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Investigations on Rice Herbicides in Egypt

I. The effect of herbicidal mixtures on rice grain yield and weeds

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ABSTRACT

Two field experiments were conducted to study the effect of four rice herbicides (Propanil, Molinate, Satrol and MCPA) and their mixtures, as compared with the conventional hand-weeding method, on rice grain yield and weeds at two locations in Egypt. The first experiment was carried out in 1972 at Sakha Agricultural Experiment Station, Ministry of Agriculture, and the second experiment was performed in 1973 at the Faculty of Agriculture Experimental Farm, Alexandria.

In general, all herbicidal applications significantly outyielded the unweeded control. Most herbicides were either equal or superior to hand-weeding in reducing the rice weeds and in increasing the grain yield. Propanil alone was one of the best herbicides because it was effective against the prevalent weeds under investigation.

Propanil and Satrol, either singly or in combinations, were outstanding in reducing rice weeds. Such applications resulted in higher grain yields of rice than hand-weeded treatment.

Molinate and its mixtures were the least effective applications in controlling rice weeds, since they resulted in low grain yield of rice.

INTRODUCTION

In a previous investigation by El-Khishen and Shaalan (5), the individual effect of Propanil and Molinate herbicides (at different concentrations) was studied on rice grain yield, yield components and weeds. It was found that the grain yield was significantly increased as the herbicidal concentrations were increased as a result of the decreasing weed population. The two herbicides showed comparable effects on rice yield, however, they controlled different weed species. It was concluded that a mixture of Propanil and Molinate might be tested on rice in the future.

The aim of applying herbicidal mixtures is to broaden the spectrum of chemical weed control (7). That is, more weed species may be controlled by a combination of several herbicides than any single one. There are three possible effects of herbicidal mixtures according to the total number of weed species being controlled. These effects are called additive, antagonistic, and synergistic. Herbicidal mixtures must be com-

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patible and beneficial in weed control. Both additive and synergistic combinations are desirable because they control more weed species than antagonistic mixtures. Another advantage of herbicidal mixtures is the possibility of applying lower concentrations than recommended of the individual herbicides in order to reduce the cost of application (7).

Several workers studied the effect of herbicidal mixtures on rice yield and weeds. Sometimes, the results showed that the application of herbicidal mixtures was more effective in weed control and produced higher yield of rice than that of single herbicides (3,4,9,13). In dry-seeded paddy rice, Roy and Smith (8) found that Propanil, applied alone as a postemergence treatment, controlled weeds as well as the combination treatments of Propanil + MCPA or Propanil + KN_3 applied postemergence. They also reported that Propanil controlled weeds better than Molinate but the mixtures of Propanil + MCPA and the single treatments of Pyriclor or Nitralin, applied preemergence, injured rice. Other reports indicated that single applications of herbicides and their combinations were similarly effective on rice yield and weeds (1,2,10,12).

The purpose of the present investigations was to evaluate the effect of four herbicides and their mixtures on rice grain yield and weeds as compared with hand-weeding at two different locations in Egypt.

MATERIALS AND METHODS

Two field experiments were conducted to study the effect of four herbicides and some of their mixtures on rice grain yield and weeds at two locations in Egypt. The first experiment was conducted in the 1972 summer season at Sakha Agricultural Experiment Station, Ministry of Agriculture, and the second experiment was performed in the 1973 summer season at the Faculty of Agriculture Experimental Farm, Alexandria. The four used herbicides were as follows:

1. Propanil (3,4-dichloropropionanilide).
2. Molinate (5-ethyl hexahydro-1 H-azepine-1-carbothioate).
3. Satrol (Propanil + 2,4,5-trichlorophenoxyacetic acid).
4. MCPA (4-methyl-2-chlorophenoxyacetic acid).

