it is usually necessary to supplement these herbicides with a post-emergent programme to eliminate those troublesome weeds that were not controlled by pre-plant incorporated and/or pre-plant herbicides.

Before discussing post-emergent herbicides, it might be pointed out that pre-plant incorporated and pre-plant herbicides may both be used in one programme. An example would be the use of a pre-plant incorporated herbicide before planting — plant the crop — and then overlay the planted row by spraying the soil with a herbicide such as diuron. This kind of operation broadens the spectrum of weeds controlled to include the total spectrum of both herbicides.

Post-emergent Herbicides

To provide for season-long weed control, post-emergent herbicides are usually needed to control those weed species which are resistant to the pre-plant incorporated and pre-plant herbicides. Examples are Johnsongrass, nutsedges, and numerous others, depending upon the area in which cotton is produced.

Again the cotton grower has at his disposal a good arsenal of weapons for use in controlling these weeds. MSMA and DSMA, which are used to control weeds and grasses prior to planting, are among the most effective. They may be used at any time after the cotton has 2 to 3 true leaves up until it begins to fruit.

The methanearsonates should be applied in sufficient water to obtain good spray coverage of the weeds and grasses to be controlled. Although these herbicides are recommended as directed sprays to avoid spray contact with the cotton plants, injury from spray contact is negligible and the cotton rapidly recovers from

any temporary herbicidal effect which is usually slight stunting. The methanearsonates are applied in many areas by airplanes with a high degree of success and little damage to cotton.

In general, DSMA and MSMA are equally effective in controlling weeds. However, in areas where vegetation makes lush growth, DSMA may be slightly less injurious to the tender cotton plants and under such conditions may be preferred when the cotton is small.

When weed species occur which are somewhat resistant to the methanearsonates, their activity may be enhanced by combining them with other herbicides to form a combination for post-emergent use.

When cotton is from 7 to 15 cm tall, the methanearsonates may be used in combination with noruron, fluometuron, and dinoseb. After the cotton is 15 cm tall, the methanearsonates may be used with prometryn and diuron.

If climatic conditions are such that weeds may present a problem late in the season, then a "lay-by" treatment may be made at about the time as the last cultivation would occur. Such herbicides as prometryn, fluometuron, diuron, linuron, and noruron have been successfully used. These herbicides are used with surfactants and at rates sufficiently high to kill small weeds and grasses as well as to provide pre-emergent activity to weed and grass seeds germinating later in the season.

In summary:

(1) Good weed control is necessary to produce a profitable yield of high quality cotton.

(2) Weeds in cotton can be controlled by the use of a combination of practices which may include hand and mechanical tillage in combination with the use of herbicides.

(3) Herbicides are available to control nearly every problem weed in cotton; however, no one herbicide is adequate to do the job alone.

(4) A good weed control programme in cotton begins weeks before planting the crop and extends far into the season, providing season-long control.

(5) A weed control programme in cotton with herbicides alone is possible, but a combination of mechanical tillage used with herbicides may often be more practical.

APPLICATION OF HERBICIDES THROUGH IRRIGATION WATER FOR WEED CONTROL IN LOWLAND TARO (*COLOCASIA ESCULENTA*)[1]

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Experiments were conducted to evaluate the technique of applying herbicides in irrigation water for weed control in lowland taro (*Colocasia esculenta*). Dripping herbicide solution into the irrigation water entering taro paddies gave erratic weed control owing to uneven and non-uniform distribution of herbicides over the paddy. An irrigation pump fitted with a gear pump which injected the herbicide solution into the water being pumped into the paddies gave uniform coverage of the fields and excellent results. This technique was especially effective in avoiding leaf injuries in taro, compared with herbicides applied by conventional sprays over the taro tops and leaves.

Using this technique of herbicide application the rates and frequency of application of nitrofen were studied using rates of 3 and 6 kg/ha and frequency of application of monthly, every two months and every three months during a period from 0 to 6 months after planting. Both rates of application gave excellent weed control and no injury to the crop was observed even at the highest frequency of application. In a period of six months, as high as 42 kg/ha was applied for the high rate without giving crop injury.

Other herbicides tried which gave satisfactory weed control when applied by this method are chloramben (3 kg/ha), VCS-438 (3 kg/ha), and RP-17623 (1.5 and 3 kg/ha), immediately after planting. With the exception of RP-17623, however, weed control with these chemicals lasted for about four to five months when applications were not repeated. RP-17623 at 3 kg/ha applied once gave good weed control up to one year after planting.

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TABLE 1: WEED CONTROL AND CROP INJURY RATING FOR PLOTS TREATED WITH NITROFEN[1]

Rate	Application Interval (months)	3 months Crop Injury	3 months Weed Control	12 months Crop Injury	12 months Weed Control
3 kg/ha	1	1	4.5	1	5
	2	1	3.8	1	5
	3	1	3.8	1	5
6 kg/ha	1	1	4.5	1	5
	2	1	4.5	1	5
	3	1	4.2	1	5
Control[2]		1	1	1	1

[1] Crop injury rating: 1 = no injury, 5 = crop killed.
Weed control rating: 1 = no control, 5 = complete control.
[2] Control plots hand-weeded at 3 and 6 months after planting.

TABLE 2: WEED CONTROL AND CROP INJURY RATINGS FOR TARO TREATED WITH SOME HERBICIDES[1]

Treatment (kg/ha)	3 months Crop Injury	3 months Weed Control	12 months Crop Injury	12 months Weed Control
chloramben 3	1	4.2	1	5
RP-17623 1.5	1	3.8	1	5
RP-17623 3	1	4.2	1	5
VCS-438 3	1	4.2	1	5
Control[2]	1	1	1	1

[1] Crop injury rating: 1 = no injury, 5 = crop killed.
Weed control rating: 1 = no control, 5 = complete control.
[2] Control plots hand-weeded at 3 and 6 months after planting.

TABLE 3: EFFECTS OF RATES AND FREQUENCY OF APPLICATION OF NITROFEN ON YIELDS OF LOWLAND TARO[1]

Rate	Application Interval[2] (months)	Total Amount Applied (kg/ha)	Yields (tonnes/ha) Main Corms	Yields (tonnes/ha) Cormels	Yields (tonnes/ha) Total Yield[3]
3 kg/ha	1	21	19.36	45.44	64.80 abc
	2	9	21.60	44.01	65.61 abc
	3	6	26.90	43.60	70.50 ab
6 kg/ha	1	42	23.43	36.27	59.70 bc
	2	18	18.54	44.42	62.96 abc
	3	12	24.04	48.90	72.94 a
Control		0	18.74	35.86	54.60 c

[1] Herbicide applied through irrigation water.
[2] From time of planting to 6 months after planting.
[3] Values with the same letter are not statistically different ($P = 0.05$).

TABLE 4: YIELDS OF LOWLAND TARO TREATED WITH HERBICIDES[1]

Treatments (kg/ha)	Yields (tonnes/ha) Main Corms	Cormels	Total Yield[2]
chloramben 3	22.21	41.57	63.78 ab
RP-17623 3	19.56	41.98	61.54 b
RP-17623 1.5	24.04	47.27	71.32 a
VCS-438 3	20.99	37.09	58.08 b
Control	18.74	35.86	54.60 b

[1] Herbicides applied through irrigation water immediately after planting.
[2] Values with the same letter are not statistically different ($P = 0.05$).

THE ACTION OF 2,4-D ON WATER LETTUCE (*PISTIA STRATIOTES*)

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Water lettuce or water soldier (*Pistia stratiotes* L.), a gregarious free-floating herb with a peculiar muriatic odour and bearing a rosette of cuneate obcordate leaves and countless fibrous roots, is widely spread over the tropics of Asia, Africa, America and South France (Ridley, 1930). It is of considerable biological interest because of the weedy nature of the species which is prolific in growth, providing a breeding ground for mosquitoes and choking fishery waters. Sculthorpe (1967) stated that *Pistia*, along with *Lemna* and *Salvinia*, have achieved notoriety and economic significance through their phenomenal spread. These create obstacles on hydro-electric reservoirs, irrigation channels and navigable waterways. It grows in tanks, ponds and old wells, occurring throughout India and ascending up to 1,000 m (Subramanyam, 1956). It is also a weed in Ceylon and in the Grand Lac region of Cambodia (Williams, 1956; Hickling, 1961). It causes problems in Coastal Angola, Cameroun, Congolese Republic, Dahomey, Gambia, Guinea, the Ivory Coast, Mali, Mauretania, Nigeria and Senegal (Wild, 1961). It is troublesome on the Upper White Nile which, from the base of the Murchison Falls, at a distance of 80 km from the Karuma Falls, becomes a broad, quiet, slow-moving stream covered with millions of the floating rosettes (Moorehead, 1960). Scattered colonies of *P. stratiotes* appeared along the eastern shore soon after Lake Volta began to fill; these increased tremendously during 1965 and formed in the westward Afram arm of the lake thick mats invaded by other plants (Ewer, 1966).

According to Kirtikar and Basu (1918) and Chopra *et al.* (1956), the plants can destroy bugs. Made into poultice, the leaves are applied to haemorrhoids. When the leaves are mixed with rice and coconut milk, they are administered for controlling dysentery and mixed with rose-water and sugar for cough and asthma. The leaf-juice, boiled in coconut oil, is a specific for chronic skin diseases. Known as "pana salt", the ash is applied to ringworm of the scalp. The plants are also used as food for pigs and ducks.

Despite the importance and distribution of *P. stratiotes*, there is very little information on its general ecology and general physiology or the micro-ecological and micro-physiological conditions under which it grows. Such information, when available, might provide a clue to the control of the plants when they become undesirable in aquatic habitats.

In an earlier paper (Datta and Biswas, 1969) of the series, the germination of seeds of *P. stratiotes* was studied and the factors affecting the process evaluated. Here it was indicated that the germination-controlling mechanisms are related to light. It was established in a second paper (Datta and Biswas, 1970) that viable seeds of the species do not germinate in nature owing to the low oxygen content or high carbon dioxide content of the pond soil in which they are dropped. Thus, rapid vegetative propagation by means of stolons accounts for the prodigious spread of the species even though seeds are formed normally and do not lose their viability readily.

Biswas (1970) demonstrated that *P. stratiotes* cannot be grown successfully by employing the Hoagland and Arnon type of nutrient medium as used in Earhart Laboratory, California, U.S.A. It is desirable to dilute the medium four times the normal amount for raising *Pistia*. For example, top and root lengths, number of stolons per plant, dry weight of top and roots, were maximum under ¼ strength compared with other strengths employed, namely, ½, ⅛ and 1/16. Further work was done to define the specific growth-requirements and, more precisely, their distribution in aquatic habitats by increasing or decreasing the amounts of nitrogen, phosphorus and potassium — three elements considered mobile in plants. This experiment showed that ½-nitrogen plants are better than 2-nitrogen plants, 2-phosphorus plants better than ½-phosphorus plants and ½-potassium plants better than 2-potassium plants. The production of stolons is more encouraged by the presence of phosphorus in the growing medium than by the presence of either nitrogen or potassium. Having established all these facts, it was thought desirable to consider the effect of 2,4-D on the growth and spread of *P. stratiotes*.

MATERIALS AND METHODS

To begin with, a 1000 ppm solution of the sodium salt of 2,4-D was prepared. This was done by weighing out accurately 1 g of the compound, dissolving it in distilled water and making up the volume to 1 litre. This formed the stock solution of 2,4-D from

which aliquot portions were taken out, put in large Pyrex beakers (1 litre capacity) and diluted with the nutrient solution (1/4 dilution of standard Hoagland-Arnon's solution) to secure the desired strength. Thus, 500, 250, 50, 10, 5 and 1 ml of the stock solution would give the respective concentrations of 2,4-D when admixed with the requisite quantities of the nutrient solution.

In the experiment mentioned above, each beaker contained 10 stolons (whose total dry weight was 15 mg for the top and 5 mg for the root), raised from seeds germinated in the laboratory, each with 2 to 3 leaves. There were three replicates per treatment and adequate controls were maintained. The pH of the solution (mixed with 2,4-D) was adjusted between 6.5 and 7.0 and the solution in the beaker was changed every week. Aeration and support were not necessary, since the stolons were allowed to float in the solution. The plants were not exposed to any particular photoperiod and were grown under diffuse light by day and no light at night in the laboratory whose temperature varied from 20 to 25° C. They grew vegetatively, but there was no flowering during the experimental period which was about four weeks.

The symptoms of toxicity were noted, the number of stolons developed recorded, the dry weight of top and root determined, and the time taken to kill was ascertained.

RESULTS AND DISCUSSION

Compared with the untreated controls, the effect of 2,4-D was evident at all concentrations (Table 1). With 1 ppm, there was no indication of toxicity; here the plants managed to survive, but in an unhealthy state; no stolons were produced compared with 5 stolons in the control plants. For the plants receiving 1 ppm of 2,4-D, the total dry weight was 16 mg for the top and 6 mg for the root whereas the values for the control plants were 43.2 and 17.2 mg, respectively.

In the rest of the treatments, the plants were dead and decomposed. The first indication of toxicity was chlorosis which was initially noted in the base of older leaves (which were in contact with the solution) and finally in the tips of younger leaves (which were not in contact with the solution). Gradually, all parts of the leaves were affected and they lay flat on the surface of the solution. Then, the leaves became detached from the rootstock one by one; this marked the death of the plant which was also accompanied by gelatinization of the root.

The degree of lethality depended upon the concentration of the herbicide employed, increasing progressively with increment

TABLE 1: OBSERVATIONS ON *P. STRATIOTES* PLANTS GROWING IN HOAGLAND-ARNON'S NUTRIENT SOLUTION IN WHICH VARYING AMOUNTS OF 2,4-D WERE INCORPORATED

(Experiment commenced 9 February 1968)

2,4-D (ppm)	*First Evidence of Toxicity*	*Date on which Plants Totally Killed*	*Other Remarks*
500	10 Feb., 1968	13 Feb., 1968	The toxic effect is evident in top, since the apex of younger leaves and base of older leaves became chlorotic and then died and decomposed.
250	11 Feb., 1968	14 Feb., 1968	
100	12 Feb., 1968	15 Feb., 1968	
50	13 Feb., 1968	16 Feb., 1968	
10	16 Feb., 1968	24 Feb., 1968	
5	23 Feb., 1968	5 Mar., 1968	
1	1 Mar., 1968	—	Plants not chlorotic, but surviving in an unhealthy state.
0			
Control	—	—	No toxicity.

in the quantity of 2,4-D. The first evidence of toxicity appeared much earlier at higher concentrations than at the lower ones. With 500 ppm, death occurred in 4 days. Similarly, it was 5 days with 250 ppm, 6 days with 100 ppm, 7 days with 50 ppm, 15 days with 10 ppm, and 26 days with 5 ppm. Thus, it appears that a concentration of 5 ppm of 2,4-D could be as effective as 500 ppm in eradicating *Pistia*, with the difference that a slower concentration would be slower in action.

This is perhaps the first record on the use of 2,4-D in controlling the growth or spread of *Pistia*. Previously, Thomas and Srinivasan (1949) could kill *Pistia* in about 10 to 12 days by applying 0.2% MCPA. At a rate of 5 to 10 ppm, diuron and, at 0.6 g/m^2, simazine, have successfully controlled *Pistia* (Sculthorpe, 1967). Also, at this Conference, Soerjani and Tirtatahardja, presented a paper entitled "Prospects for Chemical Weed Control in Indonesia" in which they observed that they could control *Pistia* (which occurs in lowland rice, irrigation system and lakes in Indonesia) by the application of paraquat.

This study opens up the possibility of chemical control of the aquatic weed, *Pistia stratiotes*. Till now, in West Bengal, man has exercised biological control over the weed by lifting it up *en masse* in the cold season, drying it and burning it to ashes.

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RECENT RESEARCH IN CONTROL OF WOODY PLANTS IN HAWAIIAN PASTURE AND RANGE LAND[1]

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Summary

Over the last six years extensive research has been carried out throughout the Hawaiian islands on the control of brush species using a wide range of chemical herbicides and spray additives. Of the herbicides used, the systemics (2,4-D, 2,4,5-T, fenoprop, picloram and dicamba) have been most efficient and have had most persistent effects on the wide range of brush species studied. The methods of application depended on the purpose of the control, including either land clearing or follow-up spot treatments as well as aerial and ground-rig spraying, stem injection and granular spot treatments.

INTRODUCTION

Of Hawaii's 1.66 million hectares, close to 800 000 are under pasture or range of varying quality (Table 1). Over 400 000 ha more are covered with wetland jungle, the majority of which could be converted into highly productive pasture by using a systems approach to the operations of clearing, sowing, fertilization and subsequent grazing and species management (Motooka *et al.*, 1967a). An estimated 600 000 ha of Hawaii grazing land is dominated by brush species, compared with a national U.S.A. figure of 130 million brush infested hectares. From these figures, Hawaii's contribution seems small but by proportion it is probably above the national average. A more significant fact is that the subtropical, moist environment is ideal for the invasion and spread of the brushy species (Tables 2 and 3) once the land has been cleared mechanically, chemically, by fire or by mismanagement of existing pastures. Economic losses from weeds in pasture lands include a lower quantity and quality of forages and animal

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products, poisoning losses, depletion of soil moisture reserves, increased cost of managing and producing the grazing animal, and increased sowings of improved pasture species. In general, needs for brush control occur at the start and finish of a systematic approach to land clearing for pasture establishment, ending with the maintenance of a favourable sward mixture using follow-up spot treatments with herbicides on invading brush species.

As is the case throughout the humid tropics, productivity of pasture and range lands of Hawaii is reduced by brush encroachment and competition. The more recent research carried out by the College of Tropical Agriculture, University of Hawaii, in co-operation with local ranchers and chemical companies, has been directed at the control of woody brush species common to most tropical regions of the world. The methods of control that are being studied include aerial and ground spraying, use of granular materials, stem injection, and biological control. Biological control methods include the use of insect and fungal parasites as well as the use of the grazing animal to control brush species by favouring dominance of the more vigorous improved pasture legumes and grasses.

TABLE 1: PASTURE AND RANGELAND IMPROVEMENTS BY BRUSH CONTROL IN HAWAII (1968)*

Class	*Total Area in Class (ha)*	*Area treated with Herbicides (ha)*	*% of Total Area Treated with Herbicides*
Pasture:			
Improved	204 271	2 000	2
Other	21 119	8 000	48
Rangeland:			
Mountains (1200-4200 m)	80 000	4 000	5
Foothills (600-1200 m)	180 000	6 000	4
Arid (0-600 m leeward)	60 000	10 000	17
Rainbelt (0-1800 m windward)	160 000	6 000	4

*Taken and modified from report submitted by Professor C. Lyman (Specialist in Pasture Management, University of Hawaii) as a part of the 1968 Triennial Weed Control Survey for the State of Hawaii.

TABLE 2: MAJOR WOODY WEEDS OF HAWAII'S PASTURE AND RANGELAND

Species	Distribution (see "Vegetation Zones" Table 3)
Guava (*Psidium guajava*)	All islands in B, C1, D1, and D2 zones.
Lantana (*Lantana camara*)	All islands in A, B, C1, D1, and D2 zones.
Hamakua pamakuni (*Eupatorium riparium*)	All islands except Kauai from 0-2000 m in moist-wet C1, C2, D, and E1 zones.
Christmasberry (*Schinus terebinthifolius*)	Widely distributed over all island in lowlands with 500-1150 mm rainfall.
Hairy fleabane (*Pluchea odorata*)	Wide range from semi-dry to wet in B, C1, C2, D1, and D2. In saline and non-saline soils and marshes.
Java plum (*Eugenia cuminii*)	All islands in wet and semi-wet regions below 600 m in B, C1, D1. At higher elevations no fruiting occurs.
Joee (*Stachytarpheta* spp.)	All islands in semi-moist to moist areas of B, C1, C2, D1 and D2.
Melastoma (*Melastoma malabathricum*)	In areas of D1 and D2 with 1250 mm rainfall and over.
Rhodomyrtus tomentosa	On Kauai and Hawaii in zones D1 and D2 at 1000 ft with 1250 mm rainfall or over.
Blackberry (*Rubus penetrans*)	All islands in C2, D2, D3 zones.
Firebush (*Myrica faya*)	All islands in C1, C2, D1, D2 with 900 mm rainfall or over.
Cat's-claw (*Caesalpinia sepiaria*)	Along stream beds and in small valleys in moist areas of all islands in C1 and D1 zones.
Elephant's foot (*Elephantopus mollis*)	Concentrated on Kauai and Hawaii in zones B, C1 and D1.
Strawberry guava (*Psidium cattleianum*)	Small stands on all islands in moist to wet areas of C1 and D1 zones.
A'alii (*Dodonea* spp.)	All islands in B, C, and E zones. Most abundant at middle elevation (750-1800 m).
Kolomona (*Acacia glauca*)	All islands in C1, D1, and D2 zones.
Hau (*Hibiscus tileaceus*)	Along streams and in swampy areas of all islands.

TABLE 3: VEGETATION ZONES OF HAWAII, THEIR ALTITUDE AND ANNUAL RAINFALL LIMITS*

Zone	Phase	Approximate Altitude Limits (m)	Approximate Total Rainfall Limits (mm/yr)	Natural Cover
A		< 300	500 or less	Xerophytic shrub with coastal fringe of trees
B		< 900	500-1000	Xerophytic shrub with some trees in upper part
C	1-low	<750		Mixed open forest and shrubs
	2-high	750-1200	1000-1500†	Mixed open forest
D	1-low	<450‡		Shrub and closed forest
	2-medium	Variable	1500 or more†	Closed forest
	3-high	1200 to <2100		Open forest
E	1-low	1200-2100		Open forest and shrub
	2-medium	2100-3000	1250 or less	Mainly upland open shrub
	3-high	>3000		No seed-bearing plants

*From *Vegetation Zones of Hawaii* (after Ripperton and Hosaka, 1942).
†Minimum rainfall is less than 1500 mm at higher levels.
‡The boundary between D_1 and D_2 varies with location and present utilization. In general, it represents the highest point of satisfactory utilization for most crops, as adjudged by climate, soil type and present crops growing.

EXPERIMENTS AND RESULTS

EXPERIMENTS AT THE KAUAI BRANCH STATION, HAWAII AGRICULTURAL EXPERIMENT STATION

Experiment 1

The first trial was located at an elevation of 150 m in a rainfall zone of 2250 mm per year. The soil has been classified as a Typic Gibbsihumox, humic ferrugenous latosol, Halii series. The jungle vegetation consisted mainly of guava, ohia (*Metrosideros collina* var. *polymorpha*), Java plum, false staghorn fern (*Dicranoptoris linearis*) and pandanus (*Pandanus tectorius*). Of the different levels of dicamba and monuron, all except the lowest rate of monuron (11.2 kg/ha) were effective to some degree (Motooka *et al.*, 1967a). The most effective treatment was dicamba which was moderately active against guava but less active on ohia and Java plum. Monuron, which is essentially translocated from the roots, needs moisture for its movement into the soil and the dry conditions at the time of application of the treatments could have contributed to the poorer performance of this treatment. Another important point brought out by this trial was the need for a follow-up application to control any regrowth after the first treatment of the woody species. This suggests that the cumulative effect of the repeated low dosage applications may prove more effective than a single high dosage.

