Table 3. Dry matter of weeds (g/m^2) at harvest. RW = Rotary weeded HW = Hand weeded.

Treatment	Echinochloa colonum	Cynodon dactylon	Cyperus difformis	Fimbristylis miliacea	Oldenlandia corymbosa	Rotala india	Alternanthera sessilis	Hydrolea zeylanica	Lindernia ciliata	Ludwigia perennis
T_1 = 2RW	0.43	0.03	0.00	0.00	0.01	0.01	1.30	0.96	0.14	0.00
T_1 = 2HW	0.00	0.02	0.00	0.07	0.01	0.02	0.57	0.98	0.09	0.00
T_3 = RW + HW	0.00	0.00	0.09	0.00	0.01	0.03	0.69	0.72	0.01	0.01
T_4 = Propanil(P)	0.34	0.00	0.00	0.30	0.01	0.04	0.86	0.80	0.01	0.77
T_5 = Butachlor(B)	0.00	0.07	0.00	0.00	0.02	0.00	0.53	0.36	0.02	0.00
T_6 = P + RW + HW	0.03	0.00	0.00	0.00	0.00	0.01	0.37	0.22	0.02	0.47
T_7 = P + RW	0.04	0.01	0.11	0.06	0.00	0.03	0.80	0.54	0.00	0.00
T_8 = P + HW	0.01	0.03	0.20	0.00	0.00	0.04	0.80	0.23	0.02	0.01
T_9 = B + RW + HW	0.01	0.02	0.00	0.32	0.00	0.00	0.54	0.09	0.02	0.00
T_{10} = B + RW	0.16	0.00	0.01	1.50	0.03	0.00	0.27	0.23	0.21	0.02
T_{11} = B + HW	[illegible]	0.09	0.00	0.39	0.00	0.00	0.29	0.14	0.03	0.17
T_{12} = Unweeded control	0.50	0.09	0.91	1.66	0.18	0.07	0.23	1.29	0.18	4.97
Percentage	4.93	1.14	4.24	17.02	0.81	0.79	28.14	21.09	2.63	19.21

Table 4. Percent weed control by the different weed control treatments.

Treatment	Echinochloa colonam	Cynodon dactylon	Cyperus difformis	Fimbristylis miliacea	Oldenlandia corymbosa	Rotala indica	Alternanthera sessilis	Hydrolea zeylanica	Lindernia ciliata	Ludwigia perennis
2 RW	29.73	70.27	100.00	100.00	100.00	50.00	35.76	10.61	44.50	100.00
2 HW	100.00	80.18	100.00	91.73	67.16	00.00	50.11	00.00	39.00	100.00
RW + HW	100.00	100.00	12.35	100.00	83.58	00.00	47.75	00.00	83.50	00.00
Propanil(P)	80.18	100.00	100.00	91.73	67.16	50.00	59.53	00.00	89.00	00.00
Butachlor(B)	100.00	30.63	100.00	100.00	67.16	100.00	30.05	46.30	66.50	100.00
P+RW+HW	90.09	100.00	100.00	100.00	100.00	00.00	45.18	78.46	78.00	00.00
P+RW	70.27	60.36	37.08	66.92	100.00	00.00	69.16	17.63	100.00	100.00
P+HW	90.09	90.09	75.28	100.00	100.00	00.00	61.18	00.00	83.50	00.00
B+RW+HW	70.27	50.55	100.00	00.00	100.00	100.00	38.12	21.54	72.00	100.00
B+RW	60.36	100.00	50.56	83.46	67.16	100.00	57.17	67.85	55.50	00.00
B+HW	100.00	39.64	100.00	49.62	100.00	100.00	73.88	96.46	55.50	00.00
Unweeded control	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00

Table 5. Yield and yield components as influenced by different methods of weed control and economics.

Treatment	No. of effective tillers/m^2	No. of grains per panicle	Test weight, g	Grain yield, q/ha	Straw q/ha	Dry matter of weeds, kg/ha	Additional profit (+) or less (—) over control Rs.	Additional profit over control/ha US$
2 RW	168.22	95.53	24.47	47.89	79.33	29.8	+ 1220.20	122.0
2 HW	182.64	101.53	25.47	50.61	85.22	18.5	+ 1584.35	158.4
RW + HW	172.92	98.27	24.93	48.55	83.33	15.6	+ 1311.60	131.2
Propanil	198.79	110.13	24.30	54.45	91.67	31.3	+ 2264.46	226.5
Butachlor	173.61	99.30	24.97	50.11	81.83	10.0	+ 1501.90	150.2
P + RW + HW	190.28	102.00	25.43	54.28	90.33	11.2	+ 2019.06	201.9
P + RW	188.96	105.73	24.20	51.33	88.78	25.9	+ 1686.51	168.7
P + HW	185.42	103.07	24.47	51.78	80.06	13.31	+ 1556.61	155.7
B + RW + HW	188.63	112.30	25.00	53.22	85.33	10.00	+ 1732.10	173.2
B + RW	170.83	94.23	24.77	46.28	83.56	24.3	+ 787.75	78.8
B + HW	177.08	101.53	24.97	50.00	88.56	11.1	+ 1354.35	135.4
Unweeded control	167.08	92.37	24.27	39.54	72.62	118.8	—	—
SEm γ	4.68	3.01	—	2.34	3.50	9.22	—	—
LSD (P=0.05)	13.73	8.83	—	6.86	10.27	27.04	—	—

Early competition of any of these weeds could be minimized by hand weeding, weeding by rotary weeder or applicationof propanil or butachlor singly or in combination of rotary weeding and/or handweeding. The harmful effect of weeds on grain yield is apparent from the significant negative correation of r = —0.798 between dry matter of weeds and grain yield. This shows that the minimum weed competition in terms of dry matter of weeds is essential to obtain higher rice yield. Considerably low weed competition under various treatments of weed control made nutrients and light more available to the main crop which in turn produced higher yield components i.e. number of panicles/m^2 as well as number of grains per panicle and finally higher yield. Propanil alone or in combination with rotary weeding and/or handweeding gave significantly higher yield components than the unweeded control but were comparable to two hand weedings. All the weed control treatments except butachlor + rotary weeding gave significantly higher grain yield than unweedecd control and they were comparable to two hand weedings. However, propanil alone at 2.0 kg/ha recorded maximum grain yield of 54.45 q/ha and additional profit of Rs. 2264.46/ha (US $226.5/ha) respectively over the unweeded control. A good weed control and higher grain yield under butachlor and propanil alone or in combination with hand weeding and weeding by rotary weeder was also reported by Pandey and Singh (1982) and AICRPWC (1981).

Weeds removed maximum amount of nitrogen in unweeded control and it was considerably high as compared to the treatments where weed control measures were adopted (Fig. 1). This indicates that if weeds are controlled in early period, i.e. within 40 DAT, weeds removed less nutrients. As a result, the crop is benefited. This is apparent from the crop performance under different weed control treatments (Table 5).

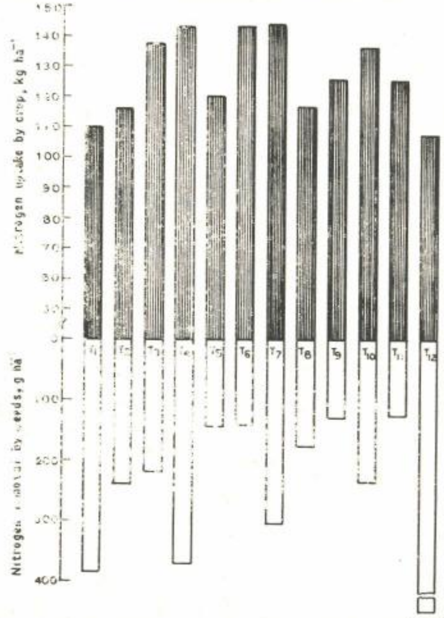

FIG.1 NITROGEN UPTAKE BY CROP AND REMOVAL BY WEEDS (EXPERIMENT-2)

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HIGHLIGHTS OF WEED SCIENCE RESEARCH IN RICE IN BANGLADESH

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ABSTRACT

The highlights of weed science work done in Bangladesh are briefly reviewed in this paper. Ecological survey of weeds in the direct sown aus rice revealed that weed infestation differed according to topography and soil moisture content. The postemergence use of Stam F-34, Rogue, and 2, 4-D was found effective to control weed population in both the aus and transplanted aman rice. While preemergence use of Prefix and planavin effectively controlled weeds in the aus and transplant aman rice field, nitrofen was effective in the rice fields of boro and transplanted aman when applied 5 days after transplanting. Weed control was done mostly by the use of hand implements like sickle, neere and rotary rice weeder.

INTRODUCTION

Rice has a pivotal position in agrarian economy of Bangladesh. It accounts for over 82 percent of the total cropped area (Anon., 1976) and though 85 per cent of the people are involved in rice production, the total production is far less than the required amount due to low yield. The reasons for low yield are attributed to many factors but one of the most important which goes unnoticed by the farmers is reduction in yield due to weeds.

There are three main classes of rice — aus (summer rice), aman (autumn rice) and boro (spring rice). The aman rice is again subdivided into two classes — transplant aman and deep water aman. The weed research in Bangladesh is mainly concentrated in aus, transplant aman and boro rice. Several investigations concerning weed science development have been carried out in rice which lead to an indepth understanding of the problem and recommendations specific to different agro-ecosystems of rice culture. This paper attempts to briefly highlight all these scattered and fragmentary information.

DISCUSSION

Ecological survey of weeds in three fields of direct sown aus rice was made with regular intervals by list and point quadrats in order to assess the frequency, percentage cover and some other related characters of weeds. The plots showed variations in soil moisture and weed flora. *Cyperus rotundus* L., *Aneilema vaginatum* and *Dopatrium junceum* (Roxb.) Buch, Ham *ex* Benth were the most widely distributed and had relatively high percentage cover values. *Anthroceros fusiformis* and *Riccia fluitans*, though found to occur with high frequency as well as percentage cover value was not considered harmful. Approximately 21% of the weed species were constantly present in the three plots surveyed (Islam and Rahman, 1979). In a weed survey in the arable lands of the East Pakistan Agricultural University Farm, Mian (1971) found 88 species of weeds belonging to 30 families. He suggested further exhaustive surveys to acquire a comprehensive knowledge of the weed flora.

Aus-rice (direct sown upland rice)

Farmers in Bangladesh extensively grow aus rice as a necessity as it is a short duration crop that comes as a mid-year harvest. Severe weed competition is the major constraint limiting the productivity. Lack of timely and efficient weed control results in the reduction of yield, sometimes to the extent of complete failure. Yield losses due to weeds range from 39-58% (Mian and Rahman 1969; and Karim and Rahman 1972).

Mechanical control measure. Mechanical weeding with different implements such as Khurpi and rake showed significant yield difference at 1% level. The highest grain yield was obtained from the two weedings. Yield was similar to that with 3 rakings and 3 weedings. Both treatments were significantly superior to the control, 2 rakings and 2 weedings, and 2 rakings. There was no significant difference between 2 rakings and the control. Alim *et al.* (1962) also reported similar effect in their experiment on weeding against no weeding. They found that two weedings are sufficient for attain the highest grain yield of aus rice.

Chemical control measures. Pre-emergence application of planavin [4(methylsulfony)-2, 6-dinitro-N, N-dipropylaniline] at the rate of 1.12 kg in 560 kg of water/ha gave a fair control of weeds such as, *Echinochloa colona* (L.) Link, *E. crusgalli* (L) Beauv., *Murdannia nudiflora* L. Brennan, *Cynodon dactylon* (L. C. Rich) Pers: *Eleusine indica* (L.) Gaertn. and *Amaranthus spinosus* L. (Mian and Rahman, 1969).

Postemergence herbicides like propanil (3, 4-dichloro-propionanilide) (Stam F-34 and Rogue) are reported to control weeds reasonably well: Stam F-34 at 11.20 kg in 493 kg of water/ha and Rogue at 8.41 kg in 247 kg of water/ha were observed to be effective in controlling grasses when applied 20 days after sowing while 2, 4-D(2, 3-dichlorophenoxy acetic acid) at 6.73

kg in 841 kg of water could control only *M. nudiflora* (Mian and Rahman, 1969). The reasonably well control of weeds by Stam F-34 and Rogue was also reported by Karim and Rahman (1972).

Transplant aman rice

The culture of transplant aman rice presupposes to have standing water in the field during almost the entire period of crop growth. This waterlogged swamp condition hardly allows any weed to grow except the swamp or marsh weeds and aquatic weeds. The minimum weed menace in this crop as compared to aus rice, may be attributed to the age gap between the transplanted rice seedlings and emerging weeds. Although weeds are not usually as much of a problem in transplant aman rice as it is in aus rice, significant depression of crop yield is inevitable if the weeds are not duly controlled (Gaffer and Rikabder, 1975; Mian and Gaffer, 1968).

Preparatory tillage. The primary objective of tillage before or after planting, is to kill weeds. And, if weeds can be controlled by any other means there is hardly any necessity of tillage in crop production. Mian and Mamun (1970) reported no appreciable effect of tillage on the performance of rice. Land tilling is not necessary to produce transplant aman rice provided the weeds can be controlled other than by tillage. Paraquat could efficiently kill the above ground parts of the weed but it possibly would do little harm if any, to the lower stem and root system of the weeds. They inferred that if paraquat was followed by another suitable herbicide applied postemergence to control subsequent weed growth, yield would be similar to that from a conventionally tilled crop.

Mechanical control measures. In the transplant aman crop two weedings by manual hand implements, each followed by rotary weeding which incororates fertilizer besides uprooting the weeds is considered, an accepted practice (Mian and Gaffer, 1968; Gaffer and Rikabder 1975).

Chemical control methods. Herbicides like 2, 4-D when used as post emergence spray controls weeds effectively. Spray application of 2,4-D 30 days after transplanting was found quite effective for weed control especially sedges and dicots. Application of nitrofen at 3.14 kg/ha 5 days after transplanting controlled weeds effectively (Gaffer and Rikabder 1975). An effective pre-emergence control of weeds with granular nitrofen (Tok-granular) applied at 6.67 kg/ha has been reported by Mian and Gaffer (1968). Stam F-34 and Rogue at 11.20 kg and 8.41 kg/ha respectively applied 24 days after transplanting were also effective. Planavin at 1.12 kg in 560 kg of water and Prefix 1.12 kg in 336 kg of water when applied 5 days after transplanting were observed to control all sedges and dicot weeds (Mian and Rahman 1969).

Deep water rice. Deep water rice is commonly known as floating rice and is grown either as mixed with aus stated earlier or as pure aman rice. The latter is grown in very low land where early entry of flood water does not permit the cultivation of aus rice. At the initial stages, the field condition of deep water rice resembles that of direct sown aus rice and supports the incidence of grasses, sedges and dicots. Subsequent water logging coupled with impeded drainage leads to the occurrence of typical aquatic weeds, such as, *Leersia hexandra* Sw., *Ipomoea aquatica* Fonsk., *Oryza rufipogon* Griff., *Monochoria vaginalis* (Burm. f.) Presl., *Hydrolea zeylanica* (L.) Vahl. etc. posing problem of their control because of the stagnant water. The conventional method of weed control is bar-drawn raking followed by one weeding with hand implement when the seedlings attain the height of 15 to 20 cm.

Boro rice

Weed problem in this crop is substantially lower than that in the direct sown upland aus rice. Weed infestation is more or less similar with that of transplant aman rice. The age-old manual had implements are used to control the weeds. Nitrofen at 3.14 kg/ha applied 5 days after transplanting was found to be effective (Mian and Gaffer 1971).

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WEED FLORA OF WHEAT AND LINSEED CROPS AT ZONAL AGRICULTURAL RESEARCH STATION POWARKHEDA (M.P.) INDIA

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ABSTRACT

A weed survey in wheat and linseed crops was done at Zonal Agricultural Research Station, Powarkheda, Hoshangabad. The most dominant weed in irrigated wheat fields at this Station was *Cichorium intybus* L. having an IVI of 33.72 with 80% frequency followed by *Chenopodium album* L., *Melilotus parviflora* Desf. *Digera alternifolia* Aschers., *Sonchus arvensis* L., *Rumex dentatus* L. and *Eclipta alba* Hassk. Among monocots, *Cyperus rotundus* L., Eragrostis spp., *Asphodelus tenuifolius* Cav., *Cynodon dactylon* Pers., *Saccharum spontaneum* L., *Dichanthium annulatum* Stapf. and *Echinochloa crusgalli* Beauv. were dominant. The occurrence of common rainy season weeds was also noted. Under unirrigated conditions, *Heliotropium eichwaldi* Steud., *C. album*, *Convolvuvus arvensis* L., *Tridax procumbens* L., A. tenuifolius, Argemone mexicana *L.*, Datura alba *Nees.*, *Oxystelma secamone* K. Schum. and *S. spontaneum* were dominant. In linseed fields higher IVI was noted in case of *Anagallis arvensis* L., *C. intybus*, *M. parviflora*, *A. tenuifolius*, *C. arvensis*, *Chenopodium album*, L. *Argemone mexicana* L., *Eragrostis* spp., *S. spontaneum and C. rotundus*.

INTRODUCTION

Zonal Agricultural Research Station, Powarkheda, caters to the research needs of wheat zone of Mdhya Pradesh with emphasis on water management and irrigation of Tawa Command area of deep black soil and wheat, in irrigated areas. This research station undertakes applied research work for determining the suitable cropping system with efficient utilization of irrigation potential of Tawa canal. To manage the water and crop, the knowledge of occurrence of weed species in this area is indispensable. So far, the weed flora of this area is unreported, hence the present weed survey was done to find out the location specific problem weeds.

MATERIALS AND METHODS

The weed survey was done by list count quadrat method (Misra, 1973) using a quadrat of $0.5m^2$ at Zonal Agriculture Research Station, Powarkheda (M.P.), India during February, 1983. This station is situated at 22.44°N, 77.42°E and 299 m high from sea level in black soil region having a representative climate of Narmada Valley famous for wheat production. It is located at state highway No. 23 on 7th km from Hoshangabab towards Itarsi. It comes under wheat zone and comprised of Vindhya Plateau and Central Narmada Valley. The soils of the farm are vertisols and commonly "deep black soils". Soybean crop was grown during the last monsoon season. The weeds of irrigated and unirrigated wheat fields and linseed crop were noted separately. The ecological analyses of the weed flora were done to determine the dominant weeds and their Importance Value Index (IVI) on the basis of relative density, frequency and dominance as suggested by Misra (1973).

RESULTS AND DISCUSSION

Weeds in irrigated wheat fields. The fields were infested with about 33 weed species (Table 1). Among the dicot weeds, *Cichorium intybus L.* was the most dominant in irrigated wheat fields and it had the highest density (6.0/0.5 m^2) and frequency (80%). Hence this weed acquired the highest importance value index (IVI) of 33.72. The next important weed of this farm was *Chenopodium album* L. which had IVI of 26.78 followed by *Melilotus parviflora* Desf. (22.98), *Digera alternifolia* Aschers. (11.26), *Sonchus arvensis* L. (9.88), *Rumex dentatus* L. (8.26), *Eclipta alba* Hassk. (7.86) and *Asphodelus tenuifolius* Cav. (5.36).

Among grasses *Eragrostis* spp. had the highest IVI (12.58) followed by *Cynodon dactylon* Pers. (8.84), *Saccharum spontaneum* L. (7.490, *Dichanthium annulatum* Stapf, and *Echinochloa crusgalli* Beauv. (4.82). *Cyperus rotundus* L. was only the sedge species which occurred in wheat fields during winter but it had a very high density and frequency acquiring the IVI of 30.02, which was next to that of *C. intybus. Phalaris minor* Retz. or *Avena fatua* L. was not found at all at this farm, though, these weeds are most common in wheat fields in Northern states of India particularly in Haryana and Punjab (Bhan *et al.*, 1978; Gill & Brar, 1977). It was very interesting to note the occurrence of *C. intybus* as the most dominant weed of this farm which was not found elsewhere in wheat fields of Madhya Pradesh at such a high density.

Some rainy season weed species viz. *Amaranthus viridis* Hook. f.; *Caesulia axillaris* Roxb., *Digera alternifolia, Eclipta alba* Hassk., Euphorbia geniculata Orteg., *Physalis minima* L., *Psoralea coryliforlia* L., *Striga lutea* Lour., *Echinochloa crusgalli (L.) Beauv.* and *Eragrostis* spp. were so observed. It was very surprising to note the presence of *S. lutea* as it has not been reported so far in wheat fields. The occurrence of these rainy season weeds was due to availability of irrigation and other ambient conditions which favored their germination.

Table 1. Weed flora in irrigated wheat at Powarkheda farm.

Species	Density (/m²)	Frequency (%)	Relative Density	Relative Frequency	Relative Dominance	IVI
1. *Amaranthus viridis* Hook. f.	0.20	20	0.66	2.73	1.43	4.82
2. *Anagallis Arvensis* L.	0.40	10	1.20	1.36	1.07	3.63
3. *Asphodelus tenuifolius* Cav.	0.40	20	1.20	2.73	1.43	5.36
4. *Argemone mexicana* L.	0.10	10	0.33	1.36	1.79	3.15
5. *Caesulia axillaris* Roxb.	0.10	10	0.33	1.36	1.79	3.15
6. *Cichorium intybus* L.	6.0	80	20.00	10.95	2.87	33.72
7. *Chenopodum album* L.	4.30	70	14.33	9.58	2.87	26.78
8. *Convolvulus arvensis* L.	0.30	20	1.00	2.73	1.07	4.80
9. *Chrozophora parvifolia* Koltz. ex Schw. fth.	0.20	10	0.66	1.36	2.15	4.17
10. *Digera alternifolia* Aschers.	1.30	40	4.33	4.78	2.15	11.26
11. *Eclipta alba* Hassk.	0.70	30	2.33	4.10	1.43	7.86
12. *Euphorbia genicalata* Orteg.	0.50	10	1.66	1.36	1.07	4.09
13. *Euphorbia prostrata* Ait.	0.20	20	0.66	2.73	1.07	4.46
14. *Launea asplenifolia Hook.* f	0.10	10	0.33	1.36	1.43	3.12
15. *Lathyrus aphaca* L.	0.20	10	0.66	1.36	1.07	2.43
16. *Melilotus alba* Desr.	0.70	10	2.33	1.36	1.43	5.12
17. *Melilotus parviflora* Desf.	4.00	60	13.33	8.22	1.43	22.98
18. *Medicago denticulata* Willd.	0.20	10	0.66	1.36	1.07	3.09
19. *Oxystelma secamone* K. Schum.	0.20	10	0.66	1.36	1.07	3.09
20. *Physalis minima* L.	0.20	10	0.66	1.36	2.87	4.89
21. *Portulaca oleracea* L.	0.10	10	0.33	1.36	1.07	2.76
22. *Psoralea corylifolia* L.	0.10	10	0.33	1.36	1.43	3.12
23. *Rumex dentatus* L.	0.50	30	1.66	4.10	2.50	8.26
24. *Sonchus arvensis* L.	0.50	20	1.66	2.73	5.49	9.88
25. *Striga lutea* Lour.	0.10	10	0.33	1.36	1.43	3.12
26. *Vicia sativa* L.	0.20	10	0.66	1.36	1.07	3.09
27. *Volutarella divaricata* Benth.	0.20	20	0.66	2.73	1.83	5.22
28. *Cynodon dactylon* Pers.	1.00	40	3.33	4.79	0.73	8.84
29. *Dichanthium annulatum* Staff	0.20	20	0.66	2.73	1.43	4.82
30. *Echinocloa crusgalli* (L.) Beauv.	0.20	20	0.66	2.73	1.43	4.82
31. *Eragrostis* spp.	1.40	50	4.66	6.85	1.07	12.58
32. *Saccharum spontaneum* L.	1.00	20	3.33	2.73	1.43	7.49
33. *Cyperus rotundus* L.	5.40	80	18.00	10.95	1.07	30.02

Weeds in unirrigated wheat fields. About 29 weed species were noted under unirrigated fields at Powarkheda farm (Table 2). The most important weeds with high IVI consisted of *Heliotropium eichwaldi* Steud. (21.24), *C. album* (20.33), *Convolvulus arvensis* (13.19), *Tridax procumbens*

L. (12.94), *Asphodelus tenuifolius* (12.16), Argemone mexicana L. (1090), *Datura alba* (10.84), *Oxystelma secamone* (9.88), *C. intybus* (.936) and *Hibiscus micranthus* L. (9.02). Under unirrigated condition *H. eichwaldi* had the highest frequency and density. It was totally absent from irrigated fields. Its occurrence under irrigated condition was very low. *C. album* was a common dominant weed under both situations. The density of *C. arvensis* was higher under unirrigated condition as compared to irrigated ones. The occurrence of *A. tenuiflius* and *A. mexicana* was higher under unirrigated condition but lower under irrigated condition.

Table 2. Weed flora in unirrigated wheat fields at Powarkheda farm.

Species	Density (/m²)	Frequency (%)	Relative Density	Relative Frequency	Relative Dominance	IVI
1. *Anagallis arvensis* L.	0.6	20	2.34	2.32	1.42	6.08
2. *Asphodelus tenuifolius* Cav.	1.2	40	4.68	4.84	2.84	12.16
3. *Argemone mexicana* L.	0.2	20	0.78	2.32	7.80	10.90
4. *Coronopus didymus* Sm.	0.6	20	2.34	2.32	2.84	7.50
5. *Cichorium intybus* L.	0.6	30	2.34	3.48	3.54	9.36
6. *Chenopodium album* L.	2.3	60	8.99	6.96	4.36	20.31
7. *Convolvulus arvensis* L.	1.4	50	5.46	5.81	2.12	12.19
8. *Chrozophora parvifolia* Koltz. ex Schwfth.	0.2	10	0.78	1.16	4.36	6.30
9. *Digera alternifolia* Aschers	0.1	10	0.39	1.16	2.84	4.39
10. *Datura alba* Nees.	0.3	10	1.17	1.16	8.51	10.84
11. *Euphorbia granulata* Forsk.	0.4	30	1.56	3.48	2.12	7.16
12. *Euphorbia dracunculoides* Lamk.	0.3	20	1.17	2.32	3.54	7.03
13. *Hibiscus micranthus* L.	0.2	10	0.78	1.16	7.08	9.02
14. *Heliotropium eichwaldi* Steud.	2.8	40	10.93	4.64	5.67	21.24
15. *Indigofera* spp.	0.3	30	1.17	3.48	2.12	6.77
16. *Launea asplenifolia* Hook f.	0.4	20	1.56	2.32	2.84	4.78
17. *Melilotus alba* Desr.	0.2	10	0.78	1.16	2.84	4.78
18. *Melilotus parviflora* Desf.	0.3	10	1.17	1.16	2.84	5.17
19. *Medicage denticulata* Willd.	0.3	20	1.17	2.32	2.12	5.61
20. *Merrimia emerginata* Hallier.	0.30	20	1.17	2.32	1.42	4.91
21. *Oxystelma secamone* K. Schum.	0.8	40	3.12	4.64	2.12	9.88
22. *Portulaca oleracea* L.	0.6	30	2.34	3.48	2.84	6.33
23. *Phaseolus trilobus* Ait.	0.3	20	1.17	2.32	2.84	6.33
24. *Tridax procumbens* L.	1.1	50	4.29	5.81	2.84	12.94
25. *Vicia sativa* L.	0.6	20	2.34	2.32	2.12	6.78
26. *Voluntarella divaricata* Benth.	0.4	30	1.56	3.48	3.54	8.58
27. *Cynodon dactylon* Pers.	3.2	30	12.50	3.48	2.12	6.00
29. *Eragrostis* spp.	1.0	40	3.90	4.36	2.84	11.10
30. *Saccharum spontaneum* L.	3.7	50	14.45	5.81	2.12	22.38
31. *Cyperus rotundus* L.	0.5	20	1.84	2.32	1.42	5.69

Among grasses *Saccharum spontaneum* was the most dominant under unirrigated conditions with an IVI of 22.38 while under irrigated condition *Cyperus rotundus* was the most dominant (30.02). *Eragrostis* spp. acquired almost the same IVI under both situations. No rainy season weed was found in the unirrigated fields except *D. alternifolia* and *Phaseolus trilobus* Ait. indicating that these weds can also germinate under limited moistureconditins.

Weed flora in linseed fields. The soil of the fields surveyed was clay loam. The crop was grown under unirrigated condition in fields followed during monsoon. The weed flora of the linseed fields (Table 3) consisted of mainly twenty-two species. Out of these, 5 were grasses, *C. dactylon*, *Dichanthium annulatum*, *Eragrostis* spp., *Digitaria* spp., and *Saccharum spontaneum*.

Table. 3. Weed flora in linseed crop of Powarkheda farm.

Species	Density (/m^2)	Frequency (%)ıcy	Relative Density	Relative Frequency	Relative Dominance	IVI
1. *Anagallis arvensis* L.	4.5	30	20.0	6.8	3.1	29.9
2. *Asphodelus tenuifolius* Cav.	2.7	40	12.0	6.8	4.1	22.9
3. *Argemone mexicana* L.	0.2	10	0.8	1.7	15.3	17.8
4. *Cichorium intybus* L.	2.5	60	11.1	10.2	7.2	28.5
5. *Chenopodium album* L.	1.2	30	5.3	5.1	8.2	18.6
6. *Convolvulus arvensis* L.	1.8	60	8.0	10.2	3.1	21.3
7. *Chrozophora parvifolia* Koltz. ex Schwft.	0.5	20	2.2	3.4	6.1	11.7
8. *Commelina bengalensis* L.	0.1	10	0.4	1.7	4.1	6.2
9. *Euphorbia dracunculoides*	0.3	20	1.3	3.4	4.1	8.8
10. *Eclipta alba* Hassk.	0.2	20	0.8	3.4	3.1	7.3
11. *Launea asplenifolia* Hook f.	0.7	30	3.1	5.1	4.1	12.3
12. *Melilotus alba* Desr.	0.3	10	1.3	1.7	4.1	7.1
13. *Melilotus parviflora* Desf.	2.4	60	10.6	10.2	4.1	24.9
14. *Rumex dentatus* L.	0.2	10	0.8	1.7	8.2	10.7
15. *Sonchus arvensis* L.	0.3	20	1.3	3.4	12.3	16.0
16. *Volutarella divaricatá* Benth.	0.2	10	0.8	1.7	8.2	10.7
17. *Cynodon dactylon* Pers.	0.6	30	2.7	5.1	2.1	9.9
18. *Dichanthium* spp.	0.3	20	1.3	3.4	3.1	7.8
19 *Digitaria* spp.	0.1	10	0.4	1.7	3.1	5.2
20. *Eragrostis* spp.	1.2	30	5.3	5.1	3.1	13.5
21. *Saccharum spontaneum* L.	0.3	20	1.3	3.4	3.1	7.8
22. *Cyperus rotundus* L.	2.6	60	11.6	10.2	2.1	23.9

Among other weeds, the highest density was noted in case of *Anagallis arvensis* L. (4.5) followed by *A. tenuifolius* (2.7), *C. intybus* (2.5) and *M. parviflora* (2.4). The latter three weeds had the highest frequency of 60%. The IVI was maximum in the case of *A. arvensis* followed by *C. intybus*, *M. parviflora*, *A. tenuifolius*, *C. arvensis*, *C. album* and *A. mexicana*. The latter weed, although it had a lower IVI was more troublesome due to its thorns.

The occurrence of *C. Intybus* in linseed fields was surprising (Tiwari, 1982; Tiwari *et al.*, 1982). This weed might have spread previously through other crop viz. berseem which is its most important dispersal agent. This survey showed that most of these weeds may occur in any crop field under a set of climatic conditions while some are related to the specific crop ecosystem and previous treatment.

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CHEMICAL WEED CONTROL IN WHEAT

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ABSTRACT

A field experiment was conducted to study the comparative efficacy of some substituted urea herbicdes for the control of weeds in wheat (*Triticum aestivum* L.) during the winter seasons of 1980-81 and 1981-82.

Preemergence as well as postemergence applications of isoproturon at 1.5 kg/ha provided effective control of *Phalaris minor* Retz. and all annual non-grass weeds, and produced grain yield significantly higher than that of methabenzthiazuron.

INTRODUCTION

Weeds are responsible for marked yield losses of wheat. With the large area cultivated to high-yielding dwarf wheat varieties, grass weeds particularly *Phalaris minor* Retz, *Avena fatua* L. and *Avena ludoviciana* Duv have posed a serious problem in wheat cultivation. The extent of losses in grain yield due to the presence of these weeds have been estimated to be 15 to 30% depending upon the species and intensity of weeds, and soil fertility (Gill and Brar, 1972; Gill *et al.*, 1979; Rao and Bhardwaj, 1979). These weeds provide more severe competition to the wheat crop since their feeding zone in soil is the same as that of wheat. These weeds defy mechanical methods of weed control due to their morphological similarities with wheat during the vegetative phase, high reproductive rate, early seed shedding behaviour, seed dormancy, and indiscriminate movement of wheat from infested to non-infested areas (Gill *et al.*, 1979). The most commonly used herbicides like 2, 4-D is less effective in controlling the mixed weed flora. Therefore, the present study was undertaken during the dry seasons of 1980-81 and 1981-82 to compare the relative effectiveness of broad spectrum substituted urea herbicides for the control of weeds in wheat.

MATERIALS AND METHODS

Isoproturon (N'-isopropylphenol)-N, N-dimethyl urea), methabenzthiazuron (N-(benzothiazol-2-yl)-N,N'-dimethyl-urea) and metoxuron (N'-(3-chloro-4-methoxyphenyl) N,N-dimethyl urea) were each applied preemergence and postemergence (40 days after sowing) at three rates (Table

1). Unweeded checks are included for comparison. The herbicides were applied with a sprayer calibrated to deliver 800 L/ha. The treatments were arranged in a randomized block design and replicated four times. Wheat cultivar block design and replicated four times. Wheat cultivar Sonalika (RR-21) was planted on December 10, 1980-81 for the first test and on December 1 for the second crop season, following the recommended practices. Weed density and dry matter/m^2 were recorded at 30, 60, 90 and 120 days of crop growth using a quadrat (25 cm x 25 cm) randomly placed in each plot. Number of spikelets per spike were collected from 10 spikes selected randomly from the fixed meter row length. For grain and straw yield, a net plot of 3 m x 1.84 m and 4 m x 1.8 m in each plot was harvested in the first and second crop seasons, respectively.

The experiment during the dry season of 1980-81 was conducted on a loam soil with pH of 7.7, 0.77% organic matter, 48.4 kg available P/ha and 172.6 kg available K/ha. During the dry season of 1981-82 the soil was silty loam with pH 7.4, 8% organic matter, 37.8 available P/ha, and 187.5 kg available K/ha.

RESULTS AND DISCUSSION

Effect of treatments on weeds. Weed population in untreated plots (check) was significantly higher than in all the other treatments (Table 1). Pre- or post-emergence application of isoproturon at 1.5 kg/ha resulted in the highest reduction in weed population at 60, 90 and 120 days of crop growth during both seasons. At 120 days of crop growth (1980-81), the effects of metoxuron at 1.6 and 2.4 kg/ha applied as pre-emergence were more or less similar to isoproturon at 1.5 kg/ha applied as pre- or post-emergence. On the other hand, postemergence application of metoxuron at 2.4-kg/ha proved to be equally effective during the 1981-82 season. Kasasian (1978) also reported that the most promising results were given by the pre-emergence application of isoproturon at 0.75 or 1.5 kg/ha. The results obtained from metoxuron at 1.6 to 2.4 kg/ha are in conformity with the findings of Gill and Brar (1976). Methabenzthiazuron was found to be effective against *P. minor* when applied at the rate of 2.25 kg/ha as pre emergence. Tyagi *et al.*, 1978 also reported that pre-emergence application of methabenzthiaruson at 2.0 kg/ha resulted in 92% control of *P. minor* and 56% control of broadleaf weeds..

Pre-emergence application of isoproturon at 1.5 kg/ha showed the best results in reducing dry matter yield of weeds at 60, 90 and 120 days of crop growth during the first crop season (Table 2). During 1981-82, the highest reduction in weed dry matter yield at 60, 90 and 120 days of crop growth was recorded when isoproturon was applied postemergence at 1.5 kg/ha. It was followed closely by the postemergence application of metoxuron at 2.4 kg/ha at 120 days.

Effect of treatments on crop. Herbicide treatments resulted in higher values of yield attributes and grain yield than the weedy check (Tables 3 and 4). During 1980-81, the highest wheat dry matter production at

Table 1. Effect of herbicides on the number of weeds/m^2 at different stages of wheat growth (1980-81, 1981-82).

Treatment		Rate (kg/ha)	Days after sowing 30		60		90		120	
			1980-81	1981-82	1980-81	1981-82	1980-81	1981-82	1980-81	1981-82
Isoproturon		Pre								
Isoproturon	Pre	0.50	400	340	269	292	140	116	140	103
Isoproturon	Pre	1.00	364	349	136	202	060	94	48	64
Isoproturon	Pre	1.50	384	354	108	132	56	70	20	20
Isoproturon	Pre	0.50	324	377	148	248	152	140	112	98
Isoproturon	Post	1.00	352	328	108	119	64	43	40	21
Isoproturon	Post	1.50	360	314	76	101	56	35	24	18
Methabenzthiazuron	Pre	0.75	392	362	229	220	168	139	140	127
Methaeenzthiazruon	Pre	1.50	336	322	208	180	120	121	100	99
Methabenzthiazuron	Pre	2.25	408	376	96	139	90	86	72	57
Methabenzthiazuron	Post	0.75	412	336	316	272	192	168	112	87
Methabenzthiazuron	Post	1.50	392	308	212	171	84	131	96	56
Methabenzthiazuron	Post	2.25	289	305	152	147	82	92	80	48
Metoxuon	Pre	0.80	416	376	208	250	164	156	112	139
Metoxuron	Pre	1.60	384	307	132	195	132	125	24	99
Metoxuron	Per	2.40	384	332	152	154	68	95	32	34
Metoxuron	Post	0.80	376	341	216	201	236	178	160	87
Metoxuron	Post	1.60	328	368	204	150	120	104	68	33
Metoxuron	Post	2.40	332	326	108	106	84	42	56	21
Weedy		—	436	343	650	448	440	359	268	214
Weed free		—	392	335	0	0	0	0	0	0
S.Em. ±			43	15	30	17	26	9	18	7
L.S.D. .05			118	42	82	47	72	24	49	19

Table 2. Effects of herbicides on the weed dry matter production (g/m^2) at different stages of wheat growth (1980-82).

		Rate (kg/ha)	Days after sowing							
			30		60		90		120	
			1980-81	1981-82	1980-81	1981-82	1980-81	1981-82	1980-81	1981-82
Isoproturon	Pre	0.50	6.9	5.0	35.3	30.3	62.0	66.9	42.3	43.5
Isoproturon	Pre	1.00	7.0	5.2	8.9	11.8	6.4	30.6	18.0	26.3
Isoproturon	Pre	1.50	8.5	5.6	2.0	6.3	5.6	7.1	3.2	3.2
Isoproturon	Post	0.50	6.9	5.7	39.4	34.2	62.2	70.1	28.4	38.2
Isoproturon	Post	1.00	7.9	5.7	16.6	6.0	29.7	23.2	19.6	5.0
Isoproturon	Post	1.50	8.2	5.4	7.4	3.5	5.5	5.5	5.1	1.7
Methabenzthiazuron	Pre	0.75	6.8	5.7	34.7	34.8	49.8	54.2	67.3	44.0
Methabenzthiazuron	Pre	1.50	7.2	5.7	27.8	20.6	41.6	31.4	40.6	38.8
Methabenzthiazuron	Pre	2.25	6.5	6.6	13.7	13.7	28.3	20.6	14.7	17.9
Methabenzthiazuron	Post	0.75	6.7	6.0	30.7	37.2	41.9	54.9	70.8	37.7
Methabenzthiazuron	Post	1.50	6.3	6.9	23.7	19.9	40.0	25.9	36.6	28.0
Methaeenzthiaaruon	Post	2.25	7.0	6.3	15.8	14.6	19.8	14.5	21.2	20.4
Metoxuron	Pre	0.80	7.4	6.5	12.6	40.0	39.6	55.9	36.4	51.5
Metoxuron	Pre	1.60	8.8	6.4	6.3	23.0	4.6	24.7	13.6	32.7
Metoxuron	Pre	2.40	7.2	5.7	2.1	12.1	5.6	13.5	7.2	12.7
Metoxuron	Post	0.80	7.7	6.6	33.6	32.5	57.4	51.6	43.2	38.1
Metoxuron	Post	1.60	6.9	5.2	13.0	9.8	18.3	20.3	21.7	12.9
Metoxuron	Post	2.40	7.6	6.5	7.8	7.6	4.6	12.9	14.8	2.6
Weedy		—	7.9	6.2	51.8	52.9	84.6	78.8	239.9	181.9
Weed free		—	7.5	5.9	00	0.0	0.0	0.0	0.0	0.0
S.Em. ±			0.9	0.5	3.1	3.7	5.8	4.1	6.1	3.2
L. S. D. .05			2.5	1.4	8.5	10.4	16.0	11.2	16.9	8.9

Table 3. Influence of herbicides on the dry matter production, plant height, number of spike-bearing shoots, and length of spike of wheat.

Herbicide *Treatment*		Rate (kg/ha)	Dry matter – (g) (120 DAS) 1980-81	1981-82	Plant height (120 DAS) 1980-81	1981-82	No. of spoke bearing shoots per row at harvest 1980-81	1981-82	Length of spike (cm) at harvest 1980-81	1981-82
Isoproturon	Pre	0.5	296.8	274.3	100.4	99.0	73	74	8.8	3.6
Isoproturon	Pre	1.0	393.0	278.5	99.8	99.5	95	83	9.3	8.8
Isoproturon	Pre	1.5	368.7	309.5	102.1	101.1	101	88	9.9	9.2
Isoproturon	Post	0.5	314.2	262.1	100.9	97.6	61	70	8.8	8.4
Isoproturon	Post	1.0	347.4	298.4	103.4	99.0	67.	81	9.0	8.9
Isoproturon	Post	1.5	291.2	310.2	102.7	100.8	94	96	9.7	9.1
Methabenzthiazuron	Pre	0.75	316.8	237.5	99.6	96.4	72	85	8.9	8.4
Methabenzhiaruron	Pre	1.50	294.4	259.3	98.4	98.7	72	85	8.9	8.6
Methabenzhiazuron	Pre	2.25	361.1	281.2	102.4	99.1	76	76	9.1	9.1
Methabenzthiazuron	Post	0.75	223.9	214.0	98.2	97.4	77	74	8.6	8.2
Methabenzthiazuron	Post	1.50	270.9	236.8	101.0	97.8	79	81	8.8	8.8
Methabenzthiazuron	Post	2.25	229.8	281.3	96.8	99.7	74	90	8.9	9.0
Metoxuron	Pre	0.8	272.3	233.8	99.7	96.9	78	67	8.8	8.2
Metoxuron	Pre	1.6	349.4	262.4	102.1	98.3	87	83	9.8	8,7
Metoxuron	Pre	2.4	341.0	286.6	102.7	99.6	93	93	9.4	9.1
Metoxuron	Post	0.8	294.6	253.4	99.9	96.9	77	61	8.8	8.2
Metoxuron	Post	1.6	310.9	275.4	100.3	99.3	88	86	8.9	8.6
Metoxuron	Post	2.4	329.8	296.8	100.8	100.4	96	93	9.0	8.9
Weedy		—	153.9	155.1	95.7	89.5	46	60	8.1	8.0
Weed free		—	287.3	308.4	102.2	99.7	100	97	9.3	9.4
	S. Em. ±		22.0	13.5	1.0	1.3	5.7	3.1	0.3	0.2
	L. S. D. .05		61.0	37.7	2.8	3.6	15.8	8.7	0.7	0.5

Table 4. Effect of herbicides on test weight, grain and straw yields of wheat during two crop seasons.

Herbidi Herbicide		Rate (kg/ha)	Weight (g) of 100 grains		Grain yield (kg/ha)		Straw yield (kg/ha)	
			1980-81	1981-82	1980-81	1981-82	1980-81	1981-82
Isip								
Isoproturon	Pre	0.5	48.1	44.9	3355	2717	7468	6525
Isoproturon	Pre	1.0	50.9	47.8	4016	3270	7399	6463
Isoproturon	Pre	1.5	51.7	49.0	4355	3816	7281	64.84
Isoproturon	Post	0.5	47.1	44.2	3527	2650	6842	6086
Isoproturon	Post	1.0	47.4	46.8	3482	3492	6922	6444
Isoproturon	Post	1.5	50.9	49.9	3957	3872	6553	6565
Methabenzthiazurn	Pre	0.75	46.5	44.6	3078	2521	6656	6170
Methabenzthiazuron	Pre	1.50	47.8	46.9	3223	2760	6361	5694
Methabenzthiazuron	Pre	2.25	48.4	49.2	3652	3547	6978	5966
Methabenzthiazuron	Post	0.75	48.7	44.6	3060	2479	7172	6142
Methabenzthiazuron	Post	1.50	47.3	46.0	3527	3048	7163	6110
Methabenzthiazuron	Post	2.25	47.9	47.9	3485	3510	6973	5941
Metoxuron	Pre	0.80	46.8	44.0	3395	2562	6933	5607
Metoxuron	Pre	1.60	50.1	46.1	3835	3044	6692	6010
Metoxuron	Post	2.40	50.6	48.8	3699	3441	6674	5914
Metoxuron	Post	0.80	46.2	45.3	3332	2513	7163	6235
Metoxuron	Post	1.60	48.5	46.9	3456	3498	6783	6144
Metoxuron	Post	2.40	51.4	49.5	3735	3737	6638	6449
Weedy		—	41.3	41.4	2616	2429	6303	5902
Weed free		—	50.1	50.3	3835	3962	6942	6587
S.Em. ±			0.3	0.6	109.1	106.3	340.6	58.4
L.S.D. .0.05			0.7	1.6	394.9	294.7	N. S	161.8

120 days of crop growth was recorded with the pre-emergence application of isoproturon at 1.5 kg/ha. In 1981-82, wheat with postemergence application of isoproturon at 1.5 kg/ha produced the highest crop dry matter, though all the isoproturon treatments, except postemergence application at lower rate (0.75 kg/ha), had similar yields. Methabenzthiazuron and metoxuron treatments were effective at higher rates.

Plant height, spike bearing shoots, length of spike (Table 3) and weight of 1000 grains (Table 4) were superior with pre-emergence application of isoproturon at 1.5 kg/ha as compared to other treatments during the 1980-18 season. As a result, significantly higher grain yield was recorded in this treatment. These results are in conformity with the findings of Ravn (1979) and Black and Henson (1980). During the 1981-82 season, the highest grain yield was recorded when plots were kept weed free. Among the herbicide treatments, postemergence application of isoproturon at 1.5 kg/ha produced the highest grain yield. This might be attributed to the higher number of spike bearing-shoots, length of spike, and weight of 1000 grains as a result of less weed population and weed dry matter production. Metoxuron at 2.4 kg/ha applied as pre- or postemergence also gave higher grain yield and yield attributes as compared to other metoxuron treatments during the 1980-81 season. Postemergence application of metoxuron at 2.4 kg/ha showed superiority over the rest of the metoxuron treatments with respect to grain yield. Methabenzthiazuron treatments did not do better probably due to ineffective control of broadleaf weeds. Gill and Brar (1976) also found that methabenzthiazuron applied as pre-emergence at 1.05 kg/ha had less reliable results than either metoxuron or isoproturon.

Differences in straw yield due to herbicide treatments were not significant during the 1980-81 season but were significant during the 1981-82 season. The highest straw yield was recorded in weed-free treatment and followed closely by the postemergence application of isoproturon at 1.5 kg/ha. The lowest straw yield was found in weedy check during both years.

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DRY MATTER ACCUMULATION AND NITROGEN DEPLETION PATTERN BY WEEDS IN WHEAT AS AFFECTED BY NITROGEN LEVELS AND WEED CONTROL

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ABSTRACT

Field and laboratory studies were conducted for two consecutive years to determine the relationship between nitrogen application and methods of weed control on dry matter accumulation and nitrogen depletion pattern by weeds in wheat (*Triticum vulgare* L.).

Dry matter production and depletion of nitrogen by weeds increased significantly with increasing levels of nitrogen at all the growth stages. Pre-emergence application of methabenzthiazuron and pendimethalin gave an excellent control of weeds and resulted in the greatest reduction in dry matter accumulation in weeds and in checking the drain of nitrogen through weeds at all levels of nitrogen.

INTRODUCTION

With the introduction of high yielding varieties, the consumption of nitrogenous fertilizers has increased many folds. Weeds, by virtue of their very fast growth rate, use up large quantities of nutrients more particularly nitrogen, within 4 to 6 weeks of crop sowing and thus subjecting the juvenile crop plants to a stiff competition, resulting in lower grain yield. Gautam *et. al.* (1974) reported a loss of about 40 kg N/ha due to weedy conditions. It is thus obvious that for tapping the maximum yield potential of meticulously tailored dwarf wheat varieties and for judicious use of nitrogen application, aggressive weed growth has to be checked in time. The present energy crisis and spiralling cost of nitrogenous fertilizers have assumed an added significance. One of several ways of increasing the efficiency of fertilizers is to follow effective weed control schedule. The present study was initiated to ascertain the interaction effect of nitrogen application and weed control methods on dry matter production of weeds and removal of nitrogen by unchecked weed growth, so that the possibility of reducing nitrogen dose can be explored.

MATERIALS AND METHODS

Field experiments were carried out during winter seasons of 1977-78 and 1978-79 with wheat cv. HD. 1553 at the Research Farm of the Banaras Hindu University, Varanasi. The soil of the experimental area was medium loam with a pH of 7.1 and 0.742% organic carbon. The treatments consisted of four levels of nitrogen: 0, 40, 80 and 120 kg/ha which formed the main plots. The weed control methods, unweeded check, manual weeding given four times, methabenzthiazuron [1,3-dimethyl-3-3(2-benzothiazolyl) urea] at 1.4 kg/ha, pendimethalin [N-(l-ethyl propyl)3,4-dimethyl-2,6-dinitrobenzenamine] at 1.5 kg/ha, nitrofen (2,4-dichlorophenyl-4-nitrophenyl ether) at 1 kg/ha, terbutryne [2-(tert-butylamine)-4-(ethyl amino)-6 (methylthio)1,3,5 triazine] at 0.8 kg/ha, metoxuron [N-(3 chloro-4-methoxyphenyl)-N,N-dimethyl urea] at 1.2 kg/ha and 2,4-D(2,4-dichlorophenoxyacetic acid) at 0.8 kg/ha were assigned to sub-plots in a split plot design with three replications.

Weed samples were collected from 100 cm x 50 cm area from two spots in each plot at 45, 75 and 105 days after wheat sowing. The samples were dried in the electric oven at 65 c to 70 C for 24 hours and their dry weights was recorded. The weed samples collected for determining dry matter accumulation at different stages of growth were powdered and analyzed for nitrogen content. The depletion of nitrogen by weeds in kg/ha was expressed on dry matter basis.

RESULTS

Effect on dry matter of weeds

Maximum dry weight of weeds was observed under the highest dosage level of nitrogen (120 kg/ha) and the minimum in the absence of nitrogen application (Table 1). The dry weight of weeds varied significantly among the various levels of nitrogen. The trend was similar in both years of experimentation. The increasing nitrogen levels proved instrumental in increasing the dry weight of weeds. All the weed control methods reduced the dry matter accumulation drastically as compared to unweeded check at all the stages of growth. Among the herbicide treatments, the dry weight of weeds was reduced significantly with methabenzthiazuron and pendimethalin (Table 1). There was no statistical variation between methabnzthiazuron and pendimethalin treatments. Metoxuron application decreased the dry matter of weeds to a level of significance over manual weeding, nitrofen, terbutryne and 2,4-D. Considerable reduction in dry matter of weeds was noted in case of terbutryne over nitrofen and 2,4-D.

The interaction effect of nitrogen levels and weed control methods was also found significant at various stages of growth in both years of experimentation. Preemergence application of methabenzthiazuron and pendimethalin resulted in the appreciable reduction in dry matter accumulation of weeds at all the stages of growth at all levels of nitrogen (Tables 2 and 3).

Table 1. Dry matter accumulation in weeds (g/m^2) at different stages of growth as influenced by nitrogen levels and weed control methods.

Treatment	Days after sowing					
	45	75	105	45	75	105
		1977-78			1978-79	
Nitrogen levels (kg/ha)						
0	17.34	24.51	32.69	20.94	27.30	36.01
40	24.99	32.31	39.23	22.69	36.77	43.41
80	49.59	62.46	76.53	53.66	67.06	80.99
120	72.71	88.90	107.49	75.27	92.79	113.71
LSD (P = 0.05)	0.38	0.28	0.33	0.08	0.18	0.51
Weed control methods						
Unweeded check	75.79	90.27	110.58	81.68	98.34	118.70
Manual weedings	36.21	45.31	81.97	39.82	48.56	52.36
Methabenzthiazuron	27.86	38.98	47.41	31.63	41.47	50.28
Pendimethalin	28.50	38.91	47.92	31.00	41.15	50.47
Nitrofen	45.85	56.39	71.14	51.42	61.90	75.63
Terbutryne	41.67	51.62	65.43	42.33	56.12	70.77
Metoxuron	30.27	41.15	50.08	33.39	43.74	52.67
2,4-D	43.12	53.04	67.36	44.27	56.61	72.36
LSD (P = 0.05)	0.31	0.32	0.44	0.22	0.32	0.64

Table 2. Dry matter accumulation in weeds (g/m^2) at different stages of growth as influenced by interaction between nitrogen levels and weed control methods (1977-78)

Weed control methods	Nitrogen levels			
	N_0	N_{40}	N_{80}	N_{120}
	At 45 days			
Unweeded check	28.58	39.51	90.84	144.24
Manual weeding	14.74	21.47	47.11	61.51
Methabenzthiazuron	10.78	18.11	38.18	46.44
Pendimethalin	10.91	18.78	37.00	47.30
Nitrofen	22.31	28.97	51.84	80.28
Terbutryne	18.50	25.44	47.10	75.60
Metoxuron	12.43	20.84	38.54	48.25
2,4-D	20.43	26.84	48.20	77.00
LSD (P = 0.05)	0.61			
	At 75 days			
Unweeded check	36.17	46.97	108.14	172.57
Manual weeding	22.06	28.96	58.04	72.20
Methabenzthiazuron	18.11	25.21	51.07	61.51
Pendimethalin	18.77	25.44	50.64	60.77
Nitrofen	29.42	27.21	61.50	97.41
Terbutryne	25.30	32.67	57.90	90.61
Metoxuron	20.31	27.54	53.14	63.61
2,4-D	25.95	34.44	59.24	92.51
LSD (P = 0.05)	0.64			
	At 105 days			
Unweeded check	45.68	54.21	126.10	216.31
Manuel weeding	27.20	32.35	66.81	72.21
Pendimethalin	24.83	31.77	61.76	73.31
Nitrofen	41.25	45.30	80.97	111.00
Terbutryne	34.24	41.64	74.27	111.55
Metoxuron	36.98	34.11	64.18	75.04
2,4-D	38.68	42.77	76.94	112.98
LSD (P = 0.05)	0.88			

Next best herbicide was metoxuron which effected a significant decrease in dry weight of weeds with and without nitrogen application over manual weeding and other herbicidal treatments. There was a significant reduction in dry matter production with manual weeding and terbutryne with 80 kg N/ha at the first and second stages of growth. At the third stage manual weeding was superior to terbutryne at 0, 40 and 120 kg N/ha. 2,4-D maintained its superiority over nitrofen and unweeded check reducing significantly the dry matter accumulation with nitrogen application at all stages of growth.

Table 3. Dry matter accumulation in weeds (g/m^2) at different stages of growth as influenced by interaction between nitrogen levels and weed control methods (1978-79).

Weed control method	Nitrogen levels			
	N_0	N_{40}	N_{80}	N_{105}
	At 45 days			
Unweeded check	36.10	42.17	19.17	151.24
Manual weeding	18.31	25.21	50.74	65.11
Methabenzthiazuron	14.34	21.34	39.34	50.31
Pendimethalin	14.04	21.91	40.61	50.96
Nitrofen	25.34	36.40	57.64	86.38
Terbutryne	21.21	29.01	50.74	72.34
Metoxuron	16.21	23.83	41.34	52.18
2,4-D	22.07	29.64	51.77	72.58
LSD (P = 0.05)	0.44			
	At 75 days			
Unweeded check	43.11	54.21	115.40	180.54
Manual weeding	25.27	32.24	61.25	76.47
Methabenzthiazuron	18.22	28.97	54.44	64.24
Pendimethalin	18.67	29.40	54.87	65.25
Nitrofen	33.27	43.97	68.64	101.71
Terbutryne	28.97	36.20	61.41	93.91
Metoxuron	20.64	31.34	56.24	66.24
2,4-D	30.17	37.73	63.57	94.90
LSD (P = 0.05)	0.63			
	At 105 days			
Unweeded check	50.24	64.64	133.24	226.57
Manual weeding	30.87	37.98	72.21	88.38
Methabenzthiazuron	25.20	32.48	64.50	78.90
Pendimethalin	25.94	31.51	68.21	79.21
Nitrofen	43.07	51.74	84.74	122.94
Terbutryne	41.47	46.77	79.57	116.25
Metoxuron	28.21	34.17	66.84	81.44
2,4-D	42.91	47.94	81.60	116.97
LSD (P = 0.05)	1.27			

Effect on nitrogen depletion

Nitrogen application as well as weed control methods and their interaction had profound effect on nitrogen depletion by weeds at various stages of growth in both years (Table 4, 5 and 6).

Application of nitrogen appreciably enhanced the nitrogen depletion by weeds. Significant variation was observed among nitrogen levels. Treatment involving 120 kg N/ha registered significantly higher amount of nitrogen removed by weeds as compared to all other nitrogen levels at all the stages of growth. The pattern of nitrogen depletion by weeds was almost similar in both seasons. Herbicidal treatments as well as manual weding caused significant reduction in nitrogen removal by weeds as compared to weedy check. Methabenzthiazuron application was most effective in arresting nitrogen drain by weeds and the next best herbicide was pendimethalin. These two herbicides did not differ statistically and were found superior to the other treatments. Postemergence application of metoxuron and manual weeding checked appreciably the drain of nitrogen by weeds as compared to other herbicidal treatments. Terbutryne and 2,4-D were found superior to nitrofen and unweeded check in this respect.

Interaction data (Tables 5 and 6) showed that nitrogen application under all the weed control methods enhanced fairly the removal of nitrogen by weeds. In the early stage of growth (at 45 days) in no nitrogen and 80 kg N/ha, the depletion of nitrogen was lowest with methabenzthiazuron and pendimethalin and it was significantly lower as compared to the rest of the treatments. A similar pattern was noted in both years. Metoxuron, terbutryne and 2,4-D with nitrogen application resulted in decreased nitrogen removal over manual weeding at 45 days of growth. Higher levels of nitrogen (80 and 120 kg/ha) methabenzthiazuron and pendimethalin differed significantly from each other in reducing the depletin of nitrogen by weeds at all the stages of growth and pendimethalin appeared to be inferior to methabenzthiazuron. Pendimethalin application was however, found superior to all other treatments. Significant reduction in removal of nitrogen occurred under terbutryne and 2,4-D with or without nitrogen application over nitrogen and unweeded check.

DISCUSSION

There was a linear increase in the dry matter production of weeds due to nitrogen levels at various growth stages. The highest dose of nitrogen (120 kg/ha) produced the highest amount of weed dry matter. The significant increase in dry matter accumulation in weeds might be due to the fact that weeds usurped greater quantities of soil applied nitrogen resulting in improved growth of weeds. Gruzdev and Satarov (1967) obtained similar results and opined that fertilizers enhanced the growth of weeds. McWhorter (1971) observed more vigorous growth of surviving weeds with increased nitrogen levels. Dry matter of weeds was significantly reduced with methabenzthiazuron and pendimethalin preemergence applications and also with

Table 4. Depletion of nitrogen by weeds (kg/ha) at different stages of growth as affected by nitrogen levels and weed control methods.

Treatments	Days after sowing					
	1977-78			1978-79		
	45	75	105	45	75	105
Nitrogen levels (kg/ha)						
0	4.64	6.46	8.29	5.75	7.29	9.66
40	6.93	8.74	10.37	8.03	10.19	11.76
80	14.27	17.45	21.14	15.86	19.46	22.48
120	21.36	25.47	30.12	22.45	27.20	31.78
LSD (P = 0.05)	0.12	0.12	0.11	0.03	0.07	0.12
Weed control methods						
Unweeded check	23.12	26.01	30.94	25.05	29.21	33.75
Manual weeding	10.17	11.39	14.01	11.37	13.47	15.59
Methabenzthiazuron	7.79	10.74	12.76	8.88	11.56	13.63
Pendimethalin	7.97	10.70	12.91	9.03	11.72	13.66
Nitrogen	13.04	15.86	19.54	15.18	17.98	21.19
Terbutryne	11.76	14.36	17.81	12.46	15.62	19.42
Metoxuron	10.15	11.32	14.04	11.42	13.38	15.54
2,4-D	12.13	14.23	18.35	12.73	16.03	19.78
LSD (P = 0.05)	0.09	0.09	0.10	0.06	0.10	0.11

Table 5. Depletion of nitrogen by weeds (kg/ha) at different stages of growth as affected by interaction of nitrogen levels and weed control methods (177-78)

Treatment	Nitrogen levels			
	N_0	N_{40}	N_{80}	N_{120}
	At 45 days			
Unweeded check	7.83	11.49	28.17	44.97
Manual weeding	3.91	5.25	13.18	17.71
Methabenzthiazuron	2.84	4.92	10.07	13.32
Pendimethalin	2.88	4.10	10.32	14.57
Nitrofen	6.02	8.08	14.78	23.28
Terbutryne	4.91	7.02	15.28	21.81
Metoxuron	3.29	5.62	13.79	17.09
2,4-D	5.44	7.29	15.56	22.12
LSD (P = 0.05)	0.19			
	At 75 days			
Unweeded check	9.73	13.05	30.93	50.32
Manual weeding	5.80	7.75	16.11	20.51
Methabenzthiazuron	4.70	6.73	14.09	17.40
Pendimethalin	4.88	6.79	13.95	17.16
Nitrofen	7.78	10.19	17.40	28.06
Terbutryne	6.65	8.79	17.10	25.86
Metoxuron	5.31	7.38	16.52	20.06
2,4-D	6.81	9.25	17.47	26.37
LSD (P = 0.05)	0.10			
	At 105 days			
Unweeded check	11.87	14.82	35.57	61.71
Manual weeding	8.82	10.48	18.31	23.82
Methabenzthiazuron	6.61	8.26	16.69	19.93
Pendimethalin	6.21	8.30	16.27	20.25
Nitrofen	10.56	12.09	22.51	32.98
Terbutryne	8.66	11.99	20.45	31.12
Metoxuron	8.77	10.95	19.50	22.68
2,4-D	9.27	11.27	21.15	31.68
LSD (P = 0.05)	0.21			

postemergence application of metoxuron as well as manual weeding. It may be because of the fact that methabenzthiazuron and pendimethalin form a thin layer on the soil surface which was responsible for killing all the susceptible weeds when they emerged, while in the case of metoxuron the growth of weeds was checked 28 days after crop sowing and meanwhile the weeds took advantage of the situation.

Table 6. Depletion of nitrogen by weeds (kg/ha) at different stages of growth as affected by interaction between nitrogen levels and weed control methods (1978-79)

Weed control methods	Nitrogen levels			
	N_0	N_{40}	N_{80}	N_{120}
	At 45 days			
Unweeded check	10.07	12.03	30.43	47.65
Manual weeding	4.94	7.00	14.56	18.81
Methabenzthiazuron	3.88	5.90	11.25	14.40
Nitrofen	7.00	10.26	17.26	26.19
Metoxuron	4.42	7.62	11.88	18.15
2,4-D	6.04	8.27	15.08	21.51
LSD (P = 0.05)	0.12			
	At 75 days			
Unweeded check	11.85	15.44	35.64	55.96
Manual weeding	6.74	8.83	17.85	21.43
Methabenzthiazuron	4.84	7.92	15.30	15.17
Pendimethalin	4.96	8.03	15.40	18.46
Nitrofen	9.13	12.26	20.21	30.31
Terbutryne	7.85	10.96	19.61	27.10
Metoxuron	6.57	9.67	17.05	21.82
2,4-D	8.15	10.39	18.22	27.33
LSD (P = 0.05)	0.20			
	At 105 days			
Unweeded check	13.75	17.99	38.10	65.13
Manual weeding	8.15	10.17	19.68	24.36
Methabenzthiazuron	6.63	8.66	17.53	21.68
Pendimethalin	6.75	8.41	17.73	21.75
Nitrofen	11.75	14.20	24.34	34.49
Terbutryne	11.27	12.63	21.82	31.93
Metoxuron	9.46	10.17	19.25	24.56
2,4-D	11.52	12.85	22.37	32.37
LSD (P = 0.05)	0.22			

Dry matter accumulation in weeds was significantly reduced in methabenzthiazuron and pendimethalin treatments under all levels of nitrogen as compared to weedy check and other weed control treatments. It clearly showed that nitrogen application increased the effectivity of these herbicides which did not allow the weeds to accumulate more dry matter. Herbicide efficiency might have been more on rapidly growing weeds due to good fertility status of soil. This reasoning finds support from the results of McWhorter (1971) that the degree of injury varied with the level of nitrogen in the growth substrata.

There was an increase in the depletion of nitrogen by weeds with the increased levels of nitrogen. This showed a positive relationship between nitrogen application and its removal by weeds. This might have been due to vigorous growth of weeds and finally more dry matter production with increased levels of nitrogen. Similar observations were made by Vengris *et al.* (1963) who reported that weeds accumulate considerable amount of nitrogen at the expense of the crop. Even at higher rates of nitrogen application, weeds competed strongly for nitrogen with the crop. The removal of nitrogen by weeds was three-fold higher when they grew uninterrupted. Reduced weed growth in all the weed control treatments was reflected in minimum depletion of nitrogen by weeds. Preemergence application of methabenzthiazuron and pendimethalin curtailed effectively the removal of nitrogen by weeds even over repeated manual weeding whereas postemergence application of metoxuron, terbutryne and 2,4-D could check the depletion of nitrogen by weeds for a shorter period. These results may be attributed to the differences in weed growth at different herbicide treatments.

The removal of nitrogen at higher dosage level of nitrogen (80 and 120 kg/ha) at 45 days was more effectively checked by methabenzthiazuron as compared to pendimethalin and other herbicidal treatments as well as manual weedings. These observations suggest that for efficient utilization of applied nitrogen, weed growth should be checked right from the sowing of crop with preemergence application of an effective herbicide.

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WEED CONTROL STUDIES IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

Dichlormate, trifluralin, nitrofen, alachlor, paraquat,fluchloralin ethofumesate, terbutryn and metoxuron were evaluated for weed control in sunflower. All herbicides tested except dichlormate were quite safe and effective.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) has been accepted by the farmers in India as an oil seed crop and the area planted to this crop is gradually expanding. As such it is imperative to develop weed control measures for sunflower in order to obtain optimum yield. Yield losses in sunflower due to weeds have been observed to reach 38% (Singh and Singh, 1978). The present investigation was carried out to evaluate the effectiveness of various herbicides for weed control in sunflower.

MATERIALS AND METHODS

Field trials were conducted at the Crop Research Center of the G.B. Pant University of Agriculture and Technology, Pantnagar (Nainital), India, during winter seasons from 1973-1978. The soil of the experimental field was silty clay loam (14.8% sand, 58.8% silt and 26.4% clay) with 1.13% organic matter, 50.2 kg/ha available phosphorus, 228.2 kg/ha available potassium and pH of 7.7. Six experiments were conducted during different years. The herbicides tested were dichlormate (3,4-dichloro-benzyl methylcarbamate), trifuluralin (α, α, α-trifuluoro-2,6-dichlorophenyl-p-nitrophenyl ether), alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide], paraquat (1,1'-dimethyl-4-4'-bipyridinium ion- as dichloride salt), fluchloralin [N-2-chloroethyl)-2,6 dinitro-N-propyl-4-4(trifluoromethyl) aniline], ethofumesate (2-ethoxy-2,3-dihydro-3, 3-dimethyl-5-benzofuranol methanesulphonate), terbutryn [2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine] and metoxuron [N-3(3-chloro-4-methoxyphenyl) N,N-diemethyl urea]. These herbicides were tried at three different rates of application (Tables 1 and 2).

Experiments were laid out in randomized complete block design with 3 to 4 replications. In all the trials "Vniimk 8931" cultivar of sunflower was planted every last week of November at a row spacing of 50 cm. Fluchloralin and trifluralin were applied preplant incorporated. Nitrofen, alachlor and ethofumesate were applied a day after sowing (DAS). Terbutryn and metoxuron were applied as blanket spray 30 DAS while paraquat was applied as directed spray in between the rows 30 DAS. Weed density and dry weight of weeds were obtained from two randomly selected quadrats (0.25 m^2) in each plot.

RESULTS AND DISCUSSION

Chenopodium album L., *Fumaria parviflora* L., *Lathyrus aphaca* L., *Vicia sativa* L., *V. hirsuta* L., *Melilotus alba* Desr., *M. indica* (L.) All. and *Anagallis arvensis* L. were the major weed species in the experimental field. *Polygonum plebigum* L. was observed late in the crop season.

F. parviflora was not controlled by metoxuron whereas all other weeds were controlled fully or partially by the herbicides tested.

All the herbicides reduced significantly the dry matter and density of weeds as compared with the weedy check (Tables 1 and 2). Increasing the rates of herbicide application resulted in further significant reduction in the density and dry matter production of weeds.

On an average, uncontrolled weeds resulted in 55.3% reduction in the grain yield of sunflower. Dichlormate and nitrofen at all rates, trifuluralin at 1.0 and 1.5 kg/ha and alachlor at 2.0 and 3.0 kg/ha produced significantly higher grain yields over the weedy check during 1973-1974 and 1974-1975 (Table 1). Grain yields increased significantly with the increasing doses of alachlor and trifuluralin in both years. In 1973-1974 none of the herbicides tested gave yield comparable with the weed free treatments. However, in 1974-1975 trifuluralin at 1.0 and 1.5 kg/ha produced yields comparable with the weed free check. In dichlormate and nitrofen treatments, grain yields increased with the increasing rates of herbicides in 1973-1974 but in 1974-1975 a significant decrease in the grain yields was obtained due to increase in the rates of these herbicides, though the weed control efficacy was increased with increase in rates in both years. This effect was attributed to the rains received during the first 20 DAS of sunflower, which could have caused contact of herbicides with crop seeds due to leaching resulting in delayed germination and stunted crop growth. That wet weather induced herbicide injury in crops has been reported by Thompson *et al.*, 1970 and Carlson and Wax (1970).

Among the herbicides, the highest grain yield was obtained with trifluralin at 1.5 kg/ha. Directed spray of paraquat provided weed control between the crop rows only (Table 1). Because of uncontrolled weeds within the rows, grain yield was low in this treatment. There was no difference between the two and one application of paraquat with respect to weed density, weed dry weight and crop yield. Drift of paraquat spray caused

Table 1. Effect of various herbicide treatments on weed counts and weights taken at 60 days after sowing and on grain yield of sunflower.

	Rate kg/ha	No. of weeds/m 60 DAS			Dry wt. of weeds (g/m^2) 60 DAS			Grain yield (q/ha)	
		1973-1974	1974-1975	1975-1976	1973-1974	1974-1975	1975-1979	1973-1974	1974-1975
Dichlormate	4.0	230	4	98	109.8	1.0	21.3	11.80	18.77
Dichlormate	6.0	89	0	42	78.9	0.0	12.0	13.54	13.04
Dichlormate	8.0	56	0	24	44.8	0.0	10.6	17.53	9.92
Trifuluralin	0.5	225	25	–	100.2	10.2	–	10.76	12.42
Trifuluralin	1.0	77	17	–	84.2	6.2	–	13.02	15.32
Trifluralin	1.5	45	13	–	41.1	4.1	–	16.32	17.28
Nitrofen	1.0	211	36	102	99.3	7.3	46.6	11.63	14.21
Nitrofen	2.0	220	21	95	114.2	2.7	20.0	13.54	10.80
Nitrofen	3.0	43	11	100	386.	3.3	33.3	12.50	8.83
Alachlor	1.0	230	37	103	121.4	9.7	32.0	11.28	6.69
Alachlor	2.0	245	25	87	136.9	5.0	26.6	13.02	8.80
Alachlor	3.0	223	17	67	113.8	2.3	17.3	14.58	14.16
Paraquat (30 DAS)	0.5	–	25	87	–	35.3	23.3	–	12.52
Paraquat (30 & 60 DAS)	0.5	–	30	90	–	31.0	24.0	–	11.03
Weeding 30 & 60 DAS	–	101	36	85	78.6	15.2	42.6	19.10	16.33
Weed-free	–	00	00	00	0.0	0.0	0.0	19.10	17.09
Weedy	–	502	463	424	283.4	188.7	174.6	9.89	5.61
L.S.D. 5%		23	19	21	13.5	4.6	3.8	1.55	1.87

injury to the sunflower stem which resulted in breakage. Two weedings done 30 and 60 DAS provided good control of weeds and grain yield comparable with the weed-free treatment.

A different set of herbicides (fluchloralin, ethofumesate, terbutryn and metoxuron) at different rates of application was evaluated in 1977-78 (Table 2). Effect of herbicides was assessed in terms of weed density, dry weight of weeds and dry matter production of crop. All the herbicides caused significant reduction in the density and dry weight of weeds and increase in the dry matter production of crop (Table 2). Fluchloralin at 0.5 kg/ha produced higher density and dry weight of weeds than its higher rates (1.0 and 1.5 kg/ha) of application. Density and dry weight of weeds decreased with the increase in the rates of ethofumesate, terbutryn and metoxuron but the differences among the different rates of application were non-significant. Crop dry matter obtained 60 and 120 DAS was higher in all the herbicide treated plots than in weedy plots (Table 2). Higher rates of fluchloralin (1.0 and 1.5 kg/ha), metoxuron (1.5 and 1.0 kg/ha) and terbutryn (1.5 and 2.0 kg/ha) produced more crop dry matter than their lower rates at both stages.

Table 2. Effect of different rates of herbicides on weeds at 60 days after sowing and on crop growth taken at 120 days in 1977-78.

Herbicide	Rate kg/ha	No. of weeds/m^2	Dry weight of weeds g/m^2	Dry wt of crop g/m^2	Dry wt. of crop
Fluchloralin	0.5	61	11.9	307.6	504.5
Fluchloralin	1.0	20	4.9	405.8	604.8
Fluchloralin	1.5	11	5.9	406.7	604.0
Ethofumesate	1.0	6	3.1	478.2	585.0
Ethofumesate	2.0	2	2.9	480.7	595.0
Ethofumesate	3.0	3	2.5	491.2	605.9
Terbutryn	1.0	19	7.5	292.5	405.6
Terbutryn	1.5	14	4.5	398.7	565.8
Terbutryn	2.0	8	3.7	382.1	575.2
Metoxuron	1.0	7	4.0	387.5	603.2
Metoxuron	1.5	3	2.5	482.8	697.5
Metoxuron	2.0	3	1.7	507.2	682.3
Weeding 30 & 60 DAS	–	21	4.7	387.2	565.2
Weed-free	–	0	0.0	502.7	767.5
Weedy	–	467	126.5	122.6	212.5
L.S.D. 5%		15	3.5	23.8	24.3

Effect of first irrigation on the efficacy of dichlormate

The increasing rates of dichlormate increased grain yield in 1973-74 but a reverse effect of increasing rates was observed in 1974-75 (Table 1). This effect was thought to be due to the rains received within 20 DAS of the crop and thereby changing the soil moisture status. To verify this separate experiment was laid out during the subsequent years with four rates of application of dichlormate (2, 4, 6 and 8 kg/ha) and three timings of first irrigation at (20, 30 and 40 DAS) along with weedy and weed free treatments. The irrigation treatments, other than the first irrigation, were given uniformly.

