WEED CONTROL EFFECT OF SOME HERBICIDES IN PADDY FIELD

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Interest in controlling weeds in paddy field by chemicals has greatly increased in recent years. During the past years, considerable amount of time has been devoted to screening herbicides for use in rice, and the Department of Agriculture and Forestry of Taiwan Provincial Government has recommended several herbicides for commercial use in the nursery and in the paddy field. However, weeding in paddy fields is still done largely by hand in Taiwan presumably because most chemicals now available are either too expensive or imperfect in the control of weeds. As industrial development of this island is progressing very rapidly, the supply of farm labor is bound to decrease in the coming days, and hand weeding may eventually be replaced by the chemical in the future. In order to meet the future demand of rice growers, the Chiayi Agricultural Experiment Station has been closely cooperating with the International Rice Research Institute in the testing of new herbicides with the purpose of finding out a more economical and effective weed control method acceptable to farmers. This paper summurizes part of the results obtained from the second cooperative experiment conducted in the second crop of 1967.

MATERIALS AND METHODS

The experiment was conducted in the second crop (wet season) of 1967 at the Wan-tien-li Farm of the Chiayi Agricultural Experiment Station. Soil of the experimental plots was sandy loam and pH, organic matter, available P_2O_5, and available K_2O of the surface soil were 5.1, 2.46%, 513 kg, and 60 kg per ha, respectively. Chianung 242, a typical panicle weight of Japonica rice variety was subjected to 16 weed control treatments as listed in Table 1. Name, formulation, and source of the herbicides used in this experiment are also given in Table 2.

Table 1. Treatments of chemical weed control experiment.

Treatment	Active rate (kg/ha)	Timing
1. Hand weeding (HW)	3 times	10, 17, and 25 days after transplanting.
2. MCPA+HW	0.8+1 HW	MCPA at 15 days, and HW, 25 days after transplanting.
3. Pyridinol	0.2	1 day befor transplanting.
4. Pyridinol+MCPA	0.2+0.8	As above; MCPA, 25 days after transplanting.
5. Molinate	3.0	Grass weeds at 1-2 leaf stage or 7 days after transplanting.

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6. Molinate+MCPA	3.0+0.8	As above; MCPA, 25 days after transplanting.
7. NPE	2.0	3 days after transplanting。
8. NPE+MCPA	2.0+0.8	As above; MCPA, 25 days after transplanting.
9. KN_3	5.0	At 2-3 leaf stage of grass weeds or 9 days after transplanting.
10. KN_3+MCPA	5.0+0.8	As above; MCPA 25 days after transplanting。
11. Trifluralin	1.0	6 days after transplanting.
12. Trifluralin+MCPA	1.0+0.8	As above; MCPA 25 days after transplanting。
13. EPTC/2,4−D	3.0	3 days after transplanting.
14. Dichlobenil	1.5	3 days after transplanting.
15. Dichlobenil+MCPA	1.5+0.8	As above; MCPA, 25 days after transplanting.
16. No weeding	—	—

Table 2. Herbicides used in the test,

Name of herbicide		Formultion	Source
Chemical	Trade		
MCPA	Agroxone-4	48% EC	Imperial Chem. Ind.
Pyridinol	Daxtron M-2901	19.3% EC	Dow Chem. Co.
Molinate	Ordram 6-E	71% EC	Stauffer Chem. Co.
NPE	TOK	7% G	Rohm & Hass Co.
KN_3	Potassium Azide	9% G	Pittsburgh Plate Glass Co.
Trifluralin	Treflan	44.5% EC	Elanco Prod. Co.
EPTC/2,4-D	Knoxweed 42	(46.9% Eptan+35. 4% 2.4-D)EC	Stauffer Chem. Co.
Dichlobenil	Casoron 133	50% WP	Phillips-Duphar

The design of the experiment was a randomized complete block with 4 replications. The plot was 3 x 4 m in size from which 2.5 x 4 m or 10 m^2 was harvested for yield determination。 The plant spacing was 25 by 20 cm with approximately 5 seedlings being transplanted at each hill. Ammonium sulphate, calcium superphosphate, and potassium sulphate were used as carriers of N, P_2O_5, and K_2O which were applied at the rate of 80, 40, and 40 kg per ha, respectively.