These herbicides were applied individually and in ten different mixtures as presented in Table 1. Such herbicidal applications were compared with hand-weeding and control (neither herbicides applied nor hand-weeding practiced). The recommended concentrations were used in the case of the herbicides applied singly. In the case of the herbicidal mixtures, four kinds of combinations were used (Table 1) as follows:

1. The recommended concentration of each herbicide in the mixture (applications 5, 9, 10, 11, 12).
2. One-half of the recommended concentration of each herbicide in the mixture (applications 6, 13, 14).
3. Three and one-fourth(s) of the recommended concentrations of the two herbicides in the mixture, respectively (application 7).
4. One and three-fourth(s) of the recommended concentration of the two herbicides, respectively (application 8).

A randomized complete block design, with four replicates, was used in the two experiments.

In the 1972 experiment, dry rice grains of Nahda cultivar (commonly grown in Egypt) were directly drilled in dry soil in plots of eight rows, six meters long and twenty centimeters apart, on 15 May. Plot size was 2 × 6 m and the seeding rate was 40 kg/f.

Table 1 Different applications and concentrations of herbicides used in the study (1972 and 1973).

Identification number	Applications	Concentrations
1	Propanil	6.0 liters/f[a]
2	Molinate	2.5 liters/f[a]
3	Satrol	1.5 liters/f[c]
4	MCPA	1.25 liters/f[a]
5	Propanil + Molinate	6.0 liters/f + 2.5 liters/f
6	Propanil + Molinate	3.0 liters/f + 1.25 liters/f
7	Propanil + Molinate	4.5 liters/f + 0.625 liters/f
8	Propanil + Molinate	1.5 liters/f + 1.875 liters/f
9	Propanil + Satrol	6.0 liters/f + 1.5 liters/f
10	Molinate + Satrol	2.5 liters/f + 1.5 liters/f
11	Propanil + MCPA	6.0 liters/f + 1.25 liters/f
12	Molinate + MCPA	2.5 liters/f + 1.25 liters/f
13	Propanil + MCPA	3.0 liters/f + 0.625 liters/f
14	Molinate + MCPA	1.25 liters/f + 0.625 liters/f
15	Hand-weeding	—
16	Control (neither herbicides nor hand-weeding)	—

[a] f = faddan = 4200 m².

Two equal increments of ammonium sulphate (20.5% N) were added to each plot at the rate of 250 kg/f three weeks after sowing and at heading time. All plots received one application of superphosphate (16% P_2O_5) at the rate of 100 kg/f during land preparation. The applications were made as follows:

1. Propanil was sprayed (6.0 liters in 525 liters of water/f) as a postemergence application by a knapsack sprayer three weeks after sowing when the weeds were at the 2–3 leaf stage. Plots were drained 24 hours before spraying.
2. Molinate was applied (2.5 liters in 525 liters of water/f) as a preplanting treatment and incorporated into the soil six hours before sowing by a knapsack sprayer.
3. Satrol and MCPA were sprayed (1.5 and 1.25 liters/f, respectively, in 437 liters of water/f) as postemergence applications by a knapsack sprayer 35 days after sowing when the weeds were at the 4–5 leaf stage. Plots were drained 24 hours before and after spraying.
4. The herbicides were applied in the case of different mixtures at the concentrations indicated in Table 1 and in a similar way to that of the individual herbicides.
5. Hand-weeding were carried out on 15 July.

The number of weeds per square meter was counted at two intervals in each plot (on 21 July and 20 August) and the readings were transformed into their square roots for statistical analysis. The fresh weight of weeds was determined one day before harvesting rice after cutting the weeds by sickles at soil surface.

Rice was harvested on 12 October and the grain yield was determined and adjusted to the 15% moisture basis. Six central rows per plot were harvested for this measurement.

In the 1973 experiment, all the applications and determinations were similar to those of the 1972 experiment with few exceptions. The two weed counts were taken on 20 August and 11 September. Hand-weeding was carried out on 27 August and rice was harvested on 5 November. The results of both experiments were analyzed statistically according to Snedecor (11) and Le Clerg *et al.* (6).

