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Effect of Pre and Post Emergence Herbicide Molecules on Weed Control Efficiency and their Phytotoxicity on Maize (*Zea mays L.*)

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ABSTRACT

A field experiment was conducted at the Regional Agricultural Research Station, Lam, Andhra Pradesh during *rabi* season of 2013 and 2014 to evaluate the efficacy of pre emergence herbicides atrazine, pendimethalin and post-emergence herbicides tembotrione and topramezone combinations on weed control efficiency and their phytotoxicity on maize. Lowest weed dry weight and high weed control efficiency was recorded in application of atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T_6), pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T8), atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence followed by tembotrione@120 g a.i ha^{-1} at 20 DAS as post-emergence (T_7) and pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by tembotrione@120 g a.i ha^{-1} at 20 DAS as post-emergence (T9) where sequential application of herbicides at all stages of crop growth. The herbicides used in the present investigation didn't cause any phytotoxicity symptoms during both the years of investigation.

Key words: *Atrazine, Maize, pendimethalin,Tembotrione, Topramezone, Weed management*

Maize (*Zea mays* L.) is one of the most important crops among the cereals in the world agricultural economy both as food and fodder crop. In India, during 2014-15 maize was cultivated in 9.2 M ha with 24.17 M t production, and with a productivity of 2.56 t ha^{-1}. In Andhra Pradesh, the crop is cultivated in an area of 0.99 M ha with 4.23 M t production and 4257 kg ha^{-1} (AICRP on Maize, 2016). Among the several factors, most dominant factor responsible for the lower yields of maize are weeds, which competes with crop for nutrients, water, sunlight and space. Wide spacing, intensive use of inputs and initial slow growth of maize are some of the factors responsible for increased weed growth. Use of herbicides to manage weeds forms an excellent alternative to manual weeding. In India, till date only pre-emergence application of atrazine / pendimethalin has been widely recommended for the control of weeds in maize. There is a need of post-emergence herbicide usage for management of weeds which occur at 15-25 days of crop and offer severe competition for growth resources, thereby lowering the productivity of maize. Hence, it is proposed to test the new post emergence herbicides without residual effect in maize has greater field applicability. In most farming systems, competition for N is the most important factor than that of for all other nutrients and it is well known that large fraction of the millions of tonnes of nutrients added to soils every year are not taken up by crop plants, as up to 50% of added nitrogen and 0.4 to 90% of added phosphorus going waste from crop fields (Simpson *et al.,* 2011). Keeping all these in view, the present investigation was proposed to evaluate different pre and post emergence herbicides against mixed weed complex in maize at the Regional Agricultural Research Station, Lam, Andhra Pradesh during *rabi* season of 2013 and 2014.

MATERIAL AND METHODS

A field experiment was conducted at the Regional Agricultural Research Station, Lam, Andhra Pradesh during *rabi* season of 2013 and 2014 in split plot design with nine weed management treatments as main plots and three fertilizer

treatments as sub plots and all the treatments replicated thrice.

Main plots

T_1- Weedy check,

T_2- Atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence

T_3- Pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence

T_4- Topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence

T_5- Tembotrione@110 g a.i ha^{-1} at 20 DAS as post emergence

T_6- Atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence, fb Topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence

T_7- Atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence fb Tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence

T_8-Pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence fb Topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence

T_9- Pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence fb Tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence

Sub-Plots

F1- 50% RDF+ bio consortium (Azospirillum (5 kg ha^{-1}) + phosphate solubilizing bacteria (5 kg ha^{-1}) + potash solubilizing bacteria (5 kg ha^{-1}) + vasicular arbuscular mycorrhiza (12.5 kg ha^{-1}) + vermicompost (500 kg ha^{-1})

F2- 75% RDF+ bioconsortium (Azospirillum (5 kg ha^{-1}) + phosphate solubilizing bacteria (5 kg ha^{-1}) + potash solubilizing bacteria (5 kg ha^{-1}) + vasicular arbuscular mycorrhiza (12.5 kg ha^{-1}) + vermicompost (500 kg ha^{-1})

F3- 100% RDF

Maize crop variety pioneer 30 V 92 used for the study in both the years in main plots of size 9.6m x 4.8m and sub plots 4.8 m x 2.9 m. Herbicides were sprayed with Knapsack sprayer fitted with flat fan nozzle. The different cultural practices recommended for maize crop were adopted during the crop growth period.

