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Influence of Integrated Weed Management Practices on Weed Dynamics, Productivity and Nutrient Uptake of Rabi Maize (*Zea mays* L.)

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A B S T R A C T

A field experiment was carried out during the *rabi* season of 2011-12 and 2012-13 at Bihar Agricultural University, Sabour (Bihar) to assess the effect of integrated weed management practices on weed dynamics, productivity and nutrient uptake of maize (*Zea mays* L.). Results revealed that weed management practices had positive influence on growth, yield attributes, yields and nutrient uptake of maize. Significantly lower weed density, weed dry weight and weed control efficiency (WCE %) were recorded in zero tillage (ZT) compared with conventional tillage (CT). Among the chemical weed control practices, ZT-Glyphosate pre-plant followed by Atrazine + Halosulfuran (1.0 kg + 90 g *a.i.*/ha) as post-em. and ZT-Glyphosate pre-plant followed by Topramezone +Atrazine @ (40 ml + 500 g *a.i.*/ha) as post-em. proved equally effective in increasing the growth and yield attributes, yields, economic advantage and recorded higher N, P and K uptake by maize, 22.7 to 24, 37.2 to 38.6 and 20.6 to 20.8%, respectively compared with unweeded check. The maximum grain yield of (8.92 t/ha) was recorded under 2 HW at 15 and 30 DAS and performed statistically at par in grain yield obtained with ZT-Glyphosate pre-plant followed by Atrazine+Halosulfuran (1.0 kg+90 g *a.i.*/ha) as post-em. (8.90 t/ha), CT-Acetochlor @ (3.0 lit. *a.i.*/ha) as pre-em. (8.57 t/ha), ZT-Glyphosate pre-plant followed by Topramezone+Atrazine (40 ml + 500 g *a.i.* /ha) as post-em. (8.45 t/ha) and these grain yield was significantly superior to the rest of weed management practices. The highest net return Rs.55767/ha was noted in ZT-Glyphosate pre-plant followed by Atrazine+ Halosulfuran (1.0 kg + 90 g *a.i.*/ha) as post-em. and the maximum B: C ratio of 1.98 was recorded under ZT-Glyphosate pre-plant followed by Maize+ Lathyrus as intercrop.

Introduction

Maize is an important crop for food, feed and fodder for livestock, raw materials for industries and nutritional security for the many sectors in the country (Kumar *et al.*, 2016 a, b). Strong market demand and resilience to the climate changes have increased area and production of maize in the country over the past decade (Kumar *et al.*, 2015a, b, c). Maize is considered as the third most important food crop among the cereals in India and contributes to the nearly 9% of the national food basket (Jeet *et al.*, 2016; Jeet *et al.,* 2013 and Jeet *et al.,* 2014). Maize is being grown in an area of 8.55 m ha with an average productivity of 2.5 t/ ha, contributes to more than half of the coarse cereal production of the country (Kumar and Bohra, 2014; Kumar *et al.,* 2017). In Bihar, total area under this crop is 6.98 lakhs ha, producing 21.11 m tons and with average productivity of 3025 kg/ha (Department of Agriculture, Bihar, 2012-13). The area under *rabi* maize is gradually increasing in Bihar due to growing market demand by feed and starch industry and increase in minimum support price from Rs.540/q in 2006-07 to Rs. 1175/q in 2012-13 led to make as more competitive crop and encouraged the farmers to grow the maize to a larger extent (Kumar 2015a,b; Prakash *et al.,* 2017; Sarkar *et al.,* 2016).

Tillage is a critical practice in crop production as it provides favourable condition for crop growth and development (Mishra *et al.,* 2016, 2017). It is reported that normal tillage may not be required for getting the optimum crop yield (Carter *et al.,* 2002; Neupane *et al.,* 2011 a, b, c). Thus, conservation tillage practices are gaining importance in recent year in maize. *Rabi* maize suffers from severe weed competition and depending upon intensity, nature, stages and duration of weed infestation causes yield losses varying from 28-100% (Patel *et al.,* 2006 and Singh *et al.,* 2009 a, b).

