Indian Journal of Agronomy **57** (3): 255–258 (September 2012)

Research Paper

Bio-efficacy and economics of herbicide mixtures in zero-till maize (*Zea mays*) grown after rice (*Oryza sativa*)

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Received : January 2012; Revised accepted : July 2012

ABSTRACT

A field experiment was conducted at Warangal, Andhra Pradesh during 2008-09 and 2009-10 to study the effect of pre-emergence application of herbicides *viz.* atrazine, glyphosate, paraquat and 2, 4-D sodium salt in zero-till maize (*Zea mays* L.) grown after rice (*Oryza sativa* L.) as sole and tank mixtures. The lowest density (no/m^2) and dry weight (g/m^2) of grasses (1.0 and 1.0, respectively), sedges (9.0 and 2.0, respectively) and broad- leaved weeds (1.0 and 0.5, respectively) were observed with the tank mix application of atrazine + glyphosate (0.75 + 0.8 kg/ha) recorded at 30 days after sowing. It was at par with atrazine + paraquat (0.75 + 0.75 kg/ha). The weed control efficiency was high with atrazine + glyphosate (93%) with the lowest weed persistence index (0.003) followed by atrazine + paraquat (84% and 0.021, respectively). Among the herbicides applied alone, glyphosate (1.6 kg/ha) was found to be superior to atrazine (1.5 kg/ha) and paraquat (1.5 kg/ha) for density, dry weight of weeds and weed-control efficiency. The grain yield obtained with tank mix application of atrazine + glyphosate (5.25 t/ha) was 170 and 70% more over weedy check and sole atrazine, respectively. Among all the herbicides and mixtures, atrazine + glyphosate gave the maximum net returns (₹29,350/ha) and benefit : cost ratio (1.71) followed by atrazine + paraquat due to the broad - spectrum control of weeds.

Key words : Bio-efficacy, Herbicide, Rice-fallows, Tank mixtures, Weed control efficiency, Zero tillage

Maize is an important and versatile cereal grown over diverse environment and geographical ranges for human food, feed and fodder for livestock and raw material for industries. Of late, its cultivation has gained popularity under zero tillage in rice fallows in Andhra Pradesh. Adoption of no-till cultivation helps in timeliness of sowing each crop in rotation, and hence leads to increase in productivity (Mohammad, 2009). Zero tillage has certain other advantages like improved soil conditions due to decomposition of crop residue in situ, increase in infiltration rate and reduced cost of field preparation (Singh *et al.,* 2001). Tillage also influences the soil seed bank and growth of weeds (Sarma and Goutam, 2010). Hence, the success of zero tillage is largely dependent on solving the key issue of weed management with economic crop yields (Hari Om *et al.,* 2006).

Maize suffers from severe weed competition and depending upon the intensity, nature, stages and duration of weed infestation, the losses in yield vary from 28-100% (Patel *et al.,* 2006). Manual weeding is often difficult due to inadequate supply of labour in time, higher cost and non workable condition of the field. In such situations, use of herbicides is the obvious choice. When grown in rice - fallows under no-till condition, certain weeds already exist at the time of sowing, and offer competition to the maize crop. Apart from this, regrowth from rice stubbles also suppresses the maize growth. Atrazine has been found to be the most effective pre-emergence herbicide and is widely used in maize (Chopra and Angiras, 2008). Being a pre-emergence herbicide it cannot kill already emerged weeds and arrest the regrowth of rice stubbles. To manage this complex and dynamic weed flora in maize grown after rice, it is essential to evaluate the tank mixtures of pre- and post-emergence herbicides to have a broad-spectrum weed control programme. Hence, the present investigation was carried to find out the effect of different herbicides applied singly or in their tank mixtures on weed growth and productivity of maize in rice fallows sown under zero tillage.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Warangal (18°00' 53.2" N Latitude,

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79° 36' 17.2" Longitude and 275 m Altitude), Andhra Pradesh during the post rainy season (*rabi*) of 2008-09 and 2009-10 in the same site. The soil of the experimental site was clay-loam in texture with EC 0.2 d S/m and pH 8.0, low in available N (275 kg/ha), medium in available P (10.9 kg/ha) and available K (247 kg/ha). The experiment was laid out in randomized block design with three replications and seven treatments (weedy check; glyphosate @1.6 kg a.i./ha; paraquat @1.5 kg a.i./ha; atrazine @ 1.5 kg a.i./ha; atrazine @ 0.75 kg a.i./ha + paraquat @ 0.75 kg a.i./ha; atrazine 0.75 kg a.i./ha + glyphosate @ 0.8 kg a.i./ha; atrazine @ 0.75 kg a.i./ha + 2, 4-D sodium salt @ 0.8 kg a.i./ha). Glyphosate and paraquat were applied three days before sowing maize after the harvest of rice, while atrazine and the herbicide mixtures were sprayed immediately after sowing with a hand operated knapsack sprayer fitted with flat fan nozzle using 500 litres of water/ha.

