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IMPACT OF HERBICIDES ON WEEDS AND SOIL ECOSYSTEM OF RAINFED MAIZE (*ZEA MAYS* L.)

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ABSTRACT

Pre-emergence application of atrazine 0.25 kg/ha either followed by one hand weeding (40 DAS) or post-emergence application of 2,4-D(0.5 kg/ha) as well as early post-emergence application of herbicides mixture atrazine 0.125 kg/ha + metolachlor 0.5 kg/ha with one late hand weeding (40 DAS) was found to keep the weed density and dry weight below the economic threshold in rainfed maize. Considerable level of phytotoxicity and yield reduction was recorded with anilofos both at 0.4 kg/ha applied as single herbicide or at 0.2 kg/ha used in the herbicide mixture. Bioassay studies conducted to assess the effect of herbicides on soil microflora of maize crop show that soil microbial population (bacteria, fungi and actinomycetes) was not affected by the herbicides *viz.*, atrazine, metsulfuron methyl, metolachlor and anilofos used for and their time of application tried for weed control in maize.

INTRODUCTION

Maize (*Zea mays*. L) occupies an important position among the cereals in India, sown on 6.11 million hectare with a total production of 9.12 million tonnes. Timely weed management practices play a important role in the successful cultivation of the crop. Removal of nutrients by weeds showed a great impact on the availability of nutrients to the crop, thus affecting its dry matter accumulation(Sreenivas and Satyanarayana, 1996). The conventional methods of weed control (hoeing/ hand weeding) are very laborious, expensive and time consuming and needs to be often repeated at different intervals. Frequent rainfall during rainfed cropping season does not permit manual and mechanical methods of weeding at the appropriate time. As a result, the crop suffers severe weed competition in its early growth period (Sharma *et al.*,1981). The present investigation was therefore planned to find out efficient herbicide application technology for weed control in rainfed maize.

Herbicides used may disturb and alter the biological equilibrium in soil (Grossbard, 1976). A successful herbicide should not only control the weeds effectively but also be safer to the soil flora and fauna. However, information on the effect of different herbicides and their application technologies on soil microflora of rainfed maize ecosystem is limited. Paucity of information on these aspect on chemical weed control necessitated to undertake the objective of studying the response of soil micro organisms to herbicides applied for weed control in rainfed maize.

MATERIAL AND METHODS

A field experiment was conducted to study the effect of herbicide application methods on yield and associated weeds of rainfed maize at Tamil Nadu Agricultural University Farm, Coimbatore during *rabi* 1997-1998 season. The soil was sandy clay loam in texture and slightly alkaline in reaction (pH 7.9). The experiment was laid out in a randomized block design with twelve treatments replicated thrice. The maize seeds (cv. CO 1) were sown with a seed rate of 20 kg/ha adapting a spacing of 45 cm x 20 cm. Pre-monsoon sowing was done and before sowing the recommended dose of 40: 20 kg N and P /ha was applied basally by the side of the seed row. The treatments consisted of four pre-emergence single herbicides (atrazine 0.25 kg, metsulfuron methyl 0.003 kg, metolachlor 1.0 kg and anilofos 0.4 kg/ha sprayed on 3 DAS), four herbicide mixture

applied as early post-emergence on 15 DAS (atrazine 0.125 kg + metolachlor 0.5 kg, atrazine 0.125 + anilofos 0.2 kg, metsulfuron methyl 0.0015 kg + metolachlor 0.5 kg and metsulfuron methyl 0.0015 kg + anilofos 0.2 kg/ha) with one hand weeding (40 DAS) and sequential application of above pre-emergence herbicides at the same rate followed by post-emergence spray of 2,4-D(Na salt) 0.5 kg/ha on 3 DAS and 25 DAS, respectively were evaluated in comparison with hand weeding twice (20 and 40 DAS). The Treatment details are as follows:

A. Single herbicide application (3 DAS)

T_1 Atrazine (0.25 kg ha^{-1}) – HW
T_2 Metsulfuron methyl (0.003 kg ha^{-1}) – HW
T_3 Metolachlor (1.0 kg ha^{-1}) – HW
T_4 Anilofos (0.4 kg ha^{-1}) – HW

B. Herbicide mixture application (15 DAS)

T_5 Atrazine (0.125 kg ha^{-1}) + metolachlor (0.5 kg ha^{-1}) – HW
T_6 Atrazine (0.125 kg ha^{-1}) + anilofos (0.2 kg ha^{-1}) – HW
T_7 Metsulfuron methyl (0.0015 kg ha^{-1}) + metolachlor (0.5 kg ha^{-1}) – HW
T_8 Metsulfuron methyl (0.0015 kg ha^{-1}) + anilofos (0.2 kg ha^{-1}) – HW