Experiment 2

Following the above initial trial a larger area of brush consisting of similar species was subjected to a series of hormone-type (systemic) herbicides (2,4-D, 2,4,5-T, dicamba, fenoprop and picloram), one rapid defoliant (contact) herbicide (paraquat), mixtures of paraquat and dicamba and mixtures of the systemic compounds (Motooka *et al.*, 1967a).

The systemic herbicides applied singly were more effective than the systemic plus rapid defoliant combinations. Dicamba controlled ohia and guava with guava being slow to respond. Melastoma and staghorn fern were moderately affected, whereas lantana, after being severely affected at the start, fully recovered at the end of one year. The picloram/2,4-D mixture at 4.48 and 672 kg/ha gave good control of guava and ohia but once again the effects did not last a full year. The 2,4-D/2,4,5-T mixture controlled melastoma, lantana, guava and ohia for 6 months but the species recovered beyond this time. The most effective treatment was fenoprop at 4.48 kg/ha which severely injured melastoma, ohia and staghorn fern while the control of lantana and guava was moderate to good. Hau-bush and Java plum were also severely affected at the start but eventually recovered. Guava and lantana recovered after one year but melastoma, most ohia and staghorn fern were controlled completely. This satisfactory control for only one year pointed to the need for a follow-up application of another 4.48 kg/ha of fenoprop after perhaps six months.

Experiment 3

Another trial was set up in a similar area to that of Trials 1 and 2 at 150 m elevation and receiving 2000-2250 mm of rainfall. The topography was very rough with several steep ridges and deep valleys extending throughout the site. A series of rapid defoliants and systemic herbicides were used alone and in com-

TABLE 4: PERIOD WHEN 90 TO 100% INJURY WAS OBTAINED ON FIVE SPECIES AS A RESULT OF AERIAL HERBICIDE TREATMENTS

Treatment (kg/ha)	*Melastoma*	*Lantana*	*Guava*	*Ohia*	*Staghorn Fern*
picloram 1.5/2,4-D 6	1-2m	2-3m	—	—	3m
picloram 3.0/2,4-D 12	1-3m	2m	—	2m	2-3m
picloram 3	1-3m	3w-3m	—	3m	2-3m
picloram 6	3w-3m	3w-3m	3m	3m	2m
picloram 3/fenoprop 9	3w-3m	3w-2m	2-3m	3m	2-3m
picloram 3/2,4-D 9/ 2,4,5-T 9	3w-3m	3w-3m	3m	—	2-3m
picloram 3/2,4-D 6/ 2,4,5-T 6	3w-3m	1-3m	2-3m	—	1-3m
picloram 4.5/2,4-D 9/ 2,4,5-T 9	3w-3m	1-3m	2-3m	—	1-3m

w = week. m = month.

bination on brush consisting of guava, ohia, Java plum, pandanus and staghorn fern (Table 4). For practical purposes the effects of the lower rates of the systemic herbicides only will be discussed.

The herbicide effects were evaluated in terms of degree of defoliation and general injury or control. The results are best presented by dealing with the main brush species separately.

Guava is a very difficult species to control. The leaves have thick and dense cuticles which reduce absorption of systemic herbicides, thus reducing the amount translocated to the roots. Picloram applied singly or in combination with fenoprop 2,4-D and 2,4,5-T provided more lasting effects than contact herbicides (Table 4). More work is needed to study the use of penetrant additives to spray mixtures and also what causes the differing reactions of guava to herbicides applied to stands in areas with different soil moisture regimes.

Lantana, like guava, is also hard to control because it sheds its leaves easily, minimizing herbicide translocation to the roots. Furthermore, when the stem touches the ground it produces roots and a new shoot soon develops. This type of proliferation as well as its profuse seeding habit, makes control difficult. From Tables 4 and 5 it will be noted that picloram alone or in combination with 2,4-D, 2,4,5-T and fenoprop killed most of the lantana and very few recovered in 22 months.

Melastoma produces many branchlets and seeds. Its numerous leaves are well exposed and are in a position to capture much

TABLE 5: PERCENTAGE CONTROL OF FIVE SPECIES 22 MONTHS AFTER AERIAL APPLICATION OF SEVERAL HERBICIDE TREATMENTS

Treatment (kg/ha)	*Mela-stoma*	*Lantana*	*Guava*	*Ohia*	*Staghorn Fern*
picloram 1.5/2,4-D 6	38	38	—	45	65
picloram 3.0/2,4-D 12	88	90	—	53	78
picloram 3	90	95	—	40	38
picloram 6	90	90	—	83	65
picloram 3/fenoprop 9	88	88	80	83	93
picloram 3/2,4-D 9/2,4,5-T 9	75	68	—	73	45
picloram 3/2,4-D 6/2,4,5-T 6	75	46	—	68	92
picloram 4.5/2,4-D 9/2,4,5-T 9	90	90	75	95	90

herbicide spray. Melastoma is relatively easy to control with both contact and systemic herbicides, the latter obviously having the more persistent effect. The susceptibility of melastoma to systemic herbicides is illustrated by the short time taken for 90 to 100% injury to occur and by the percentage control recorded at 22 months (Tables 4 and 5). The high rate of picloram and picloram in combination with 2,4-D, 2,4,5-T and fenoprop provided satisfactory control of melastoma.

Experiment 4

As a result of these trials is was decided to use aerial applications of herbicides as means to control similar brush and to establish pasture on a steep-sided valley (Motooka *et al.*, 1967b). Fenoprop (4.48 kg/ha) was applied to the brush consisting primarily of dense stands of false staghorn fern, melastoma, ohia, guava, pandanus, tree-fern (*Sadleria* sp.), Java plum and hau. The treatment provided good control of guava, pandanus and lantana but the other species showed moderate to little damage. Six months later a second application of fenoprop (4.48 kg/ha) showed a similar response to the first treatment, resulting in 70% control of the brush, a level considered adequate for sowing of pasture species following firing to burn off the heavy layer of dead vegetation. After nearly 3 years of intensive grazing, the resulting pasture is predominantly a mixture of green panic (*Panicum maximum* var. *trichoglume*) and green leaf desmodium (*Desmodium intortum*) with stylo (*Stylosanthes guyanensis*) on the poorer soils of the ridges and spurs. Centro (*Centrosema pubescens*) is rapidly increasing under grazing while glycine (*Glycine wightii*) only appears in the "drip-ring" of dead ohia trees.

A form of biological weed control is being practised in this trial wherein the area has been subdivided, facilitating the forcing of the grazing animal into the remaining weedy areas. This method has been extremely successful in opening up thickets of lantana and guava and allowing the more vigorous legumes and pangola-grass (*Digitaria decumbens*) to invade and take over those one-brush-infested areas.

Among the many attributes of the aerial herbicide method of clearing brush are, first, the possibility of clearing otherwise inaccessible terrain and, secondly, the reduction in risk of erosion once such land is cleared since the tree and brush roots are still physically present to hold the soil.

Experiment 5: Spot Treatment of Granular Herbicides

It was obvious from the previous trial that some form of follow-up treatment of isolated, invading or remaining brush species was a necessary part of the systems approach to such a land clearing, resowing and management programme. In conjunction with the use of the grazing animal to weaken the competition of those weed species, the use of granular formulations of herbicides would reduce the weight and volume problem of transporting and dispensing liquid treatments. With this in mind, trials were set up using a number of granular materials on isolated melastoma and lantana plants (Table 6). Of the 4 chemicals used the two granular formulations of karbutilate (10 and 60%) completely killed lantana after 18 months. However, in a drier location (see Kekaha trial, Kauai), karbutilate was not as effective, whereas picloram (11.2 kg/ha) provided complete kill of lantana after one year but showed poor effect in the wetter area.

Further trials are being conducted on such species as guava and hau using the above herbicides and granular formulations of bromacil, dicamba and monuron/TCA.

Experiment 6: Spot Treatment by Stem Injection

Another method of spot treating isolated stands of woody species is by stem injection of herbicide. A small trial of this nature was conducted on mango (*Mangifera indica*), guava, Java plum, camphor (*Cinnamonum camphora*), hau, koa haole (*Leucana leucocephala*) and strawberry guava. The herbicides

TABLE 6: EFFECTS OF 5.60 kg/ha GRANULAR MATERIALS

Rating Scale: Subjective rating of injury to species is as follows:
1 — No control — no visible damage to plants
3 — Slight control — some defoliation, damage transitory
5 — Moderate control — leaf kill general, regrowth general
7 — Good control — light defoliation, regrowth general
9 — Good control — heavy defoliation, slight regrowth
10 — Complete control — general defoliation

	Months after Treatment				
Treatment	1	2	4	7	16
			Lantana		
karbutilate 10%	2	2	7	9	(10)
karbutilate 60%	2	2	6	7	(10)
bromacil	2	3	3	4	2
atrazine	2	3	3	3	2
picloram	2	3	3	3	2
			Melastoma		
karbutilate 10%	2	3	5	7	2
karbutilate 60%	2	3	4	7	2
bromacil	3	3	4	5	2
atrazine	2	2	3	3	1
picloram	4	4	7	(10)	(10)

used in the injection of these species were 2,4,5-T, 2,4,5-T + 2,4-D, fenoprop, picloram and dicamba.

Table 7 illustrates the levels of effectiveness of the herbicides on the different species after 5 months.

Another trial was set up using direct stem injection and notching with a hand axe followed by spraying into the notches with squirt cans. The objective was to control stands of fire-tree (*Myrica faya*) sufficiently to allow planting and establishment

TABLE 7: RESPONSE OF VARIOUS BRUSH SPECIES TO STEM INJECTION HERBICIDES

Rating scale: 1 to 10, with 1 = no control, and 10 = complete control

	Mango	Guava	Java Plum	Camphor	Hau	Koa Haole	S. guava
2,4,5-T	2	8	7	5	2	—	10
2,4,5-T/2,4-D	2	8	8	10	10	—	—
fenoprop	2	10	6	2	2	6	—
picloram	6	2	10	10	10	—	—
dicamba	3	4	7	4	7	2	—

of forest tree species (Null, 1967; Walter, 1967). Owing to the inability of the workers involved to manipulate the stem injection efficiently, the hand axe method was used throughout the trial. The potassium salt of picloram ("Tordon 22K") was used at the rate of 1 to 3 ml per notch depending on its size. The time spent for chemically treating the area was 44 man-hours/ha.

Ten weeks after treatment significant foliage damage was evident; 77% of the fire-trees treated exhibited complete foliar kill; 21% had less than 30% of their foliage in a green or living state; and 2% showed 60% or more unaffected foliage. Of the guava trees treated, 20% were completely defoliated in 10 weeks, while 65% of the trees showed only 60% defoliation, and 15% had 60% or more of the foliage unaffected. From this it appears that fire-tree is more susceptible to picloram than guava and that the efficacy of the tree injection was below that of the machete and hand axe methods.

Experiment 7: Control of Elephant's Foot

This species has spread rapidly throughout Hawaii and together with *Pseudoelephantopus spicatus* has become widely scattered throughout the Pacific (Nicholls and Plucknett, 1971).

Although *Elephantopus* is not really a brushy species, it is a woody perennial that can grow to a height of 1.2 to 2.1 m and can produce 6 tonnes of dry material per acre. Being a heavily seeding plant, it rapidly invades poorly managed pastures in the moister regions of the tropics and sub-tropics. In Hawaii alone *E. mollis* occupies 12 000 ha of pasture land, reducing the carrying capacity and forage quality of these lands. Thus a trial was set up with the aim of controlling the weed by using a combination of herbicide treatments, mowing and nitrogen fertilization.

The herbicides used were 2,4-D alone and in combination with 2,4,5-T, dicamba and fenoprop. These treatments were superimposed over the mowing and fertilizer treatments.

After 4 months the higher rate of 2,4-D (2.24 kg/ha) + fenoprop (1.12 kg/ha) and 2,4-D (2.24 kg/ha) + 2,4,5-T (1.12 kg/ha) gave similar control of *Elephantopus* (80% on mowed plots and 65% on unmowed plots). Although 2,4-D (2.24 kg/ha) + dicamba (1.12 kg/ha) provided good control (70%) of *Elephantopus*, this treatment severely injured the pasture legume, kaimi clover (*Desmodium canum*), and was therefore not a satisfactory treatment. The effectiveness of the chemical treatments was greatly enhanced when combined with mowing if the *Elephantopus* stand was dense. In this situation the foliage was too thick to allow good penetration of spray material without mowing. If the terrain does not allow mowing, two applications of the herbicide combination would be needed to control heavy stands.

Elephantopus seedling rosettes appear in early autumn. Grazing should therefore be restricted and if sufficient moisture is available nitrogen fertilizer should be applied. These practices will reduce the population of seedlings and subsequent mature plants the following winter.

Experiments at Kekaha, Kauai

In an effort to provide a more favourable environment for wildlife such as birds, pigs and deer by controlling lantana and *Dodonea* species, a trial was set up to test the effect of various liquid and granular herbicide formulations. The area is located 450 m above sea-level and in an area of 750 mm rainfall. The materials used in the first trial were karbutilate (60%), atrazine, bromacil, and picloram granular formulations as well as combinations of 2,4-D and picloram, and fenoprop alone.

Granular picloram at 11.2 kg/ha definitely gave best control of both *Dodonea* and lantana beyond 6 months but was too severe on the grass in the understory. Picloram spray (1.12 kg/ha), however, gave good control of the weed species with little to no damage on the grass.

A second trial has just been set up on a larger scale using helicopter to apply treatments of 2,4-D + picloram, dicamba + 2,4-D, dicamba + 2,4,5-T, 2,4-D, 2,4,5-T, and dicamba. Each treatment was applied to a 0.8 ha plot; their effects will be assessed at 3 weeks, and six months.

Experiments at Hawaiian Ranch Company

As a follow-up to earlier experiments, large trials and commercial applications have been set up on various ranches over the islands to control brush, either to release more desirable pasture species or to clear the land for the resowing of pasture species.

Hawaiian Ranch Company on the island of Hawaii, in cooperation with the University of Hawaii, Ultramar Chemical Company and Murrayair Limited, provided an area of guava and Christmasberry (ranging from 1.3 cm diameter and 0.6 m tall to 20 cm diameter and 6 m tall) with kikuyugrass (*Pennisetum clandestinum*) in the understory. Chemicals used in the trial and aerially applied were mixtures of dicamba and 2,4-D with several different additives such as "Foliar 63" (complete foliar fertilizer 21-21-21 plus chelated minor elements), fenoprop 1.12 and 2.24 kg/ha, cacodylic acid, MSMA, paraquat and "Volck" oil (non-phytotoxic oil).

Four months after application 2,4-D (3.36 kg/ha) + dicamba (1.68 kg/ha) with either "Foliar 63" 8.96 kg/ha, cacodylic acid (3 l/ha), MSMA (10 l/ha) or "Volck" oil (5.6 l/ha) provided the best control of guava while 2,4-D (3.36 kg/ha) + dicamba (1.68 kg/ha) alone gave best control of Christmasberry.

After 9 months dicamba at 1.12 kg/ha + 2,4-D at 4.48 kg/ha appeared to be giving the best overall control although from earlier trials 2,4,5-T instead of 2,4-D would have provided better control of Christmasberry. It appeared that for the small guava and Christmasberry (1.3 to 5 cm diameter and 2 m tall) that control was from 80 to 90%, whereas for the larger brush (8 to 20 cm diameter and 2.3 to 6 m tall) control was only 60% at 9 months. As mentioned earlier, this result may also suggest that a follow-up treatment would be beneficial on this larger brush within 6 to 7 months of the first application.

Experiments at Mokuleia Ranch, Oahu

In 1967, trial plots using 2,4-D and 2,4,5-T + dicamba combinations were aerially applied to guava, Christmasberry, lantana and leucaena brush. Included with these chemicals were additives such as paraquat and MSMA. In stands where Christmasberry was dominant, dicamba (1.12 kg/ha) + 2,4,5-T (2.24 kg/ha) was the best treatment. For species such as lantana and leucaena which lose their leaves easily, the addition of paraquat to the spray mixture resulted in better leaf retention and therefore more effective absorption and translocation of the herbicides. However, for non-abcissing species such as guava, MSMA was more effective in prolonging the activity of the herbicides.

In 1969 a mixture of 2.24 kg 2,4,5-T + 1.12 kg dicamba + 865 ml MSMA + 20 ml of 1% non-ionic surfactant per hectare was sprayed on a large area of guava, Christmasberry, lantana and leucaena followed by burning 6 months later. A seed mixture of green panic, *Dolichos axillaris* and siratro (*Phaseolus atropurpureus*) was sown into the cool ash. After 5 months there was excellent legume establishment and growth with very little brush regrowth.

EXPERIMENTS AT ULUPALAKUA RANCH

Annual application of fenoprop (2.24 kg/ha) + dicamba (1.12 kg/ha) on blackberry has been successful in decreasing the vigour of this weed. Many chemical combinations have been tried on blackberry throughout the islands with limited results.

CONCLUSION

In an attempt to summarize the information gained so far, each species will be treated separately. Guava (*Psidium guajava*) was best controlled by the use of a spray mixture of dicamba (1.12 kg/ha) + 2,4-D (3.36 kg/ha) aided by a penetrant additive. As a stem injection treatment, fenoprop provided adequate control for a scattered stand. Lantana (*Lantana camara*) showed susceptibility to fenoprop (4.48 kg/ha) and a combination of 2,4,5-T (2.24 kg/ha) + dicamba (1.12 kg/ha) in the moist areas but only limited activity with picloram spray (1.12 kg/ha) in the drier regions. Granular materials of picloram (11.2 kg/ha) and karbutilate (5.60 kg/ha) as spot treatments provided complete control of lantana in the wet and dry areas, respectively. Biological control of lantana in Hawaii has been going on for some time and the insect parasite is most effective in the drier regions of the islands. Christmasberry (*Schinus terebinthifolius*) was best controlled by a spray mixture of dicamba (1.12 kg/ha) + 2,4-D (3.36 kg/ha) or by 2,4,5-T (2.24 to 3.36 kg/ha). Java plum (*Eugenia cuminii*) was most susceptible to 2,4,5-T (2.24 kg/ha) + dicamba (1.12 kg/ha). As a stem injection picloram was very effective. *Melastoma malabathricum* was best controlled with a spray mixture of picloram (1.12 kg/ha) + 2,4-D (4.48 kg/ha), fenoprop (4.48 kg/ha) or the granular formulations of picloram (5.60 kg/ha) and karbutilate (5.60 kg/ha). Firebrush (*Myrica faya*) was very susceptible to stem injection of picloram. Elephant's foot (*Elephantopus mollis*) was best controlled by a combination of mowing and spraying with a mixture of 2,4-D (2.24 kg/ha) + 2,4,5-T (1.12 kg/ha). Even though there has been no work using granular or spray formulations on hau (*Hibiscus tiliaceus*), trunk injections of both picloram and 2,4-D + 2,4,5-T mixture can provide control of scattered stands. Steps towards the control of kolomona (*Acacia glauca*) have been purely biological. A naturally occurring fungus of the genus *Cephalosporium* has been isolated and a suspension of the organism was found to be an effective spray for the control of kolomona (Obrero, 1970).

With an accumulation of this type of information, steps can now be taken to fit these control measures into systems of land clearing and subsequent pasture and range management programmes.

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WEED CONTROL IN UPLAND CROPS IN JAPAN USING PLASTIC MULCHING CULTIVATION

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Weed control research in Japan is conducted in four main regions (Fig. 1) which show differences in "weed emergence history", which differ in temperature. Regions 1 and 2 have a cold climate, region 3 a moderate climate and region 4 a warm climate.

The main crops in which a plastic mulching cultivation is practised are vegetables in all the regions, but in recent years its use with upland rice and groundnuts has been increasing. Upland rice is grown largely in region 2, and groundnuts mainly in region 3, though to an increasing extent also in regions 2 and 4.

The plastic mulching technique is used because of the higher yields that result from the consequent increase in soil temperature, conservation of soil moisture, disintegration of soil organic matter, and prevention of soil erosion. These features enabled upland rice and groundnuts to be cultivated in the more northern, cold region in Japan.

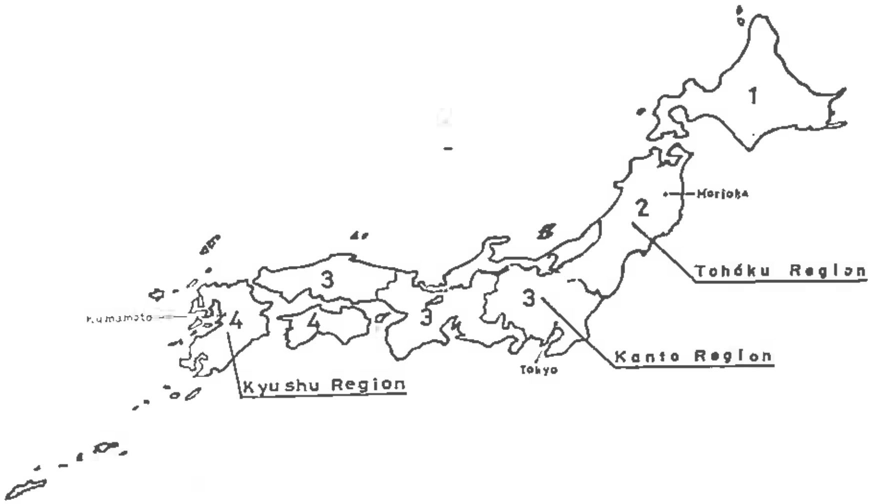

Fig. 1: Regional divisions in Japan.

Air temperatures in spring and autumn in Japan are very low. Figure 2 compares the temperatures of Malaysia, Hawaii, and Japan and Fig. 3 indicates that the monthly precipitation in Japan is between that in Kuala Lumpur and in Honolulu. Consequently, both to raise soil temperature and conserve soil

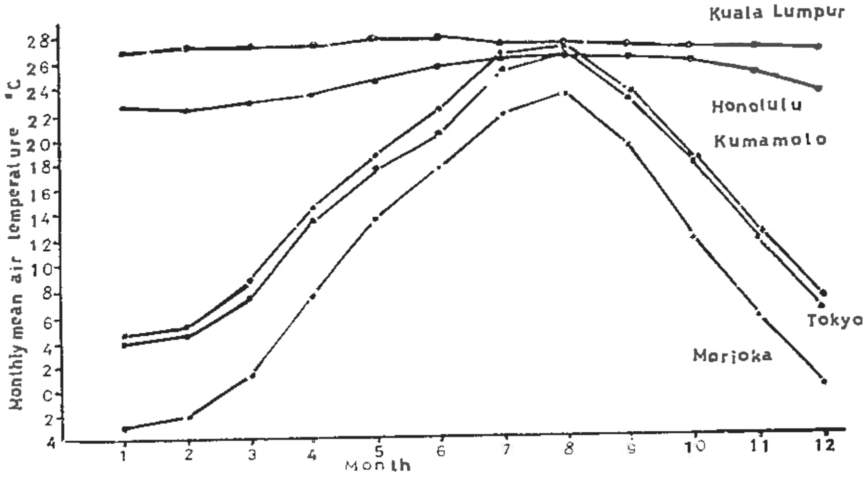

Fig. 2: Monthly mean air temperature in Kuala Lumpur, Honolulu, Tokyo, Kumamoto and Morioka.