Rainy season rice (transplanted) was harvested on 29 November and 4 December during 2008 and 2009, respectively. A light irrigation was given five days before harvesting rice to facilitate an uniform germination of succeeding maize. Maize hybrid 'Super 900 M' (Cargil) was hand dibbled @ 1 seed/hill at 4-5 cm depth in standing rice stubbles under no til condition at a spacing of 60 cm × 20 cm on 3 and 8 December during 2008 and 2009, respectively. The gross plot size was 4.8 m × 5.2 m. Recommended doses of fertilizers (120 kg N + 26.2 kg P + 41.7 kg K/ha) was applied. Full dose of P and K along with one-third dose of N was deep placed at 5 cm by the side of the seed at sowing, and the remaining dose of N was applied in two equal split doses at 30 and 60 days after sowing (DAS). All other recommended package of practices were followed for raising the maize crop. Only 3.6 and 8.6 mm of rainfall was received during the crop seasons of first and second year, respectively. The crop was irrigated as and when needed. It was harvested on 8 and 11 April during 2009 and 2010, respectively. Data on density and dry weight of grasses, sedges and broad leaved weeds were recorded at 30 DAS using a quadrant of 1 × 1 m size. The data were subjected to square root transformation $\sqrt{x+1}$ before analyzing statistically. Weed control efficiency (WCE) and Weed Persistence Index (WPI) were calculated based on the total density (no/m^2) and total dry matter (g/m^2) of the weeds. The economic analysis of each treatment was done on the basis of prevailing market price of different inputs and produces, respectively. The market price of atrazine, glyphosate, paraquat and 2, 4-D was: ₹280/kg, 300/litre, 352/litre and 245/kg, respectively. The cost of maize grain and stover was taken as ₹8.2 and 0.5 per kg, respectively.

RESULTS AND DISCUSSION

Weed density and dry weight

Dominant weed flora of the experimental site was: *Echinocloa colona* (L.) Link (13 %), *Dinebra retroflexa* (Vahl) Panzer (11%), *Panicum repens* L. (8 %) and *Leptochloa chinensis* (L.) Nees (7 %) among grasses; *Cyperus rotundus* L. (8 %) among sedges; and *Chrozophora rottleri* (Geisel) A. Juss. Ex Spreng. (11 %), *Trinathema portulocastrum* L. (9 %), *Digera arvensis* (9 %), *Merrimia emerginata* (Burm.F.) Hall. F. (12 %), *Phyllanthus niruri* (3 %) and *Euphorbia hirta* L. (9 %) among broad leaved weeds. Among the already emerged weeds present at the time of sowing of the maize crop; *Chrozophora rottleri* (Geisel) A. Juss. Ex Spreng. followed by *Dinebra retroflexa* (Vahl) Panzer dominated.

Highest density and dry weight of grasses, sedges and broad leaved weeds were found in weedy check (Table 1). All the weed control treatments except the combination of atrazine and 2, 4-D resulted in the significant reduction of the density of grasses recorded at 30 DAS. Tank mix application of atrazine + glyphosate caused the maximum reduction in the grasses, and was at par with atrazine + paraquat mixture. The density of sedges was also lowered significantly by the sole application of herbicides as well as their tank mixtures except the atrazine during 2008-09. Lowest count of sedges was observed with the combined application of atrazine + glyphosate during both the years and it was at par with atrazine + paraquat as well as atrazine + 2, 4-D sodium salt. It was significantly lowered by the tank mixture of glyphosate or paraquat or 2, 4-D sodium salt over the application of atrazine alone. The population of broad leaved weeds recorded at 30 DAS was also significantly reduced by mixing glyphosate or paraquat or 2, 4-D sodium salt with atrazine compared to it's sole application. When applied alone, glyphosate was found to record the least number of broad leaved weeds compared to paraquat and atrazine.

The effect of the weed control treatments on the dry weight of grasses was not significant during 2008-09 (Table 1), while the tank mixed application of glyphosate or paraquat or 2, 4-D sodium salt along with atrazine was found to effectively reduce the dry weight of grasses compared to atrazine applied alone during 2009-10. Among the three herbicides applied alone, application of glyphosate registered the lowest dry matter of sedges. It was also significantly reduced by the combined application of atrazine with glyphosate or paraquat or 2, 4-D sodium salt over the alone application of the atrazine. Similarly, the tank mix application of atrazine + glyphosate led to the lowest dry weight of broad leaved weeds which was followed by the combination of atrazine + paraquat and

Table 1. Effect of herbicides and their mixtures on weed growth in zero-till maize at 30 days after sowing.