C. Sequential application (3 DAS and 25 DAS)

T_9 Atrazine (0.25 kg ha^{-1}) – 2,4-D (0.5 kg ha^{-1})
T_{10} Metsulfuran methyl (0.003 kg ha^{-1}) – 2,4 - D (0.5 kg ha^{-1})
T_{11} Metolachlor (1.0 kg ha^{-1}) – 2,4-D (0.5 kg ha^{-1})
T_{12} Anilofos (0.4 kg ha^{-1}) – 2,4-D (0.5 kg ha^{-1})
T_{13} Hand weeding (twice)
T_{14} Unweeded control

DAS - Days after sowing
HW - Hand weeding (40 DAS for treatments T_1 to T_8)

Effect of herbicides on soil microorganisms was studied at different growth stages of the crop. Soil sample from each treatment plot was taken at 0, 10, 25 days after sowing (DAS) and at harvest stages of the crop. The sampling at 'zero' day represents the normal population of soil microorganisms as it was taken before application of any herbicide. The population of bacteria, fungi and actinomycetes were enumerated in nutrient agar, Martin's rose Bengal agar and Ken Knight's agar media, respectively. The observation on number of colonies of bacteria, fungi and actinomycetes were taken at 2, 4 and 7 days after inoculation, respectively.

RESULTS AND DISCUSSION

Weed flora of experimental field recorded on 60 DAS consisted of twenty species of broad leaved weeds, six species of grasses and two species of sedges. The major broad leaved weeds were *Digera arvensis*, *Trianthema portulacastrum*, *Phyllanthus niruri*, *Amaranthus viridis*. Among the grassy weeds *Cynodon dactylon* and *Dactyloctenium aegyptium* had dominated. *Cyperus rotundus* was the major sedge weed.

Effect of treatments on weeds : Broad leaved weed population gradually increased as the crop growth stage advanced to maturity in all treatments plots as well as in control plot. The relative density of grasses was minimum in the treatments where anilofos was included either alone (T_4) or in mixture with metsulfuron methyl (T_8) or sequential application with 2,4-D (T_{12}) (Table 1). Atrazine in combination with 2,4-D (T_9) or with a follow up hand weeding (T_1) caused gradual increase of sedge weed population as a result of better control of dicot weeds. The relative density of broad leaved weeds, which constituted the

Table 1. Effect of weed control treatments on relative density (per cent) of weed species at various growth stages of rainfed maize

Treatments	Crop growth stages											
	20 DAS			60 DAS			90 DAS			Harvest		
	G	S	BLW	G	S	BLW	G	S	BLW	G	S	BLW
T_1	88.9	6.3	4.8	88.6	4.7	6.7	68.7	22.8	8.5	53.6	22.6	23.8
T_2	65.6	15.2	19.2	86.9	7.0	6.1	59.9	22.0	18.1	41.9	22.5	35.6
T_3	79.3	11.8	5.9	82.5	7.8	9.7	50.0	27.4	22.6	32.7	30.4	36.9
T_4	43.9	1.8	45.3	52.0	20.5	27.5	50.0	26.6	22.4	36.1	29.8	34.1
T_5	82.9	8.2	8.9	74.8	6.7	18.5	65.8	26.3	7.9	51.5	32.7	15.8
T_6	55.3	5.1	39.6	78.9	4.3	16.8	63.9	19.3	16.8	45.6	21.3	32.1
T_7	63.4	11.2	25.4	67.4	7.7	24.9	53.1	28.7	18.2	37.6	24.8	37.6
T_8	47.6	14.7	37.7	64.2	16.2	19.6	46.8	28.5	24.7	39.4	24.7	35.9
T_9	91.9	2.8	5.3	91.2	4.0	4.8	51.9	27.8	20.3	50.7	21.7	27.6
T_{10}	71.3	12.4	16.3	84.0	12.0	4.0	56.2	19.6	24.2	40.5	19.4	40.0
T_{11}	86.6	8.1	5.3	69.6	8.5	21.9	70.2	14.7	16.1	40.6	24.9	34.5
T_{12}	48.9	8.7	42.4	72.2	11.0	16.6	41.9	16.9	41.2	37.9	22.5	39.6
T_{13}	36.9	1.4	48.7	79.7	6.7	13.6	41.0	18.1	40.9	37.4	19.0	58.6
T_{14}	47.6	12.9	39.5	22.8	6.1	71.1	18.4	7.7	73.9	15.7	14.2	70.1

G – Grasses; BLW – Broad leaved weeds; S – Sedges;
Treatments details are given in materials and methods.