Weed control efficacy due to irrigation given at 20 DAS increased and this was more evident at lower rates of application (Table 3). Irrigation 20 at DAS in plots treated with dichlormate at 8.0 kg/ha caused significant reduction in the grain yields. This effect was not observed in plots treated with the same rate of dichlormate but irrigated either at 30 or 40 DAS. These observations were in agreement with the previous findings (Table 1).

Table 3. Effect of time of first irrigation on the efficacy of dichlormate. Weed counts and weed weights taken at 60 DAS.

Rate (kg/ha)	Time of first irrigation DAS	No. of weeds/m^2 1975-76	No. of weeds/m^2 1976-77	Dry wt of weeds g/m^2 1975-76	Dry wt of weeds g/m^2 1976-77	Grain yield q/ha (1976-77)
2.0	20	86	146	16.2	116.6	7.0
2.0	30	122	229	39.3	115.6	6.3
2.0	40	112	218	31.0	150.0	7.3
4.0	20	42	67	8.4	16.2	11.9
4.0	30	86	70	11.2	16.2	11.2
4.0	40	78	72	21.1	16.6	13.0
6.0	20	45	32	9.3	10.6	13.3
6.0	30	142	27	33.0	11.2	12.4
6.0	40	130	22	32.1	12.0	14.7
8.0	20	36	12	7.0	1.1	10.0
8.0	30	42	7	7.2	0.7	13.4
8.0	40	51	4	10.3	1.1	13.9
Weed-free	–	0	0	0.0	0.0	15.7
Weedy	–	346	523	68.4	178.3	7.7
L.S.D. 5%		16	27	3.2	12.3	1.5

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WEED COMPETITION IN SORGHUM UNDER TWO MOISTURE REGIMES

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ABSTRACT

Weed occurrence and competition, and grain yield of sorghum were studied under limited and optimum irrigations. With an increase in irrigation frequency an increase in weed dry matter was observed. When the weeds were allowed to grow up to 45 days or throughout the season *Dactyloctenium aegyptium* (L.) *Richt, Digitaria ciliaris (Ritz) Koch, Digera* sp., and *Echinochloa* colona (L.) Link dominated the system irrespective of the moisture regime. Variation in dominance of weed species was observed under the six weed removal treatments imposed. Weeds which (i.e. after 45 days) later emerged had little effect on the sorghum grain yield. Higher reduction in sorghum grain yield due to weeds was recorded under limited irrigations than under optimum irrigation situation, thereby revealing better competitive ability of sorghum given optimum irrigations. Approximately the same sorghum grain yield could be obtained by giving five irrigations and allowing the weeds to grow as that with three irrigations and keeping the sorghum weed free. Under limited irrigations the water use efficiency of the sorghum maintained weed free was twice that of weedy check.

INTRODUCTION

Sorghum is one of the important crops grown under post rainy season in semi-arid tropics where water is the limiting factor for attaining optimum yield. The problem of limited water, becomes more severe by competition with weeds for light, nutrients and water (Pavlychenko, 1949). Although the effect of various levels of fertilizer on weed or crop competition has been studied (Blackman and Templeman, 1938; Nieto and Staniforth, 1961; Staniforth, 1962), there is little information about the effect of soil moisture on the competitive ability of various weeds and crops (Wiese and Vandiver, 1970). In addition, the extent to which the weeds compete depends on the resource availability, the weed species present and other factors (Fryer and Makepeace, 1977). Hitherto, no attempt was made to study the effect of soil moisture availability on the weed occurrence, dry matter accumulation, and crop productivity. Hence this study was undertaken to identify differences in weed composition and dominance and to quantify weed competition effect on grain yield and water use efficiency of sorghum at two moisture regimes.

MATERIALS AND METHODS

The experiment was conducted during the post rainy season of 1979 (November, 1979 through February, 1980) on an Alfisol, at ICRISAT centre, Patancheru, India (17 31' Long 78 16' Long). The experiment was laid out in a randomized complete block design with three replications. Each plot measured 8 m x 8 m. Sorghum cv. CSH-8 R was sown in 75 cm row. One moisture regime consisted of irrigation at the time of sowing and at 19, 39, 57 days after crop emergence (DAE) (referred to as 'optimum irrigation'). The second moisture regime consisted of irrigation at the time of sowing and at 39 and 76 DAE (referred to as 'limited irrigation'). Final plant population was 140,000 plants/ha. The treatments were:

a) Weeds uncontrolled up to 30 DAE
b) Weeds allowed to grow after 30 DAE
c) Weeds uncontrolled up to 45 DAE
d) Weeds allowed to grow after 45 DAE
e) Weed free
f) Weedy check.

Weed density and biomass were taken by clipping weeds from an area of 1 m^2 per plot at 30 DAE and 40 DAE in treatments a and c respectively, and at the time of sorghum harvest in the rest of the plots. The relative biomass, relative density and summed dominance ratio (SDR) of the weeds were calculated following Shetty and Rao (1978). Leaf Area Index (LAI) estimated at 70 DAE is presented as maximum LAI. Sorghum grain yield and yield components were recorded at the time of harvest. Water use efficiency (WUE) of sorghum at the two moisture regimes was calculated and presented as kg of total dry matter (TDM)/ ha/mm of water.

RESULTS AND DISCUSSION

Weed biomass and density at different intervals of crop growth as affected by weed control treatments and moisture regimes are presented in Table 1. In general, with an increase in irrigation frequency there was an increase in weed growth. The longer the weeds were allowed to grow the greater the weed dry matter. Preventing weeds to grow for the first 30 and 45 days reduced the weed dry matter at harvest by 89 and 94% respectively under limited irrigation, and 86 and 96% respectively under optimum irrigation in comparison to weedy check.

The density, biomass, relative density, relative biomass and summed dominance ratio of individual weeds associated with sorghum as affected by weed removal treatments and moisture regimes are presented in Tables 2, 3 and 4. *Dactyloctenium aegyptium (L.) Richt, Digitaria ciliaris (Retz) Koch, Digera* sp., and *Echinochloa* sp. were the dominant weeds at both moisture regimes when the weeds were allowed to grow up to 30 or 45 DAE or throughout the season. However the biomass of *D. aegyptium* and *Echinochloa colona (L.)* Link increased whereas those of *Celosia argentea* L. and *Digera* sp. decreased under optimum irrigation.

Table 1. Weed density (number/m^2) and biomass as affected by two moisture levels and time of weeding.

Treatments		Limited Irrigation			Optimum Irrigation		
		30 DAE	45 DAE	HARVEST	30 DAE	45 DAE	HARVEST
Weeds uncontrolled up to 30 DAE	Density	245.25	–	–	385.32	–	–
	Biomass	32.26	–	–	39.67	–	–
Weeds allowed to grow after 30 DAE	Density	–	12.8	32.5	–	60.0	70.2
	Biomass	–	8.1	12.1	–	11.2	15.56
Weeds uncontrolled up to 45 DAE	Density	261.72	221.33	–	345.16	287.7	–
	Biomass	31.42	88.81	–	37.71	110.56	–
Weeds allowed to grow after 45 DAE	Density	–	–	2.6	–	–	3.2
	Biomass	–	–	5.6	–	–	4.9
Weed free	Density	–	–	–	–	–	–
	Biomass	–	–	–	–	–	–
Weedy check	Density	252.39	184.0	191.0	330.78	302.78	298.5
	Biomass	30.79	90.62	110.2	39.42	124.73	136.4

Table 2. Relative density (RD) relative biomass (RB) and summed dominance ratio (SDR) of weeds associated with sorghum before and after 30 DAE under two moisture regimes, post rainy season. Actual values are given in parenthesis.

	Weeds uncontrolled up to 30 DAE						Weed allowed to grow after 30 DAE					
	Limited Irrigation			Optimum Irrigation			Limited Irrigation			Optimum Irrigation		
	RD	RB	SDR	RD	RB	SDR	RD	RB	SDR	RD	RB	SDR
Amaranthus sp.	1.1 (2.7)	3.6 (1.16)	4.7	3.0 (11.55)	6.4 (2.54)	9.4	–	–	–	–	–	–
Brachiaria eruciforuis	4.3 (10.55)	1.14 (0.37)	5.44	4.4 (16.95)	2.7 1.07)	7.1	9.67 (3.14)	11.1 (1.38)	20.77	3.51 (2.46)	11.0 1.71)	14.51
Celosia argentea	1.4 (3.43)	3.5 (1.13)	4.9	0.1 (0.39)	0.1 (0.04)	0.2	–	–	–	1.75 (1.75)	2.44 (0.38)	4.19
Cyperus rotundus	–	–	–	–	–	–	32.25 (10.48)	33.2 (4.11)	65.45	50.87 (35.71)	33.75 (5.25)	84.62
Dactyloctenium ciliaris	8.8 (21.58)	2.5 (0.81)	11.3	18.7 (72.1)	14.3 (5.67)	33.0	9.67 (3.14)	11.73 (1.45)	21.40	14.0 (9.83)	11.8 (1.84)	25.8
Digera arvensis	15.9 (38.99)	37.1 (11.97)	53.0	12.6 (48.55)	26.7 (10.59)	39.3	6.45 (2.1)	12.85 (1.59)	19.30	21.05 (14.77)	19.65 (3.05)	40.8
Digitaria ciliaris	20.3 (49.78)	8.7 (2.81)	29.0	20.6 (79.38)	11.5 (4.56)	32.1	19.35 (6.3)	22.6 (2.8)	41.95	8.77 (6.16)	21.36 (3.32)	30.13
Echinocloa colona	43.63 (107.02)	36.3 (11.7)	79.94	36.8 (141.8)	30.8 (12.22)	67.6	12.9 (4.19)	4.5 (0.56)	17.4	–	–	–
Euphorbia sp.	0.65 (1.59)	3.4 (1.1)	4.05	1.6 (6.17)	0.5 (0.20)	2.1	3.22 (1.04)	0.2 (1.04)	3.42 (0.33)	–	–	–
Eclipta sp.	–	–	–	–	–	–	3.22 (1.04)	2.6 (0.02)	5.82	–	–	–
Portulaca oleraceae	0.7 (1.71)	1.46 (0.47)	2.16	0.75 (2.99)	2.7	3.45	–	–	–	–	–	–

P.T.O.

Table 3. Relative density (RD) , relative biomass (RB) and summed dominance ratio (SDR) of weeds associated with sorghum when the weeds were allowed to grow before and after 45 DAE at two moisture regimes. Actual values of denisty and biomass are given in parenthesis.

	Weeds uncontrolled up to 45 DAE						Weeds allowed to grow after 45 DAE					
	Limited Irrigation			Optimum Irrigation			Limited Irrigation			Optimum Irrigation		
	RD	**RB**	**SDR**	**RD**	**RB**	**SDR**	**RD**	**RB**	**SDR**	**RD**	**RB**	**SDR**
Amaranthus sp.	3.9 (8.63)	9.9 (8.79)	13.8	1.4 (4.02)	6.9 (7.63)	8.3	–	–	–	–	–	–
Brachairia eruciformis	7.9 (17.5)	2.45 (2.17)	10.35	10.0 (28.77)	1.9 (2.1)	11.9	23.68 (6.16)	3.3 (0.18)	26.98	11.11 (3.56)	3.26 (0.16)	14.37
Celosia argentea	1.9 (4.2)	7.14 (6.34)	9.04	1.1 (3.16)	2.8 (3.1)	3.9	–	–	–	–	–	–
Cyperus rotundus	1.2 (2.65)	2.43 (2.16)	3.63	0.3 (0.86)	1.15 (1.21)	1.45	42.1 (10.95)	76.41 (4.28)	118.51	33.3 (10.6)	68.4 (3.35)	101.7
Dactyloctenium aegyptium	12.3 (27.22)	5.55 (4.93)	17.85	8.45 (24.3)	8.4 (9.29)	16.85	13.15 (3.42)	5.66 (0.32)	18.81	22.1 (7.1)	6.52 (0.32)	28.6
Digera arvensis	7.9 (17.5)	20.64 (18.33)	28.54	3.12 (8.97)	10.7 (11.83)	13.82	–	–	–	–	–	–
Digitaria ciliaris	24.4 (54.0)	13.19 (11.71)	37.59	24.74 (71.17)	27.96 (30.91)	52.70	–	–	–	–	–	–
Dinebra retroflexa	0.2 (0.44)	1.22 (1.1)	1.42	2.3 (6.61)	1.3 (1.44)	3.6	–	–	–	–	–	–
Echinocloa colonum	31.1 (68.83)	33.4 (29.66)	64.5	45.22 (130.1)	34.24 (37.85)	79.46	15.78 (4.10)	8.5 (0.47)	24.28	33.33 (10.7)	21.73 (1.06)	55.06
Euphorbia sp.	1.2 (2.65)	0.5 (0.47)	1.7	0.15 (0.43)	0.2 (0.22)	0.35	–	–	–	–	–	–
Others	8.0 (17.7)	3.58 (3.18)	11.58	3.22 (9.26)	4.45 (4.92)	7.67	5.29 (1.37)	6.13 (0.35)	11.42	0.16 (0.04)	0.09 (0.01)	0.25

Table 4. Relative density (RD), relative biomass (RB) and summed dominance ratio (SDR) of weeds associated with sorghum throughout the season (weedy check), under two moisture regimes. Actual values of density and biomass are given in parenthesis.

	Limited Irrigations			Optimum Irrigations		
	RD	RB	SDR	RD	RB	SDR
Brachiaria eruciformis	18.11	2.0	20.11	2.64	0.47	3.11
	(38.59)	(2.2)		(7.88)	(0.64)	
Celosia argentea	4.34	23.84	28.18	2.2	5.45	7.65
	(8.29)	(26.27)		(6.6)	(7.43)	
Cyperus rotundus	7.97	7.23	15.2	2.64	1.0	3.64
	(15.22)	(7.97)		(7.88)	(1.36)	
Dactyloctenium aegyptium	28.98	15.71	44.69	13.52	17.71	31.23
	(55.35)	(17.31)		(40.36)	(24.16)	
Digera arvensis	10.74	31.27	42.01	14.1	20.43	34.53
	(22.42)	(34.46)		(42.1)	(22.85)	
Digitaria ciliaris	21.0	10.66	31.66	14.11	12.74	26.85
	(22.42)	(34.46)		(42.12)	(17.38)	
Echinochloa colona	6.57	3.48	10.05	34.93	33.2	68.13
	(12.45)	(3.83)		(104.27)	(45.37)	
Eragrostis sp.	–	–	–	1.32	0.57	1.89
				(3.94)	(0.78)	
Euphoribia sp.	0.11	0.23	0.34	1.76	0.11	1.87
	(0.21)	(0.25)		(5.25)	(0.15)	
Portulaca oleraceae	–	–	–	0.9	0.3	1.2
				(2.7)	(0.41)	
Sonchus arvensis	1.23	4.86	6.09	1.3	6.31	7.61
	(2.36)	(5.36)		(3.9)	(8.61)	
Others	0.95	0.72	1.67	10.58	1.71	12.29
	(1.81)	(0.8)		(31.5)	(2.32)	

The density, biomass, relative density, relative biomass and SDR of *E. colona* L. (Link) in the weedy check increased whereas those of other weeds decreased with the increase in irrigation from 3 to 5. Results suggested that problem weeds like *C. argentea* can be eliminated completely by keeping the sorghum weed free up to 30 days. When the crop was kept weed free up to 45 days only monocot weeds dominated the system in both moisture regimes. Thus variation in weed dominance was noticed under the weed control treatments studied.

Maximum leaf area index, and grain weight per panicle of sorghum also varied under different treatments (Table 5). Sorghum leaf area index was greater under optimum irrigation than under limited irrigation when maintained weed free. However, LAI and grain weight per panicle in the weedy check at optimum irrigation were equal to those obtained from the weed-free treatment at limited irrigations.

The percentage reduction in sorghum grain yield due to weed competition under weedy check was 65% under limited irrigation and 43% under optimum irrigation (Table 6). This shows the adaptibility of associated weeds under less moisture available situations. Philips (1960) reported that one weed for each 90 cm sorghum row prevented grain production in drought condition. Comparatively less reduction in grain yield due to weed competition under optimum irrigation can be explained by the findings of Wiese *et al.*, (1964), who reported better competitive ability of sorghum under high moisture conditions. At both moisture regimes, sorghum grain yield obtained from allowing weeds to grow after 45 DAE was comparable to that of the weed-free treatment. Thus weeds that emerged later did not affect crop yield in both moisture regimes. Losses due to weed competition could be minimized by keeping the crop weed free 45 DAE.

Grain yield from the weedy check given optimum irrigation, was 1782 kg/ha whereas that of the weed free treatment was 1571 kg/ha under limited irrigation (Table 6). Water use efficiency (WUE) was the same weed free conditions under both moisture regimes. However, when the weeds were allowed to grow, WUE of sorghum under limited irrigations was lower than at optimum irrigation. Under limited irrigations, the WUE of weedy sorghum was only half that of weed free sorghum. Similarly under optimum irrigations, WUE of weedy sorghum was 16.7 kg TDM/ha/mm whereas that of weed free sorghum was 26.5 kg TDM/ha/mm. Hence, to realize maximum water use and yield potential under optimum irrigation the sorghum should be free from weeds up to 45 DAE.

Table 5. Leaf area index (LAI), panicles/ha and grain weight per panicle of sorghum as affected by different weed control treatments under two moisture regimes. Alfisols, 1979, Post rainy season, ICRISAT.

	Leaf area index		Panicles/ha		Grain weight/panicle	
	Limited Irrigation	Optimum Irrigation	Limited Irrigation	Optimum Irrigation	Limited Irrigation	Optimum Irrigation
Weeds uncontrolled up to 30 DAE	2.00	2.43	133.42	135.38	6.04	17.37
Weeds allowed to grow after 30 DAE	2.15	2.66	136.00	138.32	9.43	20.68
Weeds uncontrolled up to 45 DAE	1.83	2.57	129.78	127.82	5.45	16.30
Weeds allowed to grow after 45 DAE	2.24	3.07	137.0	141.54	10.93	21.76
Weed free	2.38	3.24	138.33	141.56	11.36	22.13
Weedy check	1.60	2.22	113.68	135.30	4.74	11.58

Table 6. Water use efficiency (WUE), grain and stover yield of sorghum cv. CSH-8R as affected by two moisture regimes and weed control treatments. Numbers within the column followed by a common letter are not significantly different at 5% level.

	Limited Irrigation			Optimum Irrigation		
	Grain yield kg/ha	Stover yield kg/ha	W.U.E. kg/T.D.M./ ha/mm	Grain yield kg/ha	Stover yield kg/ha	W.U.E. kg T.D.M./ ha/mm
Weeds uncontrolled up to 30 DAE	805.79^{ab}	1594.72^{e}	16.0	2195.67^{j}	2648.52^{op}	18.9
Weeds allowed to grow after 30 DAE	1282.79^{c}	2092.85^{f}	22.5	2861.42^{jk}	3312.84^{pq}	24.6
Weeds uncontrolled up to 45 DAE	707.64^{bd}	1511.10^{g}	14.7	1990.79^{kb}	2480.17^{qr}	17.8
Weeds allowed to grow after 45 DAE	1499.98^{ab}	2334.15^{gh}	25.5	3074.33^{lm}	3450.74^{rs}	26.1
Weeds free	1571.67^{ab}	2389.10^{gh}	26.4	3132.65^{lm}	3500.10^{rs}	26.5
Weedy check	538.89^{ac}	1349.84^{hi}	13.2	1782.47^{mn}	2401.1^{qr}	16.7

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WEED SUPPRESSING ABILITY OF FIVE CROPS INTERCROPPED WITH MAIZE

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ABSTRACT

The possibility of optimum weed suppression through elimination of hand weeding by the introduction of an intercrop along with one hoeing at 20 days after sowing (DAS) was evaluated. Maize (*Zea mays* L.) based intercropping systems with one hoeing reduced weed growth without significant reduction in the grain yield of maize. Among the five interactions tested maize/cowpea intercrop with one hoeing (20 DAS) gave less weed dry matter and the highest net monetary returns (Rs. 5239). The net monetary returns obtained with maize/groundnut + (hoeing Rs. 4809), maize/blackgram + 1 hoeing (Rs. 4506) and maize/greengram + 1 hoeing (Rs. 4059) were also higher than the maize sole given one hand weeding (20 DAS)+ one hoeing (Rs. 44500).

INTRODUCTION

Intercropping is a practice most common among small farmers througout the tropics. Under rainfed conditions, intercropping of maize with pulses and oilseeds is popular to ensure against failure of monocropping of rainfed maize (*Zea mays* L.). The yield advantage due to intercropping in maize and sorghum *(Sorghum bicolor L.)* with pulses and oilseeds have been reported by many workers (Evans, 1961; Pendleton *et al.,* 1963; Gautam *et al.,* 1964; Narang *et al.,* 1969; Willey and Osiru, 1972; Rathore *et al.,* 1980; Kalra and Gangwar, 1980; Mehta and De, 1980 and Rahman *et al.,* 1982). For maize, when grown as a sole crop, 1 hand weeding at 20 days after sowing (DAS) and 1 hoeing at 40 DAS are recommended for effective suppression of weeds. Availability of labor for hand weeding during peak periods of farm operations may not be possible in certain areas. On the other hand elimination of one hand weeding by introduction of a smother crop as an intercrop has been reported (Rao and Shetty, 1981). Hence in the present investigation the possibility of optimum weed suppression through elimination of hand weeding by the introduction of an inter crop along with one hoeing at 20 DAS was tested.

MATERIALS AND METHODS

A field experiment was carried out for two cropping seasons under rainfed conditions (Kharif, 1980 and 1981) at the Farm, College of Agriculture, Rajendranagar (17 23'N latitude, 78 25'E longitude and 542.6 m elevation), Hyderabad, A.P. (Table 1).

Table 1. Monthly total rainfall during the 1980 and 1981 cropping seasons.

Month	Total rainfall (mm)	
	1980	1981
July	123.2	65.4
August	100.0	152.6
September	65.6	348.0
October	–	113.2
Total	288.8	679.2

The experiment was conducted on a well drained sandy loam having 0.6% organic matter, 16.44 kg/ha $P_2 0_5$ and 316.62 kg/ha $K_2 0$. Plots measured 6m x 4.56m in 1980 and 6 m x 3.75 m in 1981. Treatments consisted of the following:

T_1 Maize (Ganga-5) + 1 hand weeding + 1 hoeing (Hoe) at 20 and 40 DAS
T_2 Maize (Ganga-5) + cowpea (C-152) 2 rows + no hoeing
T_3 Maize (Ganga-5) + cowpea (C-152) 2 rows + 1 hoeing at 20 DAS
T_4 Maize (Ganga-5) + Groundnut (TMV-2) 2 rows + no hoeing
T_5 Maize (Ganga-5) + Groundnut (TMV-2) 2 rows + 1 hoeing at 20 DAS
T_6 Maize (Ganga-5) + Frenchbean (Contender) 2 rows + no hoeing
T_7 Maize (Ganga-5) + Frenchbean (Contender) 2 rows + 1 hoeing given at 20 DAS
T_7 Maize (Ganga-5) + Blackgram (T-9) 2 rows + no hoeing
T_9 Maize (Ganga-5) + Blackgram (T-9) 2 rows + 1 hoeing at 20 DAS
T_{10} Maize (Ganga-5) Greengram (PS-16) 2 rows + no hoeing
T_{11} Maize (Ganga-5) + Greengram (PS-16) 2 rows + 1 hoeing at 20 DAS.

Treatments were replicated 3 times in a randomized complete block design. Maize seeds were sown at a spacing of 75 cm x 20 cm whereas two rows of each intercrop was sown at 30 cm apart in between the two rows of maize. Distance within the rows was maintained at 10 cm for all crops.

Maize crop was fertilized with 120 kg N, 60 kg $P_0 5$ $_a$nd 40 kg K_2O/ha. One third of N and entire P_2O_5 and $K_2 0$ were applied basally. A split application of the remaining N was done at knee high and tasseling stages.

However, fertilizers were not applied separately to any of the intercrops. The main crop and intercrops were sown on July 2, 1980 and July 4, 1981 in each year. Maize crop was harvested on October 9, 1980 and October 18, 1981 while the intercrops were harvested at maturity.

The yields of all crops were calculated on a per hectare basis and the net returns were worked out on the basis of current prices and cost of input prevailing in each year.

RESULTS AND DISCUSSION

Yields of main and intercrops were higher in the second year as compared to the first year, which might be due to more rainfall received during the second year (679.2 mm) as compared to that of the first year (288.8 mm, Table 2). Significant differences among various intercropping treatments were observed in grain yields of maize in both years. In both years maize alone with hand weeding and hoeing (T_1) gave the highest grain yield (33.15 q/ha) and was superior to all the other treatments (T_2 to T_{11}). However, grain yield obtained with T_3, T_5, T_7, T_9, T_{11} in the first year and T_3, T_9 and T_{11} in the second year was comparable with T_1. Hence, presence of intercrops such as cowpea, blackgram and greengram had no adverse effect on the grain yield of maize during both years. Maize-based intercropping treatments with 1 hoeing (T_3, T_5, T_7, T_9, and T_{11}) were found sinificantly superior to no hoeing treatments (T_2, T_4, T_6, T_8 and T_{10}) indicating the beneficial effect of push hoeing in suppressing weeds during the initial period of crop growth. Frenchbean as an intercrop resulted in lowest grain production of maize in hoeing and no hoeing treatments (T_6 and T_7) in comparison with other intercrops.

The dry fodder yield of maize also revealed a similar trend with that of grain yield in both cropping seasons (Table 2).

No hoeing treatments of maize intercropping gave a significantly higher weed dry matter as compared to treatments with one hoeing and hand weeding of maize. Minimum weed dry matter was found in maize + cowpea + 1 hoeing (T_3). This suggests that cowpea may be more effective in suppressing weeds compared to the other intercrops tested.

Maize-based intercropping treatments with one hoeing resulted in significantly higher net returns than no hoeing treatments in both years (Table 2). In the first year, maximum net returns were recorded in maize + groundnut + 1 hoeing (Rs 4122.28/ha) and maize + cowpea + 1 hoeing (Rs 4025.62/ha). However in the second year maize + cowpea + 1 hoeing had the highest monetary return (Rs 6452.99/ha), followed by maize + greengram + 1 hoeing (Rs 5658.11/ha). Furthermore, net returns received due to the intercropping of groundnut, greengram or blackgram with maize + 1 hoeing were comparable to that of maize + 1 hand weeding + 1 hoeing. This indicates the beneficial effect of intercrops like cowpea, groundnut, greengram or blackgram. The beneficial effect of intercrops can be attributed to the

Table 2. Effect of cultural practices on grain yield, weed dry weight and net return in maize-based intercropping systems

Treatments	Weed dry weight (g/m)		Grain yield (Q/ha)		Intercrop yield (q/ha)		Straw yield (q/ha)		Net return (Rs/ha)		Mean
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981	
T_1 Maize 1 HW + 1 HOE (20 DAS) + (40 DAS)	107.9	117.9	33.15	44.44	–	–	78.47	94.95	3422.91	5478.63	4450.77
T_2 Maize/cowpea: No HW HOE	133.6	142.0	26.55	31.34	2.37	3.59	48.33	60.40	2444.94	3846.15	3145.55
T_3 Maize/cowpea 1 HOE (20 DAS)	72.3	74.1	32.60	43.87	4.17	5.04	56.85	76.92	4025.62	6452.99	5239.31
T_4 Maize/groundnut: No HW/HOE	148.0	184.3	25.78	29.91	2.56	4.27	67.07	61.96	2706.49	3547.01	3126.75
T_5 Maize/groundnut 1 HOE (20 DAS)	96.7	103.7	31.27	37.03	4.51	6.84	75.62	74.78	4122.28	5495.72	4809.00
T_6 Maize/Frenchbean: No HW/HOE	195.9	208.6	22.74	25.64	4.08	5.98	56.56	53.85	1910.46	2358.97	2134.72
T_7 Maize/Frenchbean 1 HOE (20 DAS)	137.2	126.9	30.31	35.61	6.49	9.25	62.54	69.23	3246.65	4461.53	3854.09
T_8 Maize/Blackgram: No HW/HOE	157.1	172.2	23.88	27.35	1.76	2.92	56.29	58.13	2137.90	3017.09	2577.50
T_9 Maize/Blackgram 1 HOE (20 DAS)	132.5	106.4	30.87	39.32	2.65	4.55	60.84	74.01	3439.97	5572.64	4506.31
T_{10} Maize/Greengram: No HW/HOW	151.9	164.1	25.01	29.06	1.38	2.71	64.82	55.55	2433.57	3119.66	2776.62
T_{11} Maize/Greengram 1 HOE (20 DAS)	107.6	98.2	31.84	42.02	2.14	3.70	69.36	72.64	3661.72	5658.11	4659.92
F Test	Sig.	Sig.	Sig.	Sig.	–	–	Sig.	Sig.	Sig.	Sig.	
S. Em ±	12.8	11.6	1.53	3.16	–	–	3.69	2.42	220.16	118.72	
C.D. at 5%	37.6	34.1	4.49	9.23	–	–	10.89	7.09	642.51	1222.22	

*Cost of produce (Rs/q): Maize 140/–Groundnut 2507/– Greengram 3007/ – Maize Straw 300/ – Cowpea 300/ – Frenchbean (Green) 100/ – Blackgram 300/–.

HOE = HOEING; HW = HANDWEEDING

substantial yield contribution of the intercrops (Rao and Shetty, 1981) and to the weed suppressing ability of the intercrops which saved one hand weeding. The lower returns in the first year in all the maize-based intercropping treatments were mainly due to poor grain yields of intercrops, which might be due to low rainfall received.

Better weed suppression and higher net returns could be obtained with one hoeing when maize is intercropped with crops like cowpea, groundnut, greengram or blackgram. On the basis of the results of this experiment maize + cowpea + 1 hoeing may be recommended under rainfed conditions.

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SYSTEMS OF CONTROLLING *BOERHAVIA ERECTA* L. IN SOYBEAN (*GLYCINE MAX* L.)

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ABSTRACT

Experiments were conducted during the dry season of 1982 to identify effective systems of controlling *Boerhavia erecta* L. in soybean *(Glycine Max L.)* which are suitable for adoption by farmers.

Preemergence application of metribuzin (4-amino-6-tert-butyl-3(methythio-as-triazine-5) gave effective control of *B. erecta.* Oxyfluorfen (2-chloro-(4-(nitrophenoxy)-4-trifluoromethyl benzene) applied preemergence also gave promising control of *B. erecta* but crop injury was observed.

Weeding treatments that gave yields comparable to the hand weeded check were: off-barring and inter row weeding 14 days after seeding (DAS) followed by hilling-up 28 DAS; preemergence application of metribuzin (0.50 kg/ha) followed by handweeding at 20 DAS; and preemergence application of butralin (2.5 kg/ha) followed by hand weeding at 20 DAS.

INTRODUCTION

Boerhavia erecta L. is an annual erect to ascending dicot weed belonging to the family Nyctaginaceae. It has a slender reddish and glabrous stem and may grow up to 100-200 cm. The inflorescence is paniculate with pink to white flowers. The fruit is five-angled appearing like an inverted pyramid. It is propagated by a one-seeded fruit.

The problem of controlling this weed was first brought to the attention of researchers at the University of Southern Mindanao, Kabacan, North Cotabato in 1972 by farm technicians. The weed is tolerant to the phenoxy herbicides which Filipino farmers use in controlling broadleaf weeds and sedges in upland rice (*Oryza sativa* L.), maize (*Zea mays* L.) and sorghum *Sorghum bicolor* (L.) Moench. (Pamplona, 1976).

Pamplona (1981) identified *B. erecta* as a problem weed in most upland crops in Southern Mindanao and it was spreading rapidly in many farms. *B. erecta* may reduce yields of soybean by as much as 80%, (Pamplona et al. 1978). Compounding this problem is the fact that this species is not controlled by the standard herbicides used in soybean. While herbicides may have a place in soybean weed control, sole dependence on these materials has several limitations. Firstly, herbicides alone seldom provide adequate weed control in the tropics (Kasasian, 1970). Secondly, herbicides which can effectively control *B. erecta* such as atrazine are also toxic to soybean and therefore cannot be used in the crop.

This study was conducted to identify promising herbicides and effective systems of controlling *B. erecta* in soybean from which farmers can select a control method that could be adopted for their conditions.

MATERIALS AND METHODS

The experiments were conducted at the Southern Mindanao Agricultural Research Center for legumes at the University of Southern Mindanao, Kabacan, North Cotabato. The area had been cultivated for the last 10 years and had a natural *B. erecta* infestation of 300 to 500 seedlings $/m^2$. The area was thoroughly prepared by plowing and rotavation. Fertilizer was applied at a rate equivalent to 30 kg N and 20 kg $P2O_5$/ha. All fertilizer rates were applied basally before planting. Carbofuran was applied at 0.50 kg/ha together with the fertilizer.

Experiment 1. *Evaluation of promising herbicides for the control of Boerhavia erecta in soybean.*

Soybean was planted at 20-25 seeds/m in rows spaced 75 cm apart. A randomized complete block design replicated three times was used. The treatments are indicated in Table 1. Plot size was 4.5m x 5m. Data collected were weed counts, weed weights, crop injury rating, weed control rating at 20 and 40 DAS, and at harvest. Grain yield was also recorded at harvest.

Experiment 2. *Influence of different levels of physical and chemical weed control method for the control of Boerhavia erecta in soybean.*

The experimental design, cultural practices and data collected were the same as in Experiment 1. The treatments used are indicated in Table 3.

RESULTS AND DISCUSSION

Experiment 1. *Evaluation of promising herbicides for the control of Boerhavia erecta in soybean.*

Preemergence application of metribuzin and oxyfluorfen at the rates of 0.25, 0.50 and 0.75 kg/ha gave effective control of *B. erecta* (Table 1 and 2). No emergence of *B. erecta* was observed in the treated plots until 20 DAS (Table 1). Oxyfluorfen was however, phytotoxic to soybean (Table

2). Effective control of *B. erecta* by these two herbicides persisted until 23 DAS. Other weed species such as *Cyperus rotundus* L., *Digitaria sanguinalis* (L.) Scop., *Amaranthus spinosus* L., *Cleome rutidosperma* Dc., *Physalis angulata* L. and *Rottboellia exaltata* L. f. emerged from 5 to 10 days after application of metribuzin and oxyfluorfen. Emergence of these weed species resulted in a low soybean yield in the herbicide treated plots.

Table 1. Weed density and weed weight of Boerhavia erecta *as affected by different herbicides in soybean. Entries in each column followed by a common letter are not significantly different at 5% DMRT. Average of 3 replications.*

Treatment	Rate kg/ha	Weed Density (no/m^2)		Weed Weight (g/m^2)		
		20 DS	40 DAS	20 DAS	40 DAS	At harvest
Oxyfluorfen Pre	0.25		22.3 g		30.9 h	101.2 de
Oxyfluorfen Pre	0.50		21.3 g		40.8 gh	13.8 hi
Oxyfluorfen Pre	0.75		24.3 g		24.0 hi	47.3 fg
Metribuzin Pre	0.25		35.0 f		36.5 gh	41.3 gh
Metribuzin Pre	0.50		30.6 fg		39.6 gh	68.4 e
Metribuzin Pre	0.75		33.0 f		30.0 h	43.0 fg
Butralin Pre	3.00	65.0 def	73.6 d	12.1 cd	98.8 de	42.2 fgh
Oxyfluorfen Post	0.125	66.0 def	70.6 e	9.6 de	73.6 ef	71.7 e
Oxyfluorfen Post	0.25	63.0 def	82.0 e	12.2 def	116.2 de	86.2 d
Oxyfluorfen Post	0.50	25.3 g	18.0 gh	5.6 e	21.2 h	50.0 f
Metribuzin Post	0.25	67.0 de	19.3 gh	11.2 d	79.2 def	98.9 cd
Metribuzin Post	0.50	22.7 g	19.0 gh	2.4 ef	31.7 h	51.0 ef
Metribuzin Post	0.75	9.3 h	17.6 gh	0.4 ed	22.8 hi	49.0 f
Glyphosate Post	0.25	198.0 b	216.3 b	28.5 b	252.3 b	105.4 bc
Glyphosate Post	0.50	112.0 cd	129.3 cd	18.8 c	245.8 b	93.5 cd
Glyphosate Post	0.75	128.0 c	162.6 c	29.1 b	267.9 b	105.0 bc
Paraquat Post	0.25	106.0 cd	145.3 c	17.0 c	220.8 bc	134.5 b
Paraquat Post	0.50	83.3 d	110.6 cd	8.9 de	163.3 c	135.3 b
Paraquat Post	0.75	62.7 def	73.0 e	10.0 de	195.4 c	162.6 ab
Bentazon Post	2.50	223.0 a	235.6 b	26.6 b	240.6 b	82.5 h
Handweeded check			12.6 ghi		5.2 i	23.3 h
Unweeded check		269.70 a	332.6 a	73.40 a	357.40 a	194.3 a

Postemergence applications of metribuzin and oxyfluorfen did not give effective weed control and were slightly injurious to soybean (Table 2).

Butralin which was found by Pamplona (1980) to slightly control *B. erecta* was not effective in this study. Other postemergence herbicides such as glyphosate and paraquat when applied as directed sprays between the rows at 12 DAS did not give effective weed control. Only the weeds between the rows were controlled. Those within the row which constitute at least 30% of the total weed population were not affected.

Table 2. Effect of promising herbicides for the control of Boerhavia erecta *in soybean. Entries in each column followed by a common letter are not significantly different at 5% DMRT. Average of 3 replications. Ratings based on the European Weed Research Council Rating System.*

Treatment	Rate (kg/ha)	Crop Injury Rating 20 DAS 1	Weed Control Rating 20 DAS	Weed Control Rating 40 DAS	Grain Yield (g/plot)
Oxyfluorfen Pre	0.25	3.66 c	2.0 g	3.6 de	367.4 bc
Oxyfluorfen Pre	0.50	4.00 bc	1.3 gh	3.6 de	316.8 cd
Oxyfluorfen Pre	0.75	4.00 bc	1.3 gh	3.6 de	227.3 d
Metribuzin Pre	0.25	1.33 ef	1.3 gh	3.3 e	4695 bc
Metribuzin Pre	0.50	1.66 e	1.3 gh	3.3 e	684.8 b
Metribuzin Pre	0.75	1.66 e	1.3 gh	3.0 ef	691.2 b
Butralin Pre	3.00	2.00 de	4.0 de	5.0 bc	301.8 cd
Oxyfluorfen Post	0.125	5.00 a	5.0 bc	4.6 cd	148.1 fg
Oxyfluorfen Post	0.25	5.00 a	4.0 de	4.6 cd	187.3 e
Oxyfluorfen Post	0.50	5.00 a	4.0 de	5.0 bc	158.9 f
Metribuzin Post	0.25	4.00 bc	4.0 de	5.0 bc	201.5 de
Metribuzin Post	0.50	4.33 bc	4.0 de	5.0 bc	222.6 d
Metribuzin Post	0.25	3.66 c	5.0 bc	4.6 cd	166.7 ef
Glyphosate Post	0.25	3.66 c	5.0 bc	4.6 cd	166.7 ef
Glyphosate Post	0.50	3.66 c	3.3 f	4.6 cd	237.9 d
Glyphosate Post	0.75	4.00 bc	3.3 f	4.3 d	175.1 ef
Paraquat Post	0.25	4.00 bc	4.3 cd	5.0 bc	178.2 ef
Paraquat Post	0.50	4.66 ab	4.3 cd	0.5 bc	137.2 gh
Paraquat Post	0.75	5.00 a	4.0 de	5.0 bc	176.0 ef
Bentazon Post	2.50	2.33 d	6.0 bc	6.3 ab	82.5 h
Handweeded check		1.00 e	1.0 i	1.0 g	1,596.5 a
Unweeded check		1.00 e	8.3 a	8.0 a	66.0 hi

Experiment 2. *Influence of different levels of physical and chemical methods of weed control for the control of Boerhavia erecta in soybean.*

Soybean plots treated preemergence with metribuzin (0.50 kg/ha) and butralin (3.0 kg/ha) has significantly lower yields than the handweeded check (Table 4). Weed control treatments that gave yields comparable to the hand-weeded check were: off-barring and handweeding at 14 DAS followed by hilling-up 28 DAS; preemergence application of butralin followed by handweeding 20 DAS. Thus several weed control practices can be utilized to effectively control *B. erecta* in soybean.

While the farmers method of weed control (Off-barring 14 DAS + hilling-up 28 DAS) increased soybean yield over the unweeded check, this study clearly shows the inadequacy of this practice because only weeds between the rows are controlled.

The yield advantage of using combinations of chemical and physical methods of weed control are clearly indicated in this study. The amount

Table 3. Effect of different weed control treatments on the control of Boerhavia erecta *in soybean. Means followed by a common letter are not significantly different at 5% level. Average of three replications O — Off-barring; HU — Hilling-up; DAS — days after sowing.*

Treatments	Weed density (no/m^2)			Weed Weight (g/m^2)		
	20 DAS	30 DAS	40 DAS	20 DAS	40 DAS	At harvest
Handweeded check (weeded) 4 times until 40 DAS)	6.3 e	2.6 e	5.6 de	0.7 e	1.0 e	5.2 fg
OB 14 DAS + HU 28 DAS	25.0 d	52.0 b	32.3 bc	15.6 cd	208.0 a	71.2 b
OB + Handweeding 14 DAS + HU 28 DAS	3.0 ef	5.0 ef	3.0 e	0.6 e	2.7 e	5.6 fg
Metribuzin Pre (0.50 kg/ha)	3.0 ef	13.3 d	23.3 c	0.5 e	30.3 ab	56.bc
Metribuzin Pre + Handweeding 20 DAS	4.0 e	9.3 ef	8.6 de	1.1 e	17.3 c	11.3 e
Butralin Pre 3.00 kg/ha	68.0 c	49.0 c	54.0 b	13.4 cd	253.1 a	54.9 bc
Butralin Pre + Handweeding 20 DAS	59.0 c	8.0 ef	18.0 cd	9.9 d	8.5 d	6.3 fg
Handweeding 20 DAS	137.6 ab	16.6 d	24.0 c	69.9 ab	36.3 b	17.0 d
Unweeded check	144.3 a	152.6 a	115.0 a	91.8 a	344.5 a	122.2 a

of herbicide used could be reduced by applying the herbicide in a strip along the rows. Weeds growing between the rows can be removed by either cultivation or handweeding whichever is cheaper or adoptable to the farmers.

Table 4. Weed control rating and yield of soybean as affected by different weed control treatments Means followed by a common letter are not significantly different at 5% level. Average of 3 replications. OB — Off-barring; HU — Hilling-up. Ratings based on the European Weed Research System.

Treatments	Weed control Rating			Grain Yield (kg/plot)
	20 DAS	30 DAS	40 DAS	
Handweed check (weeded 4 times until 40 DAS	1.0 d	1.0 e	1.0 e	3.19 a
OB 14 DAS + HU 28 DAS	5.0 b	5.0 ab	5.6 ab	2.08 bc
OB + Handweeding 14 DAS + HU 28 DAS	1.3 c	1.6 d	1.6 cd	3.22 a
Metribuzin Pre 0.50 kg/ha	1.0 c	2.3 c	3.6 b	2.16 bc
Metribuzin Pre + Handweeding 20 DAS	2.0 c	1.0 e	1.3 b	3.30 a
Butralin Pre + Handweeding 20 DAS	6.0 ab	1.3 de	1.6 cd	3.18 a
Handweeding 20 DAS	8.3 a	2.3 c	2.6 c	2.79 b
Unweeded check	9.0 a	9.0 a	9.0 a	1.69 de

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WEED CONTROL IN MUNGBEAN

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ABSTRACT

Field experiments with mungbean *Vigna radiata* (L.) Wilczek indicated that the critical period of weed competition was between 30 and 60 days after planting (DAP) when the crop was spaced at 20 x 35 cm, and 30 DAP when planted at 10 x 25 cm. In herbicide evaluation trials, metolachlor applied at a rate of 2.50 kg/ha controlled grasses effectively. Butralin provided satisfactory results under moderate weed pressure without crop injury.

INTRODUCTION

Two approaches are being used at the Asian Vegetable Research and Development Center (AVRDC) to identify effective weed control measures for mungbean. The first is aimed at determining the critical period of weed competition and the second is to identify an effective means of chemical control. Studies on the critical period of weed competition emphasize the timing of manual weeding to avoid crop loss with the lowest labor requirement. These studies are based on the premise that if weeds are controlled during this period, crops can compete without significant yield loss. Alternately, chemical control studies seek to establish the most effective compound for controlling weeds without damaging the crop. Among several commercially available herbicides, alachor (Rethinam *et al.* 1976 a, b; Singh *et al.* 1971), butralin (AVRDC, 1979), and chloramben (Ikeda and Nhien, 1978) have been reported to be effective.

The objective of the study was to identify the critical period of weed competition and the most effective herbicides for controlling weeds in mungbean.

MATERIALS AND METHODS

Weed competition study

Two experiments were conducted in 1980 and 1982 at AVRDC (120° C17'E longitude, 23° 7'N altitude) on a sandy loam soil to determine the critical period of weed competition for mungbean. A randomized complete block experimental design with four replications was utilized. Hand weeding treatments included plots kept weed free or weed infested for 0.15, 30, 45, 60 and 75 DAP. Individual plots wer 3 m x 6 m and had twelve mungbean rows in 1980 and 2m x 6m with eight rows in 1982. Plant spacing was within the row was 20 cm in 1980 (2 plants/ hill) and 10 cm in 1982 (1 plant/hill). All plots were fertilized prior to planting with 20, 100 kg/ha of N, P_20_5, and K_20, respectively. Additional N (20 kg/ ha) was applied as a side dressing at flowering. Mungbean accession V2010 was used in 1980 and selection VC 1628 A in 1982. The growing period was from February 20 to May 23, 1980 and from March 16 to May 31 in 1982. Water was administered by furrow irrigation 15 and 30 days after planting.

Herbicide screening study

Individual trials were conducted in the summer of 1981 and the spring and summer of 1982 to determine the best herbicide for mungbean grown under different climatic conditions. A randomized complete block design with four replications (three replications for 1981) was utilized. The herbicides tested in 1981 were butralin, oxyfluorfen, metolachlor, a commercial mixture of metolachlor and metobromuron (Galex), and combinations of butralin and oxyfluorfen and butralin and bifenox. Only metolachlor, metolachlor plus metobromuron, and butralin were tested in 1982. Individual plots were 3m x 6m in 1981 and had six mungbean rows; 1982 plots were 2m x 6m with eight rows. Interior spacing was 60 cm in 1981 (2 plants/hill) and 25 cm in 1982 (1 plant/hill). Spacing within the row was 10 cm in both years. Fertilizer application rates were the same as those of the weed competition study. All herbicides were applied preemergence using a CO_2 sprayer with pressure adjusted to 2.11 kg/cm. The four center rows were harvested at maturity and the plant stand was counted.

RESULTS AND DISCUSSION

Weed competition study

In 1980 mungbean kept weed free from 60 DAP yielded 2.13 t/ha compared with the weed free check which yielded 1.94 t/ha (Figure 1). Controlling weeds for longer periods failed to increase yield significantly. Yield was reduced by 22% and 64% when the crop was kept weed free for 45 and 30 DAP, respectively. Yields were significantly affected by weed interference. The longer weeds were left unchecked, the higher the yield loss. Mungbean tolerated weed interference up to 30 DAP (Figure 1). Interference longer than 30 days reduced yields significantly. Yield reduction were 13% and 80% with interference for 45 days and throughout the growing season, respectively.

The response in 1982 was similar to that in 1980 (Figure 2). There was no further significant yield response to weeding when mungbean was kept free of weeds for longer than 30 DAP. Yields from plots kept weed free for 30 DAP were equivalent to the weed-free check (2.06 vs. 1.76 t/ha). Mungbean yields were significantly reduced when weeds were allowed to compete with mungbean beyond 30 DAP (Figure 2). With competition for the first 30 DAP, mungbean yielded as high as the weed-free check (1.91 vs. 1.76 t/ha).

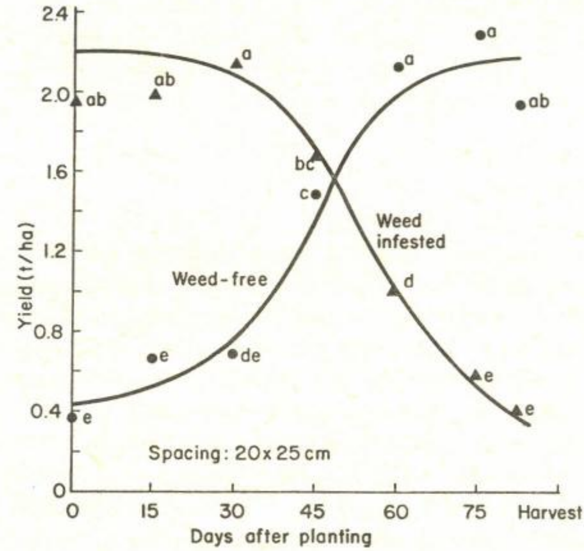

Figure 1. The relationship between duration of weed infestation and yield of mungbean, spring 1980.

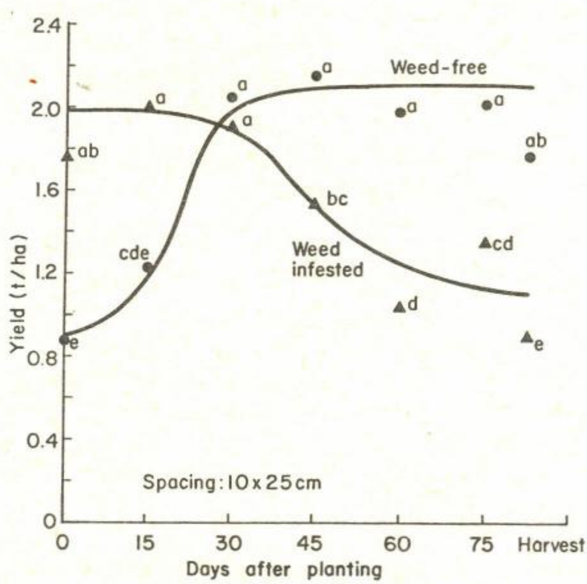

Figure 2. The relationship between duration of weed infestation and yield of mungbean. spring 1982

Mungbean tolerated weed competition for the first 30 DAP in both years. Controlling weeds beyond 60 DAP in 1980 and 30 DAP in 1982 did not result in significant yield increases. The critical period of weed competition was between 30 and 60 DAP in 1980 when plant spacing within the row was 20 cm, whereas only one weeding at 30 DAP was sufficient in 1982 when the plant spacing was 10 cm. Enyi (1973) found that mungbean yield was the highest when weeding was carried out from 14 DAP to 56 DAP. Madrid and Vega (1971) reported that the critical period of weed competition during the wet season was 21 to 35 DAP when mungbean was spaced 75 cm apart at a population density of 300,000 plants/ha. The present studies reveal that closer planting shortened the critical period of weed competition.

Herbicide screening study

Mungbean yield losses due to weed interference were as high as 95% (Table 1). Weed infestation during this season was dominated by *Digitaria spp.* Severe yield losses resulted from the application of oxyfluorfen either alone or in combination with butralin or from butralin plus bifenox due to crop injury as indicated by significant reduction in plant stand. Besides damaging the crop, oxyfluorfen did not control grasses. Application of butralin alone was not phytotoxic, but the yield did not respond to the treatment because weeds were not satisfactorily controlled (weed weight of butralin vs. weedy check = 16.6 vs. 17.0 t/ha). Metolachlor and metolachlor plus metobromuron controlled weeds and were not phytotoxic to mungbean. Although yields from these treatments (except metolachlor + metabromuron at 3 kg ha) were lower than the weed free check (1.02 t/ha), they were higher than the weedy check (0.05 t/ha). Weed competition caused reductions in plant stand, seed size and number of pods (Table 1). Reductions were 81%, 80%, and 43% for plant stand, pod, and 1000-seed weight. respectively, when weeds remained throughout the growing season.

The major weeds present during the spring 1982 trial were *Chenopodium album* L., *Amaranthus spinosus* L., *Echinochloa colona* (L.) Link, and *Eleusine indica*, (L.) Gaertn. Metolachor + methobromuron was the only treatment that controlled broadleaf weeds effectively (Table 2). Metolachlor and butralin gave good grass control. To control grasses effectively, metolachlor + metobromuron had to be applied at 3.0 kg/ha. Grasses were controlled best by metolachlor at 2.5 kg ha. None of the metolachlor treatments were phytotoxic. All treatments, except metolachlor at 2.0 kg ha, yielded higher than the weedy check and as high as the weed free check. Metolachlor + metobromuron at 3.0 kg ha gave the highest yield (2.20 t/ha) among the herbicide treatments. Yield variation was due to differences in the plant stand and pod production.

Weed infestation during the summer 1982 trial was relatively low. The maximum yield reduction (48%) was substantially less than that of the summer 1981 (95%) and spring 1982 trials (79%). Grasses were significantly controlled by all herbicide treatments (Table 3). Although broad-

Table 1. *Effect of herbicides on plant stand and yield of mungbean and weed fresh weight, summer 1981. Means within a column followed by a common letter are not significantly different at the 4% level by Duncan's multiple range test.*

Herbicide	Rate (kg ha)	Yield (t/ha)	Pods (no./plant)	1000-seed weight (g)	Plant stand (no./m^2)	Weed weight (t/ha)
Weed-free check	—	1.02 a	11.6 a	45.3 a	34.6 a	2.9 f
Butralin	2.00	0.25 c	4.7 def	41.7 a	22.3 b	16.6 bcde
Oxyfluorfen	0.10	0.02 e	3.4 defg	24.7 b	1.8 c	17.3 bcd
Oxyfluorfen	0.15	0.00 e	0.0 g	0.0 c	0.3 c	30.0 a
Butralin + Oxyfluorfen	2 + 0.10	0.03 e	3.3 defg	39.7 a	2.9 c	16.9 bcd
Butralin + Oxyfluorfen	2 + 0.15	0.00 e	0.0 g	0.0 c	2.4 c	17.1 bcd
Metolachlor	1.50	0.58 cd	6.0 cde	44.0	29.4 a	6.8 f
Metolachlor	2.00	0.56 cd	6.5 bcd	44.7 a	30.1 ab	10.2 cdef
Metolachlor	2.50	0.64 bc	7.2 bcd	45.0 a	31.4 ab	5.1 f
Metolachlor + Metobromuron	2.00	0.65 bc	6.7 bcd	45.0 a	35.4 a	6.3 f
Metolachlor + Metobromuron	2.50	0.29 de	4.5 def	41.7 a	29.7 ab	8.6 def
Butralin + Bifenox	2 + 2.00	0.00 e	0.0 g	0.0 a	0.1 c	15.7 bcde
Metolachlor + Metobromuron	3.00	0.72 abc	10.1 ab	44.0 a	32.1 ab	7.6 ef
Butralin + Oxyfluorfen	—	0.05 e	2.3 efg	25.7 b	6.5 c	17.0 bcd

Table 2. Effect of herbicides on plant stand and yield of mungbean and weed fresh weight, spring 1982. Means within a column followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

Herbicide	Rate (kg ha)	Yield (t/ha)	Pods (no./plant)	Plant stand (no./m^2)	Weed weight (t/ha) grass	broadleaf
Weed-free check	—	1.93 ab	15.7 ab	26.2 ab	0.99 d	0.00c
Butralin	2.0	1.29 hc	15.4 ab	21.3 bc	7.40 bcd	4.00 b
Metolachlor	1.0	1.16 bc	10.7 c	26.5 ab	5.30 cd	5.20 ab
Metolachlor	1.5	1.17 bc	10.6 c	26.2 ab	4.63 cd	4.75 ab
Metolachlor	2.0	1.08 cd	11.2 bc	23.2 ab	5.08 cd	5.58 ab
Metolachlor	2.5	1.42 bc	13.1 abc	26.2 ab	2.00 d	7.70 a
Metolachlor + Metobromuron	1.5	1.55 abc	13.4 abc	23.0 ab	13.18 ab	0.25 c
Metolachlor + Metobromuron	2.0	1.87 ab	15.8 ab	27.4 ab	10.20 abc	0.00 c
Metolachlor + Metobromuron	2.5	1.60 abc	13.1 abc	24.9 ab	14.30 ab	0.00 c
Metolachlor + Metobromuron	3.0	2.20 a	16.1 a	28.9 a	4.38 cd	0.00 c
Weedy check	—	0.40 d	6.0 d	15.1 c	16.25 a	2.55 bc

Table 3. Effect of herbicides on plant stand and yield of mungbean and weed fresh weight, summer 1982. Means within a column followed by a common letter are not significantly different at the 5% level by Duncan's multiple range test.

Herbicide	Rate (kg ha)	Yield (t/ha)	Pods (no./plant)	Plant stand (t/ha)	Weed weight (t/ha[1]) Grass	Weed weight (t/ha[1]) broadleaf
Weed-free check	—	1.30 a	13.9 a	20.4 ab	0.00 b	0.00 c
Butralin	2.0	1.20 a	12.8 a	20.6 ab	2.88 b	1.97 a
Metolachlor	1.0	1.42 a	13.3 a	24.4 ab	0.75 b	1.08 abc
Metolaclor	1.5	1.28 a	13.8 a	22.8 ab	0.80 b	1.85 ab
Metolachlor	2.0	1.25 a	12.6 a	22.6 ab	0.52 b	0.35 c
Metolachlor	2.5	1.38 a	14.7 a	21.7 ab	0.70 b	0.48 c
Metolachlor + Metobromurn	1.5	1.44 a	14.1 a	23.8 ab	0.93 b	0.78 bc
Metolachlor + Metobromuron	2.0	1.49 a	13.4 a	25.2 a	2.98 b	0.70 bc
Metolachlor + Metobromuron	2.5	1.34 a	14.2 a	22.6 ab	0.45 b	0.50 c
Metolachlor + Mttobromuron	3.0	1.43 a	12.7 a	24.6 ab	0.82 b	0.58 c
Weedy check	—	0.68 b	7.9 b	19.8 b	6.72 a	0.75 bc

leaf weeds were not numerous, they were not controlled by either butralin or metolachlor at rates of 1.0 to 1.5 kg ai/ha. All treatments were equally good and yielded more than the weedy check. Due to low weed infestations, plant stands were not affected by competition. Higher yields were attributed to a higher number of pods per plant.

These results show that the commercial mixture of metolachlor and metobromuron is the best herbicide treatment for mungbean. Its performance can be attributed to metolachlor's ability to control grasses and to metobromuron's effectiveness on broadleaf weeds. Metolachlor also has some activity for controlling broadleaf weeds such as *Amaranthus spp.* and *Portulaca oleracea* L. Broadleaf escapes from metolachlor were *Chenopodium album* L. and *Solanum nigrum* L. (Table 2). Metolachlor at 2.50 kg ha is the herbicide of choice at AVRDC for controlling heavy grass infestations. Under moderate weed pressure butralin, the recommended herbicide at AVRDC, is also satisfactory.

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WEEDING REGIMES IN AN UPLAND RICE-MUNGBEAN CROPPING SYSTEM

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ABSTRACT

The effect of continuous application of the same weeding treatments on weed populations and crop yields was studied in an upland rice (*Oryza sativa* L.) — mungbean [*Vigna radiata* (L.) Wilczek] cropping system in two fields.

In one field, the most intensive weeding treatment applied over the past 2 years caused a drastic reduction in the population of *Rottboellia exaltata* L.f. and in the total weed biomass. In another field which was dominated by *Amaranthus spinosus* L., *Eleusine indica* (L.) Gaertn., and *Cyperus rotundus* L., the residual effect of intensive hand weeding on the weed population was not as pronounced.

Changes in the weed flora across time were determined primarily by the weeding regime applied to the crop and to a less extent by the dominant species in the weed community.

Continuous pendimethalin [N-(l-ethylpropyl)-3, 4-dimethyl-2,6-dinitrobenzenamine] application reduced species richness and resulted in a buildup of *C. rotundus* population.

Yields of rice and mungbean varied among the difference weeding regimes and between the two fields. Differences in yields within a field were due to the weeding treatments. Variations in yields between the two fields were attributed to the differences in the weed community and soil moisture.

INTRODUCTION

Upland rice followed by mungbean, a cropping pattern practiced by some farmers in the Philippines has potential for further expansion. However, both crops suffer greatly from weed competition. The degree of weed control given to the crops varies among farmers and locations. Normally, upland rice is weeded more than mungbean. The degree of weed infestation, the level of expected output, and the labor, cash, and power resources of the farmer largely determine the amount of weed control that will be given to a crop.

Weeding has been identified as the main factor affecting the change in the weed flora under upland conditions (Drost and Moody, 1981; Ahmed and Moody, 1982). A shift from difficult to easy to control weeds or vice versa could be brought about by applying weed control practices over time. Determining the intensity of weeding that is needed to reduce weed problems in an upland rice-mungbean cropping system is essential to weed management.

Most of the applied weed control research in upland rice or mungbean has been focused on a single crop. Results from these studies are useful and have been applied successfully to some extent. In actual practice however, the farmer plants his crops sequentially on the same piece of land and employs weeding and cultural practices over time. Since the weed population is affected by these practices weed control research should be done in the context of the whole cropping system rather than on a single crop in isolation in order to have more meaningful and applicable results.

The continuous application of different weeding regimes on the same piece of land grown to an upland rice — mungbean cropping system was initiated by Bhandari and Moody in the 1980 wet season at the International Rice Research Institute (IRRI) experimental farm. The results of their research for the first 2 years of the trial have been partially summarized (Bhandari and Moody, 1981 a, b). In this paper, the results obtained in the third year of the experiment are presented. The residual effect of different weeding regimes on the weed population in two fields was examined and the effects of weeding regimes on the weed flora and on crop yield were determined.

MATERIALS AND METHODS

This experiment was started in two upland fields at the IRRI experimental farm in May 1980. The cropping pattern in each field was upland rice followed by mungbean. Five weeding treatments were laid out in a randomized complete block design with four and three replications in Field 1 and 2, respectively. The plot size was 6 by 8 m in both fields.

The five weeding treatments consisted of three hand weeding treatments, a herbicide treatment, and a no weeding treatment. There were slight variations in the hand weeding treatments across years and between fields (Tables 1 and 2). In all years and in both fields for rice, pendimethalin was applied at 2.0 kg/ha preemergence. This was followed by one postemergence application of 2,4-D (2,4-dichlorophenoxy acetic acid) at 0.5 kg/ha in 1980 and two applications of 2,4-D at 0.5 kg/ha in 1981 and 1982. Two applications of 2,4-D were used in 1981 and 1982 because one application failed to suppress *C. rotundus* in 1980. Pendimethalin was applied preemergence at 1.0 kg/ha to mungbean in all years and in both fields.

The same weeding treatments were applied to the same plots for the duration of the experiment. To avoid spread of weed seeds or propagules from one plot to another, wide alleyways were provided between plots, extra care was taken in removing the weeds after each weeding and at crop harvest, and land preparation was done plot by plot.

Table 1. Hand weeding treatments used for rice and mungbean in Field 1, 1980-1982.

Treatment	Year		
	1980	1981	1982
Rice			
One hand weeding	2 weeks after emergence (WAE)	2 WAE	3 WAE
Two hand weedings	2 & 5 WAE	2 & 5 WAE	2 & 4 WAE
Weed free	2, 4, 6, & 8 WAE	2, 4, & 6 WAE	2, 4, 6 & 8 WAE
Mungbean			
One hand weeding	2 WAE	2 WAE	3 WAE
Two hand weedings	10 & 20 days after emergence (DAE)	10 & 20 DAE	2 & 4 WAE
Weed free	10 & 20 DAE	10 & 20 DAE	2 & 4 DAE

Before planting each crop, the plot was rotovated two to three times for rice and once or twice for mungbean. A hand tractor was used for land preparation in both crops in Field 1 and for mungbean in Field 2. For rice in Field 2, a four-wheel tractor was used for initial rotovation and a hand tractor for final land preparation.

In both fields, rice cultivar IR36 was sown at 100 kg/ha in rows spaced 25 cm apart. For mungbean, cultivar CES IT2 was seeded at 20 kg/ha in 50 cm rows. Fertilizer was applied at 100 kg N, 40 kg P_2O_5, and 40 kg K_2O/ha to rice. All the P_2O_5 and K_2O were applied basally before final harrowing while the nitrogen was applied in three doses. In Field 1, 40 kg N/ha was applied at 35 days after emergence (DAE), 30 kg at 50 DAE, and the remaining 30 kg was applied at panicle initiation. In Field 2, 40 kg N/ha was applied basally and 30 kg/ha was applied at 30 DAE and at panicle initiation. For mungbean in both fields, 20 kg N, 30 kg P_2O_5, and 30 kg K_2O/ha was applied prior to planting.

In rice, weed samples were taken 2, 8, and 11 weeks after emergence (WAE) from two 50 by 50 cm quadrats in each plot and composited. In the mungbean crop, samples were taken at 2 and 8 WAE. An additional sampling was done in mungbean at 4 WAE in Field 1 because of marked differences in weed growth in some treatments. The weeds were classified by species, counted, dried, and the dry weights recorded. The summed dominance ratio (SDR) of each species was calculated using the following equations:

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

where,

$$\text{Relative density} = \frac{\text{The number of a particular species}}{\text{Total number of all species}} \times 100$$

and

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

Yield samples were taken from a 10 m^2 sampling area for rice in both fields and for mungbean in Field 1. A 20 m^2 sampling area was used for mungbean in Field 2. After processing, the yields were converted to t/ha at 14% and 12% moisture for rice and mungbean, respectively.

Statistical analyses were conducted by the Department of Statistics, IRRI.

Table 2. Hand weeding treatments used for rice and mungbean in Field 2, 1980-1982.

Treatment	Year	
	1980	1981 and 1982
Rice		
One hand weeding	2 weeks after emergence	2 WAE
Two hand weedings	2 & 5 WAE	2 & 5 WAE
Weed free	2, 4, & 6 WAE	2, 4, & 6 WAE
Mungbean		
One hand weeding	2 WAE	2 WAE
Two hand weedings	10 & 20 days after emergence (DAE)	2 & 4 WAE
Weed free	10 & 20 DAE	2 & 4 WAE

RESULTS AND DISCUSSION

Initial weed flora

The weed flora at the start of the experminet in 1980 differed between fields. The major weed species in Field 1 were: *R. exaltata*, *C. rotundus*, *Commelina diffusa* Burn.f., *Cynodon dactylon* (L.) Pers., and *Echinochloa colona* (L.) Link. In Field 2, the major weeds were *E. indica*, *A. spinosus*, *C. rotundus*, and *Digitaria* sp.

Residual effect of weeding treatments

The residual effect of weeding treatments applied for the past 2 years was observed 2 WAE in both crops. The predominant weed species in a given field influenced the residual effects.

. The unweeded plot in Field 1 was dominated by *R. exaltata*. In the weed free treatment the population of *R. exaltata* was drastically reduced (Tables 3 and 4). The drastic reduction of *R. exaltata* from the weed free plots indicates that it has no dormancy or very short dormancy, or that the seeds have a very short life. *R. exaltata* was replaced as the most important weed in the weed flora by *C. rotundus* and *Ipomoea triloba* in rice and *C. rotundus* in mungbean. However, the total number and weight of these weeds were significantly lower than those of the weedy check and some of the other treatments in rice and all of the other treatments in mungbean. The residual effect of the weed free treatment on *R. exaltata* was still observable 2 weeks after the first weeding in mungbean (Table 5). The SDR of *R. exaltata* was neglible in the weed-free treatment while in the other treatments the values were substantially higher. Moreover, the total number and weight of weeds were significantly lower in the weed free plot compared to that of the plot hand weeded twice.

Two hand weedings reduced the population of *R. exaltata* to some extent in rice, but because of further re-seeding (*R. exaltata* plants that remained after the second weeding produced and shed their seeds), its population remained high in mungbean (Tables 3 and 4). As in the weed-free treatment, *C. rotundus* and *I. triloba* increased in importance in rice and *C. rotundus* increased in mungbean with two hand weedings. The total weed growth was significantly reduced due to the residual effect of two hand weedings in rice but not in mungbean.

In both crops, one hand weeding had little or no residual effect on the weed population. The level of weed control achieved by this treatment in the preceding years was not high enough to produce major changes in the weed flora.

The residual effect of the herbicide application on the weed flora in rice was essentially the same as that obtained by maintaining a weed free condition (Table 3). However, the weed density was significantly higher. In the herbicide-treated mungbean plot, *C. rotundus* was the dominant weed but *R. exaltata* still formed an important component of the weed flora (Tables 4 and 5) in contrast to the weed free plot.

Table 3. Effect of the continuous use of the same weeding treatments on various weed parameters two weeks after emergence of upland rice. Field 1, IRRI, 1982 wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	
—					
Rottboellia exaltata	89	9	59	19	6
Cyperus rotundus	10	80	37	67	70
Ipomoea triloba	< 1	10	2	10	15
Other weed s pcies	< 1	1	2	4	9
Average no. of species	3.3 a	3.3 a	3.3 a	3.8 a	3.8 a
Total weed density (no./m^2)	1026 a	202 b	452 b	76 c	52 c
Total dry weed weight (g/m^2)	28 a	18 ab	16 ab	7 b	5 b

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 4. Effect of the continuous use of the same weeding treatments on various weed parameters two weeks after emergence of mungbean.[a] Field 1, IRRI, 1982 late wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Rottboellia exalatata	66	20	69	50	1
Cyperus rotundus	34	79	28	47	95
Other weed species	—	1	3	3	4
1					
Average no. of species	2.0 a	2.5 a	3.3 a	3.0 a	2.0 a
Total weed density (no./m^2)	108 a	214 a	134 a	124 a	38 b
Total dry weed weight (g/m^2)	18 b	49 a	26 ab	30 ab	8 c

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 5. Effect of the continuous use of the same weeding treatments on various weed parameters four weeks after emergence of mungbean.[a] *Field 1, IRRI, 1982 late wet season.*

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed Fre
Rottboellia exaltata	86	23	76	78	1
Cyperus rotundus	12	75	23	13	78
Other weed species	2	2	1	9	21
Average no. of species	3.0 b	3.0 b	2.3 b	5.8 b	3.0 b
Total weed density (no./m^2)	670 a	508 a	78 b	446 a	28 c
Total dry weed weight (g/m^2)	93 a	156 a	9 c	25 b	5 c

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Different results were obtained in Field 2 which had a more diverse flora dominated by *C. rotundus*, *E. indica*, and *A. spinosus*. The total weed growth was generally reduced by the hand weeded treatments in rice but not in mungbean (Tables 6 and 7). None of the predominant weed species was substantially reduced by the more intensive weeding treatments and there was inconsistency among the different weeding regimes in both crops. Variability was also greater between replications in this field than in Field 1. In rice, *Portulaca oleracea* L. became an important component of the weed flora in the weed free plot. It was unimportant or not present in the other weeding treatments in rice and was of no importance in mungbean. Weed weights were significantly reduced by hand weeding in rice but not in mungbean.

Pendimethalin virtually eliminated all weed species except *C. rotundus*. The herbicide did not reduce weed density or biomass significantly.

Changes in the weed flora across time in the upland rice-mungbean

The population of the highly competitive annual grass *R. exaltata* built-up over time in the weedy fallow plot in Field 1. During the later part of the season weed species other than *R. exaltata* were virtually excluded from the weed community (Tables 8 and 9). In Field 2, changes in the weed flora in the weedy fallow plot were far less drastic. No single weed species dominated the weed community throughout the growing period and those species which were the important ones 2 WAE were still important 8 WAE (Table 10). By 11 WAE *C. rotundus* had either senesced or was outcompeted by the other species and was replaced by *Commelina benghalensis* L. and *I. triloba*.

Changes in the weed flora across time in the upland rice — mungbean rotation were determined primarily by the weeding regime applied and to a certain extent by the species dominating the weed community.

Table 6. Effect of the continuous use of the same weeding treatments on various weed parameters two weeks after emergence of upland rice. Field 2, IRRI, 1982 wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Cyperus rotundus	66	100	8	32	29
Eleusine indica	15	—	50	49	20
Amaranthus spinosus	5	—	30	10	16
Portulaca oleracea	2	—	—	2	22
Cynodon dactylon	—	—	—	—	10
Other weed species	12	—	12	7	3
Average no. of species	7.3 a	1.0 c	4.7 b	5.3 b	4.7 b
Total weed density (no./m^2)	256 a	184. a	162 ab	88 bc	52 c
Total dry weed weight (g/m^2)	56 a	28 ab	24 b	12 b	25 b

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 7. Effect of the continuous use of the same weeding treatments on various weed parameters two weeks after emergence of mungbean. Field 2, IRRI, 1982 late wet season.[a]

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Cyperus rotundus	18	100	9	57	59
Amaranthus spinosus	58	—	47	24	33
Eleusine indica	8	—	42	10	7
Cleome rutidosperma	10	<1	2	<1	<1
Other weed species	6	—	—	9	1
Average no. of species	7.0 a	1.7 c	5.3 ab	5.3 ab	4.0 b
Total weed density (no./m^2)	384 a	488 a	446 a	164 a	176 a
Total dry weed weight (g/m^2)	84 b	238 a	98 ab	42 b	46 b

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 8. Effect of the continuous use of the same weeding treatments on various parameters eight weeks after emergence of upland rice.[a] Field 1, IRRI, 1982 wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Rottboellia exaltata	94	30	56	13	6
Cyperus rotundus	6	69	18	26	42
Digitaria sp.	—	—	10	2	—
Eleusine indica	—	—	1	14	16
Dactyloctenium aegyptium	—	—	4	24	16
Hedyotis corymbosa	—	—	—	2	10
Portulaca oleracea	—	—	—	7	2
Echinochloa colona	—	—	9	5	—
Other weed species	<1	1	2	7	8
Average no. of species	2.3 b	4.0 b	7.0 a	8.8 a	6.8 a
Total weed density (no./m^2)	548 a	410 a	284 a	120 b	78 b
Total dry weed weight (g/m^2)	390 a	150 b	162 b	101 b	10 c

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 9. Effect of the continuous use of the same weeding treatments on various weed parameters 11 weeks after emergence of upland rice.[a] Field 1, IRRI, 1982 wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Rottboellia exaltata	100	73	69	12	—
Cyperus rotundus	—	27	3	13	10
Hedyotis corymbosa	—	—	—	7	46
Digitaria sp.	—	—	22	33	—
Dactyloctenium aegyptium	—	—	1	12	11
Eleusine indica	—	—	2	11	7
Echinochloa colona	—	—	3	9	4
Murdannia nudiflora	—	—	—	1	10
Ageratum conyzoides	—	—	—	1	10
Other weed species	<1	<1	—	1	2
Average no. of species	1.3 c	2.3 c	5.5 b	8.5 a	7.5 a
Total weed density (no./m^2)	246 a	162 a	120 a	216 a	116 a
Total dry weed weight (g/m^2)	1135 a	950 a	755 a	346 b	17 c

[a] In a row, means followed by a common letter are not significantly different at the 5% level

In Field 1, the weed populations became more diversified at the later stages of crop growth as a result of the hand weeding treatments. An increase in the number of species was observed in rice 8 WAE (Table 8). No further increase in the number of species was observed at 11 WAE. In fact, in the plot hand weeded once a decrease was observed (Table 9). In the herbicide-treated plots, *R. exaltata* and *C. rotundus* were the only species of importance. *C. rotundus* was dominant up to 8 WAE but at 11 WAE as *C. rotundus* senesced *R. exaltata* was the dominant weed.

In the absence of a highly competitive weed such as*R. exaltata*, the weed flora in Field 2 was much more diverse in all treatments except the herbicide treatment (Tables 10 and 11).

The predominant weed species differed among weeding regimes. *E. indica* dominated in the hand weeded plots while *A. spinosus* dominated in the weedy fallow 8 WAE (Table 10). *C. rotundus* was the most important in the weedy fallow and in the plot that was weeded once but it was absent in the other plots indicating that it was controlled by the herbicide used and that it cannot withstand heavy weeding pressure. *C. benghalensis* which was unimportant early in crop growth became important in most treatments later. Similarly, *Vernonia cinerea* (L.) Less was an important weed later in the season in the treatments that were maintained weed free and those weeded twice.