Herbicide (kg/ha)	Weed density (no/m²)						Weed dry weight (g/m²)					
	Grasses		Sedges		BLW*		Grasses		Sedges		BLW	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Weedy check	2.00 (3.67)	5.92 (34.33)	11.97 (142.33)	7.27 (52.0)	4.33 (22.67)	6.53 (41.66)	2.40 (6)	4.31 (17.66)	10.40 (109.00)	5.41 (28.33)	3.43 (10.33)	4.93 (23.66)
Glyphosate (1.6)	1.27 (0.67)	3.34 (10.33)	6.60 (43.33)	4.98 (24.0)	1.95 (3.33)	4.15 (16.33)	1.38 (1.00)	2.51 (5.33)	4.66 (21.00)	3.69 (12.66)	1.62 (1.67)	3.11 (8.66)
Paraquat (1.5)	1.61 (2.33)	4.26 (17.33)	7.64 (60.67)	5.33 (27.66)	2.45 (5.67)	4.83 (22.33)	1.48 (1.67)	2.69 (6.33)	5.36 (29.67)	3.91 (15.33)	2.65 (7)	3.53 (11.66)
Atrazine (1.5)	1.61 (2.33)	4.69 (21.0)	11.62 (135)	5.64 (31.33)	3.55 (13.33)	5.33 (27.66)	1.55 (2)	2.88 (7.33)	9.09 (83.33)	4.19 (16.66)	3.09 (8)	4.00 (15.33)
Atrazine (0.75) + paraquat (0.75)	1.00 (0)	1.51 (1.33)	5.84 (36.67)	2.92 (8.0)	1.14 (0.33)	2.16 (3.66)	1.00 (0)	1.69 (2.00)	3.71 (14.33)	2.23 (4.0)	1.33 (1)	1.73 (2.0)
Atrazine(0.75) + glyphosate(0.8)	1.00 (0)	1.41 (1.0)	3.68 (13.00)	2.31 (4.33)	1.00 (0)	1.73 (2.00)	1.00 (0)	1.41 (1.00)	2.22 (4.00)	1.82 (2.33)	1.00 (0)	1.41 (1.0)
Atrazine (0.75) + 2, 4-D sodium salt(0.8)	1.80 (2.33)	2.51 (5.33)	6.45 (40.60)	3.10 (8.66)	1.24 (0.67)	2.63 (6.00)	1.51 (1.33)	1.91 (2.66)	5.53 (29.58)	2.49 (5.33)	1.14 (0.33)	2.07 (3.33)
SEm±	0.41	0.24	1.38	0.35	0.74	0.19	0.42	0.17	1.21	0.33	0.51	0.27
CD (P=0.05)	NS	0.74	4.25	1.08	2.28	0.59	NS	0.52	3.73	1.02	1.57	0.83

Data subjected to square-root ($\sqrt{X+1}$) transformation; figures in parentheses are original values

* Broad-leaved weeds

atrazine + 2, 4-D sodium salt and they were at par with each other. Alone application of glyphosate or atrazine or paraquat was found to be at par with each other but was ineffective compared to the application of mixtures.

Weed control efficiency and weed persistence index

Among all the weed management practices, the weed-control efficiency (%) recorded at 30 DAS was higher with atrazine + glyphosate (93) followed by atrazine + paraquat (84). The efficiency of the tank mixed application of glyphosate or paraquat along with atrazine substantially increased over the alone application of atrazine (Table 2). Weed persistence index (WPI) recorded with atrazine + glyphosate was the lowest during both the years of study (Table 2), followed by atrazine + paraquat. Among the three herbicides studied alone, glyphosate registered maximum WCE and minimum WPI compared to atrazine or paraquat.

Yield attributes and yield

All the herbicides alone or as tank mixtures recorded significantly higher values of cob length, grains/cob and 100-grain weight over weedy check except the sole atrazine (Table 2). The tank mixture of atrazine + glyphosate registered 74% more grains/cob than weedy check, which was at par with atrazine + paraquat with respect to all the yield attributes. Higher levels of these yield parameters could be attributed to low competition stress and clean cultivation. Among the three herbicides applied alone; glyphosate was found to be superior to atrazine in terms of cob length, number of grains/cob and 100-grain weight due to better control of weeds. Atrazine + glyphosate recorded 170 % higher grain yield than weedy check due to broad spectrum control of weeds (Table 2). It may be due to higher weed control efficiency, which provided a favourable environment for growth and development of the crop. The grain yield obtained with the combination of atrazine + glyphosate or paraquat was 72 and 58% more than the sole application of atrazine. Singh *et al.* (2007) and Srividya *et al.* (2011) reported that an additional spray of paraquat at three weeks after sowing along with the pre-emergence application of atrazine markedly increased the weed control efficiency as well as yield of maize under no-till condition. Stover yield recorded in all the weed control treatments was significantly higher than weedy check. The highest stover yield was recorded in atrazine + glyphosate which was at par with atrazine + paraquat and superior to the rest of the treatments.

