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Effect of new pre and post emergence herbicides on weed control and productivity of maize (*Zea mays* L.)

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Abstract: A field experiment was carried out during *kharif* of 2013 in sandy loam soil under irrigated condition. The experiment was laid out in RCBD with ten treatments replicated thrice. The herbicide treatments included acetochlor, atrazine, alachlor, topramezone+atrazine, tembotrione and their combinations (acetochlor, atrazine and alachlor fb 2,4-D Na salt) compared with two hand weedings and a weedy check. The study revealed significantly higher kernel yield and lower weed index with alachlor 50 EC @ 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP @ 500 g a. i. ha^{-1} at 40 DAS (8289 kg $ha^{-1}$and -4.6, respectively) followed by acetochlor 900 EC @ 2250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP @ 500 g a. i. ha^{-1} at 40 DAS (8107kg ha^{-1} and -2.4, respectively). Similar trends were also observed in respect of weed density and weed control efficiency.

Key words: Herbicides, Weed index, Kernel yield, Maize

Introduction

Maize (*Zea mays* L.) is the most versatile crop with wider adaptability in varied agro-ecological situations. Maize is one of the most important food crops in India and is increasingly gaining an important position in crop husbandry because of its higher yield potential and shorter growth duration. The rapid expansion of the biofuel industry in recent years and high fossils energy costs also influence global maize demand and supply (Yakadri *et al.,* 2015). Weeds during the growing period of a crop lower the productivity. Weed infestation poses competition for natural and applied inputs, such as space, water and nutrients. Non-availability of manual labour due to competition from other crops and higher labour wages also comes in the way of timely weed management in maize. Herbicides play a major role in managing weeds in such a situation. Wider spacing and slow growing nature of the crop during the first 3-4 weeks provide enough opportunity for weeds to invade and offer severe competition resulting in 30-96% yield reduction (Mukundam *et al.,* 2011; Reddy *et al.,* 2012; Pasha *et al*., 2012). Considering the initial 2 to 6 weeks of critical period of crop weed competition in maize, use of pre and post emergent herbicides in combination is found to be better choice (Annual Report, 2014). Keeping this in view, a field study was conducted to evaluate the effect of new pre and post emergence herbicides on weed control and productivity of maize with the objective to evaluate the bio-efficacy of pre and post-emergence herbicides against weeds in maize and to evolve efficient weed management practices for higher yield of maize.

Material and Methods

A field experiment was conducted at Main Research Station, University of agricultural Sciences, Hebbal, Bangalore, Karnataka during *kharif* 2013 to study the effect of new pre and post emergence herbicides on weed control and productivity of maize. The soil of the experimental site was sandy loam, slightly acidic (pH-5.6), medium in available nitrogen (245.4 kg ha^{-1}), available phosphorus (35.4 kg ha^{-1}), available potassium (187.0 kg ha^{-1}) and organic carbon content (0.61%). The experiment was laid out in RCBD design replicated thrice with 10 treatments viz., .,T_1- acetochlor 900 EC @ 2250 g a. i. ha^{-1} at 2 DAS, T_2 - atrazine 50 WP @ 1250 g a. i. ha^{-1} at 2 DAS, T_3 - alachlor 50 EC @ 1250 g a. i. ha^{-1} at 2 DAS, T_4 - topramezone 33.6 g lt^{-1} SC @ 25.2 g a. i. ha^{-1} + atrazine 50 WP @ 250 g a. i. ha^{-1} at 15 DAS, T_5 - tembotrione 42 SC @ 105 g a. i. ha^{-1} + isoxadifen – ethyl 21 SC @ 52 g a. i. ha^{-1} + Stefesmero adjuvant at 2.5 ml lt^{-1} at 15 DAS, T_6 - acetochlor 900 EC @ 2250 g a. i. ha^{-1} at 2 DAS followed by (fb) 2,4-D Na salt 80 WP @ 500 g a. i. ha^{-1} at 40 DAS , T_7 - atrazine 50 WP @ 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP @ 500 g a. i. ha^{-1} at 40 DAS, T_8 - alachlor 50 EC @ 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP 500 g a. i. ha^{-1} at 40 DAS, T_9 - two hand weedings at 20 and 40 DAS, T_{10} – unweeded control were sown by dibbling at a spacing of 60 cm × 30 cm with the seed rate of 15 kg ha^{-1} on 13th July, 2013. Recommended dose of FYM @10 t ha^{-1} three weeks before sowing and $ZnSO_4$@10 kg ha^{-1} at the time of sowing and inorganic fertilizers (150 : 75 : 40 kg N, P_2O_5 and K_2O ha^{-1}) were applied to maize. Pre-emergence herbicides were applied by using knapsack sprayer fitted with aspee WFN 78 nozzle with a spray volume of 750 liters ha^{-1}. At the time of herbicide application, adequate soil moisture was maintained with fewer clods. Post-emergence herbicides were applied by using knapsack sprayer fitted with Aspee WFN 40 nozzle by using 375 liters of spray volume ha^{-1}. The post-emergence herbicides

were sprayed when the weeds were in active stage without being wilted to ensure good action by the herbicides.