RESULTS AND DISCUSSION

1. Effect on grain yield

The effects of herbicidal applications in 1972 and 1973 seasons are indicated in Table 2 in which the mean values of rice grain yields are presented. In general, the grain yield of rice was highly significantly increased by the applications of herbicides, either singly or in combinations which resulted in effective weed control.

Table 2 Mean values of rice grain yields as affected by herbicidal applications in 1972 and 1973.

Applications	Grain Yield (kg/plot)	
	1972	1973
1. Propanil (6.0 liters/f)	5.74a[a]	2.44e
2. Molinate (2.5 liters/f)	3.44d	2.44e
3. Satrol (1.5 liters/f)	5.25ab	3.21ab
4. MCPA (1.25 liters/f)	4.33c	2.43e
5. Propanil (6.0 liters/f) + Molinate (2.5 liters/f)	5.28ab	3.18abc
6. Propanil (3.0 liters/f) + Molinate (1.25 liters/f)	5.21abc	2.72bcde
7. Propanil (4.5 liters/f) + Molinate (0.625 liters/f)	5.41ab	2.89abcde
8. Propanil (1.5 liters/f) + Molinate (1.875 liters/f)	5.08 abc	2.77 bcde
9. Propanil (6.0 liters/f) + Satrol (1.5 liters/f)	5.78a	3.35a
10. Molinate (2.5 liters/f) + Satrol (1.5 liters/f)	5.06abc	2.60cde
11. Propanil (6.0 liters/f) + MCPA (1.25 liters/f)	5.66a	2.91abcde
12. Molinate (2.5 liters/f) + MCPA (1.25 liters/f)	5.26ab	2.95abcde
13. Propanil (3.0 liters/f) + MCPA (0.625 liters/f)	5.16abc	3.15abc
14. Molinate (1.25 liters/f) + MCPA (0.625 liters/f)	4.71bc	2.68bcde
15. Hand-weeding	5.28ab	3.03abcd
16. Control	2.97d	2.47de

[a] Means followed by the same letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

In 1972, Propanil alone resulted in the highest grain yield (5.74 kg/plot) followed by Satrol, MCPA and Molinate (5.25, 4.33 and 3.44 kg/plot, respectively). Molinate and the control plots exhibited the lowest mean grain yields of all herbicidal applications. In 1973, however, Satrol resulted in a higher significant grain yield than the three other herbicides (applications 1, 2 and 4).

In fact, all mixtures including Propanil and Satrol resulted in higher grain yields than those combining Molinate and MCPA. Moreover, these high grain yields were not significantly different from that of hand-weeding (5.28 kg/plot).

Furthermore, Table 2 shows that the herbicidal mixtures resulted in comparable grain yields except application 14 for which the grain yield was slightly lower. This was true in both 1972 and 1973. However, the results in 1973 were slightly different from those in 1972 due to the different environmental conditions at the two locations (Alexandria and Sakha). The present results confirmed the conclusions reached by other researchers on Propanil and Satrol (8,13).

2. Effect on fresh weight of weeds

The mean values for the fresh weight of weeds per plot in 1972 and 1973 are given in Table 3. It is obvious that the fresh weight of weeds differed significantly among the various applications. The unweeded control (application 16) gave the highest mean

Table 3 Mean values of fresh weights of weeds as affected by herbicidal applications in 1972 and 1973.

