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RESEARCH ARTICLE

Productivity and profitability of zero till winter maize as influenced by integrated weed management practices

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ABSTRACT

A field experiment was carried out during the winter season of 2016-17 and 2017-18 to evaluate the effect of integrated weed management in maize under zero tillage conditions on weed control efficiency, growth, yield and economics of maize. The experiment comprised ten integrated weed management treatments, *viz.* glyphosate 1.6 kg/ha 3 days before sowing (DBS); glyphosate 1.6 kg/ha 3 DBS followed by (*fb*) power weeder at 25 days after sowing (DAS); pre-emergence (PE) application of halosulfuron 67.5 g/ha; halosulfuron 67.5 g/ha PE *fb* power weeder at 25 DAS; atrazine 1.5 kg/ha PE; atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS; imazethapyr 100 g/ha PE; imazethapyr 100 g/ha PE + post-emergence (PoE) application of fenoxaprop 100 g/ha at 20-25 DAS; weed free (3 hand weeding at 20, 40, 60 DAS) and weedy check. The weed-free treatment as well as atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS recorded maximum weed control efficiency, maize growth and yield during both years. However, the highest net returns ₹ 99887 and ₹ 100333/ha and B: C ratio 2.66 and 2.78 were obtained with atrazine PE *fb* power weeder, respectively. Thus, integrated weed management using atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS improved the weed index, weed control efficiency, growth attributes, yield as well and profitability of winter maize under zero tillage conditions.

Keywords: Integrated weed management, Maize, Power weeder, Weed control efficiency, Zero tillage

INTRODUCTION

Maize is one of the most important cereal crops in the world agriculture economy as both food for humans and animals. It is the third most important cereal crop of India after rice and wheat and is cultivated in an area of 8.69 million ha with a production of 21.81 million tonnes and a productivity of 2509 kg/ha (Kumar *et al*. 2016). In the 2017-18 cropping season, winter maize in Bihar was grown in an area of 26 lakh hectares with annual production of about 64 lakh metric tonnes and productivity of 6135 kg/ha (Anonymous 2017) indicating the acceptance of winter maize technology by farmers of Bihar. However, weeds are the most severe constraints and pose major problems in maize production by diminishing the quantity as well as quality (Yakadri *et al*. 2015, Ramesh *et al*. 2017). Yield loss due to weed in maize varies from 28 to 93%, depending on the type of weed flora and intensity and duration of crop-weed competition. Pre- and post-emergence application of herbicides may lead to cost-effective control of the weeds right from the start which otherwise may not be possible by manual weeding. No-tillage maize production conserves soil and water and reduces capital investment in machinery for land preparation and intercultural operations, but most importantly to many producers, no-tillage can also improve maize yields (Singh *et al*. 2012). This practice also leaves crop residue on the surface after planting, which promotes infiltration of water (Kiran and Rao 2014). Hence, timely weed management plays an important role in increasing productivity of maize. Herbicides are being widely used to control weeds but sole dependency on herbicides may cause development of herbicide-resistant weeds along with contamination of herbicides in food chain and causing environmental hazards (Arvadiya *et al*. 2012). The integration of chemical and mechanical weed management strategies provides better weed control than herbicide alone (Mishra and Singh 2012). Therefore, emphasis should be given to increase maize yield through the adoption of technically effective and feasible, economically viable, socially acceptable and environmentally sound proper weed management practices. Hence, this study was undertaken to study the effect of integrated weed management on weed dynamics, growth, yield and economics of winter maize under zero tillage condition.

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MATERIALS AND METHODS

The experiment was carried out at Crop research farm of Borlaug Institute for South Asia (BISA), Pusa, Samastipur (Bihar), India during winter season of 2016-17 and 2017-18. BISA farm is located in the northern part of Samastipur district (25° 57' N latitude and 85° 40' E longitude). It is situated at an elevation of about 52 m above mean sea level. The soil of the experimental site was clay loam in texture with pH of 8.4, electrical conductivity of 0.26 (dS/m), medium in organic carbon (0.55%), low in available N (188 kg N/ha), high in available P (16.71 kg/ha) and medium in available K (121.25 kg/ha). The experiment was laid out in a randomised block design with 3 replications. The treatment details of the experimental plot consisted : glyphosate 1.6 kg/ha 3 days before sowing (DBS); glyphosate 1.6 kg/ha 3 DBS followed by (*fb*) power weeder at 25 DAS; pre-emergence (PE) application of halosulfuron 67.5 g/ha; halosulfuron 67.5 g/ha PE followed by (*fb*) power weeder at 25 days after sowing (DAS); atrazine 1.5 kg/ha PE; atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS; imazethapyr 100g/ha PE; imazethapyr 100g/ha PE + post-emergence (PoE) application of fenoxaprop 100g/ha (20-25 DAS); weed free (3 hand weedings at 20, 40 and 60 DAS) and weedy check.