Table 10. Effect of the continuous use of the same weeding treatments on various weed parameters eight weeks after emergence of upland rice.[a] Field 2, IRRI, 1982 wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Cyperus rotundus	14	99	—	12	11
Eleusine indica	16	—	63	45	48
Amaranthus spinosus	51	—	25	—	—
Digitaria sp.	2	—	—	—	18
Commelina benghalensis	4	—	1	15	6
Corchorus olitorius	—	—	—	9	3
Portulaca oleracea	—	—	—	—	9
Other weed species	13	1	11	19	5
Average no. of species	6.0 a	2.0 c	4.0 b	5.7 a	3.7 b
Total weed density (no./m^2)	144 b	712 a	36 c	52 bc	38 c
Total dry weed weight (g/m^2)	616 a	342 a	464 a	14 b	10 b

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 11. Effect of the continuous use of the same weeding treatments on various weed parameters 11 weeks after emergence of upland rice.[a] Field 2, IRRI, 1982 wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One hand weeding	Two hand weedings	Weed free
Cyperus rotundus	—	82	—	5	2
Eleusine indica	22	—	59	24	45
Amaranthus spinosus	39	—	21	—	3
Digitaria sp.	5	—	—	3	12
Commelina benghalensis	16	13	4	22	5
Vernonia cinerea	—	—	—	12	14
Ipomoea triloba	12	—	—	—	5
Corchorus olitorius	—	—	—	11	—
Dactyloctenium aegyptium	—	—	9	8	—
Other weed species	6	5	7	15	14
Average no. of species	5.7 a	2.7 b	4.0 ab	6.0 a	6.0 a
Total weed density (no. /m^2)	52 b	376 a	28 b	28 b	32 b
Total dry weed weight (g/m^2)	904 a	274 b	868 a	12 c	22 c

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

In the mungbean crop, there was a less pronounced change in the weed flora among weeding regimes in both fields. In Field 1, the only major difference was between the weed-free treatment and the rest of the treatments. There were significantly more species present in the weed-free plot compared to other plots and the weed flora was much more diverse (Table 12). Important weeds in the weed free plot which were absent or unimportant in the other plots were *P. oleracea*, *Ageratum conyzoides* L., and *Euphorbia hirta* L. *R. exaltata* predominated in the other treatments.

In Field 2, the predominant weed species varied according to the weeding treatment as well. The weed flora was primarily composed of *C. rotundus*, *A. spinosus*, and *E. indica* in all treatments except in the herbicide-treated plot where *A. spinosus* and *E. indica* were absent (Table 13). *C. rotundus* was more dominant than the other two species in the plots hand weeded twice and in the weed free treatment. One hand weeding tended to minimize the dominance of one species over the others, in contrast to the unweeded plot where *A. spinosus* was dominant. Herbicide application significantly reduced the number of species compared to the other treatments.

Crop yields

Yields of rice and mungbean varied among the different weeding regimes and between the two fields. In Field 1, rice produced 1.8 t/ha in the weed free plot (Table 14). The rest of the plots produced no yield due to the combined effects of severe weed infestation and moisture stress at flowering and the early spikelet filling stages. There was a substantial increase in weed infestation in all weeding treatments from 8 WAE (Tables 8 and 9) because of sustained rainfall after an early drought coupled with nitrogen topdressing. The third and fourth hand weedings in the weed free plot checked the growth of these and later appearing weeds until crop maturity. The detrimental effect of moisture stress was aggravated by intense weed growth. Thus, more intensive weeding was needed in upland rice grown under moisture stress and high weed intensity to save the crop from total failure. Others (De Datta and Beachell, 1972; Dadey, 1973; Moody, 1975) have also commented on the deleterious effects of weeds and drought on upland rice yield.

Table 12. Effect of the continuous use of the same weeding treatments on various weed parameters eight weeks after emergence of mungbean. Field 1, IRRI, 1982 late wet season.

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Herbicide	One Hand weeding	Two hand weedings	Weed/free
Rottboelia exaltata	93	62	96	86	11
Cyperus rotundus	3	32	2	12	15
Portulaca oleracea	4	—	—	<1	25
Ageratum conyzoides	—	—	—	<1	12
Euphorbia hirta	<1	—	—	—	8
Other weed species	—	6	2	1	29
Average no. of species	4.3 b	4.0 b	4.0 b	4.3 b	8.3 a
Total weed density (no./m^2)	354 b	436 b	1054 a	436 b	66 c
Total dry weed weight (g/m^2)	940 a	660 a	432 a	119 b	31 c

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 13. Effect of th continuous use of the same weeding treatments on various weed parameters eight weeks after emergence of mungbean. Field 2, IRRI, 1982 late wet season.[a]

Weed species	Summed dominance ratio (%)				
	Weedy fallow	Hrrbicide	One hand weeding	Two hand weedings	Weed free
Cyperus rotundus	12	91	25	61	74
Amaranthus spinosus	65	—	37	5	7
Eleusine indica	11	—	32	17	10
Other weed species	12	9	5	17	9
Average no. of species	8.3 a	3.3 c	6.0 ab	5.0 bc	5.7 ab
Total weed density (no./m^2)	362 b	1216 a	234 bc	62 d	84 cd
Total dry weed weight (g/m^2)	338 a	254 a	162 a	10 b	12 b

[a] In a row, means followed by a common letter are not significantly different at the 5% level.

Table 14. Yields (t/ha) of rice and mungbean in two fields as affected by weeding treatment.[a] IRR(, 1982 wet season.

Weed control treatment	Field 1		Field 2	
	Rice	Mungbean	Rice	Mungbean
Weed free	1.8 a	0.85 a	3.00 a	1.18 a
Two hand weedings	0 bq	0.56 b	2.83 a	1.16 a
One hand weeding	0 b	0.16 c	0 c	0.30 b
Herbicide	0 b	0.01 c	0.70 b	0.31 b

[a] In a column, means followed by a common letter are not significantly different at the 5% level.

The rice in Field 2 produced higher yield than that in Field 1 because it suffered less drought stress. It was planted later and the depth to the water table was not as great as in Field 1. Yields from the weed free and two hand weeding treatments were similar and significantly higher than those from the one hand weeding and herbicide treatments (Table 14). The plot hand weeded once failed to yield due to excessive weed growth late in the growing season. The yield in the herbicide-treated plot was very low of weeding were required in the two fields because of differences in the weed flora and moisture availability.

In the mungbean crop, the weed free plot yielded significantly higher than that which received two hand weedings in Field 1 but not in Field 2 even though both plots in each field received the same amount of weeding in mungbean (Table 14). The variation between the two fields was due to the differences in the level of weed control achieved and partly to the dominant weed species present. The two hand weeding treatment in Field 1 failed to check the growth of *R. exaltata* and the weed weights were significantly higher than those in the plots maintained weed free (Table 12). In Field 2, two hand weedings controlled the weeds adequately and weed weights were not significantly different from the weed free check (Table 13). The weed-free treatment suppressed weeds better in Field 1 than in Field 2.

In both fields, the one hand weeding and herbicide treatments gave similar yields which were significantly lower than that of the other two treatments. In other trials on mungbean, one and two hand weedings gave similar results (Navarez and Moody, 1982; Elliot et al., 1983). Other workers have reported that one or two timely weedings provided adequate weed control and high mungbean yields (Madrid and Vega, 1971; Moody, 1978; Panwar and Singh, 1977; Vats and Sidhu, 1977).

One hand weeding was insufficient for the mungbean crop to produce reasonable yields under high weed pressure. The low yields from the herbicide treated plots were a result of stand reduction caused by the herbicide and the failure of the herbicide to adequately control *R. exaltata* in Field 1 and *C. rotundus* in Field 2.

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EFFECTS OF DURATION OF WEED COMPETITION ON THE GROWTH OF RUBBER SEEDLINGS

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ABSTRACT

A field experiment was conducted to study the effects of various weed competition duration on the growth of rubber seedlings in the nursery. When the seedlings were kept weed-free for the first 4 months after planting, there was no significant reduction in plant height and stem diameter. The duration of weed competition tolerated by rubber seedlings did not exceed 2 months, after which, the growth was reduced significantly. Twelve months after planting, reduction in plant height, stem diameter and dry weight of rubber seedlings due to weeds was 57%, 50% and 85% respectively.

INTRODUCTION

Rubber (*Hevea brasiliensis* Muell Arg.) is a major plantation crop in Indonesia. In 1978, the area planted to rubber was more than 2.3 million hectares (Bogor Res. Inst. for Estate Crops, 1981). In 1980, among the agricultural export products, rubber products were the second biggest foreign exchange earner after timber products (Indonesian Centr. Bureau of Stat., 1982).

Rubber seedlings must be grown in the nursery for 8 to 12 months before they are budded and then transplanted to the field. Weed control in small-scale nurseries is usually done by hand weeding four to six times, but in the larger nurseries, hand weeding is more expensive than chemical control (Mangoensoekarjo, 1975; Rubb. Res. Inst. Malaysia, 1980). Pre-emergence herbicides such as linuron and simazine (2 kg/ha), diuron (1-1.2 kg/ha) or methoxy triazine (1.5 kg/ha) suppress the weed growth for about 3 months (Mangoensoekarjo & Kadnan, 1974).

Various weed species including *Imperata cylindrica* (L.) Beauv. (Basuki *et al,* 1979; Soedarsan, 1979), *Mikania cordata* (Wong, 1964), *Cyperus rotundus* L. (Mangoensoekarjo, 1978), *Paspalum conjugatum* Berg. (Pamplona & Soerjani, 1975) and *Cyclosorus aridus* (Don) Ching (Basuki *et al,* 1979) inhibit the growth of young rubber trees. However, no study has been done on the competition between rubber seedlings and weeds in the nursery.

This study was conducted to determine the weed free period requirement and the duration of weed competition tolerated by rubber seedlings in the nursery.

MATERIALS AND METHODS

The experiment was conducted at the Cibodas Experimental Garden, Bogor, West Java, on a latosol soil type at an altitude of 250 m above sea level.

Seeds of GT 1 rubber clone were germinated on a sand medium. Two weeks after germination seedlings were transplanted to the nursery. Planting distance was 50 cm x 50 cm. The plot which contained 48 seedlings was 3m x 4m.

A randomized block design with four replications was used. Treatments for determining the weed free period required by rubber seedlings were:

1. Weed free during the life cycle of the rubber seedlings (12 months)
2. Weed free during the first 1 month
3. Weed free during the first 2 months
4. Weed free during the first 4 months
5. Weed free during the first 8 months

Treatments for determining the duration of weed competition tolerated by rubber seedlings were:

6. Not weeded for the first 1 month
7. Not weeded for the first 2 months
8. Not weeded for the first 4 months
9. Not weeded for the first 8 months
10. No weed control during the life cycle of the rubber seedlings

All weeds were removed from the nursery 2 weeks before planting. The weed free condition was obtained by hand weeding twice a month. The rubber seedlings were fertilized with 16.58 g ammonium sulphate + 4 g triple superphosphate + 2 g potassium sulphate per plant 1, 4, 7 and 10 months after planting (Angkapradipta, 1975). Protection against insect pests and diseases was routinely carried out.

The height and stem diameter (10 cm above ground level) of ten sample plants in each plot were measured every 2 months. At the end of the experiment, the dry weight of the above ground part of the plants was taken from 5 sample plants in each plot.

The weed biomass was taken from two 0.25 m^2 in each plot. The weed species were identified and weed coverage was estimated.

RESULTS

Plant height

Weed emergence 2 months after planting rubber significantly reduced plant height (Table 1). When rubber seedlings were kept weed free for the first 4 months after planting, the plant height was significantly different from that of seedlings kept weed free throughout the experiment.

Weed competition for the first 4 or 8 months significantly reduced the plant height. Uncontrolled weed growth reduced plant height by about 57%, 12 months after planting (Table 1).

Table 1. Effect of duration of weed competition on plant height of rubber seedlings

Treatments	Plant height (cm) Months after planting					
	2	4	6	8	10	12
Weed-free	36.3 a	65.7 a	115.2 a	193.8 a	264.1 a	321.2 a
Weed-free 1*	35.5 a	61.8 ab	86.4 c	132.3 d	179.4 d	227.5 cd
Weed-free 2	35.4 a	57.6 abc	88.2 c	137.7 d	183.6 d	239.8 cd
Weed-free 4	35.2 a	64.6 a	112.3 ab	190.8 a	243.3 ab	309.6 a
Weed-free 8	34.4 a	62.5 ab	109.3 ab	188.3 a	247.4 ab	311.6 a
Not weeded 1	36.1 a	59.2 ab	109.2 ab	178.3 ab	228.2 bc	288.8 ab
Not weeded 2	38.0 a	61.1 ab	99.9 bc	163.5 bc	222.5 bc	295.8 ab
Not weeded 4	35.2 a	57.5 abc	87.9 c	143.7 cd	200.6 cd	270.8 bc
Not weeded 8	34.1 a	49.9 c	70.5 d	95.4 e	127.8 e	197.6 d
No weed control	37.5 a	54.9 bc	70.1 d	97.7 e	130.5 e	138.4 e

* Weed-free 1 = weed free during the first 1 month
Not weeded 1 = not weeded during the first 1 month
Means within a column followed by a common letter are not significantly different at P = 0.05 using Duncan's Multiple Range Test

Stem diameter

Keeping the plots weed free during the first 1 or 2 months significantly reduced the stem diameter or rubberseedlings (Table 2). Weed competition during the first 2 months or the last 8 months had no significant effect on stem diameter.

Weed competition for the first 4 months significantly affected stem diameter. Weed competition began to cause reduction of stem diameter 4 months after planting and by the end of the experiment, stem diameter was reduced by 50% (Table 2).

Table 2. Effect of duration of weed competition on stem diameter of rubber seedlings.

Treatments	Stem diameter (mm)					
	Months after planting					
	2	4	6	8	10	12
Weed-free	3.7 a	6.5 a	11.0 a	18.9 a	26.1 a	30.4 a
Weed-free 1	3.5 a	5.7 bc	7.6 d	12.6 c	16.8 e	20.2 de
Weed-free 2	3.3 a	5.6 bc	8.5 cd	13.2 c	19.3 de	23.0 cd
Weed-free 4	3.5 a	6.3 ab	10.3 ab	18.1 ab	24.8 ab	28.8 ab
Weed-free 8	3.5 a	6.1 abc	10.3 ab	18.3 ab	24.9 ab	29.3 a
Not-weeded 1	3.5 a	6.2 abc	10.2 ab	17.5 ab	25.0 ab	28.8 ab
Not-weeded 2	3.5 a	5.7 bc	9.1 bc	16.1 b	22.8 bc	27.4 abc
Not-weeded 4	3.6 a	5.5 c	7.7 d	13.6 c	20.4 cd	24.4 bcd
Not-weeded 8	3.5 a	4.6 d	5.9 e	9.4 d	13.3 f	17.8 e
No weed control	3.5 a	4.8 d	5.9 e	9.7 d	13.6 f	15.1 e

* Weed-free 1 = weed-free during the first 1 month
Not weeded 1 = with-weed during the first 1 month
Means within a column followed by a common letter are not significantly different at P = 0.05 using Duncan's Multiple Range Test

Dry weight

The effect of duration of weed competition on dry weight was greater than on plant height and stem diameter. Weeds emerging 4 months after planting significantly reduced dry weight of rubber (Table 3). Weed competition for the first 2 months or more reduced dry weight. Twelve months after planting, the reduction in dry weight due to weed competition was 85%.

Table 3. Effect of duration of weed competition on dry weight of rubber seedlings 12 months after planting.

Treatments	Dry weight (g/plant)
Weed-free	621.7 a
Weed-free 1	215.6 d
Weed-free 2	221.4 d
Weed-free 4	402.2 c
Weed-free 8	549.7 ab
Not weeded 1	520.4 ab
Not weeded 2	436.5 bc
Not weeded 4	389.2 c
Not weeded 8	172.1 de
Not weed control	87.9 e

* Weed-free 1 = weed-free during the first 1 month
Not weeded 1 = with-weed during the first 1 month
Means within a column followed by a common letter are not significantly different at P = 0.05 using Duncan's Multiple Range Test.

Growth of weed

The main weeds in the experiment were *Melochia corchorifolia L., Calopogonium mucunoides Desv., Borreria alata (Aubl.) DC., Centrosema pubescens Benth., Passiflora foetida L., Ipomoea sp.,* and *Mimosa invisa Mart.* During the experiment, some annual weeds such as *M. corchorifolia, Emilia sonchifolia (L.) DC ex Wight* and *Erichtites valerianifolia DC.* died after producing seeds.

Weed species grew rapidly and almost completely covered the soil surface 2 months after emergence. Although the canopy had already closed, weeds emerging after 4 and 8 months were able to grow and cover 43% and 31% of the soil surface respectively, by the end of the experiment (Table 4).

Table 4. Percent weed coverage 12 months after rubber planting and total dry weight of weed biomass. Data were transformed to x + 1/2.

Treatments	Weed coverage (%)	Total dry weight of weed biomass* ($g/0.25\ m^2$)
Weed-free all	1	0.71 e
Weed-free 1	81	10.90 ab
Weed-free 2	90	9.69 ab
Weed-free 4	43	6.37 bcd
Weed-free 8	31	3.14 de
Not weeded 1	1	3.61 cde
Not weeded 2	1	8.58 ab
Not weeded 4	1	11.28 a
Not weeded 8	4	7.93 abc
No weed control	100	12.10 a

* Weed-free 1 = weed free during the first 1 month
Not weeded 1 = with-weed during the first 1 month
Means within a column followed by a common letter are not significantly different at P = 0.05 using Duncan's Multiple Range Test

If weeding was done only during the first 1 or 2 months, weeds would produce as much biomass as in the case of no weed control. Weeds emerging after 4 months produced less biomass than the unweeded check. Weeds growing for the first 2 months or longer produced as much biomass as that produced for 12 months. The dry weight of weeds that were growing for the first 8 months was less than that of weeds growing for 4 months (Table 4) because at the time some weed species were dead due to dry season in the 8 months after planting treatment.

These results indicate that weeds had less chance of competing successfully with the rubber seedlings when the dry weight was low.

DISCUSSION

Weeds emerging 4 months after rubber planting had no effect on plant height and stem diameter. Weeds emerging as late as 8 months after planting had no effect of plant dry weight. This indicates that the weed free period required by rubber seedlings in the nursery was the first 4 to 8 months after planting. After this, it was not necessary to control the weeds (Nieto *et al*, 1968). Five months after planting, the canopy had closed, but weeds were still able to grow. Weeds emerging after 4 and 8 months covered about 43% and 31% of the soil surface respectively. However, their growth did not affect the growth of rubber seedlings.

Rubber seedlings in the nursery were unaffected by weeds during the first 2 months of growth. Plant height and stem diameter were reduced by 8 to 10% by weed competition during the first 1 to 2 months of growth. When weed competition occurred for more than 2 months, growth of rubber seedlings was reduced significantly.

These results emphasize the importance of weed control in the early growth stages of rubber seedlings or until canopy closure to prevent growth reduction.

It is possible to use pre-emergence herbicides for controlling weeds in rubber nurseries. They can suppress weed growth for 3 months (Mangoensoekarjo & Kadnan, 1974). It might be possible to combine chemical control using pre-emergence herbicides with hand weeding for controlling weeds in the rubber nursery. However, many factors must be considered to obtain the best method.

Further research, to study weed competition in rubber nurseries in more details, must be conducted with different rubber clones in different geographic regions.

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TANK MIX COMBINATION OF ASULAM AND DALAPON FOR CONTROL OF *IMPERATA CYLINDRICA* (L.) BEAUV.

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ABSTRACT

Three experiments on varied rates of asulam ranging from 1.5 to 4.5 kg/ha and dalapon from 5 to 10 kg/ha in tank mix combination for control of *Imperata cylindrica* (L.) Beauv. were conducted in Chantaburi, Thailand, during 1980 through 1982. The herbicide performance was assessed monthly for 9 months after application. The most promising and effective combinations were asulam at 2 to 2.5 kg/ha and dalapon 7.5 to 10 kg/ha. Asulam at 1.5 kg/ha might be tried with higher rates of dalapon up to 10 kg/ha. In general, the combinations provided about 85 to 90% control, meanwhile the standard herbicides, glyphosate and dalapon, gave more than 95% control under the test condition. Effectiveness of the combinations was found significantly improved by addition of surfactant as well as timing of application to the plants at the proper growth stage.

INTRODUCTION

The combination of asulam and dalapon for control of *I. cylindrica* under field condition was reported in Malaysia (Hill and Ingram, 1980). Even though the formulation, coded as ARD 13/13 has been marketed in some country, it is readily acceptable in Thailand due to the cost of the product as well as its efficacy according to our own preliminary test. For this reason, varied concentration tests were carried out during 1980 through 1982 to find out the most effective combination with reasonable cost.

MATERIALS AND METHODS

Three experiments were laid out in orchards of Chantaburi, Thailand, 330 km east of Bangkok. Rainy season usually starts in mid April and ends in September with some pause in June. Uniform stands of *I. cylindrica* in the open were selected and the plots were arranged in randomized complete block design. Each plot accommodated 3 fixed quadrats of 50 by 50 cm.

Herbicides were applied with a knapsack sprayer equipped with a single flood jet nozzle (tip TK 2) discharging 1,000 L/ha at a pressure of 2.12 kg/cm^2. Detailed treatments are given in Table 1.

Shoots in each quadrat were counted before and periodically during 3 to 9 months after application. After 8 months assessments were made by visual observation of the percentage of overall regrowth in the plots.

Table 1. Details of the experiments showing weed stage of growth, herbicide rates and period of study.

	Varied rates tests		Experiment 3
	Experiment 1	Experiment 2	certain combinations
Plant height (cm)	80 – 120	100 – 150	100 – 150
Plot size (m^2)	3 x 5	4 x 5	4 x 8
No. quadrats/plot	3	4	4
No. replications	3	3	4
Range of asulam and dalapon to be combined (kg ai/ha)	2.5 to 4.5 and 5 to 10 without surfactant	1.5 to 3 and 5 to 10 without surfactant	2 to 2.5 and 5 to 10 without surfactant
Period of experimentation	Sept. 8, 1980 to May 5, 1981	July 1, 1981 to March 30, 1982	July 3, 1981 to March 31, 1982

RESULTS AND DISCUSSIONS

The effect of different rates of asulam and dalapon in combination is shown in Table 2 (Expt. 1). After 8 months all combinations of asulam ranging from 2.5 to 4.5 kg/ha and dalapon 5 to 10 kg/ha did not control *I. cylindrica.* Their percentage of control was in the range of 85 to 90 whereas dalapon alone and asulam alone at high rates gave only 64 and 38% control by visual observation respectively. It can be noted that in the first five months the percentage of control was mostly more than 95. Also it was found that there was not any combination which yielded complete or nearly complete control (95%) of the grass.

In Table 3 (Expt. 2) slightly different results were obtained. With asulam at 1.5 to 2.5 kg/ha, only dalapon at 7.5 and 10 (but not at 5) kg/ha for the combination showed more or less comparable results at 9 months after application. All combinations with dalapon at 5 kg/ha yielded only about 40 to 50% control. In combination with asulam 3 kg/ha dalapon at 5 did not perform very well either compared with the higher rate of 7.5 kg/ha. Simple effect analysis of the combination shows that increasing asulam rates from 1.5 to 2 or 2.5 kg/ha did not result in better control (Fig. 1 a), meanwhile dalapon from 5 to 7.5 or 10 kg/ha produced much better control (Fig. 1 b) although the difference was insignificant at 7.5 and 10 kg/ha. Interaction between asulam and dalapon is more apparent at the early months of application (Fig 2a and 2b). It can be generalized that the low rate of asulam (1.5 kg/ha) or adalapon (5 kg/ha) needs a higher rate of either one in a combination to give good control.

Table 2. Control of **I. cylindrica** *with varied rates of asulam and dalapon in tank mix combination, Experiment 1, 1980-81. Observations at 3, 5 & 8 months after application.*

Treatment asulam + dalapon (kg/ha)	Shoots/50 x 50 cm. Initial stand before application	% of initial stand 3 mos	% of initial stand 5 mos	% Shoot regrowth by visual observation 3 mos	5 mos	8 mos
4.5 + 0	65.0	19.6	25.6	23.3	43.5	61.7
0 + 10.0	64.5	6.3	12.1	5.1	17.3	36.7
2.5 + 5.0	62.5	2.1	5.6	2.3	5.5	11.7
3.0 + 5.0	50.0	0.0	1.7	1.2	4.4	8.0
3.5 + 5.0	62.0	1.8	4.6	2.2	7.1	16.7
4.0 + 5.0	58.8	0.6	6.2	2.8	6.1	13.3
4.5 + 5.0	50.0	0.7	8.7	2.0	3.7	10.3
2.5 ¡ 7.5	64.1	1.3	3.9	2.3	4.9	12.6
3.0 + 7.5	54.6	2.1	10.5	2.9	7.1	10.0
3.5 + 7.5	48.8	1.3	1.4	1.7	3.5	8.7
4.0 + 7.5	63.4	0.6	2.4	2.6	4.2	8.7
4.5 + 7.5	52.6	0.9	1.3	2.3	6.6	12.0
2.5 + 10.0	54.3	1.2	3.1	2.2	4.6	11.3
3.0 + 10.0	69.5	2.2	7.0	3.3	7.9	13.7
3.5 + 10.0	51.0	0.7	5.6	1.7	4.7	13.3
4.0 ± 10.0	53.8	0.0	0.9	1.0	1.5	9.7
4.5 + 10.0	65.6	1.4	5.3	1.8	5.0	14.0
Control	53.9	116.6	95.2	100.0	100.0	100.0

It appears that dalapon at 5 kg/ha was not enough to combine with asulam. This is possibly due to the older and bigger plants than the ones in the previous experiment. The reason was also supported by the results in another experiment in which this combination was applied to plant regrowth aged 9 and 12 weeks (80 and 120 cm. high respectively) after slashing to the ground line. The combination did work well on the younger plants but did not affect very much the older plants. (Kuladilokrat and Suwannamek, 1983). The effect of plant maturity and shading on asulam and dalapon activity was reported in a previous study (Kuladilokrat and Suwannamek, 1981). However, in this experiment (Table 3) the combination of asulam at 2 kg/ha and dalapon 7.5 kg/ha gave quite high percentage of control. This is as reported by Suwannaketnikom (1980) that asulam 2 kg/ha and dalapon 8 kg/ha could give quite perfect control after 4 months of application. In general the efficacy of the combination was not as good as the standard check herbicides, glyphosate and dalapon.

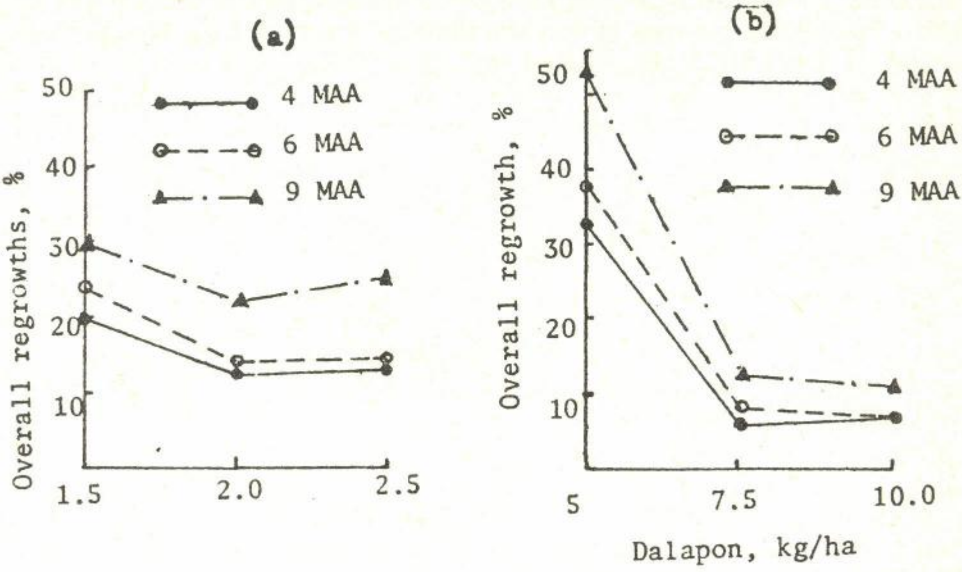

Fig. 1. Regrowth of *I. cylindrica* after treatments with different rates of asulam and dalapon.

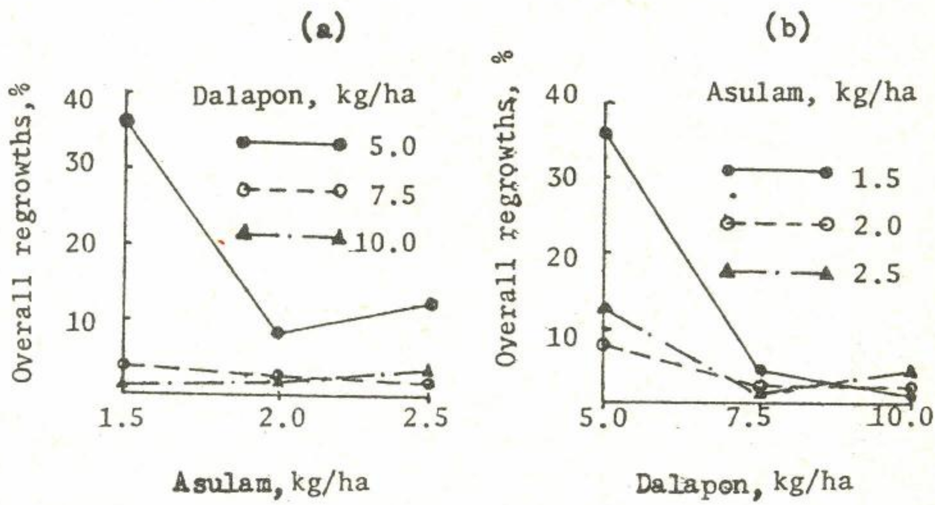

Fig. 2. Interaction between asulam and dalapon in tank mix combination at 3 months after application.

The data in Table 4 (Expt 3) are more or less confirm the performance of certain combinations which might be potentially acceptable for practical use. At 9 months after application the combination of asulam and dalapon at 2 + 10 and 2.5 + 7.5 kg/ha gave satisfactory control of *I. cylindrica* i.e. more than 95% control. As the plant size, location, and also the timing of application were very similar to Expt 2, except that the herbicides were applied with a surfactant 0.25% (V/V), the two experiments can be roughly compared.

Table 3. Control of **I. cylindrica** *with varied rates of asulam and dalapon in tank mix combination. Experiment 2, 1981-82. Observations at 3, 5 and 8 months after application.*

Treatment (kg/ha)	Shoots/50 x 50 cm.				% Shoot regrowth by visual observation			
	Initial stand before application	% of initial stand 4 mos	6 mos	9 mos	3 mos	4 mos	6 mos	9 mos
Asulam								
3.0	66.7	92.0	117.8	88.7	100	100	100	100
Asulam + dalapon								
3.0 + 5.0	83.0	15.7	20.0	29.0	6.1	19.3	20.7	31.0
3.0 + 7.5	92.3	3.7	3.6	10.3	3.2	9.3	8.0	17.7
1.5 + 5.0	78.7	30.3	45.1	57.5	35.1	44.7	54.3	59.7
2.0 + 5.0	80.0	15.3	18.4	34.3	7.7	25.7	26.3	45.7
2.5 + 5.0	88.0	12.7	20.4	39.7	11.9	27.0	30.0	18.7
1.5 + 7.5	84.7	7.7	8.8	24.5	3.8	8.7	10.7	18.7
2.0 + 7.5	81.0	1.3	3.2	3.5	2.4	2.7	5.7	5.7
2.5 + 7.5	87.3	3.0	7.2	12.5	2.0	5.0	6.7	12.3
1.5 + 10.0	81.7	3.3	4.4	13.3	1.0	5.3	5.3	8.3
2.0 + 10.0	88.0	6.0	11.4	24.6	2.0	8.3	8.0	12.3
2.5 + 10.0	98.0	4.7	8.6	16.9	3.7	6.7	6.0	10.7
Dalapon 10 x 2 [1]	79.7	0.3	2.1	10.9	0.0	1.7	2.0	3.0
Glyphosate 3.2	97.7	0.0	0.0	0.4	0.4	0.0	0.3	1.0
Control	106.0	102.3	114.7	112.8	100	100	100	100

The same rate was reapplied two weeks later.

Table 4. Effect of certain combinations of asulam and dalapon with 0.25% v/v surfactant on **I. cylindrica** *regrowth. Means followed by a common letter are not significantly different at P = 0.05 using Duncan's multiple range test.*

Treatment (kg/ha)	Overall regrowth, % (by visual observation) 4 mos	6 mos	9 mos
Herbicide			
Asulam + Dalapon			
2.0 + 10.0	0.8 a	1.3 a	2.3 a
2.5 + 5.0	4.5 a	10.1 b	18.0 b
s.5 + 7.5	1.7 a	3.0 a	4.9 a
Glyphosate 2.56	0.3 a	0.8 a	1.3 a
Control	100.0 b	100.0 c	100.0 c

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

Figure 3 shows that addition of surfactant to the combination increased the activity of the combinations. The formulated ARD 13/31 also responded to the addition of surfactant in the earlier experiment (Kuladilokrat and Suwannamek, 1983).

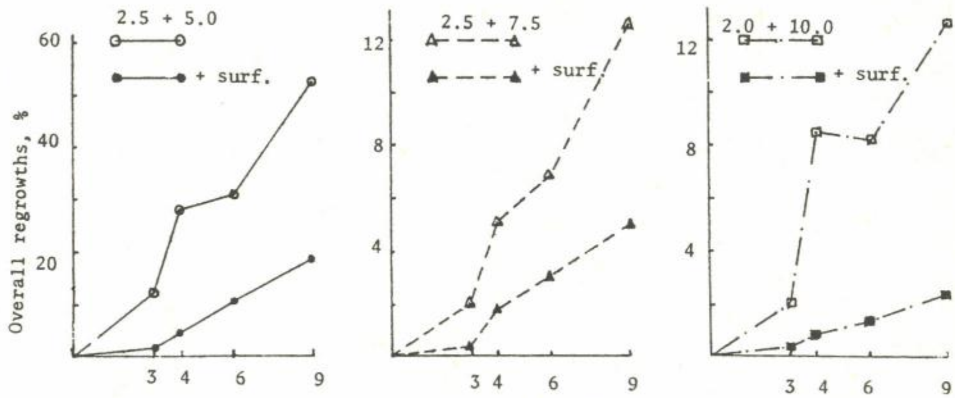

Fig. 3. Effect of certain combinations of asulam and dalapon with or without 0.25% (V/V) surfactant on regrowth of *I. cylindrica*.

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WOODY WEED CONTROL WITH TRICLOPYR ALONE AND IN COMBINATION WITH PICLORAM IN AUSTRALIA

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Dow Chemical (Australia) Limited

ABSTRACT

Herbicide combinations containing picloram (4-amino-3, 5, 6-trichloropicolinic acid) plus 2, 4, 5-T (2, 4, 5-trichlorophenoxy acetic acid) have been in commercial use for a wide range of woody weeds in Australia since 1969, and similar herbicides have been used in other countries. Triclopyr (3, 5, 6-trichlor-2-pyridinyl)oxy acetic acid) formulated as butoxyethanol ester and triethylamine was investigated from 1978 to 1982 as a substitute for 2, 4, 5-T. Triclopyr butoxyethanol ester was first registered in Australia in January 1981 as a high volume foliage spray on blackberry (*Rubus fruticosus L Agg.)* at 1.0 g ae/L in water and as a basal bark spray on woody weeds at 10.0 g ae/L in diesel distillate.

Triclopyr has given better results than 2, 4, 5-T on a wide range of woody weeds. Formulations of triclopyr plus picloram have been developed to give optimum results by stem injection, cut stump treatment and foliage spraying.

INTRODUCTION

Field trials with herbicides containing triclopyr began in Australia in 1976 on a small scale and increased to a large scale in Spring 1978. Field trials for the next three years were mostly carried out by Dow and a few cooperators. Methods of treatments, results and use recommendations for a wide range of woody weeds are presented in this paper.

Dow herbicides are available for woody weed control in Australia are given in Table 1. Those in the left column have been in use for many years. The effectiveness of stem injections with picloram based herbicides has been reported (Kimber 1967; Murphy,1970; 1973; Robertson and Moore, 1972; Johnson and Back, 1974; Robertson and Young, 1976 and Young *et al.*, 1979). Those in the right column are new formulations brought about by the substitution of triclopyr for 2, 4, 5-T.

Table 1. Dow herbicides available for woody weed control in Australia. tea = triethylmine; tipa = triisopropanolamine; ioe = iso octyl ester; ebe = butoxyethanol ester.

DOW HERBICIDES, COMPONENTS AND USES	
50 g/L picloram tea 200 g/L 2, 4, 5-T tea Stem injection, cut stump	50 g/L picloram tipa 100 g/L triclopyr tea Stem injection, cut stump
50 g/L picloram tipa 200 g/L 2, 4, 5-T 10E Foliar spray	50 g/L picloram tipa 150 g/L triclopyr ebe Foliar spray
100 g/L picloram 10E 400 g/L 2, 4, 5-T 10E Basal bark, cut stump	480 g/L triclopyr ebe Foliar spray, basal bark Cut sump
50 g/L picloram tipa 200 g/L 2, 4-D tipa Foliar spray, stem injection	120 g/L picloram ioe 240 g/l triclopyr ebe Basal bark, cut stump

These herbicides are selective on grasses and many nontarget plants such as tree ferns and mature eucalypts and other native woody weeds which may be sprayed. They usually do not damage susceptible broadleaf plants which are not directly sprayed in the work area.

Specific field trials have been carried out and recommendations made for the following wide range of plants:

Cactaceae: *Opuntia stricta* (Haw.) Haw., *O. aurantiaca;* Compositae: *Baccharis halimifolia* L., *Senecio jacobaea* L. Casuarinaceae: *Casuarina* spp.; *Cinnamomum camphora;* Mimosaceae: *Acacia* spp.; Myrtaceae: *Eucalyptus* spp., *Melaleuca* spp., *Angophora* spp. *Tristania* spp.; Oleaceae: *Ligustrum lucidum, L. sinense;* Papilionaceae: *Ulex europaeus* L., *Sarothamnus scoparius;* Pittosporaceae: *Bursaria spinosa* Cnv. Porteaceae: *Banksia spp.;* Rosaceae: *Rubus fruticosus* Agg, *Rosa rubiginosa* L. *Crataegus monogyna;* Sapindaceae: *Ailanthus altissima* (Mill) Swingle; Solanaceae: *Lycium ferocissimum* Miers; Verbenaceae: *Lantana camara* L.

METHODS AND MATERIALS

Stem injection. Dilutions were made with water. Injection pockets were made by modified axe (2 cm wide blade) or basal stem injector. The chemical was injected into the sapwood by vaccinator when using the axe or by the basal stem injector immediately after the cut is made. A range of stem injection treatments were laid down at sites in Queensland, New South Wales and Victoria.

Cut stump treatment.. Dilutions were made with water or with diesel distillate. Stems were cut as close to the ground and no higher than 15 cm. The cut surface was swabbed or sprayed immediately after cutting, and surfactant was added when using a chain saw.

Basal bark application. Dilutions were made with diesel or with diesel-water combination. The stem was sprayed or painted from ground level to a height of 30 cm. This method is suitable on plants with basal stem diameter less than 5 cm (up to 10 cm for *Acacia* spp., *L. ferocissimum*, *Ligustrum* spp. and *C. camphora*.

Foliage spraying. Dilutions were made with water. The foliage was sprayed to run-off when using motorized equipment or knapsack for high volume spraying. Spraying pressure of 750 to 1500 kPa was used for high volume gun spraying. Controlled droplet application (C.D.A.), airblast spraying (mist-blower), and aerial application trials were conducted. Evaluations were made for the number of plants killed and a control rating was made for plants not killed. The control rating which is a measure of vigor or regrowth suppression is of value because it has been found that often where the number of plants killed may be moderate, vigor reduction of the plants may be very good and this has particular relevance to herbicides containing picloram.

RESULTS

Stem injection. The formulation containing 50 g a.e. picloram as tri-isopropanolamine plus 100 g a.e. triclopyr as triethylamine per liter and that containing 50 g a.e. 2, 4, 5-T, both as triethylamine per liter diluted 1.0 plus 1.5 with water gave 95.8% (S.D.* 6.6) and 94.4% (S.D. 7.0) kill of *Eucalyptus* spp. respectively with close spaced (15 cm) stem injections of 1.0 to 2.0 ml per injection. The amount of chemical injected varied with tree size. Two ml injections were given in trees with basal diameters larger than 30 cm. The mean duration of post treatment was 17 months. The diluted formulations contained 20 g a.e. picloram and 40 g a.e. triclopyr or 80 g a.e. 2, 4, 5-T per liter of mix. The diluted mix costs about A$6/L. Both formulations produced similar results with wider spaced (30 cm) stem injections with undiluted formulations. Triclopyr alone was more effective than 2, 4, 5-T alone on *Eucalyptus* spp., *Casuarina* spp., *Angophora* spp. and *Tristania* spp. while the triethylamine (M3724) was better than the butoxyethanol ester formulation (M4021).

M3724, M4021 and 2, 4, 5-T amine diluted in water to give 100 g a.e./L were assessed at 13.0 months after treatment for *Tristania* spp. and a mean of 17.0 months for the others (Table 2).

Table 2. Percentage kill of trees after injection with triclopyr amine, triclopyr ester and 2, 4, 5-T amine. Triclopyr amine = M-3724; triclopyr ester = M-4021.

Species	No. of trees killed
Eucalyptus spp. (8 comparisons)	
M-3724	79.7 (S.D. 14.8)
M-4021	52.6 (S.D. 16.7)
2, 4, 5-t amine	47.1 (S.D. 20.7)
Casuarina spp. (5 comparisons)	
M-3724	71.6
M-4021	68.6
2, 4, 5-T amine	34.8
Angophora spp.. (2 comparisons)	
M-3724	58.5
M-4021	42.5
2, 4, 5-T	23.5

Basal bark application. Picloram + 2, 4, 5-T isooctyl ester diluted 1:50 in diesel (20 g picloram + 80 g 2, 4, 5-T/L) has given reliable results on a wide range of woody weeds during 15 years of commercial use, and gave 95-100% kill when it was used as a standard in 30 trials in which triclopyr ester (M-4021) and picloram plus triclopyr esters (M-4450) were evaluated.

Triclopyr butoxyethanol ester (M-4021) 1:48 in diesel (10 g/L) gave a similar level of kill. This rate was registered for use in January 1981 on a wide range of plants including *Eucalyptus* spp., *Acacia* spp., *Melaleuca* spp., *Hakea* spp., *Eremophila* spp., *B. spinosa. B. halimifolia*, *Cryptostegia grandiflora* R. Br. and *Ziziphus mauritiana* Lam. Specific additions in 1983 include *Ligustrum* spp., 1:10 (48 g triclopyr/L). *R. rubiginosa*, *C. monogyna*, *L. ferocissimum*, *Eucalyptus cambageana* Maiden, 1:24 (20 g triclopyr/L) and *C. camphora*, *L. camara* and *A. altissima*, 1:48 (10 g/L).

Results obtained with a spray mixture containing 30% diesel, 0.5% emulsifier (M-4168) plus herbicide and water were better with triclopyr ester (M-4021) and picloram ester plus triclopyr ester (M-4450) than with picloram ester + 2, 4, 5-T ester (Table 3). Slower necrosis and generally 5 to 10% lower kill with M-4021 1:48 10 g triclopyr/L and M-4450 1:60 (2 g picloram + 4 g triclopyr/L) and 10 to 20% reduction in kill with picloram ester + 2, 4, 5-T ester 1:50 (2 g picloram + 8 g 2, 4, 5-T/L) has been obtained with diesel/water compared with diesel alone as diluent.

The following observations were also made for basal bark spraying: a) Diesel/water gave better results on wet bark. Wet bark should be avoided when spraying with diesel. b) Diesel was a good marking agent to minimize misses. Kerosene and mineral turpentine can substitute for diesel as a bark

Table 3. Comparison of basal bark spraying of **Eucalyptus** *spp. with diesel and 30% diesel/0.5 M-4168/water.*

Herbicide[1]	Volume of Diluent	Carrier	No. of trees killed (%)	No. of Trials
M-4021	1.48	Diesel	98.2	6
M-4021	1.48	30! diesel 0.5! M-4168 Water	95.2	6
T-1040	1.50	Diesel	93.8	6
T-1040	1.50	30! diesel 0.5! M-4168 Water	79.0	4
M-4450	1.60	Diesel	96.8	6
M-4450	1.60	30% Diesel 0.5% M-4168 Water	89.0	6

[1] *M-4021 contains 480 g a.e./L triclopyr as butoxyethanol ester. T-1040 contains 100 g a.e. picloram + 400 g a.e. 2, 4, 5-T/L both as iso-octyl ester; M-4450 contains 120 g a.e./L picloram iso-octyl ester + 240 g a.e./L trichlopyr butoxyethanol ester.*

penetrant. c) When using diesel similar results on *Eucalyptus* spp. can be obtained by increasing herbicide concentration and reducing height of treatment which lowers the cost of diesel carrier.

Foliage spraying, native woody weeds. Foliage spraying is reliable on most *Acacia* spp. but many *Eucalyptus* spp. and many plants growing with eucalyptus can be tolerant to a varying degree. A formulation containing 50 g/L picloram as triisopropanolamine plus 200 g/L 2, 4, 5-T as iso octyl ester (AF520) has been used in Australia for 10 years at dilutions of 1:150 to 1:200 in water. Results generally have been more reliable in coastal areas of Queensland and Northern New South Wales, than in tableland areas of Southern N.S.W. and Victoria.

Since spring 1978 high volume foliage spray trials have been carried out comparing AF 520, triclopyr butoxyethanol ester (M-4021) and 1:4, 1:3 and 1:2 combinations of picloram amine plus triclopyr butoxyethanol ester, at dilutions of 1:100, 1:150 and 1:200 in water. AF515 50 g picloram as triisopropanolamine + 150 g triclopyr as butoxyethanol ester per liter is a satisfactory combination from a cost efficacy viewpoint (Table 3). A dilution rate of 1:150 to 1:100 has given good results on range of native woody weeds and introduced plants such as *Rubus fruticosus, Ulex europaeus* and *Rosa rubiginosa.* High volume spraying with AF520, AF515 and triclopyr (M-4021) was also done with mixed *Eucalyptus* spp. Eucalypts comprise the majority of plants sprayed under powerlines. Percent kill and control ratings for the lowest dilutions of each formulation with the addition of a specific aryl alkyl sulphonate surfactant was also made.

The use of a special surfactant (DE) at 0.25 to 0.5% v/v in the spray solution is considered necessary for optimum results (Table 4). Reduced efficacy and greater variability was observed with decreasing use rate. The addition of the surfactant DE at 0.5% v/v increased the overall % number of eucalypts killed by 21% from 74.2% to 86.6% and the control rating by 12% from 86.1% to 96.1%. In the case of AF515 1:150 with 0.5% v/v, kill improved from 87.8 to 96.1. Control rating was explained earlier and AF515 is a good example, where kill was 87.8% and control rating or vigor suppression was 94.4%.

More variability and usually less control are obtained after spraying native woody weeds which are affected by dry soil conditions or dormancy, especially in southern tableland areas. Where competitive herbicides were included in trials, control was poor to moderate except for 2, 4, 5-T which was effective on **Acacia** spp. at 2 g/L of spray. Triclopyr (M-4021) at 1 to 2 g/L gave results comparable with 2, 4, 5-T on *Acacia* spp. and was superior on Eucalyptus spp. Superiority of triclopyr over 2, 4, 5-T on eucalypts and several other plants was reported by Watson (1978).

Foliage spraying, blackberry and other introduced noxious woody weeds. Trials were conducted during 1979-1981 in N.S.W., Victoria and Tasmania for single application, high volume spraying of chemicals which included triclopyr (M-4021) AF 520, AF515 and 2, 4, 5-T butyl ester on mature plants (Table 5). Trials covering repeat spraying, burning slashing and seeding and application methods are in progress.

No treatment on a large scale can be expected to give complete regrowth suppression from a single spray. AF520 1:100 and AF515 1:100 to 1:150 have given high level of control with least variability and required less follow up treatment. Triclopyr (M-4021) 1:480 was significantly better than 2, 4, 5-T at a similar rate. Similar results have been reported in New Zealand, Forgie *et al.*, (1977, 1981). All of these treatments were selective on pasture grasses. AF515 and AF520 controls *Bursaria spinosa* and many other unwanted woody weeds growing with blackberry.

AF515 containing 50 g picloram + 150 g triclopyr/L diluted 1:100 to 1:200 has also given a high level of kill and regrowth suppression of *Ulex europaeus*, *R. rubiginosa*, *L. ferocissimum*, *C. camphora*, *L. camara*, *S. scoparius*, and *B. halimifolia.* Except for *R. rubiginosa*, *L. ferocissimum*, and *L. camara*, triclopyr ester (M-4021) was also effective at 1 to 2 g/L. A large number of trials conducted with the Prickly Pear Destruction Commission in New South Wales have shown that M-4021 at 18.5 g/L of water was an effective foliage spray for the control of common prickly pear (*Opuntia stricta*) and tiger pear (*O. aurantiaca*), (Ryan *et. al.*, 1983).

Table 4. Percent kill and control ratings of mixed **Eucalyptus** *spp. sprayed with high volumes of AF520, AF515 and triclopyr (M-4021). Picloram as triisopropanolamine, 2, 4, 5-T as iso-octyl ester, triclopyr as butoxy-ethanols ester, 2,4, 5-T as butyl-ester. Observations made 10 months after spraying.*

Herbicides	Dilution		No. of Trials	Killed Trees (%)	Standard Deviation	Control Rating (%)	Standard Deviation
Picloram + 2, 4, 5-T	1;100	50 + 200	6	90.5	8.3	96.5	4.7
Picloram + 2, 4, 5-T	1:150	33.3 ¡ 132	8	77.6	32.1	86.5	23.6
Picloram + 2, 4, 5-T	1:200	25 + 100	10	69.1	33.1	81.4	22.5
Picloram +2, 4, 5-T	1:200 DE		5	88.6	19.9	94.4	8.8
Picloram + Triclopyr	1:100	60 + 150	2	90.0		95.0	
Picloram + Triclopyr	1:150	33.3 + 99.9	5	87.8	15.6	94.4	6.6
Picloram + Triclopyr	1:150 DE		7	96.1	5.2	98.6	1.5
Triclopyr	1:120	400	9	80.7	31.6	90.6	15.9
Triclopyr	1:240	200	9	67.7	34.3	82.4	18.0
Triclopyr	1:240 DE		8	84.0	17.0	95.4	4.5
2, 4, 5-T	1:200	400	2	38.5		69.5	

Table 5. Control of blackberry with single application, high volume sprays, 1979-1981, NSW, Victoria, Tasmania. [2] *Numbers in parentheses are standard deviations,* [3] *triclopyr as butoxyethanol ester,* [4] *picloram as triisopropanolamine,* [5] *2, 4, 5-T as butyl ester.*

Herbicides	g ae/100L	No. of trials	Average regrowth (%)	Average time of post spraying (months)
Triclopyr	100	25	13.3(11.2)	10.2
Triclopyr Picloram	75 + 25	8	10.0(8.0)	10.0
Triclopyr + Picloram	99.9 + 33.3	16	4.3(4.2)	8.8
Triclopyr + Picloram	100+ 50	11	5.9(6.0)	11.8
Triclopyr + Picloram	150 + 50	19	3.0(3.2)	10.6
2, 4, 5-T	80-100	15	44.8(23.6)	10.2
2, 4, 5-T + Picloram	200 + 50	16	7.3(6.1)	10.2

Tristania spp. (1 comparison)	
M-3724	73
M-4021	87
2, 4, 5-T amine	50

Eucalyptus spp. comprise the majority of trees in areas where commercial stem injection was carried out. Observations during these stem injection trials reinforced the need to emphasize that the stem injection method requires care in making the injection pocket and placing the 1.0 to 2.0 ml dose in the sapwood to obtain optimum results.

Cut stump treatment. A high level of kill, usually better than 95%, can be obtained on *Eucalyptus* spp., *Angophora* spp., *Melaleuca* spp., *Casuarina* spp., and *Acacia* spp. with triclopyr ester (M-4021) 10 g a.e./L in diesel and 20 g a.e./L in water, triclopyr amine (M-3724) 20 g a.e./L in water or picloram amine 2.5 g a.e. + triclopyr amine 5.0 g a.e./L in water.

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EFFECT OF TILLAGE ON UPLAND RICE WEED CONTROL

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ABSTRACT

The effects of the time, degree, and method of land preparation on weed control in upland rice (*Oryza sativa* L.) were examined in a number of experiments.

The composition of the weed flora was altered when the land was prepared during the dry season compared to when it was prepared at the onset of the rains. The population shifted from *Cyperus rotundus* L. to broadleaf and grassy weeds and as a result differences in herbicide performance were observed. The total weed biomass, however, in the unweeded plots was generally not significantly affected by the time of land preparation indicating that only limited benefit was achieved from dry season land preparation.

No advantage was gained by using the stale-seedbed technique in controlling weeds compared with conventional land preparation. Elimination of a particular weed species or a group of weeds resulted in the build-up of other weed species. Little success was achieved in controlling weeds in the zero tillage plots because of the failure of pre- and post-planting herbicide applications to prevent the regrowth of perennial weeds.

Low yields were obtained in all trials primarily because of moisture stress but other factors such as intense weed competition and damage caused during hand weeding were also involved.

Based on the results obtained, the use of land preparation to reduce weed problems in upland rice does not appear to be a promising area for future research.

INTRODUCTION

Upland rice yields are below those of the other rice cultures because of problems such as lack of suitable cultivars, inadequate land preparation, erratic water supply, and poor weed control. Weed control has been ranked second after water supply as the factor most limiting high yields in upland rice (Chabrolin, 1969; De Datta and Beachell, 1972). In West Africa, once land clearing has been accomplished, weeds are recognized as the number one problem in upland rice (USDA, 1968). In Nigeria, 244 man-hr/ha were required for one hand weeding 14 days after seeding (DAS). A 1-week delay in weeding increased the time required for hand weeding by more than 44 man-hr (Moody, 1975).

Soil tillage is the first step in reducing weed problems in crop production. Nicou and Poulain (1971) stated that good plowing can remove the need for one or two hoe weedings. Sealy (cited in Moody, 1975) found that despite good land preparation weeds were a major limiting factor to high yields in upland rice. The effectiveness of land preparation in providing a weed-free seedbed depends on timing in relation to the rainy season and the composition of the weed flora. The traditional method of preparing land for upland rice consists of plowings and harrowings usually after the onset of the rainy season. The equipment used is usually determined by the resources available to the farmer. Regardless of the power source used the practice of plowing after the onset of the rain may result in a loss in cropping time and may result in tremendous weed growth because of the build-up of weeds during the fallow period.

In parts of Asia, tillage is practiced during the dry season to expose vegetative propagules to drying and to prevent weed proliferation (Elias, 1969; Zandstra et al., 1977; Partohardjono and Harahap, 1979; Moody and Mukhopadhyay, 1982). Moody and Mian (1979) and IRRI (1980) reported a significant reduction of perennial weeds such as *C. rotundus* L. and *Cynodon dactylon* (L.) Pers. when the land was prepared in the dry season compared to when plots were kept weedy. Herbicide performance varied with time of land preparation because of changes in the weed flora (Castin and Moody, 1981).

Moody (1977a) concluded that growing a crop or keeping the land weed free through the use of tillage during the dry season may or may not reduce the number of weeds growing in association with crops planted at the start of the rainy season compared with areas that are left weedy. Factors such as the previous crop, previous tillage treatments, previous weed flora, degree of weed control in the previous crop, soil type, rainfall pattern, and crop rotation would determine the composition of the weed flora and the weed density.

A major breakthrough in seedbed preparation was the use of herbicides to control weeds and to save energy. Thus, the need for tillage was reduced or completely eliminated. For successful application of this technique consistent herbicide performance is needed.

In India, Sahu and Lenka (1969) reported that in zero-tillage plots paraquat (1,1'-dimethyl-4,4'-bipyridylium ion) effectively controlled weeds in upland rice and yields were similar to those from plots prepared conventionally. Similar results have been reported by Wijewardene (1980) in Nigeria.

In contrast, Moody and Mukhopadhyay (1982) reported heavy weed infestations and poor weed control in zero-tillage plots in Nigeria and the Philippines. Perennial weeds also increased as tillage was reduced (Cussans, 1976). MacQueen (1977) stated that unless perennial weeds are controlled effectively with herbicides, no tillage techniques cannot be used.

Another concept for weed control through land preparation is the use of the stale-seedbed technique. Flushes of weeds prior to planting are destroyed by chemical, mechanical, or manual methods. Germination of most viable weed seeds is essential for the success of the stale-seedbed technique (Moody, 1982a). The herbicides should be applied or the cultivation should be done when most of the weed seeds in the soil surface have germinated and most of them are in the two- to five-leaf stage (Sarkar and Moody, 1981). Renaut (1972) noted that later weedings may be reduced or delayed after using the stale-seedbed technique.

The objectives of these studies were: a) to compare different methods of land preparation for weed control in upland rice, b) to identify weed species that are eliminated by tillage, c) to determine whether postplanting weed control practices need to be altered in response to different land preparation methods, and d) to determine the effect of different land preparation methods and postplanting weed control treatments on crop yield.

MATERIALS AND METHODS

General cultural practices, experimental design, and sampling methods

All experiments which were conducted at the experimental farm of the International Rice Research Institute (IRRI) were replicated three times and laid out in a split-plot design with tillage treatments as the main plots and weed control methods as the subplots. Subplot size was 6 x 3 m. The plowing operations were done using a tractor-drawn disc plow while rotovations were carried out using a tractor-hitched Howard rotovator.

Rice seeds were sown in rows spaced 25 cm apart at the rate of 100 kg/ha. Except for 1982, all trials were drill-seeded. In 1982, a rolling injection planter was used. Within row-spacing was 25 cm.

Fertilizers were applied at the rate of 100 kg N, 40 kg P_20_5, and 40 kg K_20/ha. Forty kilograms nitrogen and all of P_20_5 and K_20 were applied before the final rotovation. The rest of the N was split equally and top-dressed 30 days after emergence (DAE) and at panicle initiation.

Insect control was achieved by applying carofuran (2,3-dihydro-2,2-dimethylbenzofuran-7-ylmethylcarbamate) at 1.0 kg/ha 1 day before sending (DBS) and endosulfan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6, 9-methano-2,4,3-beno[e]dioxathiepin 3-oxide) at 0.75 kg/ha when necessary.

Weeds were sampled using two 0.25 m^2 quadrats per plot. The samples were bulked, classified by species, oven-dried at 70-80^oC for 48 hr, and weighed. The relative dry weight (RDW) was calculated using the following equation:

$$\text{RDW} = \frac{\text{Weight of each species in a community}}{\text{Weight of all species in a community}} \times 100$$

The harvest area for grain yield was 5.0 m^2. After processing, the grain yield per plot was converted to t/ha at 14% moisture.

Time of tillage

Three experiments dealing with time of land preparation were conducted in 1978, 1979, and 1982. In 1978, dry season land preparation (April) was compared with wet season land preparation (May). Land preparation consisted of one plowing followed by one rotovation. In all plots, rotovation was in May immediately before seeding. For each tillage treatment, six weed control methods were tested (Table 1).

Table 1. Total weed weight and grain yield as affected by time of land preparation and weed control methods.' IRRI, 1978. In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Weed control methods	Weed weight (g/m^2)		Grain yield (t/ha)	
	Dry season	Wet season	Dry season	Wet season
Weeded twice	5.0 a	5.6 a	3.1 a	2.0 ab
Weeded once	10.4 a	61.0 b	2.5 ab	2.3 a
Oxadiazon	26.6 ab	428.6 c	1.7 abc	0.0 c
Butachlor	60.6 bc	392.0 c	0.7 bc	0.0 c
Pendimethalin	91.4 c	583.4 c	0.4 c	0.0 c
Unweeded check	189.6 c	497.6 c	0.6 c	1.2 b

In 1979, tillage which consisted of one plowing followed immediately by one rotovation was done in the first week of March, April, or May. The final rotovation was done in all plots before seeding in May. The eight weed control treatments tested are listed in Table 2.

In 1982, the four tillage treatments compared were:

a. One plowing 140 DBS (February) followed by one rotovation 1 DBS (June).
b. One plowing and one rotovation 1 DBS.

c. One plowing 140 DBS followed by three rotovations 100, 30, and 1 DBS.
d. One plowing and three rotovations 1 DBS.

The weed control treatments which were compared are listed in Table 5.

C166-135 was the rice cultivar used in 1978 and UPL Ri-5 was used in 1979 and 1982.

Stale-seedbed technique

In 1977, initial land preparation consisted of one plowing followed by two rotovations. The conventional tillage plots were seeded immediately after the second rotovation. In the stale-seedbed plots which were seeded 10 days later, weeds were allowed to grow and were killed with glyphosate [N-(phosphonomethyl)glycine] (1.0 kg/ha, paraquat (0.5 kg/ha), or rotovation prior to planting. The test cultivar was C22.

For the 1979 trial, the land preparation methods and the planting times were:

a. Conventional tillage — two plowings on May 13 followed by one rotovation on May 19; planted on May 19.
b. Stale-seedbed once — two plowings on May 13 followed by one rotovation on May 19; additional rotovation on May 30; planted on May 30.
c. Two plowings plus one rotovation on May 29; planted on May 30.
d. Stale-seedbed twice — two plowings on May 13 followed by one rotovation on May 19, additional rotovation on May 31, glyphosate applied at 1.25 kg a.i./ha on June 10; planted on June 11.
e. Two plowings plus one rotovation on June 10; planted on June 11.

The weeding regimes were no weeding, one hand weeding [3 weeks after emergence (WAE)], and two hand weedings (2 and 5 WAE).

UPL Ri-5 was the test cultivar.

Zero-tillage

Zero-tillage was compared with conventional tillage (one plowing followed by three rotovations) for land preparation in the 1982 wet season. The herbicides used for the zero-tillage treatments were glyphosate at 1.5 kg /ha. ametryn (2-ethylamino-4-isopropylamino-6-methylthio-1,3,5-triazine) + paraquat at 0.55 + 0.45 kg/ha, and paraquat + diquat (1,1'-ethylene-2,2'-bipyridylium ion) at 0.5 + 0.3 kg/ha applied 10 DBS followed by paraquat at 0.5 kg/ha applied 1 DBS. The postplanting weed control treatments are listed in Table 8.

Table 2. Relative dry weight of weed species in the unweeded plots as affected by time of land preparation.

Weed species	Relative dry weight (%)					
	30 days after emergence			At harvest		
	March[a]	April[a]	May[a]	March[a]	April[a]	May[a]
Rottboellia exaltata	2.0	0.4	2.3	16.2	–	44.2
Cyperus rotundus	37.8	44.1	72.3	–	0.1	0.2
Digitaria sp.	27.4	26.0	14.0	72.1	91.9	53.3
Eleusine indica	16.3	12.2	0.3	0.6	0.7	–
Others[b]	16.5(8)	17.3(11)	11.1(11)	11.1(5)	7.3(5)	2.3(5)
Total weed weight (g/m^2)	680	565	774	638	655	899

[a]Time of land preparation.

[b]Number of species indicated in parentheses.

All plots were seeded with UPL Ri-5.

RESULTS AND DISCUSSION

Time of tillage

Good land preparation is widely recognized as a method of weed control.

In 1978, land preparation in the dry season significantly reduced weed growth compared to land preparation in the wet season (Table 1). Weed weights 45 DAE in the unweeded plots prepared during the dry season were 62% less than those from the unweeded plots prepared in the wet season.

Generally, weed control with herbicides or by hand weeding resulted in higher weed weights and lower yields in the land prepared after the onset of the rains than when it was prepared in April. However, grain yield was significantly higher in the unweeded plots prepared at the onset of the rains than in the plots prepared during the dry season because *C. rotundus* which was the dominant weed species in the plots prepared at the start of the rainy season senesced at an early stage of crop growth. As a result, the crop was able to partly recover from the competitive effects of the weeds. In the plots prepared during the dry season, more competitive broadleaf and grasses were the major weed species.

In 1979, the time of land preparation also affected the degree of weed control. When the land was prepared in May, herbicide application did not significantly reduce the weed density compared with the untreated check (Fig. 1). When the land was prepared in April, the weed density in all herbicide-treated plots was significantly lower than the untreated check plots. There was no significant difference in weed density among herbicide treatments. When the land was prepared in March, the number of weeds in all the herbicide-treated plots except those treated with 2,4-D (2,4-dichlorophenoxy acetic acid) were significantly lower than those in the untreated check. The weed densities in plots treated with fluorodifen (4-nitrophenyl 2-nitro-4-trifluoromethylphenyl ether) and propanil (3',4'-dichloropropionanilide)-fenoprop [(±)-2-(2,4,5-trichlorophenoxy)propionic acid] were not significantly different from those in plots treated with butachlor (N-butoxymethyl-α-chloro-2',6'-diethylacetanilide) and propanil but were significantly less than those in plots treated with 2,4-D.

In contrast to the first experiment the total weed weight was not affected by time of land preparation. However, the weed community was affected. Curfs (1976) observed that although there was a marked change in the weed flora between plots that had been plowed at the end of the wet season and those that were left undisturbed during the dry season and not plowed until the following wet season, the amount of weeds was not reduced.

At 30 DAE, *C. rotundus* was the major weed in all the times of land preparation. When the land was tilled in May, *C. rotundus* had a relative dry weight of 72.3% (Table 2). *Digitaria* sp. was the second most important weed comprising about 14% of the weed flora. When the land was prepared in March or April, *C. rotundus* represented only 37.8% and 44.1% of the weed community. *Eleusine indica* (L.) Gaertn. and a *Digitaria* sp. were also important components of the weed flora. In all the times of land preparation two or three weed species accounted for more than 80% of the weed flora on the basis of weed weight as has been demonstrated for other rice cultures by Moody and Drost (1981). *C. rotundus* increased in importance when the land preparation started towards the onset of the wet season, while *Digitaria* sp. and *E. indica* decreased in importance. The weed flora was also less diverse when the land was prepared in May compared to the other land preparation times. Land preparation during the dry season reduced the density of *C. rotundus* which primarily develops from tubers by desiccation but promoted the germination of *Digitaria* sp. and *E. indica.*

Moody and Mian (1979) reported that there were significantly less perennial weeds such as *C. rotundus* and *C. dactylon* and significantly more annual weeds such as *Echinochloa colona* (L.) Link in plots that were maintained weed-free by tillage than in plots that were kept as a weedy fallow. Moody (1982a) also reported that there were more annual grasses primarily *E. colona* in land that had previously been maintained as a weed-free fallow than in land that had been left as a weedy fallow.

Cultivation during the dormancy period of weed seeds or during the dry season will have little effect on their control and with the return of favorable conditions they will appear in large numbers. Moody (1982a) noted that land preparation during the dry season would have only limited success in reducing weed problems in the following dry-seeded rice crop. Tillage buries weed seeds and at the same time exposes buried seeds giving them the opportunity to germinate presumably due to the exposure to light. As the number of cultivations increases, there is a possibility that more weeds will germinate due to frequent exposure of weed seeds to light, thereby breaking dormancy.

The number of weed species and the diversity of the weed flora generally decreased at harvest compared to 30 DAE. *C. rotundus* which was dominant at 30 DAE had senesced and was replaced by *Digitaria* sp., a particularly persistent weed, and *R. exaltata* which grew very vigorously particularly when the land was prepared in May. These two species accounted for about 90% of the weed flora on the basis of weed weight. Total weed weight was essentially the same at harvest as at 30 DAE and there was little difference between times of land preparation.

A very low grain yield was obtained because the crop suffered moisture stress during panicle initiation and heading (Table 3). The highest yields were obtained in all times of land preparation when the plots were hand weeded twice. The low yields in the May land preparation were due to the intense competition from *C. rotundus* and rice destruction during the weeding operation. None of the herbicides gave satisfactory weed control and yields from these treatments were rarely significantly higher than the unweeded check. Moody (1977b) stated that rarely will recommended herbicides applied alone give season-long weed control in upland rice. Herbicide combinations offer the best possibility for achieving successful weed control in upland rice (Moody, 1975),. They control more weed species and effective weed control lasts longer than with single herbicide treatments.

Failure to weed resulted in no yield irrespective of time of land preparation. Weed pressure was so intense at all land preparation times even though the weed flora was altered by the time of land preparation. Yields were significantly lower with one late hand weeding (5 WAE) when the land was prepared in March and April compared to the plots weeded twice indicating again that upland rice cannot completely recover from an initial setback due to weed competition. Renaut (1972) noted that one hand weeding no matter how properly timed will not provide season-long weed control in upland rice.

In 1982, there were no significant differences in weed density but there were significant differences in weed biomass 14 DAE as a result of the different land preparation methods. Plots that were plowed 140 DBS followed by three rotovations at 100, 30, and 1 DBS had significantly higher weed biomass than the other preplant tillage treatments (Table 4). The fine tilth produced by this treatment was favorable for weed growth.

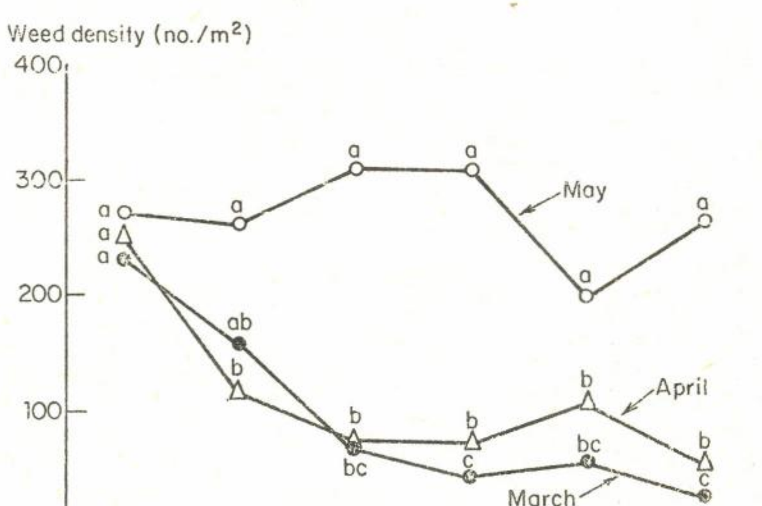

Fig. 1. Weed density (no./m^2) two weeks after emergence as affected by the time of land preparation and weed control methods used. IRRI, 1979.
(Within each time of land preparation, means followed by a common letter are not significantly different at the 5% level by DMRT.)

Table 3. Grain yield as affected by the time of land preparation and method of weed control. In a column, means followed by the same letter are not significantly different at the 5% level by DMRT. LSD for comparison among times of land preparation = 0.3 (5%).

Treatment	Grain yield (t/ha)			
	March[2]	April[2]	May[2]	Mean
Weeded 2 and 5 WAE	2.1 a	2.1 a	0.5 a	1.5
Weeded 5 WAE	1.3 b	0.7 b	0.3 ab	0.7
Propanil/fenoprop (1.0-1.1 kg/ha) post[1]	0.7 c	0.6 bc	0.3 ab	0.5
Propanil (2.0 kg/ha.) post[1]	0.3 de	0.5 bcd	0.1 b	0.3
Fluorodifen (2.0 kg/ha) pre[1]	0.4 cd	0.2 de	0.0 b	0.2
Butachlor (2.0 kg/ha) pre[1]	0.2 de	0.3 cde	0.0 b	0.2
2,4-D (1.0 kg/ha) pre[1]	0.2 de	0.0 e	0.0 b	0.1
No weeding	0.0 e	0.0 e	0.0 b	0.0
Mean	0.7	0.6	0.2	

[1] post = herbicides applied at 2 to 3 leaf stage of grasses; pre = preemergence.

[2] Time of land preparation.

The weed flora was also affected by the degree of land preparation. *C. rotundus* was the major weed in all land preparation treatments except that which received one plowing and three rotovations. This treatment reduced its relative dry weight by about 50% compared to the other treatments. While growth of *C. rotundus* was reduced by one plowing and three rotovations emergence and growth of *Ipomoea triloba* L. was encouraged. Plowing in the dry season encouraged germination of this weed as indicated by the increase in its relative dry weight in the treatment that received one plowing 140 DBS plus one rotovation 1 DBS compared to the plots that received their plowings and rotovations 1 DBS. Further rotovation during the dry season further stimulated its emergence and growth. The second most important weed in all plots except in the plot that was plowed and rotovated three times where it was the most important weed was *Digitaria* sp. This species was less important in the plots that received one plowing 140 DBS and one rotovation 1 DBS than the other plots.

The total weed weight, the weed density, and the number of weed species was essentially the same in plots that were prepared 1 DBS even though one received one rotovation and the other three rotovations. Thus,

Table 4. Relative dry weight (%), weed density, and total weed weight 14 days after crop emergence in the unweeded plots as affected by the time and degree of tillage. IRRI, 1982. Number of species indicated in parentheses. [c]In a a row, means followed by a common letter are not significantly different at the 5% level by DMRT.

Weed species	One plowing 140 DBS + one rotovation 1 DBS	One plowing + one rotovation 1 DBS	One plowing 140 DBS + three rotovations at 100, 30, & 1 DBS	One plowing + three rotovations 1 DBS
Cyperus rotundus	41.7	53.0	23.0	57.3
Digitaria sp.	13.7	41.4	36.9	30.6
Ipomoea triloba	8.6	1.9	20.9	1.6
Calopogonium mucunoides	7.9	1.9	6.1	4.0
Eleusine indica	0.1	–	–	0.8
Cynodon dactylon	2.9	0.7	–	3.2
Others	25.1(5)	1.1(3)	8.9(8)	2.5(3)
Total weed weight[c] (g/m^2)	27.8 b	32.8 b	53.0 a	25.0 b
Weed density ($no./m^2$)[c]	152.0 a	192.0 a	218.0 a	180.0 a

Number of species indicated in parentheses.

level of land preparation appears to be unimportant in suppressing weeds or affecting the weed composition when all operations are done on the same day. Moody (1977b) noted that the degree of weed control will be less and the time spent for weeding will be longer as the degree of land preparation decreases and the interval between successive tillage operations is shortened or both.

The weed flora was more diversified when the initial land preparation was done 140 DBS than when it was done 1 DBS.

The best weed control was obtained with two hand weedings irrespective of the time or degree to tillage. None of the herbicide treatments controlled weeds satisfactorily. Only when pendimethalin [N-(1-ethylpropyl)-3, 4-dimethyl-2,6--dinitrobenzenamine] + 2,4-D was applied to plots that had received one plowing 140 DBS followed by three rotovations at 100, 30, and 1 DBS was there a significant reduction in weed weight compared with the untreated check. Castin and Moody (1981) reported that as the degree of land preparation increased, the degree of weed control with herbicides also increased.

The highest yields were obtained in plots that received two hand weedings regardless of time and degree of tillage (Table 5). No grain yield was obtained when the plots were not weeded. Generally, none of the herbicide treatments yielded as well as two hand weedings because of the failure of the herbicides to control weeds adequately.

One plowing and three rotovations 1 DBS had no advantage over reduced tillage (one plowing and one rotovation 1 DBS) in terms of grain yield. Except in the untreated control, yields were significantly higher in all treatments when one plowing 140 DBS was followed by three rotovations because of less weed competition brought about by a reduction in *C. rotundus* and superior herbicide performance.

Stale-seedbed technique

In 1977, the use of the stale-seedbed technique gave no advantage to weed control compared with conventional tillage (Table 6). Insufficient rainfall caused uneven germination of weed seeds rendering the non-selective herbicides ineffective. Total weed weight in the stale-seedbed plots except those sprayed with paraquat were significantly higher than those in the plots that received conventional land preparation. Glyphosate was extremely effective against *C. rotundus* while the use of paraquat resulted in a heavy build-up of this weed. However, in the plots treated with glyphosate, *C. rotundus* was replaced by annual broadleaf and grass weeds which emerged after herbicide application.