Table 2. Effect of weed control treatments on weed dry weight (kg/ha) and weed control efficiency (WCE) at various growth stages of rainfed maize

Treatments	*Weed dry weight (kg/ha)			WCE(%)		
	20 DAS	60 DAS	90 DAS	20 DAS	60 DAS	90 DAS
T_1	2.04(110)	2.10(126)	2.00(100)	75.2	86.8	87.1
T_2	2.20(158)	2.16(145)	2.10(124)	65.3	84.8	83.9
T_3	1.93(84)	2.12(131)	2.06(114)	81.5	86.3	85.3
T_4	2.25(176)	2.32(209)	2.20(159)	61.3	78.1	79.5
T_5	2.13(135)	2.19(155)	2.04(109)	70.3	83.8	85.9
T_6	2.35(221)	2.30(201)	2.21(117)	51.4	78.9	79.3
T_7	2.21(160)	2.25(178)	2.07(117)	64.8	81.4	84.9
T_8	2.23(169)	2.30(199)	2.18(152)	62.9	79.2	80.4
T_9	2.03(105)	2.14(136)	2.06(114)	76.9	85.8	85.3
T_{10}	2.18(151)	2.29(193)	2.21(161)	66.8	79.8	79.2
T_{11}	1.98(94)	2.18(152)	2.12(132)	79.3	84.1	82.9
T_{12}	2.34(218)	2.34(219)	2.24(173)	52.1	77.1	77.7
T_{13}	2.63(430)	2.19(156)	2.18(153)	5.5	83.7	80.2
T_{14}	2.66(455)	2.98(955)	2.89(774)	0.00	0.00	0.00
CD (P=0.05)	0.13	0.19	0.11	-	-	-

*log(x+0.5) transformed; Figures in paranthesis are original values;
Treatments details are given in materials and methods.

major proportion of the weed flora of the field was very much controlled across the growth stages of the crop by atrazine application followed by a hand weeding or 2,4-D application (Table 1).

All the herbicide application practices gave better weed control as evident from dry weight production, which ranged from 126 kg/ha to 219 kg/ha against 955 kg/ha for unweeded control on 60 DAS (Table 2).

Atrazine 0.25 kg/ha + HW, metolachlor 1.0 kg/ha + HW, atrazine 0.125 kg/ha + metolachlor 0.5 kg/ha were effective in restricting the dry weight of weeds over various phenological stages compared to other weed control treatments as well as hand weeded plots. Pre-emergence application of metolachlor 1.0 kg/ha + HW recorded highest weed control efficiency (WCE – 81.54 per cent) at 20 DAS. The lowest WCE (5.49) with hand weeding twice was due to the fact that the first hand weeding was done only at 20 DAS. At 60 DAS, atrazine 0.25 kg + HW treatment recorded highest WCE of 86.8 per cent. Pre-emergence application of atrazine (0.25 kg/ha) followed by one late hand weeding (40 DAS) under rainfed condition was the most effective and profitable weed control practice for maize(Bhopal Singh *et al.*, 1991). All the atrazine and metolachlor applied treatments recorded more than 80 per cent WCE from 60 DAS onwards (Table 2).

Effects of treatment on yield and economics: Pre-emergence application of anilofos 0.4 kg/ha and sequential application of anilofos 0.4 kg/ha – 2,4-D 0.5 kg/ha recorded the lowest maize population stand of 65.7 and 68.2 per cent, respectively due to selectivity of the chemical (Table 3). Application of anilofos (Rout and Satapathy, 1996) and metsulfuron methyl caused substantial reduction in grain yield. More than 90 per cent of plant stand was noticed in atrazine and metolachlor applied treatments. Pre-emergence application of atrazine 0.25 kg + HW recorded higher grain yield of 4461 kg/ha. Lowest grain yield of 1359 kg/ha under control accounted for 69.5 per cent of yield loss as evident from weed index value (Table 3). Next to unweeded control plot, the higher values of yield loss (more than 40 per cent) were with combination of metsulfuron methyl 0.0015 kg/ha + anilofos 0.2 kg/ha. In general, irrespective of application technology all the atrazine and metolachlor based treatments enhanced the grain yield of maize. Hand weeding was equally effective (Thakur and Sharma, 1996).

Effect of herbicides on soil microorganisms: Shortly after application of herbicides (5 DAS) significant differences in population of soil microorganisms (bacteria, fungi, actinomycetes) was noticed as compared to their population before herbicide application which was in conformity with the results of Gopalswamy *et al.*,1994. Such inhibitory effect of herbicides used in the study persisted upto 25 DAS of the crop with respect to either pre-emergence single herbicide or herbicide mixture spray. However, under sequential application of pre-emergence herbicide on 3 DAS followed by post-emergence spray on 25 DAS the effect of herbicides on soil micro organisms population extended beyond 25 DAS of the crop. But at the time of harvest of the crop the microbial population with all the treatments attained the level equal to that of initial level or even more than original level of population in some treatments. The trend was similar in bacteria, fungi and actinomycetes (Table 4). It is clear that the effect of herbicides on soil microbes is only temporary.

