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Evaluation of Different Herbicides against Complex Weed Flora in *Kharif* Maize

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ABSTRACT

A field experiment was conducted at RRS Karnal, Haryana during kharif 2015 and 2016 to evaluate different herbicides in maize. Seventeen treatments were replicated thrice in Randomized Complete Block Design. Among different herbicide treatments, pre-emergence application of alachlor 2000 g ha^{-1} fb tembotrione 120 g ha^{-1} at 35 DAS gave highest grain yield (6380 and 6816 kg ha^{-1}) along with minimum density and dry weight of different weeds during both the years.

Key words: *Alachlor, Grain yield, Tembotrione, Weed density, Weed dry weight*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal grown across disparate environment and wide geographical ranges over the globe covering an area of 187.9 mha with an average productivity of 5.64 tons ha^{-1} [3]. This crop also known as "queen of cereals" is in increasing demand all over the world due to its diversified usage. Quality protein maize (QPM) has substantially higher amount of lysine and tryptophan which make the protein of QPM equivalent to 90 % of the meat protein[9] and hence can provide a cheaper source of proteins. Maize, providing an estimated 15% of the world's protein and 20% of the world's calories[2], is a dietary staple for more than 200 million people. Its demand will increase with the increase in world's population which is estimated to be 9 billion by 2050[5,6]. The renowned Nobel Laureate, Dr. Norman E. Borlaug believed that "The last two decades saw the revolution in rice and wheat, the next few decades will be known for maize era".

In India, maize is the third most important cereal crop after rice and wheat, grown in 9.63 mha area with average yield of 2.69 t ha^{-1} and accounts for nearly 9 per cent of total food grain production. In Haryana, the average productivity is 3.4 t ha^{-1}. Haryana state has an ample scope to increase its acreage and productivity[1]. Maize is grown throughout the year in India. It is predominantly a *kharif* crop with 85 per cent of the area under cultivation in the season.

Weed competition is a serious factor limiting productivity of maize crop. Excluding environmental variables, yield losses in crops are caused mainly by competition with weeds.

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Weeds compete with the crop plants for resources such as light, nutrients, space, and moisture that influence the morphology and phenology of crop, reduce the yield, make harvesting difficult, and reduce the quality of grains. Furthermore, high weed infestation increases the cost of cultivation, lowers value of land, and reduces the returns per unit of land. Weed interference is a severe problem with rainy season maize which suffers heavily from weeds and depending upon the intensity, nature, stage and duration of weed infestation, yield losses vary from 28-100%[5], especially in the early part of the growing season, due to slow early growth rate, heavy moisture and wider row spacing.

Most of the herbicides are selective and specific to the crop and persist in the soil for few months to few years depending upon the chemical and concentration used. Knowledge on the persistence and residual effect of herbicides in soil is essential to use them safely, effectively and for non-hazardous chemical weed control schedules. So it becomes imperative to work out safe combination and time of application of herbicides in maize. Keeping in view the above mentioned points, the present investigation was planned.

MATERIAL AND METHODS

The field experiment was conducted at Regional Research Station, Uchani, Karnal, Haryana during *kharif* 2015 and 2016. The experiment was laid with seventeen treatments with three replications in randomized complete block design. The soil of the experiment field was poor in available nitrogen and phosphorus and medium in available potassium. Maize hybrid HQPM-1 was sown on 1st July and 25th June during 2015 and 2016, respectively by dibbling method. In maize crop, N @ 150 kg ha^{-1} was applied in three equal splits at sowing, knee high stage and at pre-tasselling stage during both the seasons. Full dose of P, K and ZnSO4 @ 60, 60 and 25 kg ha^{-1} respectively, were applied at the time of planting before opening of ridges.

STATISTICAL ANALYSIS

The data recorded for different weeds and crop parameters were analysed using analysis of variance (ANOVA) technique[4], for randomized block design using SAS 9.1 software[7], Where ANOVA was significant, the treatment means were compared using LSD procedure at 5% level of significance (*$p<0.05$). The data on weed density and weed dry were square root transformed ($\sqrt{x+1}$) before statistical analysis.