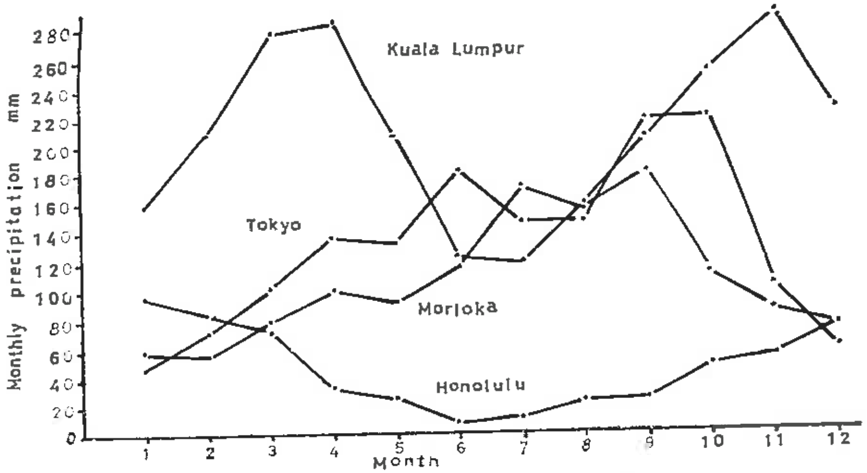

Fig. 3: Monthly precipitation in Kuala Lumpur, Honolulu, Tokyo and Morioka.

TABLE 1: YIELDS OF UPLAND RICE AND GROUNDNUTS
(tonnes/ha)

	Upland Rice (unhulled)	Groundnuts (shelled)
Without plastic mulch	3.00	2.02
With plastic mulch + herbicides	5.22	2.78
With plastic mulch — no herbicides	1.04	0.83

moisture, a clear plasic film is used in Japan, as compared with the black plastic film used in Hawaii to conserve soil moisture and control weeds.

Table 1 illustrates that the use of plastic mulching increased the yield of upland rice by about 70% and groundnuts by about 40%. However, when the plastic was used without herbicides, yields were markedly reduced as a result of injury caused by weeds in the sowing holes.

Clear plastic film mulching has the disadvantage that it encourages early emergence and vigorous growth of the weeds themselves, as Tables 2 and 3 illustrate.

As Table 2 shows, grass weeds such as *Echinochloa crus-galli, Digitaria adscendens*, and *Setaria viridis* become dominant when plastic mulching cultivation is used.

TABLE 2: DIFFERENCES IN GROWTH OF WEEDS, WITHOUT AND WITH PLASTIC MULCH

	Weeds Without Mulch No.	Weeds Without Mulch Weight	Weeds With Mulch No.	Weeds With Mulch Weight
Polygonum blumei	50.0 (29%)	59.6 (40%)	5.0	2.3
Chenopodium album	34.0 (20%)	58.8 (39%)	7.0 (7%)	4.5
Rorippa palustris	11.5 (7%)	10.3 (7%)	1.0	0.5
Commelina communis	3.0	6.8	0.5	0.5
Acalypha australis	8.5	2.0	1.5	0.8
Echinochloa crus-galli	4.0	3.5	—	—
Digitaria adscendens	44.5 (26%)	5.3 (4%)	85.5 (82%)	11.38 (92%)
Setaria viridis	5.0	1.8	2.0	1.3
Others	6.5	1.0	1.5	0.3
Total	172.0 (100%)	149.0 (100%)	104.0 (100%)	123.8 (100%)

Note: Observations made 44 days after mulching on 2 replicates of 30 × 60 cm area.

Broadleaf weeds such as *Polygonum blumei, Chenopodium album, Acalypha australis*, and *Rorippa palustris* are killed by contact with the film which reaches a high temperature (40 to 55° C) and by the damp heat under the film.

Table 3 shows severe weed injury is caused by competition from grassy weeds that multiply plentifully in the sowing holes in the plastic film.

The emergence of a perennial weed, *Pinellia ternata*, is sometimes seen under the film, but it is localized and the plant height

TABLE 3: HEIGHT OF WEEDS IN A SOWING HOLE (cm)

	Without Mulch	With Mulch
Polygonum blumei	23.6	—
Chenopodium album	20.0	—
Echinochloa crus-galli	15.1	28.6
Digitaria adscendens	8.0	17.1

TABLE 4: HERBICIDE TREATMENTS AND CROP YIELD INDEXES

Crop and Treatment (kg/ha)	Weeding Activity* Digitaria ascendens	Weeding Activity* Other Grass Weeds	Weeding Activity* BL Weeds	Weeding Activity* Total	Yield Index†
Upland rice:					
swep WP 4.0‡	0.1	0.0	0.1	0.1	100
swep G. 6.0‡	0.0	0.0	5.4	4.8	99
nitrofen EC 2.0‡	3.8		2.0	2.4	100
butachlor EC 1.0	10.0		8.6	7.2	100
prometryn HF 0.8	0.0		9.9	9.4	102
Corn:					
prometryn HF 0.8	1.0	0.0	0.0	1.0	107
swep WP 4.0‡	3.1		10.4	3.3	97
Groundnut:					
prometryn HF 0.8	8.0		0.0	8.0	104
Soya bean:					
swep WP 4.0‡	3.2		4.6	3.7	102
Sugarcane:					
prometryn HF 0.8	3.0		1.0	2.0	100
Sweet potato:					
credazine WP 1.6‡	2.0		2.0	2.0	98
Potato:					
prometryn HF 0.8	3.0		0.0	1.0	106

*Weeding activity expressed by weight of remaining weeds as percentage of untreated control.
†Yield expressed as percentage of hand-weeded control.
‡Soil surface treatment.

TABLE 5: HERBICIDES SUITABLE FOR PLASTIC MULCHING CROPS

Crop and Treatment (kg/ha)	*Application Time**	*Applicable Soils*	*Applicable Region*
Upland rice†:			
swep WP‡ 4.0	P	Alluvial and	2, 3
swep G‡ 4.5 ~ 6.0	P	diluvial soils	2, 3
nitrofen EC‡ 2.0 ~ 3.0	P	except sandy	2, 3
butachlor EC‡ 0.75 ~ 1.00	P	and sandy loam	2
prometryn HF 0.6 ~ 0.8	M	soils	1, 2, 3, 4
Corn:			
prometryn HF 0.8	M	Diluvial volcanic	2, 3
swep WP‡ 3.8	P	ash soils	2, 3
Groundnut†:			
prometryn HF 0.6 ~ 0.8	M	,,	3
Soya bean:			
swep WP‡ 3.8 ~ 5.0	P	,,	1, 2, 3
Sugarcane:			
prometryn HF 0.8	M	,,	4
Sweet potato:			
credazine WP‡ 1.5 ~ 2.0	P	All soils	3, 4
Potato:			
prometryne HF 0.8	M	Diluvial volcanic ash soils	2

*P = pre-mulch; M = mulch.
†DCPA and propanil are used for foliar treatment in upland rice, and trifluralin for groundnuts.
‡Soil surface treatment.

TABLE 6: EFFECT OF FILM MULCHING ON WEED GROWTH

	Film			
	C	*C-7*	*C-1*	*BK*
Digitaria adscendens:				
No. of plants	91	88	86	7
Total DW (mg)	283	220	139	3
DW per plant	3.2	2.4	1.5	0.4
Portulaca oleracea:				
No. of plants	109	88	57	21
Total DW (mg)	105	35	10	2
DW per plant	0.98	0.39	0.18	0.07
Cyperus serotinus:				
No. of plants	63	71	60	20
Total DW (mg)	91	77	30	1
DW per plant	1.5	1.1	0.5	0.1

Note: The experiment was with plastic boxes in a PVC film house. Seeds were sown on 26 May and observations made 20 days after sowing. The figures above are the means of three boxes.

is low, so that it causes mild injury. However, the mulching film is lifted by the early emergence of the weed, and so conditions beneath the film become favourable for the multiplication and growth of other weeds, and in addition the rate of soil temperature rise is reduced. It is therefore necessary to control both grass weeds and *Pinellia ternata*. Four methods are used in Japan — soil surface treatment, foliar treatment, the use of "herbicidal film" and the use of transparent green film. These weed control methods will be discussed below.

Table 4 illustrates the weeding activities of herbicides used with plastic mulching cultivation. These weeding activities are very high and almost no crop injury was observed. Of note are the granular formulation of swep for upland rice and the prometryn "herbicidal film" (HF) for some crops. The volatility of swep was put to practical use. Prometryn "herbicidal film" is a film in which a fixed quantity of prometryn is dissolved in the polyethylene at 140 to 150° C during manufacture. In use, the prometryn dissolves out into the condensation drops that form on the film. This herbicidal film has given good results, though when used in a cold spring in regions 1 and 2 some rice plant injury was observed.

Table 5 lists herbicides suitable for plastic mulching and conditions for their application.

To determine the properties of mulching film in providing effective soil temperature increases and weed control, a study

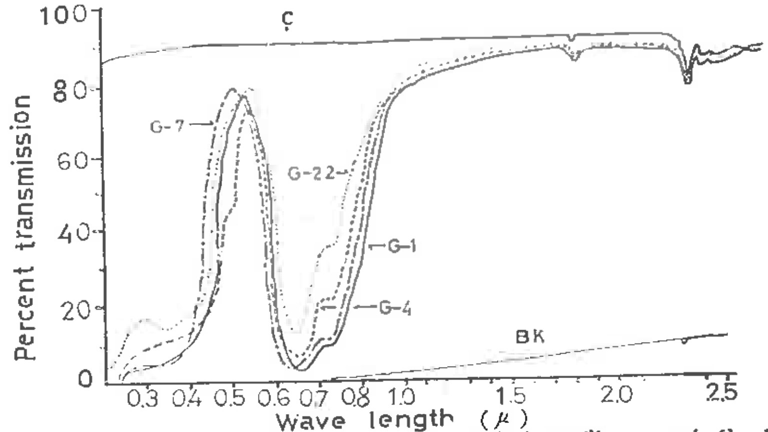

Fig. 4: Transmission spectra of 0.02 mm polyethylene films used. C, clear; G-1, light green; G-4, deep green; G-7, dark blue-green; G-22, light blue-green; BK, black.

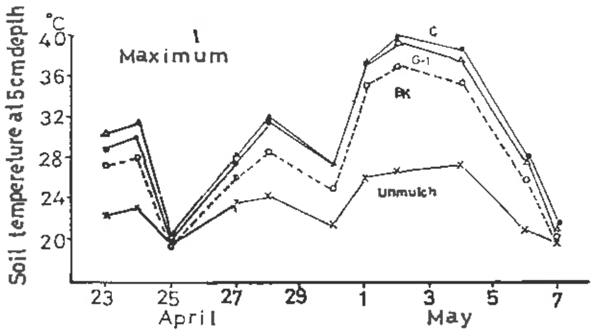

Fig. 5: Effect of film mulching on soil temperature at 5 cm depth below mulch.

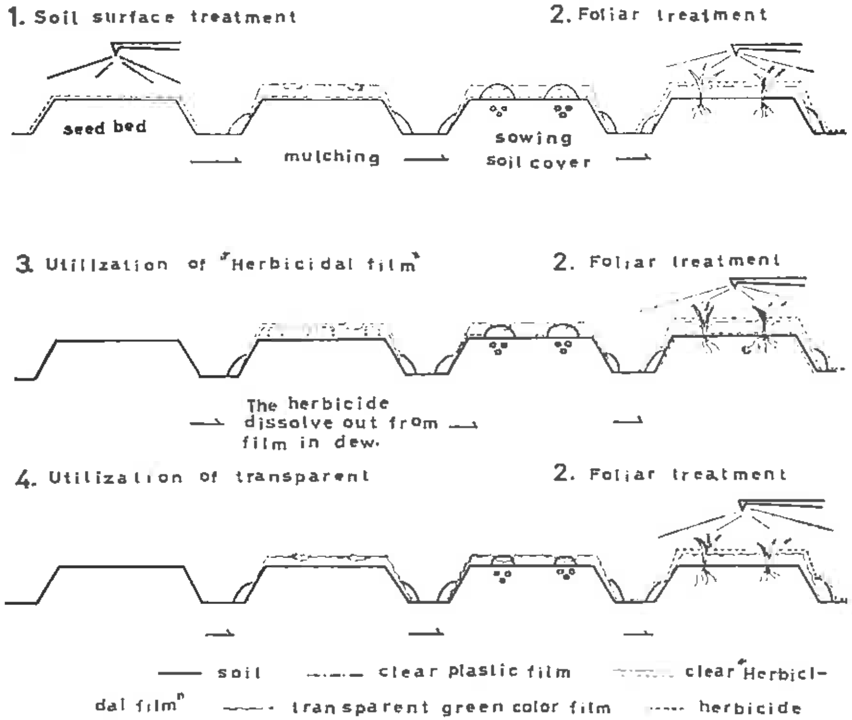

Fig. 6: Systematized weed control methods using plastic mulch in Japan.

was made of the transmission spectra of films and the wavelength dependence of weed growth.

A clear polyethylene film is very effective in raising the soil temperature but encourages weed growth; a black film, almost opaque to solar radiation, has just the reverse effect. The effectiveness of coloured films was therefore investigated by one of the writers. It was observed that the germination or growth of weeds was most inhibited under green light illumination as compared with other colours. Green films can transmit green and near infrared light but are almost opaque to the blue and red regions of the spectrum which are necessary for photosynthesis by the weeds.

Transmission spectra of the polyethylene film examined are given in Fig. 4, and, Fig. 5 shows the effects on the soil temperature at 5 cm depth of clear, black, and green film mulchings and non-mulchings. There is almost no difference in soil temperature increase using G-1 film or clear film. The effects of the different film mulchings on weed germination and growth are illustrated in Table 5. Inhibition of the germination of *Portulaca oleracea* was observed to be more severe with G-1 film than with G-7 film mulch, and weed growth was more inhibited by G-1 film than by G-7 film mulch.

As these films do not contain any herbicides, there is no crop injury. The green films have the ability to suppress weed growth, but have no phytotoxicity. For complete weed control, it is therefore necessary to use an effective herbicide in conjunction with the plastic mulch.

None of the four weed control methods discussed is used on its own, but combinations of the methods are employed in plastic mulching cultivation as illustrated in Fig. 6. These combinations include soil surface treatment/foliar treatment. herbicidal film/foliar treatment, and transparent green colour film/foliar treatment. The two latter methods give the desired results, but the most effective foliar treatment for each crop must be established.

HERBICIDAL ACTIVITY OF AMCHEM A-820, A NEW SUBSTITUTED DINITRO ANILINE

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Summary

Cotton has shown excellent tolerance of A-820 even at rates up to 6.72 kg/ha. The rate required to control weeds can be doubled and sometimes tripled without affecting cotton yields or quality. In Mississippi and other southern states, California and Arizona, 1.12 to 3.36 kg/ha (depending on soil type) controlled crabgrass (*Digitaria sanguinalis*), barnyard grass (*Echinochloa crus-galli*), seedling johnsongrass (*Sorghum halepense*), foxtail (*Setaria faberii*), signal grass (*Brachiaria platyphylla*), fall panic grass (*Panicum dichotomiflorum*), pigweed (*Amaranthus retroflexus*), purslane (*Portulaca oleracea*), lambsquarters (*Chenopodium album*), and prickly sides (*Sida spinosa*).

Results have been good with A-820 applied in the autumn as a pre-plant incorporated treatment for spring-planted cotton. For full growing season control of annual grasses and broadleaf weeds the following year, the normal spring application rate should be increased by one-quarter or one-half. This treatment has repressed growth of established johnsongrass.

The general margin of safety between weed control and general vegetable crop injury appears to be very good to excellent. The rate advisable for most vegetable crops is about 1.68 to 2.24 kg/ha.

The following vegetable crops tolerated at least 1.68 kg/ha of A-820: direct-sown tomatoes; snap, lima, red kidney, and mung beans; cantaloupes and watermelons; okra; spinach; squash; transplanted tomatoes, peppers, sweet and white potatoes, broccoli and cabbage. In general, watermelons and cantaloupes have been more tolerant than cucumbers, but the reverse was true under cool Pennsylvania conditions.

Direct-sown tomatoes and peppers seem to be slightly more sensitive than transplants, which showed little or no effect at rates up to 6.72 kg/ha. Direct-sown tomatoes tolerated 3.36 kg/ha.

A-820 shows excellent promise for use in transplanted rice giving excellent control of barnyard grass and other weeds at rates of 0.63 to 1.5 kg/ha. Tests to date indicate application should be made 3 to 7 days after transplanting the rice. Transplanted rice tolerance to A-820 treatment appears excellent.

INTRODUCTION

A-820 is the Amchem Products, Inc., designation for a new herbicide of the dinitro aniline class. The material is stable, has a melting point of 59-60° C and is orange. It has a solubility of 188 ppm in water and is readily soluble in many organic solvents.

A-820 is essentially non-volatile at 50° C. Laboratory volatility studies measured loss from the technical chemical on a dry surface. When water was added to the test dishes in the laboratory, there were significant losses as A-820 co-distilled with the water. Under field conditions apparently volatility is determined by soil moisture and moist soil would require soil incorporation.

A-820 has been formulated as a liquid and as a granule. The liquid formulation (Amchem 70-25) is a 40% emulsifiable concentrate. The formula was not broken by temperatures below 0° C, but storage below −4° C should be avoided. Various granular formulations have been prepared on different type matrices. Materials of 4 and 10% have been prepared on attaclay and 2.3 and 4% on vermiculite.

Various application methods were studied. Pre-plant power incorporation 5 to 8 cm deep gave the best weed control. However, under very dry soil conditions in irrigated areas, biological activity was very similar with either pre-emergence or pre-plant incorporation.

Weed control may be reduced by low temperature, as observed in trials conducted in Oregon on peas and lentils. Weed control was poorer when A-820 was applied early in the growing season than when applied later when temperatures were higher.

TOXICITY

A-820 has very low mammalian toxicity, but ordinary precautionary measures for handling any pesticide are advised. The toxicity of A-820 unformulated and as Amchem 70-25, the principal formulation tested in 1970, appears below.

Unformulated *N*-sec-butyl-4-tert-butyl-2,6-dinitro aniline has the following mammalian toxicities:

Acute oral, young albino rats — LD_{50} = 12,600 mg/kg
Acute dermal, albino rabits — LD_{50} = 10,200 mg/kg
Eye irritation, albino rabbits — 10.0/110 (mild irritant)

Toxicity studies of A-820 formulated as 40% emulsifiable concentrate show:

Acute oral, albino rats — LD_{50} = 2,500 mg/kg
Acute dermal, albino rabbits — LD_{50} = 4,600 mg/kg
Acute aerosol inhalation, albino rats — LC_{50} = 50 mg/l air (four hour exposure)
Eye irritation, albino rabbits — 64.0/110 (extreme irritant)
Fish: bluegills, TL_{50} = 4.2 ppm; trout, TL_{50} = 3.4 ppm

MATERIALS AND METHODS

The horticultural crops tested at Amchem Research Farm in Ambler, Pennsylvania, were Black Valentine snapbeans, Fordhook 242 lime beans, red kidney beans, Campbell 29 tomatoes, Yolo Wonder peppers, Waltham 29 broccoli, Marian Market cabbage, Early Fortune cucumbers, Hales Best Jumbo cantaloupes and New Hampshire Midget watermelons.

Weed species evaluated included redroot pigweed (*Amaranthus retroflexus*), common ragweed (*Ambrosia artemisiifolia*), velvetleaf (*Abutilon theophrasti*), wild mustard (*Brassica kaber* var. *pinnatifida*), common lambsquarters (*Chenopodium album*), tall morningglory (*Ipomoea purpurea*), Pennsylvania smartweed (*Polygonum pennsylvanicum*), common purslane (*Portulaca oleracea*), and giant foxtail (*Setaria faberii*).

A-820 was applied at rates of 1.68, 2.80 and 3.9 kg/ha with a bicycle sprayer in a volume of 450 l/ha. All plots were rotovated 5 to 8 cm deep within 30 min after application. Plot sizes were 2.4 by 3.05 m and 2.4 by 6.1 m, two rows per crop and 3 to 4 replications. Planting and evaluation dates are shown in Table 1.

The vegetable crops under test at the Amchem Research Farm in Greenville, Mississippi, were Burpee Long Green cucumbers, Hale's Best cantaloupes, Dixie Queen watermelons, Pinto beans, Henderson's lima beans, Early Ramshorn southern peas, kidney beans, mung beans, Pink Ponderosa tomatoes and California Wonder peppers.

Weed species evaluated included redroot pigweed, common lambsquarters, morningglory (*Ipomoea* sp.), barnyard grass (*Echinochloa crus-galli*), johnsongrass (*Sorghum halepense*), crabgrass (*Digitaria sanguinalis*), broadleaf signalgrass (*Brachiaria platyphylla*), teaweed (*Sida* sp.), and coffeeweed (*Sesbania exaltata*).

A-820 was applied at various rates with a tractor sprayer in a volume of 180 l/ha of water. All plots were rotovated 5 cm deep.

In cotton tests at the Amchem Research Farm in Mississippi, A-820 formulated as a 40% emulsifiable concentrate was evaluated on the following weeds and grasses in field-size plots containing 14 rows 29.3 m long: pigweed, morningglory, barnyard grass, johnsongrass seedlings, crabgrass, broadleaf signalgrass, teaweed, coffeeweed and purslane. Autumn and spring applications were tested on Sharkey clay, a medium clay loam and a light sandy loam soil. The rates of A-820 used in the fall application were 4.48 and 2.24 kg/ha for the heavy and medium soils and 2.24 kg/ha for the medium and light sandy loam soils. The spring application rates were 4.48, 3.36 and 1.68 kg/ha of A-820, respectively, on the heavy clay, medium soil and sandy loam soils. The sprays were applied in 190 l/ha of carrier. Areas for both the spring and autumn applications were double disced and hipped up. After the spring treatment, the beds were knocked down and the cotton planted. The area treated in the autumn was bedded in autumn and the beds knocked down and planted in the spring.

Rates, also, were studied at the Greenville, Mississippi, Amchem Farm. A-820 was applied at 0.56, 0.84, 1, 1.68, 2.24, 4.48 and 6.72 kg/ha. The plots contained two 21 m rows. A-820 was applied by a tractor sprayer at 190 l/ha and incorporated by a power driven tilrovator set 8 cm deep. The test was replicated four times on a light sandy loam soil. Seedling johnsongrass, crabgrass and broadleaf signalgrass were present. There was nutsedge (*Cyperus rotundus*) in most plots.

A-820 was evaluated under furrow and sprinkler irrigation on the Amchem Research Farm in Visalia, California. In a series of trials A-820 was applied at 1.12, 2.24, 4.48 and 6.72 kg/ha. The chemical was immediately incorporated with a disc in some trials and a power incorporator in other trials. After treatment, crops and weeds were planted into the areas immediately, 2, 4, 8, 16 and 24 weeks later. Areas awaiting planting were kept moist by sprinkler or furrow irrigation. Observations were made on pigweed, barnyard grass, foxtail (*Setaria* sp.), ryegrass (*Lolium* sp.), and sugarbeet (*Beta vulgaris*).