In order to insure a uniform and dense stand of weeds, 1.5 kg per ha of *Echinochloa crusgalli*, 0.5 kg per ha of *Monochoria vaginalis*, and 1.0 kg per ha of *Cyperus difformis* seeds were broadcast on the plots. Herbicides were applied to a shallow (1-3 cm) flood of water either by spraying or by broadcasting. Levees were made arround the plots to prevent the interflow of herbicides between neighbour plots.

Visual scores of weed control and rice toxicity were taken weekly started from one week

after the application of chemicals based on an arbitrary 0-4 scale devised by the author. Class 0 indicates whether complete control of weeds or no toxicity to rice plant and Class 4, no control of weeds or heaviest toxicity. Dry weed weight per plot was also recorded at the time of harvesting. Plant height and number of tillers per hill were measured once in every 20 days. Grain yield, components of yield, and other related agronomic traits were also recorded for the analysis of variance.

The weather in the early stage of rice growth was hot and rainy but a cool, dry and sunny weather prevailed during the late growing stage. Typhoon did not hit the island during the period of the experiment. The climatic data of wet season crop are presented in Table 3.

Table 3. Climatic data of the Chiayi Agricultural Experiment Station during the period of the experiment.

Ten-day Period		Rainfall amount (mm)	Number of rainy days	Number of sunshine hours	Relative humidity (%)	Temperature (°C)		
						Maximum	Mininum	Mean
Aug.	1-10	280.9	7	42.7	66	32.3	25.2	29.8
	11-20	82.9	5	22.0	70	32.2	25.3	28.8
	21-31	176.0	4	31.6	71	32.3	26.1	29.2
Sept.	1-10	62.1	6	45.1	71	31.8	25.4	28.7
	11-20	0	0	47.3	69	30.3	22.8	26.6
	21-30	9.6	2	34.0	75	29.5	22.1	25.9
Oct.	1-10	0	0	41.6	65	29.3	20.7	25.0
	11-20	2.3	1	24.9	70	28.5	21.1	24.8
	21-31	0	0	49.0	63	27.5	18.0	22.8
Nov.	1-10	7.5	2	42.7	73	28.2	20.0	24.1

RESULTS AND DISCUSSION

Effect of Herbicides on the Control of Weeds and the Toxicity of Rice.

The infestation of weeds in the experimental plots at the early stage of rice growth was mostly the broad leaves. However, the grasses developed rapidly and became the predominant weeds in some plots at the later stages. The sedges occupied only a small fraction of the total weed population. The most common broadleaves in the experimental plots were *Monochoria vaginalis*, *Marsilea quadrifolia*, *Lemma paucicostata*, and *Spirodela polyrhiza*. The grasses were predominately *Echinochloa* spp. and *Paspalum scrobiculatum*, whereas *Cyperus differmis* anb *C. iria* were the predominant sedges.

The visual scores of weed control and rice toxicity as well as dried weight of weeds are presented in Table 4. MCPA applied at 15 days after transplanting killed most of the broadleaved weeds and sedges but failed to control grassy weeds. Since broadleaves were the most predominant weeds in the experimental plots and weeds not controlled by MCPA

were removed by handweeding, treatment 2 resulted in a good control of weeds with visual scores of less than 2. The combination of MCPA followed by handweeding was also rated as one of the best treatment at the International Rice Research Institute (Moomaw *et al.*, 1966).

Table 4. Effect of herbicides on weed control, rice toxicity, and dry weed weight.