Regardless of the land preparation method no grain yield was obtained when plots were not weeded (data not presented). Plots treated with butachlor at 2.0 kg/ha applied preemergence plus one hand weeding 4 WAE

Table 5. Grain yield (t/ha) as affected by the time and degree of tillage and weed control methods. IRRI, 1982. [a]In a row or column, means followed by a common letter are not significantly different at the 5% level by DMRT. Pre = preemergence. Herbicide rate in kg a.i./ha indicated in parentheses.

Weed control treatment	One plowing 140 DBS + one rotovation 1 DBS	One plowing + one rotovation 1 DBS	One plowing 140 DBS + three 100, 30, & 1 DBS	One plowing + three rotovations	W-means
Hand weeding, 14 & 35 DAE	0.69 a	1.06 a	2.33 a	1.35 a	1.36
Pendimethalin (2.0) pre + 2,4-D (0.5) 15 DAE	0.13 ab	0.44 b	1.78 b	0.16 b	0.63
Propanil (2.0) 7 DAE + 2,4-D (0.5) 20 DAE	0.32 ab	0.00 b	1.52 b	0.11 b	0.49
Pendimethalin (2.0) pre + propanil (2.0) 15	0.27 ab	0.00 b	0.89 c	0.00 b	0.29
Untreated check	0.00 b	0.00 b	0.00 d	0.00 b	0.00
T-means[b]	0.28 b	0.30 b	1.30 a	0.32 b	

yielded statistically similar to those plots that received two hand weedings, 2 + 5 WAE. This supports Moody's (1977a) statement that dry seeding of crops should be associated with good weed control techniques such as appropriate herbicides and timely hand weedings. Yields from the stale-seedbed plots where a harrow was used to control the initial flush of weeds were lower than those from the other treatments (1.5 t/ha vs. 2.2 t/ha).

In the 1979 trial, land preparation which consisted of two plowings and one rotovation resulted in significantly higher weed weights compared with the stale-seedbed plots (data not presented). This was attributed to a significant reduction in *C. rotundus,* the only sedge, in the stale-seedbed plots compared to the conventional tillage plots for the May 30 and June 11 plantings. The grass weed weight was not affected by the degree of tillage and time of planting while the broadleaf weed weight was little affected by the treatments.

Table 6. Weed weight in the unweeded plots as affected by different methods of land preparation. In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Land preparation method and weed control	Weed weight (g/m^2) at 30 DAE[b]			
	Broadleaf weeds	Grasses	Sedges	Total control
One plowing + two rotovations	97.4 a	140.0 b	84.6 c	322.0 a
Stale-seedbed [paraquat (0.5 kg/ha)]	132.6 a	66.0 a	125.4 c	324.0 a
Stale-seedbed [glyphosate (1.0 kg/ha)]	305.4 b	263.4 c	4.4 a	573.2 b
Stale-seedbed (harrow)	283.8 b	158.4 b	27.0 b	469.2 b

Changes in the composition in the weed flora across time was observed in all treatments (Fig. 2). Similar observations have been made in dry-seeded rice by Bhandari and Moody (1981a, b) and Drost and Moody (1981).

In plots that received two plowings on May 13 followed by one rotovation on May 19, *Amaranthus spinosus* L. was the major weed at 30 DAE comprising 50% of the weed flora on the basis of weed weight. *C. rotundus, E. indica,* and *Digitaria* sp. were minor weeds. *A. spinosus* decreased in importance as the crop approached maturity. *C. rotundus* senesced while *E. indica* and *Digitaria* sp. persisted and increased in importance up to crop maturity. In the second planting where the stale-seedbed was applied once, *C. rotundus* was eliminated. The other weed species comprised 20 to 34% of the weed flora at all sampling times except at harvest when *A. spinosus* had senesced.

When the stale-seedbed was applied twice, *A. spinosus* comprised 70% of the weed flora 30 and 50 DAE. At harvest, it comprised about 30% of the weed flora. *C. rotundus* and *Digitaria* sp. were essentially eliminated from the weed flora. At harvest, *E. indica* comprised about 30% of the weed flora.

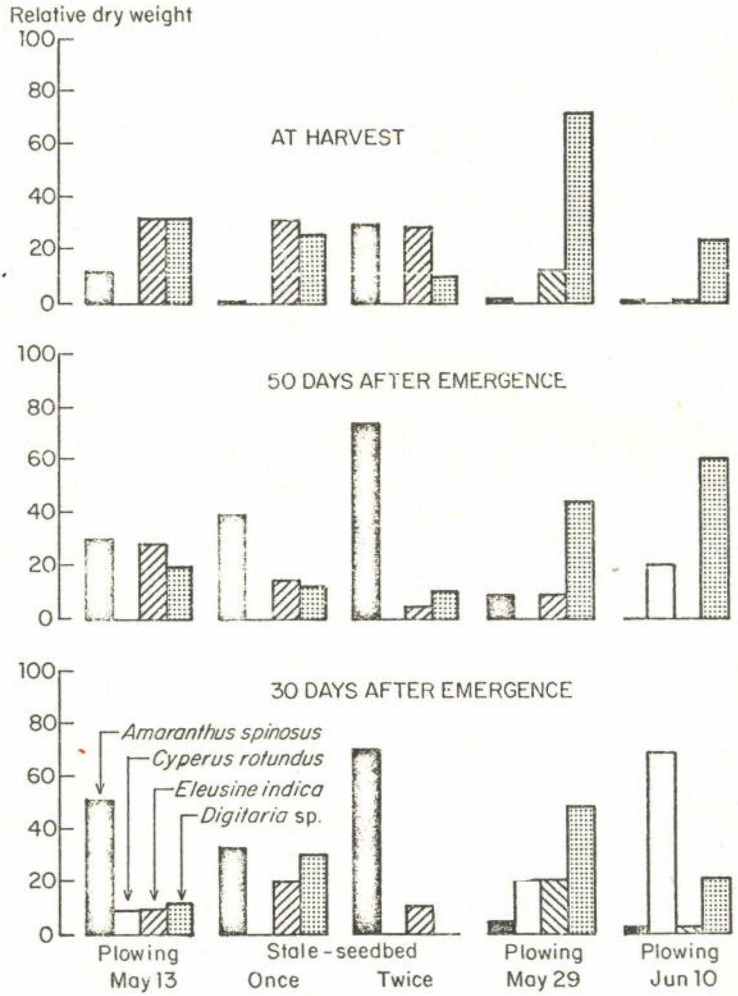

Fig. 2. **Relative dry weight of four major weed species at three sampling times as affected by time and method of land preparation.**

Digitaria sp. was the major weed species in plots conventionally prepared and seeded May 30. *C. rotundus* with a relative dry weight of 68% was the major weed in the plot that received all tillage treatments on June 10 and was planted the next day. However, by crop maturity, *C. rotundus* had senesced. A *Digitaria* sp. which was the most important weed 50 DAE was still present at harvest but other weeds — *Rottboellia exaltata* L.f. and *Commelina benghalensis* L. — were also important.

Complete yield loss occurred when plots were not weeded irrespective of the time of planting or degree of tillage (data not presented). This again illustrates that even though the weed flora in upland rice can be altered by land preparation techniques the weed pressure is so great that complete yield loss occurs.

Low grain yields from all plots was due to suffered moisture stress from panicle initiation until heading. Yields were highest in the plots that received two stale-seedbed treatments before planting. One hand weeding resulted in a yield of 1.55 t/ha compared to an average of 0.25 t/ha for the other treatments.

Grain yields of 2.13 t/ha obtained in the plots that received two stale-seedbed treatments and were weeded twice were significantly higher than the rest of the tillage treatments receiving two and weedings which average only 0.6 t/ha.

The abundance of *C. rotundus* during early crop growth made weeding more difficult in the plot that was prepared conventionally on June 10. As a result, rice stand was severely reduced by the weeding operations.

Zero tillage

Total weed weight did not differ significantly among tillage treatments. However, the composition of the weed flora was affected by the tillage treatments. Greater regrowth from tubers was observed in the zero tillage plots regardless of the preplanting herbicide combinations used. The relative dry weight of *C. rotundus* in the zero tillage plots ranged from 72.2 to 86.1 (Table 7). In contrast when the field was conventionally prepared, the relative dry weight of *C. rotundus* was only 28.4%. Glyphosate did not control *C. rotundus* in this experiment in contrast to the stale-seedbed technique because the herbicide was sprayed in the dry season when no *C. rotundus* shoots were present whereas when the stale-seedbed technique was used *C. rotundus* was actively growing when glyphosate was applied.

Other weed species that were important in the conventional tillage plots were *I. triloba, Calopogonium mucunoides* Desv., and *Paspalum* sp. *C. dactylon,* which was completely eradicated by conventional tillage, was the second most important weed in the zero tillage plots. The weed flora was more diverse in the conventionally-prepared plots than the zero-tillage plots.

The best weed control was achieved with two hand weedings regardless of tillage treatment. Herbicides gave better weed control in the conventionally-tilled plots than in the no-tillage plots. They did not significantly reduce weed weights compared to the untreated control in the zero-tillage plots whereas in the conventionally-prepared plots, they did.

Zero tillage cannot be practiced in upland rice until such time as a suitable herbicide technology involving both pre- and post-plant treatments is developed.

Table 7. Relative dry weight (%) and total weed weight in the unweeded plots 30 days after emergence as affected by tillage treatment. In a row, means followed by a common letter are not significantly different at the 5% level by DMRT. DBS = days before seeding. Herbicide rate in kg a.i./ha indicated in parentheses.

Weed species	One plowing + three rotovations	Zero tillage: Glyphosate (1.5) 10 DBS + paraquat (0.5) 1 DBS	Zero tillage: Ametryn + paraquat (0.55 + 0.45) 10 DBS + paraquat (0.5) 1 DBS	Zero tillage: Paraquat + diquat (0.5 + 0.3) 10 DBS ¡ paraquat (0.5) 1 DBS
Cyperus rotundus	28.4	86.1	72.2	76.6
Ipomoea triloba	26.2	5.2	3.1	0.6
Calopogonium mucunoides	19.2	1.3	0.9	1.2
Paspalum sp.	14.3	–	–	0.1
Cynodon dactylon	–	4.0	8.2	15.0
Ageratum conyzoides	0.3	0.5	0.6	4.4
Digitaria setigera	3.7	2.0	1.2	0.1
Eleusine indica	2.5	–	0.9	1.0
Others[1]	5.4(8)	0.9(3)	12.9(6)	1.0(7)
Total weed weight (g/m^2)	65.0 a	154.8 a	176.4 a	150.4 a

[1]Number of species indicated in parentheses.

No grain yield was obtained from the untreated check plots in the conventionally prepared plots because the weeds which replaced *C. rotundus* were more vigorous and more competitive than *C. rotundus* (Table 8). In the zero-tillage plots, *C. rotundus* senesced by 50 DAE giving the crop time to partly overcome its competitive effect.

The highest yields were obtained in plots that were hand weeded twice regardless of preplant tillage treatments. In all cases, yields from plots treated with butachlor or thiobencarb (S-4-chlorobenzyl diethylthiocarbamate) followed by 2,4-D were not significantly different from those that were hand weeded twice. Yields in plots with two hand weedings were low because at 7 DAE the weeds covered the rows of rice which caused difficulty in weeding.

None of the land preparation techniques was particularly satisfactory in reducing weed problems in upland rice compared to conventional land preparation. Changes in the weed flora were observed but only in a few cases were there reductions in weed growth. The ecological niche caused by the control of one species was rapidly filled by other species which were frequently as difficult to control. Based on the results obtained in the experiments reported in this paper, the use of land preparation techniques to reduce weed problems in upland rice does not appear to be a promising area for future research. Other alternatives will have to be found to provide the solution. Crafts (1975) and Moody (1977a) concluded that there was little benefit from dry season land preparation with respect to weed control.

The highest yields in all trials were generally obtained with two hand weedings but these are laborious, time-consuming, and costly. De Datta and Ross (1975) reported that a single hand weeding in upland rice required about 300 man-hr/ha and that often, several hand weedings were necessary to keep the crop free of weeds. Labor requirements can be substantially reduced if hand weeding is combined with other weed control methods (Moody and Mukhopadhyay, 1982). Combinations of a preemergence herbicide with a postemergence herbicide, a manual weeding, or interrow cultivation as suggested by Moody (1977b) should be explored further. The potential of herbicide combinations to control weeds in dry-seeded wetland rice has been demonstrated by Lubigan and Moody (1982).

Further research is needed to find suitable herbicides or herbicide combinations to control a wide spectrum of weeds including *C. rotundus* which is a major problem in upland rice in many parts of the world. De Datta (1981) stated that suitable control measures are needed for *C. rotundus.* Failure to control or suppress *C. rotundus* early in crop growth leads to problems such as stand reductions when hand weeding is carried out. Also, *C. rotundus* is highly competitive during early crop growth.

In all trials reported in this paper, yields were low due mainly to moisture stress. Further research is needed on the development of suitable drought-tolerant rice cultivars for upland rice production. It is unlikely that a farmer would be willing to risk his limited resources on the purchase of a

Table 8. Grain yields as affected by pre- and post-planting weed control practices. In a row or column, means followed by a common letter are not significantly different at the 5% level by DMRT. Herbicide rate in kg a.i./ha indicated in parentheses.

Weed control treatment	One plowing + three rotovations	Glyphosate (1.5) 10 DBS + paraquat (0.5) 1 DBS	Ametryn + paraquat (0.55 + 0.45) 10 DBS + paraquat (0.5) 1 DBS	Paraquat + diquat (0.5 + 0.3) 10 DBS + paraquat (0.5) 1 DBS	W-means
Untr Untreated check	0.00 b	0.79 b	0.73 a	0.88 a	0.60 b
Hand weeding 14 and 35 DAE	1.20 a	1.39 a	1.17 a	1.24 a	1.25 a
Butachlor (2.0 Pre + 2,4-D (0.5) 15 DAE	1.13 a	1.22 ab	1.04 a	0.86 a	1.06 a
Thiobencarb (3.0 Pre + 2,4-D (0.5) 15 DAE	1.05 a	1.00 ab	1.05 a	1.19 a	1.08 a
T-means	0.85 b	1.10 a	1.00 ab	1.04 ab	1.00

herbicide and to use that herbicide unless he was certain that he would obtain a substantial return from his investment. Farmers adjust their weed control intensity to the production potential of the crop under a given set of environmental conditions (Carbonell and Moody, unpublished). Farmers' weed control practices are generally based on rational considerations in that the level of weed control inputs is largely determined by the expected level of return from those inputs (Moody, 1982b).

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INTEGRATED WEED CONTROL IN TRANSPLANTED RICE

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ABSTRACT

Field experiments were conducted to compare relative efficacy of herbicides alone or in combination with cultural practices for weed control in transplanted rice at the University of Agricultural Sciences, Bangalore, India. Of the various herbicides tested, butachlor (1.25 kg/ha), thiobencarb (2.0 kg/Ha), pendimethalin (2.0 kg/ha), oxadiazon (0.5 kg/ha) within 3 to 5 DAT gave good control of weeds including *Echinochloa* spp. and resulted in yield higher than or comparable to that of the handweeded plots. These herbicides effectively controlled *Echinochloa* by 70 to 90 per cent. In addition, integrating one hand weeding or passing rotary weeder 40 to 45 DAT along with pendimethalin or thiobencarb at 1.0 kg/ha gave effective weed control and higher yield, besides being remunerative.

In different agro-climatic zones, 40 weed species occurred in the rice crop. The dominance of dicotyledonous weeds decreased with advance in rice growth and weed flora shifted in favor of monocotyledonous weeds later. *Cyperus difformis* L., *C. iria*, *Fimbristylis miliacea* L. Vahl, *Ludwigia parviflora* Roxb, *Eclipta alba* (L.)Hassk., *Rotala verticillaris* L., *Agropyron repens* (L.) Beauv. *Paspalum* sp. dominated with varying relative density (5 to 70). Of the four species of *Echinochloa* observed in different places, *E. glabrascens* and *E. oryzoides* were observed in greater proportion.

INTRODUCTION

Rice production in India is dwindled by various factors. Of these, weed menace is manifold. Rice grown in varying soil and water conditions possesses varied types of weed flora which inflict heavy loss to the crop. Weed problems are acute when rice is grown as upland under drilled condition and its menace gradually declines under transplanted condition with proper water management. Nevertheless, weeds inflict varying damage from 20 to 80 per cent in India under transplanted conditions (Mukhopadhyay *et al.*, 1972; Rao *et al.*, 1977; Mohamed Ali *et al.*, 1977). Of late, several herbicides have been screened and found effective in specific pockets due to weed specificity, soil reaction, variety grown, etc., besides being quite economical (Nanjappa and Krishnamurthy, 1981; Pande *et al.*, 1981), yet weed problem has not been solved fully. This has necessitated to integrate hand weeding or passing a weeder along with herbicidal application to eliminate serious weeds in some areas, in addition to improve the physico-chemical properties of the soil.

An attempt has been made to survey weed flora in rice fields in different agro-climatic zones in Southern Karnataka, India. In addition, studies conducted at Bangalore, India on comparative efficiency of herbicides for weed control in transplanted rice are included. Integrating cultural practices along with herbicides was also tried.

MATERIALS AND METHODS

Survey of weed flora was made in Southern Karnataka covering coastal zone (3000 to 4600 mm rainfall), southern transition zone (600 to 1050 mm assured rainfall), southern dry zone (670 to 890 mm), eastern dry zone (680 to 870 mm) and central dry zone (455 to 720 mm) in transplanted rice during tillering to panicle emergence, and flowering to maturity stages in 1982 and 1983. The weed count was made in three to five quadrats of 1 m x 1 m randomly selected in each place. The number of places visited for the survey are given in Tables 1 and 2.

The relative density was calculated using the formula of Ashby (1948),

$$\text{Relative density} = \frac{\text{Number of individuals of the species}}{\text{Number of occurrence of all species}} \times 100$$

In a preliminary study at Bangalore in summer 1979, 14 weed control treatments with 12 herbicides were evaluated for weed control and yield. Later studies were made at different agro-climatic conditions. The four promising herbicides were evaluated in comparison with hand weeding, (twice) at Mangalore in monsoon 1982. Herbicides were mixed with sand broadcast at 4 DAT. Further, an integrated weed control study was taken up in monsoon 1982 at Nagenahally, Mysore with five herbicidal doses and four cultural practices (passing rotary weeder-35 DAT, weeder-25 DAT + hand weeding + no passing weeder as control) on IR-20 variety. A fertilizer dose of 100-50-50 kg NPK/ha was applied uniformly. A spacing of 20 cm by 10 cm was followed. Herbicides were applied at 2 DAT. The relative density of every weed species observed at 35 DAT, 60 DAT and at harvest was determined. Weed dry weight was recorded at 35 DAT and at harvest. The harvest index was calculated but not presented here. Wherever necessary, data have been given along with the text.

RESULTS AND DISCUSSION

Survey of weed flora. Weed survey was made in five out of ten agro-climatic zones in Southern Karnataka, India. About 40 species of weeds were observed in transplanted rice crop. Of these, 23 wer emonocots and 17 were dicots at different stages. Weeds with low densities are not reported.

Table 1. The relative density (%) of weed species (range) observed during tillering to panicle emergence stages of transplanted paddy in differnt agro-climatic zones of Karnataka in 1982 and 1983

	Weed species	Coastal zone (15)+	Southern transition zone (11)	Southern dry zone (10)	East-dry zone (12)	Central dry zone (8)
	1	2	3	4	5	6
A.	*Monocots*					
1.	*Agropyron repens*(L.) Beauv.	—	—	1-2	—	—
2.	*Brachiaria* sp.	—	—	1-7	—	5-36
3.	*Cyperus asiatica*	1-2	—	—	—	—
4.	*C. bulbosus* Vahl.	1-2	—	—	—	—
5.	*C. difformis* Linn.	1-30	5-25	2-44	2-51	6-37
6.	*C. iria* Linn.	1-3	1-2	2-22	3-42	1-3
7.	*C. laevigatus* Linn.	—	—	—	1-2	—
8.	*C. miliacea*	4-46	—	—	—	—
9.	*C. procerus* Roxb	2-49	—	5-27	1-2	1-2
10.	*Echinochloa colona* (L.)	—	1-2	2-71	1-6	1-2
11.	*E. glabrascens*	—	1-5	1-3	1-2	1-3
12.	*E. oryzoides*	—	1-3	1-8	1-7	1-2
13.	*Ericoulon* sp.	2-37	—	—	—	—
14.	*Fimbristylis aestivalis* Vahl.	1-19	—	—	—	—
15.	*F. miliacea* Vahl.	1-3	9-46	2-5	1-33	—
16.	*F. monostachya* Hassk.	1-17	—	1-2	—	—
17.	*Fuirena glomerata* Lam.	2-3	—	—	—	—
18.	*Monochoria vaginais* Preal.	2-13	—	2-55	5-8	5-22
19.	*Panicum repens* Linn.	—	1-2	4-8	5-21	—
20.	*P. tripheron*	3-16	—	—	—	—
21.	*Scirpus* sp.	14-49	—	1-2	1-2	4-36
B.	*Dicots*					
22.	*Ammania baccifera* Linn.	—	1-3	13-22	—	—
23.	*Dopatrium junceum* B. Hm	2-9	3-5	1-22	1-29	1-3
24.	*Eclipta alba* Hassk	—	1-3	2-26	—	1-5
25.	*Glinus oppositifolius* (L.) A.DC.	—	—	2-8	2-11	1-3
26.	*Jussiuea repens* D.C.Prod.	—	—	—	1-3	—
27.	*Lindernia veronicaefolia*	5-39	1-3	2-17	1-8	—
28.	*Lobelia olecinoides* Plum	3-19	—	—	—	—
29.	*Lochnera pusilla* K. Schum.	—	—	1-2	—	—
30.	*Ludwigia parviflora* Linn.	—	—	1-2	1-3	—
31.	*Nitella* sp.	1-2	—	—	—	—
32.	*Marsela equadrifoliata* Linn.	—	—	1-2	1-3	—
33.	*Oldenladia herbacca* (L.) Roxb.	1-14	—	—	—	—
34.	*Rotala fimbriata* Ind. Or.	2-29	—	--	—	—
35.	*R. neptopitala*	1-3	—	—	—	—
36.	*R. verticillaris* Linn.	—	1-10	2-8	2-73	3-8

+ Indicates number of places where species-wise weed count was made in 1 m x 1 m quadrates in 3 to 5 spots

Monocots dominated during the early part of rice growth as well as during later stages. More species were observed in coastal (23 to 24) and southern dry zone (22), followed by southern transition and eastern dry zone (9 to 19) and central dry zone (12). Though at initial stages dicots were seen in higher proportions, their density decreased during later stages of crop growth and shifted the weed flora in favor of the monocots. In coastal zone newer species especially *Fuirena glomerata* Lam. *Cyperus asiatica*, *C. miliacea*, *Panicum tripheron* and *Eriocoulon* sp. (monocots), *Lobelia olecinoides* Plum. *Oldenlandia herbacea* (L.) Roxb. and *Rotala fimbriata* Ind. Or. (dicots) were seen in higher density. Paddy in coastal zone was characterized by having higher density of *Scirpus* sp., *Eriocoulon* sp., *C. miliacea*, *C. procerus*, *L. parviflora*, *L. veronicaefolia* and *R. fimbriata; C. difformis*, *F. miliacea* in southern transition zone; *C. difformis*, *C. iria*, *C. procerus*, *E. colona*, *M. vaginalis*, *E. alba*, *A. baccifera*, *D. junceum* in southern dry zone; *C. iria*, *C. difformis*, *F. miliacea*, *R. verticillaris*, *D. junceum*, *L. parviflora* in Eastern dry zone; *C. difformis*, *Scirpus* sp., *M. vaginalis* and *Brachiaria* sp. in central dry zone during tillering to panicle emergence stage (Table 1). During flowering to maturity, dominant weeds observed were *Eriocoulon* sp., *M. vaginalis*, *C. procerus*, *L. parviflora* in coastal zone; *M. vaginalis*, *R. verticillaris*, *D. junceum*, *J. repens*, *L. parviflora* in southern transition zone; *C. difformis*, *F. miliacea*, *E. alba*, *D. junceum*, *Paspalum dilalatum* , *Glinuz oppositifolius* in southern dry zone; *C. iria*, *C. difformis*, *E. alba* in eastern dry zone; and *M. vaginalis*, *C. difformis* and *D. junceum* in central dry zone (Table 2).

In these five zones, four species of *Echinochloa* namely, *E. picta*, *E. colona*, *E. oryzoides* and *E. glabrascens* were observed in varying degrees. Of these species, *E. glabrascens* and *E. oryzoides* were seen in proportions ranging from 1:5 to 1:50 with paddy in these zones. *E. glabrascens* was seen in more places. *E. oryzoides* was observed only in pockets specially in Southern dry zone, Southern transition zone and Eastern dry zone. *E. colona* was seen in higher proportions than *E. picta* which ranged from 1:30 to 1:60 with paddy. The density of *Echinochloa* with paddy was more in southern dry zone, followed by southern transition zone, central dry zone (paddy fed mainly by irrigation of command area), eastern dry zone (tank irrigation), whereas it was considerably less in coastal zone (mainly rainfed).

Preliminary evaluation of herbicides: Herbicides influenced the rice yields differentially. Pre-emergence application of pendimethalin (2.0 kg/ha) have higher rice yield than hand weeding twice and was comparable to yield obtained with butachlor (1.25 kg/ha), thiobencarb (2.0 kg/ha), oxadiazon (0.50 kg/ha), molinate (3.0 kg/ha) and 2,4-D EE or Na salt (0.8 kg/ha). These herbicides were effective in minimizing weed growth including *Echinochloa* from 70 to 90%. Other herbicides tried were not so effective and this was reflected in the rice yield (Table 3). 2,4-D EE or Na salt was not so effective against *Echnochloa* and *R. verticillaris*.

In a subsequent trial at Mangalore on Coastal zone, thiobencarb (2.0 kg), butachlor (1.25 kg) and pendimethalin (2.0 kg/ha) application resulted in grain yield as well as gross returns comparable to that of handweeded twice. The herbicides were cheaper than hand weeding. Oxadiazon gave slightly lower yield than hand weeding owing to more weeds particularly *C. difformis* and *Gnaphalium polycoulon* (Table 3).

Table 2. The relative density (%) of weed species (range) observed during flowering to maturity stage of transplanted paddy in different agro-climatic zones of Karnataka in 1982 and 1983

	Weed species	Coastal zone (15)	Southern transition zone (11)	Southern dry zone (10)	Eastern dry zone (12)	Central dry zone (8)
	1	2	3	4	5	6
A.	*Monocots*					
1.	*C. difformis* Linn.	2-25	1-11	5-40	2-53	5-36
2.	*C. iria* Linn.	2-5	1-3	1-17	27-59	1-3
3.	*C. laevigatus* Linn.	—	—	1-3	5-17	—
4.	*C. miliacea*	3-9	—	—	—	—
5.	*C. procerus* Roxb.	5-30	1-2	4-7	—	1-3
6.	*E. colona* (L.) Link.	1-3	—	1-8	1-8	—
7.	*Eragrostis gangetica* (Roxb) Stued	—	3-7	—	—	—
8.	*Eriocoulon* Sp.	23-55	—	—	—	—
9.	*F. aestivalis* Vahl.	1-3	1-13	2-35	1-13	—
10.	*E. monostachya* Hassk.	1-4	1-15	1-3	—	—
11.	*F. miliacea* Vahl.	1-3	1-13	2-35	1-13	—
12.	*F. glomerata* Lam.	5-15	—	—	—	—
13.	*Kylinga monocephala* Thumb	1-42	1-36	1-20	—	3-38
14.	*Monochoria vaginalis* Presl. ex Kunth	1-42	1-36	1-20	—	3-38
15.	*Paspalum haspan*	2-10	—	—	—	—
16.	*P. dilatatum* Trim.	—	—	3-48	—	—
17.	*P. psilopodium*	—	1-2	—	—	—
18.	*Panicum repens* Linn.	—	1-4	2-4	1-5	1-9
19.	*P. tripheron*	1-3	—	—	—	—
B.	*Dicots*					
20.	*A. baccifera* Linn.	1-11	2-5	1-4	—	—
21.	*Alternanthera sessilis*	—	—	3-11	—	—
22.	*D. ujunceum* B. Ham.	4-10	10-56	4-66	—	—
23.	*E. alba* Hassk.	3-7	1-16	3-32	8-43	1-3
24.	*Epaltes divericata* Cass.	1-17	—	—	—	—
25.	*G. oppositifolius* (L.) A.Dc.	—	—	1-42	—	3-38
26.	*J. repens* D. C. Prod.	—	—	3-27	—	5-47
27.	*L. parviflora* Linn.	1-32	5-15	3-15	1-3	—
28.	*L. veronicaefolia*	1-3	1-11	5-17	1-2	1-3
29.	*M. quadrifoliata* Linn.	1-3	1-3	1-10	—	—
30.	*Ottelia alsimoides* (L.) Pers.	—	—	1-25	—	—
31.	*Oldenlandia* sp.	1-17	—	—	—	—
32.	*Polygonum plebejum* R. Br.	—	—	1-9	—	—
33.	*R. fimbriata* Ind. Br.	4-15	—	—	—	—
34.	*R. verticillaris* Linn.	—	15-33	2-20	1-5	1-4

Table 3. Grain yield of rice (kg/ha) as influenced by herbicidal treatments in summer 1979 at Bangalore and monsoon 1982 at Mangalore

Treatments, kg a.i./ha	BANGALORE Grain yield kg/ha	Treatments, kg a.i./ha	MANGALORE Grain yield kg/ha	Gross returns, Rs/ha
2, 4-D E.E. 0.8 kg	5129	Thiobencarb 2.0 kg	4955 (45.0) +	6441
2, 4-D Na salt 0.8 kg	5104	Butachlor 1.25	4870 (33.2)	6331
Nitrofen (25 EC) 2.0 kg	4837	Pendimethalin 2.00	4765 (36.0)	6194
Oxadiazon (25 EC) 0.5 kg	4980	Oxadiazon 0.50	4485 (93.2)	5830
Oxadiazon (2% G) 0.5 kg	4401	Hand weeding (20 & 40	4715 (60.0)	6129
Butachlor (10% G) 1.25	5401	Not analyzed		
Thiobencarb (50 EC) 2.00	5456			
Pendimethalin (33 EC) 2.00	6478			
Fluchloralin (3% G) 0.75	3744			
Bifenox (80 WP) 1.00	4673			
Propanil (35 EC) 3.00	4534			
Handweeding (30 & 60 DAT	5240			
Molinate (10% G) 3.00	5457			
Weedy check	3651			
C. D. (P = 0.05)	1324			

Mangalore data averaged over 2 replications

\+ Weed count/0.25 m^2 at harvest, gross returns calculated at Rs. 130/ — per 100 kg rice

Integrated weed control: At 35 DAT, *R. verticillaris*, *Scirpus* sp., *E. colona* and *C. benhalensis* were dominant with relative density varying from 4 to 10Q per cent. By 60th day, in unweeded control weed species increase from 7 (5 monocots + 2 dicots) to 10 (7 monocots + 3 dicots) and at harvest it rose to 18 (9 monocots + 9 dicots). The density of *Scirpus* sp. improved with fresh emergence of *C. difformis* and *M. vaginalis* at 60 days, whereas at harvest shift favored towards *L. parviflora*, *A. baccifera*, *P. Plebejum* (in dicots), *C. procerus* and *C. iria* (in monocots). With increase in pendimethalin dosage weed flora shifted toward *Scirpus* sp. from *R. verticillaris*, while the reverse trend was observed with thiobencarb.

Rice yield differed significantly. With no herbicide application, grain yield was considerably lower (3810 kg/ha) compared to passing weeder only (4043 kg/ha) and/or with hand weeding (4569 to 4665 kg/ha). Application of herbicides under this situation also improved the grain yield mainly due to effective weed control from the beginning.

Integrating hand weeding with herbicide at lower doses (pendimethalin and thiobencarb at 1.0 kg/ha) gave yield higher (5143 to 5215 kg/ha) or comparable to that receiving herbicides at 2 kg/ha alone and/or in combinatin with cultural practices. This higher yield was correlated to better weed control coupled with higher efficiency in converting dry matter into grain as evident through higher harvest index (0.52 in control to 0.54 to 0.61

in herbicides or cultural practices). In thiobencarb alone, increasing concentration did not increase the yield owing to increase in weed dry weight particularly *Scirpus* sp. which showed an increase in dominance (relative density of 7 to 31% on 35 DAT; 4 to 40% on 60 DAT) with corresponding decrease in dominance of *R. verticillaris* (93 to 54% on 35 DAT; 95 to 52% on 60 DAT). In case of pendimethalin, the dominance of both *R. verticillaris* and *Scirpus* sp. was lower than in thiobencarb treatments. Higher yield in plots receiving both herbicide and hand weeding was due to better weed control causing higher harvesting index (0.59 to 0.61). Herbicides minimized weed growth right from transplanting. Hand weeding removed weeds uncontrolled by herbicides.

The cost of treatments for passing rotary weeder only, weeder + hand weeding, hand weeding twice, thiobencarb at 1.0 kg/ha and 2.0 kg/ha only were Rs. 114; Rs. 256, Rs. 541, Rs. 109 and Rs. 178 per ha respectively. The economics have been worked out taking the cost of grain at Rs. 130/- for 100 kg. The cost of butachlor, thiobencarb (including application cost) and hand weeding (twice 20 and 40 DAT) were Rs. 250, Rs. 300 and Rs. 500/ha respectively. There were highest monetary returns from the plot receiving hand weeding with pendimethalin 1.0 kg/ha (Rs. 6686/ha), thiobencarb 1.0 and 2.0 kg/ha (Rs. 6780 to 6904/ha) and pendimethalin 2.0 kg/ha only (Rs. 6997/ha).

Table 4. Grain yield (kg/ha) in rice as influenced by herbicides and cultural practices in monsoon 1982 at Nagenahalli

Herbicides kg a.i./ha		Cultural Practices Weeder	Weeder + Hand weeding	Hand weeding	Control
0		4043 (46.0) + (303) + +	4665 (15.1) (1112)	4569 (10.5) (987)	3810 (75.5) (–)
Pendimethalin	1.0 kg	4091 (35.2) (365)	4832 (11.3) (1329)	5143 (2.7) (1723)	4593 (12.5) (1018)
Pendimethalin	2.0 kg	4761 (26.8) (1236)	4402 (16.3) (770)	4282 (26.3) (614)	5383 (39.5) (2044)
Thiobencarb	1.0 kg	4689 (25.7) (1143)	4426 (16.3) (801)	5215 (7.7) (1827)	4785 (31.5) (1267)
Thiobencarb	2.0 kg	4832 (24.7) (1320)	4330 (25.2) (676)	5311 (1.7) (1951)	4306 (44.2) (645)
C. D. (P = 0.05)			850 (grain yield)		
C. V. %			12.0		

\+ Weed dry weight at harvest, g/0.25 m^2, original values

++ Marginal returns calculated over Rs. 4953 per ha in control with no cultural practices and no herbicides

For transplanted rice, thiobencarb (2.0 kg/ha), butachlor (1.25 kg/ha), pendimethalin (2.0 kg/ha), oxadiazon (0.5 kg/ha), and 2,-4-D EE (0.8 kg/ha) were found effective and comparable to hand weeding. Further, herbicides were found cheaper than handweeding.

Thus the study revealed the possibility of reducing the quantity of herbicides required for achieving reasonable control of weeds from the beginning of the crop growth if followed by hand weeding once around 40 to 45 days to remove surviving weeds. In areas where resistant weeds are present, one hand weeding with herbicides at half the dosage is economical. Otherwise passing weeder along with herbicides at half the dosage would be more economical.

Monocots dominated transplanted paddy in general. With advance in growth, weed flora shifted in favor of monocots.

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THE EFFECT OF TIME AND METHOD OF LAND PREPARATION ON WEED POPULATIONS IN RICE[1]

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ABSTRACT

Two field experiments were conducted to determine the effect of time of planting, method of land preparation, and water management on the weed flora associated with rice (*Oryza sativa* L.) and yield losses due to weeds.

The weed flora was affected by planting date, method of land preparation, and moisture regime. In the first experiment, which consisted of two trials in different years, puddling the soil caused a dramatic shift in the weed flora to wetland species and irrigation further altered the weed flora composition. *Echinochloa colona* (L.) Link which was a minor weed in the first trial, became the dominant weed species under all field conditions in the second trial. Weed weights were consistently higher in the unpuddled plots.

In the second experiment, the emergence and dominance of the major weeds were affected by soil moisture during the first 2 weeks after rice emergence (WAE). Dry-seeded rice planted in May was heavily infested by *Digitaria* sp. and *E. colona* whereas *Paspalum distichum L.* dominated in the later plantings. *Echinochloa glabrescens* Munro ex Hook. f. and *Sphenoclea zeylanica* Gaertn. were the major weeds in wet-seeded rice planted in July.

Weeds affected grain yield in both experiments. In the first experiment, weeds caused a significant reduction in all plots except those that were puddled and irrigated. In the second experiment, complete yield loss occurred in dry-seeded rice whereas uncontrolled weed growth caused only a 24% yield decrease in wet-seeded rice.

INTRODUCTION

In rainfed rice growing areas, one crop of transplanted rice is usually planted per year. The availability of rainfall and the rate of accumulation of water in the field determines the time when the crop is planted. A probable change in the cropping system in rainfed rice growing areas will be from one crop of transplanted rice to two crops of rice grown in sequence, the first crop being direct-seeded and the second transplanted. The direct-seeded crop will be sown in dry soil or on puddled soil depending on the rainfall intensity at the onset of the rainy season. With this change in cropping pattern, an accompanying change in weed population and composition can be expected (Moody, 1982b).

According to Drost (1982), the soil moisture after planting is the major factor influencing the composition of the weed flora and the dominance of the major weed species in the community. Emergence of *E. glabrescens* was favored by saturated conditions while *Leptochloa chinensis* (L.) Nees emerged best when the soil moisture was just below saturation. Tiwari and Nema (1967) reported that *Ludwigia perennis* L. and *Ammania baccifera* L. dominated in flooded fields and *Caseulia axillaris* Roxb. and *Sphaeranthus indicus* L. in semi-waterlogged conditions. *E. colona*, *Eclipta prostrata* (L.) L., *Commelina jacobii* Fischer, *Rumex dentatus* L., and *Ageratum conyzoides* L. became predominant as the soil moisture decreased further.

Many weeds will not germinate under water or saturated conditions but will grow in water (Moody, 1981). Civico and Moody (1979) reported that the longer the flooding was delayed after weed emergence the deeper the depth of water needed to achieve control.

The method of crop establishment affects the composition of the weed flora. Sarkar and Moody (1981) stated that puddling and good water control have a major effect on weed growth. The process of puddling results in fewer weed species (Ahmed, 1979; Mukhopadhyay, 1981), fewer weeds, and a higher proportion of broadleaf weeds in the weed flora (Moody, 1982b) than under dryland conditions. Harwood and Bantilan (1974) found that puddling greatly reduced the carry over of upland weeds. *Eleusine indica* (L.) Gaertn., *Digitaria sanguinalis* (L.) Scop., *Amaranthus spinosus* L., and *Cyperus rotundus* L. were most sensitive to puddling. *E. colona* and *Portulaca oleracea* L. were moderately sensitive and *Cyperus iria* L. was least sensitive.

The time of planting also affects the weed population. IRRI (1978) reported that in dry-seeded rice, delayed planting resulted in an increase in weed growth compared to early planting. Increase in the availability of soil moisture in the late planting favored more weed growth compared to early planting where moisture was limiting.

Fryer and Chancellor (1970) indicated that information on changing weed populations provides valuable indications of future weed problems and is indispensable for evolving suitable methods of weed control. Tiwari and Nema (1967) and Moody and Drost (1981) indicated that elimination of weeds from crop fields is possible to a great extent by proper manipulation of soil moisture, cultivation procedures, date of planting, crop spacing, and maintenance of desirable ecological conditions.

This study was conducted to determine the effect of time of planting, method of land preparation, water management, and weeding on the rice weed flora. An attempt was made to relate the effect of time of planting to method of land preparation and soil moisture conditions in the field.

MATERIALS AND METHODS

This study which consisted of two experiments was conducted at the International Rice Research Institute (IRRI) experimental farm.

In Experiment 1, a split-split plot design replicated three times was used. Methods of land preparation (puddling and no puddling) were assigned to the mainplots; level of water management (irrigated and rainfed) to the subplots; and weeding regimes (weeded and unweeded) as the sub- subplots.

In the puddled plots, 18 day-old rice seedlings were transplanted at a 20 cm x 20 cm spacing and in the plots that were not puddled, rice was dry-seeded in rows spaced 25 cm apart.

Hand weedings were done 2 and 5 weeks after transplanting (WAT) and 2, 5, and 7 WAE for dry-seeded rice.

Fertilizer was applied at a rate of 90-40-40 kg N, P_2O_5, and K_2O. Sixty kilograms N and all the P_2O_5 and K_2O were applied basally and the remaining 30 kg N was applied at panicle initiation.

In this experiment, two trials were conducted — one during the 1978 wet season and the other during the 1979 wet season. Between the first and second trials, the plots were plowed once and mungbean (*Vigna radiata* (L.) Wilczek) was broadcast-seeded. No weeding was done in the mungbean crop. The same treatments were in the same plots in each year. Each plot was prepared separately to reduce the possibility of weed seed and weed propagule contamination between plots.

In Experiment 2, a split-plot design with three replications was used. Time of planting and rice establishment methods were used as mainplots (Table 8) and weeding regimes (weeded and unweeded) as subplots.

Rice was planted at monthly intervals from May to September 1981. The method of crop establishment depended on the soil conditions at the time of planting. Dry-seeded rice was sown when the soil was dry and wet-seeded when the soil had to be puddled.

In the weeded plots, hand weedings were done 2 and 5 WAE and 3 weeks after seeding (WAS) for dry- and wet-seeded rice, respectively.

Fertilizer was applied at the rate of 100-40-40 kg N, P_2O_5, and K_2O/ha with 50-40-40 applied basally and the remaining nitrogen applied 30 DAE.

IR36 was the cultivar used for both experiments. A seeding rate of 100 kg/ha was used for direct-seeded rice.

For insect control, 1.0 kg/ha carbofuran (2,3-dihydro-2,2-dimethylbenzofuran-7-ylmethylcarbamate) was soil incorporated at planting for early insect control. For postplanting insect control, recommended insecticides were applied when necessary.

Weeds were sampled from two 0.5 m x 0.5 m quadrats per plot, classified by species, dried at 80^{o}C for at least 48 hours, and the dry weight recorded.

The weed communities were compared on the basis of their relative dry weights (RDW) and their coefficients of similarity (%). These were determined as follows:

i) $$\text{RDW} = \frac{\text{Weight of each species in a community}}{\text{Weight of all species in a community}} \times 100$$

ii) The coefficient of similarity is the sum of the lower values of the RDW's for those species which are common to two communities.

In Experiment 2, four observation wells were installed to monitor changes in ground water levels. Water depth readings were taken once a week and the values presented are the means of four observations.

The grain yield was determined from a 5 m^2 sample area at the center of each plot. The grains were threshed, dried, cleaned, weighed,and converted to t/ha at 14% moisture.

RESULTS AND DISCUSSION

Experiment 1

The weed flora was greatly affected by the method of land preparation and water management.

In 1978, puddling the soil resulted in fewer species than when the soil was not puddled (Table 1). Iririgation further decreased the number of weed species. Weed weights were also lower in the puddled plots than in the non-puddled plots.

The composition of the weed flora varied with the different field conditions (Table 2). Grasses predominated in unpuddled rainfed plots, sedges in puddled rainfed and unpuddled irrigated plots, and broadleaf weeds in puddled irrigated plots.

Irrigation practices promoted the development of certain weed species. *Monochoria vaginalis* (Burm. f.) Presl and *Cyperus difformis* L. occurred only in the puddled plots. They were major weeds in the irrigated plots but relatively minor in the rainfed plots. *Digitaria* sp. *Ipomoea triloba* L., and *Murdannia nudiflora* (L.) Brenan occurred only in the non-puddled plots.

in the irrigated plots. *I. triloba* and *M. nudiflora* were relatively minor weeds.

Table 1. Number of weed species and weight of weeds at rice maturity in the unweeded plots as affected by method of land preparation and water management. IRRI, 1978 wet season.

Field condition	Weed species (no.)				Weed weight (g/m^2)
	Broadleaf weeds	Grasses	Sedges	Total	
Puddled irrigated	3	1	2	6	10.4
Puddled rainfed	5	3	5	13	34.6
Unpuddled irrigated	6	4	4	14	108.4
Unpuddled rainfed	9	6	4	19	162.9

Table 2. Weed weight (g/m^2) and relative dry weight (RDW) of weed species in the unweeded plots at rice maturity as affected by method of land preparation and water management. IRRI, 1978 wet season. Figures in parenthesis are for RDW.

Weed species	Puddled irrigated	Puddled rainfed	Unpuddled irrigated	Unpuddled rainfed
	Weed weight (g/m^2) RDW			
Monochoria vaginalis	4.0 (38.5)	0.2 (0.6)	2.6 (2.3)	1.2 (0.7)
Ludwigia octovalvis	0,8 *7.7)	1.4 (4.2)	2.6 (2.3)	1.2 (0.7)
Murdannia nidiflora	—		9.2 (8.5)	0.8 (0.5)
Lindernia anagallis	0.8 (7.7)	5.4 (16.1)	6.4 (5.9)	2.0 (1.2)
Ipomoea triloba	—	—	4.2 (3.9)	11.4 (7.0)
Digitaria sp.	—	—	3.0 (2.8)	59.8 (36.8)
Eleusine indica	—	1.0 (3.0)	6.8 (6.3)	9.8 (6.0)
Echinochloa colona	0.2 (1.9)	2.2 (6.5)	16.2 (14.9)	24.6 (15.1)
Cyperus difformis	4.4 (42.3)	2.0 (6.0)	—	—
Cyperus iria	0.2 (1.9)	16.4 (48.8)	17.8 (16.4)	1.8 (1.1)
Fimbristylis miliacea	—	1.8 (5.4)	9.2 (8.5)	9.2 (5.6)
Others	—	2.6	2.4	11.2

Four weed species were common in all field conditions. Species that are distributed over a wide range of environmental conditions have much greater genetic variability and are more difficult to control (Moody, 1983). *E. colona* accounted for 15% of the weed flora under unpuddled conditions. Puddling greatly suppressed it. Puddled rainfed conditions were particularly favorable for the growth of *C. iria* but puddled irrigated conditions virtually eliminated it. In unpuddled plots, *C. iria* was still a major component of the weed flora. *Lindernia anagallis* Burm. f. Pennell was the second most important weed in the puddled rainfed plots but was a minor weed in the other plots. *Ludwigia octovalvis* (Jacq.) Raven was relatively unimportant under all four field conditions.

There was little similarity between the weed populations growing in association with rice in the different field conditions (Table 3). The least similiarity occurred between the puddled irrigated and the unpuddled rainfed conditions.

Table 3. Coefficient of similarity (%) of the weeds growing in association with rice at rice maturity as affected by different field conditions. IRRI, 1978 wet season.

Field condition	Puddled irrigated	Puddled rainfed	Unpuddled irrigated
Unpuddled rainfed	5.8	37.8	56.7
Puddled irrigated	—	22.3	12.0
Puddled rainfed	—	—	57.2

Weeds caused significant yield reductions in all plots except those that were puddled and irrigated (Table 4). Within a weeding regime, the rice in the plots that were not puddled yielded significantly less than that in the puddled plots.

Table 4. Grain yield (t/ha) as affected by method of land preparation, water management, and weeding regimes. IRRI, 1978 wet season.

Method of land preparation	Weeding regime Weeded	Unweeded	Difference
Irrigated			
Puddled	2.8	2.7	0.1^{ns}
Unpuddled	1.8	0.9	0.9**
Difference	1.0**	1.8**	
Rainfed			
Puddled	2.8	2.2	0.6*
Unpuddled	2.1	0.5	1.6**
Difference	0.7**	1.7**	

* Significant at 5% level (LSD).
**Significant at 1% level (LSD).
ns = Not significant.

In 1979, there were more weed species but weed weights were lower in the puddled plots than in the unpuddled plots (Table 5). This could have been due to the shorter periods of flooding and the shallower flooding that occurred in 1979 compared to 1978 because rainfall was lighter in 1979.

Unusual rainfall patterns may change the weed flora in any given year. Earlier than usual rains can promote the early development of weeds particularly grasses. Drost (1982) indicated that the time and depth of flooding affected weed establishment. Moody (1977) indicated that in rice production systems, water management and flooding depth can be used to control weeds and regulate the composition of the weed populations.

Table 5. Number of weed species and weight of weeds at rice maturity in the unweeded plots as affected by method of land preparation and water management. IRRI, 1979 wet season.

Field condition	Weed species (no.)				Weed weight (g/m^2)
	Broadleaf weeds	Grasses	Sedges	Total	
Puddled irrigated	8	6	4	18	92.6
Puddled rainfed	6	6	4	16	99.0
Unpuddled irrigated	7	4	2	13	265.2
Unpuddled rainfed	5	4	2	11	189.4

The weed flora under all field conditions were predominated by grasses and sedges (Table 6). Broadleaf weeds were of minor importance. Grubb *et al.* (1982) reported that it is usual to find appreciable variation in relative abundance from time to time and place to place even in what is commonly regarded as a single community occupying a relatively uniform habitat.

Table 6. Weed weight (g/m^2) and relative dry weight (RDW) of weed species in the unweeded plots at rice maturity as affected by method of land preparation and water management. IRRI, 1979 wet season. Figures in parenthesis are for RDW.

Weed species	Puddled irrigated	Puddled rainfed	Unpuddled irrigated	Unpuddled rainfed
Echinochloa colona	29.9 (32.2)	35.0 (35.4)	94.8 (35.7)	63.4 (33.5)
Cyperus iria	11.6 (12.5)	14.0 (14.1)	28.8 (10.9)	20.6 (10.9)
Eleusine indica	—	7.4 (7.5)	78.8 (29.7)	50.0 (26.4)
Portulaca oleracea	0.4 (0.4)	13.6 (13.7)	0.4 (0.2)	0.2 (0.1)
Ipomoea triloba	3.4 (3.7)	—	13.6 (5.1)	23.6 (12.5)
Cyperus difformis	21.4 (23.1)	1.4 (1.4)	—	—
Cyperus rotundus	8.2 (8.9)	13.6 (13.7)	29.0 (10.9)	17.2 (9.1)
Others	17.8	14.0	18.0	14.4

C. difformis occurred only in the puddled plots. It was one of the major weeds in the irrigated plots but was a minor weed in the rainfed plots. *E. indica* was the second most important weed in the unpuddled plots. It was a minor weed in the puddled rainfed plots and puddled irrigated conditions eliminated it.

There were four weed species common to all field conditions as in 1978. However, two species (*P. oleracea* and *C. rotundus*) were entirely different from those of 1978. These weeds were probably carryovers from the mungbean crop planted between the 1978 and 1979 trials. Factors such as seasons, cropping patterns, soil moisture, and rainfall patterns influence weed communities (Moody, 1983). *P. oleracea* was a dominant weed in the puddled rainfed plots but was a minor weed in the other plots. Harwood and Bantilan (1974) reported that *P. oleracea* was moderately sensitive to puddling and became prevalent after puddling when grass species were reduced. *C. iria* and *C. rotundus* had about the same importance under all field conditions. *E. colona* was the most dominant constituting more than 30% of the weed population in all field conditions. Chun (1982) reported that *E. colona* could adapt to a wide range of environmental conditions. Civico and Moody (1979) found that *E. colona* survival was not affected by the time of flooding or the moisture level. Thus, provided this weed becomes established, it can survive in lowland and upland fields.

The weed growing in the unpuddled rainfed and unpuddled irrigated were very similar as indicated by the high coefficient of similarity (Table 7). Lower similarities were obtained between unpuddled rainfed and unpuddled irrigated plots and between puddled irrigated and unpuddled rainfed plots.

No yield was obtained because of severe rat damage.

Table 7. Coefficient of similarity (%) of the weeds growing in association with rice maturity as affected by different field conditions. IRRI, 1979 wet season.

Field condition	Puddled irrigated	Puddled rainfed	Unpuddled irrigated
Unpuddled rainfed	53.6	64.0	91.2
Puddled irrigaeted	—	66.4	53.9
Puddled rainfed	—	—	67.8

Experiment 2

The rainfall pattern, water depth in the field, and depth to water table are presented in Figure 1. Light rains of less than 5 mm occurred during the weeks of May 10, 17, and 24. The depth of the water table was below 1 m — the deepest that could be measured in this experiment. During the weeks of June 22 and 29, there were heavy rains causing the water table to rise to within 10 cm of the soil surface. Further rains during the week of July 3 caused flooding of the field to approximately 5 cm deep until July 21. There was very little rain during August and the early part of September and the water table fell to more than 1 m below the soil surface. Heavy rains occurred after this period which raised the water table to the soil surface and flooding of the field occurred between the weeks of September 28 and October 12. During the week of October 19 the field dried up and the water table dropped to 68 cm below the soil surface. Thereafter, the field was flooded until November 1.

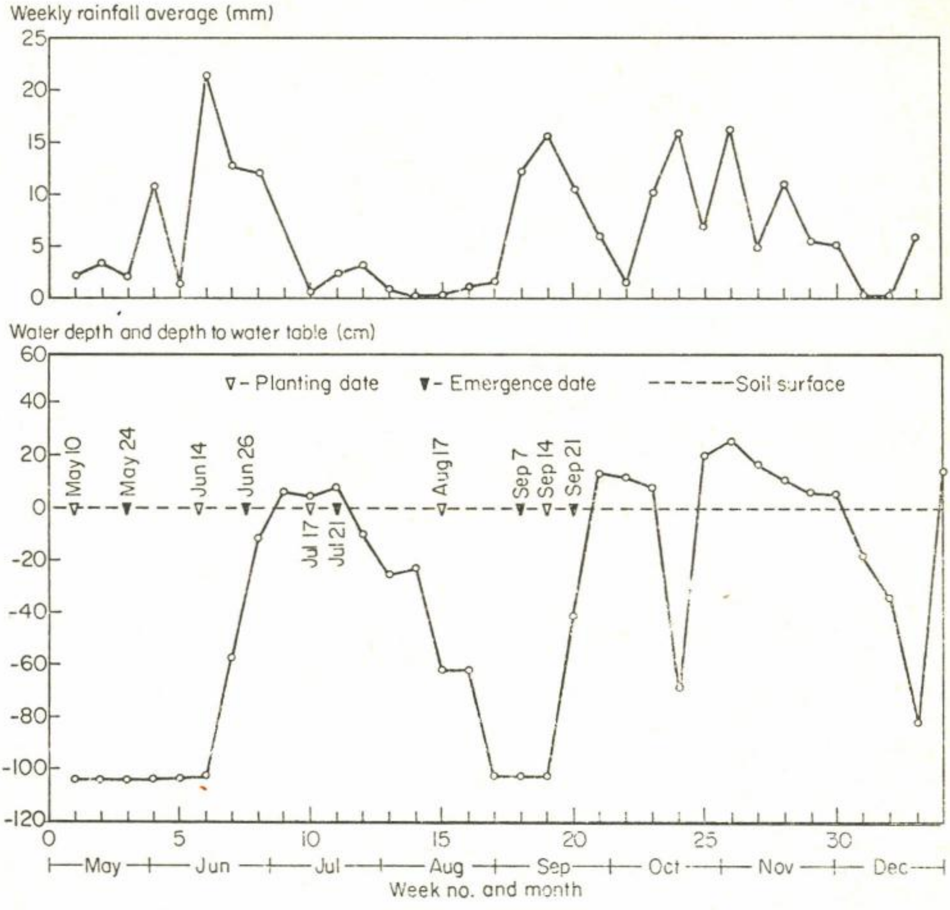

Fig. 1. Rainfall pattern, water depth in the field, and depth to water table. IRRI, May-December 1981.

A change in cultural practices involving different planting dates and different methods of land preparation modified the weed flora. The weed flora varied according to the time of planting (Table 8). Dry-seeded rice planted in May was dominated by *Digitaria* sp. and *E.colona* whereas *P. distichum* dominated the weed flora in the June, August, and September plantings. This means that weed control strategies for dry-seeded rice planted earlier (May) would probably be different from those of later planting because of the shift from annual grasses to a perennial grass. If chemical control is used, pre-emergence herbicides for annual weeds should provide good control of *Digitaria* sp. and *E.colona* but will not control *P. distichum*. Other control measures will have to be considered when *P. distichum* is a problem.

Table 8. Effect of time of planting and method of crop establishment on the relative dry weight (%)[a] 8 weeks after emergence. IRRI, 1981 wet season.

Weed species	Time of planting									
	May 14 (DSR)		June 13 (DSR)		July 17 (WSR)		Aug. 17 (DSR)		Sept. 14 (DSR)	
Digitaria sp.	36.3	bc	63	efgh	o	h	15.6	def	1.2	gh
Echinochloa colona	28.1	cd	11.3	efgh	0	h	6.2	efgh	10.4	efgh
Eleusine indica	10.5	efgh	1.1	gh	0	h	0	h	0	h
Paspalum distichum	12.2	efgh	45.8	b	0	h	69.6	a	47.8	b
Cyperus iria	7.0	efgh	34.7	bc	0	h	0	h	13.5	efg
Ludwigia octovalvis	0	h	0	h	12.9	efgh	0	h	13.1	efgh
Echinochloa glabrescens	0	h	0	h	39.9	bc	0	h	3.5	fgh
Sphenoclea zeylanica	0	h	0	h	28.0	cd	0	h	0	h
Others	5.9	efgh	0.8	gh	19.2	de	5.3	efgh	10.3	efgh
Total weed weight (g/m^2)[b]	432.7	a	426.3	a	170.6	b	131.1	c	494.1	a

[a] Means having a common letter are not significantly different at the 5% level by DMRT. DSR = dry-seeded rice, WSR = wet-seeded rice.

[b] In a row, means having a common letter are not significantly different at the 5% level of DMRT.

Wet to saturated conditions during the first 2 WAE favored the emergence of *C. iria* in the June and September plantings. The shallow flooding that occurred after rice emergence favored the emergence and growth of *L. octovalvis* when the crop was planted in July and September. Drost (1982) reported that growth of wetland weeds increased as the water table neared the soil surface whereas growth of upland weed species declined. Puddling the soil for wet-seeded rice sown on July 17 caused a dramatic shift in the weed flora to wetland weeds such as *E. glabrescens*, *S. zeylanica*, and *L. octovalvis*. Drost (1982) and Harwood and Bantilan (1974) observed that puddling favored the emergence of wetland weed species and suppressed that of upland weed species.

The growth of weeds was also affected by time and method of crop establishment (Table 8). The lowest total weed weight was obtained when dry-seeded rice was planted in August because of the very dry soil conditions after crop establishment. A prolonged dry period during germination and development of the crop may result in little or no development of weeds, therefore, avoiding the problem that normally occurs (Moody, 1982a). Weed weights obtained from the other planting dates were significantly higher but not significantly different from each other. Wet-seeded rice seeded in July had a significantly lower weed weight than the dry-seeded plantings.

Failure to weed in dry-seeded rice resulted in complete yield loss regardless of the date of planting (Table 9) whereas in wet-seeded rice uncontrolled weed growth caused only 24% yield reduction which agrees with the findings of other workers (IRRI, 1978; De Datta, 1981; Ahmed and

Moody, 1982). These findings illustrate the importance of puddling and water in weed suppression.

Table 9. Grain yield (t/ha) of IR36 as affected by weeding and time of planting. IRRI, 1981 wet season.

Weeding treatment	Time of planting [a] May 14 Dry seeded	June 13 Dry seeded	July 17 Wet seeded	Aug. 17 Dry seeded	Sept. 14 Dry seeded
Hand weeded[b]	2.7 bc	0 d	2.6 c	3.1 b	3.6 a
No weeding	0 b	0 b	2.0 a	0 b	0 b

[a] In a row, means having a common letter are not significantly different at the 5% level of DMRT. Except for the June 13 planting, values in a column within a time of planting are significantly different at the 5% level by DMRT.

[b] Dry seeded — hand weeded 3 and 5 weeks after emergence (WAE), Wet seeded — hand weeded once 3 WAE.

The yield in the weeded plot from the September planting was significantly higher than that from the other plantings. No yield was obtained from the June planting due to drought which occurred at the flowering stage.

Time of planting,method of land preparation, and water management brought about significant changes in the weed population and composition. Further studies are needed and better records of changing weed populations as the result of a change in agronomic practice or cropping system must be kept. Data on such studies are needed to fully understand the factors responsible for shifting weed populations and to plan weed control programs accordingly.

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INFLUENCE OF WATER MANAGEMENT AND SPACING ON WEED COVER AND HERBICIDAL ACTIVITY OF RILOF-H IN TRANSPLANTED RICE

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ABSTRACT

The herbicide Rilof-H is a registered trademark of Ciba-Geigy Limited Basle and it has been used for many years in transplanted lowland rice in South East Asia under conditions of good water management. Special investigations conducted in recent years have proved its effectiveness also where water management was poor, and even in rainfed transplanted rice, if it was applied at adequate rates and timings. These results reconfirmed the excellent crop safety of Rilof-H at any application timing and its unique flexibility with regard to effective timing of application at any date between transplanting and 4 weeks after transplanting. The complex interactions between herbicide rate and plant spacings have been studied and it is recommended to reduce the common plant spacing of 25 cm x 25 cm at least down to 20 cm as soon as herbicide use begins to replace the traditional handweeding.

INTRODUCTION

Rilof-H has been developed for the control of grasses, sedges and broadleaved weeds in transplanted rice (Green and Ebner, 1972, Uchida *et al.*, 1975). The product, which contains the two active ingredients piperophos and 2, 4-D ester, was mainly used at an early stage of the crop, between 208 days after transplanting, and is recommended for use only on well-flooded paddy fields. This recommended use pattern restricts the use of this product to areas where good water management is practiced. For the huge areas of less than perfectly irrigated rice crops in South East Asia, with less easily controlled irrigation systems, and for the whole rainfed rice crop, Rilof-H was generally not used. In such conditions, weed problems, however, are even bigger than in well-irrigated crops. Special investigations therefore have been done to define suitable rates and timings of Rilof-H to permit its use under such conditions.

Since the plant spacing in transplanted rice has a very strong influence on the occurrence of weeds, several trials were conducted which were aimed at defining the most suitable spacing for optimal weed control with Rilof-H.

MATERIALS AND METHODS

Trials were conducted on the Ciba-Geigy Research Station, Cikampek, in West Java. Soil type was a clay and weed species were mainly *Monochoria vaginalis* (Burm.f.) Presl., *Fimbristylis milicea* (L.) Vahl, *Cyperus iria* L. and *Scirpus juncoides* L. Soil preparation was done by hand, puddling twice before levelling. Wet bed seedlings of the rice cultivar R-36 were hand-transplanted at the Indonesian standard spacing of 25 cm x 25 cm, unless otherwise indicated. Urea, triple super phosphate and KCl were applied at rates of 200, 100 and 90 kg per hectare respectively. One third of the total nitrogen rate was applied at transplanting, at 30 and at 60 days after transplanting. Spraying was done with Knapsack sprayers, either equipped with a single Cooper-Pegler floodjet nozzle or with a special trial sprayboom consisting of 3 fanjet nozzles. Spray volume was 500 L/ha. The plot size varied between 30 to 60 m^2 and all treatments were replicated 3 or 4 times. Adjacent to each plot was an untreated checkstrip, in order to assess weed control better. For the plot separation, long parallel mud dikes between plot rows were sequenced into plots using 30 cm high zinc sheets.

Performance of Rilof-H under different water regimes. Several trials were carried out in which the water regime was manipulated. The two basic water regimes were a) normal flooded conditions, where the water level was maintained at a height of 3-6 cm and b) saturated conditions where the plots were only occasionally flooded to maintain the soil wet and to prevent it from cracking. The development and occurrence of weeds for the two water regimes was observed in checkstrips and checkplots.

Assessments were done visually at 2 week intervals, evaluating weed cover, phytotoxicity, weed control and the percent share of each weed species. Yield was taken from the whole plot and threshing was done with a portable thresher. Yield data are presented with a standardized moisture content of 13%.

The data presented in Fig. 1 and Table 1 show a very clear enhancement of the weed development under poor water regimes. Oxygen diffuses more readily through the soil surface and into the top soil, and favors the germination and development of weeds which would not, or not so easily, grow under flooded conditions. *M. vaginalis*, the dominant weed on the trial site, is reduced considerably in importance if the plot is not kept flooded. *F. miliacea* which is an almost insignificant weed in flooded fields, becomes second in importance of *S. juncoides* and *C. rotundus* seems to be less affected by the type of water regime.

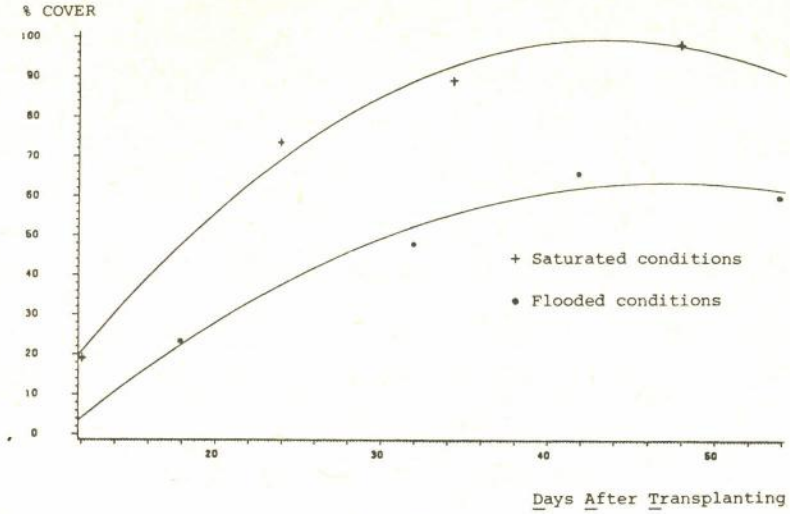

Figure 1. Development of weed cover in transplanted rice depending on the water regime in untreated checkplots (Mean values).

Table 1. Effect of the water regime on the weed population (Assessment between 40 & 50 DAT).

Species	% Share of each species in total weed population (mean values) Flooded conditions	Saturated conditions
Monochoria	63	49
Fimbristylis	9	28
Scirpus	13	9
Cyperus	15	14

All cited trials have been conducted during the rainy season. The observed effect will probably be much more pronounced during the dry season. The characteristics of the weed development and the differences between populations under the two water regimes have their impact on the performance of any herbicide used for weed control in transplanted rice. It is mainly the different speeds of weed development which suggest that we must adapt the timing of application accordingly. For these reasons, two trials with the respective water regimes were conducted with Rilof-H EC 500 at a standard rate of 1.5 L/ha applied at 2, 6, 10, 14, 20 and 30 days after transplanting. Crop tolerance of Rilof-H 500 was excellent with all the timings and no crop damage was ever observed. Weed cover assessed at about 7 weeks after transplanting is given in Table 2.

Table 2. Weed coverage in Rilof-H treated plots assessed at 46 and 50 days transplanting for flooded and saturated water conditions respectively.

Product	Timing (DAT)	% Weed cover (mean values) flooded	saturated
Untreated		78	97
Rilof-H EC 500 1.5 L/ha	2	11	30
	6	26	34
	10	38	33
	14	25	45
	20	13	33
	30	16	18

The results in the trial under flooded conditions (Table 2) allow to define two very distinct timings for a successful application of Rilof-H, which are: either rather early, at 2 to 4 (-6) days after transplanting, or truly post-emergence to weeds, at 20 to 25 days after transplanting. The relatively weak performance of Rilof-H between these two stages can only be explained by the poor pre-emergence activity on the small but already emerged weeds, and, to some extent, by the insufficient post-emergence contact activity of Rilof-H when the weeds are covered by water. A drainage prior to the application, however, proved that Rilof-H will give good weed control also at these timings. In saturated plots, a generally weaker activity of Rilof-H was recorded which is due to the higher density of weeds under such conditions. However, little difference was observed between the different timings of the product. Due to the competitive effect of the weed population on the final yield of the rice crop, the earlier timing of herbicide application must be prepared (De Datta, S.K., 1981).

With regard to the control of single weed species the following trends were observed:

- *M. vaginalis* control under flooded conditions is good, either at an early or at a late timing. In saturated conditions no preference for one or the other is suggested.

- *F. miliacea* control, independent of the water regime, is better with early than with late timings.

- *S. juncoides* and *C. rotundus* are controlled well under flooded conditions either early or late, whereas under saturated conditions, no preferred timing could be defined.

These trends are based on the results of a limited number of trials conducted at one location and therefore require confirmation elsewhere.

Effect of plant spacing in transplanted rice on the performance of Rilof-H. In Indonesia, and other Asian countries, lowland rice is commonly transplanted at a standard spacing of 25 cm x 25 cm. In order to define the required rate of Rilof-H when seedlings are transplanted at other spacings, a series of trials was conducted using 4 plant spacings: 40 cm x 40 cm, 25 cm x 25 cm, 20 cm x 20 cm and 15 cm x 15 cm. Rilof-H at 1.0 and 1.5 L/ha was applied 6 days after transplanting. The product was always completely safe on the crop. The development of weed coverage in untreated, as well as in Rilof-H treated plots, is shown in Figure 2.

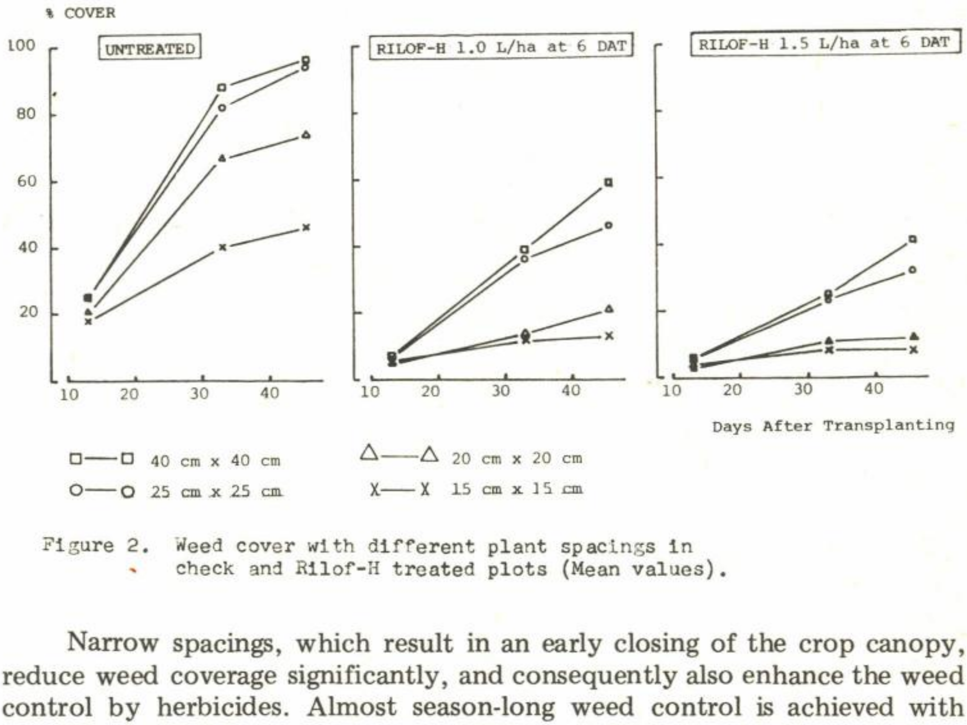

Figure 2. Weed cover with different plant spacings in check and Rilof-H treated plots (Mean values).

Narrow spacings, which result in an early closing of the crop canopy, reduce weed coverage significantly, and consequently also enhance the weed control by herbicides. Almost season-long weed control is achieved with Rilof-H at 1.0 L/ha at the spacings 20 cm x 20 cm and 15 cm x 15 cm, whereas at the standard spacing of 25 cm x 25 cm, a final weed coverage of about 50% is recorded. An increase of the herbicide rate from 1.0 t0 1.5 L/ha improves its performance in all spacings, but at the standard spacing of 25 cm x 25 cm, handweeding will still probably have to be carried out late in the season.

Based on these results, narrow spacings also seem to increase the proportion of *M. vaginalis*, whereas the proportion of *C. rotundus* in the whole population is reduced. *F. miliacea* and *S. juncoides* maintain a constant proportion in plots with the different spacings.

The selection of the most economic plant spacing in transplanted rice must be based on its respective yield potential. The yield results of such a trial are presented in Figure 3. In this trial the spacing 25 cm x 25 cm got the standard rate of fertilizer whereas for the other spacings fertilizer rate was adjusted to their tillering capacity.

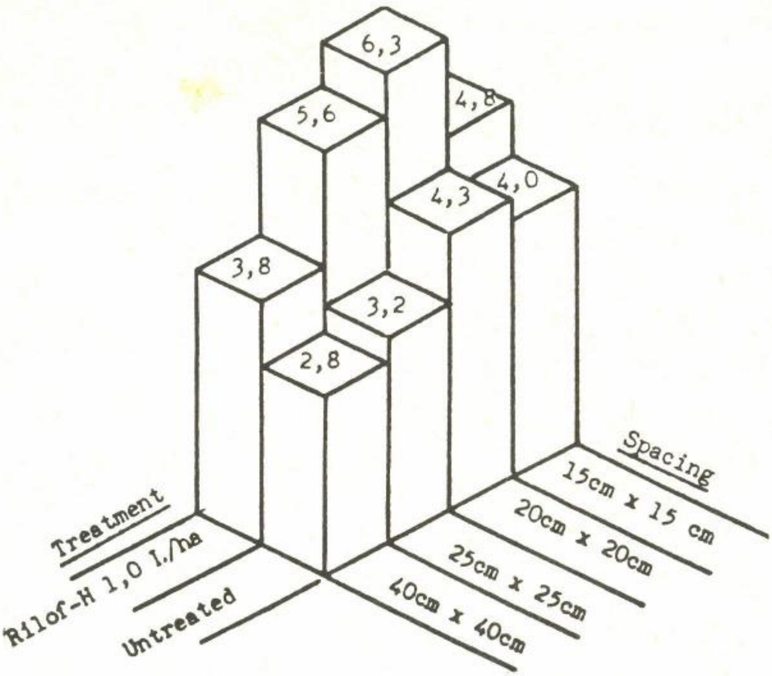

Figure 3. Yield (t/ha) with different spacings, untreated versus Rilof-H 1.0 L/ha, applied at 6 days after transplanting (Mean values).

It appears, from this single trial, as though the 20 x 20 cm spacing gave superior results to all the others, especially where the herbicide was used.

The conducted trials indicate that the present standard spacing of 25 cm x 25 cm is not the most suitable planting distance for lowland rice anymore as soon as herbicides are used. The performance of any preemergence herbicide can be enhanced substantially by a spacing of 20 cm x 20 cm. The common spacing may be better adapted to handweeding and the use of rotary weeders, but at the introduction phase of herbicides this spacing should be reconsidered for the above reasons. Whether a narrow spacing would be negative for the incidence of pests (brown plant hoppers mainly) and rats should of course be investigated as well.

Provided that no negative side-effects occur the spacing of 20 cm x 20 cm would be much more economic for farmers, due to the reduction of cost for chemicals (lower rates) and due to reduced handweeding. The additional costs for more seedlings and transplanting would be more than compensated for by these benefits, and the higher yield.

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FOMESAFEN (PP021), A NEW HERBICIDE FOR THE CONTROL OF BROAD-LEAVED WEEDS IN LEGUMINOUS CROPS IN ASIA-PACIFIC REGION

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ABSTRACT

Fomesafen (coded PP021) is a new diphenyl ether compound for the control of broadleaved weeds in leguminous crops. The compound is safe to use for weed control in soybeans (*Glycine max* (L.) Merr.), and several *Vigna* and *Phaseolus* species. Safety to *Pueraria Phaseoloides (Roxb.) Benth* and *Calopogonium mucunoides Desv.*, two leguminous species used as ground covers in plantation crops, has also been demonstrated. Annual broadleaved weeds are well controlled by early postemergence applications of 0.25-0.375 kg/ha. In general, young weeds at the 2-4 leaf stage are more susceptible than older plants. Fomesafen is also active as a soil applied pre-emergence treatment but for equivalent weed control a higher rate is required than that for post-emergence application. The presence of a nonionic surfactant improves biological activity by maximizing leaf wetting and herbicide uptake. Combinations of fomesafen with fluazifop-butyl, a selective grasskiller in broad-leaved crops, have shown promise for complete post-emergence weed control.

