

Sequential Application of Herbicides for Weed Management in Rice Fallow Maize Under Zero Tillage (*Zea mays L.*)

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ABSTRACT

A field experiment was conducted in farmers' fields in Guntur district on clay loam soils during *Rabi* 2015-16 and 2016-17 to study the effect of sequential application of various pre and post emergence herbicides for weed management in rice fallow maize under zero tillage and their influence on growth and yield of maize. The weed management treatments included hand weeding twice at 15 & 30 DAS, application of pre-emergence herbicides and sequential application of pre and post emergence herbicides. Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb paraquat @ 0.60 kg/ha at 25-30 DAS, atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS reduced the weed dry weight on par with hand weeding treatment, resulting in higher weed control efficiency in these treatments. Hand weeding treatment recorded the highest plant height at 30 & 60 DAS and harvest. Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS also recorded plant height on par with hand weeding treatment at all stages. Hand weeding treatment recorded the highest grain yield (10309 kg/ha). Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS (10016 kg/ha) and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (9766 kg/ha) were on par with hand weeding for grain yield and these three treatments were significantly superior to all other treatments. Even though hand weeding treatment recorded the highest gross income (Rs.154594/ha), net income recorded was high in atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (Rs.78639/ha) and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (Rs.75963/ha).

Key words: Maize, Pre and post emergence herbicides, Zero tillage.

Maize is one of the important crops grown in Andhra Pradesh. It was cultivated in an area of 0.91 lakh hectares during *kharif* and 2.03 lakh hectares during *rabi* in the year 2015-16 (apagris.net.in). Most of the maize area during *rabi* season is in rice fallows under zero tillage. The crop suffers from severe weed competition as it is grown under zero tillage and proper weed management is critical for the success of the crop. Uncontrolled weeds were reported to cause 30 to 100 % yield losses (Rout and Satpathy, 1996). Pre-emergence application of atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha which is widely adopted by farmers presently is able to control weeds satisfactorily up to 20-25 DAS and farmers are facing problem in managing weeds that emerge from 20-25 DAS. Even though satisfactory weed control is achieved with paraquat as directed spray at 25-30 DAS phytotoxicity to the lower 2-3 leaves due to herbicide drift is of concern in crop productivity. The herbicides like 2,4-D sodium salt & 2,4-D amine salt which are recommended for use in maize as selective post emergence herbicides can control only broad leaved weeds and sedges, while grassy weeds remain a problem. To overcome the problems encountered in post emergence use of paraquat and 2,4-D sodium salt

or 2,4-D amine salt, a selective broad spectrum herbicide for use around 25-30 DAS is needed in maize. Hence, the present trial was conducted to evaluate the relative efficacy of some newly released post emergence herbicides in sequential use with pre-emergence herbicides for weed management in rice fallow maize under zero tillage.

MATERIAL AND METHODS

An on farm trial was conducted during *Rabi* 2015-16 & 2016-17 in farmers' fields in Guntur district. The soils in experimental fields were clay loams, neutral in reaction, low in organic carbon, low in available nitrogen, medium to high in available phosphorus and high in available potassium. The average maximum and minimum temperatures during the crop growth period were 34.7 °C and 20.5 °C, respectively. The average relative humidity was 86.2 and 51.5 percent. Mostly dry weather prevailed during the crop growth and crop was given need based irrigation.

The experiment was conducted in Randomized Block Design with seven treatments viz. T₁ - Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE, T₂ - T₁ fb paraquat @ 0.60 kg/ha at 25-30 DAS (Directed Spray), T₃ - T₁ fb 2,4-D amine salt @ 0.58 kg/ha at 25-30

DAS, T₄ - T₁ fb tembotrione @ 0.100 kg/ha at 25-30 DAS, T₅ - T₁ fb topramezone @ 0.025 kg/ha at 25-30 DAS, T₆ - Hand weeding twice at 15 & 30 DAS and T₇ - Weedy check. Each of the farmer field was considered as one replication and all the treatments were replicated thrice. After the kharif rice sheaves were removed from the fields', maize was sown by hand dibbling the seed at a spacing of 60 x 20 cm in rice fallows under zero tillage. Maize was allowed to germinate with residual soil moisture and the crop was grown by adopting the recommended package of practices. Calibrated quantities of herbicides were applied as aqueous spray @ 500 L/ha by knapsack sprayer fitted with flat fan nozzle. Pre-emergence application of herbicide was done within 24 hours of sowing of crop and post-emergence herbicides were sprayed at 25-30 DAS. Observations on weeds were recorded at 30 and 60 DAS using a quadrant of 0.25

m². Data on dry weight was subjected to square root transformation $x + 0.5$ before analyzing statistically. Data on plant height were recorded at 30, 60 DAS and harvest, and yield parameters and yield at harvest.