Weed sampling was done randomly by placing a 0.5 x 0.5 m quadrate at two different locations in the experimental unit to assess the weed dry weight at 30 DAS and harvesting stages. Dry weight of total weed species was recorded after drying and expressed in g/m^2.

Weed Control Efficiency (%)

Weed control efficiency (WCE) was worked out on the basis of weed dry matter recorded in each treatment at 30 DAS and at harvest using the formula suggested by Sankaran and Mani (1974).

$$WCE = \frac{DWC - DWT}{DWC} \times 100$$

WCE - Weed control efficiency in percentage

DWC - Dry weight of weeds in unweeded check

DWT - Dry weight of weeds in weed control treatment

Crop Injury Score

Phytotoxic effect of herbicides on maize crop, if any, was assessed at 7 and 14 days after spraying by using simple rating scale of 0-10 (Table 3.5) suggested by Rao (2000).

Effect	Rating	Description on crop
None	0	No injury, normal
Slight	1	Slight stunting injury or discolouration
	2	Some stand loss, stunting discolouration
	3	Injury more pronounced but not persistent
	4	Moderate injury, recovery possible
Moderate	5	Injury more persistent, recovery doubtful
	6	Near severe injury, no recovery possible
Severe	7	Severe injury, stand loss
	8	Almost destroyed, a few plants surviving
	9	Very few plants alive
Complete	10	Complete destruction

STATISTICAL ANALYSIS

The original data on weed densities and weed weights were subjected to square root transformation (Vx+0.5) before statistical analysis. The original values were given in parentheses. Statistical significance was tested by applying F- test at 0.05 level of probability and critical differences (CD) were calculated for those parameters, which turned significant ($P \leq 0.05$) to compare the effects of different treatments (Panse and Sukhatme, 1954).

RESULTS AND DISCUSSION

Total weed dry matter

Total weed dry matter was recorded at 30 and harvesting during both the years of investigation and the results are discussed herewith. At 30 DAS (Table 1) all herbicidal treatments were significantly superior over weedy check in both the years of studies. Significantly, the lowest weeds dry weight (2.9 and 3.3 g. m^{-2}) of total weeds was recorded in atrazine @ 1.25 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T6) as compared to all other treatments except, treatments topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T4), tembotrione @110 g a.i ha^{-1} at 20 DAS as post-emergence (T5), pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T8), atrazine @ 1.25 kg a.i ha^{-1} as pre-emergence followed by tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T7) and pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T9) with which it was at par. This could be attributed to reduced weed competition in the initial stage and control of late emerged weeds by sequential spray which led to lower weeds density and lower weed dry matter. Similar findings were reported by Patel *et al.* (2016) and Ahmed (2012). Significantly lower weed dry weight was recorded in topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T4) and tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T5) treatments because of the post-emergence spray at 20 DAS which effectively controlled the weeds and resulted in low weed dry weight at 30 DAS. The highest weed dry weight (12.7 and 13.4 gm^{-2}, respectively) was recorded in weedy check during both the years of study. The same trend was continued at harvest (Table 2) also during both the years of study. Significantly, the lowest weeds dry weight (5.7 and 5.8 g. m^{-2}) of total weeds was recorded in atrazine @ 1.25 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T6) as compared to all other treatments except, treatments pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T8), atrazine @ 1.25 kg a.i ha^{-1} as pre-emergence followed by tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T7) and pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T9) with which it was at par.There was no significance among the nutrient management treatments in sub plots during the two years of study and there was no interaction affect among the treatments. An appraisal of the data indicated that the weed dry matter showed gradual increase up to harvests.. This may be because of accumulation of more dry matter in weeds was due to lower competition among weeds for resources.

Weed control efficiency (WCE) denotes the efficiency of applied herbicide or treatment effect in reducing the dry weight of weeds compared to unweeded check. Data pertaining to WCE at different stages presented in Tables 3 to 4.