INTRODUCTION

Fomesafen is a new diphenyl ether compound for the control of broad-leaved weeds in leguminous crops, principally soybean. The general properties of the compound and findings from early field trials carried out in the Americas were presented by Colby *et al.* (1983). This paper presents results from trials carried out in the Asia-Pacific Region, and highlights the salient characteristics of the compound.

MATERIALS AND METHODS

The experimental details of the trials discussed in this paper are presented in Table 1. In all trials a 25% soluble liquid formulation of fomesafen was used. Unless otherwise stated, surfactant, Agral 90, was added to all fomesafen treatments at a concentration of 0.1% v/v in the final spray solution. The herbicide standards used in these trials were applied as appropriate commercially available products.

Table 1. Experimental details.

COUNTRY	CHINA	INDIA	BRAZIL	JAPAN	THAILAND	UK	MALAYSIA
Site	Plant Protection Institute, Harbin	Bangalore	Holambra, Sao Paulo		North Thailand	Jealott's Hill Research Station	Bemban, Malacca
Crop/Weed	Soyabean	As listed in Tables 2, 4, 5	As listed in Tables 6 & 8	Adzuki bean & Kidneybean (Table 4)	Soybean & as listed in Tables 2 & 9	Japanese & UK soybean varieties (Tables 2 & 3)	Pueraria & Caopogonium (Table 4)
Plot Size	350m^2	5m x 1.5m	4.5m x 3m	Pot tests	4m x 5m	Pot test	1m x 2m
Replications	Three	Tw	Two	–	Four	Three	Two
Trial Design	Randomised Block	Randomised Block	Systematic Non-randomised Block	–	Randomised Block	–	Randomised Block
Sprayer	Knapsack Sprayer	Pressure Vessel with CO_2 as propellant	Agrale Tractor	Track Sprayer	Knapsack Sprayer	145 Track Sprayer	Oxford Precision Sprayer with Arcton propellant
Nozzle	Floodjet	Allman '00' Fan	5 x 8022 T-jet	Fanjet	Floodjet	8001-E T-jet	Allman '00' Fan
Volume 1/ha	350	500	300	1,000	500	200	400
Assessment	Visual assessment of phytotoxicity	Visual assessment of phytotoxicity and % kill over whole of the plot	Visual assessment of % kill over whole of the plot	Visual assessment of phytotoxicity on individual plants	Visual assessment of phytotoxicity and % kill over whole of the plot	Visual damage assessment	Visual damage assessment

RESULTS AND DISCUSSION

Crop Selectivity

Amongst various leguminous species tested, soybean (*Glycine max* (L.) Merr.), blackgram (*Phaseolus mungo* L.), greengram (*Vigna radiata*), red kidneybean (L.) Wilczek (*Phaseolus vulgaris* L.), adzuki bean (*Phaseolus angularis* L.), and *Pueraria phaseoloides* (Roxb.) Benth. and *Calopogonium mucunoides* Desv. (used as ground cover crops in rubber, oil palm and coconut plantations), showed most tolerance to fomesafen. Early work with fomesafen showed that the broadest spectrum of control was obtained when post-emergence application was made to young weeds. Accordingly, the commercial development of the compound and the field trials reported here have concentrated on this use pattern.

1.1 Soybean. Results from tolerance trials carried out in China, India, Thailand and the UK using a number of soybean cultivars are presented in Table 2.

The field trial using three major soybean cultivars grown in North East China was carried out by Plant Protection Institute, Heilongjiang Academy of Agricultural Sciences. Within three days of an overall application of fomesafen at 1.0 kg/ha slight phytotoxic symptoms appeared. These were necrotic spots, greying around the edges and slight curling of the first and second trifoliate leaves which were fully open at the time of spraying. However, 16 days after spraying the plants began to recover and by 25 to 30 days after spraying showed full recovery and continued to grow normally. Fomesafen had no effect on flowering, pod formation or ripening. There were only marginal differences between tolerances of the three cultivars.

The trial in India included one cultivar and fomesafen was applied at 0.25, 0.5 and 1.0 kg/ha. The initial level of phytotoxicity at 1.0 kg/ha was somewhat similar to that reported from China but the recovery was faster. The degree of phytotoxicity decreased with reducing rates of application. In the Thai trial a local cultivar was treated at 0.25, 0.375 and 0.5 kg/ha. The results were very similar to those observed in India, *i.e.* low levels of dose related initial toxicity with full recovery within 15 days after chemical application.

The trial in the UK was carried out in a glasshouse and tested the tolerance of three Japanese cultivars at 0.25, 0.5 and 1.0 kg/ha. Once again low levels of dose related transitory phytotoxicity was observed. One of the cultivars, Green Homer, appeared to be more tolerant than the other two at the highest dose.

1.2 *Comparison of the selectivity of Fomesafen with other post-emergence herbicides for broad-leaved weed control.* A trial comparing fomesafen with acifluorfen and bentazon was carried out in a glasshouse in UK. Chemicals at 0.25, 0.5 and 1.0 kg/ha were sprayed against 3 Japanese and 4 USA cultivars. Average levels of phytotoxicity observed across the two groups of varieties are presented in Table 3. Overall, bentazon was the safest of the three herbicides and acifluorfen the most damaging. The Japanese cultivars were somewhat more sensitive than the USA cultivars to fomesafen. However, the soybean plants showed full recovery in all cases.

Table 2. Tolerance of soybean varieties to post-emergence application of Fomesafen applied at the 2 trifoliate leaf growth stage.

		% Maximum Phytotoxicity[1] Rate Kg/Ha		
Country	Variety	0.25	0.05	1.0
China[2]	Hei Nong	–	–	15
	6054	–	–	15
	77-7594	–	–	20
India	KSHB-2	10	15	20
Thailand	SJ-5	5	10	20
UK[3]	Enrie	4	3	13
	Green Homer	5	10	8
	Tsurunoko	10	7	20

[1]Phytotoxicity assessed on a scale of 0-100 where 0 = no phytotoxicity and 100 complete kill. In different trials maximum toxicity occurred at different time after spraying, but in all cases the plants fully recovered and showed normal growth by 20-30 days after spraying.

[2]Data from a field trial carried out by the Plant Protection Institute, Heilongjiang Academy of Agricultural Sciences, Harbin, People's Republic of China.

[3]Data from a glasshouse trial against 3 Japanese soybean varieties.

1.3 *Vigna and Phaseolus species, Pueraria phaseoloides and Calopogonium mucunoides.* Selectivity screens against different species of *Vigna* and *Phaseolus* were undertaken in Japan and India. Tolerances of *P. phaseoloides* and *C. mucunoides,* two ground cover species used in plantation crops, were evaluated in a trial in Malaysia. Data from these trials are presented in Table 4.

The species included in the Japanese trial were adzuki bean and kidneybean. Adzuki bean showed very similar tolerance to that reported earlier for soybean, *i.e.* rapid recovery following a low level of initial phytotoxicity. Kidneybean showed greater tolerance than adzuki bean. Similarly in the Indian field trial blackgram, and greengram, were found to be tolerant to economic rates of fomesafen with only marginal initial phytotoxicity. Of the two ground cover species, *P. phaseoloides* appeared to be more tolerant than *C. mucunoides.*

Table 3. Comparison of Fomesafen selectivity to soybean with other post-emergence herbicides sprayed at 2 trifoliate leaf stage.

Chemical	Rate (ka/ha)	% Maximum Phytotoxicity[1]	
		Japanese Cultivars[2]	USA Cultivars[3]
Fomesafen	0.25	2	1
	0.50	6	2
	1.0	10	3
Bentazon	0.25	0	1
	0.50	1	2
	1.0	3	2
Aciflorufen	0.25	14	8
	0.50	13	10
	1.0	20	14

Data from a glasshosue trial carried out in the UK.

[1]Phytotoxicity assessed on a scale of 0-100 where 0 = no phytotoxicity and 100 = complete kill.

[2]Averagephytotoxicity over three varieties: Enrie, Green Homer and Tsurunoko.

[3]Average phototoxicity over four varieties: Amsoy, Anoma, Davis and Forrest.

Table 4. Tolerances of some vigna *and* phaseolus *species,* Pueraria phaseoloides, Calapogonium mucunoides *to post emergence application of Fomesafen.*

Country	Species	Growth Stage (Trifoliate Leaf)	% Maximum Phytotoxicity Fomesafen rate kg/ha			
			0.125	0.25	0.5	1.0
Japan[2]	Adzuki Bean *(V. angularis)*	2	2-3	3-4	4	–
	Kidneybean *(P. vulgaris)*	2	1	1	2	–
India[3]	Blackgram *(V. mungo)*	2-3	–	1	1	2
	Greengram *(V. radiata)*	2-3	–	1	1	2
Malaysia[3]	P. phaseoloides *C. mucunoides*	3-4	–	0	0	0

[1]Phytotoxicity grading on a 0-10 scale where 0 = no phytotoxicity and 10 = complete kill.

[2]Glasshouse test data provided by Ishihara Sangyo Kaisha Company, Tokyo, Japan. No surfactant to spray solution.

[3]Field tests.

In general it can be concluded that at rates 2 to 4 times greater than those required for effective weed control (see Section 2 below), there was only transitory damage on crop plants.

2 *Weed control following pre- and postemergence applications.* In a preliminary trial carried out in India, pre-emergence applications at 0.5 and 1.0 kg/ha were compared with post-emergence applications at 0.25, 0.5 and 1.0 kg/ha. The indicator species at 2-3 leaf growth stage in the test were: —

Grasses: *Echinochloa crus-galli* (L.) Beauv.
Digitaria marginata Link
Dactyloctenium aegyptium (L.) Richt.

Broadleaved weeds: *Datura stramonium* L.
Amaranthus spinosus L.
Bidens pilosa L.
Portulaca oleracea L.

Both pre- and postemergence applications at 0.25-0.5 kg/ha had very little effect on grass weeds (Table 5). Even at 1.0 kg/ha only partial control of grasses was achieved. *D. marginalis* proved to be the most sensitive species to pre-emergence application at 1.0 kg/ha. Against broadleaved weeds postemergence applications even at 0.35 kg/ha gave complete control of all the species. A pre-emergence applications even at 0.35 kg/ha gave complete control of all the species. A pre-emergence application at 0.5 kg/ha provided good control of *A. spinosus* and *P. oleracea* but was inadequate against *D. stramonium* nd *B. pilosa*.

Effect of growth stage on biological activity. The susceptibility of weeds to fomesafen decreases with advancing growth stage, although the degree of change varies with the species concerned. Thus, in a detailed study in Brazil against important broadleaved weeds of soybean crop, it was shown that a delay in application from cotyledon growth stage of weeds like *Euphorbia heterophylla, Amaranthus hybridus, P. oleracea, Ipomoea aristochaefolia* and *Sida rhombifolia* to 4-8 leaf stage required 2-8 times the rate of chemical to achieve similar level of weed control. The weeds were observed to be most vulnerable between the time of cotyledon developmet to 2-4 leaf stage. An assessment of crop phytotoxicity, under similar conditions, showed that for optimum selectivity the best time of fomesafen application was around 2-4 leaf stage of weed growth. The crop at this time in this trial was at first trifoliate leaf stage. Full data are presented in Table 6.

Following postemergence application, fomesafen provides much more efficient weed control than is the case with pre-emergence application. The compound is particularly active against broadleaved weeds treated at an early growth stage. These observations have now been confirmed in a number of countries and fomesafen is being specifically

Table 5. Comparison of pre and post-emergence applications of fomesafen against a range of grasses and broad-leaved weeds; data from trial carried out in India.

METHOD OF APPLICATION	RATE KG/HA	DAYS AFTER TREATMENT	% WEED CONTROL						
			GRASSES[1]			BROAD-LEAVED WEEDS[2]			
			E c	*D m*	*D a*	*D s*	*B p*	*A s*	*P o*
Pre-emergence	0.5	10	40	100	80	70	100	100	100
		25	20	80	40	20	55	100	100
		40	0	60	0	0	45	100	100
	1.0	10	80	100	100	85	100	100	100
		25	55	95	85	60	100	100	100
		40	30	80	40	25	90	100	100
Postemergence 2-3 leaf growth stage	0.25	10	25	15	15	100	100	100	100
		25	0	0	5	100	100	100	100
	0.50	10	40	40	40	100	100	100	100
		25	25	20	20	100	100	100	100
	1.0	10	55	70	70	100	100	100	100
		25	65	45	45	100	100	100	100

[1]Grasses: *E c* = *Echinochloa crus-galli*
D m = *Digitaria marginalis*
D a = *Dactyloctenium aegyptium*

[2]Broadleaved Weeds: *D s* = *Datura stramonium*
B p = *Bidens pilosa*
A s = *Amaranthus spinosus*
P o = *Portulaca oleracea*

developed for early postemergence broadleaved weed control. A list of important weeds susceptible to fomesafen applied at an early growth stage is given in Table 7.

Table 6. Effect of weed growth stage on the rate of fomesafen required for equivalent level (80-85%) of control of important broadleaved weeds in soybean crop; data from a trial carried out in Brazil.

WEED SPECIES	FOMESAFEN RATE (KG/HA) GROWTH STAGE (HEIGHT CM)		
	COTYLEDON (1-3)	2-4 LEAVES (2-5)	4-8 LEAVES (10-35)
Euphorbia heterophylla	0.5	0.5	>1
Amaranthus hybridus	0.125	0.125	>1
Portulaca oleracea	0.125	0.125	0.75
Ipomea aristochaefolia	0.75	0.75	1
Sida rhombifolia	0.75	0.375	>1
	PRIMARY (UNIFOLIATE)	FIRST	4-5
	PRIMARY (UNIFOLIATE) LEAF	FIRST TRIFOLIATE LEAF	4-5 TRIFOLIATE LEAF
	(5 cm)	(10 cm)	(30 cm)
Soybean			
% Crop Damage at Indicated Rate	26	16	>15

4 *Effect of surfactant concentration on biological activity.* Fomesafen is absorbed into the plant both by leaves and roots. It is not well translocated in the phloem and requires good spray coverage, especially of leaf surfaces, for maximum activity. Addition of a nonionic surfactant, *e.g.* Agral 90, maximizes leaf wetting and herbicide uptake.

Trials carried out in several countries, comparing a range of Agral 90 concentrations have shown that an increase in surfactant strength to 0.2% v/v improves activity, particularly against somewhat tolerant species such as *Chenopodium album* L. and improves reliability of fomesafen performance. However, higher concentration of surfactant can also increase the level of crop injury.

Results from a trial carried out in Brazil are presented in Table 8. In this trial two different strengths of Agral 90, namely 0.1 and 0.2%

v/v in the final spray solution were used. Fomesafen dosages were 0.125, 0.25 and 0.5 kg/ha. Against all the broadleaved weed species included in this trial, an increase in surfactant strength from 0.1% to 0.2% improved activity. This improvement was particularly noticeable with the highest dose of fomesafen.

Table 7. A list of susceptible weeds to Fomesafen applied at an early growth stage (1 to 3 leaves) at 0.25-0.37 kg/ha unless stated otherwise.

Abutilon theophrasti	0.25-0.375
Acalypha australis	
Acanthospermum hispidum	
A. australe	
Amarathus retroflexus	
A. viridis	
Borreria alata	0.25-1.0
Chenopodium album	0.375-0.5
Euphorbia heterophylla	
E. maculata	
Ipomoea purpurea	
Parthenium spp	
Physalis angulata	
Polygonum convolvulus	
P. Pennsylvanicum	
Sesbania exaltata	
Sida ruhumbofolia	-.5-0.75
Sonchus oleracea	
Xanthium spinosum	

The time of spraying soybean plants were at 1 to 3 trifoliate leaf stage. Unfortunately the best surfactant treatments for weed control were also the most damaging to soybean. The level of damage increased with increasing surfactant concentration irrespective of the dose of fomesafen application. However, by 9 days after application all treatments had largely outgrown this phytotoxicity. No toxicity was seen 20 days after treatment.

Further work is in progress to identify alternative surfactants, including nonionic/anionic surfactant mixtures, which could optimize weed control but avoid the associated increases in crop phytotoxicity.

5 *Broad spectrum weed control using combinations of fluazifopbutyl and fomesafen.* Recent introduction of selective herbicides, e.g. fluazifopbutyl, for post-emergence grass control in broadleaved crops, permits the possibility of a mixture treatment with fomesafen for complete postemergence weed control. The effectiveness of such treatments was tested in trials carried out in Thailand. Results from a typical trial evaluating fluazifop-butyl at 0.25 and 0.375 kg/ha in mixture with

Table 8. Effect of surfactant strength on weed control and soybean phytotoxicity with fomesafen ; data from a trial carried out in Brazil.

FOMESAFEN RATE KG/HA	AGRAL 90 STRENGTH (v/v)	% WEED CONTROL[1] 20 DAYS AFTER TREATMENT				% MAXIMUM PHYTOTOXICITY 5 DAYS AFTER TREATMENT
		E.H.	I.t./a	B.p.	S.r	Soybean
0.125	0.1	27	32	22	33	18
	0.2	25	45	27	38	22
0.25	0.1	17	38	50	50	13
	0.2	30	45	47	52	22
0.5	0.1	32	57	68	57	14
	0.2	55	72	73	75	28

[1] E.h. = *Euphorbia heterophylla*
I.T./a. = *Ipomea triloba*
B.p. = *I. aristochaefolia*
S.r. = *Bidens pilosa*
Sida rhombifolia

fomesafen at 0.25, 0.375 and 0.5 are presented in Table 9. The important weeds in the trial were:

Grasses: *Digitaria adscendens* (A.B.K.) Henr.
Echinochloa crus-galli (L.) Beauv
E. colona (L.) Link
Eleusine indica (L.) Gaertn.

Broadleaved weeds: *Xanthium pensylvanicum* Wallr.
Physalis minima L.
Amaranthus spinosus L.

As expected, fluazifop-butyl alone gave good control only of grasses, whilst fomesafen alone controlled only the broadleaved weeds. On the other hand, the mixture treatment even at the lowest combination rates of 0.25 kg fluazifop-butyl and 0.25 kg fomesafen gave good broad spectrum control of all the important weeds present in the trial. However, the mixture treatments increased the level of initial phytotoxicity over that observed from fomesafen alone, but recovery was complete within 15 to 20 days after spraying.

Further work under a wide range of agro-climatic conditions is being carried out to establish the optimum rates and timing of application for a combination treatment. Formulation work aimed at producing a pre-mixed product containing both fluazifop-butyl and fomesafen is also in progress.

Soil persistence and safety to following crops. The following brief comments are based on research carried out by the Herbicide Chemistry Section of the Jealott's Hill Research Station.

Fomesafen remains active in soil for several months after application. Evidence from a large number of trials reported to date, mainly from Brazil, USA, Argentina and Canada, suggests that at rates of 0.25-0.375 kg/ha, the residual activity in the soil will be small, thus minimizing the risk of damage to crops sown in rotation with soybean. One such crop is wheat which was shown not to be damaged when sown 5 to 6 months after application of fomesafen. Maize and sorghum are less tolerant. However, at recommended rates fomesafen is also safe to these crops in most situations. Rice, an important crop grown in rotation with legumes in the Asia-Pacific Region, is more tolerant than wheat, and can therefore be safely planted in rotation with fomesafen treated crops. Factors which influence the potential for carry-over are planting interval (carry-over decreases with increasing interval), rate of application (carry-over increases with rate), rainfall (lack of rain exacerbates carry-over), cultivation (carry-over decreases with increased cultivation), anaerobic conditions (lead to rapid degradation) and soil organic matter content (possibly increases carry-over through binding of chemical to soil organic matter content, and re-release under favorable conditions).

Table 9. Weed control using tank mixture treatments of fomesafen and fluazifop-butyl applied 15 days after soybean planting; data from a trial carried out in Thailand.

CHEMICAL TREATMENT	RATE kg/ha	% WEED KILL (WEEKS AFTER SPRAYING) 1		2		4	
		G	B	G	B	G	B
Fomesafen	0.25	30	95	0	90	0	90
	0.375	40	95	0	90	0	90
	0.50	40	95	0	95	0	90
Fluazifop-butyl	0.25	40	0	95	0	95	0
	0.375	60	0	95	0	95	0
Fomesafen + Fluazifop-butyl	0.25 + 0.25	95	95	90	90	85	90
	0.375 + 0.25	95	95	95	95	90	90
	0.50 + 0.25	95	95	95	95	95	95
	0.25 + 0.375	95	95	95	95	90	90
	0.375 + 0.375	95	95	95	95	85	95
	0.50 + 0.375	95	95	95	95	90	95

[1]G = Grass Weeds at 2-3 Leaf Stage

Digitaria adscendens
Echinochloa crus-galli
E. colona
Eleusine indica

[2]B = Broadleaved weeds at 2-3 Leaf Stage

Xantiuhm pensylvanicum
Physalis minima
Amaranthus spinosus
Ageratum conyzoides

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DOWCO 453, A NEW POSTEMERGENCE SELECTIVE HERBICIDE FOR BROADLEAF CROPS IN THAILAND

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ABSTRACT

Field experiments were carried out for two years in Thailand to evaluate the performance of DOWCO 453, a new selective herbicide, for weed control in a number of broadleaf crops. Dosages of DOWCO 453 ranging from 0.0625 to 0.25 kg ae/ha were tested in pineapple, cassava, cotton, peanuts and vegetables. Major weeds encountered in the experimental areas consisted of annual grasses, such as *Pennisetum* spp., *Brachiaria* reptans *(L.) Gard & C.E. Hubb*, *Leptochloa chinensis* L. Nees, *Eleusine indica* (L.) Gaertn., *Dactyloctenium aegyptium* L. Beauv., *Digitaria adscendens* (H.B.K., Henr. and *Echinochloa colona* (L.) Link and also annual broadleaf weeds, such as, *Amaranthus viridis* L., *Commelina benghalensis* L., *Portulaca oleracea* L., *Boerhavia erecta* L., *Corchorus aestuans* L. and *Euphorbia hirta* L.

DOWCO 453 at the rates mentioned gave excellent control of the grasses up to 55 days. Combinations of DOWCO 453 at the rate of 0.125 to 0.25 kg ae/ha with diuron or ametyrn at 0.5 to 1 kg ai/ha also provided complete control of both grasses and broadleaf weeds in cotton and pineapple. *Pennisetum* spp. was the most susceptible species to the chemical but *B. reptans* and *D. aegyptium* were tolerant.

INTRODUCTION

Chemical weeding has been practiced in some countries to overcome the shortage of labor for annual weeding. Postermergence herbicides are of great interest because their use can eliminate the need for weeding in the field when labor is urgently needed elsewhere.

DOWCO 453 [methyl- 2-(4-(chloro-5-(trifluoromethyl)-2-pyridinyl) oxy)phenoxy)propanoate] is a new selective postemergence herbicide active against annual and perennial grasses. The product is currently being developed by The Dow Chemical Company in many different countries including Thailand. DOWCO 453 has been tested on a number of crops with very satisfactory results obtained. Annual grasses, such as *Echinochloa crusgalli* (L.) Beauv., *Setaria viridis* (L.) Beauv. and perennial grasses such as *Agropyron repens* (L.) Beauv., *Cynodon dactylon* Pers. and *Sorghum helepense* (L.) Pers., were controlled with 125 g ai/ha and 250 g ai/ha of DOWCO 453 respectively. No symptom of phytotoxicity was observed on any crop tested (Gavier, 1981). DOWCO 453 at the rate of 0.25 kg/ha gave adequate control of *Axonopus compressus* (Sw.) Beauv. in tea in India (Zutshi, 1982). *Paspalum* and *Ottochloa* spp. were effectively controlled by rates of 0.125 and 0.5 kg ae/ha respectively in Malaysia (Huat, 1982). Gavin (1981) reported that growth stage of grass is not critical and a high level of control had been achieved with the optimum rate of 0.06 to 0.125 lb ai/A of DOWCO 453 on plants ranging from the 2-7 leaf to tillering stage. When surfactants were added to low rates of DOWCO 453, the herbicidal activity was increased 2 to 4 to 8 times (Hunter, 1982). Hunter (1982) also reported that Roundup at 2 lbs ai/A gave faster browning of Rihegome johnsongrass than DOWCO 453 methyl or butyl ester at 4 oz ai/A. At 3 to 4 weeks, percent control by DOWCO 453 was comparable to that of Roundup, however at 8 to 10 weeks after application DOWCO 453 was 80% better.

The experiments were conducted to determine the efficacy of DOWCO 453 and its combination with certain herbicides for the control of both grass and broadleaf weeds. Phytotoxic observations were also made on pineapple, cotton, cassava, peanuts and vegetables under field condition in Thailand.

MATERIALS AND METHODS

DOWCO 453 or XRM-4570 is an emulsifiable concentrate containing 2 lbs/gal. Triton X-77 or WK-surfactant at the rate of 0.25% v/v of final volume was added to all treatments of DOWCO 453. Some other commercial herbicides solely or in combination with ametryn, MSMA, diuron, bromacil and alloxydimsodium were also included in the test as standard treatments. The herbicides were applied directly at about 25 cm above ground level in all trials. Applications were made by a knapsack sprayer with spray volume of 500 L/ha at a pressure of 30 to 40 psi. Experiments in randomized complete block design with 3 to 5 replications were carried out in many areas of economic crops in Thailand (Table 1). Experiments 1 to 3 involved studies on postemergence treatment of DOWCO 453 in cassava, cotton, and pineapple, whereas Experiments 4 to 6 concerned early post applications in onions, garlics, and cabbage. Experiments 7-11 was conducted to confirm the effectiveness of DOWCO 453 in a number of crops. Phytotoxicity was visually rated based on a scale 1 = no injury and 5 = complete kill. Weed control rating was also made by visual observation where 1 = no control and 5 = complete control. Weed species are indicated in Tables 2a and 2b and response to DOWCO 435 are given in Table 2c.

RESULTS AND DISCUSSION

Experiment 1-3. Effect of DOWCO 453 on cotton, cassava and pineapple. DOWCO 453 at 0.5 kg ae/ha gave no visible phytotoxicity on cassava, cotton, and pineapple at 30 days after application. Greatest damage was obtained within 21 to 28 days after application (Table 3) DOWCO 453 at 0.25

Table 1. Experimental details of DOWCO 453 trials in Thailand.*

Experiment	*1*	*2*	*3*	*4*	*5*	*6*
Location	Sriracha, Cholburi	Ban-kai, Rayong	Pattananikom Lopburi	Sanpatong, Cheingmai	Sanpatong, Cheingmai	Sanpatong Cheingmai
Date	August, 1981	August, 1981	September, 1981	January, 1982	January, 1982	February, 1982
Crops	Cassava (40 DAP)	Pineapple (45 DAP)	Cotton (Flowering)	Onions (30 DAP)	Garlics (30 DAP)	Cabbage (21 DAP)
Main weeds	*Daetyloctenium eegyptium*	*Digitaria adscendens*	*Brachiaria reptans* (Flowering)	Volunteer rice (4-5 leaf stage)	Volunteer rice (4-5 leaf stage)	Jungle rice (4-6 leaf stage)
Plot size	3 m by 10 m	3 m by 10 m	2.5 m by 10	4.5 m by 0.8 m	4.5 m by 1.3 m	3.2 m by 1.2 m
Replication	3	3	3	4	3	5
Nozzle	Flood jet No. TK_2	Flood jet No. TK_2	Flood jet No. TK_2	T-jet No. 8004	T-jet No. 8004	T-jet No. 8004
Pressure	40 psi	40 psi	40 psi	40 psi	40 psi	40 psi

Experiment	*7*	*8*	*9*	*10*	*11*	*Note*
Location	Pattaya, Cholburi	Pakchong	Sriracha, Cholburi	Sriracha, Cholburi	Takfah,	DAA = Days after planting.
Date	June, 1982	May, 1982	June, 1982	June, 1982	August, 1982	
Crops	Pineapple	Vegetable crops	Peanut	Cotton	Cotton	Visual rating:
Main weeds	—	—	—	—	—	1 = No injury 2 = Slight injury
Plot size	2.5 m by 7 m	1.7 m by 6 m	1.5 m by 7 m	(Observation trial	(Demonstration trial) 200 m by 400 m	3 = Moderate injury 4 = Seven injury 5 = Dead
Replication	3	3	3	1	1	
Nozzle	T-jet No. 8004	T-jet No. 8004	T-jet No. 8004	T-jet No. 8004	T-jet No. 8004	
Pressure	30 psi	30 psi	30 psi	30 psi	30 psi	

kg ae/ha achieved good control of grass species like *Pennisetum* spp. (40-60 cm high), *Digitaria adscendens* (H.B.K.) Henr. (flowering) and *Dactyloctenium aegyptium* (L.) Beauv. (before heading). At lower rates the chemical also completely controlled the grasses at seedling stage. Even though DOWCO 453 is a foliage-applied herbicide it is believed to possess some degree of residual effect. Much less grass seedlings were obtained in DOWCO 453 treated plots than the control hand weeded plot (Pongponratn, 1982). In pineapple, DOWCO 453 showed less activity on weeds and gave less control compared to bromacil, the standard chemical, at 3 kg ae/ha. Compared with DOWPON-M for *D. aegyptium* control, there was no significant difference in weed weight between DOWCO 453 at 0.5 kg ae/ha and DOWPON-M at 4.62 kg ae/ha. No activity of DOWCO 453 was observed on broadleaf weeds.

Table 2.a Grasses susceptible to post-emergence application of DOWCO 453. (The rates indicated are required to achieve good or better control).

Very susceptible (0.0625 – 0.125 kg ae/ha)		Growth stage
Pennisetum pedicellatum	—	Seedling (50 cm high)
P. polystachyon		
P. setosum		
Echinochlora colona		Seedling
Eleusine indica		Seedling
Digitaria adscendens		Seedling
Susceptible (0.125 – 0.25 kg ae/ha)		
Brachiaria reptans	—	Seedling to tillering
Dactyloctenium aegyptium		Tillering (30 cm long)
Cynodon dactylon		
Leptochloa chinensis		Beginning of tillering

Resistant

No resistant annual grass seedling has been detected.

There was not any single seedling of annual grasses found resistant to DOWCO 453.

Experiment 4-6. Effect of DOWCO 453 on vegetables. Early postemergence experiments were conducted during January-February 1982 in onions, garlics and cabbage using DOWCO 453 at 0.0625, 0.125 and 0.25 kg ae/ha. Comparisons were made using oxyfluorofen, alachlor, and alloxydim-Na. Preemergence herbicides were applied 1 day before planting. The DOWCO 453 treatment and hand weeding were made 30 days after planting (Table 4). DOWCO 453 at all rates gave no phytotoxic effect on the tested crops, but with slight injury on garlics. Oxyflourofen and alachlor produced no injury on both onions and garlics. DOWCO 453 at all rates and alloxydim-Na at 1.5 kg ae/ha neither produced injury to cabbage nor affected its

Table 2.b. Broadleaf weeds completely killed by DOWCO 453 in combination with diuron.

DOWCO 453 + diuron (0.25 kg ae/ha + 0.5 kg ai/ha)	Growth stage
Commelina benghalensis	3 — 5 leaves
Corchlorus aestuans	5 — 7 leaves
Portulaca oleracea	5 — 7 leaves
Aeschynomeme sp.	8 — 10 l cm high
Boerhavia erecta	5 — 6 leaves
DOWCO 453 + diuron (0.125 kg ae/ha + 1 kg ai/ha)	
Commelina benghalensis	15 cm high
Amaranthus viridis	flowering (20-30 cm high).

yield. DOWCO 453 at 0.125 to 0.25 kg ae/ha gave excellent control of 4-6 leaf stage seedling of jungle rice grass (*Echinochloa colona* (L.) Link, goose-grass (*Eeusine indica* (L.) Gaertn., ginger grass (*Chloris barbata* (L.) Sw., crab grass (*D. adscendens*) and barnyard grass (*E. crusgalli*) within 10 days (Pongponratn, 1982).

Experiment 7. Effect of DOWCO 453 on pineapple. The experiment was conducted to determine minimum rates of diuron and ametryn that might be suitable combinations of DOWCO 453. Overall weed coverage was 100% grasses. DOWCO 453 at 0.125-0.25 kg/ha gave excellent grass control at 55 days after application but poor control on broadleaf weeds (Table 5). All the combinations and DOWCO 453 alone were equally effective on grass control at 20 days after application. DOWCO 453 at 0.125 kg/ha plus diuron or ametryn at 0.25-1 kg/ha showed more rapid activity than DOWCO 453 at 0.125 and 0.25 kg/ha. Burmese grass (*P. pedicellatum*) before flowering stage was found very susceptible to DOWCO 453. Combinations of bromacil and bromacil alone gave complete control of both grasses and broadleaf weeds up to 55 days after publication. DOWCO 453 plus ametryn was less efficient compared to DOWCO 453 plus diuron (Pongponratn, 1982).

Experiment 8. Effect of DOWCO 453 on vegetables. Eight vegetable crops, ie. chili, peppers, eggplant, chinese radish, shallot, cabbage, tomatoes, chinese cabbage were planted in two-row system. Six species of grass seeds, i.e. *pedicellatum*, *P. setosum*, *P. polystachyon*, *D. aegyptium*, *D. indica* and *C. barbata* were sown along the crop rows. Herbicides were applied over-the-top across crop and grass rows 16 days after transplanting. None of the tested vegetables was injured by DOWCO 453 treatment. DOWCO 453 at 0.125-0.25 kg ae/ha killed completely *Pennisetum* sp. at 3-5 leaf stage, *D. aegyptium* at 5-6 leaf stage within 15 days after spraying (Table 6). *Pennisetum* spp. were very sensitive to DOWCO 453. At 0.0625 kg/ha the herbicide gave excellent control of this weed species. Alloxydim-Na at 1 kg ai/ha did not satisfactory control the grasses, which was probably due to the rate

Table 2.c. Major weeds in cotton, pineapple, peanuts, vegetables

	Grasses		Broadleaf weeds	
	Scientific name	Common name	Scientific name	Common name
Cotton (Tak-Fa, Nakorn Sawan)	*Brachiaria reptans*	Signal grass	*Commelina benghalensis*	Wandering jew
	Pennisetum pedicellatum	Burmese grass	*Portulaca oleracea*	Common purslane
	Leptochloa chinensis	Feather grass	*Corchlous aestuans*	Wild jew's mallow
	Dactyloctenium aegyptium	Crow foot grass	*Boerhavia* spp.	Erect spiderling
	Eleusine indica	Goosegrass	*Euphorbia geniculata*	
			E. hirta	Spurge
			Ipomoea gracillis	
Pineapple & peanuts (Sriracha, Cholburi)	*Dactyloctenium aegyptium*	Crow foot grass	*Alysicarpus vaginalis*	
	Digitaria adscendens	Crab grass	*Amaranthus viridis*	
	Eleusine indica	Goosegrass		
	Pennisetum pedicellatum	Burmese grass	*Cleome viscosa*	
	P. polystachyon		*Abutilon graveolens*	
	P. setosum		*Tridax procumbens*	
			Borreria laevis	Botton weed
Vegetables (Pakchong, Korat)	*Brachiaria reptans*	Signal grass	*Amaranthus viridis*	
	Echinochloa colona	Jungle rice grass	*A. spinosus*	Spiny pig weed
	Pennisetum pedicellatum	Burmese grass	*Portulaca oleracea*	Common purslane
			P. pilosa	
	P. polystachyon		*Trianthema portulacastrum*	
	Eleusine indica	Goosegrass		
	Echinochloa crus-galli	Barnyard grass		
	Digitaria adscendens	Crabgrass		

applied that was too low compared to the recommended rate (Nippon Soda Co., Ltd.). Considering the fresh weight of grasses in plots, greater weight was obtained in the handweeded than the DOWCO 453 treatment suggesting that one hand weeding was not adequate to maintain a good weed control during the crop season (Pongponratn,, unpublished).

Table 3. Effects of DOWCO 453 applied postemergence on cotton, cassava and pineapple (Experiment 1-3, September-November 1981).

Treatment		Visual ratings, 30 DAA					
		Cotton		Cassava		Pineapple	
		Crop Tolerance	Weed Control	Crop Tolerance	Weed Control	Crop Tolerance	Weed Control
DOWCO 453	0.125 kg ae/ha	1.0	1.4	1.0	2.0	1.0	3.6
DOWCO 453	0.250 "	1.0	3.4	1.0	2.8	1.0	3.9
DOWCO 453	0.5 "	1.0	4.2	1.0	4.0	1.0	4.1
DOWPON M	4.62 "	1.0	4.1	1.0	3.3	(---)	(---)
Bromacil	3.0 kg ai/ha	(---)	(---)	(---)	1.6	1.6	4.3
Hand-weeded check		1.0	4.6	1.0	3.3	(---)	(---)
Weedy check		1.0	1.0	---	(---)	(---)	(---)

DAA = Days after application.
(---) = Treatment not included.
Crop tolerance ratings : 1 - no injury, and 5 - complete kill
Weed control ratings : 1 - no control, and 5 - complete control.

Table 4. Effects of DOWCO 453 applied at early post-emergence on vegetables (Experiment 4-6, February-April 1982).

Treatment		Visual of ratings weed control 30								
		Onions[1]			Garlics[2]			Cabbage[3]		
		Crop tole-rance	Grass -es	Broad leaves	Crop tole-rance	Grass -es	Broad leaves	Crop tole-rance	Grass -es	Broad leaves
DOWCO 453	0.0625 kg ae/ha	1	2.2	1.0	1	3.2	1.0	1	2.6	1.0
DOWCO 453	0.125 "	1	3.0	1.0	1	3.3	1.0	1	4.0	1.0
DOWCO 453	0.25 "	1	5.0	1.0	1	5.0	1.0	1	4.9	1.0
Oxyfluorfen	0.3 kg ai/ha	1	4.0	4.6	1	3.5	4.7		(---)	(---)
Alachlor	1.8 "	1	2.8	1.5		(---)	(---)		(---)	(---)
Aloxydim-Na	1.5 kg ae/ha		(---)	(---)		(---)	(---)	1	4.2	1.0
Hand-weeded check		1	4.9	5.0	1	3.0	3.0	1	4.1	5.0
Weedy check		1	1.0	1.0	1	1.0	1.0	1	1.0	1.0

Table 5. Summary results of postemergence treatment of DOWCO 453 on pineapple (Experiment 7, May-August 1982).

Treatment		Visual ratings, days after application											
		10			20			30			55		
kg ae/ha	kg ai/ha	Crop tole-rance	Grass-es	Broad leaves	Crop tole-racne	Grass-es	Broad leaves	Crop tole-rance	Grass-es	Broad leaves	Crop tole-rance	Grass-es	Broad leaves
DOWCO 453	0.125	1.0	3.6	1.0	1.0	5.0	1.0	1.0	5.0	1.0	1.0	5.0	1.0
DOWCO 453	0.25	1.0	4.5	1.0	1.0	5.0	1.0	1.0	5.0	1.0	1.0	5.0	1.0
DOWCO 453	0.125 + diuron 0.25	1.0	3.6	3.8	1.0	4.6	4.6	(---)	(---)	(---)	(---)	(---)	(---
DOWCO 453	0.125 + diuron 1.0	(---)	(---)	(---)	(---)	(---)	(---)	1.0	5.0	5.0	1.0	5.0	5.0
DOWCO 453	0.125 + Ametryn 0.25	1.0	3.8	3.2	1.0	4.3	4.3	(---)	(---)	(---)	(---)	(---)	(---)
DOWCO 453	0.125 + Ametryn 1.0	(---)	(---)	(---)	(---)	(---)	(---)	1.0	4.9	4.7	1.0	4.9	3.7
DOWCO 453	0.125 + Bromacil 2.0	(---)	(---)	(---)	(---)	(---)	(---)	1.0	1.0	1.0	1.0	1.0	1.0

(---) = Treatment not included.

Table 6. Effects of DOWCO 453 applied postemergence on chili, peppers, egg plant, chinese radish, shallots, cabbage, tomatoes, chinese kale, chinese cabbage (Experiment 8, May-July 1982).

Treatment		Visual ratings, days after application 15			30			Fresh weight of grasses in 0.5 x 0.5 m quadrat	
		Crop tolerance	Grasses	Broad leaves	Crop tolerance	Grasses	Broad leaves	g	As % of weedy check
DOWCO 453	0.0625 kg ae/ha	1.0	4.6	1.0	1.0	4.4	1.0	95.7 ab	6.0
DOWCO 453	0.125 "	1.0	4.9	1.0	1.0	4.8	1.0	18.3 a	1.0
DOWCO 453	0.25 "	1.0	5.0	1.0	1.0	5.0	1.0	6.67a	0.4
Alloxydium-Na	1.0 kg ai/ha	1.0	3.3	1.0	1.0	1.8	1.0	445.0 a	30.0
Hand-weeded check		1.0	4.1	3.4	1.0	3.0	2.3	303.3 ab	20.0
Weedy check		1.0	1.0	1.0	1.0	1.0	1.0	1506.7 d	100.0
				CV (%)				43.4	

Means followed by a common letter are not statistically different at the 5% level of significance by DMRT.

Experiment 9, Effect of DOWCO 453 on peanut. Early post-emergence treatment of DOWCO 453 was conducted on peanuts in June 1982. DOWCO 453 did not injure the peanut plant even at 0.25 kg/ha (Table 7). Only 0.0625 kg/ha of DOWCO 453 was required to give good control *D. adscendens* 3-5 leaves, *P. setosum* 3-4 leaves within 10 days after herbicide application (Pongponrathn; unpublished). Grasses and some broadleaf weeds i.e. *Hyptis sauveolens* (L.) Poit. (1-8 cm high), *Borreria laevis* (Lam.) Griseb (1 cm high), *Stachytarpheta jamaicensis* (L.) Vahl. (1 cm high) were completely controlled by DOWCO 453 at 0.125-0.25 kg/ha plus diuron 0.75 kg ai/ha within 10 days. However, this combination killed all the peanut plants. DOWCO 453 plus MSMA produced slight injury on broadleaf weeds. Growth was suppressed for a short period of time. Combinations of DOWCO 453 and diuron still showed outstanding performance on weed control up to more than 33 days after application.

Table 7. Effects of DOWCO 453 applied early post-emergence in peanuts (Experiment 9, June-August 1982).

Treatment		Visual ratings, days after treatment					
			10			17	
kg ae/ha	kg ai/ha	Crop Tolerance	Grasses	Broad leaves	Crop Tolerance	Grrasses	Broad Leaves
DOWCO 453	0.0625	1.0	5.0	1.0	1.0	5.0	1.0
DOWCO 453	0.125	1.0	5.0	1.0	1.0	5.0	1.0
DOWCO 453	0.125 + diuron 0.75	4.5	5.0	5.0	4.8	5.0	5.0
DOWCO 453	0.125 + MSMA 1.0	1.0	4.5	1.0	1.0	4.9	1.0
Hand weeded check		1.0	4.2	4.9	1.0	3.5	4.8
Weedy check		1.0	1.0	1.0	1.0	1.0	1.0

Experiment 10-11. Effect of DOWCO 453 on cotton. DOWCO 453 at the rate of 0.0625-0.25 kg ae/ha, and DOWCO 453 at the rate of 0.125-0.25 kg ae/ha plus diuron at 0.75 kg/ha or MSMA at 1 kg/ha or nitrogen at 1 kg/ha were included in the trial. These herbicides were applied as directed spray. DOWCO 453 provided high selectivity on cotton even at seedling stage 17 days after application (data not presented). In addition, DOWCO 453 and its combination with certain herbicides as discussed above also gave no injury to cotton. DOWCO 453 plus diuron gave outstanding performance. Even though it was applied to sandy loam soil, crop injury was not detected. Although there was no official report of this observation DOWCO 453 alone and its best combination with diuron were confirmed by large scale application.

Demonstration plots of DOWCO 453 on cotton. DOWCO 453 at the rate of 0.25 kg ae/ha and DOWCO 453 at 0.25 kg ae/ha plus diuron 0.5 kg/ha were directly applied in 3 locations of cotton areas. Cotton plants were 15-40 cm in height. The weeds included *P. pedicellatum, D. aegyptium, B. reptans Leptochloa chinensis* (L.) Ness, *E. indica, Commelina benghalen-*

sis L., *Portulaca oleracea* L., *Corchorus aestuans* L., and *Euphorbia hirta* L. Almost all of them were in seedling stage with 2 to 5 leaves, except some which were at tillering stage. At 7 days after application DOWCO 453 at 0.25 kg/ha completely controlled only the grasses but in combination with diuron at 0.5 kg/ha provided complete control of all the weeds.

Diuron injured a few leaves of the cotton plants especially the upper ones which were sprayed by chance. The treated leaves showed chlorotic spots. However, plant growth was not suppressed by the herbicide either alone or in combination. No difference in height between the treated and and non-treated plants was observed.

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HOE 39866, A NEW NON-SELECTIVE HERBICIDE: CHEMICAL AND TOXICOLOGICAL PROPERTIES; MODE OF ACTION AND METABOLISM

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ABSTRACT

Hoe 39866 (glufosinate-ammonium) is a new herbicidal compound with a chemical structure based on an amino acid. It is a contact herbicide with a limited degree of systemic action. The active ingredient is rapidly detected in the various crops tested. Metabolite residues were detected in trace quantities. Based on all hitherto available toxicological data, the risk of fatal poisoning following acute accidental exposure seems to be limited. Taking into account the possible occupational and user exposure levels, the toxicological data generated so far represents a high safety margin, indicating a low hazard potential to human health. Referring to the low residue levels, the risk to consumers seems to be negligible.

INTRODUCTION

Hoe 39866 or DL-homoalanin-4yl (methyl) phosphinic acid was synthesized in the laboratories of Hoechst AG and was first tested in 1976 under greenhouse conditions. The active ingredient is the ammonium salt of the amino acid phosphinothricin, a phosphinic acid analogue of glutamic acid.

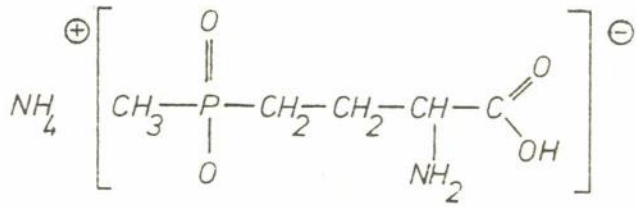
Since 1979 the new compound has been tested extensively in greenhouses (Schwerdtle et al., 1981), fruit orchards and vineyards in Germany (Langeluddeke *et al.*, 1981) and other European countries (Langeluddeke *et al.*, 1982). Since 1981 the compound has also been tested for weed control in plantation crops such as rubber and oil-palm (Langeluddeke *et al.*, 1983). In Japan, Hoe 39866 was tested in fruit orchards and for industrial weed control (Kassebeer *et al.*, 1983)

At present the compound is under further testing in fruit orchards (Europe, North America, Japan, Australia), weed control prior to the planting of soybeans, cotton and wheat in minimum-tillage systems (North America, Brazil and Australia), for weed control in plantation crops such as rubber, oil-palm, tea, coffee and cocoa (West Africa, East Africa, India and South East Asia).

Chemical Designation: Chemical and Physical Properties

Chemical Designation: DL-homoalanin-4yl (methyl) phosphinic acid

Common name : glufosinate-ammonium (proposed)
Structural formula :



Molecular formula : $C_5H_{15}N_2O_4P$

The active ingredient has a molecular weight of 198.1, and slightly pungent. It is water soluble and formulated to an aqueous solution containing 200 g active ingredient per liter.

Toxicity Data

Based on the acute toxicity studies of the active ingredient of Hoe 39866 by various routes of administration, the following LD_{50} values were obtained:

Rat	males	oral	2000 mg/kg
	females	oral	1620 mg/kg
Mouse	males	oral	431 mg/kg
	females	oral	416 mg/kg
Rat	males + females	percutaneous	approx. 4000 mg/kg
Rat	males + females	inhalation	621 mg/m^3

The predominant signs of intoxication given lethal and/or sublethal doses were passiveness, disequilibrium, hypersensitivity, generalized body tremors and convulsive movements, salivation and lacrymation. Overdosed animals exhibited signs of hemorrhages within the gastro-intestinal tract.

Testing the primary irritation to skin and eye mucosa in rabbits did not show positive results.

In a subchronic study in rats Hoe 39866 was administred in the daily feed for 90 consecutive days. Based on this study the "no toxic effect level" of 64 ppm equivalent to 4.1 mg/kg body weight/day was defined.

In a subchronic study in dogs Hoe 39866 was administered in the daily feed for 90 days. Up to a dose level of 64 ppm equivalent to 2.0 mg/kg body weight/day was tolerated without any sign of intoxication. At the highest dose level of 256 ppm only a marginal inhibition of body weight gains due to decreased food intake was detected.

The embryotoxicity study in rats did not give any indication for teratogenic potential.

A mutagenicity screening in vitro failed to show any mutagenic activity in the Ames-Test and the Rec Assay.

There was no evidence of acute delayed neurotoxicity in hens up to the maximal applicable dose level of 4000 mg/kg bodyweight.

Mode of Action

Hoe 39866 is a non-selective, partially systemic contact herbicide. In spite of this partial systemic action it should be considered primarily as a contact herbicide. After uptake the active ingredient acts via the leaf. No damage is caused to seedlings before emergence. No action via the roots could be detected in plants after emergence.

One day after foliar application of the formulated product to *Sorghum halepense*, 19% of the active ingredient penetrated the leaves. Two days after application this value increased to 35%. Translocation studies carried out with ^{14}C-labelled glufosinate-ammonium showed that three days after application on a leaf, a certain amount of active ingredient was recovered in the untreated parts of the plants: *Echinochloa crus-galli* — 13%, *sorghum halepense* — 4%, *Agropyron repens* — 3%.

When leaves of *S. halepense* and *Ipomoea sp.* were treated, phytotoxic symptoms were also observed on the younger, untreated leaves and on the growing points.

Shortly after application of Hoe 39866 the ammonium metabolism of the plant was disturbed and at the same time photosynthesis was severely inhibited. Accumulation of NH_3 (ammonia), which is toxic to plant cells in higher concentrations, occurred.

Hoe 39866 is an inhibitor of the enzyme glutamine synthetase. Under normal conditions the ammonia produced by various metabolic processes in the plant cell combines with glutamic acid to form glutamine. Since ammonia in the plan is produced mainly in the course of processes linked with photosynthetic electron transport, the accumulation of ammonia is higher when the treated plants are exposed to light, and lower when the plants are kept in the dark. Exposure to light also accelerates the development of phytotoxic symptoms which start with a pale yellowish discolouration of the green parts of the plants. After two to five days, the plants wither and die.

Metabolism in Soil and Plants

The physical and chemical properties of Hoe 39866 are very similar to those of protein components synthesized by living organisms. Since the solubility in water is very high, there is no accumulation of Hoe 39866 in the food chain. The active ingredient is highly stable as a chemical compound, but degradation is very rapid in a microbiologically active environment such as the soil. Leaching tests carried out in the laboratory on artificial soils showed that the active ingredient was transported into the deeper layers of the soil. Trials in the field with radioactively labelled material showed that under natural conditions there is no translocation into soil layers deeper than 15 cm indicating rapid biodegradation. Further tests with radioactively labelled material showed that glufosinate-ammonium is rapidly decomposed to 3-methylphosphinico-propionic acid and ultimately to carbon dioxide.

In trials with radioactively labelled glufosinate-ammonium in both greenhouses and fields, the active ingredient was never detected as a residue in lettuce, apple, wheat and grapes. In the soil traces of methylphosphinico the metabolite 3-methylphospninico-propionic acid were found. This metabolite also occurred occasionally in plant tissues (leaves and fruit). Nonetheless the level of residues detected was very low, ranging between 0.02 and 0.1 ppm.

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SOFIT, A NEW HERBICIDE FOR USE IN DIRECT-SEEDED RICE (WET-SOWN RICE)

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ABSTRACT

Sofit is a new herbicide discovered and being developed by CIBA-GEIGY Ltd. for use in mud-sown rice (tropical/subtropical conditions) as well as in water-sown rice in the temperate climate zones. Sofit consists of a mixture of pretilachlor, 2-chloro-2, 6-diethyl-N-(2-propoxyethyl)-acetanilide, a new highly active early-season herbidide being developed by CIBA-GEIGY Ltd. for use in transplanted rice, and a safening agent CGA 123'407, 4, 6-dichloro-2-phenyl-pyrimidine. This new safening agent, CGA 123'407 permits the safe application of pretilachlor as a pre-emergence herbicide in direct-seeded rice. The broad activity spectrum of Sofit includes control of the most important rice weeds such as *Echinochloa* spp., sedges and various broadleaf weeds such as *Monochoria vaginalis.* (Burm. f.) Presl.

INTRODUCTION

Weed control has a major impact on rice production since a large portion of the total labor is devoted to weeding (De Datta 1980). Based on laboratory and field work, a high yield of rice can only be obtained with an early elimination of weeds. Chisaka (1977) reported that *Echinochloa crus-galli* (L.) Beauv. which germinated twelve days after transplanting of rice at a density of 20 plants per m^2 did not significantly reduce rice yields, whereas *E. crusgalli* which germinated soon after transplanting, at the same density, reduced rice yield by 16%. Since the competitive effect of weeds is higher on direct-seeded rice than on transplanted rice, the early weed elimination in wet-sown rice is very important in obtaining high yields (Chiang, 1980).

Pretilachlor is a new highly active early-season herbicide being developed by CIBA-GEIGY Ltd. for use in hand- and mechanically transplanted rice (Murakami and Ebner, 1983). It can be applied pre-transplanting or at any time between transplanting and weed emergence. The most important weeds in rice, such as *Echinochloa crus-galli*, sedges etc., are well controlled with pretilachlor.

For direct-seeded rice (wet-sown) pretilachlor cannot be used without safener at its optimal time for weed control (pre-mergence) as shown in Table 1. In order to avoid the risk of phytotoxicity, pretilachlor can be used as other C1-acetanilides, only with many restrictions, as an early post-emergence herbicide (6 to 8 days after sowing) in wet-sown rice, but its herbicidal activity is very much reduced (Table 1).

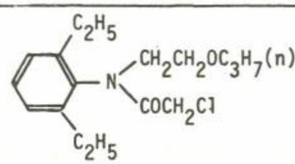
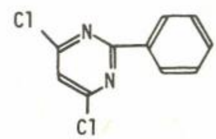
Table 1. Influence of application timing on crop tolerance and weed control of pretilachlor in transplanted and direct-seeded rice (% phytotoxicity of weed control) 0.5 kg a. i./ha.

	Application timing, days after transplanting or after sowing	0	4	6	9
Phyto	Transplanted rice	0	0	0	0
	Direct-seeded rice (wet-sown)	90	60	0	0
Activity	*Echinochloa crus-galli*	100	95	20	0
	Scirpus spp.	100	100	80	10
	Cyperus difformis	100	100	100	100

At present no pre-emergence herbicide in wet-sown rice provides the consistent broad-spectrum weed control required for obtaining high yields, because a selective control of the most competitive weeds with a pre-emergence application is extremely difficult. These prevalent weeds can successfully be controlled with pretilachlor, but the marginal selectivity of this highly active herbicide applied pre-emergence to wet-sown rice requires the addition of a crop safening agent. Thus CIBA-GEIGY Ltd. has developed CGA 123'407, a safening agent which permits pretilachlor to be used safely as a pre-emergence herbicide in direct-seeded rice; this means that pretilachlor can be utilized at its optimal rate and application timing. The trade name of this unique and successful combination of pretilachlor with CGA 123'407 is *Sofit.* When applied to the soil just before or after sowing, Sofit will provide safe pre-emergence control of many economically important weeds in direct-seed rice.

This report describes the characteristics of this new herbicide and summarizes the results obtained from field experiments in 1982/83. In Table 2 are given some physical and biological properties of Sofit.

Table 2. Some physical and biological properties of pretilachlor and CGA 123'407.

	Pretilachlor	CGA 123'407
Trade names	Rifit®, Solnet®	—
Chemical name	2-chloro-2', 6'-diethyl- -N-(2-propoxyethyl)- -acetanilide	4, 6-dichloro-2-phenyl- pyrimidine
Structural formula		
Characteristics of a.1.		
Appearance	colourless liquid	colourless crystals
Boiling point	135°C at 0.001 mm Hg	
Melting point		96.9°C
Vapour pressure	1×10^{-6} mm Hg at 20°C	9×10^{-5} mm Hg at 20°C
Solubility	50 mg/1 in water at 20°C soluble in most organic solvents	2.5 mg/1 in water at 20°C slightly soluble in organic solvents
Acute toxicity of technical materials		
LD_{50} oral (rat)	6099 mg/kg	> 500 mg/kg
LD_{50} dermal (rat)	> 3100 mg/kg	> 2000 mg/kg
LC_{50} inhalation (rat 4h)	> 2800 mg/m^3	2931 mg/m^3
Skin irritation (rabbit)	moderate	slight
Eye irritation (rabbit)	minimal	minimal
	Pretilachlor has a medium acute toxicity to fish.	The compound has shown skin sensitizing potential in a guinea pig test.

MATERIALS AND METHODS

Sofit®, a mixture of pretilachlor and CGA 123'407 is available in the following formulation:

- For mud — sown rice in tropical/subtropical climates: EC 300 containing 300 g/1 pretilachlor and 100 g/1 CGA 123'407.
- For water-sown rice in temperate climates: G 1.5 (A-6746 A) containing 1.5% (w/w) pretilachlor and 0.75% (w/w) CGA 123'407.

Field trials. Field tests have been conducted in Indonesia, Thailand, Egypt, Sri Lanka and Italy in 1982/83. Representative tests have been selected to illustrate the activity of Sofit (pretilachlor + safener). Experimental details are presented for each of these trials. The plot design was always a randomized complete block with 20-200 m^2 plots and 3 to 4 replicates. All crop phytotoxicity or weed control evaluation are based on a (%) scale. All rates are expressed in active ingredient (a.i.).

Experiments in temperate climates. Trials were conducted in Italy (4 locations in the Pavia and Novara province) to assess the tolerance of rice to Sofit. Dry rice (cv. Arborio and Balilla) was sown into water on April 15-30, 1982. Sofit (granule formulation) was applied just after sowing.

Experiments under subtropical conditions. A screening test was initiated in the CIBA-GEIGY Experimental Station in Kaha (Cairo) on June 7, 1982. Pregerminated rice (1 day soaking + 2 days incubation) cv. Giza 172 was sown into the mud. Sofit was applied just after sowing.

Experiments under tropical/subtropical conditions.
Indonesia: The trial was conducted at the CIBA-GEIGY Experimental Station, Cikampek on October 15, 1982. Pregerminated rice (pregermination according to IRRI recommendations) cv. IR 36 was sown into the mud. Just after sowing Sofit was applied.

Thailand: A small-scale test was conducted in the Chainat area (3 locations) to assess crop tolerance and weed control of Sofit. Pregerminated rice (1 day soaking + 2-3 days incubation) cv. RD 7 was sown into the mud on January 18-31, 1983. Sofit was applied at 1 DBS (day before sowing) and 4 DAS (day after sowing). Water management was according to the local practice.

RESULTS

The results reported in Tables 3 and 4 show that pretilachlor, if applied alone at its optimal time for weed control, causes severe injury to direct seeded rice in the form of stand loss and stunted plants. The intensive field testing over the last two years clearly indicates that the injury to direct seeded rice caused by pretilachlor alone can be perfectly well eliminated, if pretilachlor is applied together with the safening agent CGA 123'407 (Tables 3 to 6).

CGA 123'407 itself has no herbicidal activity. The results obtained in 1982 and 1983 show clearly that the addition of CGA 123'407 does not negatively influence the herbicidal activity of pretilachlor nor its flexibility in application timing. Based on the present knowledge, the safening activity of CGA 123'407 is not dependent on temperature, soil type or rice varieties. The safening effect obtained in water-seeded rice (temperate climate zone) has been as good as that in mud-sown rice (tropical/subtropical conditions).

Table 3. Performance of Sofit® (granular formulation) in water-sown rice under temperate climate conditions, Italy (average of 4 trials)

Treatment	Rates (g a.i./ha)	Application timing	% Crop phytotoxicity at 25-35 DAS	% Weed control at 60 — 90 DAS: *Echinochloa crus-galli* (3)	*Scirpus mucronatus* (1)	*Scirpus maritimus* annual (1)
Pretilachlor	750	O DAS	61	90	80	60
	1000		94	94	98	—
Sofit®	750*		6	93	80	60
	1000		6	93	96	90
Molinate	2500	18 DAS	1	93	20	25

** = rates relate to pretilachlor*

Figures in brackets denote number of trials from which means are derived.

Table 4. Performance of Sofit® (EC formulation) in mud-sown rice, Egypt

Treatment	Rates in g a.i./ha	Application timing	% Crop phytotoxicity 64 DAS*	% Control of Cyperus difformis 64 DAS*	Yield in t/ha
Check untreated			—	—	3.0
Pretilachlor	800	0 DAS*	88	100	3.4
Sofit®	800**	0 DAS*	4	100	8.3
Saturn-D®	1000	8 DAS*	4	100	7.6

Table 5. Performance of Sofit® (EC formulation) in mud-sown rice, Indonesia

Treatment (Rates in g a.i./ha)	Application timing	% Weed control: *Scirpus spp.* 11 DAS	*Scirpus spp.* 20 DAS	*Fimbristylis littoralis* 11 DAS	*Fimbristylis littoralis* 20 DAS	*Monochoria vaginalis* 11 DAS	*Monochoria vaginalis* 20 DAS	Yield *in* t/ha
Check, unweeded		0	0	0	0	0	0	0.4
Sofit® 600**	0 DAS	90	98	95	98	95	90	3.7
Saturn-D® 1200	6 DAS	100	70	80	50	80	30	2.8

Table 6. Performance of Sofit® (EC formulation) in mud-sown rice, Thailand (average of 3 trials)

Treatment (Rates in g a.i./ha)		Application timing	% Crop phytotoxicity 20 DAA	% Crop phytotoxicity 40-49 DAA	% Weed control at 56 to 65 DAA (all weeds were present in all 3 trials): *Cyperus difformis* + C. iria	*Fimbristylis littoralis*	*Sphenoclea zeylanica*	*Leptochloa chinensis*
Sofit®	400*	1 DBS	12	3	94	92	90	100
	600*		13	2	92	96	90	100
Sofit®	400*	4 DAS	3	1	95	93	87	96
	600*		3	1	94	95	94	98
Butachlor	930	7 DAS	14	2	75	55	37	88
Saturn-D®	1750		7	1	77	81	75	50

** = rates relate to pretilachlor content*

These results show that the level of the safening activity of CGA 123'407 is also independent of the sowing method.

Weeds provide the greatest competition and cause most damage at early crop growth, therefore early control is important for obtaining high yields. Sofit controls weeds from the beginning. The results obtained in 1982 (Tables 3 and 4) show clearly that the highest yield has been achieved with Sofit. This demonstrates the greatest importance of an early weed elimination.

The duration of weed control is an important parameter. De Datta (1981) indicates that, for example, 20 days of weed-free growth appears best in short-statured plant types such as IR 8 but for C 4-63, an intermediate-statured variety, the weed-free period should be extended to the first 30 days after transplanting. Field trials indicate that at the recommended doses Sofit will give residual control of weeds for 30 to 50 days depending on external conditions such as water management. Under good water management a pre-emergence treatment of Sofit is usually sufficient to provide season-long weed control.

De Datta (1981) reported a dramatic shift in rice cultivation from the traditional transplanting method to that of direct-seeded rice in Iloilo province of Philippines. Since experimental results indicate that the yield potential for direct-seeded rice is similar to that for transplanted lowland rice, the acreage of wet-sown rice in Southeast Asia is expected to expand in the future. Direct-seeded rice culture will become an increasingly attractive alternative to transplanted rice as a consequence of the rising cost of labor. However, crop stand establishment in direct-seeded rice is often poor because of weed competition. The problem of a sufficient weed control to overcome this severe weed competition is twofold: first — early weed control by handweeding is for obvious reasons very difficult, secondly — the lack of sufficiently selective herbicide which is one of the main factors limiting the extension of direct-seeded rice (Chiang, 1980). A farmer chooses a particular method of planting rice for various reasons, but crop competition with weeds and use of weeding methods are important considerations for specific choice (De Datta, 1981).

In conclusion, these trials strongly indicate that Sofit shows an excellent crop selectivity and a very good control of the most important weeds in direct-seeded rice (Table 7). Sofit will allow to improve weed control where the cultivation method of direct seeding is already introduced (Sri Lanka, India, Thailand, Philippines) and will offer an opportunity to farmers who may wish to change from the labor-intensive transplanting method to that of direct-seeded rice.

Table 7. Weed control spectrum of Sofit®

Susceptible	*Moderately susceptible.*
Alisma canaliculatum	Borreria ssp.
Ammania senegalensis	Callitriche verna
Cyperus difformis	Scirpus hotarui
Cyperus iria	
Dinebra retroflexa	
Dopatrium junceum	*Moderately resistant*
Echinochloa colonum	Cyperus serotinus
Echinochloa crus-galli	Scirpus maritimus
Eclipta alba	
Elatine triandra	
Eleocharis acicularis	*Totally resistant*
Eleusine indica	Green algae
Fimbristylis littoralis	Potamogeton distinctus
Leptochloa chinensis	Sagittaria pygmaea
Lindernia pyxidaria	
Ludwigia ssp.	
Monochoria vaginalis	
Rotala indica	
Scirpus juncoides	
Scirpus zeylanica	

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GLUFOSINATE-AMMONIUM (HOE 39866) – A NEW HERBICIDE FOR *IMPERATA CYLINDRICA* (L.) BEAUV. AND FOR GENERAL WEED CONTROL IN TROPICAL PLANTATION CROPS

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ABSTRACT

Glufosinate-ammonium (Hoe 39866), a new nonselective broad spectrum contact herbicide, was tested for *Imperata cylindrica* L. Beauv. as well as for general weed control in established plantation crops in Malaysia. *I. cylindrica* can be effectively controlled with 3 to 4 kg/ha for several months. Within 3 weeks after application the green parts of the plants were practically killed, and regrowth was suppressed for more than 5 or 6 months. No influence of spray volume (500 to 1500 1/ha) or waterquality(clean tap vs. acidic ditch water) was found.

In established rubber and oil palm plantations the product effectively controlled important weeds such as *Paspalum conjugatum* Berg., *Axonopus compressus* (Sw.) Beauv., *Ottochloa nodosa* (Kunth) Dandy, *Mikania cordata* (Burm. f.) Robinson, some other broadleaved weeds and some ferns at 0.5 to 1.0 kg/ha.

INTRODUCTION

Hoe 39866, proposed common name glufosinate-ammonium; chemical name; ammonium-(3-amino-3-carboxy-propyl)-methyl-phosphinate is a new nonselective partly systemic contact herbicide developed by Hoechst AG, details of which were first published by Schwerdtle et al (1981). After uptake the active ingredient acts via the leaf. Seedlings, which have not emerged are not affected. The speed of action is quicker than that of glyphosate, but slower than that of paraquat. Gotz et al. (1983) gave more details on mode of action, toxicology and behavior in soil etc.

In Europe, the product has been tested predominantly for weed control in orchards and vineyards, and initial results from Germany and other European countries have been given by Langelüddeke et al. (1981, 1982). In recent years, the product has been tested for weed control in tropical plantation crops as well as for *Imperata cylindrica* (L.) Beauv. control. In the following paper, a first report on the trial in Malaysia is given.

MATERIALS AND METHODS

Field trials for mixed control were carried out mostly in established (mature) rubber of oil palm plantations, but also some young (immature) plantations. Plot size was 16 m^2, with usually 3 or 4 replicates, in some trials only 2 replicates were used. Applications were made when foliage was well developed using a Van der Weij boom sprayer with flat fan nozzles and a pressure of 3 kg/cm^2. The spraying volume ranged from 400-500 L/ha. Trials for *I. cylindrica* control were mostly laid down at open sites. Applications were made when the weed was 40-100 cm high using a boom sprayer delivering 1000 L/ha spray volume. In some trials with taller plants, a knapsack sprayer with fan jet nozzles size 7/64 was used.

Assessments were made at regular time intervals, using a 0 to 100 scale for assessing the direct effect on the green parts of the weeds (percent weed control) up to 2 or 4 weeks after application. At later assessments, the coverage of the regrowth was recorded in absolute figures. Percent weed control was then calculated using the Abbott or Henderson-Tilton formulas.

In preliminary crop tolerance trials young rubber trees were sprayed at the base of the stem; young oil palms were sprayed over the top omitting only the centre of the plants.

Glufosinate-ammonium was formulated as an aqueous solution with 200 g a.i. L. Two reference products were used containing 200 g L paraquat or 360 g L glyphosate.

RESULTS

Trials for I. cylindrica control. The first series of trials was started in October 1980 using rates of glufosinate-ammonium ranging from 1.5 to 5.0 kg a.i./ha. The results are given in Table 1 (the lowest rates being omitted). Glufosinate-ammonium at 3 kg/ha was sufficient to achieve good initial effect within 2 to 4 weeks after treatment. Control decreased slowly as regrowth began and continued throughout the remainder of the trial period. The highest rate of glyphosate used in this series (2, 6 kg/ha) resulted in a lower initial effect, but the regrowth started somewhat later. The recommended rate of dalapon never reached the 90% control level, and the regrowth was stronger than in the plots treated with glufosinate-ammonium or glyphosate. In one trial, within 1 month after application of glufosinate-ammonium all green parts (stems and leaves) of *I. cylindrica* were completely killed even by low rates (Fig. 1). However, differentiation between the different rates could be observed in the following months until the end of the trial. With 5 kg/ha the level of control was 79%, 8 months after application at 1.5 kg/ha only 48% control was achieved.

Table 1. Control of **Imperata cylindrica** *with glufosinate-ammonium in five trials, Malaysia 1980/81*

Treatment	kg a.i/ha	6-8 (5)	14-15 (5)	27-36 (5)	82-85 (5)	194-196 (4)	308-310 (2)
		% Control (days after application)					
CONTROL (coverage in %)		(82)	(85)	(87)	(97)	(100)	(80)
glufosinate ammonium	3.0	68	91	99	94	86	72
glufosinate ammonium	4.0	71	93	99	96	87	74
glufosinate ammonium	5.0	73	93	96	96	90	80
glyphosate	2.6	49	75	69	96	94	80
dalapon	16.0	66	74	68	85	73	62

** in ( ) = number of trials*

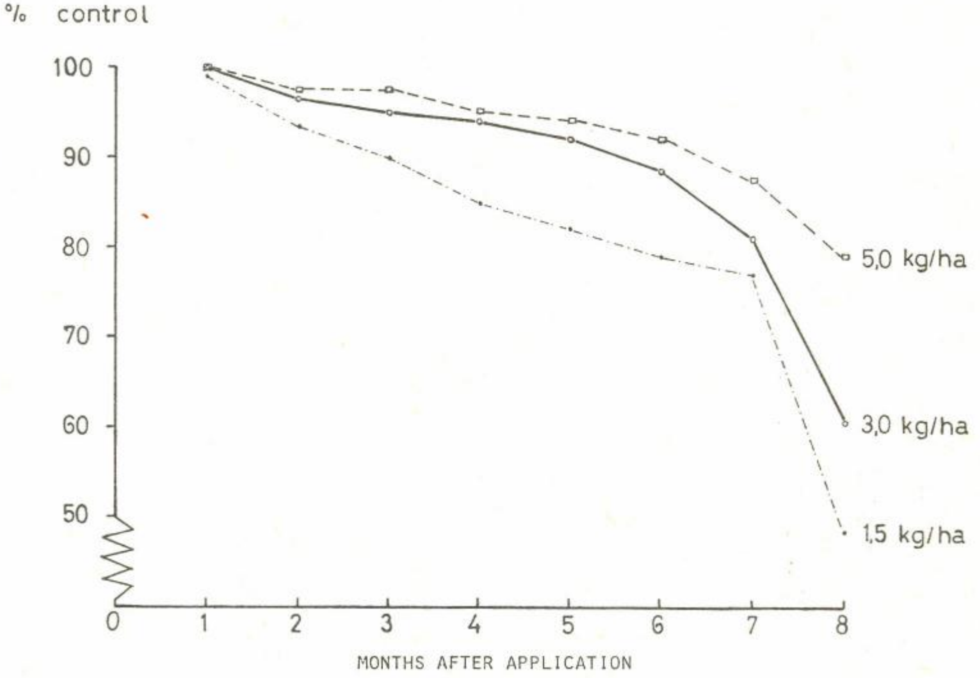

Figure 1. Imperata cylindrica control with different rates of glufosinate-ammonium.

To obtain the same lasting effect as glyphosate at 2.6 kg/ha, 3 to 4 kg/ha glufosinate-ammonium was necessary (Table 2).

Table 2. Comparison of glufosinate-ammonium (Hoe) and glyphosate (gly) in five trials for **Imperata clyndrica** *control*

Trial number and characterization	Treatment kg/a.i/ha	Coverage at application (%)	% control days after application 27-36	41-44	82-85	140-143	194-198	254	308-310
02: open area, h: 60-110 cm,	Hoe 3.0	75/85	100	100	98	96	91		
mineral soil	Hoe 4.0		100	100	99	97	93		
	gly 2.6		73	84	95	97	95		
03: rubber plantation, h: 50-100 cm,	Hoe 3.0	70/80	100	94	93	90	80	60	58
matured stage; reduced coverage	Hoe 4.0		100	95	95	93	84	69	60
at later stages; peat soil	gly 2.6		75	86	97	95	91	74	67
04: open area, h: 40-100 cm,	Hoe 3.0	90/100	94	83	89	67			
mineral soil	Hoe 4.0		96	93	92	75			
05: op	gly 2.6		41	61	91	81			
05: open area, h:60-100 cm, matured	Hoe 3.0	85/95	100	97	95	92	81		
stage, vigorous growth, mineral	Hoe 4.0		100	97	96	92	83		
soil	gly 2.6		89	100	100	98	96		
06: rubber plantation, 75% shade,	Hoe 3.0		100	100	96	98	91	85	86
h: 65-90 cm, matured stage,	Hoe 4.0		99	99	97	96	88	87	88
mineral soil	gly 2.6		70	83	96	100	94	90	94

h = height at time of application

The objective of the second series of trials started in March 1981 was to re-apply the same product at the same rates if the regrowth had reached a certain stage (30-50% coverage). This was successfully done at only one site (trial number 05) out of five (Table 3). All other trials were destroyed by fire or by accidental slashing. Even trial number 5 was destroyed by fire soon after the second herbicide application and could not be continued. However, the speed of control by glufosinate-ammonium was generally faster than that of glyphosate.

Table 3. Comparison of glufosinate-ammonium (Hoe) and glyphosate (gly) in five trials for **Imperata clylindirca** *control (Malaysia 1981)*

Trial number and characterization	Treatment kg/ha a.i.	cover at application	% control at DAA 28	56-70	84-112	140-168	196
01: open area, h: 40-50 cm,	Hoe 3.0	50/65	98	91	88	75	
fresh foliage, silty	Hoe 4.0		100	98	94	90	
clay, pH 4.4, o.m.	gly 3.0		66	88	94	88	
02: open area, h: 60-125	Hoe 3.0	80/90	98	88	79	48	43
silty clay, pH 4.6, o.m.	Hoe 4.0		100	95	89	70	54
1.5%; appl. 4 months after cutting	gly 3.0		72	94	96	87	82
03: open area, h: 60-80	Hoe 3.0	75/85	99	90	85	71	
cm, silty loam clay,	Hoe 4.0		100	90	86	73	
pH 4.9, o.m. 1.5%; applied 5 monts after fire	gly 3.0		97	99	97	91	
04: open area, h: 50-75	Hoe 3.0	75/90	98	88	77	48	
cm, flowering, clay,	Hoe 4.0		98	90	82	64	
pH 4.5, o.m. 4, 5%	gly 3.0		96	99	99	92	
0:5 open area, h:70-90 cm,	Hoe 3.0	55/65	83	55			
mature shoots, organic	Hoe 4.0		90	67	(follow-up applic.)		
soil, pH 4.0, o.m. 75%	gly 3.0	55/65	35	55			

h = height at time of application.