Applications	Fresh weights of weeds (kg/plot)	
	1972	1973
1. Propanil (6.0 liters/f)	0.29d[a]	1.30bc
2. Molinate (2.5 liters/f)	2.98b	0.48de
3. Satrol (1.5 liters/f)	0.44cd	1.45bc
4. MCPA (1.25 liters/f)	0.85cd	1.96ab
5. Propanil (6.0 liters/f) + Molinate (2.5 liters/f)	0.43cd	0.03e
6. Propanil (3.0 liters/f) + Molinate (1.25 liters/f)	0.64cd	0.23e
7. Propanil (4.5 liters/f) + Molinate (0.625 liters/f)	0.50cd	0.08e
8. Propanil (1.5 liters/f) + Molinate (1.875 liters/f)	1.15c	0.05e
9. Propanil (6.0 liters/f) + Satrol (1.5 liters/f)	0.13d	0.24e
10. Molinate (2.5 liters/f) + Satrol (1.5 liters/f)	0.20d	0.12e
11. Propanil (6.0 liters/f) + MCPA (1.25 liters/f)	0.25d	0.69cde
12. Molinate (2.5 liters/f) + MCPA (1.25 liters/f)	0.54cd	1.17bc
13. Propanil (3.0 liters/f) + MCPA (0.625 liters/f)	0.21d	1.77ab
14. Molinate (1.25 liters/f) + MCPA (0.625 liters/f)	0.89cd	1.31bc
15. Hand-weeding	0.21d	0.48de
16. Control	4.70a	2.36a

[a] Means followed by the same letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

fresh weight of weeds in 1972 and 1973 (4.70 and 2.36 kg/plot, respectively). The herbicidal applications were either as effective as hand-weeding, if not better, in reducing rice weeds. Propanil + Satrol, Molinate + Satrol, Propanil + MCPA, and Propanil alone (applications 9, 10, 11 and 1) resulted in the lowest fresh weight of weeds in both seasons. On the other hand, Molinate alone, Molinate + MCPA, and Propanil + Molinate (applications 2, 14, and 8) gave the highest fresh weight of weeds in both seasons. These results explained the superiority of grain yields in the case of applications 1, 9, 10 and 11 (Table 2). Results of Molinate application disagreed with those reported by El-Khishen and Shaalan (5). This might be due to the differences in weed population and conditions prevailing in the two investigations.

3. Effect on number of weeds

Six weed species were prevalent in the present study; namely, sedge [*Cyperus difformis* L.], nut-grass [*Cyperus rotundus* L.], jungle rice [*Echinochloa colonum* (L.) Link], tiger-grass [*Dinebra retroflexa* (Forsk.) Pan], smartweed [*Polygonum salicifolium* L.], and cocklebur [*Xanthium spinosum* L.].

The mean values for number of weeds per square meter in the first count (early growth stage) in 1972 and 1973 are given in Table 4. Obviously, the number of weeds in this early count was significantly different among the different applications. In general, all applications (1–15) were more effective in reducing weed number below that of the control. As for hand-weeding, the data showed that the applied herbicides lead to a number of weeds either equal to or lower than those of hand-weeded plots. Among the herbicidal applications, Molinate alone, Propanil + Molinate, Molinate + MCPA (applications 2, 8, 14, and 12) gave the highest number of weeds. On the other hand, Propanil + Satrol, Propanil + MCPA, Propanil alone, and Propanil + Molinate

Table 4 Mean values of number of weeds (first count) as affected by herbicidal applications in 1972 and 1973. (Transformed data).