Economics

All herbicidal treatments recorded higher net returns and benefit: cost ratio over weedy check (Table 2). Among

Table 2. Effect of herbicides and their mixtures on weed control efficiency, weed persistence index, yield attributes, yield and economics in zero till maize grown after rice (Pooled data of two years)

Herbicide (kg/ha)	Weed control efficiency (%)	Weed persistence index	Cob length (cm)	Grains/cob	1,000 - grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	B:C ratio
Weedy check	-	-	14.7	220	31.3	1.94	3.55	15.58	2.07	0.13
Glyphosate (1.6)	64.10	0.106	15.8	345	32.6	4.33	5.94	17.30	21.17	1.22
Paraquat (1.5)	49.82	0.201	15.7	328	32.5	4.09	5.70	17.15	19.22	1.11
Atrazine (1.5)	21.82	0.527	15.1	312	31.9	3.06	4.68	16.78	10.69	0.64
Atrazine (0.75) + paraquat (0.75)	83.67	0.021	15.9	368	32.1	4.85	6.47	17.05	26.00	1.52
Atrazine(0.75) + glyphosate (0.8)	93.00	0.003	16.1	382	32.3	5.25	6.86	17.12	29.35	1.71
Atrazine (0.75) + 2, 4-D sodium salt (0.8)	56.33	0.109	15.5	334	32.4	3.99	5.61	16.76	18.78	1.12
SEm±	-	-	0.20	12.5	0.19	0.18	0.18	-	-	-
CD (P=0.05)	-	-	0.64	39.1	0.58	0.55	0.55	-	-	-

Price (₹/kg): Grain = 8.2, Stover = 0.5
Spraying charges of herbicides/ha = ₹500

the herbicides and mixtures, atrazine + glyphosate gave the maximum net returns due to excellent control of grasses, sedges and broad leaved weeds with out any adverse effect on crop growth. Tank mixture of atrazine + paraquat was found to be the next best treatment. Lower net returns and benefit: cost ratio were recorded with sole application of the herbicides i.e., atrazine or glyphosate or paraquat due to poor control of weeds. Mixing 2, 4-D with atrazine was also found to be uneconomical with lower net returns and benefit cost ratio.

The study suggests that pre emergence application of tank mixed atrazine (0.75) + glyphosate (0.8 kg/ha) followed by atrazine (0.75) + paraquat (0.75 kg/ha) were the most remunerative and effective herbicide mixtures for controlling the complex weed flora in zero-till maize grown in rice fallows of Telangana region in Andhra Pradesh.

REFERENCES

Chopra, P. and Angiras, N.N. 2008. Effect of tillage and weed management on productivity and nutrient uptake of maize (*Zea mays*). *Indian Journal of Agronomy* **53**(1): 66-69.

Hari Om, Nandal, D.P., Dhiman, S.D. and Ram, Mangat. 2006. Weed control in wheat (*Triticum aestivum*) sown by zero tillage. *Indian Journal of Agronomy* **51**(3): 202-05.

Mohammad, S. 2009. Modern concepts of agriculture research: Ripples and options for conservation agriculture and resource use efficiency. *Indian Journal of Agronomy* **54**(2): 149-58.

Patel, V.J., Upadhyay, P.N., Patel, J.B. and Meisuriya, M.I. 2006. Effect of herbicide mixture on weeds in *kharif* maize (*Zea mays* L.) under middle Gujarat conditions. *Indian Journal of Weed Science* **38**(1 and 2): 54-57.

Sarma, C.K. and Gautam, R.C. 2010. Weed growth, yield and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed control method. *Indian Journal of Agronomy* **55**(4) : 299-03.

Singh, R., Sharma, A.R. and Behera, U.K. 2007. Tillage and crop establishment practices for improving productivity of maize (*Zea mays*) under different weed control methods. *Indian Journal of Agricultural Sciences* **77**(11): 731-37.

Singh, Ravigopal, Singh, V.P., Singh, Govindra and Yadav, S.K. 2001. Weed management in zero-till wheat in rice-wheat cropping system. *Indian Journal of Weed Science* **33**(3 and 4): 65-99.

Srividya, S., Chandarasekhar, K. and Veeraraghavaiah, R. 2011. Effect of tillage and herbicide use on weed management in maize (*Zea mays* L.). *The Andhra Agricultural Journal* **58**(2): 123-26.