In a third series of trials which was started in 1982 and which is still going on, some trials were conducted on peat soil (pH 3.5, 80% o.m. content). At the time of application the *I. cylindrica* plants were in the late flowering stage or had matured and were 60 to 105 cm high. In the control plots, they were cut on the day the herbicide was applied. The spraying solution was prepared using drain (peat) water with a pH of 3.5. Under these conditions the effect of 3 kg/ha glufosinate-ammonium was far better than that of 3 kg/ha glyphosate or 16 kg/ha dalapon (Table 4).

Table 4. **Imperate cylindrica** *control with glufosinate-ammonium in peat soil (average of two trials).*

Treatment	kg a.i/ha	Days after application 28	56	112	196	223*
untreated (% coverage)**		(32)	(61)	(91)	(100)	(100)
glufosinate-ammonium	3.0	97	82	77	68	54
glufosinate-ammonium	4.0	99	93	80	72	66
glyphosate	3.0	46	57	65	45	29
dalapon	16.0	77	66	69	40	15

* *one trial only*

** *coverage at time of application 63% (mean of all plots)*

For practical use the water volume necessary for good spray coverage and consequently for optimal efficacy can play an important role. Therefore different amounts of spraying liquid were compared in a number of trials. 500, 1000 or 1500 L/ha can be used without difference in efficiency when 3 kg a.i./ha is applied (Table 5).

Table 5. **Imperata cylindrica** *control with glufosinate-ammonium (3.0 kg a.i/ha) in different water volumes*

Water volume 1/ha	Days after application 28	56	84
trial no. 1: boom sprayer (nozzle type: 110-02) height of I. cylindrica 80-110 cm			
1000	98	90	87
1500	97	90	87
trial no. 2: knapsack sprayer (nozzle type: cross-mark fan jet 7/64) height of I. cylindrica 95-120 cm			
500	95	94	91
1000	95	93	91
1500	96	95	95

Trials for mixed weed control. From January to May 1980 a series of five trials for mixed weed control was started. These were followed by a second series of eight trials from March to May 1981. In most of these trials, perennial grasses were the predominant weeds. Glufosinate-ammonium was generally somewhat slower acting than paraquat (Table 6). *Paspalum conjugatum* Berg. plants, however, were completely killed by rates of glufosine-ammonium as low as 0.5 kg/ha. Paraquat at the same rate of active material damaged the plants severely, but they survived and recovered quickly. The two other grass species, *A. compressus* and *O. nodosa* were severely damaged by both products, the initial effect of glufosinate-ammonium being somewhat slower. The efficacy of glufosinate-ammonium at 0.5 kg/ha was similar to that of paraquat at the same rate. In most plots the plants were not completely killed and recovered slowly within 3 months after application. Higher rates of glufosinate-ammonium suppressed the regrowth better than the lower rate. In one of these trials conducted in a young oil palm plantation the effect of both products on *O. nodosa* was somewhat weaker than that in the other trials which were conducted in older plantations giving up to 70 or 80% shade.

Table 6. Effect of glufosinate-ammonium on three perennial grasses

Treatment	kg ai/ha	% weed control (days after application) 7	14	28	56	84-98
Paspalum conjugatum: 6 trials						
glufosinate-ammonium	0.5	57	74	99	97	92*
	0.75	59	75	99	99	95*
	1.0	61	85	100	100	89*
paraquat	0.5	88	93	85	69	59*
*) 5 trials only						
new germination in glufosinate-ammonium plots started about 56-70 DAA, paraquat treated plants survived and recovered						
Axonopus compressus: 5 trials						
glufosinate-ammonium	0.5	55	82	90	92	46*
	0.75	59	87	90	96	52*
	1.0	59	88	98	96	87*
paraquat	0.5	96	99	96	92	67*
*) 4 trials only, assessment 91-112 DAA						
Ottochloa nodosa: 7 trials						
glufosinate-ammonium	*0.5*	*90*	*100*	92	79*	58**
	0.75	93	100	92	88*	61**
	1.0	92	100	94	90*	70**
paraquat	0.5	99	100	88	79*	59**
*) 6 trials only						
**) 4 trials only						

Other weeds occurring in these or similar trials were *Eupatorium odoratum* L., *Stenochlaena palustris* (Burm.) Bedd., *Pueraria phaseoloides* Benth. and *Centrosema pubescens* Benth. These were controlled at rates between 0.5 and 1.0 kg/ha glufosinate-ammonium for a longer period. Annual weeds such as *Asystasia coromandeliana* Nees., or *Borreria latifolia* Schum., normally were controlled by 0.5 kg/ha glufosinate-ammonium. In many cases, however, new plants emerged from seed.

In two trials in the second series the fern *Nephrolepis biserrata* (SW.) Schott. was the predominant weed. Both trials were conducted in established rubber plantations under about 70% shade. The effect of glufosinate-ammonium on *N. biserrata* at rates between 0.5 and 1.25 kg/ha was good; the long term effect of the higher rates being slightly better than those of the lower ones (3 months or longer) (Table 7).

In another trial conducted under similar conditions on *Gleichenia linearis* (Burm. f.) Clarke, another fern, glufosinate-ammonium was compared to paraquat, both products being applied at 1.0 kg/ha. The immediate burning effect was very good; in the paraquat plots, however, regrowth started soon after application, whereas glufosinate-ammonium suppressed regrowth for a period of several months.

M. cordata occurred in several trials; however, in most of these trials its occurrence was too irregular. Only in one experiment conducted in a young rubber plantation (10% shade) was this weed predominant. In this trial, glufosinate-ammonium at 0.5 to 1.0 kg/ha controlled the regrowth of *M. cordata* for more than 3 months after application. However, the trial had to be abandoned as the plots became overgrown with other weeds.

Table 7. Control of **Nephrolepis biserrata** *(two trials)*

		Days after application			
	kg a.i/ha	27-29	55-58	112-117	195-196
Control (coverage %)		(93)	(98)	(98)	(90)
glufosinate-ammonium	0.5	91	90	78	81
glufosinate-ammonium	0.75	94	93	84	92
glufosinate-ammonium	1.0	96	95	95	86
glufosinate-ammonium	1.25	100	98	95	94
MSMA +	2.0	71	64	56	44
diuron	1.0				
paraquat	0.5	100	100	97	92

A trial for the control of *C. hirta*, a shrubby weed, was conducted in an established rubber plantation. Very good control was achieved by application of 1.0 kg/ha glufosinate-ammonium, the plants being almost completely killed. Shrubs treated with 1.0 kg/ha praquat or with a tank mixture of 2, 4-D amine + 2, 4, 5-T (2.3 + 2.2 kg/ha) were severely damaged, but recovered rapidly.

Crop tolerance trials. In one trial, the stem base of 12 month old rubber seedlings was treated by spraying a liquid containing 0.1 or 0.4% a.i. At both concentrations slightly bleached and crinkled leaves could be observed 30 days after application. However, the plants grew away from the damage and 3 months after application symptoms were no longer visible. In another trial, the fronds of young oil palms which were hit directly by the spray liquid (same concentrations as in the rubber trial) were scorched and burned. Even here the new shoots grew healthily unless the growing point was hit.

DISCUSSION

I. cylindrica is a troublesome weed in Southeast and South Asia and is ranked among the ten worst weeds in the world (Holm and Herberger, 1969). Dalapon and glyphosate have been found to be suitable herbicides for its control in Malaysia (Yeoh, 1976; Wong, 1976). The results reported in this paper show that glufosinate-ammonium effectively controls *I. cylindrica.* Under open conditions, applications of 3 to 4 kg/ha glufosinate-ammonium resulted in a relatively quick burning of leaves and stems within 2 to 4 weeks after application and relatively long suppression of regrowth. In most trials this effect was better than that of dalapon and more or less equal to that of glyphosate.

As far as the direct effect on stems and leaves is concerned the performance of the product is very consistent. For practical use however the more important question is the period of suppression of regrowth, and here a certain variability has been observed indicating that suppression lasts for at least 6 months. Consequently, a follow-up application in the form of a spot treatment will be necessary as the rhizomes are not killed by glufosinate-ammonium. However, the duration of suppression of regrowth is related to the rate indicating that the active ingredient has a certain influence on metabolism in the rhizomes.

In some trials on organic soils the long lasting effect of glufosinate-ammonium was clearly better than that of glyphosate; whether this advantage can be attributed to a greater susceptibility of a specific growth type of *I. cylindrica* on these soils, or to the apparent lack of influence of the water quality on the activity of glufosinate-ammonium, is not clear at the moment and needs further investigation.

In rubber and oil palm plantations a wide spectrum of annual and perennial weeds can occur including perennial grasses, shrubs and ferns (Barnes and Chandapillai, 1972; Whycherley and Ahmad, 1974). Herbicides used for the control of these weeds are 2, 4-D, dalapon, amitrole, MSMA, DMSA, glyphosate and especially paraquat (Seth, 1977). Our trials with glufosinate-ammonium for weed control in established plantations were carried out mainly in mature plantations, i.e. under shady conditions. Rates of 0.5 kg/ha provided control of perennial grasses, *M. cordata* and *N. biserrata* for at least 8 weeks and in many cases for 12 weeks or longer. *P. conjugatum* was completely killed by glufosinate-ammonium. Plants of the other grass species were able to survive and to slowly recover from application of higher rates. *G. linearis* also required higher rates (1.0 kg/ha). Against *P. conjugatum* and *G. linearis* the efficacy of glufosinate-ammonium was distinctly better than that of paraquat. A special advantage over paraquat and over a commercially recommended mixture of 2, 4-D + 2, 4, 5-T was the control of the shrubby species *C. hirta*, a troublesome weed especially in South Malaysia (Johore). However only very few data have been obtained so far on *G. linearis*, *M. cordata* and *C. hirta*, and further investigations on the number of applications (rounds) per year in mature and in young plantations are necessary.

Glufosinate-ammonium has been found to be a very suitable herbicide for postemergence weed control in established plantations or prior to planting for control of the following species:

a)	Perennial grassy weeds	*Axonopus compressus* (Swartz) P. Beauv. *Imperata cylindrica* (L.) P. Beauv. *Ottochloa nodosa* (Kunth) Dandy *Paspalum conjugatum* Berg.
b)	Dicotyledonous weeds Perennials	 *Centrosema pubescens* Benth. *Clidemia hirta* Don. *Eupatorium odoratum* L. *Mikania cordata* (Burm. f.) B.L. Robinson *Pueraria phaseoloides* Benth.
	Annuals	*Asystasisa coromandeliana* Nees. *Borreria latifolia* Schum.
c)	Ferns	*Gleichenia linearis* (Burm. f.) Clarke *Nephrolepis biserrata* (SW.) Schott. *Stenochlaena palustria* (Burm.) Bedd.

As mentioned before, glufosinate-ammonium acts only via the leaves and has no influence on germinating weeds. Young rubber trees and oil palms are not damaged unless the foliage is directly hit by the spray liquid.

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LOW-COST HERBICIDE APPLICATING MACHINE WITH WEEDER ATTACHMENT

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One of the major causes of low production of crops in our country is weed infestation which at times is so alarming that it even leads to total crop failure. So far no single means of curbing weeds has been found suitable for all situations and different farm sizes. However, application of herbicides in developing as well as in agriculturally prosperous countries has become a common practice in farming. In our country, till date, use of herbicide is very limited but, with the development of agriculture, it is now realized beyond doubt that for effective control of weeds herbicide application has to be taken up on a large scale. Moreover, to economize the control operation, an integrated approach combining, chemical and mechanical methods is now considered to be a viable one. Keeping these points in view, and considering the average farm size, a simple and cheap Herbicide Applicating Machine with Weeder Attachments, "IITWAM-82" (Plates I, II and III) has been designed and developed for the first time in the country at the Indian Institute of Technology, Kharagpur, West Bengal.

METHODOLOGY

The "feed tank", which holds the herbicide, is supported on a platform and connected with a tank mounted on the back of the operator. The chemical from the "feed tank" flows by gravity into a plastic tube from where a regulated amount of the chemical is allowed to drip and wet a sponge roller. The machine is pushed forward in between the crop rows such that the wet roller wipes itself against the weeds which are, in turn, smeared with the chemical and subsequently killed. The platform with wheel has provision for attaching different weeder blades for mechanical control of weeds for which the herbicide application system has to be detached from the platform.

SPECIAL FEATURES

1. Practically, no loss of herbicide solution during application and no chance of herbicide coming in contact with crop plants and/or soil.

2. No drift action. Hence, all types of herbicides including total weed killers can be used to control the weeds in almost all situations of the standing field crops as well as fallow lands.

3. Designed and developed to combat weeds even in mixed (line sown) stand of strip crops or row crops.

4. Economizes the herbicide consumption as well as labor requirements. Herbicide requirement is reduced to one-tenth as compared to the quantity required in an ordinary sprayer. Reduction in the volume of the spray solution eventually leads to considerable saving of labor and avoids adverse effects of herbicide residue.

5. No additional pressure is required for flow of the herbicide solution as well as very low driving force is needed for operation and hence causes comparatively less fatigue to the operator.

6. As a multi-row applicator it can be trailed behind a power source like bullock/power tiller/tractor.

7. Not much skill is needed in its operation and maintenance.

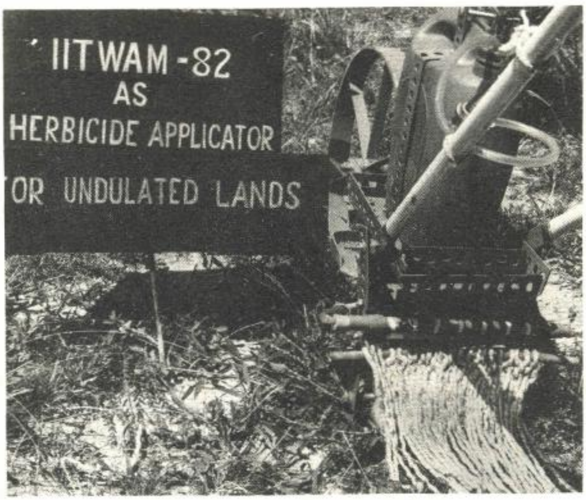
8. Can also be used as a weeder in different row crops including upland paddy.

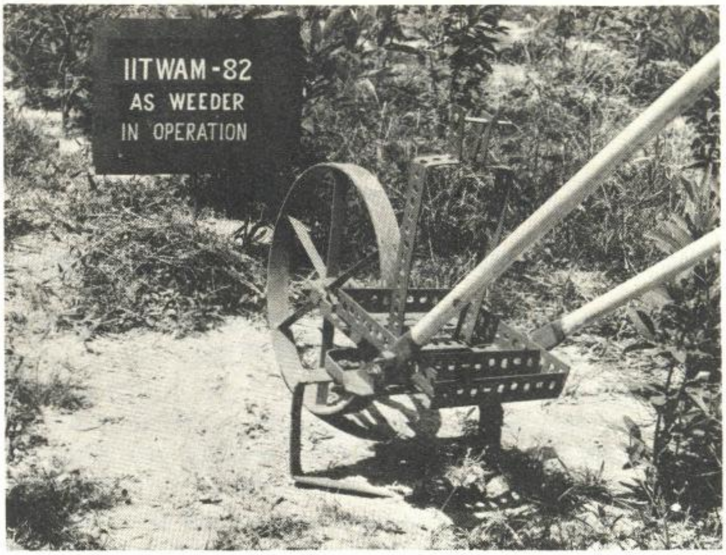
Table 1. Performance test of different weeding blades attached to IITWAM-82.

Type of weeding blade	Width of cut (cm)	Actual field capacity (ha/hr)	Field efficiency (%)	Remarks
Straight blade	15.0	0.01	71.05	Different spacing can be accommodated by using different sizes of blades
5-tine blade	22.00	0.10	78.56	Good for weeding in light and medium soils and also for thinning operation
Double blade (Aspee make)	25	0.12	79.20	Row spacing can be adjusted by varying the distance between the two blades
Double blade (Philippine design)	24	0.11	77.70	–do–
Improved double blade	16	0.01	68.86	Good for turning the weeds on the sides but not on the plants

SPECIFICATIONS

1. Field capacity: 0.07 ha/hr (for a 25 cm row crop)
2. Field efficiency: 94%
3. Weed-killing efficiency : 98 to 100%
4. Speed of operation : 4.0 kmph
5. Solution required : 60 liters/ha (approx.)
6. Labor cost per application : Rs. 20/-(Rs. 10/-man-day) per ha
7. Total operating cost : Rs. 90/-per ha approx. (including cost of paraquat)
8. Total weight of the machine: 15 kg. approx. (without spray solution)
9. Total cost of the machine : Rs. 150/-(approx.)




IITWAM-82
AS WEEDER
IN OPERATION

AC 252, 925: A NEW HERBICIDE FOR USE IN RUBBER AND OIL PALM PLANTATIONS

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ABSTRACT

In field trials conducted in the Philippines, AC 252,925 showed good selectivity to 1.5-year-old rubber tree seedlings when applied as a postdirected treatment at 0.125 to 0.5 kg/ha[2] and on 4- to 5-year-old rubber trees (*Hevea brasiliensis* Muell.) when up to 1.5 kg/ha was applied either as a single or split application. AC 252,925 was selective to 5-year-old oil palm trees (*Elaeis guineensis* Jacq.) at 0.125 to 1.0 kg/ha when applied 1.5 m away from the bole.

In rubber and oil palm split applications of AC 252,925 provided control of *Imperata cylindrica* (L.) Beauv. equivalent to single applications of the same total dosage. Since all treatments gave excellent control at the last assessment date, further work at dosages lower than those tested is required to identify possible advantages of split treatments.

Results to date indicate that germination of weeds following the removal of *I. cylindrica* with AC 252,925 occurred later in the split than in the single application.

Single applications of AC 252,925 at 0.25 to 1.5 kg/ha provided excellent control of *I. cylindrica* in rubber plantations.

An increase in light intensity enhanced the onset of activity of AC 252,925 against *I. cylindrica* for up to 45 days after treatment. Thereafter, no difference attributable to light intensity was recorded in the control of this weed.

INTRODUCTION

AC 252,925 is a new broad-spectrum herbicide being developed by American Cyanamid Company for industrial weed control and for use in plantation crops. The compound is the isopropylamine salt of 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinic acid. Both AC 252,925 and the parent acid, AC 243,997, have been tested for control of *I. cylindrica* and other weeds in rubber and oil palm.

This paper summarizes studies conducted in the Philippines to determine the following: 1) the selectivity of AC 252,925 to 1.5- and 4- to 5-

year-old rubber and oil palm trees; 2) the efficacy of single versus split applications of AC 252,925 for control of *I. cylindrica* and other weeds in rubber and oil palm and 3) the length of time effective weed control was maintained with a single application of AC 252,925 at various rates.

MATERIALS AND METHODS

Selectivity to 1.5-year-old rubber and oil palm trees

Two 1.5-year-old rubber and two oil palm seedlings, both at the 2- to 3-leaf stage, were planted on small plots measuring 1.5 m x 1.6 m (2.4 m^2). AC 252,925 at 0.125, 0.25, 0.375, 0.5, 0.75, 1.0 and 2.0 kg/ha was applied four months after planting. An untreated control plot was maintained for comparative purposes. On rubber trees, treatments were applied either broadcast over-the-top or postdirected, and oil palm treatments were broadcast over-the-top. Rate of spray delivery was 300 L/ha at 1.40 kg/cm^2. The experimental design was a randomized complete block replicated three times.

Single versus split application of 4- to 5-year-old rubber and 5-year-old oil palm trees

Experimental plots measured 4 m x 9 m (26 m^2) and each contained two rubber trees. Split applications of AC 252,925 at 0.625 and 0.75 kg/ha were made on June 3 and July 20, 1982, while single applications at 1.25 and 1.5 kg/ha were made on June 3, 1982.

In oil palm, experimental plots measured 4 m x 4 m (16 m^2) and were located between rows, 1.5 m away from the base of the trees. Split applications of AC 252,925 at 0.0625, 0.125, 0.25, 0.5, and 0.75 kg/ha were made on June 11 and July 22, 1982, while single applications of AC 252,925 at 0.125, 0.25, 0.5, 0.75, and 1.0 kg/ha were made on June 11, 1982.

In both experiments, a 0.2% (w/v) nonionic surfactant was added to the spray solutions. An untreated control plot and a standard glyphosate treated plot were also established. The experimental design used was a randomized complete block, replicated three times.

Efficacy of single application under 4- to 5-year-old rubber and 5-year-old oil palm trees

Plots measuring 4 m x 9 m (36 m^2), with two rubber trees/plot, were laid out. AC 252,925 at 0.125, 0.25, 0.5, 0.75, 1.0, or 1.5 kg/ha was sprayed under the trees on June 3, 1982. Under oil palm, plots measuring 4 m x 4 m (16m^2) were located between rows, 1.5 m away from the base of the trees. AC 252,925 at 0.125, 0.25, 0.375, 0.5, 0.625, or 0.75 kg/ha was sprayed on June 11, 1982.

Table 1. Effect of broadcast and postdirected application of AC 252,925 on 1.5-year-old rubber and oil palm seedlings at CARFI Station, Calamba, Laguna.[1]

Treatment	Rate (kg/ha	RUBBER				OIL PALM	
		% Phytotoxity 16 DT[2]		Plant height (% of control 186 DT[2]		% Phytotoxicity[2]	
						16 DT	31 DT
		Broadcast	Postdirected	Broadcast	Postdirected	Broadcast	Broadcast
AC 252,925	0.125	7	10	59.7	127.5	27	43
	0.25	13	7	53.7	114.1	43	75
	0.375	20	7	33.6	115.6	40	77
	0.5	50	0	47.6	121.7	53	80
	0.75	63	0	20.9	90.0	50	63
	1.0	43	0	41.7	83.1	57	87
	2.0	53	37	24.1	82.4	67	93

[1]AC 252,925 was applied broadcast over-the-top and postdirected on rubber and broadcast over-the-top on oil palm months after planting.

[2]Mean of 3 replications. DT = days after treatment.

In both experiments an untreated control plot and a standard gylphosate-treated plot were included. A 0.25% (w/v) nonionic surfactant was added to the spray solutions. Spray delivery was 350 L/ha at 1.40 kg/cm^2. The experimental design was a randomized complete block replicated three times.

RESULTS AND DISCUSSION

Selectivity to rubber trees

AC 252,925 applied as a postdirected treatment at 0.125 to 0.5 kg/ha was selective to 1.5-year-old rubber tree seedlings (Table 1). At 0.75, 1.0, and 2.0 kg/ha, plant height was reduced by about 10 to 20%. However, broadcast applications of AC 252,925 was moderately phytotoxic, as indicated by chlorosis, inhibition of terminal shoot growth, and dwarfing.

Selectivity to oil palm trees

Broadcast applications of AC 252,925 were extremely phytotoxic to 1.5-year-old oil palm seedlings (Table 1). Rates from 0.125 to 2.0 kg/ha caused complete kill of the plants. Between-the-row application at 1.5 m from the base of the plants in a 5-year-old established plantation was selective at 0.125 to 1.0 kg/ha.

Weed control

Split applications of AC 252,925 at 0.625 and 0.75 kg/ha (47-day interval) under rubber trees and at 0.0625, 0.125, 0.25, and 0.75 kg/ha (41-day interval) under oil palm trees and single treatments in rubber and oil palm trees at 1.25 and 1.5 kg/ha; and 0.125, 0.25, 0.5, 0.75, and 1.0 kg/ha, respectively, gave excellent control of *I. cylindrica* (Tables 2 and 3). Further assessments will be made. Since all treatments gave equivalent control of *I. cylindrica*, further work at lower dosages is required.

Single treatments of AC 252,925 at 1.25 and 1.5 kg/ha gave 83% and 82% control of *I. cylindrica*, respectively, in rubber trees compared to 75% and 73% for the split rates of 0.625 and 0.75 kg/ha, respectively, as early as 47 DAT (Table 2). *I. cylindrica* control at 95 DAT was 100% in plots where single treatments were applied and 98% in plots with the split rates at 48 days after the second application. All rates, whether applied as single or split treatments, gave 100% control of *I. cylindrica* 139 days after the first application.

Germination of other weed species in rubber plantatins was observed as early as 47 DAT with AC 252,925 applied either as a split or single dose. The weed species were: *Rottboellia exaltata* L. f., *Synedrella nodiflora* (L.) Gaertn., *Calopogonium mucunoides* Desv., *Ageratum conyzoides* L., and *Euphorbia heterophylla* L. Growth of these weeds, although not markedly different, tended to be less in plots treated with the split applications of 0.625 and 0.75 kg/ha, than in plots given single applications of 1.25 and 1.5 kg/ha (Table 2).

Table 2. Control of I. cylindrica and extent of growth of other weeds in 4-to 5-year-old rubber trees following single and split treatments of AC 252,925.

Treatment	Rate (kg/ha)[1]	% content of *Imperata cylindrica*			% Cover of other weeds[2]
		47 DT	95 & 48 DT[3]	139 & 92 DT[4]	139 & 92 DT
AC 252,925	1.25	83	100	100	37
	1.5	82	100	100	53
	0.625 + 0.625	75	98	100	30
	0.750 + 0.750	73	98	100	22
Glyphosate	2.5	100	100	100	32

1 Single applications were made on June 3, 1982, and split on July 3 and July 20, 1982.

2 Other weed species noted as early as 47 DT were: *R. exaltata, S. nodiflora C. muconoides, A. conyzoides,* and *E. heterophylla.* Predominantly *I. cylindrica* in untreated control.

3 Refers to same day: 95 days single or first (split) treatment and 48 days after second (split) application.

4 Refers to same day: 139 days after single or first (split) treatment and 92 days after second (split) application.

In oil palm (Table 3), 0.0625 kg/ha applied as a split treatment gave 97% control of *I. cylindrica* 88 days after the first treatment or 47 days after the second application. All other rates, whether applied as single or split treatments, gave excellent control of *I. cylindrica.* At 136 and 95 days after the first and second split application, respectively, AC 252,925 as a single dose at 0.5, 0.75, and 1.0 kg/ha or as a split application at 0.25, 0.75, and 1.0 kg/ha or as a split application at 0.25, 0.5, and 0.75 kg/ha still maintained excellent control of *I. cylindrica.* Split application at the lower rates of 0.0625 and 0.125 kg/ha provided control of *I. cylindrica* equivalent to the single rates of 0.125 and 0.25 kg/ha. Weed species which germinated 41 DAT with either single or split treatments were: *Cleome rutidosperma* Dc., *Commelina benghalensia* L., *Borreria* sp., *Calopogonium mucunoides, Vernonia cinerea* (L.) Less, *Agreatum conyzoides,* and *Cyperus rotundus* L. As in rubber, growth of these weeds tended to be less in plots receiving split treatments, compared to single-dosage plots, indicating a possible advantage with split over single applications.

Table 3. Control of I. cylindrica and extent of growth of other weeds in 5-year-old oil palm trees following single and split treatments of AC 252,925. (Ken Ram Philippines Isulan, Sultan Kudarat).

Treatment	Rate (kg/ha)	% Control of Imperata cylindrica			% Cover of other weed species[2]
		41 DAT	88 & 47 DAT[3]	136 & 95 DAT[4]	136&95 DAT
AC 252,925	0.0625 + 0.0625	57	97	98	48
	0.125	61	100	92	33
	0.125 + 0.125	57	100	97	38
	0.25	63	100	99	53
	0.25 + 0.25	80	100	100	4
	0.5	90	100	100	33
	0.5 + 0.5	75	100	100	12
	0.75	83	100	100	25
	0.75 + 0.75	89	100	100	12
	1.0	97	100	100	32
Glyphosate	2.5	95	100	100	45
Untreated	—	0	0	0	98

[1] Single application were made on June 11, 1982, and split on June 11 and July 22, 1982.

[2] Other weed species noted as early as DT were: *C. rutidosperma, C. benghalensis Borreria* sp., *C. mucunoides, V. cinerea, A. conyzoides,* and *C. rotundus.*

[3] Refers to same day: 88 days after single or first (split) treatment and 47 days after second (split) application.

[4] Refers to same day: 136 days after single or first (split) treatment and 95 days after second (split) application.

[5] Predominantly *I. cylindrica*

Initial symptoms on *I. cylindrica* in rubber were apparent at 47 DT with AC 252,925 at 0.125 to 1.5 kg/ha (Table 4). At 95 DT, rates of 0.5 to 1.5 kg/ha gave 95 to 100% control. With the lower rates of 0.125 and 0.25 kg/ha, control at 95 DT was 60% and 83%, respectively.

Rates of 0.25 to 1.5 kg/ha AC 252,925 gave excellent control of *I. cylindrica* at 139 days. Results were better than with glyphosate at 2.5 kg/ha. *I. cylindrica* had been eradicated.

Table 4. Control of Imperata cylindrica and extent of growth of other weeds in 4 to 5-year old rubber trees following postemergence application of AC 252,925. (Experimental Station of the University of Southern Mindanao, Kabakan, North Cotabato)

Treatment	Rate (kg/ha)	% Control of *Imperata cylindrica*			% Cover of other weed species[2]
		47 DT	95 DT	139 DT	139 DT[3]
AC 252,925	0.125	50	60	0	72[c]
	0.25	57	83	98	57
	0.5	70	95	99	40
	0.75	70	100	99	52
	1.0	67	95	99	53
	1.5	70	95	99	50
Glyphosate	25	91	100	80	70[4]

1 AC 252,925 applied on June 3, 1982.

2 Other weed species noted as early as 47 DT were: *R. exaltata, S. nodiflora, I. triloba, C. mucunoides, E. heterophylla, E. hirta,* and *C. rotundus.* Predominantly *I. cylindrica* in untreated control.

3 DT = days after treatment.

4 Including *I. cylindrica.*

Table 5. Control of I. cylindrica and extent of growth of other weeds in 5-year-old African oil palm following postemergence application of AC 252,925. (Ken Ram Philippines, Isulan, Sultan Kudarat)

Treatment	Rate (kg/ha)	% Control of *Imperata cylindrica*			% Cover of other weed species[2]
		40 DT	88 DT	131 DT	131 DT[3]
AC 252,925	0.125	60	95	95	45
	0.25	63	98	98	12
	0.375	73	100	100	13
	0.5	73	100	100	37
	0.625	93	100	100	30
	0.75	98	100	100	12
Glyphosate	2.5	97	100	100	18
Untreated	—	0	0	0	97[4] 974

1 Other weed species noted as early as 40 DT were: *C. rutidosperma, Borreria* sp., *E. hirta, E. heterophylla, C. rotundus, C. benghalensis, D. sanguinalis, A. conyzoides, C. mucunoides, V. cinerea,* and *S. nodiflora.*

4 Predominantly *I. cylindrica*

Excellent control of *I. cylindrica* in an African oil palm plantation was obtained with AC 252,925 at 0.125 kg/ha (Table 5). Weed species which predominated following the elimination of *I. cylindrica* were: *C. benghalensis*, *C. rutidosperma*, *Borreria* sp., *C. rotundus*, *Digitaria sanguinalis* (L.) Scop., *Euphorbia hirta* L., *E. heterophylla*, *C. muconoides*, *Vernonia cinerea*, *A. conyzoides*, and *S. nodiflora*.

Better initial control of *I. cylindrica* has been obtained under open compared with shade conditions. A rubber plantation in Firestone, Makilala, North Cotabato, received approximately 50% lower light intensity than one in Kabacan, North Cotabato. Higher light intensity above the weed canopy enhanced the onset of activity of AC 252,925 against *I. cylindrica* up to 45 DT (Tabled 6 and 7). Thereafter, no difference attributable to light intensity was recorded in the control of this weed.

Table 6. Average light meter reading above the weed canopy of experimental sites in Makilala and Kabacan on October 20, 1982 (135 days after postemergence treatment with AC 252,925).

	Light meter reading (foot candles)[1]			
Location	9:00 a.m.	12:00 noon	3:00 p.m.	Mean
Makilala	2900	3700	1900	2833
Kabacan	3875	4958	3229	4021

Table 7. Control of I. cylindrica with AC 252,925 in rubber plantations in Makilala and Kabacan

		% Control of *I. cylindrica*	
Location	Rate (kg/ha)	45 DT	139 DT
Makilala	0.125	20	60
Kabacan	0.125	50	0
Makilala	0.25	35	98
Kabacan	0.25	57	98
Makilala	0.5	45	98
Kabacan	0.5	70	99
Makilala	0.75	50	100
Kabacan	0.75	70	99
Makilala	0.1	60	100
Kabacan	10	67	99

AC 252,925 – A NEW BROAD-SPECTRUM HERBICIDE

R.R. FINE, T.R. PEOPLES, and D.R. CIARLANTE

American Cyanamid Company, Princeton, New Jersey, U.S.A.

ABSTRACT

Isopropylammonium 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinate is a new, broad-spectrum herbicide being developed by American Cyanamid Company under the code number AC 252,925. This new compound has demonstrated excellent activity against sedges, annual and perennial grasses and broadleaves, and woody species when applied either pre- or postemergence. For perennial weed species, however, optimal control has been obtained with postemergence application. AC 252,925 is nonselective to annual crops. AC 252,925 is absorbed through both the foliage and roots; uptake after soil application is through both the shoot and root of the germinating weed. The meristematic region of the treated plants is affected first. In perennial weeds the herbicide is readily translocated to storage organs, thus preventing regrowth. Although plant growth is arrested shortly after application, kill is slow. Depending on the weed species, complete kill may take from one to several weeks after application.

AC 252,925 has been extensively evaluated worldwide as an industrial and non-cropland herbicide and is presently undergoing tests for control of aquatic weeds, ditchbank weeds, and weeds in oil palm and rubber plantations; and for conifer release.

INTRODUCTION

AC 252,925 is a new, broad-spectrum herbicide discovered at the Agricultural Research Center, American Cyanamid Company, Princeton, New Jersey, U.S.A. The compound has undergone extensive laboratory, greenhouse, and field tests. In greenhouse and field tests, Orwick *et al.* (1983a, b, and c) demonstrated that AC 252,925 controls a wide range of annual and perennial weeds. In testing to date, no selectivity to annual crops has been identified.

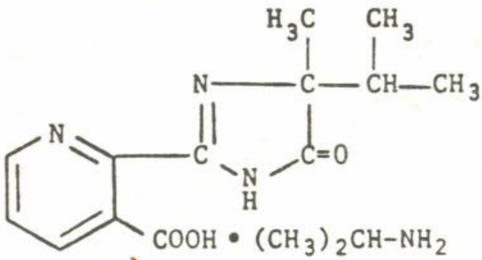
AC 252,925 at dosages of 0.56 to 1.12 kg ae/ha has provided long-term control of many major problem weeds on the railways of the eastern and southeastern U.S.A. Results of field trials on industrial sites in Japan indicate that approximately 0.75 kg/ha will provide excellent long-term weed control (Ciarlante *et al.*, 1983; Hasui *et al.*, 1983).

In field trials conducted in the Philippines, AC 252,925 showed good selectivity to 1.5-year-old rubber trees when applied as a postdirected spray. AC 252,925 was also selective to 5-year-old oil palm trees when applied 1.5 m away from the bole. Excellent control of *Imperata cylindrica* (L.) Beauv. was obtained in rubber and oil palm plantations with 0.5 to 1.0 kg a.e./ha (Lapade *et al.*, 1983).

This paper describes briefly the chemical and physical properties of AC 252,925 and summarizes results obtained in laboratory and field investigations of aquatic and ditchbank weed control and conifer release.

Chemical and Physical Properties

AC 252,925 is representative of a new class of herbicides (Los *et al.*, 1983). The chemical name for AC 252,925 is isopropylammonium 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) nicotinate. The molecular formula is $C_{13}H_{15}N_3O_3 \cdot C_3H_9N$, and the structural formula is as follows:

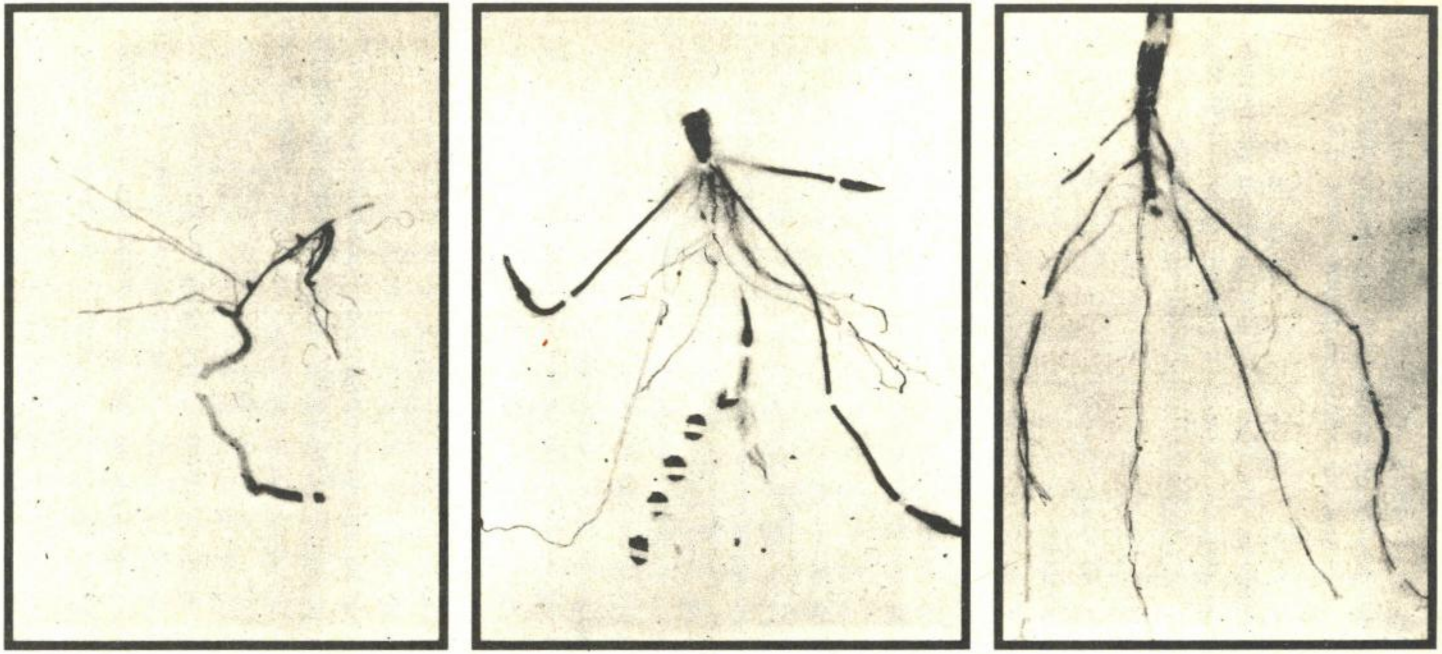


AC 252,925 is an odorless, white solid with a molecular weight of 320.4, a melting point of 128 to 130°C, and a solubility in water of approximately 62% to 65% at 25°C.

AC 252,925 is available as aqueous formulations containing 200 to 250 g a.e./liter or 2 lb a.e./U.S. gallon. For optimum postemergence activity a nonionic surfactant is required.

Mode of Action

AC 252,925 is readily absorbed through the roots and foliage and is translocated rapidly throughout the plant, with accumulation in the meristematic regions. Plant growth is arrested shortly after application. Chlorosis appears first in the newest leaves, and necrosis spreads from this point. In perennial weed species, the herbicide is rapidly translocated to underground storage organs, thus preventing regrowth (Figure 1). Despite rapid translocation, kill of treated plants is slow. In some weed species toxic signs are not



a b c

Figure 1. Translocation of the ^{14}C-labeled free acid of AC 252,925 into the underground storage organs of three perennial weeds: 1) Rhizome of *Convolvulus arvensis* 7 days after foliar treatment; b) Rhizome and tubers of *Cyperus rotundus* 14 days after foliar treatment; c) Rhizome of *Sorghum halepense* 14 days after foliar treatment.

apparent until two weeks after application, and complete kill of plants may not occur until several weeks after treatment.

Toxicology, Mutagenicity, and Metabolism

Acute Toxicity

Initial studies have been completed to determine the acute oral and dermal LD_{50} values in the rat and rabbit, respectively, as well as eye irritation in rabbits (Table 1).

Table 1. Acute toxicity of AC 252,925 to mammals.

Test Species	LD_{50} (mg/kg body wt.) or result Technical Material	Formulation (22.6% a e w/w)
Acute Oral		
Rat	>5,000	>21,000
Acute Dermal		
Rabbit	>2,000	>2,000
Eye Irritation (0.1 g in conjunctival sacs)		
Rabbit	Nonirritating	Nonirritating

Fish Toxicity

In a four-day static toxicity test with rainbow trout, *Salmo gairdneri*, the 96-hour LC_{50} of the free acid of AC 252,925 was > 100 mg/L (> 100 ppm).

Mutagenicity

AC 252,925 is nonmutagenic, as determined by the Ames test (Ames *et al.*, 1975).

Rat Metabolism

Twenty-four hours after dosing rats with the ^{14}C-labeled free acid of AC 252,925 approximately 87% of the dose was excreted in the urine and feces. The blood and fat, muscle, kidney, and liver tissues contained < 0.01 ppm residual radioactivity after 24 hours.

Environmental Behavior

Soil

The biological activity of AC 252,925 persists for three months to one year in the soil, depending on dosage and soil moisture content. Under drought conditions, the herbicide may persist for more than one year. In laboratory studies, aerobic microbial activity slowly decomposed the free acid of AC 252,925 in the soil. No degradation occurred under anaerobic conditions.

Laboratory and field studies indicate that, once AC 252,925 is adsorbed to soil, lateral and vertical movement are limited.

Photolysis in Aqueous Media

When the free acid of AC 252,925 was added to distilled water or to PH 5, PH 7, or pH 9 buffered solutions and then exposed to simulated sunlight, extensive degradation of the compound occurred. The half-life of the free acid of AC 252,925 in distilled water was approximately six days.

Hydrolysis

In a standard 30-day hydrolysis test, the free acid of AC 252,925 was essentially stable when stored in the dark in distilled water and in pH 5, pH 7 and pH 9 buffered solutions.

MATERIALS AND METHODS

Aquatic Weeds

Laboratory Studies. In 1981 in Florida, U.S.A., an experiment was conducted in environmental control chambers to determine the effect of the free acid of AC 252,925 on *Hydrilla verticillata* (L.f.) Royle, *Egeria densa* Planch., and *Spirodela polyrhiza* (L.) Schleid. *H. verticillata* and *E. densa* were grown from apical cuttings in 1-liter glass jars and 50 *S. polyrhiza* plants were grown in 50-ml Petri dishes. The plants were maintained at 23 to 25^{o}C with 12 hours of light per day at an intensity of 9.3 to 11.2 lux. The required concentration of the free acid of AC 252,925 was injected into the nutrient solution following one week of acclimation. Per cent kill (*H. verticillata* and *E. densa*) and per cent population reduction (*S. polyrhiza*) were evaluated at 2-week intervals.

Field Studies. In the Philippines, *Pistia stratiotes* L. was established in 12 m^2 paddies in April 1981. Herbicide treatments were applied in August 1981 when the paddies were fully covered with *P. stratiotes* L. The herbicides were applied with a CO_2 sprayer at 1.4 kg/cm^2 at a spray volume of 333 L/ha. A nonionic surfactant at a concentration of 0.5% ai (w./v) was added to the spray solution in all AC 252,925 treatments. Glyphosate and 2, 4-D ester were included as standard treatments. The experimental design used was a randomized complete block replicated three times.

Eichhornia crassipes (Mart.) Solms was established in 20 m^2 plots and treated on June 30, 1981 when the weed was in its early reproductive stage. Treatments were applied in the same way as in the experiment on *P. stratiotes.* Glyphosate was included as the standard treatment. The experimental design used was a randomized complete block replicated four times.

Ditchbank Weeds

During 1982, two trials were conducted in Florida, U.S.A., to determine the effect of various rates of AC 252,925 on ditchbank weed species. The trials were established on April 20, 1982 at South Bay, and on April 21, 1982 at Palm Beach Gardens. AC 252,925 was applied at 0.14, 0.28, 0.56 and 1.12 kg/ha with 0.25% (w/v) nonionic surfactant. Glyphosate at 1.12, 3.36 and 5.6 kg/ha was included as the standard treatment. All treatments were applied with a small plot sprayer in a spray volume of 400/ha. Each plot was 1.8 m wide and 9.1 m long.

In South Bay, the soil was a muck with 95% to 97% organic matter and pH 7.1. The major weed species present at application were: *Cassia obtusifolia* (L.) (5 to 10 cm), *Eupatorium capillifolium* (Lam.) Small (60 to 90 cm), *Cyperus esculentus* L. (10 to 15 cm), *Cynodon dactylon* (L. C. Rich.) Pers. (15 to 20 cm), and *Setaria* spp. Beauv. (30 to 60 cm).

In Palm Beach Gardens, the soil was a sand with 1.5% to 2.0% organic matter and pH 6.6. The major weed species present at application were: *Panicum repens* L. (10 to 20 cm), and *Brachiaria mutica* (Forsk.) Stapf (60 to 90 cm).

Visual ratings were taken at various times. AO to 100 rating scale was used where 0 = no effect and 100 = complete control (kill), with 85 considered commercially acceptable control. Control ratings are presented as the mean of four replications for each treatment.

Conifer Release

In 1982 Japanese field trials, postdirected applications of AC 252,925 were made to the base of Japanese black pine (*Pinus thunbergii* Parl.) and Japanese cypress (*Chamaecyparis obtusa* Sieb. and Zucc.). The trees were three years old and had been transplanted four months before the treatments were made. AC 252,925 was applied in a spray volume of 600L/ha. A 0.25% (w/v) nonionic surfactant was added to the spray solutions.

RESULTS AND DISCUSSION

Aquatic Weeds

Laboratory Studies. At 10 weeks after treatment (WAT), the free acid of AC 252,925 at 1.0 to 15.0 ppm provided 85% to 100% control of *H. verticillata*, a submersed species (Table 2). Concentrations as low as 0.5 ppm of the free acid provided 98% or greater control of *H. verticillata* at 12 WAT. *E. densa* (submersed species) and *S. polyrhiza* (floating species) were more sensitive to the herbicide than *H. verticillata* (Tables 3 and 4). At 6 WAT, 85% or greater control of both species was observed with 5.0 ppm, and at 8 WAT, 96% or greater control was provided by dosages as low as 0.5 ppm for *E. densa* and 1.0 ppm for *S. polyrhiza.*

Table 2. Effect of AC 252,925 on **H. verticillata** *in laboratory studies conducted in Florida, U.S.A., in 1981. Mean of three replications.*

Free Acid of AC 252,925 (ppm)	Per cent kill (WAT) (Weeks after treatment)					
	2	4	6	5	10	13
0.0	0	0	0	5	10	13
0.5	0	0	10	25	77	98
1.0	0	15	28	40	85	100
2.5	0	25	40	68	90	100
5.0	0	20	58	70	95	100
10.0	0	33	60	99	100	100

Table 3. Effect of AC 252,925 on **E. densa** *in laboratory studies conducted in Florida, U.S.A., 1981. Mean of three replications.*

Free Acid of AC 252,925 (ppm)	Per cent kill (Weeks after treatment)			
	2	4	6	8
0.5	10	40	74	98
1.0	12	50	80	97
2.5	10	55	80	100
5.0	10	60	85	100
10.0	15	65	90	100

Table 4. Effect of AC 252,925 on S. polyrhiza *in laboratory studies conducted in Florida, U.S.A. in 1981. Mean of three replications.*

Free Acid of AC 252,925 (ppm)	Per cent population reduction (Weeks after returnment) 2	4	6	8
0.0	0	10	18	27
0.5	0	35	50	65
1.0	0	48	75	96
2.5	0	60	83	100
5.0	10	67	90	100
10.0	10	70	98	100

The free acid of AC 252,925 was shown to be effective against *H. verticillata*, *E. densa*, and *S. polyrhiza* at dosages as low as 0.5 ppm in laboratory tests. At 0.5 ppm, the herbicide was slow acting and required 8 to 12 weeks from complete control of these weeds. This characteristic would prevent the rapid depletion of oxygen in the water due to rapid decomposition of the weeds.

Field Studies. Although signs of herbicidal activity of AC 252,925 and glyphosate were slow to appear on *E crassipes* by 87 days after treatment (D T) all herbicide treatments provided 100% control of this weed (Table 5). Essentially, no regrowth of *E. crassipes* occurred during the experimental period (196 days) in the AC 252,925 treatments, but 80% regrowth was observed in the glyphosate treatment as early as 119 DT. By the end of the study *E. crassipes* had completely regrown in the glyphosate treatment, while less than 3% regrowth had occurred in the plots treated with AC 252,925 at 0.125 kg/ha.

The effects of AC 252,925 and glyphosate on *P. stratiotes* were apparent as early as 11 D T. AC 252,925 at all levels tested gave 100% control of this weed at 46 D T (Table 6). In the glyphosate and 2, 4-D treatments, *P. stratiotes* had completely recovered by 46 D T. By the end of the experimental period (114 D T), no regrowth was observed in plots treated with 0.250 kg/ha AC 252,925 and above; with 0.125 kg/ha only 40% regrowth occurred.

Ditchbank Weeds

In South Bay, AC 252,925 at 0.56 kg/ha provided 10% to 66% control of *C. obtusifolia*, *E. capillifolium*, and *Paspalum urvillei* at 28 D T (Table 7). Control of *C. dactylon*, *Pennisetum purpureum*, and *Dactyloctenium aegyptium* (L.) Richt was 64% to 80% and for *Setaria* spp. and *Echinochloa walteri* Pursch) Hellar control was 63% to 71%. Glyphosate at 1.12 kg/ha provided 88% or better control of all weeds.

Table 5. Effect of postemergence applications of AC 252,925 on **E. crassipes** *in field studies conducted at CARFI Station, Calamba, Laguna, Philipines*

Compound	Dosage (kg / ha)	Per cent control (Weeks after treatment) 35	57	87	Per cent regrowth (DAT) 119	155	196
AC 252,925	0.125	60	60	100	0	2	
	0.250	70	70	100	0	<1	2
	0.50	80	90	100	0	0	0
	1.0	90	100	100	0	2	2
Glyphosate	1.0	40	40	100	80	87	93

Table 6. Effect of postmergence applications of AC 252,925 on P. stratiotes *in field studies conducted at CARFI Station, Calamba, Laguna, Philippines, 1981.*

Compound	Dosage (kg/ha)	Per cent control (Weeks after treatment) 11	46	Per cent regrowth (DAT) 78	114
AC 252,925	0.125	70	100	33	40
	0.25	80	100	0	0
	0.5	80	100	0	0
	1.0	90	100	0	0
Glyphosate	1.0	80	0	100	100
2,4-D ester	1.0	10	0	100	100

At 57 D T, AC 252,925 at 0.56 kg/ha provided 86% or greater control of all weed species, except **E. capillifolium** (70%). At 1.12 kg/ha control of *E. capillifolium* was 81%. Glyphosate at 3.36 kg/ha provided 85% or greater control of all weeds, except *C. dactylon* (75%) and *P. urvillei* (80%). Eighty-five per cent or greater control of both species was obtained with glyphosate at 5.6 kg/ha. AC 252,925 at 0.56 kg/ha provided 89% or greater control of all weeds at 112 D T with glyphosate at 5.6 kg/ha providing approximately 78% control of all species. AC 252,925 at 0.28 kg/ha provided 76% over all control.

At 27 D T, in Palm Beach Gardens, AC 252,925 at all dosage levels tested provided less than 70% weed control (Table 8). *B. mutica*, *P. repens*, *C. esculentus*, and *P. urvillei* were more resistant to AC 252,925 than *Portulaca oleracea* L. Glyphosate at 1.12 kg/ha provided 93% or better control of all weeds.

AT 57 D T, AC 252,925 at 0.56 kg/ha provided 86% or greater control of all species. With glyphosate a dosage of 5.6 kg/ha was required to obtain 83% or greater control of these weeds.

Table 7. Weed control ratings of several weed species treated with AC 252-925 in field studies conducted in South Bay, Florida, 1982.

Compound	Dosage (kg / ha)	Weed control (%) C.o.	E.c.	C.d.	P.u.	E.w.	S.s.	P.p.	D.a.
AT 28 days									
AC 252,925	1.12	70	18	71	60	63	71	70	80
	0.56	66	10	64	56	59	66	65	80
	0.28	59	18	50	54	63	64	60	76
	0.14	53	5	41	58	50	41	58	58
Glyphosate	5.60	100	100	96	100	100	100	100	100
	3.36	100	100	91	100	100	100	100	100
	1.12	91	91	88	100	100	100	100	100
AT 57 days									
AC 252,925	1.12	100	81	94	100	100	100	100	100
	0.56	96	70	86	97	91	94	86	95
	0.28	88	61	73	75	70	84	80	86
	0.14	59	20	40	67	60	60	64	65
Glyphosate	5.60	95	99	85	99	99	99	99	99
	3.36	85	90	75	80	89	85	90	99
	1.12	40	69	65	69	74	73	75	64
AT 112 days									
AC 252,925	1.12	98	91	95	99	100	99	98	100
	0.56	90	89	89	95	95	91	95	95
	0.28	80	66	71	84	81	80	84	81
	0.14	59	50	53	65	66	70	75	64
Glyphosate	5.60	76	79	76	76	73	75	75	75
	3.36	57	63	56	56	61	65	55	54
	1.12	50	59	40	46	50	54	46	45

C.o. — Cassia obtusifolia
E.c. — Eupatorium capillifolium
Cynodon dactylon
Paspalum urvillei
Echinochloa walteri
Setaria spp.
Pennisetum purpureum
Dactyloctenium aegyptium

Table 8. Weed control ratings of several weed species treated with AC 252,925 in field studies conducted at Palm Beach Garden, Florida, 1982.

Compound	Dosage (kg/ha)	Weed control (%) P.o.	B.m.	P.r.	C.e.	D.s.	P.u.
AT 27 days							
AC 252,925	1.12	70	59	60	68	60	65
	0.56	49	55	50	50	50	46
	0.28	45	50	50	49	48	49
	0.14	40	30	30	45	30	33
Glyphosate	5.60	100	100	100	100	100	100
	3.36	100	100	100	100	100	100
	1.12	95	93	95	95	95	95
AT 57 days							
AC 252,925	1.12	99	95	100	96	100	100
	0.56	90	90	100	86	95	95
	0.28	76	75	84	75	83	71
	0.14	45	39	50	40	61	41
Glyphosate	5.60	100	95	83	95	100	100
	3.36	75	69	75	75	81	79
	1.12	43	60	33	50	50	65
AT 102 days							
AC 252,925	1.12	90	89	91	80	90	89
	0.56	80	76	75	61	79	76
	0.28	61	60	60	46	59	70
	0.14	56	46	55	40	60	65
Glyphosate	5.60	91	95	84	80	93	96
	3.36	84	80	74	71	78	79
	1.12	60	75	54	46	56	69

P.o. — *Portulaca oleracea*
B.m. — *Brachiaria mutica*
P.R. — *Panicum repens*
C.s. — *Cyperus esculentus*
D.S. — *Digitaria* spp.
P.u. — *Paspalum urvillei*

At 102 DT, AC 252,925 at 1.12 kg/ha provided 89% or better control of all weeds, except *C. esculentus* where control was 80%. Glyphosate at 5.6 kg/ha provided similar control.

In summary, AC 252,925 demonstrated effectiveness against ditchbank weeds in two locations in Florida. In South Bay, 0.56 kg/ha AC 252,925 gave greater than 89% control of all species while 5.6 kg/ha glyphosate was required to provide the same control. A similar trend was seen in Palm Beach

Gardens, where 1.12 kg/ha AC 252,925 provided an over-all control of 88%, while 5.6 kg/ha glyphosate was required to provide 89% over-all weed control.

AC 252,925 activity was slow, with less than 80% control at 27 or 28 D T; however, at 102 and 112 D T, excellent control (>89%) of most weed species was obtained. In contrast, glyphosate provided 91% or greater control at 27 and 28 D T, but at 112 D T in South Bay 5.6 kg/ha provided less than 80% control. In Palm Beach Gardens, however, glyphosate at 5.6 kg/ha continued to provide at least 80% control.

Conifer Release

At four months after treatment (MAT) three-year-old Japanese black pine (Table 9) and Japanese cypress (Table 10) were tolerant to postdirected applications of AC 252,925 at dosages as high as 2.0 kg/ha applied either as a single treatment or as split treatments 40 days apart. No weed control efficacy data were collected in this trial; however, other studies in this area have shown that most weeds are controlled with AC 252,925 dosages of 0.75 to 1.5 kg/ha (Hasui *et al.*, 1983).

Table 9. Effect of single and split postdirected applications of AC 252,925 on Japanese black pine in field studies conducted at Tahara, Aich, Japan, 1982.

Treatment	Dosage (kg / ha)	Per cent phytotoxicity[1] (MAT)[2] 1	2	4	Height (% of untreated) 4 MAT	Shoot length (% of untreated) 4 MAT
SINGLE APPLICATION						
AC 252,925	2.0	3	7	7	98	91
	4.0	15	30	35	89	81
	8.0	13	35	45	88	75
SPLIT APPLICATION						
AC 252,925	0.5 + 0.5	3	7	7	94	96
	1.0 + 1.0	2	5	12	89	91
	2.0 + 2.0	0	12	20	94	86
	4.0 + 4.0	7	28	43	91	71
Untreated[4]		0	0	0	(49 cm)	(14 cm)

[1] *Expressed as inhibition of new growth and chlorosis of basal leaves.*
[2] *MAT = Months after single or first (split) application.*
[3] *Interval between first and second application was 40 days.*
[4] *Figures in parentheses indicate height and shoot length of the trees in the control plot at the end of the trial.*

Table 10. Effect of single and split postdirected applications of AC 252,925 on Japanese cypress in field studies conducted in Tahara, Aich, Japan, 1982.

Treatment	Dosage (kg / ha)	Per cent phytotoxicity[1] (MAT)[2] 1	2	4	Height (% of untreated)	Shoot length (% of untreated) 4 MAT
SINGLE APPLICATION						
AC 252,925	2.0	3	10	10	97	93
	4.0	23	33	28	94	99
	8.0	13	20	23	93	94
SPLIT APPLICATION[3]						
AC 252,925	0.5 + 0.5	7	·13	10	93	96
	1.0 + 1.0	0	3	2	98	104
	2.0 + 2.0	3	10	12	95	97
	4.0 +	10	20	23	93	95
Untreated4		0	0	0	(59 cm)	(21 cm)

1 Expressed as inhibition of new growth and chlorosis of basal leaves.

2 MAT = Months after single of first (split) application.

3 Interval between first and second application was 40 days.

4 Figures in parentheses indicate height and shoot length of the trees in the control plot at the end of the trial.

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AC 252,925, A NEW HERBICIDE FOR CONTROL OF PERENNIAL WEEDS IN JAPAN

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ABSTRACT

In field studies conducted in Japan from 1980 through 1982, AC 252,925 provided excellent long-term weed control on noncrop areas. The research efforts were directed primarily toward vegetation control such as is required on roadsides, ditch-banks, paddy dikes, fence rows, and industrial sites, and included test sites located at three different latitudes to evaluate the effect of temperature differentials on herbicidal activity. Optimum activity against perennial weeds followed treatments at early growth stages when the weather was warm (median temperature 22°C). Single application was compared with split (two applications at half rate each, applied 40 days apart), and results demonstrated that the split method enhanced efficacy two- to four-fold over a single treatment. Weed growth was arrested shortly after treatment, but weed kill was slow. The meristematic region of the weed was the first to be affected. Complete kill occurred in one to five months, depending upon weed species and temperature. Residual activity of AC 252,925 lasted for four to 12 months.

INTRODUCTION

Results of preliminary trials with AC 252,925 showed it to be a non-selective, broad-spectrum herbicide which is readily absorbed through both the foliage and the roots. It has provided excellent control of sedges and annual and perennial grasses and broadleaved weeds when applied either pre- or postemergence; however, postemergence application has been more effective.

The purpose of this study was to investigate the use of AC 252,925 for vegetation control in Japan, such as is required in rights-of-way along high-ways, railways, pipe and power lines, and at industrial sites. Some work was also undertaken to evaluate weed control on ditch-banks.

The objectives of these studies with AC 252,925 were to determine rates and timing of application by stages of growth of the target weeds and the duration of residual control following application.

MATERIALS AND METHODS

In 1981 field studies, herbicides were applied at a spray volume of 1000 liters/ha. All AC 252,925 treatments included a nonionic surfactant at 0.25% v/v a.i. In 1982 studies, the spray volume used was 600 liters/ha with 0.25% v/v a.i. nonionic surfactant added to the AC 252,925 treatments. Weed control was recorded on a per cent basis compared to the untreated checks, and control ratings were based on the means of three replications for each treatment. Glyphosate treatment was included in all tests as a standard for comparison.

Stage-of-growth studies to determine optimum application time were conducted with *Miscanthus sinensis* Anderss. and *Solidago altissima* L. or *S. gigantea* Ait., representative Japanese pernnial weeds, when they were 15, 30, and 60 cm tall. In 1982, AC 252,925 treatments were applied from late May to early June, and efficacy was evaluated two months after treatment.

Split application of AC 252,925 was studied in 1982. Target weeds and their heights were: *M. sinensis,* 30 to 40 cm; *S. altissima,* 15 cm; *Cyperus rotundus* L., 15 to 20 cm; *Pueraria lobata* Ohwi, 3 meters long; *Rumex japonicus* Houtt., 15 to 30 cm; and *Rumex obtusifolius* L., 15 to 20 cm. The interval between split treatments was 40 days. Efficacy was evaluated two to five months after the initial treatments and was compared with the results of a single application at the same total dosage.

Field studies to determine the weed control spectrum of AC 252,925 were conducted from 1980 through 1982 on irrigation canal beds, roadsides, paddy dikes, ditchbanks, and industrial sites in the cool area of Hokkaido, the moderately warm area of Tahara on Honshu, and the warm area of Oita on Kyushu (see Fig. 1). Median temperatures at these locations during the growing season were 16,22, and 24^{o}C, respectively. In Table 1, the perennial weed spectrum results from 20 studies in 1980 and 1981 are summarized.

RESULTS AND DISCUSSION

Stage-of-growth/application timing

A comparison of results obtained in the control of *M. sinensis* at test sites in Hokkaido, Tahara, and Oita is shown in Table 2. AC 252,925 was more effective in the warm area of Oita than in the cool area of Hokkaido. Stage of growth of the grass at application time was not a factor. AC 252,925 at 3 kg a.e./ha gave 96% to 97% control for all growth stages. In the intermediate temperature test location at Tahara, AC 252,925 was most effective when applied to grass at the 15-cm height. From these studies, it was concluded that application to *M. sinensis* at an early growth stage is the most suitable.

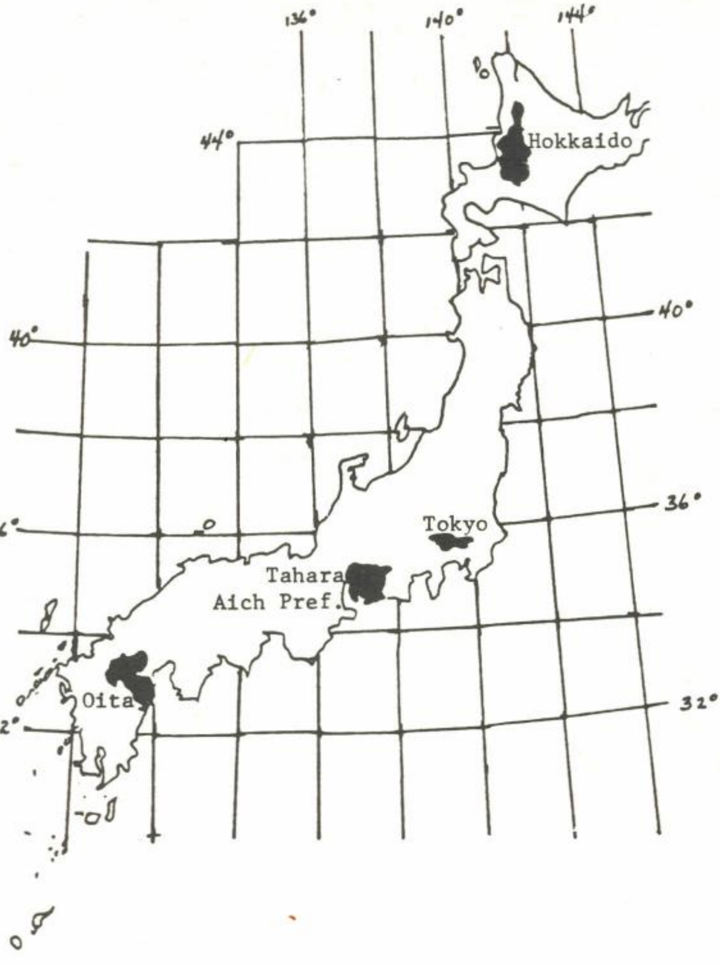

Fig. 1. Location of test sites in Japan where AC 252,925 was evaluated in 1981 and 1982. Sites in Hokkaido, the cool, northern zone, have an average year-round temperature of 8.0 °C, rainfall averages 1200 mm, snow is common, and the growing season is short, from late May through September. The Tahara sites in Aich Prefecture are in the moderate climatic zone, with year-round temperature averaging 15.5 °C, rainfall averaging 1700 mm, no snow, and a growing season that starts one month earlier than in Hokkaido. Oita Prefecture is in the southern zone with a semitropical climate, year-round temperatures averaging 15.6 °C, 1700 mm rainfall, no snow, and crops grown 9 to 12 months of the year.

Results from the same test sites in studies of control of *S. altissima* and *S. gigantea* are also included in Table 2. AC 252,925 provided better control of these weeds in the warmer areas of Oita and Tahara than in the cool area of Hokkaido. In the warmer areas, the size of the weeds at application made no difference in herbicidal efficacy; 94% to 100% control was obtained with 2 kg a.e./ha regardless of the growth stage. However, on cooler Hokkaido, best results against *S. gigantea,* followed application at the earliest growth stages. The 2 kg a.e./ha rate gave 95% control when applied at the 15-cm stage. From these studies, it was concluded that the most suitable application timing for *Solidago* spp. is at the early growth stage of the weed.

Table 1. Weed control spectrum of AC 252,925 after postemergence application (Japan, 1980-81).

Weed	Dosage (kg a.e./ha) for 90% control	Elapsed time for pronounced herbicidal effects (months)
HERBACEOUS PERENNIALS		
Grasses and sedges		
Agropyron repens	1.5	1
Bromus catharticus	0.75	2
Cyperus rotundus	1.5	1
Imperata cylindrica	1.5-2.0	2*
Miscanthus sinensis	1.0-2.0	2*
Phragmites communis	2.0-4.0	4*
Pteridophytes		
Equisetum arvense	3.0	1
Broadleaves		
Artemisia princeps	2.0 - 4.0	2*
A. montana	2.0 - 4.0	1*
Oenanthe javanica	1.0	1*
Oxalis corniculata	0.75	1
Petasites japonicus	2.0	2*
Phytolacca americana	4.0	1
Plantago asiatica	1.5	2*
Rumex acetosa	2.0 - 4.0	1
R. japonicus	2.0 - 4.0	2*
R. obtusifolius	1.5 - 3.0	1*
Solidago altissima	0.75 - 1.0	2*
Trifolium pratense	4.0	
WOODY PERENNIALS		
Akebia quinata	3.0	2*
Ampelopsis brevipedunculata	1.5	1*
Cyratia japonica	0.75	1*
Paederia scandens	3.0	1*
Parthenocissus tricuspidata	1.5	2*
Pittosporum tobira	3.0	2*

*An asterisk indicates that weeds were controlled for 12 months.

Split versus single application method

A summary of comparative results between single and split applications for control of various weeds is presented in Table 3.

Efficacy of split applications of AC 252,925 for control of *M. sinensis* was tested at Tahara and Oita. At Oita, 0.375 followed by 0.375 or 0.25 followed by 0.5 kg a.e./ha provided nearly full control of *M. sinensis* five months after the initial treatment; the results were equal to those following a single application at 1.5 kg a.e./ha. At Tahara, the same rates against *M. sinensis* gave poor control two months after application; but, after four months, control ranged between 82% and 85% and efficacy was still increasing at the last observation date for the rest. It is concluded from these results that AC 252,925 is two times more efficacious against *M. sinensis* by split dosages than by a single treatment at twice the rate.

Table 2. Timing of application of AC 252,925 to stage of growth of selected perennials for optimum control in three different temperature zones in Japan.

Weed	Optimum application timing at location		
	Oita (Warm)	Tahara (Moderate)	Hokkaido (Cool)
Miscanthus sinensis	No difference between 15-60 cm tall	15 cm	No difference between 15-60 cm tall
Solidago altissima	No difference	No difference	Early growth stage
S. gigantea	15 cm to flowering	15 cm to flowering	$<$15 cm tall

The results of split applications against *S. altissima* from test sites in Hokkaido, Tahara, and Oita are summarized in Table 3. At Hokkaido and Tahara, evaluations were made two and four months after initial treatments. At Oita, results were evaluated at three and five months. The efficacy of AC 252,925 against *S. altissima* was greater at the four- or five-month observations than at two or three months after initial treatment. This was particularly evident in the cool area of Hokkaido. At the later observation dates, split dosages of 0.375 followed by 0.375, 0.25 followed by 0.5, or 0.5 followed by 0.5 kg a.e./ha gave 90% to 98% control in all locations and were equal to a single dosage of 1.5 kg a.e./ha. From these results, it was concluded that for control of *S. altissima* split applications of AC 252,925 were twice as effective as single treatments at double the rate.

Split application of AC 252,925 for control of *C. rotundus* was tested at Oita. Doses of 0.375 followed by 0.375 or 0.5 followed by 0.25 kg a.e./ha gave 97% and 96% control, respectively. Split treatments were equal to a single application of 2 kg a.e./ha three months after the initial treatments. It was concluded from these results that split application enhanced AC 242,925 activity more than two-fold compared to a single dosage of 2 kg a.e./ha.

In tests at Oita to evaluate control of *Pueraria lobata,* the efficacy of AC 252,925 was much enhanced by split application compared to a single application (Table 3). Dosages of 0.75 followed by 0.75 or 0.5 followed by 1.0 kg a.e./ha gave 97% control five months after initial treatment. This was better than a single treatment at 4 kg a.e./ha.

Table 3. Comparison of single versus split dosages of AC 252,925 required for 90 + % control of listed weeds. The interval between split applications was 40 days.

Lowest dosage (kg a.e./ha) tested for 90+% control				
Single application	Split	(Total split)	Weeds controlled	Test location
1.5	0.375/0.375	(0.75)	*Miscanthus sinensis*	Tahara & Oita
			Solidago altissima	Hokkaido, Tahara, & Oita
2.0	0.25/0.25	(0.5)	*Rumex japonicus*	Oita
			R. obtusifolius	Hokkaido
2.0	0.375/0.375	(0.75)	*Cyperus rotundus*	Oita
4.0	0.75/0.75	(1.5)	*Pueraria lobata*	Oita

Three months after initial treatment of *R. japonicus* at Oita with split applications of 0.25 followed by 0.25 or 0.375 followed by 0.375 kg a.e./ha, control was 96%, the treated mother plants were completely killed two months after the initial treatments; however, at three months, new growth from germinating seeds of *R. japonicus* was observed and this accounts for the 4% reduction from full control. In the mother plants treated with the single dosages of 1 or 2 kg a.e./ha some regrowth occurred.

Control of *R. obtusifolius* was evaluated at Hokkaido. Split applications of 0.25 followed by 0.25, 0.375 followed by 0.375, and 0.75 followed by 0.75 kg a.e./ha gave 90% to 97% control three months after the initial treatments. In the single treatment plots of 1 and 2 kg a.e./ha, regrowth was observed.

Suitability to various noncrop, vegetation control situations

AC 252,925 was tested for vegetation control on irrigation canal beds, along roadsides, on an industrial site, on paddy dikes, and along a ditch bank to evaluate its suitability as an herbicide in various noncrop situations. In trials on irrigation canal beds at Tahara in 1981 (Table 4), the target weeds were the perennial grass *Phragmites communis* Trin.; the perennial broadleaved weeds *Artemisia princips Pampan., Rumex japonicus,* and *Oenanthe javanica* DC.; and the annual weeds *Agropyron tsukushiense* Ohwi and *Commelina communis* L. All treatments of AC 252,925, which ranged from 1 to 4 kg a.e./ha, gave total vegetaion control four months after application. Control of initial weed infestations was maintained for 12 months; however, new annuals germinated from seed after the fourth month. No soil erosion was observed on the treated areas.

Results from trials on roadsides near Oita in 1981 are summarized in Table 5. The target weeds were the perennial grasses *M. sinensis* and *Imperata cylindrica* (L.) Beauv., the perennial vine *P. lobata,* and the perennial broadleaved weed *A. princeps.* At 1.5 to 3 kg a.e./ha, AC 252,925 gave total vegetation control four months after treatment and control of initial perennial weed infestations was maintained for 12 months. Several annual weeds germinated from seed after the fourth month, however, no soil erosion was observed.

Table 4. Percent weed control along an irrigation canal four months after postemergence treatment with AC 252,925 (Tahara 1981). A nonionic surfactant at 0.25% v/v a.i. was added to all AC 252,925 treatments. Herbicides were applied on 21 May 1981 when weed height ranged between 30 and 90 cm. Figures in parentheses indicate height (in cm) of weeds in control plot at end of trial.

		Weed control (%)					
Herbicide	Rate (kg a.e./ha)	*Phragmites communis*	*Artemisia tsukushiense*	*A. princeps*	*Rumex japonicus*	*Commelina communis*	*Oenanthe javanica*
AC 252,925	1.0	95 ·	100	100	100	100	100
	2.0	90	100	100	100	100	100
	4.0	94	100	100	100	100	100
Glyphosate	4.8	91	100	100	100	0	100
Untreated		(100)	(48)	(138)	(33)	(109)	(15)

Table 5. Percent roadside weed control four months after postemergence application of AC 252,925 (Oita, 1981). A nonionic surfactant at 0.25% v/v a.i. was added to all AC 252,925 treatments. herbicides were applied on 26 May 1981, when weeds were full grown and at the flowering stage. The herbicidal effects were assessed four months later.

		Weed control (%)			
Herbicide	Rate (kg a.e./ha)	*Imperata cylindrica*	*Miscanthus sinensis*	*Pueraria lobata*	*Artemisia princeps*
AC 252,925	0.75	97	88	75	100
	1.7	98	92	96	100
	3.0	99	94	94	1000
Glyphosate	4.8	89	99	99	100

Table 6 contains the results from a trial on an industrial site at Tahara in 1981. The target weeds were the perennial grasses *I. cylindrica* and *Andropogon virginicus* L. and the perennial broadleaved weeds *S. altissima* and *A. princeps.* AC 252,925 at 1.5 kg a.e./ha gave 100% vegetation control from two months after treatment through the eighth month, at which time the experiment was terminated.

In Table 7 the results from evaluations on paddy dikes at Oita in 1982 are presented. The target weeds were the perennial grasses *M. sinensis* and *I. cylindrica,* the perennial broadleaved weed *Artemisia princeps,* the perennial horsetail species *Equisetum arvense* L., and the annual broadleaved weed *Erigeron annuus* L. AC 252,925 at 1 kg a.e./ha in a single application gave good control of the target weeds three months after treatment. In the case of

M. sinensis split application of 0.25 followed by 0.25 kg. a.e./ha gave control equal to a single application of 1 kg. The weeds were 30 cm tall at treatment and no increase in height followed application of the herbicide. No phytotoxicity was observed on paddy rice located one meter from the downside of the treated plots.

