PERSISTENCE OF RICE AND COTTON HERBICIDES IN SOILS [1]

W. L. Chang [2]

INTRODUCTION

In Taiwan, handweeding has been a standard method of controlling weeds in rice until 1966 when a number of herbicides became available to rice growers (Chang, 1967). Due largely to the soaring cost of labors caused by the rapid industrial development, chemical control practice has become increasingly popular among rice farmers. As a result, the acreage of chemical weed control has rapidly increased from 485 ha in 1966 (Chang, 1969) to 123,496 ha in 1972, (Chang, 1973) an impessive increase of 250 times in 7 years. It appears that in the next few years, traditional handweeding will be gradually replaced by herbicides for the control of weeds in rice.

With widespread and repeated use of herbicides in rice, questions have often been posed as to the movement and the length of time these herbicides remain toxic in soil. The soil is an area of our environment which may be seriously affected by the application of herbicides. However, very little information is available at the present moment on the persistence of herbicides in paddy soils. In the field bioassays, Chang (1972) found that herbicides residues did not appreciably affect the infestation of weeds and the growth of rice in the succeeding crop. Problems generally arise when insufficient information is available to ascertain the behavior and eventual fate of the herbicides. Therefore, it is important that the residual life of the compound should be made clear in order that the herbicide can be used safely and effectively.

Farmers in Taiwan grow a short—duration crop between two rice crops on the same piece of land in summer or in winter. This intensive crop production system may render the problem of herbicides residue more complicate to handle. It may be desirable, therefore, to have a herbicides which persists long enough to provide control of weeds for a full season of rice crop, but not too long to affect the suceeding upland crops which are sensitive to such materials. This investigation was undertaken to determine the effect of herbicides residues in the soil on crops normally grown in rotation with rice.

MATERIALS AND METHODS

This investigation was conducted in the screenhouse of the Chiayi Agricultural Experiment Station in November, 1971. Soil samples were collected from three locations in

This experiment was supported in part by the National Science Council (NSC) and the Joint Commission on Rural Reconstruction (JCRR) under the project number of 72—A11—A—2228 (NSC).

1. Series No. (Q) 605.

2. Agronomist, Chiayi Agricultural Experiment Station, TARI.

Chianan area for crop bioassays. Paddy soils were sampled from the experimental farms of the Chiayi Branch station of the Tainan District Agricultural Improvement Station (DAIS) and the Chiayi Junior College of Agriculture (JCA). Cotton soils were obtained from the experimental farm of the Tainan Fiber Crop Experiment Station (FCES). The chemical and physical properties of these soils are presented in Table 1.

Table 1. Chemical and physical properties of four soils*.

Soil site	Crop grown	Herbicide applied	Soil texture	PH	Organic matter (%)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Chiayi Branch Station Tainan DAIS	Rice	5% Machete G 30 kg/ha	Loam	6.0	3.0	Higher than 200	152
		8.7% MO—401 G 30 kg/ha	Loam	7.3	3.1	Higher than 200	142
		7% TOK G 30 kg/ha	Loam	6.9	3.0	Higher than 200	154
		13% Saturn—M G 30 kg/ha	Loam	6.2	3.3	Higher than 200	169
		Non--treated control	Loam	8.0	2.0	Higher than 200	Higher than 400
Chiayi Junior College of Agriculture	Rice	5% Machete G 30 kg/ha	Silt loam	7.8	1.9	200	178
		8.7% MO—401 G 30 kg/ha		7.5	1.7	165	164
		7% TOK G 30 kg/ha		7.8	1.8	Higher than 200	183
		Non--treated control		7.8	1.8	Higher than 200	195
Tainan Fiber Crop Experiment Station	Cotton	49% Butisan EC 8 l/ha	Sandy loam	6.5	1.5	573	320
		49% Butisan EC 10 l/ha	Sandy loam	6.8	1.5	573	371
		42.3% Herban—M EC 6 l/ha	Sandy loam	6.7	1.4	573	666
		Non--treated control	Sandy loam	6.9	1.4	573	345

*Soil analysis was made by the Tainan District Agricultural Improvement Station.