Treatment	Weed control score					Rice toxicity score					Dry weed weight at harvest (g/10 m²)			
	Weeks after application					Weeks after application					Grasses	Broad-leaves	Sedges	Total
	1	2	3	4	5	1	2	3	4	5				
1	1.0	1.0	1.0	1.0	1.0	0	0	0	0	0	205	160	—	365
2	1.9	1.3	1.5	—	—	0	0	0	—	—	371	153	1	525
3	2.7	3.5	4.0	4.0	4.0	2.0	1.0	0	0	0	610	1,040	9	1,659
4	2.8	3.5	3.5	1.5	1.8	2.0	1.0	0	1.0	2.0	851	143	—	994
5	3.4	4.0	4.0	4.0	—	0	0	0	0	—	661	849	1	1,511
6	3.8	4.0	1.5	1.5	—	0	0	1.6	2.1	—	811	103	—	914
7	1.0	1.0	1.3	1.9	2.5	1.0	0.5	0	0	0	1,540	189	2	1,731
8	1.0	1.0	1.3	1.3	1.3	1.0	0.5	0	1.0	2.0	1,034	105	—	1,139
9	1.3	1.3	1.3	1.5	—	0	0	0	0	—	1,255	108	—	1,363
10	1.3	1.3	1.3	1.5	—	0	0	1.0	2.0	—	1,248	245	1	1,494
11	1.5	2.2	2.8	3.1	—	0	0	0	0	—	1,063	432	1	1,496
12	1.5	2.0	1.3	1.0	—	0	0	1.0	2.0	—	404	89	—	493
13	1.0	1.0	1.8	2.7	3.2	1.0	1.0	0	0	0	728	438	23	1,189
14	1.0	1.0	1.5	2.3	2.6	0	0	0	0	0	1,092	494	—	1,586
15	1.0	1.3	1.5	1.5	1.5	0	0	0	1.3	2.2	696	112	—	808
16	4.0	4.0	4.0	4.0	4.0	0	0	0	0	0	1,626	1,253	—	2,879

Treatments with Pyridinol and Molinate applied alone gave poor control of weeds showing that these two chemicals could not control broadleaves which were the major weeds of the experimental plots. However, a good weed control was obtained when these chemicals were followed by an application of MCPA at 25 days after transplanting. Although Pyridinol and Molinate performed very poorly in this experiment, these two chemicals have been frequently rated by other workers as the most effective weed killers. Tang and Tsai (1967) reported that Pyridinol applied 10 days after transplanting at the rate of 0.25 kg per ha gave a good control of both grassy and broadleaved weeds. Molinate was found to be very effective in controlling various weeds in general and barnyardgrass in particular (Tang and Wu, 1965 a, b). Good control of barnyardgrass of Molinate was also observed in experiments in California and Arkansas (Smith and Shaw, 1965). Moomaw (1967) also reported that Pyridinol and Molinate were among the few best chemicals which were superior or equal to the handweeding or to the recommended practice of using 2,4-D (or MCPA) before

handweeding. Apparently, method of application and the infestation of weeds can greatly affect the effectiveness of these two chemicals.

NPE and Dichlobenil controlled weeds very effectively. The plots of these two treatments were as clean as those of the handweeded check. However, the effect of these two chemicals lasted for only about 3 weeks and the infestation of weeds became serious in the fourth week after the application of these chemicals. Thus, an application of MCPA at 25 days after transplanting was effective in controlling these newly emerged weeds. Good weed control of Dichlobenil was also found in the previous experiment (Chang, 1965). At present, NPE and Dichlobenil are among the herbicides recommended for use in rice by the government in Taiwan.

KN_3 was able to maintain a good weed control for approximately 4 weeks after its application. KN_3 applied alone and with combination of MCPA gave the same visual scores of weed control, indicating that KN_3 was very effective in controlling broadleaved weeds and, under the condition of this experiment, a follow-up application of MCPA appeared unnecessary. Tang and Tsai (1967) reported that KN_3 controlled both grassy and broadleaved weeds in their experiment. It was also effective for the control of some common aquatic weeds in rice when applied as post-emergence treatment in the United States (IRC Report, 1967).