RESULTS AND DISCUSSION

Weed flora

The weed flora recorded in the experimental field were *Cyperus rotundus* among sedges, *Alternanthera sessilis*, *Trianthema portulacastrum*, *Cleome viscosa*, *Euphorbia geniculata*, *Asteracantha longifolia*, *Amaranthus viridis*, *Digera arvensis*, *Parthenium hysterophorus*, *Ocimum canum*, *Phyllanthus niruri* and *Geniosporum tenuiflorum* among dicots and *Cynodon dactylon*, *Panicum repens*, *Echinochloa colona*, *Dinebra arabica*, *Dactyloctenium aegyptium*, *Leptochloa chinensis* and *Chloris barbata* among grasses.

Table 1: Weed dry weight, weed control efficiency by as influenced by weed management treatments in rice fallow maize (Pooled means of 2015-16 & 2016-17)

Treatments	Weed dry weight (g/m ²) *		Weed control efficiency (%)	
	30 DAS	60 DAS	30 DAS	60 DAS
T1- Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE	7.3 (52.5)	9.1 (82.5)	67	68
T2- T1 fb paraquat @ 0.60 kg/ha at 25-30 DAS (Directed Spray)	5.1 (25.8)	3.2 (10.0)	83	96
T3- T1 fb 2,4-D amine salt @ 0.58 kg/ha at 25-30 DAS	6.2 (37.5)	6.4 (40.8)	76	84
T4- T1 fb tembotrione @ 0.100 kg/ha at 25-30 DAS	4.8 (20.8)	3.6 (12.5)	87	95
T5- T1 fb topramezone @ 0.025 kg/ha at 25-30 DAS	4.7 (21.7)	3.6 (12.5)	86	95
T6- Hand weeding at 15 & 30 DAS	4.6 (20.8)	4.1 (16.7)	86	94
T7- Weedy check	12.5 (154.2)	16.1 (259.2)	-	-
SE m+	0.13	0.19	-	-
C.D. (P=0.05)	0.38	0.61	-	-
C.V. (%)	6.3	5.2	-	-

*Data subjected to square root transformation -SQR(X+0.5) and figures in the parenthesis are the original values.

Table 2: Phytotoxicity and plant height as influenced by weed management treatments in rice fallow maize (Pooled means of 2015-16 & 2016-17)

Treatments	Phytotoxicity				Plant height (cm)		
	PE herbicides		POE herbicides		30 DAS	60 DAS	At harvest
	7 DAS	14 DAS	7 DAS	14 DAS			
T1- Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE	0	0	0	0	54.0	131.5	200.0
T2- T1 fb paraquat @ 0.60 kg/ha at 25-30 DAS (Directed Spray)	0	0	1	1	50.6	132.5	207.0
T3- T1 fb 2,4-D amine salt @ 0.58 kg/ha at 25-30 DAS	0	0	1	0	50.5	145.0	214.0
T4- T1 fb tembotrione @ 0.100 kg/ha at 25-30 DAS	0	0	0	0	53.5	171.0	233.5
T5- T1 fb topramezone @ 0.025 kg/ha at 25-30 DAS	0	0	0	0	54.0	173.5	240.0
T6- Hand weeding at 15 & 30 DAS	0	0	0	0	54.5	176.5	244.5
T7- Weedy check	0	0	0	0	42.0	121	169.5
SE m+	-	-	-	-	0.82	2.42	2.59
C.D. (P=0.05)	-	-	-	-	2.53	7.47	7.98
C.V. (%)	-	-	-	-	3.8	4.8	4.1

Effect on weeds**Weed dry matter**

All the weed control treatments recorded significantly lower weed dry matter than weedy check at 30 and 60 DAS (Table.1). At 30 DAS the lowest weed dry matter (4.6 g/m²) was recorded in hand weeding treatment and was followed by atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS (4.7 g/m²) and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (4.8 g/m²). At 60 DAS the lowest weed dry matter (3.2 g/m²) was recorded in atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb paraquat @ 0.60 kg/ha at 25-30 DAS as directed spray followed by atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS (3.6 g/m²), atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (3.6 g/m²) and hand weeding (4.1 g/m²). These four treatments were significantly superior to all other treatments in reducing the weed dry matter at 60 DAS.