In Japan, 1.5 and 3.0 kg/ha of A-820 was applied to rice 3 and 6 days after transplanting into 60 × 60 cm concrete pots. Observations were made on rice tolerance and control of *Monochoria vaginalis* and *Eleocharis acicularis*. In a second trial, 1.0 and 1.4 kg/ha of A-820 was applied as a 4% granule to a rice paddy 3 and 6 days after transplanting the rice. *Echinochloa* sp., *Monocharia vaginalis, Elatine triandra* and *Cyperus difformis* were the weed species evaluated for control.

RESULTS AND DISCUSSION

Table 1 is a summary of annual broadleaf weed and annual grass control and crop injury ratings at the Amchem Research Farm, Ambler, Pa. The rating system is 0 to 100; 0 represents no control or no crop injury and 100 represents complete kill of weeds or crop.

In eight tests, annual broadleaved weed and annual grass control averaged 75 and 95% respectively at 1.68 kg/ha. Watermelons and cucumbers were slightly stunted. Later observations indicated vigorous growth and normal fruit production.

In seven tests at 2.80 kg/ha, broadleaved weed and grass control were 82 and 98%, respectively, with slight stunting of cucumbers and moderate stunting of watermelons. Later observations indicated that cucumbers had completely recovered. Watermelons continued to show growth inhibition.

In four tests at 3.92 kg/ha, broadleaved weed and grass control was 83 and 98% respectively. Transplanted tomatoes were

TABLE 1: ANNUAL WEED CONTROL AND CROP SELECTIVITY WITH PREPLANT INCORPORATED TREATMENTS OF A-820, AMCHEM RESEARCH FARM, AMBLER, PA., 1970

Crop	Date Planted	Rate (kg/ha)	% Weed Control Broadleaves	% Weed Control Grasses	Crop Injury*	Date Rated
Direct-sown:						
Snapbeans	May 4	Jun. 18	1.68	86	90	0
			2.80	85	95	0
			3.92	90	98	0
Lima beans	May 12	Jun. 19	1.68	82	95	0
			2.80	83	97	0
			3.92	85	100	0
Red kidney beans	May 15	Jun. 22	1.68	58	100	0
Cucumber	Jun. 17	Jul. 17	1.68	70	90	5
			2.80	80	100	5
Cantaloupe	Jun. 25	Jul. 24	1.68	86	97	0
			2.80	90	98	0
Watermelon	Jun. 25	Jul. 24	1.68	86	98	10
			2.80	91	98	30
Transplanted:						
Tomatoes	May 21	Jun. 21	1.68	67	98	0
			2.80	71	100	0
			3.92	75	100	8
Peppers	May 21	Jun. 21	1.68	67	98	0
			2.80	71	100	0
			3.92	75	100	8
Broccoli and Cabbage	May 28	Jun. 25	1.68	67	90	0
			2.80	77	100	0
			3.92	83	100	0

*Rating system: 0-100: 0 = no control or crop injury. 100 = complete kill of weeds or crop.

slightly stunted, but there was no detrimental effect on yield. Lower rates had no effect on vegetative growth.

Table 2 shows the average weed control by species in the nine separate tests at the Amchem Research Farm, Ambler, Pa. The numbers in parentheses represent the number of tests in which the species was abundant enough to rate.

At 1.68 kg/ha there was excellent control of redroot pigweed, lambsquarters, Pennsylvania smartweed, purslane and giant foxtail. Control of velvetleaf, wild mustard and tall morningglory was not commercially acceptable. Ragweed was not controlled.

At 2.80 kg/ha there was excellent control of tall morningglory in addition to the excellently controlled species mentioned above. Wild mustard control was commercially acceptable and velvetleaf marginally acceptable. Ragweed was not controlled.

At 3.92 kg/ha there was excellent control of all species listed in Table 2 except wild mustard, which showed very good control, and ragweed, which was tolerant.

TABLE 2: PERCENTAGE WEED CONTROL BY A-820 INCORPORATED PREPLANT. AMCHEM RESEARCH FARM, AMBLER, PA., 1970

Species	A-820 (kg/ha) 1.68	2.80	3.92
Redroot pigweed	96% (8)*	96% (7)*	98% (5)*
Common ragweed	0 (9)	0 (8)	0 (6)
Velvetleaf	63 (3)	77 (3)	92 (1)
Wild mustard	61 (5)	85 (4)	88 (4)
Common lambsquarters	99 (8)	99 (7)	99 (8)
Tall morningglory	79 (6)	92 (5)	96 (3)
Pennsylvania smartweed	93 (6)	98 (5)	98 (6)
Common purslane	90 (1)	— —	100 (1)
Giant foxtail	93 (9)	98 (9)	99 (9)

*Number of tests in which species was rated.

Although barnyard grass population was spotty, control appeared to be excellent in all the tests.

Table 3 is a partial summary of 1969 and 1970 trials at the Amchem Research Farm in Greenville, Mississippi. Southern peas and various type beans all showed good tolerance of A-820. Increasing the rate from 2.24 to 3.36 kg/ha increased crop phytotoxicity only slightly. In one trial at 6.72 kg/ha the injury to lima, pinto and mung beans was rated 0, 15 and 0%, respectively. Under the warm growing conditions of the South, 1.12 kg/ha controlled weeds adequately.

TABLE 3: SUMMARY OF CROP INJURY AND WEED CONTROL IN A-820 SCREENING TRIALS. AMCHEM RESEARCH FARM, GREENVILLE, MISSISSIPPI. 1969 AND 1970

Crop or Weed	*% Injury or Control Rate (kg/ha)* 0.56	1.12	1.68	2.24	3.36
Southern peas	0	0	—*	15	20
Lima beans	0	0	0	15	0
Snapbeans	0	0	—	10	25
Pinto beans	—	0	0	15	25
Sunflower	—	0	0	0	0
Kidney beans	—	0	0	0	0
Mung beans	—	0	0	0	15
Peppers†	—	0	0	0	0
Tomatoes†	—	0	0	0	0
Okra	0	0	0	—	—
Crabgrass	70	100	98	100	99
Seedling johnsongrass	70	100	98	100	99
Signalgrass	75	100	98	100	95
Pigweed	—	95	95	95	100

*Rate not used in any of the trials.
†Transplants.

Cucurbit tolerance was determined in replicated trials (Table 4). The Southern data are somewhat different from the data produced in the Northeast. Watermelons showed complete tolerance. Cucumbers were injured slightly more than the cantaloupe. The observations in Table 4 were made 33 days after planting. At rates up to 2.24 kg/ha cantaloupe and cucumber stunting was temporary. Growth was very good and a heavy crop was produced, but yields were not taken. No selectivity among annual grasses was noted in these trials, thus signalgrass, johnsongrass, crabgrass and barnyard grass are grouped as "grass".

TABLE 4: THE EFFECT OF 0.84 TO 4.48 kg/ha OF A-820 ON THE GROWTH OF CUCURBITS AND WEEDS. AMCHEM RESEARCH FARM, GREENVILLE, MISSISSIPPI, 1970

Rate (kg/ha)	*Crop Injury* *Watermelon*	*Cantaloupe*	*Cucumber*	*% Control* *Pigweed*	*Grass†*
0.84	7	0	3	91	92
1.12	0	7	25	92	97
1.68	0	30	58	100	97
2.24	0	92	80	100	99
4.48	0	93	93	100	100
0*	10	57	13	55	40

*Tractor cultivated check.
†Signalgrass, johnsongrass, crabgrass, barnyard grass.

Table 5 summarizes the cotton trial results, broadleaf weed and grass control as well as average yields from both spring and fall applications of A-820 on all three soil types. The 4.48 kg/ha rate applied to Sharkey clay more than 5 months prior to planting produced excellent weed control. Cotton stands were not good in the checks or the treated plots. Cotton growth was not affected by 4.48 kg/ha of A-820. As can be seen from the cotton yield figures as well as the weed and grass control ratings, 2.24 kg/ha of A-820 applied to a medium clay loam soil in the fall is not a satisfactory treatment. Residual weed control was good at time of planting, but "broke" between planting and date of evaluation. These results suggest that a 3.36 kg/ha rate would be required for sufficient persistence on medium clay soil to produce good weed control from fall applications. The cultivated check yields are very low, reflecting a high weed and grass infestation. There was no hoed check in this test. The 2.24 kg/ha rate on sandy loam produced excellent results. Weeds were controlled and the cotton yield was over 2,240 kg/ha.

Table 6 shows the average grass control ratings and cotton yields from 4 replications. This test was on a light sandy loam soil. There was no injury to the cotton at the highest rate of A-820 applied. Grass control was satisfactory on this soil type at 0.84 kg/ha of A-820. The 1.68 kg/ha rate produced excellent weed control and excellent yields. Rates of 1.68 kg/ha and above maintained weed control throughout the growing season.

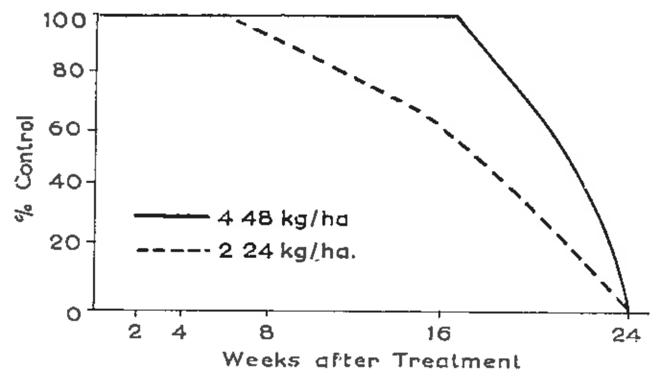

Fig. 1: Rate of A-820 disappearance from moist soil. Weed control level averaged from disc and power incorporation trials. Percentage control is average of pigweed, barnyard grass, ryegrass, foxtail and volunteer sugarbeet.

TABLE 5: RESULTS OF AUTUMN AND SPRING PRE-PLANT INCORPORATION STUDY WITH A-820 ON COTTON*

Rate (kg/ha)	Soil Type	Cotton	Pigweed	Seedling Johnson grass	Crabgrass	Brachiaria	Coffee Weed	Barnyard Grass	Teaweed	Cotton (kg/ha)
4.48	Sharkey clay	0	98	99	99	95	80	95	85	2075
2.24	Medium clay	0	75	70	70	65	65	65	40	977
Check	Medium clay	0	0	0	0	0	0	0	0	32
2.24	Sandy loam	0	100	100	99	95	95	95	80	2495
Check	Sandy loam	0	0	0	0	0	0	0	0	194
4.48	Sharkey clay	0	100	100	100	—	65	100	80	1101
Check	Sharkey clay	0	0	0	0	0	0	0	0	242
3.36	Medium clay	0	99	99	100	100	60	95	60	1512
1.68	Sandy loam	0	100	95	100	100	—	93	55	637
Check	Sandy loam	0	0	0	0	0	0	0	0	25

*Treated and planted 12 May, 1970; evaluated 19 June, 1970; variety Stoneville 213. Weed and crop rating scale: 0 = no injury; 100 = complete kill.

TABLE 6: ANNUAL WEED CONTROL AND COTTON SELECTIVITY WITH PPI TREATMENTS OF A-820. AMCHEM RESEARCH FARM, GREENVILLE, MISSISSIPPI

(Average of 4 replications)

Rate (kg/ha)	% Control Seedling Johnsongrass	Crabgrass	Brachiaria	Cotton Yield (kg/ha)
0.56	65	84	84	1320
0.84	88	94	89	2256
1.12	78	94	85	2888
1.68	94	99	95	3825
2.24	97	99	95	4375
4.48	97	99	98	3659
6.72	95	100	98	3989
Weedy check	0	0	0	578
Clean check	99	99	99	2888

Planted and treated 13 May, 1970; evaluated 15 June, 1970; variety: Stoneville 213. Weed and crop rating scale: 0 = no injury; 100 = complete kill.

A number of other unreplicated trials were run in Mississippi, Arkansas, Louisiana and Tennessee; results were very encouraging. Weed control was equal or superior to the standard pre-emergence or pre-plant incorporated chemical used by the co-operator. The cotton was carried to maturity and harvested. The quality appeared to be unaffected by the A-820 treatment. In one test site, teaweed was a severe problem. A-820 was superior to the standard pre-plant incorporated treatment plus a post-emergence chemical treatment, especially for teaweed control.

In the California trials, furrow and sprinkler irrigation produced almost identical results on crops and weeds in plots treated with 1.12 to 6.72 kg/ha of A-820. Figure 1 summarizes the results obtained in a considerable number of experiments. At the Visalia, California, Amchem Research Farm, a number of factors appeared to produce little or no difference and could be pooled to plot the activity and disappearance of A-820 from the moist soil. Thorough disc incorporation gave weed control equal to that obtained in the power incorporation trials. With the 2.24 and 4.48 kg/ha rates of A-820 application, there were no differences from the sequential plantings of 0, 2 and 4 weeks; weed control was 100%. At 8 weeks, the 2.24 kg rate began to break and at 16 weeks average weed control was reduced to about 60%. In 24 weeks, the 2.24 kg/ha rate of the A-820 appeared to have been inactivated. The 4.48 kg rate of A-820 maintained 100%

weed control for 16 weeks, and then effectiveness decreased very rapidly with an average of only 8% weed control for the 24-week planting.

In the trials where the soil was treated with A-820 and then kept dry without irrigation, A-820 showed no loss during the 24-week period. This result was true for surface-applied or incorporated A-820. Under these conditions there was no indication of volatility, photo-decomposition or microbial breakdown of A-820.

Trials conducted in Japan with A-820 on transplanted rice show very encouraging results. Table 7 shows the results of A-820 applied 3 and 7 days after transplanting the rice into concrete pots. Control of barnyard grass was excellent at 1.5 and 3 kg/ha; moderate to good control was obtained on *Monochoria vaginalis* and *Eleocharis acicularis*, respectively. There was no observable injury to the rice.

TABLE 7: OBSERVATIONS 35 DAYS AFTER TREATMENT WITH A-820. JAPAN, 1970

Rate (kg/ha)	*DAT**	% Weed Control: Echinochloa *sp.*	Monochoria vaginalis	Eleocharis acicularis	*Other*	*Injury to Rice*
1.5	3	100	50	80	80	0
3.0	3	100	50	50	80	0
1.5	7	100	50	80	100	0
3.0	7	100	50	80	100	0

*Days after transplanting.

In a tolerance test, 1.5, 2.5 and 5.0 kg/ha of A-820 applied 8 days after transplanting had no significant effect on the height, tillering or weight of the treated rice plants compared with untreated controls, nor was there any variation with or without leaching.

A-820 applied as a 4% granular formulation on transplanted rice at rates of 1.0 and 1.4 kg/ha of A-820, 3 and 6 days after transplanting, gave very good to excellent control of barnyard grass. Control of *Monochoria vaginalis, Elatine triandra* and *Cyperus difformis* was fair to good. Again, no effect on the rice was noted. Results are reported in Table 8.

In another trial on weeds found in upland rice, A-820 at 0.63 kg/ha completely controlled *Echinochloa* sp., *Digitaria adscendens* and *Chenopodium album*. At 1.25 kg/ha complete control of *Cyperus microiria* and *Portulaca oleracea* was obtained. These weeds had been severely reduced by the lower rate. Rice

TABLE 8: WEED CONTROL AND TOLERANCE OF TRANSPLANTED RICE WITH 4% GRANULAR A-820. JAPAN, 1970

Rate (kg/ha)	*DAT*	*% Weed Control: Grass*	*Broadleaf*	*Rice Plant Growth: Height (cm)*	*No. of Tillers*
1.0	3	75	80	58.1	26.0
1.4	3	99	43	58.6	22.0
1.0	6	100	73	60.7	21.0
1.4	6	89	64	57.8	24.0
Control	—	0	0	60.5	22.7

was not injured by 1.25 kg/ha, the highest rate of A-820 in this trial.

Echinochloa sp. and *Cyperus difformis* were controlled by the 0.63 kg/ha rate in paddy weed trials and stands of *Monochoria vaginalis* and *Rotala indica* were reduced by the rate, *Monochoria* being completely controlled by the 1.25 kg/ha rate.

STUDIES ON CONTROL OF NUTSEDGE (*CYPERUS ROTUNDUS*) DURING SUMMER FALLOWS IN RED LOAMS

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INTRODUCTION

Nutsedge (*Cyperus rotundus*) is a common weed in red loams of Tamilnadu State, and its persistence in the soil is quite well known. Earlier investigations by the writers (1968) had shown that control of this weed for short periods is possible with herbicides like dicamba, diuron, EPTC and simazine during summer fallows. However, in field trials with crops like cotton and onion, control of nutsedge was not satisfactory with the triazines and ureas. In fact, the weed became more dominant in such situations with the suppression of other species by the herbicides. It was, therefore, considered necessary to test these herbicides in established infestations of nutsedge, since the earlier studies were made in weed stands with freshly planted tubers. Four herbicides, namely, diuron, EPTC, MSMA and simazine, were included in the studies, and the trials were laid out in fallow plots infested with nutsedge for nearly two years.

MATERIALS AND METHODS

The trials were conducted at the Agricultural College and Research Institute, Coimbatore, during 1969 in red loams with nutsedge infestation, under irrigation conditions during the summer fallow season (April-July). The plots measured 2.5 × 1.5 m, replicated four times. The treatments were:

(1) Hand-weeding (control), once at the start of the experiment

(2) Diuron (pre-emergence), at 2.5 kg/ha

(3) EPTC (pre-emergence), at 6.6 kg/ha

(4) MSMA (post-emergence), at 2.0 kg/ha

(5) Simazine (pre-emergence), at 2.5 kg/ha

The spray volume was maintained at 250 l/ac (or 625 l/ha) and surfactants were not added to any of the herbicides except MSMA, which includes wetters in the formulation.

The green shoot counts were recorded from the entire plots at weekly intervals for a total period of 13 weeks (three months). The fresh weight of the green shoots and count of tubers from different regions (0-15 cm, 15-30 cm and 30-45 cm) in the soil were also recorded. Bioassay studies were made using field bean (*Dolishos lablab*) and cotton (*Gossypium* sp.) to assess the residual effects of the herbicides in the soil.

RESULTS

Green Shoot Counts

The weekly populations of green shoots were expressed as a percentage of the initial counts in each treatment (Table 1), and as a percentage of the hand-weeded control (Table 2). These were reduced to 100% to enable the precise and convenient evaluation of the relative merits of the different treatments.

The observations on the performance of the individual herbicides are as follows:

Diuron

The highest green shoot counts (145 to 282% on control) was recorded with diuron. From the beginning of the experiment, the trend was the same. The tuber counts further substantiated this increasing trend.

EPTC

The only herbicide recording low green shoot counts up to the last week (2 to 10%) was EPTC.

TABLE 1: WEEKLY GREEN SHOOT COUNTS (MEAN OF FOUR REPLICATES) EXPRESSED AS PERCENTAGE OF INITIAL COUNTS (IC)

		Weeks												
Treatment	*IC*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Control	100	43	63	82	98	110	131	152	188	279	333	366	368	355
diuron	100	131	132	257	267	277	316	324	331	591	604	629	608	571
EPTC	100	6	6	6	6	7	. 5	7	7	6	7	9	7	13
MSMA	100	100	9	11	22	107	154	220	224	221	218	217	217	203
simazine	100	41	75	89	95	100	114	123	145	374	412	452	373	441

TABLE 2: WEEKLY GREEN SHOOT COUNTS (MEAN OF FOUR REPLICATES) EXPRESSED AS PERCENTAGE OF CONTROL

		Weeks												
Treatment	*IC*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
Control	100	100	100	100	100	100	100	100	100	100	100	100	100	100
diuron	100	274	189	282	245	226	217	192	162	191	163	155	149	145
EPTC	100	146	10	7	6	6	4	5	4	2	2	2	2	3
MSMA	100	165	10	10	16	69	83	103	85	56	47	42	42	41
simazine	100	91	113	104	92	86	82	77	73	124	120	117	96	118

MSMA

This herbicide killed the aerial shoots within a fortnight after spraying and kept down the regrowths throughout the trial period. The weed check, though not as convincing as that with EPTC, was better than that in the control (hand-weeding). diuron and simazine plots. But for a short period spell between the 6th and 9th weeks, the weed growth was less than control (10 to 56%, where control recorded 100%).

Simazine

Simazine was as ineffective as diuron in established nutsedge stands. For most of the trial, green shoot counts exceeded the control and even the minimum was 73% in the eighth week. The effect of the chemical in reducing the vigour of the weed is discussed under shoot weight.

SHOOT WEIGHT

The final shoot weight was recorded just before digging for collection of tubers. EPTC recorded the maximum shoot weight per plant (0.71 g), followed by diuron (0.42 g), control (0.40 g), simazine (0.37 g) and MSMA (0.35 g).

The poor stand of the weeds, four plants per square metre, in the EPTC plots might have enabled the weeds to grow competition-free and show the highest weight of weeds of the herbicide treatments. The inhibitory effect of simazine and MSMA on the growth of weeds might be the reason for the reduced shoot weight, while the fact that diuron weights were very close to control, might indicate that there was no effect of this chemical on the weed.

TUBER PRODUCTION

The production and distribution of tubers were studied at the end of the 13th week, and the following observations were made (see Table 3).

The maximum number of tubers was found in diuron-treated plots, followed by the simazine and EPTC plots. The least number was noted in the MSMA plot which recorded even lower than control.

TABLE 3: DATA ON THE PRODUCTION AND DISTRIBUTION OF TUBERS (MEAN OF FOUR REPLICATES) EXPRESSED AS PERCENTAGE OF CONTROL

	Tuber Production (%)				Tuber Distribution (%) on Total*			
Treatment	*0-15 cm*	*15-30 cm*	*30-45 cm*	*0.45* cm*	*0-15 cm*	*15-30 cm*	*30-45 cm*	*0-45* cm*
Control	100.0	100.0	100.0	100.0	32.8	42.5	24.7	100.0
diuron	190.2	185.6	123.4	166.7	39.9	41.2	21.9	100.0
EPTC	118.0	128.9	135.6	128.4	31.5	42.4	25.1	100.0
MSMA	29.3	117.2	91.4	81.5	11.8	51.2	37.0	100.0
simazine	188.2	149.0	93.1	144.9	46.7	43.4	9.9	100.0

*The total number of tubers produced in each treatment.

The distribution pattern indicated that, in general, most of the tubers produced (74-90%) were concentrated in the first and second (0-15 and 15-30 cm) zones, and particularly in the 15-30 cm depth containing 41 to 51% of tubers. About one-third of the total tubers (32-37%) were in the first zone and the rest (22-26%) in the deeper zones (30-45 cm). Very low tuber counts were noted in the first zone in MSMA, with 51% and 37% in the second and third zones, respectively. In simazine plots, just 10% of the tubers were seen in the third zone and the maximum number (47%) in the first zone.

The concentration of tubers in different regions seemed to be influenced by the herbicides as can be seen from Table 3.

The maximum concentration of tubers was in the first zone in simazine, in the second and third zones in MSMA plots. Likewise, the minimum number of tubers was in the first zone of MSMA, in the second zone of diuron and simazine. Control plots showed 75% tubers in the first and second zones (33% and 42%, respectively) with the rest (25%) in the third zone.