RESULTS AND DISCUSSION

The major weed flora infesting the crop were *Cyperus rotundus* among sedges, *Brachiaria reptans* and *Dactyloctenium aegyptium* among grassy weeds and *Amaranthus viridis*, *Digera arvensis*, *Phyllanthus niruri* and *Portulaca oleracea* among broad leaf weeds.

WEED STUDIES

WEED DENSITY

All the weed control treatments significantly reduced the density of weeds compared with weedy check at 25 DAS (Table 1). The minimum weed density was in weed free treatment and maximum in weedy check.

Among all herbicidal treatments, the density of sedges was minimum in alachlor 2000 g ha^{-1}as PRE *fb* tembotrione 120 g ha^{-1}+S at 35 DAS (T_{13}) (26.7 and 22.7 plants m^{-2}) which was at par with alachlor 2000 g ha^{-1} as PRE (T_7), alachlor 2000 g ha^{-1} as PRE *fb* hoeing at 35 DAS (T_8) and alachlor 2000 g ha^{-1} as PRE *fb* 2,4-D 500 g ha^{-1} at 35 DAS (T_9) during both the years.

The density of grassy weed was minimum in treatments involving hoeing at 20 DAS i.e. one hoeing at 20 DAS *fb* atrazine 500 g ha^{-1} at 35 DAS (T_6) and hoeing at 20 and 35 DAS (T_{15}) which was at par with weed free during *kharif* 2015 and 2016. Among different herbicide treatment, minimum density of grassy weeds was in alachlor 2000 g ha^{-1} as PRE (T_7) and atrazine 375 g ha^{-1} + alachlor 1000 g ha^{-1} as PRE (T_{10}) during first year while in alachlor 2000 g ha^{-1}as PRE *fb* tembotrione 120 g ha^{-1}+S at 35 DAS (T_{13}) during second year.

The treatments one hoeing at 20 DAS *fb* atrazine 500 g ha^{-1} at 35 DAS (T_6), alachlor 2000 g ha^{-1} as PRE (T_7), alachlor 2000 g ha^{-1} as PRE *fb* hoeing at 35 DAS (T_8), alachlor 2000 g ha^{-1} as PRE *fb* 2,4-D 500 g ha^{-1} at 35 DAS (T_9), atrazine 375 g ha^{-1} + alachlor 1000 g ha^{-1} as PRE (T_{10}), alachlor 2000 g ha^{-1}as PRE *fb* tembotrione 120 g ha^{-1}+S at 35 DAS (T_{13}) and hoeing at 20 and 35 DAS (T_{15}) gave complete control of broadleaf weeds at par with weed free at 25 DAS during both the year.

WEED DRY WEIGHT

The dry weight of different weeds was significantly influenced with different weed control treatments during both the years (Table 2).

The minimum dry weight of sedges among all herbicide treatments was in treatment alachlor 2000 g ha^{-1}as PRE *fb* tembotrione 120 g ha^{-1}+S at 35 DAS (T_{13}) (1.44 and 1.28 g m^{-2}) at par with one hoeing at 20 DAS *fb* atrazine 500 g ha^{-1} at 35 DAS (T_6), alachlor 2000 g ha^{-1} as PRE (T_7), alachlor 2000 g ha^{-1} as PRE *fb* hoeing at 35 DAS (T_8) and alachlor 2000 g ha^{-1} as PRE *fb* 2,4-D 500 g ha^{-1} at 35 DAS (T_9). The weed dry weight in treatment hoeing at 20 and 35 DAS (T_{15}) was at par with T_{13}.

The dry weight of grassy weeds was significantly influenced with different weed control treatments and minimum dry weight was in weed free treatment. Dry weight of grassy weed in treatments hoeing at 20 and 35 DAS (T_{15}) and one hoeing at 20 DAS *fb* atrazine 500 g ha^{-1} at 35 DAS (T_6) was at par with weed free. Among herbicide treatment, lowest dry weight of grassy weed was in atrazine 375 g ha^{-1} + alachlor 1000 g ha^{-1} as PRE (T_{10}) alachlor 2000 g ha^{-1} as PRE *fb* 2,4-D 500 g ha^{-1} at 35 DAS (T_9) followed by during first year and in alachlor 2000 g ha^{-1}as PRE *fb* tembotrione 120 g ha^{-1}+S at 35 DAS (T_{13}) followed by alachlor 2000 g ha^{-1} as PRE *fb* hoeing at 35 DAS (T_8) during second year of experimentation.