Manual weeding is often difficult due to inadequate supply of labour in proper time, higher cost and non-workable condition of the labour (Rana *et al.,* 2013). In such situation, use of herbicides is an obvious choice. Adoption of zero tillage cultivation helps in timeliness of sowing each crop in rotation and hence leads to increase in productivity and profitability of the maize growers farming community engaged. Zero tillage has certain advantage like improved soil conditions due to decomposition of crop residue in situ, it increase in infiltration rate, less soil compaction and reduced the cost of seed bed preparation (Singh *et al.,* 2001 and Singh *et al.,* 2010). Weed infestation is one of the major constraints for low yield of maize as weeds compete with crop plants for light, space and nutrients. It is reported that weed alone depletes 30-40% of applied nutrients from the soil (Mundra *et al.,* 2003).

The losses caused by weeds exceed from any other category of agricultural pests (Sharma and Behera, 2009). Under such a situation, the concept of zero tillage offers ample scope for combating weeds without any threat to eco-system. To realize the maximum benefit of applied inputs and high yields, control of weeds is inevitable. Therefore, growing intercrops in widely spaced maize crop not only reduce the intensity of weeds but also give additional yield (Hussain *et al.,* 2003). Hence, keeping the above fact in mind, the present investigation was undertaken.

Materials and Methods

A field experiment was carried out during *rabi* seasons of 2011-12 and 2012-13 at Bihar Agricultural University, Sabour (25^{O}04’ N Latitude, 87^{O}04’ E Longitude and 37.19 m altitude) in a randomized block design with three replications. The experimental soil was sandy-loam in texture with neutral in reaction (pH 7.1). Experimental plot was having the low in organic carbon (0.57%), available nitrogen (270.6 kg/ha) and potassium (289.13 kg/ha) but medium in available phosphorus (15.34 kg/ha).

In conventional tilled treatment three ploughing by cultivator followed by planking was done. Under zero tilled condition, crop was sown directly and glyphosate @ 1.0 lit a.i/ha was sprayed one week prior to crop sown to kill the existing weeds flora. The treatments comprised 10 weed management practices i.e. Un-weeded check, conventional tillage-HW at 15 and 30 DAS, conventional tillage-Maize + Lathyrus as intercrop, conventional tillage - Atrazine@ 1.5kg a.i/ha as pre-em., conventional tillage-Acetochlor @ (3.0 lit. a.i/ha) as pre-em, conventional Tillage-2,4-D @ 400 ml a.i/ha as post-em, conventional tillage-Topramezone+Atrazine @ (40 ml + 500 g a.i/ha) as post-em, zero tillage-Glyphosate Pre-plant followed by Atrazine +Halosulfuran(1.0 kg+90 g a.i/ha) as Post-em, Zero tillage -Glyphosate Pre plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) as Post-em, zero tillage - Glyphosate Pre-plant followed by Maize+ Lathyrus as intercrop, maize cv. DHM-117 was sown on 11^{th} Nov and 16^{th} Nov in 2011 and 2012, respectively. In maize, one - third of N was applied as basal along with full dose of P and K and the remaining nitrogen were applied in two splits only in rows of maize each at knee high and pre-taselling stage. Pre-emergence and post-emergence herbicides were applied at next day and 30 DAS, respectively using water volume of 700 liters/ha.

The rainfalls received during the crop season of the respective years were 12 mm and 20.1 mm. The data on weed density, weed dry weight and weed control efficiency were recorded at different stages of crop. Weed control efficiency (WCE) was calculated by using the standard procedures. Plant height and yield attributes of maize were collected at harvest from random selected five plants.