It could be concluded that integrated weed management of atrazine 0.25 kg/ha followed by one hand weeding (40 DAS) reduced the weed dry weight increased the grain yield (4461 kg/ha) and net return (Rs. 19358/ha) of rainfed maize. Early post-emergence application of atrazine 0.125 kg/ha + metolachlor 0.5 kg/ha with one hand weeding was proved to be with a net return of Rs. 18050/ha. Chemical weed control with application of pre-emergence atrazine 0.25 kg/ha (3 DAS) followed by post-emergence 2,4-D(Na salt) 0.5 kg/ha (25 DAS) recorded higher grain yield and net income (4140 kg/ha and Rs. 17563/ha, respectively) in rainfed maize. The herbicides and application

Table 3. Effect of weed control treatments on maize yield and economics

Treatments	Crop stand (%)	Grain yield (kg/ha)	Weed index (%)	Net return (Rs./ha)	B:C ratio
T_1	91.7	4461	-	19358	2.06
T_2	80.1	3131	29.8	1140	1.21
T_3	91.8	3858	13.5	15291	1.58
T_4	65.7	2673	40.1	7917	0.85
T_5	91.3	4277	4.1	18050	1.89
T_6	85.7	3573	19.9	13838	1.48
T_7	83.6	3323	25.5	12170	1.28
T_8	78.3	2466	44.7	6599	.71
T_9	91.8	4140	7.2	17563	1.92
T_{10}	82.5	3099	30.5	11239	1.24
T_{11}	90.4	3656	18.0	14340	1.52
T_{12}	68.2	2532	43.2	7272	0.80
T_{13}	91.3	4186	6.2	17031	1.71
T_{14}	90.4	15	69.5	569	0.07
CD (P=0.05)	-	254	-	-	-

Treatments details are given in materials and methods.

Table 4. Effect of herbicides on soil micro organisms at different days after application in rainfed maize

Treatments	Crop growth stages (DAS)											
	0			10			25			Harvest		
	B	F	A	B	F	A	B	F	A	B	F	A
T_1	48.0	41.3	27.3	19	13.3	13.3	25.3	12.7	13.7	57.0	49.0	35.7
T_2	42.0	40.7	17.3	14.0	10.7	9.3	27.7	11.0	16.3	56.3	48.7	28.3
T_3	50.3	37.7	17.3	15.3	13.3	11.3	27.0	13.7	11.0	59.7	42.3	31.3
T_4	52.0	38.7	18.3	10.3	12.3	14.3	29.0	16.3	17.3	61.3	58.3	39.7
T_5	46.0	41.7	26.3	51.3	74.3	20.7	14.0	14.7	4.3	58.0	42.3	21.3
T_6	54.7	41.3	17.7	52.3	53.0	24.7	15.3	8.3	4.0	60.3	49.7	26.0
T_7	44.3	49.7	23.7	49.0	52.3	21.0	8.0	9.3	4.7	55.3	53.0	22.3
T_8	40.3	37.3	26.0	48.3	50.3	23.3	9.0	11.3	6.3	57.0	48.7	28.3
T_9	42.3	33.7	20.3	14.3	9.7	9.7	2.0	3.3	2.7	52.3	46.3	26.3
T_{10}	49.3	43.3	23.7	17.7	12.7	11.3	4.3	0	2.0	56.0	51.3	33.7
T_{11}	50.3	41.7	21.3	16.0	11.0	10.3	4.0	3.3	4.3	52.0	57.0	24.0
T_{12}	51.7	36.3	28.7	11.0	8.7	13.7	2.3	2.3	5.3	58.3	52.3	38.7
T_{13}	51.3	44.3	20.7	52.7	58.3	21.3	56.0	61.7	25.3	56.0	79.3	33.0
T_{14}	53.3	48.0	25.3	54.3	61.7	21.3	58.3	83.3	33.0	57.3	82.7	39.7
CD (P=0.05)	NS	NS	NS	11.1	30.3	NS	7.9	16.3	8.3	NS	NS	NS

B – Bacteria; F – Fungi; A - Actinomycetes;
Treatments details are given in materials and methods.

technologies were found not detrimental to the soil microbes (bacteria, fungi and actinomycetes). However, a temporary reduction in number of microbes was observed immediately after herbicide application.

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