The weed dry matter reduction was significantly superior at 30 and 60 DAS in treatments which received a follow up post emergence spray at 25-30 DAS in supplementation to the pre-emergence spray, indicating the need of post emergence spray to reduce the weed competition to maize crop. The knock down effect of paraquat on weeds could be attributed to the lowest weed dry matter recorded when paraquat

was applied as post emergence spray at 25-30 DAS. Even though treatments which included topramezone and tembotrione as post emergence spray at 25-30 DAS reduced the weed dry matter significantly and were on par with the best treatments, relatively high weed dry matter recorded in these treatments when compared to paraquat can be attributed to gradual chlorophyll bleaching and mortality of weeds. The results on weed parameters recorded in the trial are in agreement with the results reported by Nagalakshmi *et al.*, (2006), Sunitha *et al.*, (2011) and Sonawane *et al.*, (2014).

Effect on maize crop**Crop injury score**

No phytotoxicity symptoms were observed with preemergence herbicide treatments i.e. atrazine @ 1.00 kg/ha + paraquat @ 0.60 kg/ha. The results are in agreement with the results reported by Ishrat *et al.*, (2012).

Post emergence spray of 2,4-D amine salt @ 0.58 kg/ha at 25-30 DAS recorded an injury score of one (0-10 scale) up to seven days after spray with slight reddish brown discolouration. However, the phytotoxic symptoms disappeared by 14th day after spraying. The results were in agreement with the results reported by Umamaheswari *et al.*, (2014). Paraquat @ 0.60 kg/ha at 25-30 DAS as directed spray damaged the lower 2-3 leaves due to herbicide drift.

Table 3: Yield attributes as influenced weed management treatments: (Pooled means of 2015-16 & 2016-17)

Treatments	No. of cobs/plant	No. of kernel rows/cob	No. of kernels/row	No. of kernels/cob
T1- Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE	1	14.3	26.5	381
T2- T1 fb paraquat @ 0.60 kg/ha at 25-30 DAS (Directed Spray)	1	14.7	28.9	424
T3- T1 fb 2,4-D amine salt @ 0.58 kg/ha at 25-30 DAS	1	15.0	30.3	456
T4- T1 fb tembotrione @ 0.100 kg/ha at 25-30 DAS	1	16.0	32.0	512
T5- T1 fb topramezone @ 0.025 kg/ha at 25-30 DAS	1	16.0	32.7	523
T6- Hand weeding at 15 & 30 DAS	1	16.0	32.0	520
T7- Weedy check	1	13.7	22.9	312
SE m+	-	0.35	0.43	15.34
C.D. (P=0.05)	-	1.1	1.35	48.82
C.V. (%)	-	4.3	6.9	5.3

Table 4: Grain yield, stover yield and economics as influenced by weed management treatments in rice fallow maize (Pooled mean data of 2015-16 & 2016-17)

Treatments	Grain yield (kg/ha)	Stover Yield (kg/ha)	Gross income (Rs./ha)	Cost of cultivation (Rs./ha)	Net income	CB ratio
					(Rs./ha)	
T1- Atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE	8065	10807	122499	67125	55374	1.8
T2- T1 fb paraquat @ 0.60 kg/ha at 25-30 DAS (Directed Spray)	8402	11030	127658	68875	58783	1.9
T3- T1 fb 2,4-D amine salt @ 0.58 kg/ha at 25-30 DAS	9063	11620	136284	68875	67409	2
T4- T1 fb tembotrione @ 0.100 kg/ha at 25-30 DAS	9766	12348	149228	71375	77853	2.1
T5- T1 fb topramezone @ 0.025 kg/ha at 25-30 DAS	10016	12445	152825	72375	80450	2.1
T6- Hand weeding at 15 & 30 DAS	10309	12459	154594	83125	71469	1.9
T7- Weedy check	5985	8884	90611	64125	26486	1.4
SE m+	149.7	249.8	-	-	-	-
C.D. (P=0.05)	461.3	769.8	-	-	-	-
C.V. (%)	6.9	5.8	-	-	-	-

Plant height

All the weed control treatments significantly increased the maize plant height at all the three stages of crop growth i.e. 30, 60 DAS and harvest (Table.2). Hand weeding twice at 15 & 30 DAS recorded the highest plant height of 54.5, 176.5 and 244.5 cm at 30, 60 DAS and harvest, respectively. The results for plant height at different stages of crop growth were in conformity with the results reported by Sunitha *et al.* (2011). At 30 DAS atrazine @ 1.00 kg/ha + paraquat @ 0.60 kg/ha PE fb paraquat @ 0.60 kg/ha at 25-30 DAS and atrazine @ 1.00 kg/ha + paraquat @ 0.60 kg/ha PE fb 2,4-D amine salt @ 0.58 kg/ha at 25-30 DAS recorded significantly lower plant height, when compared to other weed control treatments tested in the trial. Scorching of lower leaves due to drift of paraquat and slight discolouration of plants for a week time with 2,4-D amine salt application could be attributed to the reduction in plant height in these treatments. At 60 DAS and harvest atrazine @ 1.00 kg/ha + paraquat @ 0.60 kg/ha PE followed by either tembotrione or topamezone as post emergence spray recorded plant height statistically on par with hand weeding and these three treatments were significantly superior to all other treatments. This could be attributed to the higher weed control achieved in tembotrione or topamezone as follow up post emergence spray and absence of phytotoxicity when compared to paraquat and 2, 4-D amine salt.