Table 6. Percent weed control at an industrial site eight months after post-emergence application of AC 252,925 (Tahara, 1981). A nonionic surfactant at 0.25% v/v a.i. was added to all AC 252,925 treatments. Herbicides were applied on 27 August 1981 when weed height ranged between 30 and 40 cm. Figures in parentheses indicate height (in cm) of weeds in the control plot at the end of the trial.

Herbicide	Rate (kg a.e./ha)	Weed control (%) *Imperata cylindrica*	*Andropogon virginicus*	*Solidago altissima*	*Artemisia princeps*
AC 252,925	0.75	96	98	100	100
	1.7	100	100	100	100
	3.0	100	100	–	100
Glyphosate	4.8	60	100	–	100
Untreated	–	(40)	(25)	(40)	(5)

The results in Hokkaido in 1982 for a ditchbank trial are summarized in Table 8. The target weeds were the perennial broadleaves *Trifolium repens* L. and *Taraxacum officinale* Weber., the perennial grasses *Agropyron repens* (L.) Beauv. and *Poa pratensis* L., and the perennial horsetail *E. arvense.* A single treatment of AC 252,925 at 0.75 kg a.e./ha or a split treatment of 0.25 followed by 0.25 kg a.e./ha when the weeds were 20 to 30 cm tall gave good control three months after treatment. Even though control was slow, no further growth occurred after either method of application.

Weed spectrum

Table 1 contains a list of the herbaceous and woody perennials controlled by AC 252,925, the dosage required to give 90% or better control, and the period between application of AC 252,925 and evidence of weed control. AC 252,925 required from one to five months to achieve effective control, depending upon the weed species. Effective control was achieved on the 25 species listed, and residual activity against 17 of the species lasted for 12 months.

Optimum efficacy follows application of AC 252,925 at early growth stages of the weeds under warm temperature conditions.

Table 7. Percent weed control on paddy dikes three months after single or split postemergence application of AC 252,925 (Oita, 1982). A nonionic surfactant at 0.25% v/v a.i. was added to all AC 252,925 treatments. Herbicides were applied on 3 June 1982 when weed height was 30 cm. The interval between split applications was 40 days. Figures in parentheses indicate height (cm) of weeds in control plot at the end of the trial.

Herbicide	Rate (kg a.e./ha)	Weed Control (%) *Miscanthus sinensis*	*Imperata cylindrica*	*Artemisia princeps*	*Equisetum arvense*	*Erigon annuus*	Phytotoxicity (%) in paddy rice 1 m from treated area
Single Application							
AC 252,925	0.5	55	91	85	100	98	0
	0.75	79	96	99	99	100	0
	1.0	86	98	99	100	100	0
Split application							
AC 252,925	0.25/0.25	87	95	92	100	100	0
	0.375/0.375	94	97	92	97	97	0
	0.5/0.5	96	97	96	100	77	0
Treated Control							
Glyphosate	3.6	74	69	30	98	83	0
Untreated	–	(196)	(96)	(76)	(25)	(10)	0

Table 8. Percent ditchbank weed control three months after postemergence application of AC 252,925 (Hokkaido, 1982). A nonionic surfactant at 0.25% v/v a.i. was added to all AC 252,925 treatments. Herbicides were applied on 31 July 1982 when weed height ranged between 20 and 30 cm. The interval between split applications was 40 days. Figures in parentheses indicate height (in cm) of weeds in the control plot at the end of the trial.

Herbicide	Rate (kg a.e./ha)	Weed Control (%)				
		Equisetum arvense	*Trifolium repens*	*Taraxacum officinale*	*Agropyron repens*	*Poa pratensis*
Single Application						
AC 252,925	0.5	77	90	33	87	60
	0.75	82	97	67	90	87
	1.0	83	100	73	93	93
Split application						
AC 252,925	0.25/0.25	77	100	80	93	92
	0.35/0.375	80	100	73	100	90
	0.5/0.5	85	100	87	95	100
Treated control						
Glyphosate	4.8	67	53	13	70	80
Untreated		(33)	(13)	(22)	(28)	(38)

Split applications enhance the weed control two- to four-fold, compared to a single application.

AC 252,925 is suitable for weed control on irrigation canal banks, roadsides, paddy dikes, and industrial sites in Japan.

FIELD STUDIES ON AC 252,214 – A NEW BROAD SPECTRUM HERBICIDE FOR SOYBEANS

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ABSTRACT

3-Quinolinecarboxylic acid, 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl) — being developed under the code number AC 252,214, is a new selective soybean herbicide which can be applied as a preplant incorporated, preemergence or early postemergence treatment. Broadleaved weeds are the major species controlled by AC 252,214 although many important grasses, such as foxtails (*Setaria* spp.) are also controlled. AC 252,214 is absorbed by the foliage and roots of plants and translocated via both the xylem and phloem. A nonionic surfactant is necessary for optimal postemergence activity.

INTRODUCTION

3-Quinolinecarboxylic acid, 2-(4-isoproplyl-4-methyl-5-oxo-2-imidazolin-2-yl)-acid is a new broad-spectrum herbicide being developed under the code number AC 252,214 by American Cyanamid Company for use in soybeans (*Glycine max* L.). It is also being tested for use in a variety of other crops including tobacco (*Nicotiana tabacum* L.) and coffee (*Coffea arabica* L.), and for non-crop uses (American Cyanamid Company, 1982).

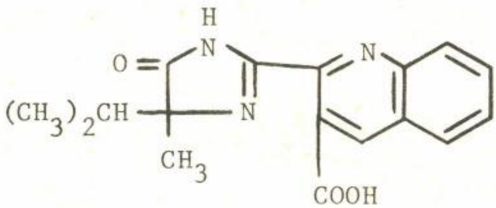
Results of laboratory studies have shown that AC 252,214 is absorbed by the foliage and roots of plants and is translocated via both the xylem and phloem (Orwick *et al.*, 1983; Shner *et al.*, 1983; Umeda *et al.*, 1983).

AC 252,214 has been field tested since 1981 in the United States and Brazil. Testing has been extended to numerous other countries including Canada, Japan, Argentina, and the Philippines. This herbicide shows broadleaved, sedge and grass weed activity and will control many annuals and some perennial species (American Cyanamid Company, 1982; Martin, 1983).

CHEMICAL AND PHYSICAL PROPERTIES

Chemical Name and Structure

3-Quinolinecarboxylic acid, 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)-CA



Molecular formula: $C_{17}H_{17}O_3N_3$
Molecular weight: 311.3

AC 252,214 is a white odorless solid with a melting point of 219-222°C. Solubility in distilled water is 60 mg/1 at 25°C. The octanol/water partition coefficient is 2.5.

Toxicology

The results of toxicity tests to date are summarized in Table 1.

Table 1. Mammalian toxicity of AC 252,214 technical.

Test	Animal	Value/Result
Acute oral LD_{50}	Rat	> 5,000 mg/kg body weight
Acute dermal LD_{50}	Rabbit	> 2,000 mg/kg body weight
Eye irritation	Rabbit	Nonirritating
Skin irritation	Rabbit	Mildly irritating
28-day feeding: no-effect level	Rat	> 10,000 mg/kg diet

Mutagenicity

Ac 252,214 is nonmutagenic as determined by the Ames test (Ames *et al.*, 1975).

Rat metabolism

Parent compound was excreted rapidly from rats dosed with ^{14}C-labeled AC 252,214. No significant residues were found in tissues or blood.

MATERIALS AND METHODS

Herbicides were applied with knap-sack or tractor mounted CO_2 sprayers in small-plot replicated field trials on soybeans in the U.S. and Brazil. Spray volume ranged from 150 to 300 1/ha. Trials were conducted over a wide range of soil types and climatic conditions. All ratings are based on percent control of individual weed species as compared to untreated control plots. Crop injury ratings and final yields were also taken.

Formulations of ACT 252,214 tested aqueous solutions and dry flowables.

Applications were made preplant incorporated (PPI), preemergence (PRE) and early postemergence (EPOST). Incorporation was made with several different types of equipment to depths ranging from 3 to 10 cm. AC 252,214 was applied EPOST from the 1st to 3rd trifoliate stage of the soybeans and treatments included a nonionic surfactant at the rate of 0.25% w/v a.i. in the spray solution.

RESULTS

Weed susceptibility

PPI and PRE applications of AC 252,214 consistently provided good to excellent (85-100%) control of a wide variety of broadleaved and grass weeds in the United States (Table 2 to 4) and Brazil (Table 4). Although AC 252,214 will control a number of important grass species, broadleaved weed species in general tend to be more susceptible.

Table 2. Weed control and soybean yield from preplant incorporated AC 252,214, 6 to 8 WAT. Means from U.S. field trials in 1982.

	% Control			
	AC 252,214			Alachlor + Metribuzin
Species	0.56	0.28	0.14	Use Rate
Amaranthus retroflexus	100	100	99	77
Abutilon theophrasti	92	88	77	82
Polygonum spp.	100	99	96	82
Xanthium pensylvanicum	96	86	78	50
Zea mays	100	99	91	7
Setaria faberi	95	93	81	84
		Yield (kg/ha)		
Glycine max (Example from test at Fowler, IN, U.S.A)	3226	3226	2890	2688

Table 3. Weed control and soybean yield from preemergence AC 252,214, 6 to 10 WAT. Means from U.S. field trials, 1981 and 1982.

Species	% Control			
	AC 252,214			Alachlor + Metribuzin
	0.56	0.28	0.14	Use Rate
Amaranthus retroflexus	97	95	100	—
Xanthium pensylvanicum	99	96	58	—
Sida spinosa	97	88	73	—
Ipomoea spp.	87	80	44	—
Echinochloa crus-galli	91	85	40	28
Bracharia platyphilla	90	84	35	35
Digitaria ishmaeum	93	85	77	95
Eleucine indica	98	92	77	97
	Yield (kg/ha)			
Glycine max (Example from test at Cheneyville, LA, U.S.A)	3494	3629	3629	3360

Table 4. Weeds susceptible to PPI and PRE applications of AC 252,214 at rates of 125 to 250 g a.i./ha. Data taken from U.S. and Brazilian field trials, 1981 and 1982.

Broadleaved Weeds		
	Abutilon theophrasti	*Helianthus annuus*
	Acanthospermum australe	*Ipomoea* spp.
	Amaranthus spp.	*Polygonum persicaria*
	Bidens pilosa	*Portulaca oleracea*
	Borreria alata	*Sida rhombifoia*
	Chenopodium album	*Sida spinosa*
	Euphorbia heterophylla	*Xanthium pensylvanicum*
Grass Weeds		
	Brachiaria platyphylla	*Eriochloa villosa*
	Digitaria ciliaris	*Setaria* spp.
	Digitaria ischaemum	*Sorghum bicolor*
	Echinochloa crus-galli	*Sorghum halepense*
	Eleusine indica	*Zea mays*
Other Weeds		
	Commelina spp.	*Cyperus esculentus*

In Brazil, preemergence treatments were slightly superior to preplant incorporated treatments for broadleaved weed control.

AC 252,214 has shown excellent season long residual control of susceptible weeds. In a Brazilian delayed planting trial, AC 252,214 provided excellent weed control until the latest delayed planting time of 28 days after treatment. Total rainfall during the delay period (28 days) was 294 mm.

Early postemergence application of AC 252,214 also controlled a wide variety of weeds (Tables 5 and 6), with broadleaved weeds being more susceptible than grass weeds. Both broadleaved and grass weeds are most susceptible to AC 252,214 from emergence through the two-leaf stage. In general, broadleaved weeds treated beyond the 3-leaf stage are stunted and offer little competition to the crop. A notable exception in the United States is *Xanthium pensylvanicum Wallr.* which can be controlled at heights up to at least 76 cm.

Table 5. Weed control and soybean yield from postemergence AC 252,214 applied 1st to 3rd trifoliate, 4 to 8 WAT. Means from U.S. field trials, 1981 and 1982.

	% Control			
	AC 252,214			Acifluorfen
Species	0.56	0.28	0.14	Use Rate
Amaranthus retroflexus	96	90	84	82
Xanthium pensylvanicum	100	98	95	65
Ipomoea spp.	90	89	94	67
Cassia obtusifolia	97	84	72	50
Ambrosia artemisiifolia	97	94	96	50
Zea mays	99	96	96	—
Setaria faberi	92	81	61	53
	Yield (kg/ha)			
Glycine max (Example from test at Pine Bluff, AR, U.S.A.)	1882	1814	2016	1277

Crop Selectivity

Selectivity in soybeans. In general, soybeans show good tolerance to PPI, PRE and EPOST treatments of AC 252,214 at rates up to 500 g ai/ha. Some temporary dwarfing has been observed at rates of 250 to 500 g ai; however, there has been no adverse effect on yields (Tables 2, 3 and 5).

Selectivity in other crops. In early testing, several crops other than soybeans have shown some tolerance to AC 252,214. These are: tobacco *(Nicotina tabacum)* (POST), snapbeans *(Phaseolus vulgaris)* (PRE), English peas *(Pisum sativum)* (PRE), dormant alfalfa *(Medicago sativa)* (POST), and hardwood trees (POST).

Table 6. Weeds susceptible to early postemergence applications of AC 252, 214 at rates of 125 to 250 g a.i./ha. Data taken from U.S. and Brazilian field trials, 1981 and 1982.

Broadleaved Weeds	
Acanthospermum australe	*Hibiscus trionum*
Acanthospermum hispidum	*Ipomoea* spp.
Amaranthus spp.	*Mollugo verticillata*
Ambrosia artemisiifolia	*Polygonum pensylvanicum*
Bidens pilosa	*Polygonum persicaria*
Casia obtusifolia	*Sida rhombifolia*
Chenopodium album	*Sida spinosa*
Euphorbia heterophylla	*Suckleya suckleyana*
Helianthus annuus	*Santhium pensylvanicum*
Grass Weeds	
Digitaria ciliaris	*Setaria faberi*
Echinochloa crus-galli	*Sorghum halepense*
Oryza sativa	*Zea mays*
Other Weeds	
Commelina spp.	

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PLANT GROWTH REGULATING OF ETHYL 2-N-ARYLAMINOPROPIONATES

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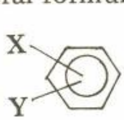
ABSTRACT

Twenty-eight derivatives of ethyl-2-N-arylaminopropionate were synthesized and tested for plant growth regulating activities on some species. The results on structure-activity relationships are reported.

INTRODUCTION

Many compounds were synthesized from ethyl 2-bromopropionate and substituted anilines.

General formula was as follows:



-NH CH(CH_3) COO C_2H_5 X, Y: H, CH_3, C_2H_5, i-pr, t-Bu, -O CH_3, -OC_2H_5, Cl Bu

We discuss herein their herbicidal and plant growth regulating activities on several kinds of plants and their structure-activity relationships.

MATERIALS AND METHODS

We synthesized the following ethyl 2-N-arylaminopropionates from substituted anilines and ethyl 2-bromopropionate.

(1) Substituted anilines with halogen groups were as follows 2-chloro, 3-chloro, 4-chloro, 2,3-dichloro, 2,3-dichloro, 2,5-dichloro, 2,6-dichloro, 3,4-dichloro, 35,dichloro, and 3-chloro 4-fluoro aniline.

(2) Substituted anilines with alkyl and alkoxy groups were as follows: 2-methyl, 3-methyl, 4-methyl, 2,3-dimethyl, 2,4-dimethyl, 2,5-dimethyl, 2,6-dimethyl, 3,4-dimethyl, 3,5-dimethyl, 2-methoxy, 3-methoxy, 4-methoxy, 2-ethoxy, 3-ethoxy and 4-ethoxy aniline.

(3) Another group of anilines were 2, 6-di-isopropyl, 4-dimethyl amino, 4-tert-butyl and non substituted aniline.

The structures of these ethyl 2-N-aryl amino propionates were confirmed by m.p., b.p., IR. and NMR.

We examined root elongation of rice and cucumber in vitro tests for the plant growth regulating activities and also examined Lamina joint test and Raphanus test for hormonal action at 0, 20 and 100 ppm concentration.

To prevent the growth of new shoots on *Citrus japonica*, 2000 and 5000 ppm of the chemicals were sprayed at the green fruit stage. Effects on preventing shoots on *citrus japonica* was observed. Observations were taken after 4 months.

Table 1. Activity of the different ethyl-2-N-arylaminopropionates

Groups	Chemicals			Root elongation		Lamina	Raphanus
	No	X	Y	Rice	Cucumber	Joint Test	Test
	2	2-Cl	H	h	h	h	h
	3	3-Cl	H	h	m	h	h
(a)	4	4-Cl	H	h	m	h	h
	6	2-Cl	4-Cl	m	h	h	h
	1	H	H	m	m	m	m
	7	2-Cl	5-Cl	h	h	h	m
(b)	11	2-Me	H	m	m	h	m
	12	3-Me	H	m	l	h	m
		3-Cl	4-F	h	h	m	h
(c)		2.4-D		h	h	m	h

Remarks

(a) Chemicals showed high auxin activity

(b) High auxin activity but the activity in Raphanus Test was not so high.

(c) Reference

h : high activity
m : medium activity
l : low activity

RESULTS AND DISCUSSION

Differences in activity were found among the substituted groups of aniline. The groups can be divided as follows:

(a) Inhibiting activity on the root elongation of rice seedling and the auxin activity in Lamina joint test was very high. 2-chloro, 3-chloro, 4-chloro, 2.4-dichloro, 3.4-dichloro, 3-chloro, 4-fluoro.

(b) Auxin activity was very high, but the activity in Raphanus test was low.
non-substituted, 2-methyl, 3-methyl, 2.5-dichloro.

(c) A strong effect for preventing the new shoosts on *Citrus japonica* was observed.
3-chloro-4-fluoro, 3-methyl, 3-methoxy.

(d) No activity was observed in monosubstitutions with methoxy and ethoxy.

(e) Other substituted compounds showed low activities in these tests.

THE INFLUENCE OF NITROGEN, DIURON AND AMETRYNE ON THE NITRATE STATUS OF PAPAYA FRUIT

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ABSTRACT

Diuron and ametryne were applied at 2 and 4 kg/ha on papaya trees fertilized with 20 and 40 g N/tree/application.

Mature-green and cannery-ripe fruits were harvested simultaneously and analyzed for NO_3-N in the exocarp (skin), mesocarp (flesh), and endocarp (placental wall).

NO_3-N was significantly increased by nitrogen fertilizer in the mature-green fruit exocarp and mesocarp only. The herbicides did not affect NO_3-N content in these tissues.

The mature-green fruit contained 15 to 23 times more NO_3-N than the cannery-ripe fruit suggesting a "climacteric-type" NO_3-N reduction during fruit ripening.

INTRODUCTION

Papaya is one of the exotic tropical fruits which is canned in the Philippines for export. It forms part of a special pack called "Tropical Fruit Salad" exported to Europe and North America.

Unfortunately, it was observed both here and abroad that papaya fruit accumulates nitrate (Kruger and Menary, 1968a; 1968b; Menary and Jones, 1971; 1974; Lucas et al., 1979). The tendency of papaya fruit to accumulate nitrate at the canning stage of ripeness is affected by climatic changes and fertilization practices. Cool weather and high cloud cover which usually prevail in elevated or mountainous areas are claimed to favor nitrate accumulation in papaya. This is aggravated by the application of high rates of nitrogen to attain high yields.

High nitrate in the papaya fruit for canning is undesirable because it causes oxidation of the interiors of the tin containers, leading to discoloration and rapid deterioration of the product. Also, the presence of large amounts of nitrate in processed (or raw) food is said to cause methemoglobinemia in infants.

To improve the competitive position of the industry the use of other improved cultural management practices like chemical control of weeds is imperative. Photosynthetic-inhibitor herbicides like diuron [(2-ethylamino)-4-(isopropylamino-6-(methylthio)-S-trizine)] have been found very effective in controlling annual weeds in papaya plantings in Hawaii (Romanowski, *et al.*, 1972). These herbicides which are potent inhibitors of photosynthesis have been demonstrated to adversely affect nitrate reduction in many annual plants (Klepper, 1974; Finke *et al.*, 1977; Churchill and Klepper, 1979). It is possible then that if these herbicides are used to control weeds in papaya fields, they may predispose papaya to accumulate nitrate in their fruit, especially under a high nitrogen fertilization regime. The quality of the canned product may thus be adversely affected.

MATERIALS AND METHODS

Mature-green and cannery-ripe fruit were harvested from trees which received the following treatments:

Nitrogen levels (Main Plots):
- a) 20 g N/tree/application
- b) 40 g N/tree/application

Herbicide rates (sub-plots):
1) Control (hand-weeded check)
2) Diuron, 2 kg/ha/application
3) Diuron, 4 kg/ha/application
4) Ametryne, 2 kg/ha/application
5) Ametryne, 4 kg/ha/application

The plots were arranged in a 2 x 5 split-plot, replicated 4 times.

The fruit was cut longitudinally into 8 sections and the exocarp (skin), mesocarp (flesh), and endocarp (placental wall) separated for NO_3-N analysis. The tissue samples were cut into 5 x 5 mm. sizes and homogenized in distilled water. The homogenate was filtered and diluted to contain 1-4 ppm NO_3-H. NO_3-N was analyzed using the diphenylbenzidine method of Iwamoto (1968).

RESULTS

NO_3-N Content of Mature-Green Fruit

Exocarp (Skin).. Ametryne and diuron slightly increased the level of NO_3-N in the skin of mature-green fruit of trees fertilized with 40 g N/tree. However, when the trees were fertilized with 20 g N/tree, ametryne and diuron tended to decrease the NO_3-N concentration in the fruit skin (Table 1). None of the differences between the herbicide treatment means were, however, statistically significant.

The rate of nitrogen fertilizer application was observed to have a more profound effect on NO_3-N accumulation in the fruit's skin than that of herbicides. For instance, when no herbicide was applied, the trees which received 20 g N/tree contained 80 ppm NO_3-N in the fruit exocarp, but the trees receiving 40 g N/tree increased the average NO_3-N in the fruit exocarp from 69.8 to 115.2 ppm (Table 1).

Table 1. NO_3-N concentration (ppm, oven-dry weight basis) in the exocarp, mesocarp, and endocarp of mature-green fruit of papaya as affected by nitrogen, diuron, and ametryne.

Herbicide Treatment (kg ai/ha)		Exocarp			Mesocarp			Endocarp		
		N1	N2	Mean	N1	N2	Mean	N1	N2	Mean
Control		80.0	109.5	94.8	323.0	400.5	361.8	24.5	23.8	24.1
Diuron, 2 kg		66.2	129.2	97.8	335.5	416.5	375.9	27.5	27.2	27.4
Diuron, 4 kg		65.0	111.2	88.1	383.0	412.8	397.9	28.5	36.0	32.2
Ametryne, 2 kg		70.0	109.8	89.9	366.2	405.0	385.6	32.0	19.5	25.8
Ametryne, 4 kg		67.5	116.2	91.9	327.8	422.5	375.1	26.0	28.2	27.1
	Mean:	69.8	115.2		347.1	411.4		27.7	26.9	
Hsd:										
a) Between N levels:										
	0.05		24.9		56.5		N.S.			
	0.01		N.S.		N.S.		—			
b)	Between Herbicide Treatments:									
	0.05		N.S.		N.S.		N.S.			
c)	N level x herbicide treatments:									
	0.05		N.S.		N.S.		N.S.			

N1 = 20 g N/TREE/APPLICATION: N2 = 40g N/TREE/APPLICATION.

These findings on the effect of nitrogen fertilizers on nitrate accumulation in papaya fruit exocarp were in conformity with the observattions made in Australia on papaya by Kruger and Menary (1968a; 1968b) and again in later studies by Menary and Jones (1971; 1974) and on vegetables (Maynard and Barker, 1972; Cantliffe, 1972; Maynard, et al., 1976).

Mesocarp (Flesh). The herbicides tended to trigger NO_3-N accumulation in the flesh of mature-green papaya fruit, regardless of nitrogen fertilization rate. In general, trees treated with diuron at 2 and 4 kg/ha tended to accumulate more NO_3-N in their fruit flesh by an average of 14.1 and 36.1 ppm, respectively, compared to the untreated trees. Trees treated with ametryne at 2 and 4 kg/ha had 23.8 and 13.3 ppm more NO_3-N, respectively, than the untreated trees. However, the differences between the NO_3-N levels in the herbicide treated and untreated plots were not statistically significant (Table 1).

In general, the higher rate of nitrogen fertilization (40 g N/tree) caused a significant build-up of NO_3-N in these fruit mesocarp from 347 to 411 ppm. This trend was more or less the same as that found in the fruit exocarp, i.e. the build-up of NO_3-N in these fruit tissues was mainly due to nitrogen fertilizer applied, and only to a less magnitude to the herbicides used.

Endocarp. None of the herbicides had any marked influence on the NO_3-N accumulation in the placental wall (endocarp). Likewise, increasing the nitrogen fertilizer did not cause any build-up of NO_3-N in this tissue (Table 1).

NO_3-N Content of Cannery-Ripe Fruit

Exocarp. The concentration of NO_3-N in the fruit skin was significantly increased by the application of more nitrogen, especially when diuron or ametryne were applied at 4 kg/ha. For instance, it was found that the fruit exocarp contained only 18.5 to 23.2 ppm NO_3-N when herbicides were not applied. When diuron and ametryne were used at 4 kg /ha on trees fertilized with 40 g N/tree, the fruit skin contained 38.5 ppm and 47.2 ppm NO_3-N, respectively (Table 2). The data suggest a synergistic effect between the herbicides and nitrogen fertilizer in triggering the build up of NO_3-N in the fruit exocarp.

Table 2. The effect of nitrogen, diuron, and ametryne on the NO_3-N content of the exocarp, mesocarp, and endocarp of cannery-ripe papaya fruit.

Herbicide Rates (kg ai/ha)	Exocarp			Mesocarp			Endocarp		
	N1*	N2	Mean	N1	N2	Mean	N1	N2	Mean
Control	18.5	23.2	20.9	5.0	24.0	14.5	18.8	15.2	17.0
Diuron, 2 kg	17.5	29.5	23.5	6.8	22.8	14.8	11.0	21.2	16.1
Diuron, 4 kg	19.8	38.5	29.1	20.5	32.5	26.5	20.2	24.0	22.1
Ametryne, 2 kg	16.5	30.0	23.2	23.5	40.2	31.9	21.8	19.0	20.4
Ametryne, 4 kg	22.2	47.2	34.8	18.8	37.8	28.3	16.5	20.2	18.4
Mean:	18.9	33.7		14.9	31.4		17.7	19.9	
Hsd:									
a) Between N levels									
0.05			19.5			11.99			N.S.
0.01			N.S.			N.S.			—
b) Between herbicide treatments:									
0.05			15.4			N.S.			N.S.
0.01			21.0			—			—
c) N level x herbicide treatments:									
0.05			N.S.			N.S.			N.S.

* N_1 = 20 N/TREE APPLICATION; N_2 = N/TREE/APPLICATION.

The NO_3-N in the exocarp of ripe fruit was found to be about 30% less than that of mature-gree fruit.

Mesocarp. In general, the application of diuron and ametryne tended to increase the NO_3-N in the ripe fruit mesocarp. Ametryne applied at 2 kg /ha increased NO_3-N by 18.5 and 16.2 ppm in the trees which were fertilized with 20 and 40 g N/tree, respectively (Table 2). At 4 kg/ha, ametryne increased NO_3-N by an average of 13.8 ppm.

Diuron at 2 kg/ha did not affect NO_3-N, but at 4 kg/ha it increased the NO_3-N by 15.5 and 8.5 ppm when the trees were fertilized with 20 and 40 g N/tree, respectively.

Increasing the nitrogen application from 20 to 40 g N/tree/application significantly increased the NO_3-N in the mesocarp (Table 2).

The NO_3-N level in the ripe fruit mesocarp was found to be only 4.0 - 7.5% that of the mature-green fruit, suggesting decreased uptake of NO_3-N upon maturation of the flesh, or re-translocation of the NO_3-N.

Endocarp. The concentration of NO_3-N in the placental wall was not affected by diuron or ametryne. Likewise, doubling the rate of nitrogen fertilization did not significantly influence the NO_3-N content of the endocarp (Table 2).

The concentration of NO_3-N in the endocarp of ripe fruit was found to be 50-75% of that in the same tissue of mature-green fruit (Tables 1 and 2).

DISCUSSION

The finding that the exocarp of mature-green fruit contained about 4 times more NO_3-N, while the mesocarp contained 13 to 23 times more NO_3-N than that of the cannery-ripe fruit suggests that during ripening, there was a rapid reduction of the NO_3-N in the endocarp and mesocarp. Simultaneous with this rapid nitrate assimilation was probably a complete cessation of NO_3-N flux to the ripening fruit, i.e., the ripe fruit has stopped being a 'sink' for NO_3-N.

The increase in NO_3-N in the mature green and ripe fruit's mesocarp due to N fertilizer was understandable because nitrate uptake in papaya as well as in other plants has been known to be mainly dependent on the available nitrate in the growth media (kruger and Menary, 1968a; 1968b; Ashley , *et al.*, 1975; Jackson *et al.*, 1976). As a matter of fact the level of NO_3-N in the plant could be easily varied, within limits, by manipulating nitrogen fertilization (Viets and Hageman, 1971; Maynard and Barker, 1972; 1974).

The general tendency of fruit from herbicide-treated trees to accumulate NO_3-N especially at mature-green stage could have been due to the repressive effect of the herbicides on the process of nitrate reduction. It has been shown that to a certain extent the photosynthetic reduction of nitrate is directly coupled to the light reactions of photosynthesis (Losada and Guerrero, 1979). The herbicides used being potent photosynthetic inhibitors, could have disrupted either the generation or transfer of the reductive energy to transform nitrates into amino acids or proteins.

The apparent build-up of NO_3-N due to diuron and ametryne in ripe fruit could have been due also to direct interruption of the reduction process and not due to suppression of NR activity since it was noted that the herbicides had a stimulatory effect on NR activity, but still, the tissues tended to accumulate NO_3-N.

The absence of NO_3-N build-up in the endocarp of both mature-green and cannery-ripe fruit regardless of the nitrogen or herbicide rate applied, suggests two possibilities, namely:

1) the NO_3-N measured could have been in the labile pool and in the process of being transported to other tissues.
2) reduction of NO_3-N was faster than influx, hence there was no NO_3-N build-up.

Menary and Jones (1971) reported that NO_3-N going to the fruit passes through the endocarp prior to its translocation into the mesocarp or exocarp. This may partly explain why NO_3-N does not build-up in the endocarp but rather it was only in a transient or labile state in this tissue, and only a small portion was in the storage pool. It was possible also that some of the NO_3-N was reduced rapidly in the endocarp, especially in the mature-green fruit, hence the low concentration of nitrate.

In the ripe fruit, the low NO_3-N in the endocarp (placental well) may simply suggest that the uptake of NO_3-N was already minimal, and in fact re-translocation to the developing seeds or other "sinks" could have commenced at some period before the fruit turned yellow. Hence, there was no build-up of NO_3-N in the endocarp, or for that matter even in the mesocarp of ripe papaya fruit when analyses were made.

Nitrogen fertilizer triggers NO_3-N accumulation in the papaya fruit more than photosynthetic-inhibitor herbicides, such as diuron and ametryne.

The degree of ripeness of papaya fruit has a great influence on the NO_3-N status of papaya fruit. The exocarp (skin) and endocarp contains substantial NO_3-N in the cannery-ripe fruit, hence, care should be exercised to exclude these tissues from the canned product.

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DISSIPATION OF THIOBENCARB, ISOPROTURON, AND AMMONIUM SULPHAMATE IN SOIL, WATER AND PLANT RESIDUES

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ABSTRACT

The dissipation of thiobencarb, isoproturon and ammonium sulphamate in soil and water and their residues in plant was investigated. Ninety percent of isoproturon and thiobencarb were dissipated in the soil within 30 to 45 days. In water only three days were required to reach this level of dissipation. The dissipation of ammonium sulphamate was much faster in soil than in water. Detectable amounts of all three herbicides were found in plant residues. The study suggests that thiobencarb, isoproturon and ammonium sulphamate applied to rice *(Oryza sativa* L.), wheat *(Triticum nestiyum* L.) and selected fruit crops pose no apparent residue problem in soil, water and edible portions of the plant.

INTRODUCTION

Herbicides are generally short-lived in the environment. Many of them are rapidly degraded into innocuous and harmless products by microbial, chemical and photodegradation pathways. They are also subject to leaching in the soil by rain or irrigation water, resulting in their eventual accumulation in water systems.

The herbicide, absorbed by the plant when applied to the soil or plant foliage, is also degraded within the plant system to become less phytotoxic or nontoxic. Some of them may accumulate as original parent molecules in the edible parts of the plant, thus posing a residue problem to the consumer.

As herbicide usage increases, the residue problems in the environment including soil, water, and plant become increasingly acute. Therefore, it becomes very essential to study them in an effort to make the use of herbicides safe to the environment.

Isoproturon (N'-isopropylphenol-N,N-dimethyl urea) and thiobencarb (S-4-chlorobenzuf,N,N-diethyl carbamate are two new herbicides being developed commercially in the Indian market. Isoproturon is used to control many grass weeds including *Phalaris minor* Retz in wheat. Thiobencarb, in various tests, was found to be an effective preemergence herbicide in rice and is soon expected to be used commercially. Recognizing their present and future importance for weed control in wheat and rice in India, several experiments were conducted to study their dissipation in soil and water and residues in grain and straw. This paper also reports a similar work done on ammonium sulphamate, an inorganic herbicide, which when introduced can aid not only in industrial weed control but for controlling weeds in orchard crops like mango and cashew as well.

MATERIALS AND METHODS

Dissipation studies in soil. Thiobencarb was applied to the soil (light sandy loam, pH 7 to 7.54; organic matter content 0.60 to 0.68%), at 1.5, 2.5 and 3.0 kg ai/ha at 1 to 3 days after transplanting rice, isoproturon at 1.0, 1.5 and 2.0 kg/ha (postemergence) to wheat foliage, and ammonium sulphamate to soil at 12.5, 25 and 50 kg/ha (postemergence) to weeds in mango (*Mangifera indica* L.), cashew (*Anacardium occidentale* L.0 and coconut (Cocos *nucifera* L.) plantations. For residue determination soil samples were collected at different intervals, and from 8 locations in a plot up to a depth of 15 cm using a soil auger. A pooled sample was taken from each replication.

Dissipation studies in water. Studies in water were conducted in 3 m x 2 m x 1 m water tanks. The tanks were filled with soil for about 80 cm with a 15 cm standing water. The herbicide was applied at different concentrations into the water and samples were drawn at different intervals for residue determination.

Residues in plant. Representative plant samples (grain and straw) were collected at harvest time. In the case of ammonium sulphamate, mango fruits were collected for determining residues in the pulp, fruits and nuts were used for residue analysis in cashew, and coconut water in coconut.

Extraction and estimation of residues. Thiobencarb: Thiobencarb was determined according to the procedure described by Eastin (1977) with a few modifications. Soil sample (500 g), water (500 ml), grain (1 kg) or straw (1 kg) was extracted with a suitable volume of N-hexane. The extract was dried over anhydrous sodium sulfate. The extract was passed through a column of Hyflor-Supercel-Charcoal and the eluate concentrated to dryness in vacuum. The residue was dissolved in acetone and made up to a suitable volume. A standard solution of thiobencarb was prepared in acetone so that 1 ml is equal to 1 mg of active ingredient.

Estimation of thiobencarb was done by thin-layer chromatography. Silica gel G-coated glass plates (20 by 20 cm) were dried and activated at 110°C for 40 minutes and stored. Standard solutions ranging from 1 to 10 ug were spotted using a micro pipette, along with 1 ul of the sample. After the spots were dried the chromatogram was developed in a solvent system of ethyl-acetate methanol (4:1). Gibbs reagent (0.5% 2.6 dichloro-quinone-chloromide in acetic acid) was used to detect thiobencarb which appeared as yellow spots. The exact amount of thiobencarb present in the test solution was calculated based on color intensity. The chromatogram was also developed in silica gel GF plates and viewed under UV fluorescence at 254 nm. Thiobencarb was seen as a quenching spot on a fluorescent background. Recovery through this method ranged from 88 to 91%.

Isoproturon: Soil sample (500 g), water (500 ml), grain 1 (kg) or straw (1 kg) was added with an appropriate volume of chloroform in a separatory funnel and placed in a shaker overnight. The extracts were filtered through Whatman No. 1 filter paper and rinsed three times with 25 ml chloroform. The yellow colored extract was concentrated to less than 2 ml with a drop of propylene glycol under reduced pressure.

Clean up was done by passing the concentrated extract through a 1.25 cm glass column containing 10 g charcoal-celite-magnesium oxide (2:1:1) which was activated at 110°C for 2 hr before use. The column was washed with 25 ml hexane and the eluate was discarded. Elution was carried out with chloroform. The clear eluate (150 ml) was concentrated to dryness under made up to 1 ml with chloroform, and kept at O C.

Estimation of isoproturon residues was done by thin-layer chromatography. The thin-layer plates (20 by 20 cm) were coated to a 0.25 mm thickness with silica gel suspension (30 g silicagel, 13% gypsum binder, 64 ml distilled water). Five drops of methanol were added to the suspension to ensure uniform coating of the plates. The coated plates were air-dried, then oven-dried at 110 C for 30 minutes before use.

One microliter of extract was spotted along with standard isoproturon solutions containing 1,2,3,4 and 5 ug herbicide (1,2,3,4, and 5 ug of 1 mg/ml solution of analytical grade isoproturon) on the plates. The chromatograms developed in a solvent system of chloroform: ethyl acetate (9:1) to a distance of 18 cm. The plates were air-dried for 5 minutes and sprayed with Dragendorff's reagent, (1% bismuth nitrate in 1 N HCl and 1% potassium iodide in water). Isoproturon appeared as a dark orange spot on a light yellow background within 2 min.

Ammonium sulphamate: Residues of ammonium sulphamate were determined according to the procedure described by Pease (1966). Air-dried soil (1 kg) were extracted three times with deionized water and filtered into 5 ml of 12% sodium hydroxide and added with charcoal. The mixture was heated for 10 min, vacuum-filtered and concentrated to 90 ml at pH 11.5 to 12.0. The sample was cooled and stirred for 1 hr with 2 teaspoonfuls of acid-washed alumina and 10 ml HCl. It was filtered through Whatman no. 40 filter paper, passed through an alumina column and washed, first with dilute HCl, then with deionized water to remove any sulphate present in the sample. The eluate was stirred for 30 min with 0.1 g sodium nitrite to convert sulphamate to sulphate. This was passed through another alumina column and washed successively with 1N and 0.1 N ammonium hydroxide. The eluate was concentrated to 1 ml.

The spots were quantitatively measured by carefully circumscribing, tracing on to a graph paper and then measuring the area of each spot in terms of the number of squares. A straight line was obtained when the square root of each area was plotted against the logarithm of the quantity of isoproturon (Lakshminarayan and Menon, 1971). This is used to determine the amount of isoproturon in unknown samples. The recovery with this method ranged from 80 to 85%.

The concentrated extract was placed in a 100 ml round bottom flask connected with a reflux condenser, which in turn was connected to a 250 ml flask containing 130 ml zinc acetate and 5 ml 12% NaOH. Nitrogen was introduced immediately after addition of 20 ml reducing acid mixture to the flask. The mixture was heated for 10 min. Refluxing was continued for another 5 min. After washing the sample with water, 25 ml of p-amino-dimethylaniline sulphate solution and 5 ml of ferric chloride solution were added. The resulting mixture was diluted to 250 ml and the absorbance of the blue solution recorded at 665 nm. Quantification of residues is done by comparing the sample with a standard curve. Recovery with this method ranged from 85 to 90%.

This method was also used for determining residues of ammonium sulphamate in water, mango leaf and fruit, cashew fruit and nut, and coconut water.

RESULTS AND DISCUSSIONS

Thiobencarb. The dissipation of the herbicide reached its maximum by the 60th day at 1.5 kg/ha and 75th day at 2.5 and 3.0 kg/ha (Table 1). The loss of the herbicide within the first 15 days was about 63%. The RL_{50} value of thiobencarb range between 13.08 and 14.33 days.

When thiobencarb was applied to water the dissipation was complete within 3 days at all three rates (Table 2). Grain and straw samples of rice collected from thiobencarb-treated experiments showed no evidence of residues (data not presented). The residues were below the detectable level of 0.1 ppm.

Table 1. Dissipation of thiobencarb in soil.

Thiobencarb (kg/ha)	Days after application	Dissipation[a] (%)
1.5	0	—
	15	63.0
	30	78.0
	45	89.3
	60	100.0
	75	100.0
2.5	0	—
	15	62.0
	30	79.7
	45	89.2
	60	96.3
	75	100.0
3.0	0	—
	15	62.5
	30	77.2
	45	90.4
	60	94.4
	75	100.0

[a]RL_{50} values: 13.08 to 14.33 days

Table 2. Dissipation of thiobencarb in water.

Thiobencarb (kg/ha)	Days after application	Dissipation (%)
1.5	0	—
	1	76.0
	3	100.0
	5	100.0
2.5	0	—
	1	73.7
	3	100.0
	5	100.0
3.0	0	—
	1	81.1
	3	100.0
	5	100.0

Isoproturon. When applied to the soil, isoproturon was found to dissipate completely by the 60th day at 1.0 and 1.5 kg/ha and by the 75th day at 2.0 kg/ha (Table 3). The RL_{50} values ranged from 10.75 to 13.08 days. When applied to water, no isoproturon was found beyond the 3rd day of application (Table 4).

Table 3. Dissipation of isoproturon in soil

Isoproturon (kg/ha)	Days after application	Dissipation[a] (%)
1.0	0	—
	15	79.9
	30	85.3
	45	92.4
	60	100.0
	75	100.0
	0	—
	15	80.0
1.5	30	90.6
	45	95.1
	60	100.0
	75	100.0
2.0	0	—
	15	79.6
	30	88.3
	45	94.5
	60	96.5
	75	100.0

[a]RL_{50} value: 10.75 to 13.08 days

Table 4. Dissipation of isoproturon in water

Isoproturon (kg/ha)	Days after application	Dissipation (%)
1.0	0	—
	1	67.3
	3	90.4
	5	100.0
1.5	0	—
	1	63.6
	3	87.9
	5	100.0
2.0	0	—
	1	65.4
	3	88.9
	5	100.0

When wheat grain and straw samples from a field experiment on isoproturon were analyzed for herbicide residues, the extracts contained no detectable limit being 0.1 ppm.

Ammonium sulphamate. Dissipation of ammonium sulphamate in the soil was complete on the 3rd day at 12.5 kg/ha and on the 5th day at 25 and 50 kg/ha (Table 5). More than 90% of the herbicide was dissipated in water within one week at all the rates tested (Table 5).

Table 5. Dissipation of ammonium sulphamate in soil

Ammonium Sulphamate (kg/ha)	Days after application	Dissipation (%)
12.5	0	—
	1	80.6
	3	100.0
	5	100.0
25.0	0	—
	1	84.6
	3	91.6
	5	100.0
50.0	0	—
	1	88.6
	3	91.8
	5	100.0

Table 6. Dissipation of ammonium sulphamate in water.

Ammonium sulphamate (kg/ha)	Days after application	Dissipation[a] (%)
12.5	0	—
	1	41.5
	3	68.9
	5	79.3
	7	93.3
	10	100.0
25.0	0	38.7
	1	
	3	60.7
	5	81.5
	7	91.8
	10	98.8
	15	100.0
50.0	0	—
	1	39.4
	3	68.5
	5	82.3
	7	90.2
	10	95.8
	15	100.0

[a]RL_{50} value: 1.94 tp 2.25 days

No residues could be detected within the detectable level (0.1 ppm) from mango leaves and fruits (pulp), coconut water and cashew fruits and nuts.

These studies show that 90% of isoproturon and thiobencarb were dissipated in the soil within 30 to 45 days after application. Faster dissipation was observed in water. The herbicide disappeared within 10 days of application. It took 3 days for ammonium sulphamate to dissipate 90% of the applied quantity in the soil and 7 days to reach this level in water. The edible portions of test plant did not contain residues of these herbicides in detectable quantities. The three herbicides applied to different crops and in different situations did not appear to pose residue problems in the soil, water, and edible portions of the plant.

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EFFECT OF HERBICIDES ON SOIL MICROFLORA IN RICE AND WHEAT FIELDS

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ABSTRACT

Investigations on the effect of herbicides on soil microflora showed that in the case of rice herbicides, granular forms of isopropyl and ethyl esters of 2,4-dichloro phenoxy-acetic acid (2,4-D) at 1.0 and 1.5 kg/ha each, butachlor (G) at 2.0 kg/ha, nitrofen (G) at 2.0 kg/ha, propanil 3.0 at kg/ha, and Na-2,4-D at 0.8 kg/ha in transplanted rice during *kharif* (warm wet) season of 1979, the granular herbicides either stimulated or produced no adverse effect either on the total microfloral population or on the bacterial and fungal components when observed at 7, 32 and 45 days after application.

In the wheat experiment conducted during the cool dry seasin *(rabi)* the herbicides fluchloralin at 0.75 kg, nitrofen at 1.5 kg, metabenzthiazuron at 1.5 kg, metoxuron at 1.5 kg, pendimethalin at 1.0 kg, isoproturon at 1.0 kg, oxyfluorfen at 0.25 kg and Na-2, 4-D at 0.75 kg/ha did not alter significantly the total microflora population as well as the bacteria, fungi and actinomycetes. This results suggests these herbicides could be used safely to control weeds in wheat fields without any detrimental effect on the microbiological balance in the soil.

INTRODUCTION

Soil fertility depends in part on the balance of various types of microorganisms active in the soil. Addition to the soil of any potentially toxic chemical, such as herbicides may affect the biological equilibrium of the soil and affects adversely the future soil fertility and the general growth and development of crop plants. With the increase in the use of herbicides in field crops in recent years, there is likelihood of a serious and persistent threat to the biological balance in the soil. For example, granular herbicides like butachlor, nitrofen and 2,4-D esters have been recommended for pre-emergence weed control in transplanted rice (Mukhopadhyay and De, 1980; De Datta, 1981). Some work has been done on the effects of liquid and wettable formulations of 2,4-D and some other herbicides on microflora in some crop fields by (Mukhopadhyay *et al,* 1968, 1973, 1981; Mukhopadhyay, 1980), but little work and isopropyl esters of 2,4-D on rice soil microflora.

Similarly, even though there has been quite a large scale use of herbicides to control weeds in wheat fields, not much work has been done in India on the effect of the herbicides on soil microflora in wheat fields. With this idea in view, investigations were conducted in West Bengal, India to find out the effects of some of these herbicides in use for weed control in rice and wheat fields on the population of nontargetted soil microflora.

MATERIALS AND METHODS

The field and laboratory experiments were conducted in the Agricultural Farm and Plant Pathology Laboratory of the College of Agriculture, Visva-Bharati University, Sriniketan, W. Bengal, India, during the 1979 *kharif* (warm humid season) on rice crop and in the 1980-81 *rabi* (cool dry) season on wheat crop. Treatments in the field test were set in randomized block design with four replications (Tables 1 and 2). Soil samples were collected from 10 cm from 5 locations of each plot at 7, 32 and 45 days after application (DDA) of treatments.

Soil sample (25 g corrected for moisture) was taken for soil suspension. Three dilutions of 10^{-3}, 10^{-4}, and 10^{-5} were made, and 1 ml of each suspension was used to innoculate three media, namely: potato dextrose agar (Harrigan and McCance, 1966), peptone dextrose agar, and soil extract agar (Crossan 1967) for microbial counts in petridishes of 10 cm diameter. Colonies of bacteria and fungi were counted periodically but final counts were taken after a maximum of 144 hours of incubation.

RESULTS AND DISCUSSION

Effect of herbicides on rice soil microflora. Soon after application, the granular herbicides nitrofen and butachlor stimulated the total microbial population while the other herbicides did not significantly alter the total population (Table 1). The herbicides 2,4-D EE at 1.0 kg/ha and butachlor at 2.0 kg/ha inhibited the bacterial population initially, while nitrofen stimulated it. The other herbicides had no effect on the bacterial population. The fungal population was inhibited at higher dose (1.5 kg) of both the isopropyl and ethyl esters of 2,4-D and the mixture of propanil + Na-Salt of 2,4-D. Likewise, nitrofen and the lower dose of 2,4-D esters (1.0 kg) stimulated fungal population but the other herbicides did not.

Irrespective of the effects after application, all the granular herbicides at 32 days after application (DAA) stimulated the total microbial and bacterial populations, except that of 2,4-D IPE at 1.0 kg/ha which produced no effect. On the other hand, 24-D EE at 1.0 kg/ha stimulated only the fungal population and the rest of the herbicides had no effect at all. At 45 DAA, 2,4-D EE at 1.5 kg/ha stimulated the total and bacterial populations but lower doses of 2,4-D esters, nitrofen and 2,4-D EE 1.5 kg/ha caused slight inhibition of the fungal population, while the other herbicides had no

Table 1. Effect of four herbicides on microbial population per gram of rice soil x 10^{-5} at various days after application of treatments.

Herbicide	kg ig/ha	Total population			Bacterial population			Fungal population		
		7	32	45	7	32	45	7	32	45
1. 2,4-D IPE(G)	1.0	201.00	95.25	101.75	165.75	81.00	96.00	35.25	14.25	5.75
2. 2,4-D IPE(G) ai/ha	1.5	190.25	131.00	145.25	177.50	144.00	136.50	12.75	17.00	9.75
3. 2,4-D EE(G) ai/ha	1.0	127.25	302.00	169.50	93.75	272.25	161.75	33.50	29.75	7.75
4. 2,4-D EE(G) ai/ha	1.5	163.50	174.50	236.50	157.50	158.25	233.00	6.00	16.25	3.50
5. Butachlor (G) ai/ha	2.0	258.50	246.00	210.00	24.50	234.50	196.00	17.00	11.50	14.00
6. Nitrofen (G) ai/ha	2.0	272.25	131.00	101.75	238.75	120.25	95.00	33.50	11.00	6.75
7. Propanil (EC) 2,4-D Na Salt (WP	3.0 0.8	101 00	273.00	219.50	89.25	265.50	196.00	11.75	10.50	23.50
8. Unweeded control		173.75	41.25	155.75	151.25	37.75	139.00	22.50	3.50	16.75
SEm		26.74	18.49	22.71	26.84	17.29	23.14	3.25	5.08	3.05
LSD (0.05)		77.60	53.85	65.91	77.89	50.16	67.15	9.44	14.73	8.87

Table 2. Effect of herbicides on microbial population of wheat soil population X 10^{-5}/gm of dry soil.

Herbicide kg/ha	Time of application	Total Microflora			Bacterial population			Fungal population			Actinomycetes population		
		7	32	45	7	32	45	7	32	45	7	32	45
Fluchloralin 0.75 kg	1 DBS	169.9	196.7	197.1	153.3	183.6	182.3	3.6	3.7	3.9	10.9	9.4	10.7
Fluchloralin 0.75 kg	7 DAS	188.1	187.1	200.9	176.7	172.8	185.7	2.8	4.0	0.5	8.5	10.4	11.0
Nitrofen 1.5 kg	11 DAS	174.8	200.3	185.7	162.4	187.2	171.1	3.1	3.6	3.9	9.3	9.5	10.7
Methabenzthiazuron 1.5 kg	1 DAS	203.1	184.4	175.6	191.8	170.1	161.5	2.8	3.7	3.8	8.4	9.6	10.2
Metoxuron 1.5 kg	35 DAS	174.3	184.7	180.7	261.0	170.5	166.1	3.3	3.9	3.9	9.9	10.2	10.6
Pendimethalin 1.0 kg		196.5	171.5	169.2	184.7	159.3	155.0	2.9	3.4	3.7	8.8	8.7	10.3
Pendimethalin 1.0 kg	35 DAS	210.4	170.2	159.0	196.6	157.9	180.7	3.4	3.4	3.8	10.3	8.8	10.4
Isoproturon 1.0 kg	35 DAS	212.1	178.7	194.0	196.9	164.7	179.5	3.8	3.9	3.8	11.4	10.1	10.6
Oxyfluorfen 0.25 kg	1 DAS	189.5	215.1	194.0	175.5	199.8	180.6	3.5	4.2	3.6	10.5	11.1	9.7
Oxyfluorfen 0.25 kg	35 DAS	203.0	187.1	186.7	189.3	173.2	173.8	3.4	3.8	3.4	10.2	10.0	9.5
2,4-D (Na-Salt) 0.75 kg	35 DAS	208.0	194.9	195.6	195.2	180.9	181.9	3.2	3.9	3.6	9.6	10.1	10.0
Hand weeding	35 DAS	160.2	217.4	203.2	148.2	203.8	188.2	3.0	3.7	4.0	9.0	9.8	10.9
Unweeded control		209.1	193.2	196.5	194.3	177.7	181.9	3.7	4.2	3.8	11.1	11.3	10.7
S.Em		19.69	19.83	12.93	19.45	19.48	12.59	0.32	0.28	0.26	1.10	9.96	0.73
C.D at 5%		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
C.V.		20.58%	20.75%	13.59%	21.47%	21.96%	14.30%	19.31%	15.11%	13.90%	22.54%	19.45%	14.29%

effect compared to the unweeded control. In short, most of the herbicides either stimulated or decreased the microbial population but tended to stabilize 45 days after application.

Effect of herbicides on wheat soil microflora. Herbicides applied during the cool dry season on dry soil in wheat fields did not have any significant influence on the total microflora and population on the bacterial, fungal, and actinomycetes compared with the unweeded population control plots (Table 2). The recommended doses of herbicides commonly used in wheat fields did not adversely affect the soil microflora.

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CHANGES WITH PLANT AGE IN FRACTIONATED PHYTOMASS, PRODUCTIVITY AND CHLOROPHYLL DENSITY OF CROPS AND WEEDS ON A RIPARIAN AGRO-ECOSYSTEM

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ABSTRACT

Riparian ecosystems in North Indian Plains which are usually left as waste or neglected land when managed for winter cropping showed to be highly productive.

The productivity and chlorophyll density estimated for total crops and total weeds showed high values of community productivity and community chlorophyll density (1.99 g m^{-2}).

There were distinct variations in fractionated standing phytomass and productivity in the three zonations of the riparian agro-ecosystem.

Total crops and weeds had significant positive correlation between productivity and chlorophyll density.

INTRODUCTION

Maximization of production from agricultural lands is a must as a result of rapid increase in human population. In quest of increasing production, neglected areas which remain under natural calamities like food, silting, erosion etc. are also extensively and intensively used for agricultural practices. One of such neglected land is a riparian ecosystem. Present study has been conducted on such a piece of riparian agro-ecosystem of River Gomti at Jaunpur in the Gangetic Plains of North India in the year 1981 and 1982. There is a constant flux in the edaphic environment of a riparian ecosystem due to variety of forces like flood, silting, runoff, erosion and other biotic stresses. Crop production is greatly influenced by the nature of stress of erosion, submergence period, deposition of fresh soils etc. on these banks during rainy season. According to Etherington (1975) the soil of such systems are being maintained in a pedogenetically young condition by repeated input of silt.

Various workers in India have given accounts of weed flora of certain agro-ecosystem (Sharma 1961; Tripathi 1965; Pandey 1968; Soni and

Ambasht 1977; Ambasht and Chakhaiyar 1979; Ambasht 1977, 1982) but very little attention has been given on the riparian agro-ecosystems in India.

Nowbould (1967) and Milner and Hughes (1968) indicated the importance of chlorophyll concentration estimation as a quantitative measure of the photosynthetic system in all International Biological Programme projects. The community chlorophyll concentration per unit area according to Odum (1971) is an example of "community homeostasis." Several ecological processes, particularly phytomass and production are influenced by amount of chlorophyll density per unit area (Brougham 1960; Black 1963; Ovington and Lawrence 1967; Knight 1973; Misra and Mall 1975).

This paper describes an evaluation of the magnitude of the changes in phytomass, productivity and chlorophyll concentrations in terms of both dry weight of plant material and of ground area of a riparian agro-ecosystem with special reference to the crop-weed contribution in different ages of winter season crops.

THE EXPERIMENTAL SITE

The experimental site was selected along the River Gomti on a convex side at Jaunpur, India (23°24', 26°12' North latitude and 82°7', 83°5' East longitude). The soil was alkaline. Keeping in view the slope aspect, the number of days of inundation, the moisture availability and soil texture the riparian slope was divided into three zonations; upper, middle and lower from top upland, sloping bank and lower region near water margin. These riparian slopes are left as fallow land in summer and rainy seasons whereas in some of the areas the winter crops are cultivated.

The climates is monsoonal with three distinct season: summer (March-June), rainy (July-October) and winter (November-February). The total rainfall for 1981 was 1130 mm. The mean monthly maximum temperature ranged from 26.6°C to 40.6°C in 1981.

Altogether forty-nine weed species were found to infest the area in the cropping season from November 1981 to March 1982.

METHODS

After the flood water receded in October 1981 intensive ploughing was done. In the mid of November wheat (variety RR 21) and mustard (variety Varuna, Type 59) were sown together. A small quantity of urea (50 kg ha^{-1}) as a nitrogenous fertilizer was applied along with the sowing of seeds. The crop and weed productivity chlorophyll content were estimated from 15, 30, 45, 60, 75, 90, 105 and 120 days old crops. Along with crops, on the basis of Important Value Index (IVI) two dominant weeds (*Cynodon dactylon* corded (Linn.) Pers. and *Cyperus rotundus* (Linn.) were separated and other were included in rest of the weeds for the above estimations.

Phytomass and Productivity

The harvest method (Odum, 1960) was followed to determine the phytomass and net dry matter production. Three replicates of monoliths (size, 25 cm 25 cm x 30 cm) were taken in each sampling. The fractionated phytomass of crops and weeds in root, stem, leaves, fruits, grains and husks, and standing dead parts were taken. Rhizomes of weeds were included into underground part. Samples were dried at 80^{o} for 24 hr in oven. The phytomass was determined in g m^{-2} and it was divided by the plant age to obtain nėt primary productivity (g m^{-2} day^{-1}).

Chlorophyll Concentration

At every sampling the fresh vegetation samples (leaves, stem and reproductive parts) were collected from around the harvested plots. 0.25 g plant sample was placed in 15 ml of 80% acetone in a stoppered conical flask, kept overnight in a refrigerator at $4^{o}C$, and later homogenized and centrifuged at 3000 X for 15 minutes. With 80% acetone the final volume of 25 ml was made and optical density of the above extracts were measured in a spectro-colorimeter at 645 and 663 nm wavelengths for chlorophyll determinations. The amount of chlorophyll *a*, b and total were calculated by using the formulae developed by Maclachlan and Zalik (1963) as given below.

$$\text{Chlorophyll } a \text{ (mg-}^{1}\text{ dry weight)} = \frac{12.3\ D663\text{-}0.86\ D645}{d \times 1000 \times W} \times V$$

$$\text{Chlorophyll } b \text{ (mg g}^{-1}\text{ dry weight)} = \frac{19.3\ D645 - 3.6\ D663}{d \times 1000 \times W} \times V$$

Where, V is ml volume of chlorophyll extract, d is cm length of light path and w is gram dry weight of plant samples taken.

The total chlorophyll value was obtained by adding chlorophyll *a* and *b*. The density of chlorophyll was then calculated per unit area of ground.

RESULTS AND DISCUSSION

Phytomass and Productivity

Crops (wheat and mustard) had maximum phytomass at 120 days whereas of weeds at 105 days. Among the crops, wheat showed highest phytomass value of 1015.05 g m^{-2} and mustard 801.68 g m^{-2}. On the riparian slope, the lower zone had the highest phytomass and lowest in the upper zone. The reason of variation in the phytomass is mainly due to the soil texture and soil moisture. The upper zone was more sandy with little water retention capacity. If we see the maximum phytomass (Fig. 1) of crops in three zonations, it decreases from lower to upper (lower zone — 1816.73 g m^{-2}; middle zone — 1319.78 g m^{-2}; and upper zone — 1086.77 g m^{-2}). The same trend was obtained for the total weed phytomass at 105 days (Fig. 1) as there were: 95.93 g m^{-2} below ground and 165.89 g m^{-2} above ground phytomass in lower zone; 87.81 g m^{-2} below ground and 148.90 g m^{-2} above ground phytomass in middle zone; and 56.32 g m^{-2} below ground and 139.78 g m^{-2} above ground phytomass in upper zone. The fractionated phytomass of crops varied differently with the crop age: leaf phytomass increased upto 75 days and decreased from 90 days onwards as crop matured; stem phytomass increased up to the final harvest; reproductive parts appeared at 60 days and the phytomass increased up to the final harvest; root phytomass was maximum at 105 days and it decreased in the last sampling at 120 days.

Productivity of crops was highest at 105 days (wheat, 23.5 g m^{-2} day^{-1} and mustard 23.17 g m^{-2} day^{-1}) in contrast to 90 days in weeds (*Cynodon dactylon* 2.6 g m^{-2} day^{-1}, rest weeds 0.82 g m^{-2} day^{-1} and *Cyperus rotundus* 0.75 g m^{-2} day^{-1}). Highest value of total crop production (46.67 g m^{-2} day^{-1}) was obtained at 105 days and total weed production (4.17 g m^{-2} day^{-1}) at 90 days (Fig. 3). The productivity at 105 days in three zonations when compared showed maximum in lower, intermediate in middle and minimum in the upper zone for the crops.

Chlorophyll

Concentration

The concentration of chlorophyll (a + b) per unit dry weight of component plant material for crops and weeds had different trend with advance of plant age. The chlorophyll (a + b) concentration per unit dry weight of leaf phytomass had a similar increasing trend up to 75 to 90 days in both the crops (wheat and mustard) and dominant weeds (*C. dactylon* and *C. rotundus*). The highest leaf chlorophyll (a + b), 8.53 mg g^{-1} was obtained in mustard at 75 days (Table 1a). The chlorophyll concentration in the reproductive parts were highest in both crops and rest weeds at the initial stage and decreased sharply thereafter. Govil (1981) reported maximum concentration of chlorophyll (a + b) 15.58 mg g^{-1} wheat leaf at 27 plants m^{-2} density at 81 days of plant age.

The chlorophyll concentration of each component of crops and dominant weeds reached maximum at the same time (75 to 90 days), although it fluctuated up to 90 days in the rest of the weeds as 47 rest weed species re-

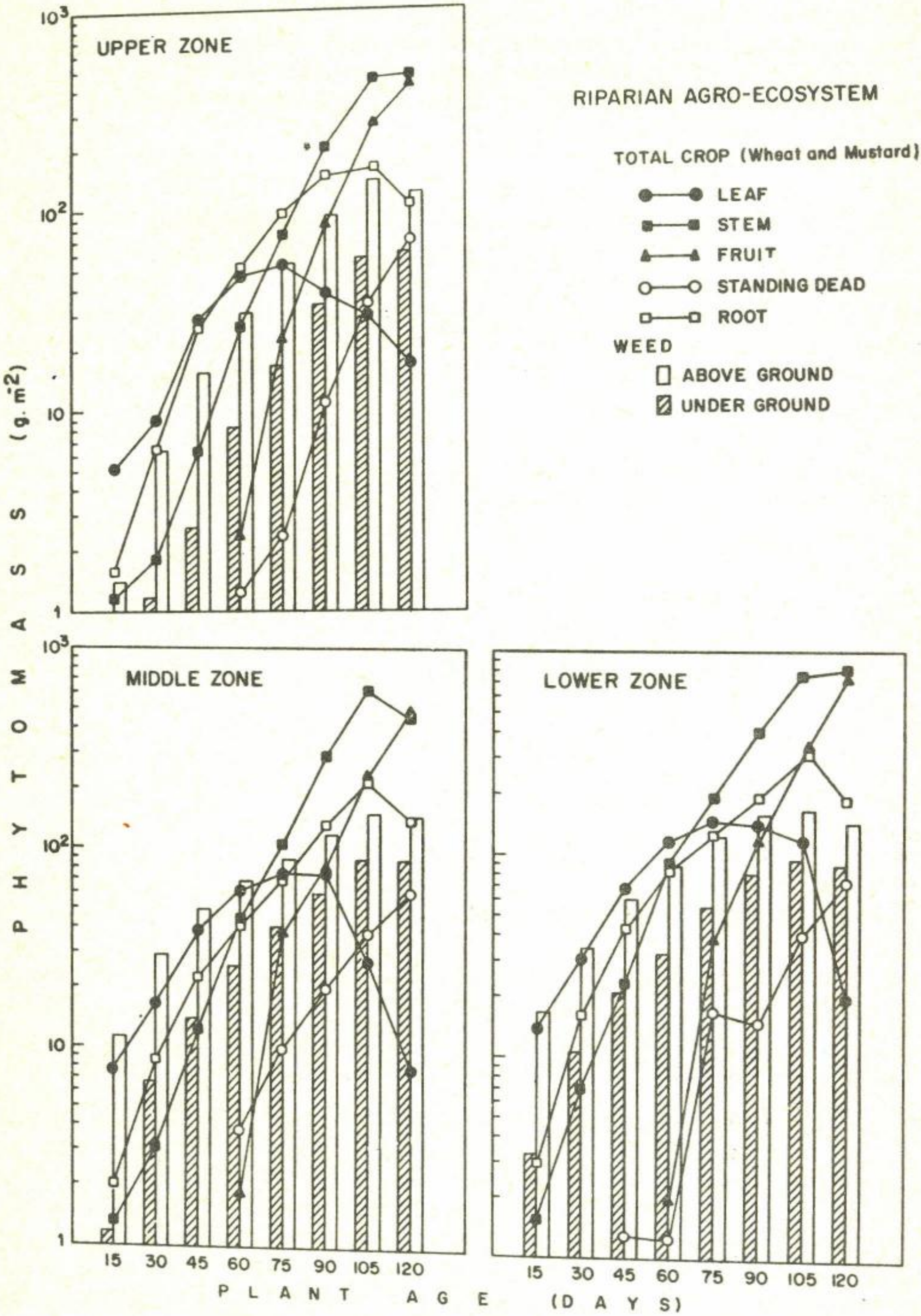

Fig. 1 Mean standing crop biomass of different components of mixed crop (Wheat and Mustard) and associated weeds at different ages and zonations.

had different periodicity, some extremely short lived and some remained up to the end of crop maturity. Their appearance was largely attributed to dormancy, germination requirements and soil moisture which gave the fluctuation in the chlorophyll concentration. Branchley and Warington (1933) pointed out the most significant feature of recurrence of weed flora at intermittent intervals is through staggered germination brought about by dormancy phenomenon.

Density

The graph of changes in amount of chlorophyll per unit area with the crop age for total crop chlorophyll and total weed chlorophyll is roughly bell-shaped (Fig. 2) with a maximum value in 90 days, the period of maximum productivity.

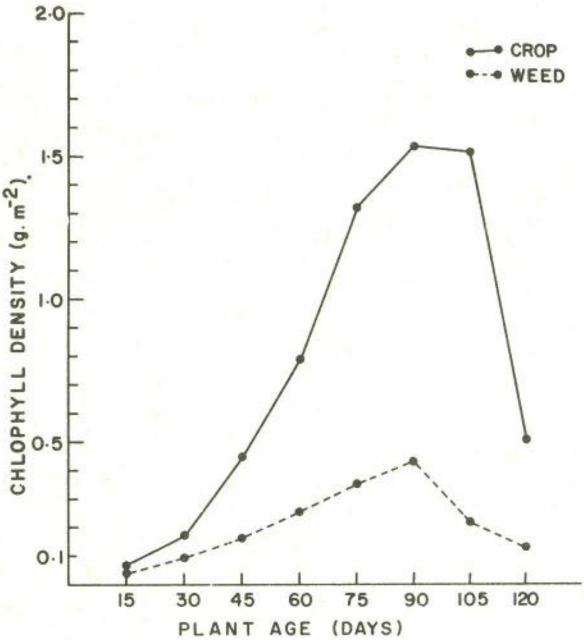

Fig. 2 Changes in total chlorophyll (a+b) density per unit ground area in a riparian agro-ecosystem.

The chlorophyll density for total crops and total weeds vary significantly showing the contrast in the productivity of total crops and weeds as chlorophyll concentration gives direct relationship with the rate of production. There was a significant positive correlation between the chlorophyll content and productivity for individual crops, total crops and total crops and weeds (Table 2). Though positive correlation was obtained for total weeds between chlorophyll content and productivity but was not significant. At 90 days both the total crops and total weeds had maximum chlorophyll density of 1557.09 mg m^{-2} and 432.84 g m^{-2} respectively (Table 1b).

Table 1a. Changes in chlorophyll (a + b) concentration per unit dry weight of plant material components (mg g^{-1}) with the advance of crop and weed age for the riparian agro-ecosystem.

Plant	Component	Plant age							
		15	30	45	60	75	90	105	120
Crops	Leaf	5.53 ±0.19	5.40 ±0.19	6.13 ±0.20	6.28 ±0.0.12	6.51 ±0.52	7.62 ±0.55	7.17 ±0.25	3.81 ±0.37
Wheat (RR21)	Stem	0.08 ±0.02	0.14 °.03	0.23 ±0.03	0.26 ±0.03	0.35 ±0.02	1.02 ±0.09	0.58 ±0.13	0.14 ±0.04
	Ear	—	—	—	1.53 ±0.31	1.76 ±0.27	0.99 ±0.10	0.76 ±0.05	0.21 ±0.03
	Leaf	4.75 ±0.67	5.80 0.29	6.49 ±0.49	6.79 ±0.59	8.53 ±0.18	8.03 ±0.54	—	—
Mustard (Varuna type 59)	Stem	0.22 ±0.06	0.52 ±0.04	0.51 ±0.08	0.62 ±0.03	1.18 ±0.03	0.97 ±0.05	1.88 ±0.15	0.45 ±0.05
	Reproductive part	—	—	—	—	1.75 ±0.07	1.31 ±0.07	0.65 ±0.06	0.37 ±0.04
Weeds	Leaf	5.72 ±0.20	5.96 ±0.05	6.69 ±0.41	7.57 ±0.24	8.04 ±0.24	7.30 ±0.11	3.84 ±0.56	2.86 ±0.19
Cynodon dactylon	Stem	0.16 b0.02	0.30 ±0.05	0.44 ±0.04	0.54 ±0.04	0.58 ±0.04	1.04 ±0.07	0.28 ±0.03	0.20 ±0.02
Cyperus rotundus	Shoot	2.67 ±0.35	5.21 ±0.28	5.49 ±0.22	5.68 ±0.32	6.56 ±0.42	5.06 ±0.39	3.53 ±0.20	2.93 ±0.10
Other weeds	Leaf	2.63 ±0.38	9.29 ±0.28	7.74 ±0.36	7.67 ±0.09	6.96 ±0.21	6.48 ±0.41	2.64 ±0.37	2.63 ±0.16
	Stem	0.93 ±0.07	1.60 ±0.13	1.17 ±0.05	0.97 ±0.08	0.62 ±0.03	0.53 ±0.07	0.54 ±0.03	0.48 ±0.08
	Reproductive part	—	—	—	—	—	0.40 ±0.05	0.28 ±0.05	0.18 ±0.03

Table 1b. Changes in chlorophyll (a + b) density per unit area of ground (mg m^{-2}) in different components as well as total crop and weed with the advance of crop age for the riparian agro-ecosystem.

Plant	Component	Plant age 15	30	45	60	75	90	105	120
Crops	Leaf	36.72	85.21	181.82	335.42	399.06	439.67	258.26	74.37
Wheat	Stem	0.05	0.39	2.43	7.48	35.82	209.01	211.42	53.89
(RR21)	Ear	—	—	—	3.03	60.97	74.40	144.64	86.02
	Leaf	33.58	87.41	251.94	428.59	726.93	661.03	—	—
Mustard	Stem	0.19	2.22	6.44	21.48	104.01	187.81	721.47	190.77
(Varuna, type 59)	reproductive part	—	—	—	—	6.91	59.57	102.92	119.88
Weeds	Leaf	30.49	53.58	98.88	143.68	180.26	197.98	118.96	69.56
Cynodon dactylon	*Steam*	1.34	6.04	15.49	26.82	38.48	85.68	23.36	13.40
Rest weed	Leaf	6.59	22.76	32.43	48.63	66.96	67.52	18.74	8.07
	Stem	0.67	2.74	4.03	4.81	5.31	7.39	8.96	8.23
	Reproductive part	—	—	—	—	—	1.25	1.43	1.44
Total for wheat		36.77	85.6	184.25	345.93	495.85	648.68	614.32	214.28
Total for mustard		33.77	89.63	258.38	450.07	837.85	908.41	824.39	310.65
Cyperus rotundus	Shoot	1.63	7.61	16.09	27.09	60.02	73.02	52.53	35.57

Table 2. Correlation coefficient and regression equation with productivity (g m^{-2} day^{-1}) as dependent variable and chlorophyll density (g m^{-2}) as independent variable.

Plants	d.f.	r	regression equation
Wheat	6	0.88*	Y = − 1.98 + 29.08 X
Mustard	6	0.74**	Y = − 0.47 + 15.40 X
Total crops	6	0.79**	Y = − 0.82 + 20.14 X
Weeds	6	0.68	Y = − 0.18 + 9.86 X
Total crops and weeds	6	0.80**	Y = − 0.15 + 17.12 X

Significant * $P < 0.01$; **$P < 0.05$

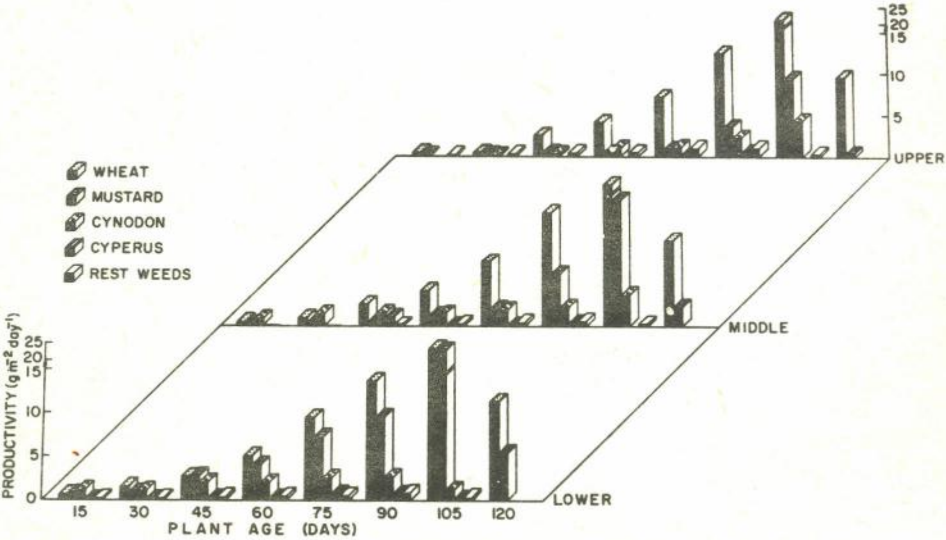

Fig. 3 - Productivity of crops and weeds at different ages in three zones of a riparian agroecosystem.

Maximum density of chlorophyll per unit area of ground (g m^{-2}) of various vegetation types in India are as follows: Berhampur *Aristida* grassland 1.2 (Misra and Misra 1981); Ratlam *Sehima* grassland 0.7 (Billore and Mall 1976); Ujjain *Dichanthium* grassland 1.4 (Misra and Mall 1975); Rajasthan desert 0.8 to 1.5 (Kumar and Joshi 1972); and riparian agro-ecosystem at Jaunpur 1.99 (present study). Thus the riparian slopes which are usually left as waste land if used for winter crop cultivation can be highly productive.

If managed properly the riparian ecosystems which are neglected can be an important source of additional production of crops to supplement the increasing demand of population. As the riparian ecosystems are fragile and receive extremes of stresses in rainy season as floods and most dry condition in summer, they can be used for winter crop cultivation only. The erosion is checked to greater extent by the weed species in the rainy season. Weeds with their faster turnover rate increase the nutrient level and fertility of soil. The rainy season submergence and exposure in the later period also help in recharging fertility status on the riparian slopes which result in the bumper crops from sandy, low grade neglected areas.