The grain and stover yields of maize were recorded in kg and converted into t/ha. Gross returns, net returns and benefit:cost ratio were worked out on the basis of prevailing market price of inputs and produce. The field data obtained for 2 years were pooled and statistically analyzed using the F-test (Gomez and Gomez, 1984). Test of significance of the treatment differences were done on the basis of t-test. The significant difference between treatment means were compared with critical differences at 5% levels of probability.

Results and Discussion

Weed dynamics

Dominant weed species present in the experimental site were *Cynodon dactylon* L., *Cyperus rotundus* L., *Amaranthus viridis* L., *Anagalis arvensis* L., *Argemone maxicana* L., *Chenopodium album* L., *Melilotus indica* L., *Oxalis corniculzta* L., *Convolvulus arvensis* L., *Rumex retroflex* L. and *Parthenium hysterophorus* L. The density and dry weight of weeds were significantly affected due to different tillage systems. There was reduction in total weed density in zero tillage compared with conventional tillage. Higher weed density was recorded in conventional tillage may be due to better tilth and exposure of weed seeds to the upper soil layers (Singh *et al.,* 2001). The density and dry weight of all the grasses weeds was recorded the maximum in conventional tillage system. All the herbicides treatments reduced the density and dry-weight of weeds over the weedy check. The minimum density and dry weight of all major weed species were significantly reduce due to application of 2 HW at 15 and 30 DAS, ZT-Glyphosate pre-plant followed by Atrazine +Halosulfuran (1.0 kg+90 g a.i/ha) as post- em. and ZT-Glyphosate pre-plant followed by Topramezone+Atrazine (40 ml + 500 g *a.i.*/ha) as post-em.

Growth and yield attributes

Different weed management practices significantly influenced the growth and yield attributes of maize (Table 1). Two hand weeding at 15 and 30 DAS being statistically at par with weed control treatments i.e. ZT-Glyphosate Pre-Plant followed by Atrazine+ Halosulfuran (1.0 kg+90 g *a.i*./ha) as post-em. and ZT-Glyphosate pre-plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) as post-em recorded significantly higher values of growth and yield attributes and yield as compared to the rest of the weed control treatments. This might be probably due to the creation of modified micro-climate in turns of physical environment for mechanical manipulation of soil and lower crop-weed competition under two hand weeding led to better yield component and thus resulted in higher yield (Mundra *et al.,* 2003). The yield advantage due to different weed management practices over weedy check were mainly attributed for better yield attributing parameters and comparatively less weed population and weed biomass along with higher weed control efficiency. The results are in conformity with those reported in maize by Singh *et al.,* (2005).

Yields

Different weed management practices significantly influenced the maize yield and maize equivalent yield. Hand weeding at 15 and 30 DAS being statistically at par with ZT-Glyphosate pre-plant followed by Atrazine+Halosulfuran (1.0 kg + 90 g *a.i.*/ha) as post-em and ZT-Glyphosate pre-plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) as Post-em recorded significantly higher grain yield to the rest of the weed control treatments. Intercropping systems significantly reduced weed population and weed dry weight than sole cropping (Table 2).

Intercropping with Maize + Lathyrus was recorded the more effective in suppressing weeds and hence the less weed density and weed dry weight was noticed. The reduction in weed density and weed dry biomass in intercropping systems may be attributed to shading effect and competition stress created by the canopy of more number of crop plants in a unit area having suppressive effect on associated weed, thus preventing the weeds to attain full growth. All weed control treatments significantly reduced the density and weed dry weight compared with weedy check. Hand weeding at 15 and 30 DAS proved the most effective in reducing the population of weeds and weed dry weight. The performance of hand weeding twice, ZT-Glyphosate pre-plant followed by Atrazine+ Halosulfuran (1.0 kg + 90 g a.i./ha) as post-em, CT-Acetochlor @ (3.0 lit a.i/ha) as Pre-em and ZT-Glyphosate pre plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) as post-em were statistically alike and inturn were significantly superior to the remaining weed control treatments (Table 2).