CROP STUDIES

There was no significant effect of different weed control treatments on plant population at 30 DAS during both the years (Table 3).

Maximum crop dry weight at 25 DAS, was in weed free treatment (27.2 and 30.1 g plant^{-1}) at par with all other treatments except tembotrione 120 g ha^{-1} +S at 35 DAS (T_{11}), tembotrione 140 g ha^{-1} +S at 35 DAS (T_{12}) and weedy check during both the years.

Highest grain yield was recorded in weed free (6505 and 6903 kg ha^{-1}) and minimum in weedy check (2950 and 3278 kg ha^{-1}). Among all herbicide treatments, highest grain yield during both the years was in alachlor 2000 g ha^{-1}as PRE *fb* tembotrione 120 g ha^{-1}+S at 35 DAS (T_{13}) (6380 and 6816 kg ha^{-1}) at par with T_8, T_{14}, T_5, T_6, T_{11} and T_{12}.

Table 1: Effect of different weed control treatments on density (No. m^{-2}) of different weeds at 25 DAS during both the years

	Treatment	Dose (g ha^{-1})	Time of application (DAS)	2015-16			2016-17		
				Sedges	Grasses	BLW	Sedges	Grasses	BLW
T1	Atrazine	750	PRE	11.4 (128.0)	8.1 (65.3)	3.0 (8.0)	9.8 (96.0)	9.4 (86.7)	3.4 (10.7)
T2	Atrazine	1000	PRE	11.1 (121.3)	7.7 (58.7)	3.0 (8.0)	9.3 (85.3)	8.8 (76.0)	3.2 (9.3)
T3	Atrazine *fb* atrazine	750 *fb* 500	PRE & 35 DAS	11.0 (120.0)	8.4 (69.3)	3.2 (9.3)	10.0 (98.7)	9.7 (93.3)	3.4 (10.7)
T4	Atrazine *fb* 2,4-D	750 *fb* 500	PRE & 35 DAS	11.2 (125.3)	8.5 (70.7)	3.2 (9.3)	9.6 (92.0)	9.3 (85.3)	3.0 (8.0)
T5	Atrazine *fb* one hoeing	1000	PRE & 35 DAS	11.2 (124.0)	7.4 (54.7)	3.0 (8.0)	7.5 (56.0)	8.0 (62.7)	2.7 (6.7)
T6	One hoeing *fb* atrazine	500	20 & 35 DAS	7.5 (56.0)	1.0 (0.0)	1.0 (0.0)	6.3 (38.7)	1.0 (0.0)	1.0 (0.0)
T7	Alachlor	2000	PRE	5.2 (26.7)	6.4 (40.0)	1.0 (0.0)	4.7 (21.3)	6.9 (46.7)	1.0 (0.0)
T8	Alachlor *fb* one hoeing	2000	PRE & 35 DAS	5.5 (29.3)	6.6 (42.7)	1.0 (0.0)	4.6 (20.0)	6.5 (41.3)	1.0 (0.0)
T9	Alachlor *fb* 2,4-D	2000 *fb* 500	PRE & 35 DAS	5.7 (32.0)	6.8 (45.3)	1.0 (0.0)	5.0 (24.0)	6.9 (46.7)	1.0 (0.0)
T10	Atrazine + alachlor	375 & 1000	PRE	8.5 (72.0)	6.4 (40.0)	1.0 (0.0)	7.6 (57.3)	6.8 (45.3)	1.0 (0.0)