Bioassay Studies

Bioassay studies made with the seeds of cotton and beans dibbled in the treated plots, *in situ*, and the end of the trials indicated that EPTC and MSMA were slightly phytotoxic to beans for a month. The bean leaves were wilted and the plant stunted in the bean plant. Diuron proved phytotoxic to beans for a period of four months, and the bean plants did not survive beyond one week after their germination. Simazine was highly phytotoxic to both cotton and bean, even after six months. The symptoms of wilting appeared in about a week's time and in another fortnight the plants completely withered.

DISCUSSION

In general, EPTC and MSMA were better than control in recording lower weed counts (green shoots). Diuron produced the maximum, EPTC the minimum green shoots throughout the experimental period. Simazine plots showed fluctuating trends.

Among the herbicides, EPTC incorporated in the soil gave the best check of the weed for a continuous period of 13 weeks, but did not reduce the tuber production that increased 36% over control. Thus, the temporary inhibiting effect of the herbicide was evident, preventing the sprouting of the tubers. This delaying effect of the herbicide was also noted by Horowitz (1965).

The next best herbicide was MSMA. With this, the weed stand was lower than control throughout the trial period. However, compared with the initial stand of the same plot, the green shoot counts had more than doubled by the end of the 13th week (see Table 1). Such increases were noted by Long *et al.* (1962) in Bermuda turf, treated with arsenicals for nutsedge control. This was further confirmed by Holt *et al.* (1967) who attributed it to the apical dominance system in the nutsedge tuber, inducing multiple sprouts. The tuber counts with MSMA recorded the lowest figure (81%) compared with control and the top zone contained the minimum of tubers (12% of total). This decrease is a good sign, since the potential top zone was fairly devoid of the tubers.

Simazine, despite its check of aerial shoots during the first five weeks, was not very satisfactory. The top zone contained 47% of the total tubers produced. In addition, the persistence of the chemical for prolonged periods in the soil (six months) was a disadvantage.

Diuron was the most discouraging among the herbicides tried, since both green shoot counts and tuber production were the maximum, registering 145% of green shoots and 167% of tubers, compared with control (100%) in both. Moreover, the potential top zone had the largest number of tubers in this plot.

In conclusion, the use of EPTC as a pre-emergence soil-incorporated herbicide appears to be the best for red loams, and the next best would be MSMA for post-emergence treatments.

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RATE OF BREAKDOWN AND RESIDUAL TOXICITY OF SODIUM CHLORATE AND ALACHLOR IN SOIL*

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INTRODUCTION

Post-emergent herbicides like sodium chlorate have been applied very widely to control weeds in rubber plantations in West Malaya (Rubber Res. Inst., 1967; Pushparajah, 1970). Some pre-emergent herbicides may also be applied, especially where cash cropping is practised. The residual effects of these herbicides applied either to rubber tree rows or to cash crops are, therefore, of great importance, but little information is now available in this country.

Many workers (Aslander, 1928; Loomis *et al.*, 1933; Crafts, 1939b; Schwendiman, 1941) have studied the breakdown of sodium chlorate in soils. The importance of temperature and moisture on the decomposition rate had also been demonstrated. They have, however, worked with rates of sodium chlorate that were frequently much higher than the application rate commonly used in rubber cultivation.

This paper, which presents some results from an investigation on the breakdown and residual toxicity of sodium chlorate and alachlor in a silty clay soil of Germany as influenced by different temperatures under glasshouse conditions, may therefore provide some relevant data.

MATERIALS AND METHODS

A silty clay soil was collected from the 0-5 cm layer in the field. It was air-dried and passed through a 5 mm sieve. The soil data are given in Table 1. The soil was mixed thoroughly with the respective herbicides — *i.e.*, sodium chlorate (99% a.i.) at 100 ppm and alachlor (emulsifiable concentrate 48% a.i.) at

*This study was conducted during postgraduate training at the Institute for Plant Protection, University of Hohenheim, Federal Republic of Germany.

TABLE 1: SOIL DATA

pH (KCl): 6.9	
Organic carbon: 3.22%	
Fine silt (0.0063-0.002 mm): 35.4%	
Clay (< 0.002 mm): 28.4%	
Cation exchange capacity —	
Total exchangeable cations incl. hydrogen	= 17.5 me/100 g soil
	= 14.7 me/100 g soil
NO_3-nitrogen = 115.7 ppm	
Total P_2O_5 = 360 ppm	
Total K_2O = 240 ppm	

10 ppm. All rates were calculated on oven-dried weight basis. Water was added to bring the moisture content in the soil to about 16.5% by weight. The soil was filled into containers which were kept at either 12, 25 or 35° C in a "Wisconsin Installation". The tops of the containers were covered with a sheet of black polythene to keep light out and to minimize water evaporation. A pump facilitated the circulation of water at a constant temperature in the installation. A check after 2 months showed very little water loss and no additional water was supplied during the remaining course of the experiment. Soil samples were taken out at intervals and stored at —25° C until they were chemically analysed for herbicide residues. For the determination of sodium chlorate, the method suggested by Roth (1967) was adopted. The test consisted of releasing available chlorine through the following reaction with concentrated hydrochloric acid:

$$NaClO_3 + 6HCl = NaCl + 3H_2O + 3Cl_2$$

With the addition of ortho-tolidine, a yellow colour was developed and its intensity was measured in a spectrophotometer.

The test for alachlor (P. L. Berthet, pers. comm.) involved the extraction with acetonitrile, dissolving the residue of the extract in *n*-hexane and estimation by gas-liquid chromatography.

In addition, soil samples were taken out at two weekly intervals for a biotest with hybrid sorghum var. Sioux. The soil was immediately filled into pots (400 g soil/pot) and 12 seeds per plot were planted just below the soil surface. Treatments were replicated three times. Overhead watering was carried out. After one week, the plants were selectively thinned to 10 plants per pot and, at two weeks, the fresh weights of above-ground plant parts were recorded. For a comparison, standard sprayed controls from untreated soil were prepared simultaneously with the above biotests.

RESULTS

Residue Analysis

Recovery values for the chemical determination of residues in the soil were 85% for 20 ppm sodium chlorate and 76% for 0.1 ppm alachlor.

The logarithm of the percentage residual concentrations relative to the original concentration was plotted against time in days after application. The relationship is shown to be linear and the correlation coefficient is highly significant. This indicates that the breakdown of the herbicides occurred according to a first-order reaction — *i.e.*, within the limits of the concentrations in the experiment, the time required for a certain percentage of the existing concentration to degrade is constant.

Increase of temperature from 12 to 25° C brought about a much faster rate of breakdown in both herbicides. For sodium chlorate, however, an increase of temperature from 25 to 35° C did not result in a faster breakdown.

Alachlor decomposed faster than sodium chlorate in soil and their half-lives in days were calculated as follows:

	12° C	*25° C*	*35° C*
Sodium chlorate	117	22	23
Alachlor	22	7	

PLANT TOXICITY

Preliminary experiments were conducted to find a suitable test plant. The response of garden cress (*Lepidium sativum*), oats (*Avena sativa* var. Flamings Krone) and hybrid sorghum to the herbicides was observed. Sorghum was selected because of its sensitivity to the lower concentrations even though it was not so responsive at the higher rates.

Sodium Chlorate

At 12° C, not much reduction in toxicity with time was shown. At the higher temperatures, toxicity was reduced rapidly, and it was found that at 35° C no reduction in plant weight could be detected when sorghum was planted 53 days after treatment. At 25° C, no significant reduction in plant weight was observed after 68 days.

Alachlor

Here again, little reduction of toxicity with time was observed at 12° C. At 25° C, however, plant toxicity was reduced rapidly and sorghum planted 68 days after the herbicidal application showed no difference in weight between treated and the control.

Although controls were carried out throughout the investigation, much variation in growth was found between the different sets of sprayed and unsprayed controls. This was due mainly to insufficient control of the glasshouse conditions. Therefore, no attempts are made here to estimate herbicidal concentration in the soil through interpolation with the standard sprayed controls.

DISCUSSION

In rubber areas, sodium chlorate applications often are usually carried out at intervals of two and a half months or more. Owing to its solubility and leachability (Rosenfels and Crafts, 1941; Pushparajah, 1970) and to its rate of breakdown in warmer regions, it is not likely that build-up to toxic levels can occur. Where cash crops are planted in rubber inter-rows, movements of sodium chlorate may occur to affect the crops. In this case the resistance of the crops may be increased through the application of nitrogen or easily decomposed organic material (Bowser and Newton, 1935; Crafts, 1939a). A combination of nitrogen application and seed inoculation was found to have the same effect on a legume crop (Haines, 1933).

Although alachlor is not easily leached in the soil (Eshel, 1968), its rapid rate of breakdown makes it a convenient herbicide for use where crop rotation is practised, provided the duration of weed control is sufficient. For weed control in rubber, a chemical with longer lasting herbicidal properties will be required.

It must be noted that the conditions under which this investigation was carried out are very different from those in the field, where the loss of herbicides from the soil is influenced by a complex of factors (Hartley, 1964).

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R-7465, A NEW NAPHTHOXY HERBICIDE

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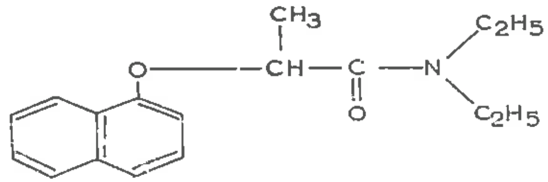
Summary

R-7465 is a new pre-plant incorporated or pre-emergence herbicide. In past years, in trials in the U.S.A., Canada, Europe and Asia, a number of economic crops showed high tolerance to R-7465. The tolerant crops include tobacco, potatoes, tomatoes, oil seed rape, certain other species of brassicas, sweet potatoes, sunflowers, grapes, citrus and deciduous fruits, while cotton, peanuts, and lima beans showed variable tolerance. At rates from 2 to 4 kg/ha, R-7465 exhibited excellent activity against most annual grass weeds and many annual broadleaf weeds. In some tests, when soil-incorporated at rates of 4 kg/ha or higher, it also killed or retarded the growth of certain perennial weed species such as *Cyperus rotundus, C. esculentus, Cynodon dactylon* and *Agropyron repens*. The mammalian toxicity of R-7465 is very low. It is relatively stable and persists in the soil for a reasonable period of time even under high temperature and high rainfall conditions. The effectiveness of R-7465 is increased by soil incorporation. When combined in the spray tank with contact herbicides such as paraquat, R-7465 showed promising weed control in orchard and tropical plantation crops.

INTRODUCTION

R-7465 has the following structure:



The technical grade is a brown/pink crystalline powder with a melting point of 69.5° C, and molecular weight of 271.36. Water solubility is 73 ppm at 20° C. It is soluble in acetone and ethanol but only slightly soluble in most other common organic solvents including kerosene, ether, benzene, and chloroform.

Toxicity data for standard tests are as follows:

Mammalian Tests		*Technical*	*50 WP*
Acute oral LD_{50}, male rats	....	4640 mg/kg	4640 mg/kg
Acute oral LD_{50}, female rats	....	4640 mg/kg	4640 mg/kg
Acute dermal LD_{50}, rabbits	....	4640 mg/kg	4640 mg/kg
Acute ocular irritancy	....	Non-irritating	
Acute dermal irritancy	....	Non-irritating	
Fish Test			
Goldfish LC_{50}, 96-hr exposure		10.0 ppm	

Bioassays showed that R-7465 disappeared slowly in most soils. A leaching column test, run by a Japanese co-operator in a volcanic ash soil, revealed that a precipitation of 6 cm in two days moved R-7465 2 to 2.5 cm, while "Dimid" moved 3.5 to 4 cm and alachlor moved 3 to 3.5 cm. Field persistence tests conducted in California and Florida indicated that, 4 to 7 months after pre-plant incorporation at 6.7 kg/ha, sufficient material remained in the soil to cause damage to susceptible crops grown in rotation. Applications made in the autumn prior to winter weed germination controlled the winter weeds and the summer weeds in the following summer. Precautions must be taken when rice, oats and other small-seeded crops in the grass family are planted following a tolerant crop treated with R-7465. Lower dosage shortened the duration of an effective soil residue. Large-seeded crops in the grass family, such as corn, are tolerant to R-7465 at dosages of 0.5 to 1 kg/ha.

A wettable powder containing 50% active ingredient by weight is the standard formulation. However, a granular formulation is under study and may soon be available for field evaluation.

APPLICATION METHODS AND RATES

Structurally, R-7465 is related to auxins of the naphthoxy type which cause malformation of broadleaf weeds. However, R-7465 does not show these hormonal-type symptoms and, especially important, it is more active on grass weeds than on broadleaf weeds. R-7465 is more effective when incorporated into the soil 4 to 8 cm deep than when applied as a pre-emergence surface treatment. Its herbicidal activity was reduced by photodecomposition after one week's exposure to sunlight on the surface of dry soil. Thus, in order to be effective when applied pre-emergence to the soil surface, it must be carried into the soil by either rainfall or by irrigation, preferably within one week after application.

Therefore, in arid areas it is recommended that R-7465 be incorporated into the soil mechanically or by irrigation. In areas of frequent and high rainfall under subtropical or tropical conditions, R-7465 should work well when applied pre-emergence as a surface treatment without further effort.

In addition to the application methods mentioned above, a convenient method using drenching has been developed for Asian countries. This is somewhat tedious but practical for application in small vegetable patches. Vegetable growers in Asian countries water their vegetable beds frequently by pouring water from a container. R-7465 wettable powder can be added to the water at a dilution rate of 1:2000 and the chemical applied without extra time or labour as the vegetable beds are watered.

Application rates of R-7465 vary, depending on the crop, soil type, method of application and other factors. Generally speaking, application by soil incorporation requires a lower rate than application to the soil surface. Rates as high as 6 kg/ha are used for weed control on established perennial crops such as fruit trees. Under vinyl mulch such as used in Japan, slightly lower rates are recommended. Appendix 3 suggests rates of application for various crops, weeds, and situations.

Field application volumes vary with the type of spray equipment. A volume of 200 to 800 l/ha is recommended. An even distribution of the herbicide over the treated area is essential for both weed control and crop safety. Since R-7465 is primarily a pre-emergence herbicide, it will not control the existing weeds. Prior to the application of R-7465, an established weed population must be destroyed by mechanical means or by a directed post-emergence herbicide. A spray of R-7465 at field strength will not damage the foliage of tolerant transplanted crops.

RESULTS OF FIELD STUDIES

R-7465 has been tested in field trials for four years in many countries around the world. The following test results are just a few examples of the efficacy of R-7465 in controlling weeds in different crops, under various conditions.

SOLANACEOUS CROPS

Trials on several solanaceous crops were carried out in Italy, Yugoslavia, Canada, the U.S. and Taiwan.

In numerous potato trials, mostly in the U.S., R-7465 exhibited excellent control of annual grass weeds and good broadleaf weed

TABLE 1: WEED CONTROL AND CROP TOLERANCE IN A FIELD TRIAL OF R-7465 ON TRANSPLANTED WINTER VEGETABLES IN TAIWAN

Treatment (kg/ha) 27 Oct., 1970	*Application Methods**	*% Weed Control at 20 days*		*% Weed Control at 50 days*		*Fresh Weed wt. at 107 days*		*Crop Tolerance†*
		Grasses	*Bdleaf*	*Grasses*	*Bdleaf*	*kg/10 m*	*Index %*	
R-7465 3.5	PPI	99	95	99	90	1.56	12.9	No injury
R-7465 3.5	POD	100	95	100	95	0.92	7.6	"
R-7465 3.5	PPS	100	95	99	90	1.18	9.8	"
alachlor 2.5	PPS	95	90	85	80	6.81	56.6	"
Control	....	0	0	0	0	12.04	100.0	"

*Application methods:
PPI — Pre-plant, soil incorporated 5 cm deep by rake.
POD — Post-transplant drench (dilution rate 1:2000) by sprinkler can.
PPS — Pre-plant soil surface spray.
†Crop tolerance: Transplanted tomatoes, eggplant, bell peppers and cauliflower grew normally in all treated plots.

control at rates of 2 to 4 kg/ha pre-plant incorporated. Trials in Florida, U.S.A., in soil which contained 97% sand indicated no loss of potato yield at dosage rates as high as 8 kg/ha.

In trials on transplanted tobacco in Italy, Yugoslavia, Canada and the U.S., R-7465 applied pre-plant incorporated performed favourably in comparison with standard herbicides. Superior annual grass and broadleaf weed control, longer residual effectiveness, and greater selectivity were obtained. Other solanaceous crops, including direct-sown and transplanted tomatoes, peppers and eggplant, showed good tolerance to R-7465.

Results of a trial on transplanted winter tomatoes, eggplant, peppers, and cauliflower, conducted by the Department of Horticulture, National Taiwan University, are shown in Table 1.

Weed species in check plots included the following:

Family and Species	*% of Total Weed Population**
Compositae	
Soliva anthemifolia	30
Caryophyllaceae	
Stellaria elusine	10
Labiatae	
Leucas mollissima	6
Caryophyllaceae	
Stellaria aquatica	3
Chenopodiaceae	
Chenopodium ficifolium	2
Scrophulariaceae	
Mazus japonicus	2
Cruciferae	
Capsella bursa-pastoris	1
Cardamine flexuosa	1
Gramineae	
Eleusine indica	15
Alopecurus aequalis	10
Digitaria chinensis	10
Setaria viridis	3
Poa annua	1
Echinochloa crus-galli	1
All others	5

*Average of four readings.

Treatments were applied 27 October and fresh weed weight was measured 12 February 1971. During this period of 107 days, a total of 482 mm of rain fell. The average temperature during this period was 16.2° C.

Cruciferous Crops

Ludwig (1968) screened R-7465 on oil seed rape at a rate of 4.5 kg/ha pre-emergence in England in 1967 with promising results, and used it at 0.56, 1.1, and 2.2 kg/ha pre-emergence in large trials. In 1968, 2.2 kg/ha gave good control of *Stellaria media*, the predominant weed, with no crop damage.

Trials in France in 1968 on autumn-sown rape established the tolerance of this crop. In a treatment using 1.4 kg/ha pre-plant incorporated, R-7465 gave good to excellent control of *Alopecurus myosuroides*, *Matricaria* spp., *Chenopodium album*, *Veronica* spp., *Papaver* rhoeas and *Galium aparine*. Crop tolerance was excellent.

In the United Kingdom, Holroyd (1968) screened R-7465 in several drill-sown brassica crops including brussels sprouts, kale, rutabagas, and cauliflower. Good weed control without crop damage was obtained at rates of 1.1 to 2 kg/ha applied pre-emergence.

Trials in the U.S.A. indicated that transplanted cabbage, broccoli and cauliflower showed good tolerance to R-7465 either incorporated or applied to the surface of the soil. In other trials, direct-sown brassicas, including radish, kale, turnips, collards, cabbage, broccoli and cauliflower, showed greater tolerance to pre-emergence surface applications than to soil-incorporated applications. Data from Europe indicated that pre-emergence surface applications gave generally good and consistent weed control at relatively low rates of 1 to 2 kg/ha. However, in the U.S.A., consistent results required pre-plant soil-incorporated applications at rates of 2 to 4 kg/ha.

Further work, especially in Asia, is necessary to determine rates, methods of application and crop tolerances.

Tree and Bush Fruits

Studies on annual crops indicated that R-7465 was active for a relatively long time and controlled a wide spectrum of weeds. Consequently a number of trials on perennial crops were conducted in the U.S.A. Phytotoxicity studies in California showed that newly planted almonds, plums, apricots and peaches had excellent tolerance to R-7465 at rates up to 18 kg/ha applied pre-emergence followed by flood or basin irrigation. In this trial a total of 15 standard and experimental compounds were compared. At the rate of 18 kg/ha, R-7465 was the safest material in the group.

Limited trials on citrus in Florida showed that 5-year-old orange trees were tolerant to R-7465 at rates up to 22.3 kg/ha applied pre-emergence followed by overhead irrigation. A rate of 4.5 kg/ha gave fair broadleaf weed control after one month; residual control of grasses was still apparent after 5 months.

Control of Perennial Weeds

The control and suppression of several perennial weed species including *Cynodon dactylon*, *Cyperus rotundus*, *C. esculentus*, *Rumex* spp., *Agropyron repens*, and *Sorghum halepense*, were not uncommon in laboratory and field trials. An example of results obtained in greenhouse trials against perennial weeds is shown in Table 2.

TABLE 2: PERCENTAGE CONTROL OF PERENNIAL WEEDS BY R-7465 IN GREENHOUSE TESTS USING PRE-PLANT INCORPORATION

R-7465 (kg/ha)	Cyperus esculentus *(tubers)*	Agropyron repens *(rhizomes)*	Sorghum halepense *(rhizomes)*	Rumex crispus *(seeds)*
0	0	0	0	0
0.56	75	80	60	65
1.1	85	100	80	65
2.2	85	100	95	90
4.5	95	100	99	90

In Florida, sprinkler irrigation, applied after pre-emergence surface application of R-7465, increased the control of *Cyperus esculentus* from zero, where no irrigation was applied to 95% where 10 cm of water was applied. Control of *Cynodon dactylon* has followed similar patterns.

In laboratory trials, Parker *et al* (1969) obtained control of *Cyperus rotundus* tubers planted in soil treated with 1.1 kg/ha R-7465. More than 60% reduction in vigour was experienced for at least 2 to 4 weeks. It was concluded that R-7465 might be successful for *Cyperus* control in solanaceous crops.

Some of the studies indicated that perennial sedges and grasses were controlled or suppressed when R-7465 was applied in the soil prior to the emergence of the new shoots from tubers and rhizomes of the weeds.

Combinations With Other Herbicides

Increased and prolonged weed control effects were obtained with combinations of R-7465 at rates from 0.5 to 1 kg/ha plus a corresponding 3/4 to 1/2 portion of the recommended separate rates of thiocarbamate herbicides on major crops as follows:

Irish potatoes	R-7465 + EPTC
Peanuts and soya bean	R-7465 + vernolate
Tomatoes and tobacco	R-7465 + pebulate
Corn	R-7465 + butylate

For weed control in plantation crops and in citrus groves, where heavy weed populations exist, a fast-acting contact herbicide can be combined effectively with R-7465. In a citrus grove at Chung-Hsiung University, Taiwan, R-7465 at a rate of 3.5 kg/ha either following a treatment of paraquat or tank mixed with paraquat, gave good weed control for 2 months under high rainfall conditions.

Other Crops

A number of other crops showed good tolerance to R-7465 applied pre-emergence or pre-plant incorporated and further investigations are warranted (Stauffer, 1971 and unpubl. data). These include lima beans, asparagus, peanuts, English peas, okra, sunflower, sweet potatoes, green beans, forests, sugarcane and many tropical plantation crops. Cotton has shown variable tolerance to R-7465 in U.S.A. In California, cotton was not injured when R-7465 was incorporated pre-plant at 3 kg/ha, but 6 kg/ha caused injury. Cotton in Spain treated with R-7465 at rates of 4 to 5 kg/ha pre-plant incorporated showed good weed control, without crop injury.

In 1971, the field test programme for R-7465 includes Japan, Korea, Taiwan, the Philippines, and Malaysia. The crops include tobacco, tomatoes, peppers, bananas, pineapples, sugarcane, tea, oil palm, eggplant, forest nurseries, orchards, and cocoa. No final results are available at this time. The interim results indicate that R-7465 is giving good control of most annual grass and broadleaf weeds without phytotoxicity at rates of 3 to 4 kg/ha.