Maize variety *Shaktiman-3* was sown on 18th November 2016 and 14th November of 2017 with row to row and plant to plant spacing of 60 and 20 cm, respectively. Seed rate of maize was 20 kg/ha and the net plot size was 4.6 × 2.4 m. The uniform dose of fertilizer used was 120:60:60 (N: P: K) kg/ha. The sources of fertilizer used for N, P and K were urea, diammonium phosphate and muriate of potash respectively. Full dose of P, K and 50% of N were applied as basal to maize. The rest of the nitrogen was top dressed in two splits *i.e.* first split of N was 30 kg/ha applied at 20 DAS and the remaining 30 kg/ha of N was given at 35 DAS. The khurpi (hand operated spade) is one of the most common tool which were used in the field for weeding. The power weeder being an efficient machine for intercultural operation in row crops that was used as per the treatment. Stock solution of respective quantity of each herbicide were prepared separately, by dissolving in half a litre of water and made up to required quantity of spray solution (spray volume) by adding water. The spray solution was dissolved in water as per requirement (600 L/ha) and applied with knapsack sprayer by using the flat fan nozzle. All the necessary cultural practices were carried out uniformly during the crop season. To record weed biomass, weeds were cut at ground level, washed with tap water, sun-dried in hot air oven at 70 °C for 48 hrs and then weighed. For the statistical analysis, weed density and biomass were converted to 1 m^2 and imposed square root transformation to normalize their distribution. Further weed control efficiency (WCE) was calculated by using the formulae given by Mani *et al.* (1973). The grain yield was taken from 1 m^2 area in the centre of each plot and expressed in t/ha at 14% moisture content. Economic analysis was done as per the prevailing cost of inputs and selling price of output in the concerned year. Statistical analysis was done by adopting appropriate method of Analysis of Variance (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Weed biomass, weed control efficiency and weed index in zero till winter maize

In both years, weed management treatments significantly reduced the weed biomass and increased the weed control efficiency. The lowest value of weed dry weight was recorded under weed free. Among the different herbicidal treatments, minimum weed dry weight was recorded under application of atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS and was found to be significantly more effective over all the other treatments in respect of suppressing weeds (**Table 1**) as reported earlier by Ram *et al.* (2017), Shantveerayya and Agasimani (2012) and Verma *et al.* (2009). The maximum weed control efficiency was registered under weed-free treatment followed by atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS during both years due to lower dry matter production of weeds. However, a reverse trend was recorded with the weed index. In case of weed index, it was found lowest with atrazine PE *fb* power weeder at 25 DAS during the years 2016-17 and 2017-18. The study further indicated that herbicides were more effective in reducing weed density and biomass next to 3-hand weeding as compared to weedy check. Lower weed index denoteed the less yield losses due to weeds as reported by Kakade *et al.* (2020), Dobariya *et al.* (2015), Stanzen *et al.* (2016) and Susha *et al.* (2014).

Crop growth and yield attributes

During both years, the integrated weed management practices significantly increased growth attributes in winter maize (**Table 2**). The maximum plant height was recorded under the weed free 205.94 and 206.87 cm whereas among herbicidal treatments, atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS recorded 23.98% and 24.21% taller plants over weedy check during 2016-17 and 2017-18, respectively. Plant height is an important vegetative character as it is an index of plant growth and vigour.