All the weed control treatments significantly influenced the weed control efficiency at 30 and at harvest. At 30 DAS (Table 3), the highest (77.3 and 75.5%) weed control efficiency (WCE) was recorded in atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T6) during both the years of studies and this was superior over all other treatments except pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T8), atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence followed by tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T7) and pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence followed by tembotrione@110 g a.i ha^{-1} at 20 DAS as post-emergence (T9). The lowest WCE (58.1 and 56.6 %) was observed in pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence (T3) and atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence (T2) (58.2 and 56.7 %) when compared to other treatments. The main attributing factor might be that, these two herbicides

Table 1. Dry weight of total weeds at 30 DAS (g m^{-2}) in maize as influenced by and microbial inoculants on *rabi* maize-greengram crop sequence

	Weed management practices (Main)	2013-14 Nutrient Levels (Sub)				2014-15 Nutrient Levels (Sub)			
		F1 50% RDF+ MI	F2 75% RDF+ MI	F3 100%RDF+ MI	Mean	F1 50% RDF+MI MI	F2 75% RDF+ MI	F3 100%RDF+ MI	Mean
T1-	Weedy check	13.1 (171.5)	12.5 (156.4)	12.7 (159.7)	12.8 (163)	13.6 (184.8)	13.1 (173.1)	13.6 (184.4)	13.4 (180.8)
T2-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence	5.3 (27.8)	5.5 (31.6)	5.2 (26.8)	5.3 (28.7)	5.8 (33.8)	5.9 (34.2)	5.7 (32.0)	5.8 (33.3)
T3-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence	5.7 (32.5)	5.4 (28.6)	5.4 (28.3)	5.5 (29.8)	6.6 (43.2)	5.7 (31.8)	5.7 (32.5)	6.0 (35.8)
T4-	Topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	3.3 (10.7)	3.8 (14.3)	3.5 (11.8)	3.6 (12.2)	3.9 (14.9)	3.9 (16.1)	3.9 (14.9)	3.9 (15.3)
T5-	Tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	3.8 (14.3)	4.0 (16.1)	3.5 (11.6)	3.8 (14.0)	3.8 (14.3)	4.0 (15.7)	4.3 (18.3)	4.1 (16.1)
T6-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	2.7 (6.7)	3.0 (9.0)	2.9 (8.2)	2.9 (8.0)	3.2 (9.9)	3.3 (10.7)	3.4 (11.3)	3.3 (10.6)
T7-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	3.2 (9.5)	3.3 (10.7)	3.2 (10.1)	3.2 (10.1)	3.4 (10.8)	3.8 (13.9)	3.7 (13.6)	3.6 (12.8)
T8-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	3.0 (8.5)	3.4 (11.4)	2.9 (8.1)	3.1 (9.4)	3.2 (10.1)	3.4 (11.2)	3.6 (12.7)	3.4 (11.3)
T9-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	3.3 (10.5)	3.5 (12.0)	3.2 (10.0)	3.4 (10.9)	3.6 (12.8)	3.5 (12.1)	3.6 (12.8)	3.6 (12.6)
Mean		4.8 (32.4)	4.9 (32.2)	4.7 (30.5)		5.2 (37.2)	5.2 (35.4)	5.3 (36.9)	
		SEm±	**CD (0.05)**	**CV%**		**SEm±**	**CD (0.05)**	**CV%**	
	Weed management practices (Main)	0.3	0.9	18.4		0.3	1.0	19.1	
	Nutrient levels (Sub)	0.1	NS	10.8		0.1	NS	12.6	
Weed management practices X Nutrient levels		0.5	NS			0.6	NS		

Table 2. Dry weight of total weeds at harvest (g /m^{-2}) in maize as influenced by herbicides and microbial inoculants on *rabi* maize-greengram crop