The experimental data on weed parameters, and yield subjected to analysis by using Fisher's method of "Analysis of Variance" (ANOVA) (Panse and Sukhatme, 1954). The level of significance used in "F" and "t" test was at 5 % level of probability.

Results and Discussion

Weed management practices significantly influenced the sedge, grass, broad leaf and total weed density (no. m^{-2}) and weed dry weight (g 0.25m^{-2}). At 60 DAS, significantly lower density of sedge and grasses were observed in treatments acetochlor fb 2,4-D (2.7 and 17.3, respectively)and alachlor fb 2,4-D (3.0 and 16.7, respectively). Significantly lower broad leaf weed density was observed in treatment T_6 i.e., acetochlor 900 EC - 2250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS(8.7) with which alachlor 50 EC - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS (11.0) was on par. This may be due to selective action of 2, 4-D applied on broad leaf weeds as reported by Veeresh *et al*. (2015). Application of pre-emergence herbicides (acetachlor, alachlor and atrazine) followed by post emergence herbicides (2,4 –D Na salt), two hand weedings and application of only post emergence herbicides (topramezone + atrazine and tembotrione) recorded significantly lower total weed density (Table 1).The major weeds controlled were *Cyperus rotundus* among sedges, *Digitaria marginata*, *Dactyloctenium aegyptium* among grasses, *Ageratum conyzoides, Cleome viscosa, Borreria articularis, Alternanthera sessilis, Commelina benghalensis* among broad leaf weeds (Ramesh and Nadanassababady, 2005). At harvest significantly lower density of sedge (3.3) was observed in treatment two hand weedings at 20 and 40 days after sowing due to pulling off weeds from its base. Significantly lower broad leaf and total weeds density was noticed in T_6 i.e., acetochlor 900 EC - 2250 g a. i. ha^{-1} at 2 DAS

Table-1: Category wise weed density (number m^{-2}) at 60 DAS and harvest in maize as influenced by weed management practices

Treatments	60 DAS				Harvest			
	Sedge #	Grasses #	Broad leaf weeds #	Total #	Sedge #	Grasses #	Broad leaf weeds #	Total #
T_1	1.00 (8.0)	1.37 (21.3)	1.59 (36.7)	1.83 (66.0)	1.27 (16.7)	1.83 (66.0)	1.86 (70.3)	2.19 (153.0)
T_2	1.10 (10.5)	1.42 (24.5)	1.61 (38.3)	1.88 (73.3)	1.39 (22.3)	1.87 (72.0)	1.83 (90.0)	2.21 (184.3)
T_3	1.00 (8.0)	1.37 (21.3)	1.56 (34.7)	1.82 (64.0)	1.24 (15.3)	1.66 (50.3)	1.86 (84.7)	2.14 (150.3)
T_4	0.86 (6.0)	1.38 (21.9)	1.39 (25.4)	1.67 (53.3)	1.04 (12.0)	1.76 (55.0)	1.72 (61.7)	2.12 (128.7)
T_5	0.86 (5.3)	1.40 (25.3)	1.44 (25.3)	1.76 (56.0)	1.12 (11.3)	1.76 (55.7)	1.78 (58.0)	2.10 (125.0)
T_6	0.67 (2.7)	1.29 (17.3)	1.03 (8.7)	1.49 (28.7)	1.01 (8.3)	1.81 (62.7)	1.49 (29.0)	2.01 (100.0)
T_7	0.84 (5.0)	1.38 (22.2)	1.19 (13.6)	1.63 (40.7)	1.07 (9.7)	1.83 (65.0)	1.67 (45.0)	2.09 (119.7)
T_8	0.70 (3.0)	1.27 (16.7)	1.11 (11.0)	1.51 (30.7)	0.80 (4.3)	1.75 (54.0)	1.62 (39.3)	1.96 (97.7)
T_9	0.70 (3.0)	1.20 (14.0)	1.29 (17.7)	1.56 (34.7)	0.72 (3.3)	1.79 (60.3)	1.74 (53.0)	2.07 (116.7)
T_{10}	1.17 (12.7)	1.76 (55.0)	1.79 (60.3)	2.11(128.0)	1.18 (13.0)	2.11 (126.3)	2.15 (110.7)	2.40 (250.0)
S.Em+	0.05	0.05	0.05	0.09	0.07	0.05	0.06	0.04
CD at 5%	0.14	0.14	0.15	0.27	0.22	0.16	0.19	0.13