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APPENDIX 1

Weed Species Controlled by R-7465

1. Annual Grasses

Bluegrass, annual *(Poa annua)*
Brome, ripgut *(Bromus rigidus)*
Canarygrass *(Phalaris canariensis)*
Crabgrass, hairy *(Digitaria sanguinalis)*
Crabgrass, smooth *(Digitaria ischaemum)*
Crowsfootgrass *(Dactyloctenium aegyptium)*
Cupgrass, southwestern *(Eriochloa gracilis)*
Foxtail, giant *(Setaria faberii)*
Foxtail, green *(Setaria viridis)*
Goosegrass *(Eleusine indica)*
Johnsongrass seedling *(Sorghum halepense)*
Lovegrass *(Eragrostis* spp.)
Panicum, Texas *(Panicum texanum)*
Ryegrass, annual *(Lolium multiflorum)*
Signalgrass *(Brachiaria platyphylla)*
Volunteer barley *(Hordeum vulgare)*
Watergrass/barnyard grass *(Echinochloa* spp.)
Wild oats *(Avena fatua)*

2. Annual Broadleaved Weeds

Beggarweed, Florida *(Desmodium tortuosum)*
Carpetweed *(Mollugo verticillata)*
Chickweed, common *(Stellaria media)*
Cudweed *(Gnaphalium* spp.)
Dogfennel *(Eupatorium capillifolium)*
Filaree, redstem *(Erodium cicutarium)*
Groundsel, common *(Senecio vulgaris)*
Henbit *(Lamium amplexicaule)*
Knotweed *(Polygonum* spp.)
Lambsquarters *(Chenopodium album)*
Lettuce, prickly *(Lactuca scariola)*
Malva *(Malva parvifolia)*
Nettle, burning *(Urtica urens)*
Nettle, small stinging *(Urtica dioica)*
Pigweed, redroot *(Amaranthus retroflexus)*
Pineappleweed *(Matricaria matricarioides)*
Puncturevine *(Tribulus terrestris)*
Purslane *(Portulaca* spp.)
Purslane, Florida *(Richardia scabara)*
Ragweed *(Ambrosia* spp.)
Red Maids *(Calandrinia ciliata)*
Rocket, London *(Sisymbrium irio)*
Shepherdspurse *(Capsella bursa-pastoris)*
Smartweed *(Polygonum* spp.)
Sowthistle, annual *(Sonchus oleraceus)*
Spurge, spotted *(Euphorbia maculata)*

3. Perennial Weeds

Bermudagrass (rhizomes) *(Cynodon dactylon)*
Johnsongrass (rhizomes) *(Sorghum halepense)*
Nutgrass, purple *(Cyperus rotundus)*
Nutgrass, yellow *(Cyperus esculentus)*
Quackgrass (rhizomes) *(Agropyron repens)*

APPENDIX 2

Crops Tolerant to R-7465

1. Annual Crops

Asparagus (established)
Broccoli (seed and transplants)
Brussels sprouts (seed and transplants)
Cabbage (seed and transplants)
Cauliflower (seed and transplants)
Collards
Eggplant
English peas
Irish potatoes
Lima beans
Oil seed rape
Peanuts
Peppers (seed and transplants)
Radish
Safflower
Sunflower
Tobacco (transplants)
Tomatoes (seed and transplants)
Turnips
Watermelons

2. Perennial Crops

Almonds
Apples
Apricots
Caneberries
Cherries
Figs
Grapes
Lemons
Limes
Nectarines
Olives
Oranges
Peaches
Pears
Persimmons
Pineapples
Plums
Pomegranates
Prunes
Quinces
Sugarcane
Walnuts (English and Black)

3. Crops of Unknown Tolerance under Investigation

Bananas
Cocoa
Coconuts
Coffee
Macadamia nuts
Mangos
Oil palm
Papayas
Rubber
Tea

APPENDIX 3

Suggested Application Methods and Rates

Suggested Methods of Application

1. *Horticultural and Agronomic Crops*

(a) Pre-plant incorporated. Incorporate* to a depth of 2 to 5 cm within 2 days of application.
(b) Pre-emergence surface: Apply to soil surface immediately after sowing and follow with sprinkler irrigation (1 to 3 cm), if no rainfall occurs within 2 days.

2. *Tree Fruits, Vines, etc.*

(a) Preplant incorporated: Incorporate* to a depth of 2 to 5 cm within 7 days of application. (Do not place treated soil directly on bare roots.)
(b) Surface application after planting or to established plants†: Apply to weed-free soil surface (if weeds are present at time of application, tank mix with a contact herbicide) and follow with irrigation (1 to 3 cm) if no rainfall occurs within 7 days.

Suggested Rates of Application

1. *When Used Alone:*

(a) Horticultural and agronomic crops: 1 to 2 kg active ingredient per broadcast (overall) hectare for annual weeds.
(b) Tree fruits, vines, and ornamentals: 3 to 6 kg active ingredient per broadcast (overall) hectare for annual weeds and 4 to 8 kg active ingredient for perennial weeds.
(c) Rights-of-way, fence-lines, industrial, etc.: 10 to 20 kg active ingredient per broadcast (overall) hectare.

2. *When Combined as a Tank Mix with Thiocarbamates*

(a) Rate: 0.5 or 1 kg/ha of R-7465 plus a corresponding 3/4, or 1/2 part of the recommended rate of the thiocarbamate.
(b) Crops and combinations:
Irish potatoes — R-7465 + EPTC
Peanuts — R-7465 + vernolate
Soya beans — R-7465 + vernolate
Tomatoes — R-7465 + pebulate
Tobacco — R-7645 + pebulate
Corn — R-7465 + butylate

3. *When Combined as Tank Mix with Paraquat*

R-7465, 3 to 5 kg/ha as a tank mix with diluted paraquat at the recommended concentration.

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*Use equipment which will mix the R-7465 into the top 2 to 5 cm of soil.
†Applications made in the fall prior to winter weed germination will control the winter weeds and the summer weeds the following summer.

ACCUMULATIVE RESIDUAL EFFECT OF SOME PERSISTENT HERBICIDES ON WEEDS AND CROPS IN MULTIPLE CROPPING AREAS

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Summary

Accumulative residual effect of some persistent herbicides, *s*-triazines and diuron, were investigated in the field and in water-table-controlled beds with two crops yearly, during 1967-1970. Simazine and diuron were repeatedly applied in corn alone on the same plot every crop by pre- and by post-emergence spray, respectively. Hand-weeding and non-weeding were used as checks. The accumulative residual effects could more or less be inferred by the increased effectiveness in the weed control by the same dose of the two herbicides in the successive crops and years. They could more easily be demonstrated by the growth and yield of the crop and by a bioassay using milk vetch *(Astragalus sinicus)*. The latter was very sensitive to both diuron and simazine. The plant heights of corn were gradually reduced by diuron application from 99.5% (initial effect) to 57.0% (accumulative residual effect after the 7th application), and the grain yields from 80.6 to 47.3% of hand-weeding. However, there was little, if any, accumulative residual phytotoxicity to corn by simazine treatment to which the plant heights were from 99.4 to 96.5% and grain yield from 102.5 to 103.7%. Five water-tables were controlled in concrete beds at 0, 20, 40, 60 and 80 cm with soil moistures of 34.7 to 48.5, 29.4 to 43.9, 23.4 to 26.9, 21.3 to 26.5 and 19.3 to 25.4%, respectively. Simazine, atrazine, prometryn and simazine/prometryn were applied separately in the rotational crops from corn to peanut. The two bioassay crops, milk vetch and wheat, were planted after peanut in winter. The weed control and phytotoxic effects both increased adversely as the soil moisture decreased. Moreover, the accumulative residual effect tended to increase after every application of *s*-triazine, particularly in the lower soil moisture ones. Milk vetch was also very sensitive, while wheat and peanut were more tolerant to the accumulative phytotoxicity of *s*-triazines.

INTRODUCTION

Some persistent herbicides, *s*-triazines and substituted ureas, give excellent weed control in Taiwan. However, extension of such experimental results to practical use by farmers will meet some difficulties, particularly in the multiple and rotation cropping areas.

Most of the weed species in the tropics and subtropics, like Taiwan, are perennials. They are very aggressive and cannot be successfully controlled under warm and humid conditions unless persistent herbicides are used. But this leads to problems of herbicide residues and their accumulation in the soil in relation to subsequent crop production. These problems are closely related with soil moisture and rainfall frequency and intensity during the growing season of crops.

Several investigators have found that simazine and diuron are rather persistent in soil. Although these herbicides can be leached by water, they are adsorbed on mineral and organic fractions of the soil and tend to remain near the soil surface (Sheet *et al.*, 1962; Dawson *et al.*, 1968; Liu and Cibes-Viade, 1968; Liu *et al.*, 1970). At selective rates, annually applied simazine and diuron decompose rapidly enough that quantities toxic to most crops usually do not accumulate in the soil (Arle *et al.*, 1965; Dawson *et al.*, 1968). However, quantities lethal to certain sensitive plants may persist for one year or more (Weldon and Timmons, 1961; Arle *et al.*, 1965). Arle *et al.* (1965) measured the persistence of diuron in soils, and found that quantities toxic to sensitive plants persisted for 6 to 12 months, but there was no significant accumulation from repeated use. According to Dawson *et al.* (1968), the total herbicide that remained one year after the last of six consecutive annual applications of diuron at 2.69, simazine at 1.12 and 3.36 kg/ha represented 60 to 117% of one annual application.

Three years after the last of four consecutive applications of monuron at 8.06 kg/ha, the total had been reduced to 11% of one annual application. Severe injury to sensitive species of plants may be expected during the second year after application of diuron or simazine, but dangerous accumulations are unlikely to occur from repeated annual applications at recommended rates.

Accumulation and dissipation of residual herbicides are directly related to the problems of adsorption, desorption and leaching. Burnside *et al.* (1961) concluded that simazine was leached by percolating water, indicating this could be a factor in simazine dispersion into the soil. The depth to which simazine moved was not great, but it increased with the amount of water applied (Burnside *et al.*, 1961; Arle *et al.*, 1965). Some extensive adsorption studies involving a series of *s*-triazine analogs and substituted ureas were carried out by Harris (1966), Talbert and Fletchall (1965) and others. These herbicides are adsorbed by various soil constituents in strikingly different degrees. The capacity of soils to adsorb herbicides depends on their clay and organic matter content and the cation exchange capacity. Moreover, increased adsorption usually occurs with decreased pH and temperature (Harris and Warren, 1964; Talbert and Fletchall, 1965; McGlamery and Slife, 1966; Weber *et al.*, 1968; Liu *et al.*, 1970). Temperature has been shown to have little effect on leaching of herbicides but considerable effect on microbial and chemical breakdown of herbicides (Burnside *et al.*, 1961; Arle *et al.*, 1965).

No published report in which the influence of the accumulative residual *s*-triazines and diuron after repeated application in double or triple cropping areas can be found. The seasonal variation of the weed control effect has been observed by applying herbicides under variable climatic conditions, especially in the rainy and dry seasons or with different soil moistures. The studies reported herein were conducted during 1967-70 to investigate the accumulative residual effect of persistent herbicides repeatedly applied in the multiple cropping area. Special consideration was given to soil moisture to find out not only the accumulative residual effect on crops, but also the optimum soil moisture for chemical weed control and crop production.

MATERIALS AND METHODS

Accumulative Residual Effects of Simazine and Diuron

Corn (maize, *Zea mays*, variety Tainan 5) was planted on the permanent plots, two crops every year, from 1967 to 1970. The plot size was 1.5 m × 2.5 m or 3.75 m². The seeds were sown three rows per plot, 50 cm between rows. The sowing rate per row was 20 grains, and seedlings were thinned to 10 plants after the observations and records of the germination and herbicidal injury had been taken. Simazine was applied at 2.5 kg/ha as pre-emergence spray, and diuron at 2 kg/ha for directed post-emergence spray four weeks after planting. The first applications of simazine and diuron were on 11 August and 10 September, 1967, respectively. The two herbicides were repeatedly applied on the same plots every crop. The experiment was laid out in a randomized block design with two replications on sandy soil. A basal fertilization of 60 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha was applied before planting, and topdressing of 45 kg N/ha, five to six weeks after the basal application. Hence the same amount of fertilizer was used on every crop to determine whether yield reductions of corn would be caused by repeated applications of simazine and diuron or not. Besides the two crops of corn each year, milk vetch (*Astragalus sinicus*) was sown by broadcasting in winter. right after the harvest of corn and the separate land preparation within each plot, about four months following the first application of simazine, and three months after the application of diuron, for bioassay. No weed control treatment was given to any of the plots in the bioassay crop.

Accumulative Residual s-triazines under Different Water-tables

Water-table-controlled beds were used to maintain five water levels of 0, 20, 40, 60 and 80 cm from the soil surface, and tended to maintain a range of different soil moistures. Soil samples were taken at 0 and 20 cm of each water-table for the analysis of water content. The water-table-controlled bed, which was surrounded with concrete walls, was 1 m³ in volume, with drainage holes at 10 cm intervals on one side for controlling the water-table level. The concrete beds were filled with sandy loam soil. Prior to this study two crops of corn had been grown, and simazine and atrazine were applied consecutively. Peanut (*Arachis hypogaea*), which was used as a crop indicator to determine the growth and yield to the accumulative residual *s*-triazines, had been grown two crops a year during 1967-70. Prometryn and 15% simazine/40% prometryn were consecutively applied as pre-emergence at 2.5 kg/ha every crop during 1967-8 and 1969-70, respectively. Wheat (*Triticum vulgare*) and milk vetch were planted on 11 December, 1967, almost four months following the last of three applications of *s*-triazines. When the bioassay was undertaken, the water-tables of all treatments were maintained at the same level of 40 cm instead of the way described earlier. Fertilizers for these studies were applied as usual.

RESULTS AND DISCUSSION

Accumulative Residual Effects of Simazine and Diuron

Background of Climatic Conditions

Precipitation is one of the most limiting climatic factors to crop production as well as to chemical weed control in the tropics and subtropics. Temperature, sunshine duration, and humidity are also important factors influencing the growth and yield of crops. The characteristics of the climate in Taipei are listed in Table 1.

TABLE 1: AVERAGE CLIMATIC DATA OF THE UNIVERSITY FARM, TAIPEI

Month	Precip. (mm)	R.H. (%)	Sunshine (hr)	Temp. (°C) Max.	Min.	Av.
Jan.	77.6	83.1	77.4	18.5	12.4	15.2
Feb.	143.9	83.7	69.0	18.6	10.5	15.3
Mar.	158.0	82.3	82.9	21.0	14.1	17.2
Apr.	162.0	81.8	102.0	24.8	17.8	20.6
May	190.4	81.8	122.0	28.5	20.9	24.7
Jun.	355.8	83.4	121.5	30.8	23.1	26.4
1st half-year	1,087.7	82.6	574.8	23.7	16.4	19.9
Jul.	266.5	79.1	200.1	32.7	24.2	27.9
Aug.	292.1	78.9	210.4	30.8	24.3	27.9
Sep.	195.3	79.3	181.1	30.6	23.3	26.5
Oct.	148.1	86.3	129.8	26.6	20.6	23.1
Nov.	64.5	81.7	96.6	23.6	17.3	20.3
Dec.	79.7	82.0	83.1	20.8	14.5	17.2
2nd half-year	1,046.2	81.2	901.1	27.5	20.7	23.8
Annual	2,133.9	82.0	1,475.9	25.6	18.6	21.8

Taiwan is located in the monsoon area. Typhoons often accompanied by heavy rainfall, are destructive to the crops on the island. Rainfalls reached 453.2 and 354.7 mm per day in October and September, respectively, owing to two heavy typhoons in 1969.

Accumulative Residual Effects on Weeds

The accumulative residual effect of diuron on weed control could be easily observed, especially in the periods prior to herbicide application. The average percentage weed control of the 4-week pre-treatment period from the first to seventh crop during 1967-1970 increased gradually from —31.0 (no herbicide treatment), 22.0 (primary residual effect), 6.6, 56.5, 67.1, 71.0 to 82.4% (6th accumulative residual effect), respectively. In the middle and late growth periods after herbicide application, percentage weed control increased as the number of applications increased.

Pre-emergence applications of simazine had a similar weed control trend, except in the second crop of 1969, in which the curve dropped down much more drastically after the eighth week after heavy rainfall accompanying a great typhoon, as did the hand-weeding curve. It could therefore be assumed that diuron was more resistant to leaching than simazine. The effect of hand-weeding depended mostly on the weather when it was under-

taken. Compared with the unweeded check, it seemed there was some reduction of weed population on the hand-weeded plot. This comparative result might partially be due to the increasing aggressiveness of the weeds on the unweeded check year after year; the ground cover of the weeds at the end of each succeeding experiment increased from 45.0% (1967) to 92.5% (1970).

Bioassay of Milk Vetch for Residual Phytotoxicity

The germination and survival rates, plant height, fresh and dry weights of milk vetch as well as the ground cover of the weeds were investigated.

From the reduction of the germination and survival rates, plant height, fresh and dry weights of milk vetch and the ground cover of the weeds, the carry-over of simazine and diuron could be ascertained. The phytotoxicity of the residual diuron decreased the growth and yield of milk vetch more severely than did the residual simazine. The difference might partially be due to the different application times of these two herbicides. From the bioassay of milk vetch, the residual simazine and diuron, four and three months after only one application, were strong enough to injure subsequent susceptible crops. In addition, their residues still had considerable effects on weed control.

Accumulative Residual Effects on Corn Production

Corn was more tolerant or resistant to simazine, but not to diuron, even when applied by directed post-emergence spray on weeds. Seven successive crops of corn, 1967 through 1970, were grown and harvested, except the second crop in 1969 which was destroyed by two heavy typhoons in September and October. There were no significant differences in the percentages of germination and survival of the corn seedlings among the simazine and diuron treatments, the hand-weeded and the unweeded checks. But the differences in plant heights and grain yields were quite remarkable.

Generally, there was a tendency towards a decrease in both plant height and grain yield even in hand-weeding. Besides the accumulative residual effect of the herbicides, special consideration was given to the relative effects of seasonal variation (first crop always yields more than second crop in a year), continuous cropping twice a year, sowing date, climatic conditions and weed competition.

Excluding the variations caused by these factors, comparisons in percentage were made, based on the performance of hand-weeding. The plant height in the repeated application of diuron decreased immensely from 99.5, 102.4, 91.4, 63.9, 87.9 to 57.0%, from 1967 to 1970, respectively, while simazine showed just a slight decrease from 99.4 to 96.5% in the same period. Regarding grain yield, diuron reduced this severely from 80.6, 83.4, 77.7, 34.3, 41.1 to 47.3%, respectively, and simazine also gave some variable yields from 102.5, 85.9, 78.7, 104.6, 99.6 to 103.7%. Certainly, the residual herbicides of both simazine and diuron could carry-over (as they did from the bioassay of milk vetch) and accumulate in the soil. The only difference between them was their phytotoxic activity. Corn was susceptible to diuron but tolerable to simazine by detoxification. The plant heights and grain yields from the unweeded plots also decreased gradually year after year, owing to the increasing competition from the aggressive weed population. Following the decreasing trend, the sudden increase in plant heights, and particularly the grain yields in the fifth crop in 1970, might be attributed to the semi-fallow of the land after four continuous crops as the typhoons occurred. Moreover, the heavy rainfall brought by the typhoons flooded the land for one day and tended to leach out the residues to a certain extent.

Accumulated Residual s-triazines under Different Water-tables

Water Contents and pH Values of Soil with Five Water-tables

The soil moisture percentages at 0 and 20 cm from the soil surface were measured. They were 34.7 to 48.5, 29.4 to 43.9, 23.4 to 27.0, 21.3 to 26.5, and 19.3 to 25.4%, inversely proportional to the water-tables 0, 20, 40, 60 and 80 cm, respectively (Table 2).

TABLE 2: SOIL MOISTURES AND pH VALUES AT FIVE DIFFERENT WATER-TABLES

Sample of Soil taken at	*Depth from Soil Surface* 0 cm	20 cm	40 cm	60 cm	80 cm
	Soil moisture (%)				
0 cm Variation	32.7-36.9	27.3-31.6	22.7-24.2	21.0-21.5	18.0-20.6
Average	34.7	29.4	23.4	21.3	19.3
20 cm Variation	46.8-50.2	42.1-45.6	26.3-27.7	24.7-28.3	24.9-25.9
Average	48.5	43.9	27.0	26.5	25.4
	pH value after the last application in 1970				
1 water : 1 soil	5.3	4.9	5.0	5.0	4.9
10 water : 1 soil	5.6	5.7	5.7	5.5	5.7
Average	5.45	5.30	5.35	5.25	5.30

The pH value of the soil prior to the herbicide application was presumably the same. No significant differences among various treatments were observed four years after repeated applications of s-triazines.

Ground-cover of Weeds on Soils under Five Water-tables

The ground-cover of weeds under the five controlled water-tables responded positively to the quantitative residual s-triazines which carried over and accumulated in the soil with varying soil moistures. The percentage of weed cover was directly correlated to the height of water-table or percentage soil moisture.

The residual s-triazines in high moisture soil, such as at 0 and 20 cm water-tables, were more readily leached and dissipated than in low moisture soil. The leaching reduced the necessary concentration toxic to weeds, and thus increased the weed population. Contrarily, with lower soil moisture or below the 40 cm water-table, there was accumulation of the residual s-triazines which was toxic to weeds. The residue tended to reduce weed population as well as their ground-cover.

The different trends of the relative dissipation or accumulation of the residual s-triazines approaching two extremes in the soils with higher and lower soil moistures could be shown from the changes of the percentage weed cover from year to year. Comparing the water-tables 0 cm and 40 cm, the weed covers of the former increased 3 to 8 times more than the latter during the three years. On the other hand, the weed cover of the 80 cm water-table plot decreased an average 75.4% to 39.1% of that of the 40 cm water-table plot.

Bioassay of Milk Vetch and Wheat for Residual Phytotoxicity

Milk vetch and wheat were planted four months after the last application of prometryn for peanut; prior to this prometryn application, simazine and atrazine were consecutively applied in two previous crops of corn in 1966-7. The percentages of survival, plant height, fresh weight and number of spikes of wheat and number of pods of milk vetch were investigated and compared as percentages of the untreated check.

There was almost no difference in the survival of wheat responding to the residual s-triazines at different water-table levels, but the plant height, fresh weight and number of spikes were reduced slightly in the plots with water-tables of 60 and 80 cm as a result of slight accumulative residual effect. The milk vetch was very sensitive in the bioassay. The percentage survival, plant height, fresh weight and number of pods were strikingly reduced by the residual *s*-triazines as the water-table levels decreased.

Accumulative Residual s-triazines on Peanut Production

Two crops of peanut had been planted yearly since 1967, with consecutively repeated applications of *s*-triazines.

Plant heights with most water-tables tended to decrease, except at 0 cm and 80 cm where, on the contrary, there was a trend to increase gradually, but as a result of different factors. With water-table 0 cm, rapid dissipation might have reduced the residual *s*-triazines to a minimum, which was not likely to be injurious, and probably even had some stimulating effect to peanut growth as the writers found in corn (Wang *et al.*, 1969). On the other hand, the weed population of the soil at water-table 80 cm decreased as the residual herbicides accumulated yearly. The residues might result in the reduction of weed competition.