It is affected by various causes and effects medicated by herbicides and their application time. Treatment combinations, which exhibited better control of weeds, were also able to record more plant height than treatments having unacceptable weed control. Maize crop with better weed control attained greater plant height due to reduction in weed density. Increase in overall growth of crop at all stages of observation was mainly due to significant reduction in weed competition, which was a major factor affecting crop yield as reported by Barad *et al.* (2016) and Bibi *et al.* (2010). Dry matter accumulation was significantly influenced by the different herbicidal treatments at all the crop growth stages. Among the herbicidal treatments, maximum dry matter 364.3 g and 367.2 g/plant was observed with atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS during 2016-17 and 2017-18, respectively. However, weed free and atrazine PE *fb* power weeder recorded 54.77%, 56.55% and 43.03%, 44.62% higher dry matter as compared weedy check during both years, respectively. This might be due to less weeded environment at critical growth stages which improved growth and yield attributes of the crop. In general, the aforesaid improvements seem to be on account of direct impact of different weed management treatments through least crop-weed competition whereas, indirect effect might be least competition for plant growth inputs, *viz.* light, space, water, nutrients *etc*. (Gul and Khanday 2015). Uncontrolled weeds in weedy check plot created conditions similar to poor aeration and smothering effect on crop plants thus crop became vulnerable against different growth resources and this resulted in minimum dry matter accumulation conforming the previous findings of Rani *et al.* (2021), Dobariya *et al.* (2014), Mukundam *et al.* (2011) and Sarma and Gautam (2010).

The integrated weed management practices enhanced the yield attributes *viz*., number of cobs/m^2, number of grains/cob and 1000 grain weight. The grain yield is the function of interplay between yield attributes and growth characters. The higher number of cobs/m^2 (18 and 19) were recorded under weed free, which was found to be statistically at par with atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS

Table 1. Weed biomass, weed control efficiency and weed index of zero till winter maize as influenced by different weed management practices

Treatment	Weed biomass (g/m^2)		Weed control efficiency (%)		Weed index	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Glyphosate 1.6 kg/ha 3 DBS	9.43	8.65	60.52	57.89	10.28	11.13
Glyphosate 1.6 kg/ha 3 DBS *fb* power weeder at 25 DAS	4.68	4.23	76.08	77.61	6.18	5.45
Halosulfuron 67.5 g/ha PE	9.67	9.16	54.71	54.71	21.01	20.62
Halosulfuron 67.5 g/ha PE *fb* power weeder at 25 DAS	5.36	4.78	74.89	75.88	8.29	5.71
Atrazine 1.5 kg/ha PE	6.21	5.96	70.91	70.91	9.86	7.69
Atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS	3.45	4.08	83.84	78.07	4.82	3.49
Imazethapyr 100 g/ha PE	16.07	15.48	24.73	26.22	31.55	29.03
Imazethapyr PE + fenoxaprop PoE 100 +100 g/ha (20-25 DAS)	14.62	14.16	31.52	31.52	29.14	26.73
Weed free (3 hand weeding at 20, 40 and 60 DAS)	2.06	1.67	90.39	90.39	0	0
Weedy check	21.36	21.12	-	-	48.50	44.00
LSD (p=0.05)	0.65	0.85	-	-	-	-

DBS: days before sowing; *fb*: followed by; DAS: days after sowing; PE: pre-emergence PoE: post-emergence

Table 2. Effect of integrated weed management on crop growth and yield attributes of winter maize under zero tillage conditions

Treatment	Plant height (cm)		Dry weight (g/plant)		No. of cobs/m^2		No. of grains/cob		1000 seed weight (g)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Glyphosate 1.6 kg/ha 3 DBS	191.3	192.2	321.6	324.8	12	14	479	483	312.6	315.2
Glyphosate 1.6 kg/ha 3 DBS *fb* power weeder at 25 DAS	200.9	201.8	339.9	338.5	14	16	515	524	363.3	364.0
Halosulfuron 67.5 g/ha PE	184.3	185.5	313.7	311.6	11	10	444	448	264.6	267.9
Halosulfuron 67.5 g/ha PE *fb* power weeder at 25 DAS	196.2	197.9	332.5	335.3	16	16	513	523	348.1	348.7
Atrazine 1.5 kg/ha PE	192.8	195.1	327.9	330.5	12	15	495	501	335.2	335.6
Atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS	201.7	204.2	364.3	367.2	16	17	523	528	363.6	365.4
Imazethapyr 100 g/ha PE	175.9	176.3	295.1	295.4	10	12	406	409	222.0	223.4
Imazethapyr PE + fenoxaprop PoE 100 +100 g/ha (20-25 DAS)	174.3	179.4	302.8	305.5	11	12	418	420	234.8	235.5
Weed free (3 hand weeding at 20, 40 and 60 DAS)	205.9	206.9	394.2	397.5	18	19	537	542	365.9	369.2
Weedy check	162.6	164.4	254.7	253.9	7	10	336	338	200.2	203.3
LSD (p=0.05)	14.9	14.5	16.98	17.02	3.24	3.39	5.04	5.38	4.77	4.72