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HOE 39866 (GLUFOSINATE-AMMONIUM) – A NEW AND VERSATILE HERBICIDE: EXPERIENCE IN JAPAN

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ABSTRACT

Hoe 39866 (glufosinate-ammonium) is a new nonselective contact herbicide. Tested in Japan under a wide variety of situations, it showed a broad spectrum of annual and perennial weed control at 0.5 to 1.0 kg a.i./ha. Possible fields of application include noncrop situations, forestry, orchids, citrus, vineyards, mulberries, vegetables and others.

INTRODUCTION

In 1976 the herbicidal activity of ammonium-(3-amino-3-carboxypropyl) methyl-phosphinate was discovered in the laboratories of Hoechst AG, West-Germany (Schwedtle *et al.*, 1981). During the following years the substance was tested intensively in many countries under the code name Hoe 39866 (Langeluddeke et al, 1981, 1982, 1983). The active ingredient with the suggested common name of glufosinate-ammonium proved to be a contact herbicide active against a very wide spectrum of annual and perennial weeds. Glufosinate-ammonium is formulated as an aqueous solution with 200 g/1 a.i. The proposed tradename is BASTA.

This paper presents the results of the experiments with glufosinate-ammonium conducted in Japan since 1979. The product has been tested in a wide variety of crop and noncrop situations on official and private testing sites.

MATERIALS AND METHODS

Field trials with glufosinate-ammonium have been conducted under different situations of noncrop land where perennials were predominant and in mulberry, apple, orchards or citrus plantations. Plot size ranged from 5 to 15 m^2, the number of replicates from 2 to 4. Applications were generally made when the weed foliate was well developed. A Van de Weij boom sprayer with flat fan nozzles or a normal knapsack sprayer was used. The spraying volume was usually 1000 L/ha. Assessments were made at regular time intervals, using a 0 to 100 scale for assessing the direct effect on the green parts of the weeds (% weed control) up to 2 to 4 weeks after application. At later assessment on the coverage of the regrowth was recorded in absolute figures.

RESULTS

Control of perennial weeds. The green parts of most perennial weeds were killed relatively quickly with rates of 5 to 10 L/ha. Some hard to control species on waste lands, however, required higher ates. One of these was *Miscanthus sacchariflorus Bentt ex Hook f.*, and here it was demonstrated that both the rate and the application time are very important for the control of this weed (Figure 1). Applications too early in spring may result in fast regrowth. The upper part of Figure 1 shows the result of a trial in which glufosinate-ammonium and glyphosate had been applied on young *M. sacchariflorus* plants at the end of April. The upper plant parts having reached a height of about 30 cm were killed within about 10 days, but regrowth started 29 days after the application, even with 20 L/ha Hoe 39866 (glufosinate ammonium) had been applied. In the lower part of Figure 1 the result of another trial conducted in the same field is demonstrated. The herbicides were applied mid-May on *M. sacchariflorus* plants which were 40 to 50 cm tall. Although the time interval between both applications was not more than two weeks the effect of all herbicides was much better in the second application. Rates of 10 and 15 L/ha Hoe 39866 suppressed the growth nearly completely for over 70 days. Thereafter the regrowth was week. A second application at the end of August killed the plants completely.

Generally, later applications proved to be more efficient against perennial grasses. However, the reaction of perennial dicotyledonous weeds varied from species to species.

In Table 1 rates of Hoe 39866 which were necessary to control or suppress some important perennial weeds are listed. Those data were taken from our trial work done in Japan.

Control of annual weeds. In Table 2 typical results of glufosinate-ammonium in comparison with paraquat and glyphosate against some important annual weeds are listed. These data were obtained from 1982 trials in mulberries or in fields which were prepared for planting of vegetables. Generally, glufosinate-ammonium gave a better weed control than paraquat particularly against older and taller weeds. For the control of older annual weeds up to the flowering states, 1.0 kg a.i./ha was required.

Table 1a. Perennial weeds controlled by glufosinate ammonium at 1 kg/ha.

Agropyron tsukushiense var. *transiens* Ohwi	*Hydrocotyle maritimia* Honda
Allium grayi Regel	*Ixeris japonica* Nakai
Artemisia princeps Pampan.	*Lolium perenne* L.
Aster ageratoides Turcz.	*Mazus miquel ii* Makino
Aster yomena Honda	*Oxalis corniculata* L.
Bromus catharticus Vahl	*Plantago asiatica* L.
Calystegia hederacea Wall.	*Poa pratensis* L.
Cerastium caespitosum Gilib.	*Rorippa atrovirens* Ohwi et Hara
Equisetum arvense L.	*Rubia akane* Nakai
Eragrostis multicaulis Steud.	*Taraxacum officinale* Weber
Erigeron philadelphicus L.	*Trifolium pratense* L.
Glechoma hederacea L.	*Trifolium repens* L.

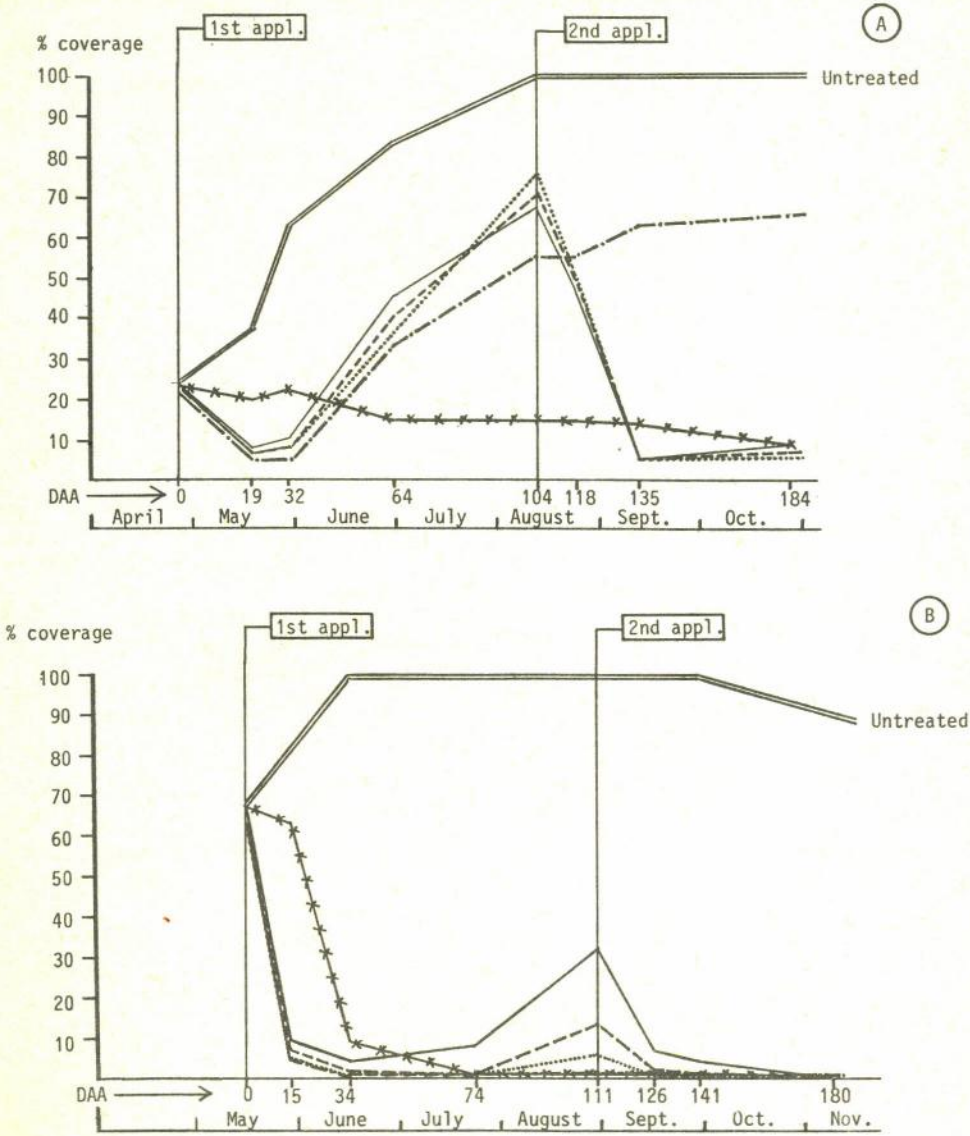
Table 1b. Perennial weeds controlled by glufosinate ammonium at 2 kg/ha.

Cyperus rotundus L.	*Phragmites communis* Trin.
Dioscorea sp.	*Polygonum cuspidatum* Sieb. et Zucc.
Humulus japonicus Sieb. et Zucc.	*Pueraria lobata* Ohwi
Imperata cylindrica P. Beauv.	*Taraxacum platycarpus* Dahlst.
Miscanthus sacchariflorus Benth. et Hook. f.	*Rumex acetosa* L.
Petasites japonicus Maxim.	*Rumex japonicus* Houtt.
Phalaris arundinacea L.	

Hoe 39866 showed no advantage over paraquat against some species such as *Stellaria media* or *Veronica persica.* Against a few species, e.g. *Commelina communis* or *Cyperus microiria*, glufosinate-ammonium is definitely weaker than paraquat.

The initial effect of glufosinate-ammonium was faster than that of glyphosate. The rates of both products required to control annual weeds were often very similar. Most annual species were controlled at 0.6-0.8 kg a.i./ha (Table 3). In some cases it was necessary to differentiate between younger and older plants, the latter requiring rates up to 1.0 kg a.i./ha, or, as in the case of *Portulaca oleracea*, even higher rates.

A general impression on annual weed control compared with that of paraquat is given in Table 4. Equal rates of both products were compared against all species occurring in the field. Most of these trials, as those demonstrated in Table 2, were conducted in mulberries or on field newly prepared for planting of vegetables, or in paddy field prior to cultivation in spring. The average weed control of Hoe 39866 at 2.5 to 4.0 1/ha was significantly better than that of paraquat at similar dose rates.



Treatments:
- Hoe 39866 7,5 + 7,5 l/ha
- Hoe 39866 10,0 + 7,5 l/ha
- Hoe 39866 15,0 + 7,5 l/ha
- Hoe 39866 20,0 l/ha
- Glyphosate 10,0 l/ha

Figure 1:

Miscanthus sacchariflorus control by split applications of Hoe 39866 in % coverage.
part A: first application April 27, second application August 9,
part B: first application May 12, second application August 31.

DISCUSSION

Hoe 39866 was proven to effectively control annual and perennial weeds. The data from Japan over several years show that rates required for the control of annual weeds ranged from 3 to 5 L/ha = 0.6 to 1.0 kg a.i.

Table 2. Comparison of annual and biennial weed control by glufosinate-ammonium, paraquat and gluphosate.

Weed species (Stage of application)	DAA[2]	Coverage[2]	Ammonium 1/ha			Paraquat 1/ha		Glyphosate 1/ha		Glufosinate -ammonium
	3)	2.0	3.5	5.0	2.0	3.5	5.0	2.5	5.0	
Erigeron canadensis	14	10	94	9.0	94	70	83	90	83	93
(10 - 15 cm high)	30	15	70	67	93	83	70	67	86	88
Youngia japonica	14	5	80	8 80	90	40	10	70	86	88
(benginning flowering)	30	10	93	97	100	33	17	60	90	100
Polygonum nodosum	9	30	92	86	92	84	99	88	—	—
(5 cm high)	28	35	99	100	100	80	95	92	—	—
Polygonum thunbergigii	9	5	60	17	73	27	72	72	—	—
(7 — 10 cm high)	28	5	100	93	100	27	53	64	—	—
Commelina communis	9	5	17	17	42	100	100	100	—	—
(5 — 10 cm high)	28	5	25	33	58	100	100	100	—	—
Stellaria media	9	20	89	82	84	100	100	100	—	—
(5 — 10 cm high)	28	25	100	100	100	100	100	100	—	—
Vicia angustifolia	9	25	95	—	95	86	—	93	57	62
(flowering)	28	40	100	—	100	87	—	96	87	100
Veronica persica	9	5	59	—	99	100	—	100	33	16
(Flowering)	28	5	88	—	99	100	—	100	100	100
Eclipta prostrata	6	5	78	80	88	98	88	85	25	—
(40 cm, flowering)	28	5	100	100	100	75	100	100	100	—
Cyperus Microiria	6	5	30	60	50	60	75	90	15	—
(30 cm, flowering)	28	5	40	83	100	60	100	100	65	—
Chenopodium album	6	15	95	95	97	75	78	90	70	—
(20 mm high)	28	15	95	98	100	60	65	70	98	—
Setaria viridis	9	65	70	73	78	70	80	95	70	—
(20 — 30 cm high)	28	90	97	98	100	65	73	88	100	—
Galium spurium	18	25	75	89	100	60	35	50	80	100
	31	30	87	100	100	33	25	50	100	100
Digitaria adscendens	13	10	95	95	99	79	95	95	93	—
(beginning tillering)	25	25	77	100	100	65	89	88	99	—
Digitaria adscendens	6	70	88	85	70	70	78	78	33	—
(40 — c0 cm, flowering)	28	65	63	73	90	40	60	60	99	—

1 — DAA = days after aplication

2 — coverage in % in untreated plots

Table 3. Annual and biennial weed control spectrum of glufosinate-ammonium.

a) 3-4-1 (= 0, 6-0, 8 kg a.i./ha) were required for the control of

Alopecurus aequalis Sobol. var. *amurensis* Ohwi (y)
Amaranthus lividus Loisel.
Astragalus sinicus L.
Capsella bursa-pastoris Medicus *(y)*

Chenopodium album L.
Chenopodium serotinum Torn.
Digitaria adscendens Henr. (y)
Eclipta prostrata L.
Erigeron Annuus L.
Erigeron canádensis L.
Fatoua villosa Nakai
Galium spurium L.
Lamium amplexicaule L. (y)
Polygonum lapathifolium L.
Polygonum nodosum Pers.
Polygonum thunbergii Sieb. et Zucc.
Portulaca oleracea L. (y)
Rorippa palustris Bess.
Setaria viridis *P. Beauv.*

Solanum nigrum L.
Sonchus asper Hill.
Sonchus oleraceus L.
Stellaria alsine Grimm var. *undulata* Ohwi

Stellaria aquatica Scop.
Stellaria media Villars
Youngia japonica D. C.
Veronica arvensis L.
Veronica persica Poir.
Vicia angustifolia L.

b) 5 1/ha (= 1, 0 kg a.i./ha) were required for the control of

Alopecurus aequalis (o)
Amphicarpaea edgeworthii Benth. var. *japonica* Oliver
Capsella bursa-pastoris (o)
Cyperus iria L.
Cyperus microiria Steud.
Digitaria adscendens (o)
Lamium amplexicaule (o)

c) not sufficiently controlled with 5 1/ha were

Commelina communis L.
Portulaca oleracea

Commelina communis L.
Portulaca oleracea (o)

Y = younger plants
o = older plants

Table 4. Annual weed control — average of all trials from 1979 to 1982.

Dosage rate		Hoe 39866	% weed control Paraquat		
1.875 — 2.0	L/ha (59)	80.6	81.7		
2.5 — 3.5	L/ha (62)	90.2	863	86.3	(62)
3.75 — 4.0	L/ha (78)	98.2	94.3		
5.0	L/ha (56)	91.4	90.9		

in brackets ( ) : number of individual figures.

/ha) depending on species and growth stage at application time. Perennial weeds were controlled by rates of 5 to 10 L/ha, and varied according to species. The time of application may be important for the duration of regrowth as has been shown by the experiment on *M. sacchariflorus*. Glufosinate-ammonium is only a partly systemic material and the roots or rhizomes were affected but not destroyed; so it is apparently better to apply the product when the nutrient reserves are fully mobilized and the plant development is more advanced.

The spectrum of annual and perennial weed control by glufosinate-ammonium opens a number of possibilities for practical use. At present we see the following:

Fields of use	*For the control of*
Nonagricultural land, such as railways, industrial sites, farm sites, roads and highways, etc.	perennial weeds
forestry	perennial weeds
mulberry	mostly annual weeds
orchards and citrus	annual and perennial weeds
vineyards	annual and perennial weeds
vegetables before land preparation prior to planting	annual weeds
vegetables directed spray with spray shield	annual weeds
ornamental shrubs	annual weeds
paddy dikes	perennial weeds
paddy fields prior to cultivation in spring	annual weeds

In these fields paraquat and glyphosate are widely used. The advantages over paraquat are better effects on a number of annual weeds and longer lasting effect on the regrowth of perennials. The control of mixed weed populations of annual and perennial weeds in perennial crops such as orchards, citrus, grapes or mulberries will probably be the most interesting field of application. Kubota (1980) pointed out that weeds are required to prevent soil erosion especially in orchards on slopes. Similar demands were mentioned by Hirose (1980) for citrus plantations. Under these conditions the use of Hoe 39866 may be of great advantage over glyphosate as weed growth is sufficiently suppressed for a period of several weeks or months without destroying their root system. Another advantage may be to prevent new suckers to develop in stone fruits like peaches, plums etc. Trials conducted in Germany demonstrated that an application of Hoe 39866 controlled these suckers without damaging the trees.

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ECOLOGY OF LAMBSQUARTER (*CHENOPODIUM ALBUM* L.) IN CROP FIELDS OF VARANASI, INDIA

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ABSTRACT

Lambsquarter (*Chenopodium album* L.), a common winter season weed of crop fields, was investigated from the ecological point of view. The plant was widely adapted to micro-climatic and edaphic factors and was capable of maintaining its population due to very high reproductive capacity. The dry matter production followed a sigmoid curve. High protein, phosphorus, and energy contents of the plant suggest its utility as a valuable green vegetable.

INTRODUCTION

Lambsquarter (*Chenopodium album* L.), locally called "Bathua", is a common winter season weed of both crop fields and wastelands of Northern India. The plant is used as a green vegetable and has also been valued as a medicinal plant in Ayurved. The weed's competitive ability with wheat, pèa, mustard and barley however makes its control very necessary to improve crop production. On the other hand, to control the weed more effectively the ecology should be known. The following study was conducted to understand the reproductive behaviour, dry matter production and nutritive suitability of lamsbquarter *C. album* in competition with wheat, pea and gram.

MATERIALS AND METHODS

The study was confined to crop fields within the campus of Banaras Hindu University which is about 5 km south of Varanasi City (25° 18' N: 83° 1' E). The climate is typically monsoonic characterized by three distinct seasons; rainy, winter and summer. The maximum rainfall, temperature and relative humidity were 415.7 mm (July) 40°C (April) and 90% (July) respectively during the study year (1981/82).

The soil is an old alluvial deposit categorized as Banaras type 111 soil by Agrawal and Mehrotra (1952).

The phenological observations were recorded from the three crop fields. The reproductive behaviour was determined and expressed in terms of seed output and reproductive capacity using the formula given by Salisbury (1942).

Evaluation of plant biomass was made at 15 days intervals using the harvest method. Five plants of similar age were sampled at random and were washed with a jet of water to remove the soil. Plants were separated into their component parts, oven dried at 65 C for 48 hr and weighed. The productivity was calculated from the differences between two successive samples of biomass values.

Crude protein was calculated from the total nitrogen estimated by micro-Kjeldahl method. Phosphorus content was estimated by the chloro stannous reduced molybdophosphoric blue color method in sulphuric acid system (Jackson, 1958). The energy value (Cal/g dry weight) was determined using an oxygen bomb calorimeter (Leith, 1968).

RESULTS

Phenology. Freshly collected seeds did not germinate under laboratory conditions. Seeds stored for a period of 20 to 24 months germinated well. Mechanical scarification and chemical treatment for 10 minutes with dilute H_2SO_4 promoted germination of *C. album* seeds. However, in spite of regular weeding, the plants emerged in the crop fields every year in the months of October and November. After a month of vegetative phase, flowering started and continued up to February. The vegetative and reproductive growth continued simultaneously. Flowering was closely followed by fruit setting. By the end of March the ripened fruits dehisced and seeds shed nearby the parent plant. The plants were seldom seen in the cultivated fields beyond second week of April.

Reproductive behaviour. Maximum seed output (129000 seeds/plant) and percentage germination (96%) of *C. album* were recorded in wheat, pea and gram (Table 1). Maximum reproductive capacity (123840) was achieved with the plants growing in association with the wheat crop.

Biomass and net primary productivity. Maximum dry matter production of the above ground parts of *C. album* in wheat field was highest at the age of 105 days compared with those in pea and gram fields. An increasing trend in the aboveground biomass was recorded in all the cultivated fields till the plant attained the age of 105 days. Between 105 to 120 days of age, there was a decline in the aboveground biomass (Table 2).

Wheat gave maximum productivity of *C. album* of .0620 g/plant/day while gram and peanut gave .0656 g and .0624 g/plant/day respectively (Table 3.).

Table 1. Reproductive behaviour of Chenopodium album *in different crop fields.*

Crop Field	Average of fruits/ plant	Average number o seeds/fruit	Average seed out put/plant	% Germination 2 years old seeds	Reproductive capacity
Wheat	1290	100	129000	96	123840
Pea	930	100	93000	90	83700
Gram	760	100	76000	94	71440

Table 2. Biomass structure (g/plant) of Chenopodium album *at different ages in wheat, pea and gream fields.*

	Wheat field			Gram field			Pea field		
Age	Above ground	Under ground	Total	Above ground	Under ground	Total	Above ground	Under ground	Total
15	.05	.01	.06	.02	.01	.02	.04	0.01	.04
30	.11	.02	.13	.04	.02	.05	.08	00.1	.08
45	.47	.06	.53	.15	.04	.19	.18	.03	.21
60	.99	.13	1.12	.35	.1	.45	.83	.10	.93
75	1.67	.22	1.87	1.29	.14	1.43	1.65	.15	1.80
90	2.56	.28	2.84	2.08	.17	2.26	2.36	.21	2.58
105	3.22	.29	3.51	2.45	.19	2.64	2.71	.26	2.97
120	3.17	.32	3.49	2.35	.20	2.56	2.61	.27	2.88

Table 3: Net primary productivity (g/plant/day) of *Chenopodium album* at different ages (days) in wheat, gram and pea fileds.

	Wheat field			Gram field			Peal Field		
Age	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total
15	.003	.000	.004	.001	.000	.001	.002	.000	.002
30	.004	.000	.004	.001	.000	.001	.002	.000	.003
45	.023	.003	.027	.007	.001	.009	.006	.001	.008
60	.035	.004	.043	.013	.003	.030	.043	.004	.047
75	.045	.006	.051	.062	.003	.065	.054	.003	.057
90	.059	.003	.062	.053	.002	.055	.047	.004	.051
105	.04	.001	.001	.024	.001	.025	.023	.002	.062
120	(−).0033	(+) .001	(−) .001	(−) .006	.000	(−) .005	(−) .005	.000	(−) .004

Protein, Phosphorus and Energy contents. Protein, phosphorus and energy contents increased with age in wheat, pea, and gram fields (Table 4). Maximum amount of protein was found in leaves of 75 day old plants. On the other hand, maximum protein content in root and stem was found in 90 and 105 day old plants respectively. Maximum phosphorus was found in root, stem and leaf at 90 days. Maximum energy was found at 90 days.

DISCUSSION

The phenological characters indicated that *C. album* is a short-day winter season annual and widely distributed in different cropping systems. Its reproductive behaviour and productive potentialities were variable. The plant perpetuated in crop fields due to high reproductive potential and the ability of its seeds to remain viable for a very long period up to 40 years (Toole and Brown 1946). On a worldwide basis, *C. album* was rated as one of the first five most widely distributed weeds (Coquillat 1951). In India, its distribution extends up to 3500 m altitude (Duthie 1903-20). The low reproductive capacity in gram field as compared to wheat and pea fields may be due to competition. Gram plants formed a canopy which prevented the growth of *C. album.*

Total biomass of aging *C. album* followed a sigmoidal curve. The variations in the biomass from wheat, pea, and gram fields were attributed to marked microclimatic and edaphic conditions. The fall in biomass after a certain age was due to degeneration of tissues and loss of litter in old age. High protein, phosphorus and energy contents in aboveground parts suggest

Table 4. Protein, Phosphorus and Energy contents of component, parts of C. album at different age stands in wheat, pea, and gram fields.

Stand		Root			Steam			Leaf		
Age	Field	Protein %	Phosphorus %	Energy Calg. drywt	Protein %	Phosphorus %	Energy Calg dry wt.	Protein %	Phosphorus %	Energy Calg dry wt.
15	W	1.2	.1	3460	3.6	.16	3415.	6.4	.37	3818
	P	.9	.07	3120	2.7	.12	3320	4.9	.35	3785
	G	.8	.04	3030	2.1	.10	3240	4.4	.31	3632
30	W	1.3	.13	3360	5.6	.26	3510	8.5	.39	3940
	P	1.1	.09	3420	4.7	.24	3505	7.4	.35	3760
	G	1.0	.04	3110	4.6	.22	3460	7.1	.32	3680
45	W	1.3	.16	3560	8.7	.29	3640	14.6	.39	3890
	P	1.2	.14	3520	8.0	.24	3630	14.2	.35	3840
	G	1.1	.12	3480	8.0	.22	3600	13.8	.32	3780
60	W	2.2	.19	3690	8.9	.31	3820	22.6	.43	3920
	P	2.1	.16	3640	8.2	.26	3750	20.4	.36	3860
	G	2.0	.14	3560	8.1	.23	3610	20.1	.34	3810
75	W	3.1	.21	3710	12.6	.38	3860	28.0	.81	4240
	P	2.9	.18	3640	11.9	.32	3810	27.6	.69	4180
	G	2.8	.15	3610	11.8	.30	3790	26.1	.66	4120
90	W	3.7	.24	3610	14.3	.41	3910	17.0	.92	4130
	P	3.6	.19	3560	12.6	.48	3877	16.8	.86	4090
	G	3.4	.16	3540	12.1	.36	3867	16.6	.78	4068
105	W	2.4	.18	3508	15.3	.39	3844	16.1	.88	3860
	P	2.0	.14	3470	15.1	.36	3818	15.9	.82	3810
	G	1.9	.11	3458	14.6	.34	3796	15.7	.69	3780
120	W	1.6	.16	3365	14.4	.36	3677	15.4	.48	3610
	P	1.6	.13	3315	13.8	.34	3649	15.0	.43	3605
	G	1.5	.10	3295	13.8	.31	3634	14.8	.41	3570

its nutritional value as a green vegetable. An upward and decreasing trend in the protein, phosphorus and energy contents with age in the component parts followed the usual pattern of storage and loss of materials in green plants.

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EFFICIENCY OF HERBICIDES ON RICE AND SUCCEEDING WHEAT CROP

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ABSTRACT

Field experiments involving herbicidal weed control treatments in different systems of rice (*Oryza sativa* L.) culture were conducted at the I.A.R.I. Farm, New Delhi in kharif (wet) season of 1978 and 1979. Weed dynamics in transplanted puddled and non-puddled soil were significantly less than in direct-seeded non-puddled soil. Highest grain yield of 60.89 q/ha was obtained in transplanted rice on puddled soil, followed by rice transplanted on non-puddled soil (53.17 q/ha) by the use of paraquat at 1.00 kg ha a week before transplanting and direct-seeded rice on non-puddled soil (33.66 q/ha). Among the weed control treatments, hand weeding was the most efficient, followed by thiobencarb fb propanil, butachlor fb propanil and thiobencarb fb bentazon in reducing weed dry matter accumulation and for higher rice grain yield. Yield of wheat suffered a significant reduction in plots where rice was grown under puddled condition. The herbicides applied to rice left no phytotoxic residues in the soil that adversely affected the succeeding wheat crop sown after rice.

INTRODUCTION

The area devoted to rice production in India in 1980-81 was 39.77 million hectares with a total production of 53.23 million tons, 1338 kg/ha as compared to 6 t/ha in Korea. One of the major reasons of low rice productivity in India is severe weed competition. The magnitude of losses caused by weed infestation varies from 10 to 70% in rice grain yield (Hedaytullah and Sen, 1942; Tiwary, 1953; Mani *et al.*, 1968). The severity of loss was more in direct-seeded under upland condition which amounted to 50 to 60% whereas in the case of transplanted rice on puddled soil was only 15 to 20% (Pillai, 1977). Hand weeding is a conventional method of weed control in rice but it is time consuming and tedious. De Datta and Barker (1971) reported that for direct-seeded flooded rice granular formulation of butachlor, thiobencarb and C-288 (Avirosan) were highly selective in controlling barnyard grass and other annual weeds under tropical condition. Kakati and Mani (1977) obtained good weed control with a single application of butachlor as pre-emergence under both direct-seeded and transplanted rice comparable to manually weeded treatments. Kaushik and Mani (1980) also reported that propanil at 2.0 kg/ha was as good as hand weeding for direct seeded rice. Moreover, a combination of thiobencarb at 4.0 kg/ha as pre-emergence followed by propanil 3-5 kg/ha as postemergence proved very effective in weed control in rice (Smith, 1977). Thus, the use of herbicides to control weeds seems to be efficient and less time consuming. Keeping these points in view, the present experiment was conducted to determine the effectiveness of herbicides on rice and succeeding wheat crop.

MATERIALS AND METHODS

A field trial was conducted during the monsoon seasons of 1978-79 and 1979-80 at the farm of the Division of Agronomy, I.A.R.I. New Delhi. The soil was sandy loam in texture with 0.65% organic carbon, 0.06% total N, 58.2 kg/ha availalble P_2O_5, 217.5 kg/ha available K_2O, and with pH 7.6. The experiment was set in a split-plot design with methods of planting as the main plots and weed control treatments as the sub-plots. Each treatment was replicated three times. Methods of planting consisted of direct-seeding (DS) on non-puddled soil, transplanting on puddled soil (PT), and transplanting on non-puddled soil (WPT) using paraquat 1 kg/ha applied a week before transplanting. The weed control treatments comprised of two pre-emergence herbicides and butachlor and thiobencarb which were applied separately at 20 kg (G) per ha and two postemergence herbicides of propanil and bentazon each at 2 kg /ha also applied separately, and four combinations of pre-emergence and postemergence herbicides vis. butachlor (G) at 20 kg/ha as preemergence fb propanil at 2 kg/ha as post-emergence, butachlor (G) at 20 kg/ha as preemergence fb bentazon at 2 kg /ha as post-emergence, thiobencarb (G) at 20 kg/ha as pre-emergence fb propanil at 2 kg ai/ha as postemergence and thiobencarb (G) at 20 kg/ha as pre-emergence fb bentazon at 2 kg/ha as post-emergence. The net area of the sub-lot was 4.0 m x 1.6 m. Pusa 33 was the test variety of rice. Direct sowing and transplanting of rice was done on June 27, 1978 and July 24, 1978 in the first and June 20, 1979 and July 15, 1979 in the second year of the experimentation, respectively. In direct-seeding 100 kg while in puddled transplanting 50 kg/ha seeds per ha was used. A uniform dose of 120 kg N + 50 kg P_2O_5 + 40 kg K_2O/ha was applied in both years. Initially ½ N + full P_2O_5 and K_2O were applied and rest of the N was applied at panicle initiation stage.

Weeds enclosed in a quadrat of 50 cm x 50 cm randomly placed at two places in both sides of the plots were uprooted and air dried. The weeds were then ovendried at 75-80°C for 48 hours and final weight was converted to g/m^2 expressed as weed density.

Crop productivity was assessed in terms of growth and yield attributing characters and grain yield of rice. Weed control efficiency was assessed in terms of weed population and dry matter accumulation. The residual effects of these herbicides were studied on the basis of weed intensity in wheat and wheat grain yield.

RESULTS AND DISCUSSION

Effect of weed control efficiency

Method of Planting. The lowest monocot and dicot weed population were recorded in transplanted rice on puddled and non-puddled soil at 90 days crop stage (Table 4). The dry matter accumulation obtained from PT and WPT plot being at par brought down dry matter of weeds to a significant lower level than DS (PT = WPT > DS) in both years. Puddling operation and use of paraquat kept a good check over monocot and dicot weeds. Sahu and Das (1969), Noda (1973) and Pillai *et al.* (1976) also revealed that weed growth in direct seeded rice assumed alarming proportion as weed seeds germinated prior to rice.

Weed control treatments. All the weed control treatments with the exception of HW caused a significant reduction in monocot weed population as compared to unweeded control in the first year (Table 4). In the second year all the weed control treatments decreased monocot weed population to a significant lower level over unweeded control. Sequential application of thiobencarb and bentazon which registered the lowest monocot weed population was significantly superior to the treatment with each herbicide alone. In the second year the most effective treatments which decreased monocot weed population was thiobencarb fb bentazon.

Dicot weed population in all weed control treatments caused a significant reduction in weed population as compared to the unweeded (Table 4). The lowest weed population recorded in hand weeding and butachlor fb bentazon was significantly less than that in propanil, butachlor and thiobencarb while in the second year butachlor fb bentazon and thiobencarb fb bentazon-treated plots recorded lowest dicot weed population. This agrees with Smith's (1977) report on the effectiveness of sequential application of herbicides in checking weed growth. All the weed control treatments decreased weed dry matter accumulation significantly compared to the unweeded control and hand weeded.

Effects on rice crop

Planting method. In the first year, rice grain obtained in puddled transplant was significantly superior to unpuddled transplant and direct seeding The grain yield in the latter was significantly less than in the other three. In the second year the yield under puddled transplant and unpuddled transplant was superior to direct-seeding. The grain yield differences in the pooled analysis (Table 1 & 2) revealed that puddled transplanting was significantly superior to unpuddled transplant which in turn was significantly superior to direct-seeded.

Weed control treatments. In both seasons the grain yields under all weed control treatments were significantly superior to the unweeded (Table 1). In the pooled analysis all the weed control treatments increased grain

Table 1. Effect of different treatments on growth, yield attributes and grain yield of rice.

Planting method	Height of plant (cm)		No. of panicle/m^2		No. of fertile *grain/panicle*		Grain yield (q/ha)		
	1978	1979	1978	1979	1978	1979	1978	1979	Pooled
Direct seeding (DS)	48.48	52.10	920	688	86.65	58.56	35.25	38.06	36.66
Puddled transplanted (PT)	52.52	61.32	821	576	110.51	79.00	64.93	56.86	60.89
Without puddled transplanted using paraquat	59.39	62.04	821	450	102.65	76.00	52.32	54.01	53.17
C.D. at 5%	+ 5.42	+ 5.21	62.22	67.51	8.53	8.86	5.21	4.65	2.90
Weed control treatments									
Unweeded control	48.68	57.52	735	514	93.69	67.45	40.78	42.50	41.64
Hand weeding	54.59	58.02	864	581	102.62	68.84	54.20	55.29	54.75
Machete	54.03	56.96	823	592	91.42	71.35	50.14	50.24	50.19
Saturn	55.07	59.34	852	600	105.82	76.53	52.58	48.23	50.41
Propanil	54.62	61.11	823	594	97.84	71.31	50.33	49.44	49.88
Bentazon	53.75	59.63	932	544	98.84	69.78	53.09	47.46	50.28
Nachete fb propanil	53.5	58.51	849	568	106.04	70.27	52.10	50.80	51.45
Machete fb bentazon	53.02	57.67	886	601	101.11	78.44	51.35	50.90	51.13
Saturn fb propanil	53.76	59.50	889	578	101.40	64.27	53.35	50.80	52.08
Saturn fb bentazon	53.76	56.60	887	540	100.55	73.89	50.45	50.78	50.61
C.D. at 5%	3.09	N.S.	95.50	N.S.	N.S.	N.S.	5.21	3.57	3.14

fb = followed by

production to a significantly higher level as compared to unweeded. Considering both seasons as well as pooled analysis, hand weeding occupied the first position followed by thiobencarb fb propanil, butachlor fb propanil and thiobencarb fb bentazon. The performance of bentazon was not consistent in the two years of trial. In pooled grain yield, interaction between planting methods and weed control treatment was signficant. Interaction effects of pooled data (Table 2) were almost similar to those obtained in 1978 (Table 3). Adoption of weed control method in puddled transplanted rice increased the grain yield by 8.8 q/ha over the unweeded check. In transplanted non-puddled soil using paraquat, there was a marginal gain of 1.32 q/ha. In direct-seeded, 18.6 q/ha more grain was produced due to adoption of weed control treatments. To summarize, weed control treatment resulted in largest increment in grain production in direct-seeded rice. This is supported by Venkateshwarlu (1980) who indicated exploring possibilities to dispense with transplanting which consumes 30 to 40% of the investment in rice culture, provided weeds are checked by a suitable method.

Table 2. Pooled rice grain yield (q/ha) as affected by the interaction between planting methods and weed control treatments.

Weed control treatments	Planting methods		
	DS	PT	WPT
Unweeded control	19.92	52.99	52.00
Hand weeding	44.40	64.35	55.49
Machete	33.57	63.23	53.78
Saturn	39.06	58.91	53.25
Propanil	36.61	60.73	52.32
Bentazon	39.56	60.83	50.44
Machete fb propanil	39.17	61.64	53.54
Machete fb bentazon	38.20	63.26	51.93
Saturn fb propanil	39.06	62.32	53.87
Saturn fb bentazon	37.08	60.70	54.06

	C.D. at 5%
Weed control treatments at the same planting method —	5.45
Planting methods at the same weed control treatment —	5.91

Regarding ancillary characters of rice, direct seeding produced more panicles/m^2 as compared to the other two methods of planting. When higher seed rate was used in direct-seeding, height of the plant and number of fertile grains/panicle were highest in puddled transplanting. Weed control treatments in the first year resulted in plant height and number of panicles/m^2 significantly greater than those in the unweeded control.

Residual effects

Methods of planting. The effects of rice planting methods had no significant effect on the wheat grain yield in the first year. In the second

Table 3. Rice grain yield (g/ha) as affected by interaction between planting methods and weed control treatments in 1978.

Weed control treatment	Planting methods		
	Direct seeding(DS)	Puddled transplanting (PT)	Without puddled transplanting using paraquat (WPT)
Unweeded control	14.84	54.48	53.02
Hand weeding	45.21	65.00	52.39
Machete	29.48	68.69	52.24
Saturn	38.17	65.62	53.96
Propanil	35.78	63.91	51.25
Bentazon	40.73	66.77	51.77
Machete fb propanil	39.17	64.77	52.66
Machete fb bentazon	37.40	68.44	48.23
Saturn fb propanil	36.25	68.85	55.00
Saturn fb bentazon	35.52	63.12	52.71

	C.D. at 5%
Weed control treatments at the same planting methods —	9.03
Planting methods at the same weed control treatment —	9.93

Table 4. Weed dynamics and weed density as influenced by method of rice planting and weed control treatments.

	Weed dynamics (No/m^2)				Weed density[2] (g/m^2)	
	1978		1979		1978	1979
	Monocot	Dicot	Monocot	Dicot		
Main plot						
Direct seeding	50.78	34.20	26.98	41.91	192.33	113.72
Puddled transplanted	30.08	23.23	14.80	20.36	25.67	51.28
Without puddled transplanted using paraquat	24.07	17.28	15.85	25.33	61.87	48.98
C.D. at 5%	2.63	3.00	4.16	14.31	43.00	14.12
Sub-plots						
Unweeded control	59.83	43.67	31.94	33.89	241.01	189.22
Hand weeding	21.33	14.17	13.28	46.22	32.57	29.41
Machete	40.89	37.22	14.72	35.44	107.35	56.40
Saturn	39.75	38.72	14.55	34.55	104.87	55.24
Propanil	35.28	22.05	22.78	45.11	96.26	58.11
Bentazon	34.55	20.50	25.50	15.55	100.11	80.92
Machete fb propanil	25.00	18.11	18.94	27.50	106.12	56.69
Machete fb bentazon	32.50	17.61	18.33	15.05	106.83	59.14
Saturn fb propanil	32.22	18.33	14.55	25.05	87.87	63.70
Saturn fb bentazon	31.39	18.67	17.17	13.72	92.29	63.45
C.D. at 5%	7.82	3.87	5.26	16.14	50.00	19.30

1 — Weed population 2 — Weed dry matter

year however, transplanted on non-puddled soil and direct-seeding gave comparatively significant higher wheat grain yield than the puddled transplanted. This may be due to the fact that puddling operation given to rice might have exerted adverse effect on soil structure which ultimately resulted in lower wheat grain yield. In both years there was no significant effect of the planting method of rice on number of dicot weeds and weed dry matter accumulation in the wheat crop. Grass weeds in wheat field were absent but dicot weeds were present in low number.

Weed control treatment. There was no adverse effect of herbicides applied to rice on succeeding wheat crop. Dicot weeds were significantly reduced in number in herbicide-treated plots in the first year. Weed dry matter accumulation in both years was significantly less than that in unweeded control and hand weeding given to rice. The grain yield of wheat crop during both years of study were found similar in all the chemical treated plots, which were comparable with each other (Table 4). This supports the findings of Chela and Gill (1980) who did not find any adverse carry over effect of herbicides applied to rice on the suceeding wheat crop.

Table 5. Residual effects of herbicides applied to rice on succeeding wheat crop.

	Weed intensity in wheat field				Wheat grain yield (q/ha)		
	No. of Dicot weed		Dry matter weeds (g/m^2)				
	1978	1979	1978	1979	1978	1979	Pooled
Main plots							
Direct seeding	15.73	18.06	21.63	18.29	48.35	62.94	55.64
Puddled transplanting	15.60	16.13	19.81	16.11	43.96	55.54	49.75
Without puddled transplanting using paraquat	15.63	18.47	20.27	16.87	45.60	63.14	54.37
C.D. at 5%	—	—	—	—	—	5.12	2.71
Sub-plots							
Unweeded control	27.33	24.22	45.69	42.51	44.09	48.62	51.35
Hand weeding	22.89	19.78	33.63	31.27	45.24	64.46	54.95
Machete	15.22	15.55	19.15	10.25	44.19	62.06	53.12
Saturn	14.22	17.78	17.64	10.70	43.54	62.24	52.89
Propanil	15.22	20.00	21.44	14.38	46.81	53.15	49.98
Bentazon	14.33	20.44	16.29	14.81	48.61	58.49	53.55
Machete fb propanil	11.44	14.22	13.13	12.61	48.54	61.16	54.85
Machete fb bentazon	9.77	13.55	10.84	11.10	46.62	61.79	54.21
Saturn fb propanil	14.00	14.44	14.79	10.90	45.74	64.19	55.97
Saturn fb bentazon	12.11	15.55	13.08	12.40	46.29	61.01	53.65
C.D. at 5%	3.28	—	4.07	4.69	—	—	—

ACKNOWLEDGEMENT

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BIOCONTROL OF *PARTHENIUM HYSTEROPHORUS* L.: USE OF FUNGI AS CONTROL AGENTS

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ABSTRACT

A model based on *Parthenium hysterophorus* L. as weed host and *Alternaria* and *Helminthosporium* as test pathogens indicated that the major barriers posed by the weed host include inactivation of pathogen-produced enzymes through catabolite repression or binding of toxins by leaf surface waxes. Dewaxing or use of lipolytic carrier agent helps in development of blight. Use of obligate parasites as control agents is limited by weather conditions. Modification of pathogen virulence is also possible through use of briding weed-hosts.

INTRODUCTION

Chemical weed control technology has progressed greatly during the past 40 years. The discovery of new classes of highly selective, effective, safe and relatively inexpensive herbicides have revolutionized modern weed control. It is becoming more apparent, however, that reliance on a single method is hazardous and in this period of increasing awareness of environmental pollution, indiscriminate use chemicals needs caution. Biological control of weeds with pathogens offers opportunities for overcoming several of the drawbacks posed by chemical herbicides like injury to non-targets from spray drifts, residual toxicity, alteration of environment beyond tolerable limits and adverse interactions with pesticides and fertilizers (Wilson, 1969; Ohr, 1976; Emge & Templeton, 1981; Deshpande, 1981, 1982).

Attributes needed for a biocontrol agent to be successful include specificity of action, distribution coinciding with the host, high virulence and production of abundant inoculum. Phytopathogenic species of the genus *Helminthosporium* and *Alternaria* satisfy all these criteria and offer an acceptable choice for weed control strategy. A few species of these genera produce phytopathogenic toxins and cell-wall degrading enzymes capable of initiating disease in plants. Strains of *Alternaria* and *Helminthosporium* attacking foliage of *Parthenium* and *Xanthium* have been developed and their pathogenicity to these weed-hosts had been established (Deshpande & Wadje, 1976; Deshpande and Pappu, 1978, 1982; Deshpande, 1981; Deshpande *et al.*, 1982).

Toxic metabolites synthesized by fungi affect morphogenic responses in plants and provide as yet untapped reservoir of substances for induction of wilt, defoliation and dessication in test weeds.

MATERIALS AND METHODS

The fungi bacteria were isolated from rhizosphere and phyllosphere through dilution plates and through leaf impressions. Induction of leaf blight and wilt was accomplished through foliar sprays or seedling-dip method. Enzyme assays were carried out using either viscometry or colorimetry. Efficacy of bridging weed-host relationship was assessed by leaf replica.

RESULTS AND DISCUSSION

The test weeds

Of the three test weeds, *Parthenium hysterophorus* L. has been the subject of most intensive investigations throughout the country. Attempts to control this weed mechanically or chemically have not been proven economically feasible (Gautam 1981). *Xanthium strumarium* L., the other test weed occupies all available waste lands and also invades cultivated fields. *Ipomea fistulosa* Mart ex Choicy a fenceweed has restricted distribution, however, extensive root system exerts adverse effects on the development of the crop in the vicinity.

In 1976, we developed a model for the control of *Xanthium*, then a problem weed in the area, which was based on selected strains of *Alternaria tenuis*. This fungus developed blight in young seedlings when used as foliar spray. Later, when *P. hysterophorus* emerged as an aggressive weed, a search for pathogens attacking it was made.

The test pathogens

Several insects have been observed attacking *P. hysterophorus* as foliage feeders or wilt inducers. Many of them have not been properly identified and some attack crop species as well so that the use of insects needs caution. Introduction of highly selective pests and MLO has been suggested (Raodev and Tayde, 1970; Mali and Vjanjane, 19979). However, these possibilities are yet to be realized.

A systematic study of fungi and bacteria attacking *P. hysterophorus* was therefore undertaken. As no visible symptoms were evident, rhizosphere and phyllosphere fungi and bacteria were isolated to find out the basis of resistance of the weeds to pathogens. The rhizosphere of healthy weed yielded yellow colored rods, *Fusarium*, *Helminthosporium*, *Rhizoctonia* and *Trichoderma*. The former three fungi are known to develop wilt, foot rot or root rot. Presence of *Trichoderma* probably or its metabolites inactivated enzyme systems of the pathogens. A study of enzymes near the root zone indicated decrease in polygalacturonase activity. Pectic enzymes are important in root rot/wilt induction. Decrease in activity indicated inhibition presumably through antibiotics produced by *Trichoderma. P. hysterophorus* thus appeared to exert its inhibitory effect on soil borne pathogens through *Trichoderma.* The antibiotics viridin and gliotoxin are both known to inhibit pectic enzymes. Alternatively release of glucose of celluloses of *Trichoderma* may repress enzymes of pathogens through catabolite repression. A search for catabolite repression resistant mutants is in progress.

Toxins from *Fusarium* and *Helminthosporium* induced wilt in seedlings of *P. hysterophorus.* The wilt-inducing toxins were peptide toxins and were non specific. When used as foliar sprays, neither the toxin nor the pathogen induced blight in *P. hysterophorus.* The spores of the test pathogens,' however, germinated in extracts from roots, stems and leaves. This indicated that the toxin produced by the pathogens was somehow inactivated in the phylloplane. In another study it was observed that blight susceptible leaves of tomato and safflower were protected from *Altermaria solani* and *Alternaria*, when coated with wax from *P. hysterophorus. P. hysterophorus* wax thus appeared to bind toxin and prevent foliar damage to the weed. As expected, removal of wax from leaves, followed by toxin sprays resulted in development of water soaked patches which became necrotic later (Plate 1). The toxin was, then sprayed on the leaves using a lipolytic strain of *Aspergillus flavus* as a carrier. The fungus developed lesions in the waxy layer and the toxin developed water soaked patches which in turn became necrotic later. At this stage plants in open plots suffered from leaf-blight by *Alternaria.* The fungus and its toxin, when tested for pathogenicity, induced blight in *P. hysterophorus.* Blight developed earlier when mutant strains were used with a lipolytic carrier/fungus at appropriate stage of growth.

Use of facultative fungal parasites as weed control agents is discouraged on the basis that the pathogens may affect non-targets, i.e., crops. This fear is justified. However, development of host-specific strains can be an answer. In our experiments, EMS — induced mutants were selected only on the basis of virulence to *P. hysterophorus* and tolerance to *parthenin.* These mutants developed leaf blight earlier. Early blight could also be induced through addition of unsterilized extracts from blight affected leaves to the inoculum. The basis of this synergistic effect needs further investigation.

Search for bridging host

Alternaria attacking 18 hosts in the area were used to inoculate detached leaves of *I. fistulosa.* After sporulation the fungus was transferred to *P. hysterophorus* through leaf replica technique. Twelve of the 18 species developed leaf spots. This opened up a possibility that weakly virulent or avirulent strains can be modified by passage through a non-host weed.

P. hysterophorus, thus proved to be a model for studying the barriers associated with development of mycoherbicides, based on ubiquitous fungi like *Helminthosporium* and *Alternaria*. For wilt or rot induction, strains tolerant to root — exudates and antibiotics secreted by antagonists can be used. Where catabolite repression is operative, catabolite repression resistant strains may be the answer.

Mycoherbicides for inducing foliar blight can be developed by judicious selection of mutant strains. Their use with a lipolytic carrier adds to their effectivity. When toxins are used problems of host specificity are minimized.

The results obtained with *P. hysterophorus* may well apply to other weeds also when mycoherbicides are to base on facultative fungal parasites. In case of obligate parasites — rust, powdery mildews — our experiments with *X. strumarium* and *I. fictulosa* revealed that weather plays a decisive role and restricts their utilization in control strategy. Each weed, however, has to be studied as a separate ecological entity.

Failure in the effective control of *P. hysterophorus* in India stimulated studies on its use. *Parthenin*, the dominant lactone in plant, has antimicrobial activity (Usha Deshpande, personal communication) and this property can be exploited for biocontrol of pathogens. *Parthenin* has antigibberellin-like activity. Inhibition of germination of cereal seeds soaked in exudates from leaves or roots reported so far, probably has its origin in this property. Suppression of gibberellin-induced amylase synthesis may be responsible for the allelopathic effects report so far. Reports therefore on allelopathic effects of other weeds also need reinvestigation.

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TANNIN PATTERN OF *EICHHORNIA CRASSIPES* (MART) SOLMS

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ABSTRACT

Leaves of *Eichhornia crassipes* (Mart) Solms contain condensed tannins only, averaging 3.1% leucon athocyanin on a dry weight basic. Total phenols and stringency (determined by haemanalysis), both expressed as tannic acid equivalent, averaged 1.1 and 2.1, respectively. The hydrolysable tannins, galloyl esters and ellagi-tannins were absent. Chromatography of the acid hydrolysate of the leucoanthocyanin revealed the presence of cyanidin and biflavonyl, but no delphinidin.

INTRODUCTION

Eichhornia crassipes (Mart) Solms, an aquatic monocotyledon, exhibits remarkable resistance to its pests and more recently there have been several scientific reports attributing tannin content as one of the factors in plant resistance. Therefore, investigation on the tannin pattern of water hyacinth leaves was carried out. Tannin is a behavioral antifeedant, conferring plant repellance to potential predators, whether animal, fungal or bacterial (Schultz and Baldwin, 1982). Red oak tannins retard gypsy moth larval growth at concentrations above 0.5% tannin acid equivalent and incremental increases in tannin contents from 0.1 to 1% dry weight significantly reduced the growth of larval lepidoptera. In response to destruction by insects or by mechanical defoliation, the leaves of attacked willow and maple trees as well as leaves of nearby trees show increased concentrations of tannins and resins (Maugh, 1982).

Tannins are polyphenolic compounds which form stable complexes with proteins and are widespread in herbaceous plants. They are divided into hydrolysable and condensed tannins. Tannic acid, gallotannin and ellagitannin are examples of hydrolysable tannins. The condensed tannins are comprised of the leucoanthocyanins (proanthocyanins) which produce cyanidin and/or delphinidin upon heating with mineral acid.

MATERIALS AND METHODS

Total phenols could be determined by the Follin-Denis method (Schultz and Baldwin, 1982). The tannin content could be measured by haemanalysis which depends on the protein-precipitating ability of tannins (Bate-Smith, 1975). Leucoanthocyanidins are determined by boiling the sample in butanolic hydrochloric acid. In this solvent cyanidin and other products of procyanidin have — max 547 nm, while delphinidin has 558 nm (Bate-Smith, 1975). Ellagitannin is determined by treating methanolic extract of the sample, after exclusion of oxygen, with nitrous acid and measuring the absorption of the reaction product at 600 nm (Bate-Smith, 1977). The result is expressed as the % hexahydroxydiphenic acid ester with glucose (HH). Hydrolysable tannins are determined by treating the methanolic extract of the plant tissues with KIO_4 at 0°C, and measuring the absorption of the red color produced, at λ max 550 nm (Bate-Smith, 1977).

Chromatographic procedures were done according to the method of Harborne (1973).

RESULTS AND DISCUSSION

Table 1 shows the tannin pattern of water hyacinth leaves. Based on dry weight, the total phenols and astringency are 1.1% tannic acid equivalent (TAE) and 2.1% TAE, respectively. The latter is determined by haemanalysis and is a measure of the tannin coefficient, i.e., the ability of tannin to precipitate protein and thus, it is an indication of the tannin content. The astringency value of 2.1% TAE is more than adequate to contribute to plant resistance. Gallylesters expressed as hydrolysable tannins, as well as ellagitannin could not be detected. Thus, the tannin of water hyacinth is of the condensed type only and is equivalent to 3.1% leucoanthocyanin. Treatment of the leucoanthocyanin with butanolic HCl yielded cyanidin, which in the said solvent has λ max 547 nm, while in methanolic HCl its λ max is 535 nm. The acid hydrolysate of the leucoanthocyanin was chromatographed on paper and on cellulose thin layer plate, using Forestal solvent (acetic acid: HCl: water = 30.3:10). The resulting thin layer chromatogram (Fig. 1) shows the cyanidin spots with R_f = 0.49 and the biflavonyls. The latter are of very high R_f and are colored dull brown: which is unchanged by exposure to ammonia. As can be seen from the chromatogram there are no spots corresponding to delphinidin, which should be below that of cyanidin. The delphinidin spot is colored magenta and has R_f = 0.32. Table 2 shows the properties of water hyacinth leucoanthocyanins as observed in the course of the experiment. These characteristics are used in identifying leucoanthocyanins from various sources.

Table 1. Tannin pattern of **Eichhnornia crassipes**

	Average**	Reference
Total phenols, % Tannic acid equivalent	1.1.	Schultz and Baldwin, 1982
Hydrolysable tannins, % Tannic acid equivalent	0.0	
Leucoanthocyanin, %	3.1	Bate-Smith, 1977
Ellagitannin	0.0	
Astringency, % Tannic acid equivalent	2.1	

* *Tannic acid equivalent*
** *All values based on dry weight*
*** *Hexahydroxydiphenic acid (ellagitannin)*

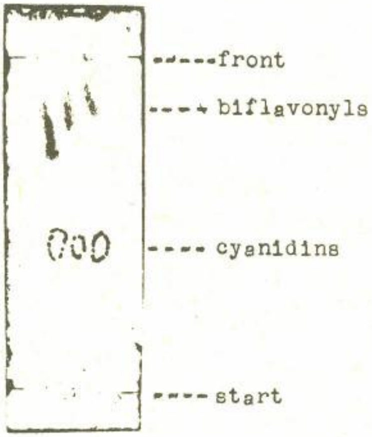

Fig. 1. Forestal chromatogram of acid hydrolysate of leucoanthocyanin from water hyacinth.

Table 2. Properties of water hyacinth leucoanthocyanins

1. Mainly colorless
2. Yield anthocyanidins (color extractable into amyl alcohol) when tissue is heated for 0.5 hour in 2M-HCl
   cyanidin —
   R_f in Forestal solvent = 0.49
   Visible color is magenta which changes to blue upon exposure to NH_3
   λ max in methanolic HCl = 536 nm
   λ max in butanolic HCl = 547 nm

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PRETILACHLOR – A NEW SELECTIVE HERBICIDE FOR TRANSPLANTED RICE IN JAPAN

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ABSTRACT

Pretilachlor [2-chloro-2', 6'-diethyl-N-(2-propoxyethyl)-acetanilide] is a new selective rice herbicide being developed by CIBA-GEIGY in various rice-growing countries.

In Japan pretilachlor has been successfully developed for use in transplanted rice. Pretilachlor at as low as 0.6 kg ai/ha controls a wide spectrum of rice field weeds when applied pre to at emergence and can be used pre to post transplanting with good crop tolerance.

INTRODUCTION

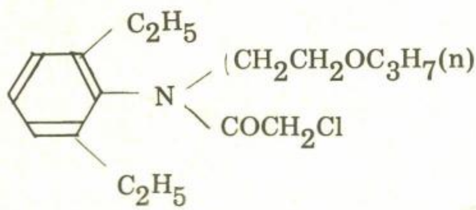
Pretilachlor is the proposed common name for 2-chloro-2', 6'-diethyl-N-(2-propoxyethyl)-acetanilide. It was discovered by CIBA-GEIGY Ltd., Switzerland as a selective rice herbicide and is being developed in various rice-growing countries by CIBA-GEIGY.

In 1974, pretilachlor was evaluated for the first time in field screening trials in Japan. Since 1977 pretilachlor 2% granules have been tested throughout Japan by national and prefectural stations in cooperation with the Japan Association for Advancement of Phytoregulators (JAPR). In addition to 2% granules, a 12% EC formulation and several mixtures are being developed to meet various requirements of Japanese rice growing.

This paper describes the biological properties of pretilachlor 2% granules in transplanted rice in Japan in addition to physico-chemical and toxicological properties of the technical material.

Physico-chemical and toxicological Properties

The chemical formula of pretilachlor is:



The technical material is a colorless liquid with a boiling point of 135°C (0.001 mb) and a water solubility of 50 ppm (20°C). It is readily soluble in methanol, methylene chloride, benzene and hexane.

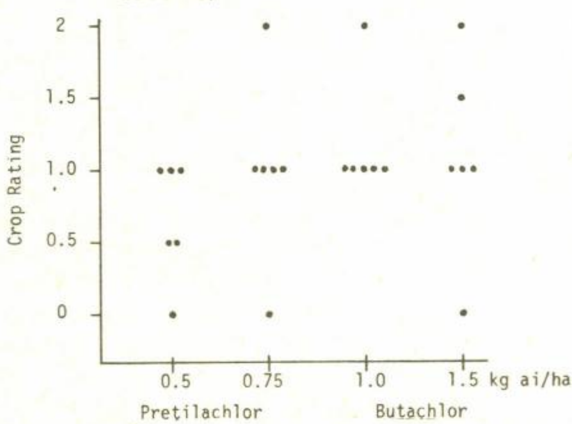
Its acute oral LD_{50} is 6099 mg/kg and acute dermal LD_{50} is more than 3100 mg/kg for male rats. The TLm48 value for Japanese carp is 2.17 ppm.

Biological Properties

Dosage rate and Application Time

Field evaluations in 1974-76 showed that 0.5 to 0.75 kg ai/ha of pretilachlor applied preemergence to weeds possessed good selectivity under Japanese conditions (Table 1 and Figure 1). Based on these trials, official field trials using 0.6 kg/ha have been conducted by JAPR since 1977. It has performed well in those trials.

Figure 1. Summary of six field trials in four different Locations in Hyogo, Central Japan, in 1975-76.



Each dot indicates median value of JAPR scoring system* (3-4 replications) of a respective treatment in a trial.

Table 1. Summary of two field screening trials in 1974 in Sanda, Central Japan

Rate of pretilachlor kg ai/ha	Application Time	Crop Rating* (JAPR System)	Weed Control in [%]			
			Ecg	Mon	Sgp	Blw
0.5	2-3 DAT	0	100	95	0	85
1.0		1	100	98	0	98
2.0		2	100	100	0	100
4.0		3	100	100	80	100
0.5	9 DAT	0	90	60	0	60
1.0		1	95	60	0	85
2.0		1	98	85	60	100
4.0		3	100	90	70	100

Ecg: Echinochloa crus-galli, *Mon: Monochora vaginalis*
Sgp: Sagittaria pygmaea, *Blw: Broadleaved Weeds such as Rotala indica and Lindernia procumbens*

Evaluation date: 17-24 DAT
**) 0 = no phytotoxicity* *5 = Very severe phytotoxicity*

Pretilachlor can be applied pre- to post-transplanting (Figure 2 and Table 2) and pre-to at -emergence of weeds.

Table 2. Influence of application time on crop tolerance of pretilachlor at 0.6 kg ai/ha — A summary of official trials in 1977 and 1978.

Crop Rating* (JAPR System)	NUMBER OF TRIALS		
	Around 3 DBT	Just after transplanting	Around 3DAT
0	29	29	32
1	12	11	10
2	8	9	6
3	1	1	2
4	0	0	0
5	0	0	0

* *0 = No phytotoxicity* *5 = Very severe phytotoxicity*

Herbicidal Activity

The herbicidal spectrum of pretilachlor at 0.6 kg/ha is characterized by its high activity on *Echinochloa crus-galli, Eleocharis acicularis and Scirpus hotarui* Owhi which are of high agronomical importance in Japan (Table 3).

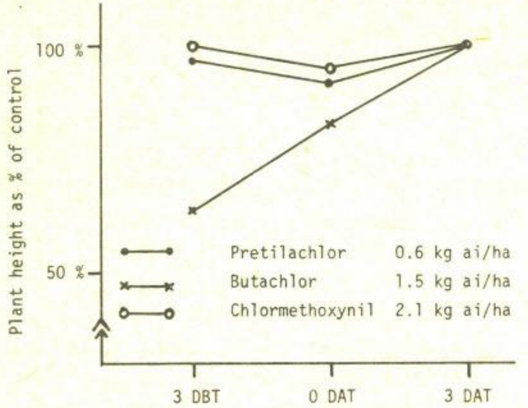


Figure 2. Influence of Application Time on Crop Tolerance of pretilachlor (Summary of Greenhouse Trials)

Table 3. Herbicidal spectrum of pretilachlor at 0.6 kg ai/ha in transplanted rice of Japan.

Weed Species	Activity
Echinochloa crus-galli (L.) Beauv. Cyperus difformis L. Eleocharis acicularis (L.) Roem. & Schult. Eriocaulon spp.	Excellent
Monochoria vaginalis (Burm. f.) Presl. Scirpus hotarui Ohwi Alisma canaliculatum A. Br. & Bouche Elatine triandra Sch K. Lindernia procumbens (Krock.) Philcox Rotala indica (Willd.) Kochne Dopatrium junceum (Roxb.) Buch, -Ham ex Benth	Good
Cyperus serotinus Rottb.	Fair
Sagittaria pygmaea Miq. Sagittaria trifolia L. Potamogeton distinctus A. Benn Eleocharis kuroguwai Ohwi Oenanth javanica (Bl.) Dc.	Poor

Granular mixtures such as pretilachlor/ pyrazolate and pretilachlor/ naproanilide are also being developed for the control of other important weed species, such as *Sagittaria pygmaea* Miq.

Crop Tolerance

From 1977 to 1982, pretilachlor at 0.6 kg/ha was well tolerated by transplanted rice in about 95% of the official field trials when applied about 3 days after transplanting. However, in the rest of trials slight to moderate phytotoxicity was observed. The trial conditions of those trials were analyzed and greenhouse trials (Tables 4 and 5) on some possible factors affecting crop tolerance were conducted (Tables 6 and 7 and Figure 3). High water leaching associated with low clay content and organic matter and shallow planting play the most important roles in causing phytotoxicity. Pretilachlor was inadequately tolerated only in a location in which the soil was a type of Andosol. Studies are in progress to elucidate this case.

Table 4. Influence of clay and organic matter content on crop tolerance of pretilachlor at 0.6 kg ai/ha applied around 3 days after transplanting in official Field Trials from 1977-82.

Content in Soil		Numbers of Trials Crop Rating (JAPR System)					
Clay	Organic Matter	0	1	2	3	4	5
	<3 %	13	4	6	0	0	0
⩾37.5⩽	⩽5	7	4	0	0	0	0
	⩾5	4	1	2	3	0	0
	<3 %	6	2	0	0	0	0
>37.5%	⩽5	20	14	0	0	0	0
	⩾5	10	10	0	0	0	0

Table 5. Influence of water leaching on crop tolerance of pretilachlor at 0.6 kg ai/ha applied around 3 days after transplanting in official field trials in which the soil contained less than .3.75. clay and less than 3% organic matter.

Water Leaching	Numbers of Trials Crop Rating * (JAPR System					
	0	1	2	3	4	5
<10 mm/day	5	1	0	0	0	0
<20	7	1	1	0	0	0
>20	1	2	5	0	0	0

**) 0 = No phytotoxicity 5 = Very severe phytotoxicity*

Table 6. Influence of planting depth and water leaching on pretilachlor-phytotoxicity to transplanted rice (Greenhouse Trials)

Compound	Planting Depth mm	Shoot fresh weight as % of Control Water Leaching	
		None	3 cm/day x 3 days
Pretilachlor (0.9 kg ai/ha)	20	100	96
	5	87	61
Butachlor (2.25 kg ai/ha)	20	90	85
	5	64	59

Note: Aplication: 1 DAT
Evalution: 24-29 DAT
Soil: ONO sandyloam

Table 7. Influence of depth of standing water and water leaching on pretilachlor-phytotoxicity to transplanted rice (Greenhouse Trials)

Compound	Water Depth cm	Shoot fresh weight as % of Control Water Leaching	
		None	1.5 cm/day x 3 days
Pretilachlor (0.6 kg ai/ha)	6	100	70
	1.5	83	44
Butachlor (1.5 kg ai/ha)	6	85	55
	1.5	9!	47

Note: Application: 1 DAT
Evaluation: 25 DAT
Soil: : Tarazuka sandyloam

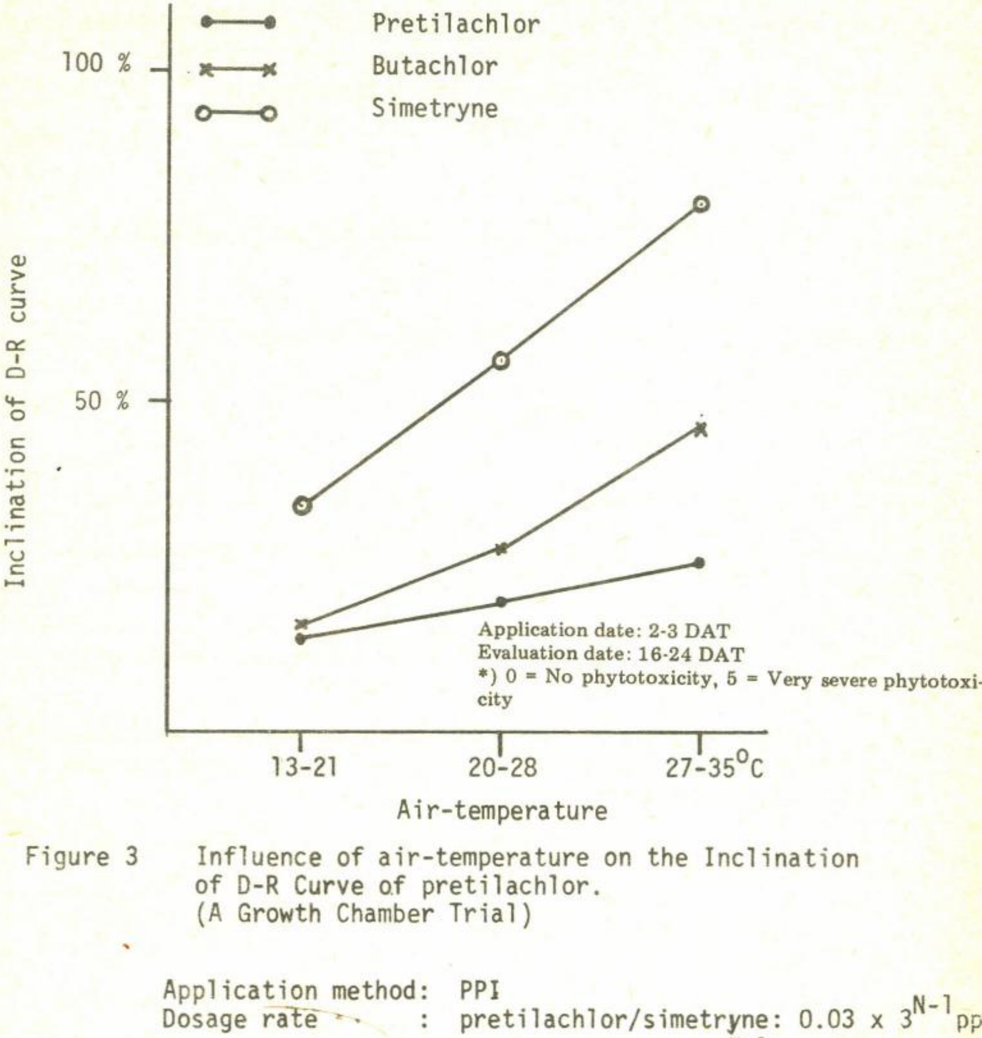


Figure 3 Influence of air-temperature on the Inclination of D-R Curve of pretilachlor. (A Growth Chamber Trial)

Application method: PPI
Dosage rate : pretilachlor/simetryne: $0.03 \times 3^{N-1}$ ppmW
butachlor: $0.06 \times 3^{N-1}$ ppmW

Inclination, % inclination of shoot weight/N.

ACKNOWLEDGEMENTS

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ERADICATION OF WEEDS BY HERBICIDES IN FOREST TREE PLANTATION

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ABSTRACT

After spraying Dowpon for 2 months in the first year of teak plantation, *Imperata* mortality rate was about 70-80%. This reduced competition encouraged flushing with new leaves and promoted shoot height in tree crops compared to plots with no spraying.

Temporary browning of leaves occurred and growth was blocked for only 1 month after spraying. Healthy leaves and shoots appeared within the second month after spraying.

The general effect of Dowpon on the teak trees planted in 1978 and 1976 is leafburning and necrosis but there was recovery within 2 months. This effects occurred through root absorption.

No significant difference in three height was found between sprayed and control plots.

Dowpon showed no growth effects on *Afzelia xylocarpa* but growth performance seemed better than in the control plot.

Dowpon should not be used with young *Gmelina* trees, especially when height is not beyond the level of the spraying nozzle.

Spraying was perhaps done too late in the growing season. The first spraying was done in July when *Imperata* was at the mature stage. These caused difficulty with spraying as well as chemical consumption.

The recommended time to spray is 1 month after staking.

INTRODUCTION

Weeds play an important role in reforestation. It is not only a source of forest fires but they reduce tree growth. Weeds compete successfully with tree crops by being more aggressive in growth habit, obtaining and utilizing the essentials of growth and development at the expense of tree crops, and, in some cases, excreting chemicals that adversely affect the growth and development of surrounding tree crops.

Hand-cutting has long been the traditional method of weed control. Two or three hand-weedings may be required for the first year or two after planting. To be effective these must be done in the proper time period. Herbicides offer the prospect of improvement in tree growth due to a more efficient removal of weeds.

Herbicides are currently recommended overseas for use in controlling grasses and herbaceous broadleafed mixtures. Dalapon or Dowpon is effective on grasses. Therefore, this herbicide is recommended so that crops may not be damaged.

This study implies that Dowpon is recommended for use in controlling grasses in tree planting and intends to clarify dosage required for controlling *Imperata* spp.

MATERIALS AND METHODS

Non-replicated experiment was conducted in Lum Nam Wang Thong Plantation, Pitsanulok, Thailand from July 1979 to October 1979.

Dowpon (2,2-dichloropropionic acid) was sprayed once at 3.0 kg/Rai (18.75 kg/ha) and once at 2.0 kg/Rai (12.5 kg/ha) followed by 1.6 kg/Rai (10.0 kg/ha) 30 days apart on different tree plantation. One rai is 1,000 m^2. It was applied at normal walking speed using portable hand operated sprayer with multiple nozzles and swath of 6.25 cm at volume delivery of 170 liters/Rai or 1063 liters/ha.

The different tree plantations were:

Plantation 1. This was planted to teak in 1979. Five plots measuring 1,600 m^2 each were laid out and treated as follows:

1. Sprayed with Downpon at 3 kg/Rai while teak trees were covered with tin cans to protect contamination by the chemical,
2. Sprayed with the same rate as in (1) but trees were not protected from contamination.
3. Sprayed with Downpon at 2 kg/Rai followed by 1.6 kg/Rai 30 days after the first spraying. Trees were protected from contamination for the first spraying,
4. Sprayed with the same rate as (3) but trees were not protected and
5. No spraying (control).

Plantation 2. Plantation planted to teak in 1978 was divided into 3 plots of 1,600 m^2 each and treated as follows:

1. Sprayed with Dowpon at 3 kg/Rai.

2. Sprayed at the rate of 2 kg/Rai and then at 1.6 kg/Rai 30 days after the first spraying.

3. No spraying (control).

Plantation 3. Same as in 2 but teak planted in 1976 was used.

Plantation 4. Same as in 2, but *Gmelina aborea* planted in 1978 was used.

Plantation 5. Same as in 2 were applied to *Afzelia xycolarpa* planted in 1977.

RESULTS

Disappearance of *Imperata* after 1 and 2 months of spraying.

Table 1. Mortality of Imperata *spp. in each plantation at 1 month after spraying with Dowpon.*

Plantation Time planted (years)	3.0 kg/Rai or 18.75 kg/ha (%)	2.0 kg/Rai or 12.5 kg/ha (%)
Teak: 1979 with cover	76.67	66.67
Teak: 1979 without cover	76.67	66.67
Teak: 1978	81.67	66.67
Teak: 1976	80.00	75.00
Afzelia: 1977	86.67	76.67
Gmelina: 1978	80.00	70.00

Table 2. Mortality of Imperata *in each plot at 2 months after spraying with Dowpon.*

Plantation Time planted (years)	3.0 kg/Rai or 18.75 kg/ha (%)	2.0 + 1.6 kg/Rai or 12.5 + 10.0 (%)
Teak: 1979	85.00	89.00
Teak: 1978	85.00	89.00
Teak: 1976	84.00	91.67
Afzelia: 1977	81.67	85.00
Gmelina: 1978	73.33	81.00

Effect of dowpon application on tree growth:

Teak. All leaves which were directly in contact with the herbicide became brown and shed within 2 days after spraying. After 2 months, normal leaves flushed with bigger and longer stem shoots while trees in the control plot still had not flushed.

In trees where height was beyond the direct effect by chemical, leaves were slightly affected by the chemical through root absorption but, after 2 months, flushing also occurred.

Gmelina aborea. All trees which were directly contacted by chemical spraying dried out. Sprouting from the stem base was seen one month later.

Damage through root absorbtion was not evident.

Afzelia xylocarpa. No damage was found due to Dowpon spraying. Flushing was seen in the sprayed plot while in the control plot there was none.

Height growth of trees as affected by dowpon spraying:

Height was investigated only in teak plantation. The other plantations could not be monitored because of the drying back of top shoots.

Height was measured 1 year after spraying. The results are summarized as follows:

1. In younger plantation (planted in 1979), average tree height was significantly greater in the sprayed plot than control plot.

2. In the older plantation; (planted in 1976 and 1978), weed control through Dowpon spraying had no effect on tree height as compared with sprayed and control plots.

ABBREVIATIONS

a.i.	=	active ingredient
a.e.	=	acid equivalent
cm	=	centimeter
DAE	=	days after emergence
DAS	=	days after seeding
DAT	=	days after transplanting
DBT	=	days before transplanting
DBS	=	days before seeding
DMRT	=	Duncan's multiple range test
DT	=	days after treatment
EC	=	emulsifiable concentrate
Early post	=	early postemergence
fb	=	followed by
G	=	granules, granular fomurlation
g	=	gram
ha	=	hectare
HW	=	hand weeded, handweeding
kg	=	kilogram
L	=	liter
m	=	meter
mg	=	milligram
mm	=	millimeter
ppm	=	parts per million
Pre	=	preemergence
Post	=	postemergence
v/v	=	volume for volume
w/w	=	weight for weight
WAE	=	weeks after emergence
WAT	=	weeks after treatment
WP	=	wettable powder