There seemed to be no close relation between plant height and grain yield in this experiment. Regardless of the rapid dissipation of the residues, high water-tables of 0 cm and 20 cm favoured the top-growth, but not the grain yield of peanut, because most of the seeds in the pods were actually not developed. Undoubtedly two factors, accumulative residual herbicides and soil moisture, influenced both grain yield and top-growth. The water-table of 40 cm, with a water content of 23.4 to 26.9%, gave the best grain yield, which was suggested as due to optimum soil moisture and better weed control. However, the water-table of 80 cm with a water content of 19.3 to 25.4%, which showed the best weed control, yielded only 83.0 to 87.1% of the 40 cm water-table, probably because of insufficient soil moisture.

CONCLUSIONS

The differences and changes between weed populations on simazine and diuron plots and on hand-weeded and unweeded check plots during the successive years 1967-70 were apparently due to the accumulative activity of the herbicides, which showed some increasing effects on weed control.

The carry-over and accumulation of the residual diuron and *s*-triazines from the subsequent crops and years were substantiated. Severe injury to sensitive crops might be expected even in the second crop, four months following the first application. The toxicant could accumulate as a consequence of repeated application. The accumulated residual herbicides in soil thus become more a problem in a multiple cropping area.

The tolerance of crops and the selectivity of the persistent herbicides are the key factors in determining the cropping system and the utility of herbicides. Tolerant crops, such as corn to *s*-triazines and peanut to prometryn, can be grown as continuous crops, or in rotation, while susceptible crops, milk vetch or soyabean, should be avoided after tolerant crops.

Climatic factors generally influence the dissipation rate of herbicides. Increased frequency and intensity of rainfall, particularly flooding, resulted in decreased concentration of accumulative residues toxic to crops as well as weeds. Simazine is more readily leached than diuron.

Different soil moistures or ground water-tables markedly affect the dissipation of accumulated residual herbicides and tend to influence the weed control effect and crop production. Soil moisture of 23.4 to 26.9%, or a water-table of 40 cm, is favourable for both weed control and peanut production. Higher soil moisture, or more rainfall, decreases the weed control effects and the grain yield of peanut.

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TRIALS WITH "FRENOCK" IN JAPAN AND WEST MALAYSIA

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Summary

Results of field tests of "Frenock" against some important perennial grasses in Japan are summarized. It showed excellent long-term control against eulalia *(Miscanthus sinensis)*, common reed *(Phragmites communis)*, bamboo grasses *(Sasa* spp.), and needle grass *(Imperata cylindrica)*, when used at the rate of less than 5 kg/ha. "Frenock" is a slow-acting herbicide that does not kill grasses quickly but inhibits their growth for long periods so that it gives good control effect. Preliminary tests on lalang (*Imperata cylindrica)* in West Malaysia showed that "Frenock" also has long-term control effect on this grass.

INTRODUCTION

"Frenock" is a herbicide with distinct selectivity, and of very low mammalian toxicity (Table 1). It has strong activity on gramineous and cyperaceous weeds, and on some leguminous weeds (Nakamura and Yoshimura, 1965). Being a slow-acting herbicide, it controls weeds by inhibiting the growth over a long period.

TABLE 1: TOXICOLOGICAL DATA OF "FRENOCK"

Item	*Result*
Acute oral LD_{50}:	
Mice	♂ 9,236 mg/kg ♀ 9,816 mg/kg
Rats	♂ 11,800 mg/kg ♀ 10,420 mg/kg
Acute dermal toxicity for rats	No change 96 hr after 2,600 mg/kg application
Subchronic oral toxicity (3 months):	
Mice	No influence up to 182 ppm in daily food
Rats	No influence up to 115 ppm in daily food
Acute toxicity for young rainbow trout	No influence after 96 hr at 10,000 ppm
Subchronic toxicity (3 months) for young carp	Grew normally at 50 ppm

Therefore, "Frenock" is useful particularly for the control of "big and tough" perennial grasses rather than small annual grasses in view of the recent shortage of labour. Sometimes only one application can control these troublesome grasses for as long as two years (Yamada, 1970, 1971).

Recently, "Frenock" has become popular in the forest industry in Japan since it has outstanding control effect on eulalia (*Miscanthus sinensis*), one of the most noxious perennial grasses widely distributed in Japan (Yamada, 1970, 1971). This paper presents the results of some field tests of "Frenock" on eulalia, bamboo grasses (*Sasa* spp.), common reed (*Phragmites communis*), and needle-grass (*Imperata cylindrica*) in Japan, and for lalang (*Imperata cylindrica*) in West Malaysia.

MATERIALS AND METHODS

All experiments were carried out under fully open conditions, and exuberantly growing vegetation of each weed was used for the experiments. "Frenock" 30% liquid (300 g a.i./kg) and 10% granules (100 g a.i./kg) formulations were used. The liquid was dissolved in an adequate amount of water and sprayed with a knapsack sprayer. The granules was applied simply by hand. Sometimes spot treatment aimed at only a "clump" was employed for eulalia instead of broadcast treatment. This application technique is economical if the approximate number of eulalia clumps is less than 3,000/ha.

Observations were made when the difference in appearance between the treated plot and the control plot became very distinct, usually a few months after application.

RESULTS AND DISCUSSION

EULALIA

"Frenock" showed excellent long-term control of eulalia both in liquid and granular formulations (Tables 2 and 3). In the case of spot treatment of the liquid, 25 g/m² was required to prevent the growth of eulalia completely, whereas 5 kg/ha was found sufficient to obtain practical control in broadcast treatment of the granular formulation. In the spot treatment experiment, the application rate was higher than that in the broadcast treatment when expressed in terms of the area of eulalia clump only. However, for practical application, a much smaller rate, about 1/10 to 1/20 of 25 g/m², should be enough for good results (Yamada, 1970, 1971).

TABLE 2: EFFECT OF SPOT TREATMENT WITH "FRENOCK" LIQUID ON EULALIA (KANAGAWA, 1968-9)
(Observations made on 15 September, 1969)

Date of Application	*Rate (g/m² clump)*	*No. of Treated Clumps*[1]	*No. of Dead Clumps*	*No. of Growth-retarded Clumps*[2]	*No. of Flowering Clumps*[3]
8 Dec., 1968	8.3	12	7	3	2
	16.7	12	12	0	0
	25.2	12	12	0	0
6 Feb., 1969	8.3	15	10	4	1
	16.7	15	14	1	0
	25.2	15	15	0	0
7 Apr., 1969	8.3	13	4	6	3
	16.7	15	13	2	1
	25.2	15	14	1	0
Control		23	0	0	23

[1] Eulalia clumps, about 30 cm in diameter, were used for this test.
[2] Number of generated stems of the treated clumps was much less than that of the untreated, and the height of the treated stem was shorter than half of the untreated stem. Abnormal stems were often observed.
[3] A clump, even a single stem of which flowered, was recorded as "flowering clump"; the number of flowered stems in the treated clumps was much less than that in the untreated.

In both tests weight of the top section shorter than 50 cm of the "Frenock" plots was much smaller than that of the control plot. This indicates that the growth of eulalia treated with "Frenock" was greatly inhibited, and this was also substantiated by the fact that the flowering stems in the treated plots were much fewer than those in the control plot (Table 2). Attendant on this growth retardation of eulalia, alternation of the flora occurred in the "Frenock" plots, resulting in an increase of shrubs and broadleaf weeds which replaced eulalia (Table 3).

It is interesting to note that the applications in December and February gave somewhat better results than the application in April. It has been reported that, after being absorbed via the plant roots, "Frenock" is translocated to the growing point of the plant where it strongly inhibits growth of the newly developing plant tissues only at the beginning stage of the growth (Nakamura *et al.*). But "Frenock" does not affect plant tissues that have already fully developed. Therefore, no new shoots nor leaves of grasses regenerate after "Frenock" application, although, occasionally, abnormal and deformed new shoots and leaves may be formed. In the tests conducted, the eulalia tested had already started to grow in April when it was more resistant than in winter. From these results, winter application of "Frenock" is recommended for eulalia in Japan, and more so in view of availability of labour for the application.

Bamboo Grasses

"Frenock" also showed excellent control against bamboo grasses (Table 4). A rate of 3.5 kg/ha was sufficient to give

TABLE 3: EFFECT OF BROADCAST TREATMENT OF "FRENOCK" GRANULE ON EULALIA (SHIZUOKA, 1969-70)

Plot: 100 m², two replications.
Applications: Winter — 10 Dec., 1969. Spring — 23 April, 1970.
Observations: 10 Jul., 1970. Two small observation plots, 1 m² in size, were made at random in one plot, and all the plants in the plots were cut into three pieces at the points of soil level, 50 cm and 100 cm in height. Sections of the plant body which belong to each class were pooled and weighed.

Treatment (kg/ha)	Plants[1]	Top Weight (g/m²) Height Section (cm) 0-50	50-100	> 100	Total
Winter:					
3.5	E	195	55	5	255
	S	905	110	0	1,015
	B	90	0	0	90
	Total	1,190	165	5	1,360
5.0	E	258	63	0	321
	S	173	0	0	173
	B	403	0	0	403
	Total	834	63	0	897
7.5	E	5	0	0	5
	S	655	170	0	825
	B	115	0	0	115
	Total	775	170	0	945
Control	E	1,450	1,000	130	2,580
	S	200	140	0	340
	B	210	0	0	210
	Total	1,860	1,140	130	3,130
Spring:					
5.0	E	685	0	0	685
	S	1,063	0	0	1,063
	B	290	0	0	290
	Total	2,038	0	0	2,038
Control	E	1,400	650	0	2,050
	S	1,250	0	0	1,250
	B	100	0	0	100
	Total	2,750	650	0	3,400

[1] E: Eulalia, S: Shrub, B: Broadleaves and vines.

TABLE 4: EFFECT OF BROADCAST TREATMENT OF "FRENOCK" GRANULE ON BAMBOO GRASSES (GIFU, 1970)

Plants: Mixed stand of *Sasa kurilensis* and *Sasa paniculata*.
Plot: 100 m², two replications.
Application: 13 May, 1970.
Observation: 3 Sept., 1970 (113 days after treatment).

Rate (kg/ha)	No. of stems/m²	No. of Generated Stems Appearance of Stems[1] 0	1	2	3	4	No. Open Leaves	Top Weight Height Section 0-50	> 50	Total
3.5	111	0	38	27	45	1	114	830	50	880
5.0	77	0	22	32	23	0	80	823	135	958
7.0	77	0	20	29	26	2	47	610	70	680
Control	108	100	4	1	2	1	205	1,450	2,250	3,700

[1] 0: Normal.
1: Growth of new shoots and leaves was inhibited.
2: Old leaves were discoloured and began to dry.
3: Leaves were discoloured and about to die.
4: Died.

practical control. Decrease of weight of the top section shorter than 50 cm was very conspicuous in the treated plots. Decrease in number of new stems implies that the absorbed herbicide inhibited generation of new stems from rhizomes, and the decrease in number of new leaves means that it prevented generation of new leaves from old stems. However, it took about 1½ to 2 years to kill old stems of bamboo grasses (Yamada, 1970, 1971).

Common Reed

The control of common reed was similar to that with eulalia and bamboo grasses (Table 5). Application rates of more than 10 kg/ha gave excellent control of this tough grass and even 5 kg/ha was very effective. However, alternation of flora was slow after control of the reed, since the test field was completely covered by this species only.

Needle Grass (*Imperata cylindrica* in Japan)

Spring application of "Frenock" at the rate of 4.5 kg/ha practically controlled needle grass in Japan (Table 6), and long-term control was also obtained as with eulalia, bamboo grasses, etc.

Lalang (*Imperata cylindrica* in Malaysia)

A preliminary test of "Frenock" was carried out against lalang in West Malaysia. Unfortunately, however, the test field was

TABLE 5: EFFECT OF SOIL SURFACE SPRAY OF "FRENOCK" LIQUID ON COMMON REED (IBARAGI, 1969)

Application: 4 April, 1969.
Observation: 6 June, 1969.

Rate (kg/ha)		*Top weight (g/m²) Height Section (cm)* < 50	50-100	> 100	*Total*
5	G[1]	175	118	120	413
	B	211	64	0	275
10	G	183	59	38	280
	B	98	3	0	101
20	G	134	78	32	244
	B	41	0	0	41
30	G	23	8	2	33
	B	58	0	0	58
Control	G	1,500	1,144	1,580	4,224
	B	658	602	40	1,300

[1] G: Grasses, B: Broadleaves.

TABLE 6: EFFECT OF "FRENOCK" LIQUID ON NEEDLE-GRASS (SHIGA, 1969)

Plot: 100 m², two replications.
Application: 1 April, 1969.
Observation: (1) 25 Jul., (2) 30 Sept., 1969.

Rate (kg/ha)	*25 Jul. (105 days)* *Visual Kill Grade*[1]	*Top Weight (g/m²) Height Section (cm)* 0-50	> 50	*Total*	*30 Sep. (183 days)* *Visual Kill Grade*[1]	*Top Weight (g/m²) Height Section (cm)* 0-50	> 50	*Total*
1.5	1	33.5	14.0	47.5	1	27.0	10.5	37.5
3.0	2	19.5	3.5	23.0	2	24.0	3.0	27.0
4.5	3	4.0	0	4.0	3	3.5	0	3.5
6.0	3	2.5	0	2.5	3	2.0	0	2.0
7.5	4	0	0	0	4	0	0	0
9.0	4	1.5	0	1.5	4	2	0	2.0
10.5	4	0	0	0	4	0	0	0
15.0	4	0	0	0	4	0	0	0
Control	0	31.5	22.0	53.5	0	42.0	28.5	70.5

[1] 0: Normal.
1: About ¼ of total leaves killed.
2: About ¼-½ killed.
3: More than half killed.
4: Completely killed.

TABLE 7: EFFECT OF "FRENOCK" LIQUID ON LALANG IN WEST MALAYSIA (SELANGOR, 1970-1)

Plot: 0.004 ha, two replications.
Spray water volume: 3 litres/plot.
Application: 4 May, 1970.
Observation: (1) 4 Jun., 1970; (2) 2 Oct., 1970; (3) 8 Feb., 1971.
The test field was accidentally bunrt about two weeks after the application so that the regeneration of lalang thereafter was observed.

Rate (kg/ha)	*Regeneration Grade*[1] 30 days	150 days	280 days
11.0	0	0	0
5.5	0	1	3
2.8	3	4	4
Control	4	4	4

[1] 0: No regeneration.
1: Regeneration density little.
2: Regeneration density about ¼.
3: Regeneration density about ½.
4: Normal regeneration.

burnt by accident about two weeks after the application; therefore, the regeneration of lalang thereafter was observed to assess the effect of the treatment. The result shown in Table 7 indicates that "Frenock" had ability to prevent the regeneration of lalang for quite a long period. However, no visual change was observed on the "Frenock"-treated lalang before it was burned. The top of needle grass in Japan dies in winter so that one application in early spring easily prevented the generation of new leaves completely (Table 6). But "Frenock" did not kill standing lalang immediately as was the case with bamboo grasses in Japan. To find the effective application methods for "Frenock" against lalang, further studies are required.

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INCORPORATION OF PRE-PLANT HERBICIDES IN PADDY FIELDS IN JAPAN

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INTRODUCTION

Almost all the herbicides used in lowland rice fields are applied after transplanting. In the past, there has been no herbicide with sufficient selectivity between rice plants and weeds, especially barnyard grass, and applications have therefore been made to take advantage of soil protection and differences in growth stages of rice plants and weeds. However, application of herbicide in this way raises the possibility of herbicidal injury to rice plants in certain conditions and decrease in herbicidal activity to weeds as a result of delayed application time through shortage of labour.

If a herbicide were available having selectivity between rice plants and weeds in the root zone, it could be incorporated into the soil prior to transplanting of rice plants. Generally, herbicides applied to the soil surface in lowland rice fields may become ineffective through decomposition, irrigation water and the action of ultraviolet light. Soil incorporation can prevent this loss of herbicidal activity.

Since 1963, many types of herbicides have been examined for their suitability for soil incorporation. Recently, some of them have given favourable results and evaluation tests in the field have been conducted. The experiments are reviewed in this paper.

RESULTS AND DISCUSSION

THE SITE OF UPTAKE AND ACTION OF SOIL-INCORPORATED HERBICIDES

Plant Material

Rice plants and barnyard grass (*Echinochloa crus-galli*) were sown at the rate of 25 plants per pot.

Herbicide Application

Herbicides used in the experiment were chlornitrofen, nitrofen, Tope, simetryn, prometryn, swep, B-3015, TDW-6643, molinate, S-45865, and RP 17623 (G-315).

Each herbicide was applied at double the normal surface application rate. For testing root uptake, soil treated with herbicide was placed below the rice and barnyard grass seeds, and, for plumule uptake, treated soil was placed in a layer above the seed allowing 0.5 cm of untreated soil above the seed as a buffer zone.

Results

The results indicating the site of uptake and herbicidal action are summarized in Table 1.

TABLE 1: THE EFFECT OF HERBICIDES IN PLUMULE AND ROOT ZONES ON DRY WEIGHT OF RICE PLANT AND BARNYARD GRASS

Herbicide	*Phytotoxicity to Rice Plant**		*Killing Power to Barnyard Grass*		*Selectivity between Rice Plant and Barnyard Grass†*	
	plumule	*root*	*plumule*	*root*	*plumule*	*root*
chlornitrofen	2-3	1	5	1	3	1
nitrofen	3	1	5	1	2	1
Tope	1-2	3	5	2-3	5	1
simetryn	1	3	5	4-5	5	3
prometryn	1	3	5	4-5	5	3
swep	1-2	2	4-5	3	4	1
B-3015	1	1	5	3	5	2-3
TDW-6643	1	1	4-5	2	4	1-2
molinate	2	2	5	4	4	3
S-45865	1	2	5	2	5	2
RP 17623	2	1	5	3	4	3-4

*1 = no injury, 5 = all plants killed. Injury of rice plant consisted of growth inhibition or browning of leaf sheath.
†1 = none to very little, 2 = little, 3 = medium, 4 = much, 5 = very much.

Chlornitrofen, nitrofen: The main site of action in emerging rice plants and barnyard grass was the plumule; root zone effects did not significantly reduce the dry weight of either plant. Selectivity between plumules of rice plant and barnyard grass was moderate.

Tope: Tope slightly reduced elongation of the plumule or primary root of rice. This chemical was most effective against barnyard grass when applied to the plumule zone. Selectivity between plumules of rice and barnyard grass is very high.

Simetryn, prometryn: Simetryn and prometryn had little effect on the rice plant when applied in the plumule zone, but injury resulted from root zone treatment. On the other hand, barnyard grass was controlled exceptionally well in the plumule as well as in the root zone. A high degree of selectivity between rice and barnyard grass was demonstrated by the plumule zone treatment and a medium degree by the root zone treatment.

Swep, B-3015, TDW-6643: These showed a similar tendency, the herbicidal effects on rice plants being much less than on barnyard grass. Thus there was some selectivity between rice plant and barnyard grass. B-3015, especially, did not affect either part of the rice plant.

Molinate, S-45865, RP 17623: These had little effect on rice plants. However, all barnyard grass was killed with applications in either the plumule or the root zone. The toxicity of RP 17623, in particular, was notable. Selectivity between rice and barnyard grass was exhibited to a large degree in both plumule and root zones.

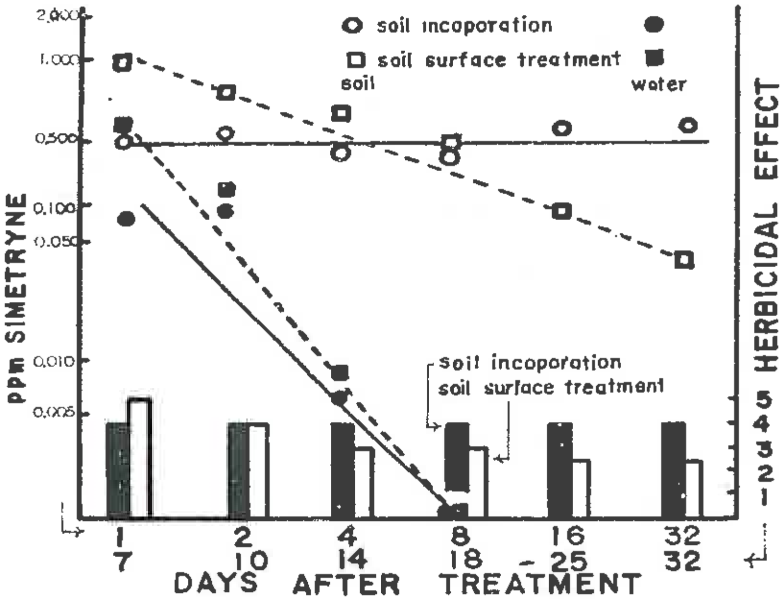

Fig. 1: Loss of simetryn from soil and water in a paddy field treated with 0.9 kg/ha.

Disappearance of Simetryn from the Soil and Water in Lowland Rice Fields

A study was made of the disappearance of incorporated simetryn from soil and water, as compared with soil surface treatment in a lowland rice field. During the course of the experiment the residual herbicidal effects in the field were recorded. As shown in Fig. 1, the amount of simetryn in water declined with time. The tendency for simetryn to disappear was similar with both soil-incorporated and surface treatments. However,

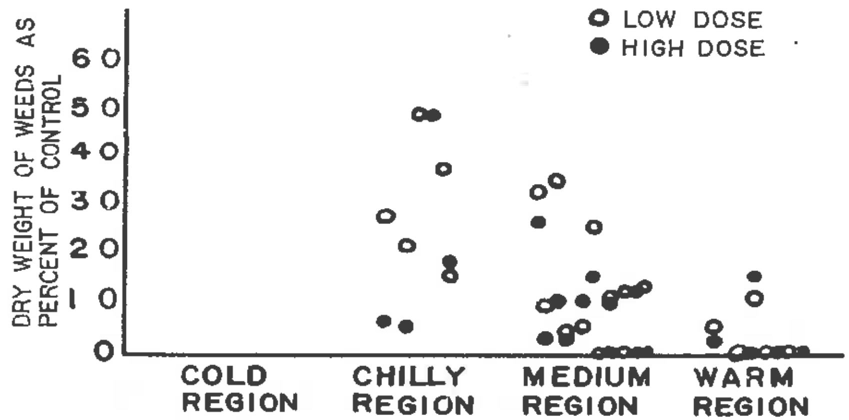

Fig. 2: Percentage of weeds controlled with B-3015 G when incorporated in the paddy field.