Significant reduction of weed density and weed dry biomass under hand weeding and mixed herbicides, Atrazine+Halosulfuran, Topramezone+Atrazine might be due to fact that these weed control treatment gave almost season-long control of weeds obviously due to their persistence in soil for a sufficiently long time and broad spectrum control of weeds. The results are in conformity with those reported by Ram *et al.,* (2003). All the weed control methods resulted significant increase in grain and biological yield over weedy check.

Nutrient uptake

Among chemical weed control methods, ZT-Glyphosate Pre-Plant followed by Atrazine+ Halosulfuran (1.0 kg + 90 g a.i./ha) as Post-em and ZT-Glyphosate Pre plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) as Post-em were statistically alike and higher N,P and K uptake by the maize crop 22.7 to 24.0, 37.2 to 38.6 and 20.6 to 20.8%, respectively compared with unweeded check (Table 3). The effective weed control by these two treatments provided a competition free environment and improved physical, biological condition of the soil, which led to increased growth of crop and thereby increase in nutrient uptake by increasing the grain yield of maize.

Table.1 Effect of weed management practices on growth and yield attributes of *rabi* maize (Pooled data of two years)

Treatments	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Grain row/r cob (No.)	Grain/ row (No.)	Cob weight (g)	100-grains weight (g)
Un-weeded check.	140.8	12.6	4.4	13	36	211	31
CT-HW at 15 and 30 DAS	158.2	17.7	5.5	15	43	217	37
CT-Maize+ lathyrus as intercrop	146.1	13.9	4.6	13	39	213	34
CT-Atrazine@1.5kg a.i/ha as pre-em	148.9	14.8	4.6	14	40	214	35
CT-Acetochlor @ 3.0 lit a.i /ha as pre-em	151.3	16.7	4.9	14	42	215	36
CT-2,4-D @ 400 ml a.i/ha as post-em	149.8	15.2	4.7	14	40	214	35
CT- Topramezone+Atrazine (40 ml + 500 g a.i/ha) as post-em	150.4	15.5	4.7	14	40	214	35
ZT-Glyphosate pre plant followed by Atrazine +Halosulfuron(1.0 kg+90 g a.i/ha) as post-em	156.9	17.5	5.4	15	42	216	36
ZT-Glyphosate pre plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) post-em.	151.6	16.6	4.9	14	41	215	35
ZT-Glyphosate pre plant followed by Maize + Lathyrus as intercrop.	149.3	14.8	4.7	14	39	213	35
SEm±	0.85	0.23	0.18	0.62	0.79	0.22	0.94
CD (P=0.05)	1.9	0.48	0.37	1.3	1.68	0.46	1.95

Table.2 Effect of weed management practices on weed dynamics of rabi maize (Pooled data of two years)

Treatment	Weed count (No./m^2)		Weed dry wt (gm/m^2)		WCE (%) at 40 DAS
	20 DAS	40 DAS	20 DAS	40 DAS	
Un-weeded check.	210	286	54	107	-
CT-HW at 15 and 30 DAS	19	25	8	11	89.7
CT-Maize+ lathyrus as intercrop	86	106	30	62	42.0
CT-Atrazine@1.5kg a.i/ha as pre-em	53	181	28	75	30.0
CT-Acetochlor @ 3.0 lit a.i /ha as pre-em	12	35	4	13	87.8
CT-2,4-D @ 400 ml a.i/ha as post-em	106	83	30	22	79.4
CT- Topramezone+Atrazine (40 ml + 500 g a.i/ha) as post-em	110	123	22	31	71.0
ZT-Glyphosate pre plant followed by Atrazine +Halosulfuron(1.0 kg+90 g a.i/ha) as post-em	15	31	9	21	80.3
ZT-Glyphosate pre plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) post-em.	14	41	6	17	84.1
ZT-Glyphosate pre plant followed by Maize + Lathyrus as intercrop.	39	95	13	30	72.0
SEm±	6.1	6.3	2.2	4.3	-
CD (P=0.05)	12.4	13.5	4.7	9.1	-