Each soil site received one application of herbicides in the second crop (rice) or fall planting (Cotton) of 1971 except one plot in the Chiayi Branch Station, Tainan DAIS which was continuously treated with TOK for the last three years. The soil samples were collected approximately five months after the application of herbicides. The herbicides used in the Chiayi Branch Station, Tainan DAIS included 2,4—dichlorophenyl ether (TOK), S—(4—chlorobenzyl)—N—diethyl thiolcarbamate+2,4,6—trichlorophenyl—4—nitrophenyl ether (Saturn—M), N—(butoxymethyl)—2—chloro-2′ 6′—diethyl acetanilide

(Machete), and 2, 4, 6—trichlorophenyl—4—nitrophenyl ether+2—methyl—4—chlorophenoxyacetic acid (MO—401). The rice farm of the Chiayi JCA was treated with granular TOK, Machete and MO—401. The cotton field of the Tainan FCES was applied with Prynachlor (2—chloro—N—propynyl) —acetanilide (Butisan) and Norea 3—(hexahydro—4, 7—methanoindan—5yl)—1—dimethylurea+monosodium acid methanearsonate (Herban—M). Untreated soil samples were also collected from each soil site for comparison.

Soil samples were taken from the upper 10 cm of each field plot. The soil samples were air—dried, ground and thoroughly mixed. A sample of soil weighing 500g was taken and placed in a 4—inch diameter clay pot. Ten to 20 seeds or cuttings of bioassay plants were planted in each pot depending on the size of seeds. The stand was thinned to 5 to 10 most unifrom plants one week after emergence. Bioassay indicators included barnyard grass, rice, wheat, corn, sorghum, flax, rape, radish, and sweet potato for paddy soils while only rice was used for cotton soil. Assays were conducted separately for each soils site. The experimental design for rice soils was a split—plot arrangement of treatments in a randomized complete block. The main plot treatments were bioassay inddicators while herbicides constituted subplot treatments. For cotton soil, a randomized complete block design was employed. All treatments were replicated three times.

Barnyard grass and rice was continuously flooded with shallow water during the growing period while the other upland crops were watered periodically as needed to maintain adequate moisture for crop growth. No fertilizer was, however, applied. Approximately 30 days after planting, all living plants were harvested. The length of each plant was measured and recorded for the calculation of average plant height. The fresh weight of the plants was taken immediately after harvest. The plant samples were then dried 24 hours at 70°C for the measurement of dry weight. An analysis of variance was computed on all bioassay data. Differences among treatments were tested with Duncan's multiple range test at the 5% level of significance.

RESULTS AND DISCUSSION

Persistence of Rice Herbicides in Soils

The bioassay data from soil of the Chiayi Branch Station of Tainan DAIS are presented in Table 2. It was observed that bioassay indicatore in soil treated with rice herbicides generally grew taller than those grown in untreated clean soil. Differences in plant height among herbicide treatments were, however, not significant for all bioassay indicators with the exception of wheat and rape. Similarly, the fresh and dry weights of bioassay indicators in soils treated with herbicides were also heavier than those grown in soil of untreated control. Differences in fresh weight among herbicide treatments were significant only for barnyard grass, wheat, and rape but the dry weight of all bioassay indicators reached a level of significance except for rice and flax. The poor initial growth of most bioassay crops in the untreated clean soil of the Chiayi Branch station, Tainan DAIS could be ascribed to its lower organic matter content (Table 1).

Table 2. Growth of bioassay plants in paddy soils from the Chiayi Branch Station, Tainan DAIS that received one application of herbicides in the second crop of 1971.

Trait	Herbicide treatment	Barnyard grass	Rice	Wheat	Corn	Sorghum	Flax	Rape	Radish
Plant height (cm)	Machete	29.8[a]*	31.6[a]	46.5[b]	43.1[a]	7.7[a]	18.6[a]	13.1[ab]	17.0[a]
	MO—401	26.3[a]	24.8[a]	48.8[b]	42.1[a]	10.9[a]	17.5[a]	12.2[bc]	16.1[a]
	TOK	25.2[a]	30.1[a]	52.6[a]	36.7[a]	9.1[a]	19.5[a]	11.4[c]	16.1[a]
	Saturn—M	28.4[a]	30.7[a]	48.1[b]	37.7[a]	8.6[a]	18.0[a]	14.1[a]	17.5[a]
	Untreated control	26.1[a]	23.9[a]	46.4[b]	40.4[a]	8.5[a]	15.3[a]	9.0[d]	14.5[a]
Fresh weight (g/plant)	Mechete	1.82[ab]	1.03[a]	2.77[b]	7.67[a]	0.50[a]	0.45[a]	3.46[ab]	6.90[a]
	MO—401	0.89[bc]	0.45[a]	3.78[a]	6.08[a]	0.49[a]	0.49[a]	3.99[ab]	5.80[a]
	TOK	0.95[bc]	0.57[a]	3.61[a]	5.47[a]	0.49[a]	0.56[a]	2.90[b]	5.70[a]
	Saturn—M	2.28[a]	0.76[a]	2.61[b]	6.54[a]	0.46[a]	0.54[a]	5.11[a]	6.89[a]
	Untreated control	0.71[c]	0.52[a]	2.80[b]	6.24[a]	0.23[a]	0.37[a]	1.61[c]	3.79[a]
Dry weight (g/plant)	Machete	0.27[ab]	0.23[a]	0.71[bc]	1.19[a]	0.17[a]	0.09[a]	0.50[a]	0.67[a]
	MO—401	0.15[b]	0.13[a]	0.85[ab]	0.97[a]	0.17[a]	0.11[a]	0.51[a]	0.53[ab]
	TOK	0.17[b]	0.17[a]	0.92[a]	0.88[a]	0.13[ab]	0.13[a]	0.44[b]	0.55[a]
	Saturn—M	0.37[a]	0.22[a]	0.74[bc]	1.06[a]	0.14[a]	0.11[a]	0.67[a]	0.63[a]
	Untreated control	0.13[b]	0.15[a]	0.66[c]	0.88[a]	0.09[b]	0.06[a]	0.22[c]	0.33[b]