EPTC/2,4-D showed a good control of weeds, but its effect lasted for only two weeks, when it was applied alone. Trifluralin gave only moderate control of weeds, indicating that it could not kill broadleaved weeds completely. It was found that Triflaralin followed by an application of MCPA at 25 days after transplanting reduced considerably the visual scores of weed control. Tang and Tsai (1967) also observed that Trifluralin gave good control of grassy weeds but it controlled poorly of broadleaved ones. It appears that, Trifluralin may be unacceptable in areas where broadleaved weeds are usually a mojor problem.

Visual scores of rice toxicity in Table 4 shows that Pyridinol, NPE, EPTC/2,4-D, and the late application of MCPA were quite toxic to rice, whereas no toxicity was detected for Molinate, KN_3, Trifluralin, Dichlobenil, and the early application of MCPA. Pyridinol caused chlorosis of rice seedlings and leaf blades turned white when they were seriously injured. A serious injury of Pyridinol was also reported by Tang and Tsai (1967). The submerged leaves of rice seedlings were completely destroyed by NPE, indicating that the paddy field should be flooded with a shallow water at the time of NPE application, if the occurrence of its toxicity is to be prevented. The phytotoxicity of EPTC/2,4-D was manifested in stunting growth and yellowish leaves of rice seedlings. The late application of MCPA caused outspreading of tillers and drooping of leaves. However, the injuries caused by these chemicals did not result in a complete kill of rice plants and they were found to recover within 2 weeks.

Dry weed weight measured at the time of harvesting, indicated that grasses and broadleaves comprised the majority of the final product of weeds and, sedges occupied only a small fraction of the total weight. *Paspalum scrobiculatum* which was only a minor weed at the early stage of rice growth grew vigorously and eventually dominated the weed population at the late stage of rice growth. Thus, weed control rating at the early stage of rice

growth did not agree with the dry weight of grassy weeds. However, dry weight of broad-leaved weeds was generally in parallel with weed control score, indicating that good weed control treatments generally produced small amount of weeds. The control of *Paspalum scrobiculatum* appears necessary in the area where it is potentially an important weed of the paddy field.

From the standpoint of weed control and rice toxicity, an application of MCPA at 15 days after transplanting followed by a handweeding appears to be an effective weed control method for transplanted rice as suggested by Moomaw *et. al.*, (1966). It is also the most practical one because MCPA is the cheapest chemical now commercially available. KN_3 may be an ideal chemical to replace NPE if the cost of KN_3 is lower than NPE. At present, an application of NPE costs about NT$ 900 or US$ 22.5 per ha and farmers consider it too expensive to accept, even though it is highly effective. It is also suggested that NPE and Dichlobenil followed by MCPA may control weeds more effectively than the single application of NPE and Dichlobenil now recommended for use in Taiwan. Since late application of MCPA was toxic to rice, more research will be needed regarding the time or rate of MCPA application. Tang and Tsai (1967) suggested that the active rate of MCPA should not exceed 0.2 kg per ha.

Effect of Herbicides on the Growth of Rice.

Plant height and number of tillers per hill were measured every 20 days to indicate the growth of rice plants. Figure 1 shows that plant height at 20 days after transplanting did not differ greatly among treatments, suggesting that application of chemicals did not