T11	Tembotrione +S	120 +1000	35 DAS	11.4 (129.3)	12.8 (164.0)	4.3 (17.3)	10.0 (100.0)	12.0 (142.7)	4.1 (16.0)
T12	Tembotrione +S	140 +1000	35 DAS	11.3 (128.0)	12.9 (165.3)	4.1 (16.0)	10.0 (98.7)	12.1 (145.3)	4.0 (14.7)
T13	Alachlor *fb* tembotrione +S	2000 *fb* 120+1000	PRE & 35 DAS	5.2 (26.7)	6.8 (45.3)	1.0 (0.0)	4.8 (22.7)	6.4 (40.0)	1.0 (0.0)
T14	Atrazine *fb* tembotrione +S	1000 *fb* 120+1000	PRE & 35 DAS	11.3 (126.7)	7.9 (61.3)	3.0 (8.0)	9.8 (96.0)	7.5 (56.0)	2.7 (6.7)
T15	Hoeing		20 & 35 DAS	7.3 (52.0)	1.0 (0.0)	1.0 (0.0)	6.8 (45.3)	1.0 (0.0)	1.0 (0.0)
T16	Weedy check			11.5 (130.7)	7.9 (173.3)	4.3 (17.3)	10.1 (101.3)	15.5 (238.7)	4.4 (18.7)
T17	Weed free			1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
	SE(m) ±			0.24	0.19	0.08	0.23	0.20	0.12
	CD at 5%			0.68	0.54	0.24	0.65	0.59	0.35

*Original values are in parenthesis and before statistical analysis were subjected to square root transformation (√x+1)

Table 2: Effect of different weed control treatments on dry weight (g m^{-2}) of different weeds at 25 DAS during both the years

	Treatment	Dose (g ha^{-1})	Time of application (DAS)	2015-16			2016-17		
				Sedges	Grasses	BLW	Sedges	Grasses	BLW
T1	Atrazine	750	PRE	3.18 (9.1)	5.8 (32.9)	2.19 (3.8)	2.81 (6.9)	6.1 (36.8)	2.55 (5.6)
T2	Atrazine	1000	PRE	3.16 (9.0)	5.7 (31.8)	2.25 (4.1)	2.80 (6.8)	6.0 (34.9)	2.47 (5.1)
T3	Atrazine *fb* atrazine	750 *fb* 500	PRE & 35 DAS	3.19 (9.2)	6.0 (35.8)	2.41 (4.8)	2.84 (7.1)	6.5 (41.2)	2.63 (6.0)
T4	Atrazine *fb* 2,4-D	750 *fb* 500	PRE & 35 DAS	3.16 (9.0)	6.0 (35.0)	2.72 (6.4)	2.82 (7.0)	6.4 (40.0)	2.62 (5.9)
T5	Atrazine *fb* one hoeing	1000	PRE & 35 DAS	3.17 (9.1)	5.7 (31.7)	2.14 (3.6)	2.24 (4.0)	5.7 (31.8)	2.08 (3.3)
T6	One hoeing *fb* atrazine	500	20 & 35 DAS	1.58 (1.5)	1.0 (0.0)	1.0 (0.0)	1.56 (1.4)	1.0 (0.0)	1.0 (0.0)
T7	Alachlor	2000	PRE	1.70 (1.9)	5.4 (27.8)	1.0 (0.0)	1.65 (1.7)	5.0 (24.3)	1.0 (0.0)
T8	Alachlor *fb* one hoeing	2000	PRE & 35 DAS	1.67 (1.8)	5.1 (24.8)	1.0 (0.0)	1.62 (1.6)	4.9 (23.3)	1.0 (0.0)
T9	Alachlor *fb* 2,4-D	2000 *fb* 500	PRE & 35 DAS	1.70 (1.9)	5.0 (24.1)	1.0 (0.0)	1.65 (1.7)	5.0 (24.5)	1.0 (0.0)
T10	Atrazine + alachlor	375 & 1000	PRE	2.48 (5.2)	4.9 (23.5)	1.0 (0.0)	2.26 (4.1)	5.0 (23.6)	1.0 (0.0)
T11	Tembotrione +S	120 +1000	35 DAS	3.19 (9.2)	8.2 (66.8)	2.97 (7.8)	2.76 (6.7)	8.5 (70.6)	2.99 (8.0)
T12	Tembotrione +S	140 +1000	35 DAS	3.10 (8.6)	8.3 (67.3)	3.06 (8.4)	2.70 (6.3)	8.4 (69.9)	3.06 (8.4)
T13	Alachlor *fb* tembotrione +S	2000 *fb* 120+1000	PRE & 35 DAS	1.56 (1.4)	5.1 (25.0)	1.0 (0.0)	1.51 (1.3)	4.9 (23.2)	1.0 (0.0)
T14	Atrazine *fb* tembotrione +S	1000 *fb* 120+1000	PRE & 35 DAS	3.17 (9.1)	6.0 (34.9)	2.56 (5.6)	2.80 (6.8)	5.7 (31.0)	2.39 (4.8)
T15	Hoeing		20 & 35 DAS	1.59 (1.5)	1.0 (0.0)	1.0 (0.0)	1.60 (1.6)	1.0 (0.0)	1.0 (0.0)
T16	Weedy check			3.21 (9.4)	8.9 (78.5)	3.45 (10.9)	2.88 (7.3)	10.0 (99.2)	3.70 (12.7)
T17	Weed free			1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
	SE(m) ±			0.06	0.14	0.09	0.05	0.17	0.09
	CD at 5%			0.17	0.40	0.25	0.16	0.50	0.26