Table-2: Category wise weed dry weight (g 0.25 m^{-2}) at 60 DAS and harvest, kernel yield and weed index in maize as influenced by weed management practices

Treatments	60 DAS				Harvest				Kernel yield (kg ha^{-1})	Weed index
	Sedge #	Grasses #	Broad leaf weeds #	Total #	Sedge #	Grasses #	Broad leaf weeds #	Total #		
T_1	0.72 (3.2)	1.30 (18.2)	1.36 (20.8)	1.65 (42.2)	1.14 (11.9)	1.73 (51.2)	1.82 (64.0)	2.11 (127.1)	7083	10.6
T_2	0.76 (3.8)	1.43 (25.1)	1.37 (21.5)	1.72 (50.4)	1.16 (12.5)	1.76 (55.3)	1.83 (69.7)	2.14 (137.5)	6909	12.8
T_3	0.64 (3.1)	1.29 (17.5)	1.32 (19.1)	1.62 (39.7)	1.12 (11.3)	1.67 (45.2)	1.86 (65.9)	2.09 (122.4)	7134	9.9
T_4	0.60 (2.0)	1.15 (12.1)	0.84 (6.2)	1.31(20.3)	1.06 (9.5)	1.66 (43.6)	1.70 (51.2)	1.98 (104.3)	7408	6.5
T_5	0.59 (1.9)	1.05 (12.2)	1.04 (8.9)	1.40 (23.0)	1.00 (8.0)	1.60 (42.1)	1.72 (50.7)	2.01 (100.8)	7689	2.9
T_6	0.40 (0.5)	1.84 (5.0)	0.52 (1.4)	0.95 (6.9)	0.45 (0.8)	1.75 (54.6)	1.43 (25.0)	1.92 (80.4)	8107	-2.4
T_7	0.45 (0.8)	1.11 (11.0)	0.88 (2.4)	1.68 (14.2)	0.48 (1.0)	1.75 (53.7)	1.58(36.0)	1.97 (90.7)	7699	2.8
T_8	0.40 (0.5)	0.87 (5.5)	0.56 (1.7)	0.99 (7.7)	0.41 (0.6)	1.74 (52.9)	1.45 (26.5)	1.91 (80.0)	8289	-4.6
T_9	0.43 (0.7)	0.67 (2.7)	0.79 (4.2)	0.98 (7.6)	0.48 (1.0)	1.75 (54.2)	1.56(34.6)	1.96 (89.8)	7921	0.0
T_{10}	0.90 (6.0)	1.84 (66.5)	1.86 (70.9)	2.16 (143.4)	0.90 (5.9)	2.02 (102.0)	1.98 (94.3)	2.31 (202.2)	2535	68.0
S.Em+	0.06	0.08	0.07	0.08	0.07	0.05	0.04	0.05	273	NA
CD at 5%	0.18	0.24	0.22	0.24	0.20	0.14	0.11	0.15	811	

In table 1 and 2: Data within parentheses are original values; **# -** data analyzed using log(x+2) transformation; DAS-Days after sowing. NA – Not analyzed, T_1- acetochlor 900 EC 2250 g a.i. ha^{-1} – 2 DAS, T_2 - atrazine 50 WP 1250 g a.i. ha^{-1} – 2 DAS, T_3 - alachlor 50 EC 1250 g a.i. ha^{-1} – 2 DAS, T_4 - topramezone 33.6 SC 25.2 g a.i. ha^{-1} + atrazine 50 WP 250 g a.i. ha^{-1} – 15 DAS, T_5 - tembotrione 42 SC 105 g a.i. ha^{-1} + isoxadifen – ethyl 21 SC 52 g a.i. ha^{-1} + Stefesmero adjuvant @ 2.5 ml lt^{-1} – 15 DAS, T_6 - acetochlor 900 EC 2250 g a.i. ha^{-1} – 2 DAS fb 2,4-D Na salt 80 WP 500 g a.i. ha^{-1} – 40 DAS , T_7 - atrazine 50 WP 1250 g a.i. ha^{-1} - 2 DAS fb 2,4-D Na salt 80 WP 500 g a.i. ha^{-1} – 40 DAS, T_8 - alachlor 50 EC 1250 g a.i. ha^{-1} – 2 DAS fb 2,4-D Na salt 80 WP 500 g a.i. ha^{-1} – 40 DAS, T_9 - two hand weedings at 20 and 40 DAS, T_{10} - unweeded control

Table-3: Correlation for weed growth and kernel yield of maize as influenced by weed management practices

y	*x*	r
Kernel yield (kg ha^{-1})	Total weed density at 60 DAS (No. m^{-2})	-0.930**
Kernel yield (kg ha^{-1})	Total weed density at harvest (No. m^{-2})	-0.890**
Kernel yield (kg ha^{-1})	Total weed dry wt. at 60 DAS (g. 0.25m^{-2})	-0.988**
Kernel yield (kg ha^{-1})	Total weed dry wt. at harvest (g.0.25 m^{-2})	-0.955**

fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS (29.0 and 100.0, respectively) as compared to all other treatments except alachlor 50 EC - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS(39.3 and 97.7, respectively) and atrazine 50 WP - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS (45.0 and 119.7, respectively).