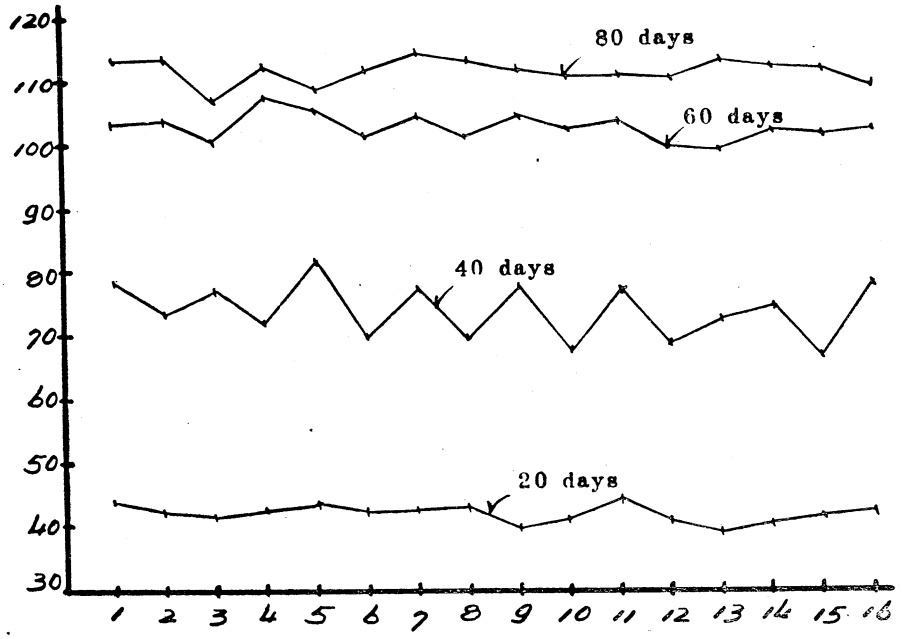

Figure 1. Effect of herbicides on plant height at different stages of growth.

affect plant height. Plant height was shorter in the treatments with late application of MCPA when it was measured at 40 days, indicating that MCPA applied at 25 days after transplanting was highly toxic to rice plants. However, the growth of rice plant recovered quite rapidly and at 60 days after transplanting, the toxicity of MCPA disappeared completely. Weed competition with rice was reflected on plant height at 60 and 80 days after transplanting. As a result, treatments with poor weed control were generally associated with shorter plant height.

Figure 2 shows that number of tillers per hill at 20 days after transplanting were smaller in the treatments of NPE and EPTC/2,4-D, showing that phytotoxicity of these chemicals was manifested in the reduction of tillers. However, number of tillers per hill was not affected by the late application of MCPA. Poor control of weeds also reduced number of tillers per hill at 60 and 80 days after transplanting, suggesting that weed competition with rice was most serious in the later stages of rice growth.