*Means within a column followed by the same letter are not significantly different at the 5% level.

In the soils from the Chiayi Junior College of Agriculture, plant height of bioassay indicators in soils treated with rice herbicides appeared similar to that grown in the untreated clean soil (Table 3). Differences in plant height among herbicides treatments were not significant for sweet potato, wheat, and rape. However, radish grown in the soil of untreated control was significantly shorter than that grown in soils treated with Machete and MO—401. The fresh and dry weights of bioassay indicators in soils treated with rice herbicides were also similar to those grown in the untreated clean soil. Differences in both fresh and dry weights among herbicides treatments all failed to attain significance for the bioassay indicators,

Table 3. Growth of bioassay plants in paddy soils from the Chiayi junior College of Agriculture that received one application of herbicides in the second crop of 1971.

Trait	Herbicide treatment	Sweet potato	Wheat	Rape	Radish
Plant height (cm)	Machete	15.1 a*	29.8 a	12.7 a	19.0 a
	MO—401	16.4 a	31.7 a	11.4 a	18.3 a
	TOK	14.7 a	32.5 a	9.5 a	16.5 b
	Untreated control	17.1 a	31.7 a	10.8 a	16.9 b
Fresh weight (g/plant)	Machete	5.90 a	0.93 a	1.61 a	3.79 a
	MO—401	6.85 a	0.78 a	1.67 a	3.81 a
	TOK	7.03 a	1.03 a	1.22 a	2.83 a
	Untreated control	7.33 a	0.83 a	1.62 a	3.00 a
Dry weight (g/plant)	Machete	1.13 a	0.24 a	0.23 a	0.44 a
	MO—401	1.37 a	0.22 a	0.20 a	0.41 a
	TOK	1.38 a	0.31 a	0.16 a	0.35 a
	Untreated control	1.45 a	0.23 a	0.21 a	0.34 a

*Means within a column followed by the same letter are not significantly different at the 5% level.

It was observed that bioassay indicators such as barnyard grass, rice, and several upland crops were not affected by the herbicide residue approximately five months after the initial application. This indicates that one application of granular Machete, MO—401, TOK or Saturn—M at rates necessary to provide adequate control of weeds in the second crop of rice does not persist in amounts toxic to the growth of succeeding crops. The results of this screenhouse bioassays agreed with those of field bioassays conducted in the first crop of 1972 which showed that the application of herbicides in the second crop of 1971 did not cause any harmful effect on the infestation of weeds and the growth of rice in the first crop of 1972 (Chang, 1972). The absence of harmful residual effect of herbicides also indicates that most upland crops could probably be grown safely in rotation with rice. Thus, continuous use of herbicides in rice is not likely to bring a dramatic change in the current cropping system for the foreseeable future.

The finding that bioassay indicators grew without injury in TOK treatment of the Chiayi Branch Station, Tainan DAIS was highly encouraging. Soil samples were collected from the plot which was continuously treated with TOK for the last three years or six

crops. The normal growth of bioassay indicators in this soil clearly demonstrates that there is no residue build-up in the soil from the repeated application of granular TOK in transplanted rice. This may partly explain the reason why up to the present time, no evident residual toxicity of TOK has been detected on rice or upland crops grown in rotation with rice even though it has been used continuously as a preemergence herbicide for transplanted rice since 1966 (Chang, 1967). It appears unlikely, therefore, that continuous usage of rice herbicides will create a serious residue problem for the transplanted rice.