At 60 DAS, significantly lower sedge, grass and total weed dry weight was noticed in treatments having application of pre-emergence herbicides (acetachlor, alachlor, atrazine) followed by post emergence herbicide (2,4 –D Na salt) and two hand weedings at 20 and 40 days after sowing (Table 2).This may be due to continuous action of herbicides and hand weeding on weeds. Dry weight of grasses was significantly lower in treatment two hand weedings at 20 and 40 DAS (2.7 g) followed by alachlor 50 EC - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS(5.5 g). At harvest significantly lower sedge and total weed dry weight were recorded in treatment T_8 i.e., alachlor 50 EC - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS (0.6 g and 80.0 g, respectively) as compared to all other treatments except acetochlor fb 2,4-D(0.8 g and 80.4 g, respectively), Atrazine fb 2,4-D(1.0 g and 90.7 g, respectively), two hand weedings (1.0 g and 89.8 g, respectively) with which it was at par. It was mainly due to action of herbicides for longer period. Singh *et al.* (2012) and Anil *et al.* (2015) reported that post- emergence application of herbicides enhanced the complete control of broad spectrum weeds and hence significantly lowered weed density, weed dry weight and higher weed control efficiency. At 60 DAS and harvest significantly higher density and dry weight of sedges, grasses, broad leaf weeds and total weeds were recorded in T_{10} i.e., unweeded control compared to all other treatments because of unchecked weed growth. These results are in conformity with Ishrat *et al.* (2012).

Kernel yield of maize was significantly influenced by weed management practices (Table 2).Among different treatments, T_8 i.e., alachlor 50 EC - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS recorded significantly higher kernel yield (8289 kg ha^{-1}). However, T_6 i.e., acetochlor 900 EC - 2250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS (8107 kg ha^{-1}), T_9 i.e., two hand weedings at 20 and 40 DAS (7921 kg ha^{-1}), T_7 i.e., atrazine 50 WP - 1250 g a. i. ha^{-1} at 2 DAS fb 2,4-D Na salt 80 WP - 500 g a. i. ha^{-1} at 40 DAS (7699 kg ha^{-1}) and T_5 i.e., tembotrione 42 SC - 105 g a. i. ha^{-1} + isoxadifen – ethyl 21 SC - 52 g a. i. ha^{-1} + stefesmero adjuvant at 2.5 ml lt^{-1} at 15 DAS (7689 kg ha^{-1}) treatments recorded on par kernel yield with treatment T_8. The reason for increased yield might be due to efficient and broad spectrum weed management achieved by the above treatments besides, increased availability of plant nutrients and moisture to crop throughout the growth period (Kolage *et al.,* 2004). The effective use of herbicides at optimum dosage and time of application might have enabled the crop to utilize available resources like light, nutrients, moisture and space resulting in higher yield (Veeresh *et al.,* 2015). Kernel yield had negative significant correlation (Table 3) with total weed density and dry weight throughout the growth period of maize. So there was significantly lower kernel yield was observed in T_{10} *i.e.*, unweeded control (2535 kg ha^{-1}) as compared to all other treatments (Quddus *et al.,* 2012). Higher kernel yield obtained by sequential application of herbicides was also reported by Srividya *et al*. (2011) and Reddy *et al*. (2012).

Weed index indicating yield reduction due to weed competition, was higher in unweeded control (68 %). This was due to less maize kernel yield associated with unchecked weed growth throughout the crop growth period. Since, there is negative correlation between weed density and dry weight at 60 DAS and at harvest with kernel yield, the kernel yield will decrease with increase in Weed density and weed dry weight. This statement was supported by Veeresh *et al.* (2015). However the lower weed index (-4.6 to 2.8 %) was noticed in combination of pre and post emergence herbicides treatments and two hand weedings at 20 and 40 DAS, as a result of satisfactory control of weeds owing to reduction in the crop weed competition.

Combination of pre and post emergence herbicides (alachlor or acetochlor or atrazine along with 2,4-D Na salt) recorded higher maize kernel yield (8289 - 7699 kg ha^{-1}) as compared to application of only pre emergence (7134 - 6909 kg ha^{-1}) or only post emergence herbicides (7689 - 7408 kg ha^{-1}).

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