*Original values are in parenthesis and before statistical analysis were subjected to square root transformation (√x+1)

Table 3: Effect of different weed control treatments on plant population (No. m^{-2}) at 30 DAS, dry weight of plant (g $plant^{-1}$) at 25 DAS and grain yield (kg ha^{-1}) of *kharif* maize during both the years

	Treatment	Dose (g ha^{-1})	Time of application (DAS)	2015-16			2016-17		
				Plant height (cm)	Crop dry weight	Grain yield (kg ha^{-1})	Plant height (cm)	Crop dry weight	Grain yield (kg ha^{-1})
T1	Atrazine	750	PRE	4.7	24.8	4,730	4.3	27.4	5,080
T2	Atrazine	1000	PRE	4.7	25.8	5,140	4.3	28.4	5,500
T3	Atrazine *fb* atrazine	750 *fb* 500	PRE & 35 DAS	4.7	24.8	5,560	4.7	27.4	5,940
T4	Atrazine *fb* 2,4-D	750 *fb* 500	PRE & 35 DAS	4.7	25.3	4,840	4.7	27.6	5,190
T5	Atrazine *fb* one hoeing	1000	PRE & 35 DAS	4.7	25.9	5,807	4.3	28.2	6,193
T6	One hoeing *fb* atrazine	500	20 & 35 DAS	5.0	26.6	5,930	4.7	29.0	6,280
T7	Alachlor	2000	PRE	4.7	26.2	5,620	4.3	28.8	5,790

T8	Alachlor *fb* one hoeing	2000	PRE & 35 DAS	4.7	26.4	6,150	4.7	28.9	6,570
T9	Alachlor *fb* 2,4-D	2000 *fb* 500	PRE & 35 DAS	4.7	26.3	5,480	4.3	28.6	5,860
T10	Atrazine + alachlor	375 & 1000	PRE	5.0	25.8	5,330	4.7	28.4	5,690
T11	Tembotrione +S	120 +1000	35 DAS	4.3	19.5	5,819	4.3	22.1	6,187
T12	Tembotrione +S	140 +1000	35 DAS	4.3	19.6	5,860	4.3	22.0	6,244
T13	Alachlor *fb* tembotrione +S	2000 *fb* 120+1000	PRE & 35 DAS	5.0	26.2	6,380	5.0	29.0	6,816
T14	Atrazine *fb* tembotrione +S	1000 *fb* 120+1000	PRE & 35 DAS	4.7	25.6	5,940	4.7	27.9	6,350
T15	Hoeing		20 & 35 DAS	5.0	26.6	6,180	5.0	29.4	6,625
T16	Weedy check			4.3	19.4	2,950	4.0	21.5	3,278
T17	Weed free			5.0	27.2	6,505	5.0	30.1	6,903
	SE(m) ±			0.26	1.25	247	0.28	1.29	255
	CD at 5%			NS	3.61	714	NS	3.74	738

CONCLUSION

It can inferred from two year study that pre emergence application of alachlor 2000 g ha^{-1} *fb* tembotrione 120 g ha^{-1} + Surfactant at 35 DAS gave minimum density and dry weight of sedges, grassy and broadleaf weeds at par with hoeing twice at 20 and 35 DAS during both the years. The different treatments applied have non-significant effect on plant stand at 30 DAS. The highest dry matter accumulation and grain yield was in treatment alachlor 2000 g ha^{-1} *fb* tembotrione 120 g ha^{-1} + Surfactant at 35 DAS at par with alachlor 2000 g ha^{-1} *fb* one hoeing at 35 DAS.

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