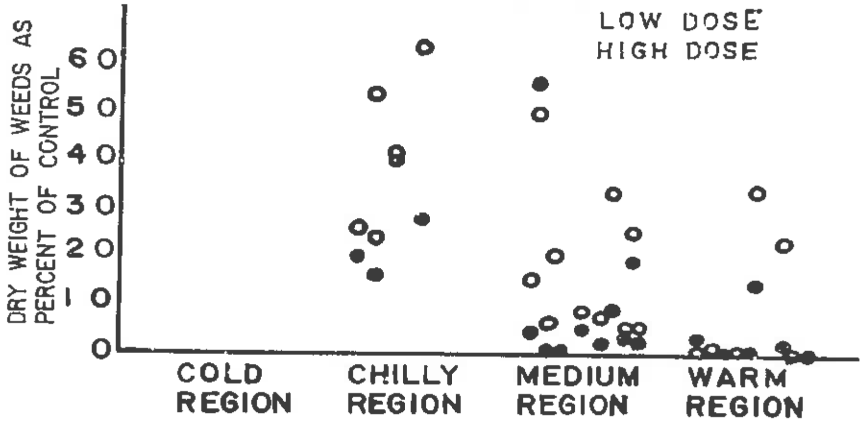

Fig. 3: Percentage of weeds controlled with BM-3015 G when incorporated in the paddy field.

there was a big difference in the rate of disappearance of simetryn from the soil between incorporation and soil surface treatments. In the incorporated treatment, the simetryn was stable, the residual amount 32 days after treatment being almost the same as one day after treatment. When applied to the soil surface, simetryn in the upper soil layer one day after treatment was about double that of the incorporated material. However, by 32 days after treatment, the residual simetryn had decreased to about one-twentieth of the amount one day after treatment. Herbicidal

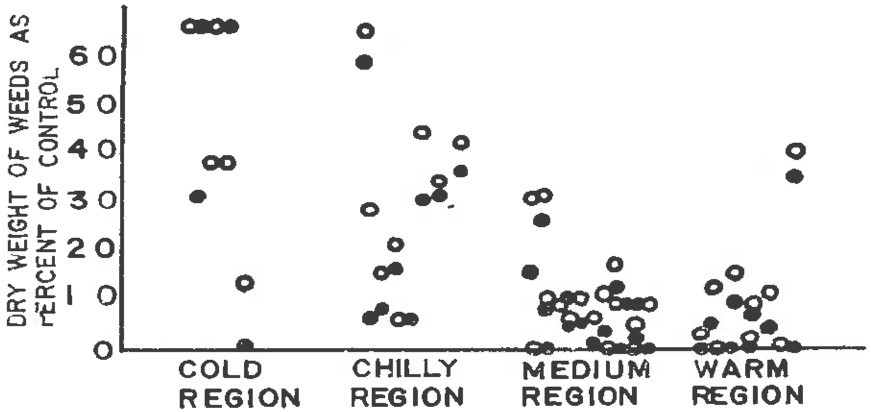

Fig. 4: Percentage of weeds controlled with RP 17623 G when incorporated in the paddy field.

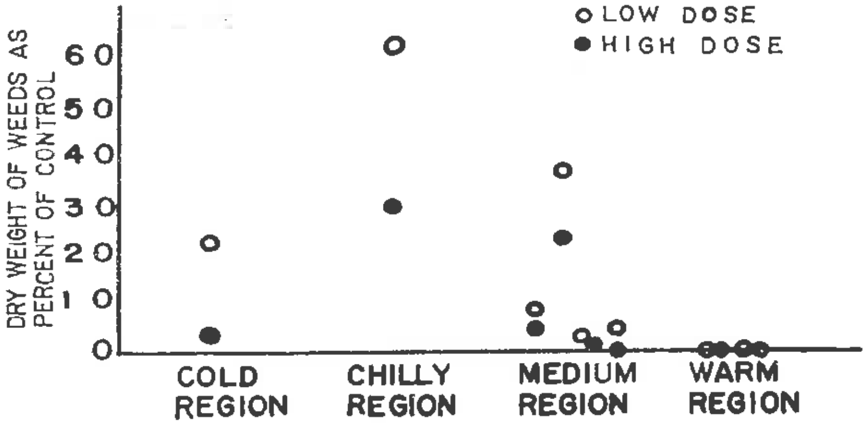

Fig. 5: Percentage of weeds controlled with RP 17623 EC when incorporated in the paddy field.

effects on weeds in the field showed a similar tendency to analytical results.

When simetryn was applied to soil surface there was a medium degree of crop injury, some of the rice plants having yellow leaves, but there was no crop injury with the incorporated treatment.

These results indicate that if the herbicide is incorporated 3 to 5 cm deep before transplanting rice plants, weed control would be better than with soil surface treatment and crop injury would be decreased.

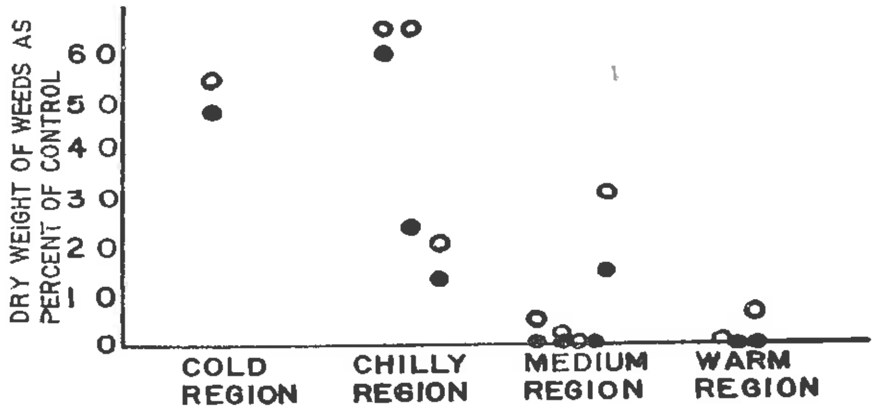

Fig. 6: Percentage of weeds controlled with RP 17623 WP when incorporated in the paddy field.

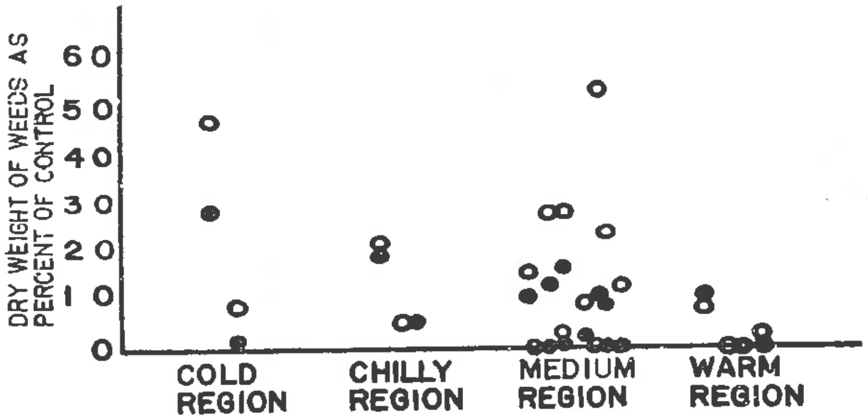

Fig. 7: Percentage of weeds controlled with RP 17623 (mixed with fertilizer — type A) when incorporated in the paddy field.

Evaluation Tests at Various Places in Japan in 1970

The herbicidal effect varied greatly between the four regions (Figs. 2 to 9). B-3015 and BM-3015 (a mixture of B-3015 and chlornitrofen) gave weed control above 80% in medium and warm regions, but poorer weed control in cold and chilly regions.

Weed control with RP 17623 (and various formulations) was almost completely effective in the warm region, but gave poorer weed control in cold and chilly regions.

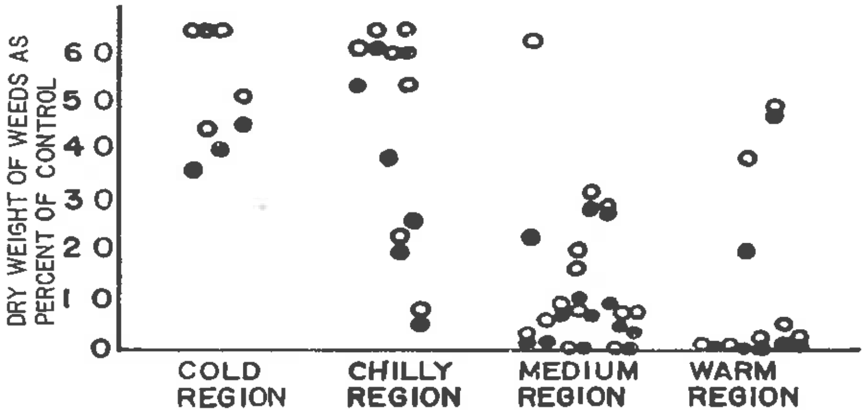

Fig. 8: Percentage of weeds controlled with RP 17623 (mixed with fertilizer — type B) when incorporated in the paddy field.

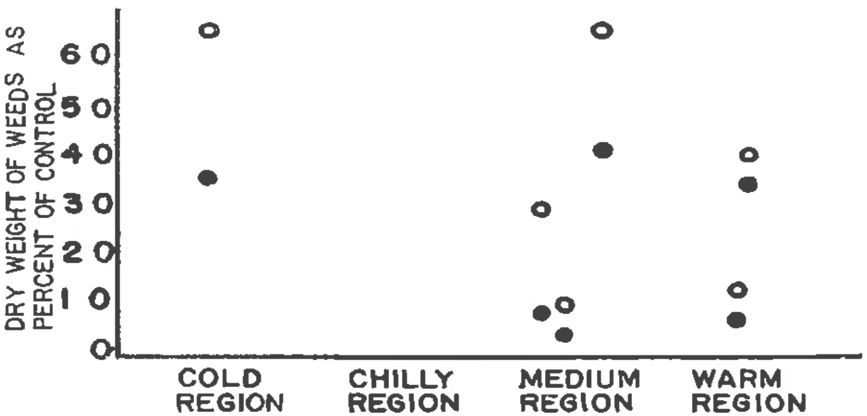

Fig. 9: Percentage of weeds controlled with nitrofen G when incorporated in the paddy field.

The high success of the B-3015 and RP 17623 group in the medium and warm regions may be explained by the warm temperatures some days after application, the methods of cultivation before and after herbicide application, and suitability of the machine used for incorporation.

Thus, the studies revealed that herbicides are available with properties suitable for soil incorporation. It also became clear from the field tests that the success of soil incorporation of herbicides in lowland rice fields depends on maintaining the herbicide in the upper 2 to 3 cm of the soil for a period. Shallow incorporation of some herbicides gave better control than surface application, but control lessened as the depth of incorporation was increased over 3 cm.

Fig. 10: Climatic regions of Japan.

The advantages of incorporation in comparison with soil surface treatment may be summarized as follows:

(1) The layer of herbicide in the soil is stable.

(2) Herbicidal activity continues for a long time.

(3) The herbicide is able to attack the weakest stage of weeds.

(4) Herbicide application and fertilization are simplified.

(5) There can be uniform distribution of herbicide in lowland rice fields.

THE WORK OF SEAMEO-BIOTROP IN RELATION TO WEED PROBLEMS

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Summary

The establishment of the South East Asian Ministers of Education Organization (SEAMEO) and its projects, among others the Regional Center for Tropical Biology (BIOTROP), is briefly presented. One of the priorities to be developed by BIOTROP is the Tropical Weed Biology sub-project. The activities can be classified as research activities, research scholarships, training courses and seminars. Research in weed biology will emphasize the distribution of important weed species in important crops in S.E. Asia and autecological studies of important weed species. Limited research scholarships are offered to young scientists of the region to work in close co-operation with the research work of BIOTROP. Since there is a general lack of knowledge of the principles and practices of chemical weed control, a short-term training course on weed science is badly needed. The content of the training programme will include aspects of chemical weed control, as this represents the real need, although it is less directly related to weed biology. Seminars on specific topics will be organized to allow better communication among researchers and workers engaged in weed control.

It is BIOTROP's intention to fill gaps in the existing activities in tropical weed science in S.E. Asia.

SEAMEO

The Ministers of Education of eight independent nations in South East Asia have joined together in a formal and duly chartered international organization, to form a structure and mechanism whereby regional co-operation might be implemented.

The subject which brought these nations together is education. Education is the key to progress in South East Asia. It provides the manpower needed for economic growth; it develops an enlightened citizenry capable of effective participation in national affairs: it frees the mind of man to dream, to create, to communicate and to appreciate. The purpose of the organization, simply stated, is to promote co-operation among the South East Asian nations through education, science and culture in order to further respect for justice, for the rule of law and for human rights and fundamental freedom which are the birthright of the people of the world.

The Ministers who took this bold step are the Ministers of Education of Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand and Vietnam who represent the educational aspirations of over 200 million people. Recently the Government of Khmer Republic also joined SEAMEO commencing January, 1971. This co-operation and dedication resulted in the signing of the SEAMEO charter on 7 February, 1968. Subsequently the charter was formally ratified and came into force in March, 1969.

For the implementation of its objectives, regional programmes have been designed and appropriate priorities established in order to accelerate educational development in the region by providing significant regional centres for specialized and advanced study and training in support of education at all levels.

The major projects which were approved at the Second Ministerial Conference in Manila 1966 and the Third Ministerial Conference in Singapore 1968 are:

(1) Six National Tropical Medical Centres (TROPMED) in member countries with a Central Co-ordinating Board located in Bangkok.

(2) The Regional Center for Graduate Study and Research in Agriculture (SEARCA), Los Banos.

(3) The Regional Center for Education in Science and Mathematics (RECSAM), Penang.

(4) Regional English Language Center (RELC), Singapore.

(5) Regional Center for Tropical Biology (BIOTROP), Bogor.

(6) Regional Center for Educational Innovation and Technology (INNOTECH), Saigon — temporarily located in Singapore.

BIOTROP

The SEAMEO - Regional Center for Tropical Biology (BIOTROP) in Bogor, Indonesia, is established to provide for the member countries opportunities for high quality study and research in tropical biological sciences in the region related directly or indirectly to the economic development of the region and to dissemination of the findings of its research and experimentation.

The functions of BIOTROP are:

(1) To undertake research activities in tropical biology.

(2) To organize seminars on specific subjects.

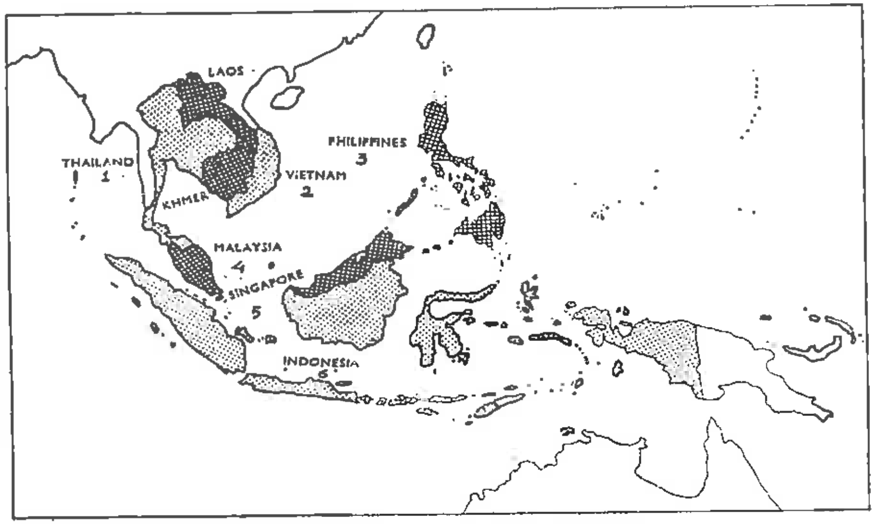

Fig. 1: SEAMEO member countries and their regional centres. 1, TROPMED. 2, INNOTECH. 3, SEARCA. 4, RECSAM. 5, RELC. 6, BIOTROP.

(3) To provide training course programmes in specific disciplines of biological sciences.

(4) To serve as a biological clearing-house.

(5) To provide assistance, co-ordinative and consultative services if so desired by the member countries.

The BIOTROP Center will be organized and administered in close relationship with the National Biological Institute (NBI) at Bogor, Indonesia, which is its host institution. The existing programme of the NBI will be fused, developed and implemented so as to serve the needs and purposes of SEAMEO member countries.

The BIOTROP Development Plan has in principle four environmental emphases of prime importance and equal merit:

(1) Tropical Forest Biology

(2) Tropical Pest Biology

(3) Freshwater Study

(4) Marine Study.

TROPICAL PEST BIOLOGY

The scope of the Tropical Pest Biology Project is really broad and diversified, since "pest" in this case applies to any destructive organism which impedes the natural growth, development and welfare of domesticated animals, cultivated plants and other renewable natural resources and hence of human beings. It is therefore necessary to limit the project to three working categories or sub-projects — *i.e.*, Public and Veterinary Health, Tropical Weed Biology, and Pesticide Problems. The three sub-projects receive equal merit and will be implemented in close association with each other according to the urgency and feasibility of the problem and facilities.

TROPICAL WEED BIOLOGY

To consider feasible working programmes for weed research and training, a Task Force Meeting on Weed Biology was called on 2-3 October 1970 at Bogor. Representatives from Malaysia, Thailand, the Philippines, Indonesia and the Netherlands participated in the meeting. Subsequently consultants were invited to help to prepare the programme of the BIOTROP Weed Biology sub-project. The Director of the Weed Research Organization, Oxford, U.K., and Prof. R. der Veen of the Utrecht University, the Netherlands, were among BIOTROP's visitors to assist this project.

The proposed programme was agreed in principle by the Fourth BIOTROP Advisory Council Meeting at Singapore in November 1970, then reconfirmed by the Fifth BIOTROP Advisory Council Meeting at Manila in May 1971.

BIOTROP activities in Weed Biology will be classified as research activities, research scholarships, training courses, and seminars on specific problems.

RESEARCH IN WEED BIOLOGY

The biology of weeds and the biological aspects related to control methods are very important in understanding problems of crop-weed systems and in achieving more efficient control measures.

THE DISTRIBUTION OF IMPORTANT WEED SPECIES IN IMPORTANT CROPS IN SOUTH EAST ASIA

Weed, which is not a purely botanical concept, is natural vegetation since it is unsown, but semi-natural with respect to its growth in a man-made habitat. Therefore, the importance of weed species is not only dependent on environmental conditions such as soil type, altitude, temperature, light, and rainfall, but also on man's activities — *i.e.*, his cultivated crops and related environments.

In agriculture, weed control is among the most expensive steps in crop production. To achieve better and more efficient weed-control measures in South East Asia, it is essential to know what important weed species are commonly found in our agriculture and how they are distributed in various crops which are regionally important.

The objective of the work is to study various conditions which might influence the growth and distribution of specific weed species. The compilation of a list of common weed species in important crops of the region so as to draw a dispersion map of a weed community is of prime importance to achieve better measures of control, using either herbicides or other alternative means to eliminate weeds at their early stage of development.

Referring to the recommendation of the Task Force Meeting on Weed Biology (October, 1970) the agro-ecological conditions, the weeds of which should be studied are: rice, corn, rubber, tea, oilpalm, irrigation and open-water systems. This consideration was based on two reasons — the importance of those crops as factors in advances in regional welfare, and the recent increase of chemical use in the various conditions mentioned above.

AUTECOLOGICAL STUDIES OF IMPORTANT WEED SPECIES

This is to study patterns of weed growth, their seasonal changes, survival abilities and weaknesses, so that they may be manipulated in employing better control measures. Seed ecology is also recognized as among the most important factors by which weeds are distributed and established in agricultural and related environments. This includes studies on seed production, population buried in the soil, germination, dormancy, and longevity. The study of crop-weed competition is to aid understanding of how to strengthen the competing power of the crop against weeds and minimize the harmful effects of weeds. This includes studies on the critical period of competition, possibilities of heavier seeding, etc.

The study is also to discover how biological characteristics of weed and crops (morphology, physiological processes, etc.) influence control measures applied to them. In the long run this should also include study of the biological consequences of the use of herbicides and possible ways to maintain natural enemies as alternative methods of control.

Since available manpower and facilities are limited, work should correspondingly be limited to the most important weed species abundantly found in the region and relatively difficult to control by existing methods. Referring to the Task Force Meeting on Weed Biology, the weed species to be studied are: *Imperata cylindrica*, *Cyperus rotundus*, *Eichhornia crassipes*, *Mikania cordata*, *Salvinia* spp., and *Rotboellia exaltata*.

SCHOLARSHIPS

As there are only limited effort and manpower available for weed research work in South East Asia, research scholarships are offered by BIOTROP to young, promising scientists to work in close co-operation with the on-going research work.

TRAINING

It is recognized that weed control is changing its emphasis from manual operation using simple tools to chemical weed control. However, there is a general lack of knowledge of the principles and practices of chemical weed control in this area. Therefore, a short-term training course for key persons in the development of weed control techniques is badly needed. It is envisaged that the trained persons will initiate further training programmes for their local staff.

The content of the training programme comprises various topics which will be given in combination during one course. It depends on further consideration, whether or not one single specific topic will be covered during one entire course to give a more specialized training.

The various topics which will be given at the first training course in April - May 1972 are:

1. *Weed biology*

   (a) Weed identification
   (b) Weed survey
   (c) Biology of weed seeds
   (d) Biology of rhizomatous grasses
   (e) Special weed problems — *e.g.*, parasitic weeds.
   (f) Weed competition.

2. *Methods of control*

   (a) Mechanical methods
   (b) Biological methods
   (c) Chemical methods
   (d) Aquatic weeds and control
   (e) Application techniques
   (f) Review of weed control in various crops.

3. *Special aspects of chemical weed control*

   (a) Principles of selective phytotoxicity
   (b) Factors influencing the foliar and soil applied herbicides
   (c) Persistence of herbicides in plants, soil and water (incl. bioassays)
   (d) Properties of herbicides, methods of formulation
   (e) Role of herbicides in influencing tillage and crop production practices.

4. *Experimental technique*

   (a) Planning, objectives, design, procedure, equipment, etc.
   (b) Recording, analysing, preparing a report, etc.

5. *Others*

   (a) Socio-economical considerations influencing the choice of control methods
   (b) Regulatory and approval schemes
   (c) Pollution of environments
   (d) Philosophy, etc.

SEMINARS

Seminars on specific topics, such as biological control of weeds, distribution of weed species, will be organized to allow better communication among the researchers and workers engaged in their own specific topics and problems. It is BIOTROP's intention to be a co-sponsor of meetings or seminars like the Asian-Pacific Weed Control Interchange in terms of providing expenses to allow young scientists from this region to participate in and present their research reports to the meetings in the future.

These plans will be implemented during the BIOTROP fiscal year 1971-2 commencing 1 July, 1971. A five-year programme commencing 1 July, 1972 will subsequently be drawn up to continue this work for the benefit of the region.

It is to be noted that there is also significant work related to tropical weed control done by various governmental as well as private/industrial institutions or groups outside the region. The following list mentions only a few names.

U.P. College of Agriculture, Los Banos
Rubber Research Institute of Malaya, Kuala Lumpur
International Rice Research Center, Los Banos
Kasetsart University, Bangkok
International Plant Protection Center, Oregon
Weed Research Organization, Oxford
Institute for Biological and Chemical Research of Crops and Herbages, Wageningen
Dutch Working Group on Tropical Weed Control
University of Hawaii

It is BIOTROP's desire to fill gaps in the weed science activities of the region left by the already existing activities of the many institutions in South East Asia and elsewhere engaged in tropical weed research. It is also BIOTROP's intention to work closely together with other institutions engaged with related problems, for instance with SEARCA and TROPMED.

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