	Weed management practices (Main)	2013-14 Nutrient Levels (Sub)				2014-15 Nutrient Levels (Sub)			
		F1 50% RDF+ MI	F2 75% RDF+ MI	F3 100%RDF+ MI	Mean	F1 50% RDF+ MI	F2 75% RDF+ MI	F3 100%RDF+ MI	Mean
T1-	Weedy check	16.8 (281.0)	16.6 (277.6)	16.2 (266.0)	16.5 (275.0)	17.5 (305.0)	16.0 (257.0)	15.9 (255.0)	16.5 (272.0)
T2-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence	8.5 (73.5)	9.4 (91.2)	8.5 (74.5)	8.8 (79.7)	9.0 (79.9)	9.3 (87.1)	8.8 (78.8)	9.0 (81.9)
T3-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence	10.3 (108)	9.1 (82.8)	9.7 (93.0)	9.7 (94.5)	10.1 (103)	9.6 (92.9)	9.8 (98.4)	9.9 (98.0)
T4-	Topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	8.1 (65.0)	8.2 (67.5)	7.9 (63.3)	8.1 (65.3)	8.8 (76.3)	8.1 (65.3)	8.0 (65.7)	8.3 (69.1)
T5-	Tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	8.5 (71.9)	7.5 (56.4)	8.6 (74.1)	8.2 (67.5)	8.3 (69.9)	8.2 (67.5)	8.4 (70.1)	8.3 (69.2)
T6-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	5.5 (30.1)	6.4 (41.5)	5.2 (26.4)	5.7 (32.7)	5.6 (32.0)	6.4 (41.7)	5.4 (28.7)	5.8 (34.1)
T7-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	5.8 (33.2)	6.6 (44.5)	5.9 (34.0)	6.1 (37.2)	6.0 (35.4)	6.7 (45.7)	6.0 (35.9)	6.2 (39.0)
T8-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	5.5 (29.9)	6.4 (41.0)	5.7 (31.6)	5.8 (34.2)	5.6 (30.7)	6.6 (43.8)	5.8 (32.7)	6.0 (35.7)
T9-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	6.2 (38.0)	6.8 (45.5)	6.0 (35.8)	6.3 (39.7)	6.4 (40.0)	6.9 (48.0)	6.1 (37.3)	6.5 (41.8)
Mean		8.3 (81.1)	8.6 (83.1)	8.2 (77.6)		8.6 (85.7)	8.7 (83.3)	8.3 (78.1)	
		SEm±	**CD (0.05)**	**CV%**		**SEm±**	**CD (0.05)**	**CV%**	
	Weed management practices (Main)	0.5	1.6	18.7		0.5	1.5	18.1	
	Nutrient levels (Sub)	2.6	NS	16.1		0.2	NS	9.6	
	Weed management practices X Nutrient levels	0.9	NS			0.9	NS		

Note: Data transformed to $\sqrt{x+0.5}$ transformations. Figures in parenthesis are original values

Table 3. Weed control efficiency (%) at 30 DAS in maize as influenced by herbicides and microbial inoculants on rabi maize-greengram crop sequence

	Weed management practices (Main)	2013-14 Nutrient Levels (Sub) F1 50% RDF+MI	F2 75% RDF+MI	F3 100% RDF	Mean	2014-15 Nutrient Levels (Sub) F1 50% RDF+MI	F2 75% RDF+MI	F3 100% RDF	Mean
T1-	Weedy check	-	-	-	-	-	-	-	-
T2-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence	59.7	56.1	58.7	58.2	56.8	55.4	57.8	56.7
T3-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence	57.7	57.6	59.2	58.1	57.3	58.7	53.8	56.6
T4-	Topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	74.6	70.8	70.9	72.1	66.2	68.4	69.0	67.9
T5-	Tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	68.2	67.4	75.1	70.2	67.0	67.3	67.5	67.3
T6-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	75.0	80.2	76.5	77.3	76.7	75.0	74.7	75.5
T7-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* tembotrione@ 110 gai ha^{-1} at 20 DAS as post-emergence	75.7	73.9	73.5	74.4	75.1	70.9	72.7	72.9
T8-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	77.8	73.1	76.5	75.8	76.0	74.1	73.9	74.7
T9-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* tembotrione @110 gai ha^{-1} at 20 DAS	74.5	71.6	74.2	73.4	73.1	73.1	73.7	73.3
	Mean	62.6	61.2	62.7		60.9	60.3	60.3	
		SEm+	CD (0.05)	CV%		SEm+	CD (0.05)	CV%	
Weed management practices (Main)		2.2	6.6	10.6		2.1	6.4	10.6	
Nutrient levels (Sub)		1.1	NS	9.1		0.9	NS	8.1	
Weed management practices X Nutrient levels		3.8	NS			3.7	NS		

Table 4. Weed control efficiency (%) at harvest in maize as influenced by herbicides and microbial inoculants on rabi maize-greengram crop sequence