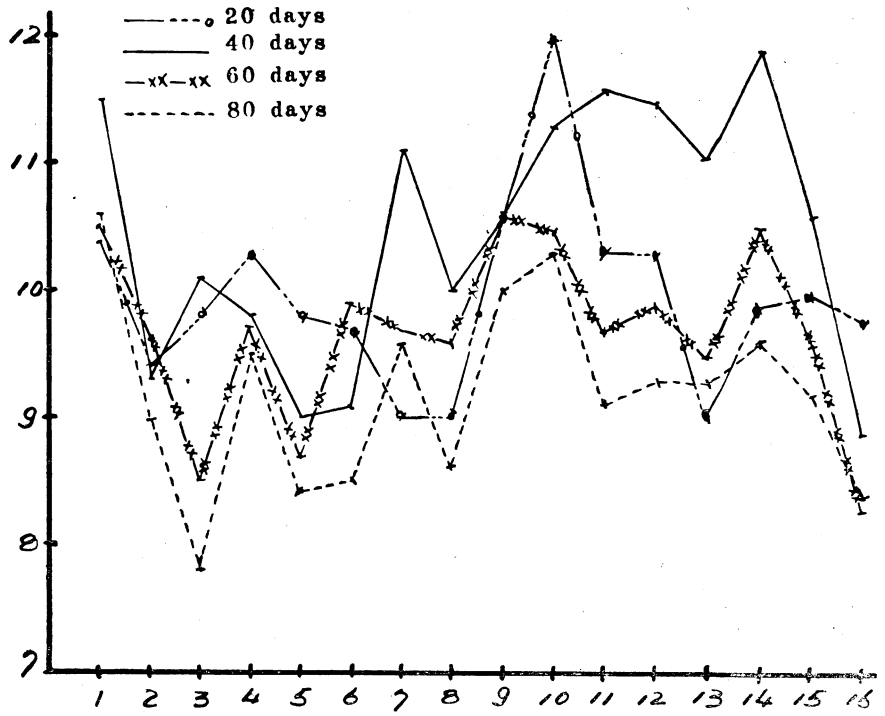

Figure 2. Effect of herbicides on number of tillers per hill at different stages of growth.

Effect of Herbicides on Grain Yield, Components of Yield, and Other Agronomic Characters of Rice.

Growing conditions during the period of rice growth were rather good but grain yield was slightly affected by the injury caused by plant hopper about one week before harvest-

ing. Weeded check, Pyridinol+MCPA, Dichlobenil+MCPA, Dichlobenil, and KN3+MCPA generally produced higher yields whereas Pyridinol, non-weeded check, and Molinate, the lowest. Weeded check produced 926 kg per ha or 30.5% more grain yield than non-weeded check, a difference greatly exceeding the 1% level of probability. Shaw and Danielson (1961) also reported that weed competition reduced yield production by 37.5%. The high yield of Dichlobenil was also obtained in the previous experiment (Chang, 1965). Weeded check outyielded all treatments, indicating that most chemicals or chemical combinations tested in this experiment were more or less harmful to the productivity of rice. It was observed that herbicides which were followed by MCPA generally gave higher yields than those applied alone, indicating that an additional application of MCPA contributed greatly to the increase of yield. The low yields of Pyridinol and Molinate may be largely attributable to severe competition of weeds.

Table 5 shows that number of panicles per hill and number of grains per panicle were significantly affected by the treatments, whereas 100-garin weight was not affected. Difference among treatments in number of grains per panicle was greater than that of number of panicles per hill, suggesting that the former was more susceptible to weed competition than the latter. It was found that treatments with higher grain yield were generally associated with more panicles per hill and/or more grains per paincle, indicating that the increase in grain yield was caused largely by these two components.

Table 5. Effect of herbicides on grain yield, components of grain yield and some agronomic characters of rice.

Treatment	Grain yield (kg/ha)	Number of Panicles Per hill	Number of grains per panicle	Weight of 100 grains (g)	Heading date (days)	Plant height (cm)	Panicle weight (g)	Panicle length (cm)
1	3,958	9.7	141.3	2.85	62.2	113.0	3.48	23.2
2	3,449	8.6	162.2	2.75	65.5	112.4	4.05	23.8
3	2,958	8.4	114.5	2.85	60.7	107.6	3.03	22.2
4	3,847	9.4	143.4	2.85	60.0	111.7	3.78	23.2
5	3,094	8.2	120.4	2.80	60.0	110.1	3.25	23.2
6	3,528	8.9	137.0	2.85	60.7	111.8	3.43	23.1
7	3,443	9.1	138.9	2.85	62.2	111.9	3.45	22.9
8	3,368	9.4	147.9	2.83	62.2	112.3	3.75	23.5
9	3,238	9.9	129.7	2.78	62.2	111.7	3.25	23.2
10	3,535	10.0	127.2	2.88	61.5	110.9	3.35	22.9
11	3,353	9.3	130.2	2.78	60.7	110.5	3.35	23.0
12	3,466	9.4	155.9	2.75	61.5	111.2	4.08	24.5
13	3,423	9.4	132.7	2.98	64.0	111.0	3.43	23.1
14	3,560	9.6	138.6	2.73	61.5	111.5	3.40	23.3