Table.3 Effect of weed management practices on yield, economics and nutrient uptake and nutrient uptake of *rabi* maize (Pooled data of two years)

Treatments	Grain yield (t/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio (₹)	Nutrient uptake (kg/ha)		
					N	P	K
Un-weeded check.	6.60	66000	37980	1.35	168.2	28.3	115.3
CT-HW at 15 and 30 DAS	8.92	89200	52540	1.43	224.7	46.8	146.2
CT-Maize+ Lathyrus as intercrop	7.73 (8.11)	77300 (81100)	47648 (51448)	1.60 (1.73)	199.5	42.6	142.3
CT-Atrazine@1.5kg a.i/ha as pre-em	8.16	81600	52188	1.77	214.0	42.3	144.2
CT-Acetochlor @ 3.0 lit a.i /ha as pre-em	8.57	85700	55748	1.86	215.2	44.5	144.9
CT-2,4-D @ 400 ml a.i/ha as post-em	8.39	83900	55308	1.93	214.3	43.2	144.7
CT- Topramezone+Atrazine (40 ml + 500 g a.i/ha) as post-em	8.37	83700	50956	1.55	214.1	43.0	143.5
ZT-Glyphosate pre plant followed by Atrazine +Halosulfuron (1.0 kg+90 g a.i/ha) as post-em	8.90	89000	55767	1.67	221.4	46.1	145.6
ZT-Glyphosate pre plant followed by Topramezone+Atrazine (40 ml + 500 g a.i/ha) post-em	8.45	84500	55756	1.93	217.6	45.1	145.3
ZT-Glyphosate pre plant followed by Maize + Lathyrus as intercrop.	7.66(8.06)	76600 (80600)	50948 (54948)	1.98 (2.14)	209	42.3	142.0
SEm±	0.042	4710	1617	0.13	5.6	1.3	3.2
CD (P=0.05)	0.085	9896	3398	0.29	11.2	2.6	6.8

Data in parenthesis are maize equivalent yield and their gross return, net return and B: C ratio

Economics

Higher gross return, net return and B:C ratio was recorded in zero-tillage as compared to conventional tillage (Table 3). Among the treatments, ZT-Glyphosate pre-plant followed by Atrazine+ Halosulfuran (1.0 kg + 90 g a.i./ha) as post-em and ZT-Glyphosate pre plant followed by Topramezone +Atrazine (40 ml + 500 g a.i/ha) Post-em had the higher net return and B:C ratio (Rs.55767/ha and Rs,55756/ha)(Rs.1.93) and ZT-Glyphosate Pre-plant followed by Maize+ Lathyrus as intercrop B:C ratio (1.98) as compared to rest of weed control methods. All weed management practices gave more net return and benefit: cost ratio than weedy check (Table 3). Thus, it may be concluded that Zero tillage (ZT)-Glyphosate Pre-plant followed by Topramezone +Atrazine (40 ml + 500 g a.i/ha) post-em, ZT-Glyphosate pre-plant followed by Atrazine+ Halosulfuran (1.0 kg + 90 g a.i./ha) as post-em and 2 HW at 15 and 30 DAS appeared to be the best in reducing weed growth and producing maximum grain yield in maize.

Possible impact

In the future, it will be difficult to find or afford labour for hand weeding. Therefore, there is a need to evaluate different pre, post herbicides and tank mixture of post herbicides, so that hand weeding could be eliminated. In addition, there is a need to integrate the different weed management strategies to achieve the effective and sustainable weed control in maize for strengthening its production and sustaining the food security in the country. There is also a possibility of reducing herbicide dosage through the integration of different weed management strategies. Hence, these two herbicides combination may be recommended in maize for controlling the predominant weeds flora.

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