Weed management practices (Main)	2013-14 Nutrient Levels (Sub)				2014-15 Nutrient Levels (Sub)			
	F1 50% RDF+MI	F2 75% RDF+MI	F3 100% RDF	Mean	F1 50% RDF+MI	F2 75% RDF+MI	F3 100% RDF	Mean
T1- Weedy check	-	-	-	-	-	-	-	-
T2- Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence	49.5	31.2	47.7	42.8	40.6	41.8	45.5	42.6
T3- Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence	39.3	41.4	39.4	40.0	41.9	40.1	33.5	38.5
T4- Topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	45.5	50.4	49.8	48.6	49.8	49.3	44.6	47.9
T5- Tembotrione@110 g ai ha^{-1} at 20 DAS as post-emergence	49.4	54.4	40.5	48.1	52.7	48.5	42.3	47.8
T6- Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	67.5	61.3	63.3	64.0	62.4	58.5	62.1	61.0
T7- Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* tembotrione @110 g ai ha^{-1} at 20 DAS as post-emergence	65.4	56.0	63.4	61.6	57.2	53.6	64.0	58.3
T8- Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	67.1	58.4	64.5	63.3	68.0	55.9	59.2	61.0
T9- Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 g ai ha^{-1} at 20 DAS as post-emergence	63.0	59.1	58.2	60.1	60.8	53.1	59.1	57.7
Mean	49.6	45.8	47.4		48.2	44.5	45.6	
	SEm+	CD (0.05)	CV%		SEm+	CD (0.05)	CV%	
Weed management practices (Main)	2.9	8.7	18.2		2.3	6.8	14.7	
Nutrient levels (Sub)	1.4	NS	16.2		1.3	NS	14.3	
Weed management practices X Nutrient levels	5.0	NS			3.9	NS		

Table 5. Phytotoxic effect of different herbicide treatments on maize crop at various growth stages.

Treatments		2013-14		2014-15	
		7 days aftr application	14 days after application	7 days after application	14 days after application
T1-	Weedy check	-	-	-	-
T2-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence	0	0	0	0
T3-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence	0	0	0	0
T4-	Topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	0	0	0	0
T5-	Tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	0	0	0	0
T6-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	0	0	0	0
T7-	Atrazine@ 1.25 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	0	0	0	0
T8-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* topramezone @ 25 g ai ha^{-1} at 20 DAS as post-emergence	0	0	0	0
T9-	Pendimethalin @ 0.75 kg ai ha^{-1} as pre-emergence *fb* tembotrione@110 gai ha^{-1} at 20 DAS as post-emergence	0	0	0	0

0– No injury
1 – Slight stunting and yellowing of leaves
10 – Complete kill of crop
— Treatment without herbicides

doesn't controlled the later emerged weeds unlike sequential treatments. The highest weed control efficiency at 30 DAS also reported by Srividya *et al.* (2011) and Deshmukh *et al.* (2014).

However, in treatments where only pre-emergence herbicides were applied weed control efficiency (WCE) decreased with time up to harvest as late emerged weeds beside, resulting in reduced weed control efficiency. Similar results were also reported by Sinha *et al.* (2005) and Ramadevi (2013). Similar trend was recorded at harvest (Table 4) in both the years of study. The WCE was in the decreasing order of T6 >T8>T7>T9 during both the years. There was no significant influence of nutrient management treatment on weed control efficiency at any stage of the crop during both the years. Interaction among the treatments was also non significant at any stage. Weed control efficiency gradually reduced from 30 DAS to harvest in all the treatments it is because of the gradual increment in the weed dry matter which reflected in gradual decline in weed control efficiency in all the treatments.

Observations on Maize Crop

Crop Injury Score

The data on phytotoxicity scoring (crop injury score) as effected by different herbicide treatments recorded at 7 and 14 days after application are presented in (Table 5).

The herbicides used in the present investigation didn't cause any phytotoxicity symptoms during both the years of investigation.

It can be concluded that application of atrazine@ 1.25 kg a.i ha^{-1} as pre-emergence followed by topramezone @ 25 g a.i ha^{-1} at 20 DAS as post-emergence (T6) is very effective in reducing the weed dry matter with high weed control efficiency.

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