Factors which influence the disappearance of herbicides in soils include leaching, fixation by soil colloides, microbial decompsition, volatilization, chemical reaction, photodecomposition, and absorption by plants (Sheets and Danielson, 1960). These factors responsible for herbicide disappearance can be influenced by various environmental factors. For example, the amount, frequency, and intensity of rainfall have been shown to be important factors in soil longevity of herbicides (Hartley, 1964) since moisture affects every mode of herbicide dissipation. Also, herbicide breakdown by biological and nonbiological means has been found to decrease with reduced soil temperature. In Taiwan, frequent rainfall and high temperature are usually available for rice growth especially in the second crop of rice. Sufficient supply of irrigation water is also available for the continuous flooding of rice field during the important growing stages of rice. It appears that the abundant supply of water and high temperature may greatly enhance the process of herbicide degradation in rice soils. Thus, herbicide carryover in soil in a from toxic to crop plant is likely to be less serious in the wet paddy field than in the dry upland field.

Persistence of Cotton Herbicides in Soil

The fresh and dry weights of rice plants grown in soil samples of the Tainan Fiber Crop Experiment Station are given in Table 4. It was observed that both the fresh and dry weights of rice plants grown in soils treated with cotton herbicides Herban—M and Butisan were heavier than those of untreated control. Differences in fresh and dry weights among herbicide treatments were, however, not significant. Obviously, residues from one application of these two commercial cotton herbicides do not affect the growth of rice planted approximately five months after the treatment. This indicates that rice can be grown rather safely in rotation with cotton which has been controlled with herbicides. This finding is of practical significance in view of the recent interest in growing cotton at the Chianan area. However this observation is based on the results of one application of two cotton herbicides and it is necessary that additional evidence should be obtained to establish whether residues from continuous application of herbicides in cotton will accumulate in amounts toxic to the growth of succeeding crop of rice.

Table 4. Weight of rice plants grown in cotton soils from Tainan Fiber Crop Experiment Station that received one application of Herban—M and Butisan in the Fall Crop of 1971.

Herbicide treatment	Fresh weight (g/plant)	Dry weight (g/plant)
Herban—M 6 l/ha	1.02	0.26
Butisan 8 l/ha	1.24	0.29
Butisan 10 l/ha	1.22	0.28
Untreated control	0.92	0.23
LSD 5%	NS	NS

SUMMARY

The persistence of four rice herbicides and two cotton herbicides in soils was evaluated by screenhouse bioassays in November, 1971 at the Chiayi Agricultural Experiment Station. The upper 10 cm surface soil was collected approximately five months after the application of herbicides. Bioassay indicators for rice soils included barnyand grass, rice, wheat, corn, sorghum, flax, rape, radish, and sweet potato while only rice was used for cotton soil. Preliminary results indicate that rice herbicides Machete, MO—401, TOK, and Saturn—M applied in the second crop of 1971 and cotton herbicides Herban—M and Butisan applied in the Fall planting of 1971 do not persist in amounts toxic to the growth of bioassay indicators planted approximately five months later.

LITERATURE CITED

1. Chang, W. L. 1967. Rice weed control in Taiwan. Proc. First Asian—Pacific Weed Control Interchange, Honolulu. 73—76 p.
2. Chang, W. L. 1969. Progress report of rice weed cntrol experiment and extension in Taiwan. Proc. Second-Pacific Weed Control Interchange. Philippines. 60-71P.
3. Chang, W.L. 1972. Residual effect of herbicides on the succeeding crop of rice. Jour. Taiwan Agr. Res. 21 (4) : 227—232.
4. Chang, W. L. 1973. Development of chemical weed control practices for rice in Taiwan. Paper presented at International Rice Research Conference April 23—27, 1973. Philippines.
5. Hartley, G. S. 1964. Herbicide behavior in the soil, P. 111—161. In L. J. Audus (ed.). The Physiology and Biochemistry of Herbicides. Academic Press, New York.
6. Sheets, T. J. and L.L. Danielson. 1960. Herbicides in soils. In the nature and fate of chemicals applied to soils, plants, and animals, U.S. Dept. Agr., Agr. Res. Serv. 20—9. 221 p.

若干水稻與棉花除草劑在土壤中之持續性

張　萬　來

摘　要

嘉義農業試驗分所於民國60年11月在網室舉行四種水稻除草劑與兩種棉花除草劑在土壤中持續性之植物檢定試驗。土壤樣本爲使用除草劑後約五個月之土面10公分之表土，用於測定水田土壤之檢定作物包括稗草、水稻、小麥、玉米、高粱、亞麻、油菜、蘿蔔、甘藷，而棉花園土壤之測定則只用水稻一種。初步結果顯示民國60年第二期作使用之水稻除草劑馬上除、益歐 401、多谷與掃丹—M，及民國60年秋作使用棉花除草劑禾爾邦砷與拔地草等，在土壤中之殘留量均不足以影響除草劑使用後約五個月種植檢定作物之正常發育。