15	3,572	9.3	129.0	2.93	60.7	110.6	3.50	22.9
16	3,032	7.7	121.6	2.83	60.0	108.3	3.25	22.5
Mean	3,427	9.1	135.7	2.83	61.6	111.0	3.48	23.2
F value	2.72	2.56	3.09	0.63	3.89	1.17	2.06	2.12
LSD 5%	456	1.14	20.63	—	2.14	—	0.57	1.01
LSD 1%	610	—	27.55	—	2.86	—	—	—

Early application of MCPA and EPTC/2,4-D significantly delayed the date of heading whereas the plots heavily infested with weeds such as non-weeded check and Molinate headed earlier than others. No significant difference among treatments was found in plant height taken at maturity, but treatments with lower yield were generally associated with shorter plant height. Panicle weight and Panicle lenght were also significantly affected by the treatment, showing that weed competition was effective in reducing panicle weight and panicle length of rice.

SUMMARY

The effects of some herbicides and herbicides combinations on the control of weeds in paddy field evaluated at the Chiayi Agricultural Experiment Station, Chiayi, Taiwan, in the second crop of 1967 are summarized.

Broadleaves were the major weeds of the experimental plots at the early stage of growth. but grasses, particularly *Paspalum scrobiculatum* became the predominant weeds in some plots at the later stages. Sedges never became an important weed in the experimental fields,

NPE, KN_3, and Dichlobenil gave good control of weeds which were followed by EPTC/2,4-D, and Trifluralin. Pyridinol and Molinate controlled weeds poorly under the conditions of this experiment. MCPA+handweeding also resulted in a satisfactory control of weeds. In general, chemicals followed by MCPA gave more effective control of weeds than those applied alone.

Rice plant was injured by Pyridinol, NPE, EPTC/2,4-D, and late application of MCPA. As a result, the growth of rice plant was inhibited in the early stage, showing the reduction in tillers per hill and plant height. Weed competition with rice became apparent at heading stage, and plant height and tillers per hill in the plots with heavy weed infestation were greatly affected.

Weeded check, Pyridinol+MCPA, Dichlobenil +MCPA, Dichlobenil, KN_3+MCPA and Molinate+MCPA outyielded non-weeded check, differences being significant statistically. Weed competition with rice caused a loss of yield by 926 kg per ha or a reduction of 30.5 %. Single application of Pyridinol gave the lowest yield due to its toxicity to rice and poor control of weeds, whereas low yield of Molinate was caused primarily by heavy infestation of weeds.

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稻田殺草劑之治草效果

張　萬　來

摘　要

本文係報告嘉義農業試驗分所與國際稻米研究所合作於民國56年第二期作舉辦之稻田殺草劑藥效觀察試驗之結果。

NPE, KN_3 與 Dichlobenil 殺草效果最佳，EPTC/2.4-D 與 Trifluralin 次之， Pyrldinol 與 Molinate 最劣， MCPA十人工除草之處理治草效果亦佳，試驗區之什草以濶葉草居多，故一般言之，各種殺草劑加用 MCPA 之處理，治草效果均較其單獨使用者爲佳。

Pyridinol, NPE, EPTC/2.4-D 與後期施用之 MCPA 對水稻均具藥害，水稻初期之株高，每株分蘖均受到抑制，其發育乃受影響，水稻受什草生長競爭之爲害情形，在其抽穗期前後始顯出。一般治草效果較差之處理，其株高，每株分蘖均受到影響。

人工除草， Pyridinol+MCPA, Dichlobenil+MCPA, Diohlobenil, KN_3+MCPA, 與 Molinate+MCPA 之稻谷產量均超過不除草區 ， 水稻因什草生長競爭而每公頃稻谷減產 926公斤， 達 30.5%。 Pyridinol 單用處理因受藥害及什草競爭等雙重影響， 致每公頃稻谷產量最低 ， Molinate 單用處理之低產，顯受什草爲害所致。