Yield attributes

No differences in number of cobs per plant were observed due to weed control treatments in maize (Table.3). All the weed control treatments significantly increased the kernel rows/cob when compared to weedy check (13.7), except atrazine @ 1.00 kg/ha + paraquat @ 0.60 kg/ha PE (14.3), where there was no follow up post emergence spray. The competition exerted by the weeds that germinated around 20-25 DAS could be the reason for the reduction in kernel rows/cob in this treatment. Hand weeding at 15 & 30 DAS, and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE followed by either topamezone @ 0.025 kg/ha or tembotrione @ 0.100 kg/ha at 25-30 DAS recorded a kernel row/cob value of 16 and was the highest. All the weed control treatments increased the number of kernels/ row significantly when compared to weedy check (22.9). Hand weeding at 15 & 30 DAS and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS which recorded 32 kernels/row, were on par with atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topamezone @ 0.025 kg/ha at 25-30 DAS which recorded the highest number of kernels /row (32.7). Kernels /cob

which is a derivative of kernel rows/cob and kernels / row followed the same trend as kernels /cob.

Grain yield

All the weed control treatments significantly increased the grain yield when compared to 5985 kg/ha recorded in weedy check (Table.4). The highest grain yield (10309 kg ha⁻¹) was recorded in hand weeding twice at 15 & 30 DAS (Rao *et al.*, 2009) also reported similar results in zero till maize. Hand weeding treatment was followed by atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topamezone @ 0.025 kg/ha at 25-30 DAS (10016 kg ha⁻¹) and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (9766 kg ha⁻¹). These three treatments were at par amongst them and were significantly superior to all other weed control treatments. Broad spectrum of weed control achieved by topamezone and tembotrione as post emergence herbicides and absence of phytotoxicity due to these herbicides could be attributed as the reasons for the higher grain yield recorded in these treatments. Though paraquat controlled weeds effectively when used as directed spray at 25-30 DAS, the herbicide drift caused injury to the lower leaves of maize crop which resulted in lesser crop height, yield parameters and consequently lesser grain yield. 2,4-D amine salt as follow up post emergence spray could control only broad leaved weeds and sedges but not grasses and the competition exerted on crop by the uncontrolled grasses could be the reason for lower yields recorded in this treatment.

All the weed control treatments significantly increased the stover yield when compared to 8884 kg/ha recorded in weedy check. The highest stover yield (12459 kg ha⁻¹) was recorded in hand weeding twice at 15 & 30 DAS. Hand weeding treatment was followed by atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topamezone @ 0.025 kg/ha at 25-30 DAS (12445 kg ha⁻¹) and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (12348 kg ha⁻¹). These three treatments were at par amongst them and were significantly superior to all other weed control treatments for stover yield. The reasons that could be attributed for the better performance of these treatments can be the same as was discussed in grain yield.

Economics

The highest gross income (Rs.15459 ha⁻¹) was recorded in hand weeding twice at 15 & 30 DAS, and was followed by atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topamezone @ 0.025 kg/ha at 25-30 DAS (Rs.152825 ha⁻¹) and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100

kg/ha at 25-30 DAS (Rs.149228 ha⁻¹) and these treatments were superior to all other weed control treatments tested in the trial.

Even though hand weeding treatment recorded highest gross income, the net income recorded was highest in atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS (Rs.80450 ha⁻¹) with a CB ratio of 2.1 and was followed by atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS (Rs.77853ha⁻¹) also with a CB ratio of 2.1, relegating the hand weeding treatment which recorded a net income of Rs.71461 ha⁻¹ with a CB ratio of 1.9 to the third position. High expenditure incurred towards human labour which increased the cost of cultivation in manual weeding and low cost of weed control in herbicide treatments could be attributed to the inverse of gross and net profit economics in manual and herbicide treatments. The results are in agreement with the results reported by Srinivas and Satyanarayana (1994), and Sunitha *et al.*, (2011).

CONCLUSION

Hence, in the present scenario of high cost of human labour for hand weeding it can be concluded that atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb topramezone @ 0.025 kg/ha at 25-30 DAS and atrazine @ 1.0 kg/ha + paraquat @ 0.60 kg/ha PE fb tembotrione @ 0.100 kg/ha at 25-30 DAS as the most economical measures for weed management in maize in rice fallows under zero tillage.

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