Applications	Number of weeds/m²	
	1972	1973
1. Propanil (6.0 liters/f)	3.67 def[a]	3.53bcdefg
2. Molinate (2.5 liters/f)	12.45a	2.99cdefg
3. Satrol (1.5 liters/f)	5.01bcde	5.43bc
4. MCPA (1.25 liters/f)	6.16bc	6.09b
5. Propanil (6.0 liters/f) + Molinate (2.5 liters/f)	4.30cde	1.55g
6. Propanil (3.0 liters/f) + Molinate (1.25 liters/f)	5.66bcd	2.16efg
7. Propanil (4.5 liters/f) + Molinate (0.625 liters/f)	4.71bcde	1.95efg
8. Propanil (1.5 liters/f) + Molinate (1.875 liters/f)	6.51b	1.85efg
9. Propanil (6.0 liters/f) + Satrol (1.5 liters/f)	1.87f	2.26defg
10. Molinate (2.5 liters/f) + Satrol (1.5 liters/f)	4.00de	1.70fg
11. Propanil (6.0 liters/f) + MCPA (1.25 liters/f)	2.96ef	3.73bcdefg
12. Molinate (2.5 liters/f) + MCPA (1.25 liters/f)	4.67bcde	5.10bcd
13. Propanil (3.0 liters/f) + MCPA (0.625 liters/f)	4.51bcde	4.01bcdef
14. Molinate (1.25 liters/f) + MCPA (0.625 liters/f)	6.48b	4.59bcde
15. Hand-weeding	6.10b	2.05efg
16. Control	11.50a	8.40a

[a] Means followed by the same letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

(applications 9, 11, 1, and 5) gave the lowest number of weeds. These findings were comparable in both seasons.

The results obtained from the second count of weeds (late stage of growth) for both seasons were almost similar to those of the first count as shown in Table 5. Such results further explained the high grain yields of rice as presented in Table 2.

Table 5 Mean values of number of weeds (second count) as affected by herbicidal applications in 1972 and 1973. (Transformed data).

Applications	Number of weeds/m²	
	1972	1973
1. Propanil (6.0 liters/f)	4.93de[a]	3.85de
2. Molinate (2.5 liters/f)	10.35a	3.94de
3. Satrol (1.5 liters/f)	4.69de	6.44bc
4. MCPA (1.25 liters/f)	5.61cd	9.10a
5. Propanil (6.0 liters/f) + Molinate (2.5 liters/f)	6.43c	2.03e
6. Propanil (3.0 liters/f) + Molinate (1.25 liters/f)	6.84c	1.87e
7. Propanil (4.5 liters/f) + Molinate (0.625 liters/f)	6.23c	2.43e
8. Propanil (1.5 liters/f) + Molinate (1.875 liters/f)	8.06b	2.26e
9. Propanil (6.0 liters/f) + Satrol (1.5 liters/f)	2.70g	2.80e
10. Molinate (2.5 liters/f) + Satrol (1.5 liters/f)	3.33fg	2.11e
11. Propanil (6.0 liters/f) + MCPA (1.25 liters/f)	2.40g	3.30de
12. Molinate (2.5 liters/f) + MCPA (1.25 liters/f)	4.39def	5.35bcd
13. Propanil (3.0 liters/f) + MCPA (0.625 liters/f)	4.05ef	5.75bcd
14. Molinate (1.25 liters/f) + MCPA (0.625 liters/f)	6.49c	6.52b
15. Hand-weeding	4.52def	4.02cde
16. Control	10.25a	9.14a

[a] Means followed by the same letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

The effectiveness of the mixtures combining Propanil and Satrol might be attributed to their complementary or additive lethal effect on several weed species. It was observed that Propanil was effective mainly against jungle rice, tiger-grass, and cocklebur. On the other hand, Satrol was lethal to sedge, nut-grass, and smartweed. In fact, the former group of weeds was more prevalent than the latter one in the present study. Hence, Propanil alone was almost as effective as its combination with Satrol or other herbicides in controlling the weeds. These results were in close agreement with the findings of Smith (10), Baker (2), and Aryeetey (1).

From the above results, the following conclusions might be drawn under the present experimental conditions:

1. The mixture of Propanil + Satrol proved to have either an additive or synergistic effect on many weed species prevalent in rice fields. Combinations of different concentrations could be used. Moreover, both herbicides singly might also be effectively applied.
2. The mixture of Molinate + MCPA proved to have an antagonistic effect on the rice weeds at different concentrations. Also, both herbicides were not effective in rice weed control. Therefore, these applications may not be recommended.
3. It is suggested that further studies are necessary to determine the effective concentrations of herbicides in different mixtures.

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