DBS: days before sowing; *fb*: followed by; DAS: days after sowing; PE: pre-emergence PoE: post-emergence

Table 3. Effect of different weed management practices on yield and economics of winter maize under zero tillage condition

Treatment	Grain yield (t/ha)		Stover yield (t/ha)		Stone yield (t/ha)		Net returns (x10^3 ₹/ha)		B:C ratio	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
Glyphosate 1.6 kg/ha 3 DBS	6.38	6.49	12.76	12.85	1.18	1.24	85.74	86.98	2.32	2.40
Glyphosate 1.6 kg/ha 3 DBS *fb* power weeder at 25 DAS	6.84	6.91	14.14	14.34	1.35	1.53	94.50	96.55	2.58	2.64
Halosulfuron 67.5 g/ha PE	5.57	5.80	12.08	12.12	1.08	1.11	74.61	75.66	2.01	2.12
Halosulfuron 67.5 g/ha PE *fb* power weeder at 25 DAS	6.55	6.89	13.84	13.99	1.38	1.46	93.49	95.71	2.58	2.66
Atrazine 1.5 kg/ha PE	6.73	6.74	13.57	13.75	1.19	1.39	92.12	93.37	2.52	2.61
Atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS	7.08	7.05	14.32	14.34	1.74	1.82	99.89	100.33	2.66	2.78
Imazethapyr 100 g/ha PE	5.03	5.18	10.10	10.26	1.04	1.09	60.99	62.99	1.68	1.76
Imazethapyr PE + fenoxaprop PoE 100 +100 g/ha (20-25 DAS)	5.12	5.35	10.86	11.19	1.07	1.10	62.95	64.65	1.55	1.68
Weed free (3 hand weeding at 20, 40 and 60 DAS)	7.23	7.30	16.43	16.63	1.85	1.93	89.99	91.79	1.60	1.72
Weedy check	4.05	4.09	8.81	8.96	0.84	0.86	42.86	45.46	1.24	1.33
LSD (p=0.05)	0.50	0.42	0.54	0.47	0.34	0.26	6.38	6.42	0.15	0.18

DBS: days before sowing; *fb*: followed by; DAS: days after sowing; PE: pre-emergence PoE: post-emergence

during the year 2016-17 and 2017-18 (**Table 3**). Among the herbicidal treatments, maximum number of grains/cob (523 and 528) was observed under weed free and with atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS during both years, respectively. Test weight is a general indicator of grain quality and higher test weight normally means higher quality grain. The maximum 1000 grain weight 365.93 g in 2016-17 and 369.2 g in 2017-18 was found with weed free check. Due to severe crop-weed competition throughout the growth period, weedy check recorded the least yield attributes confirming findings of Barkhtair *et al.* (2011), Hawaldar and Agasimani (2012) and Saman *et al.* (2015).

Yield and economics

Grain yield of winter maize was significantly affected by integrated weed management practices under zero tillage condition (**Table 3**). The highest grain yield of 7.2 and 7.3 t/ha was recorded with weed free treatment during 2016-17 and 2017-18, respectively. Among the herbicidal treatments, atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS showed 74.91% and 72.34% higher grain yield as compared to weedy check during the experimental year 2016-17 and 2017-18, respectively. Controlling weeds at the early growth as well as at later stages provided conducive atmosphere for better utilization of natural resources and external inputs by the crop as reported by Wasnik *et al.* (2022), Shekhar *et al.* (2014) and Mukundam *et al.* (2011). Stover yield also differed significantly due to the various treatments and similar trend was followed like grain yield. Weedy check scored 38.45% and 37.51% less stover yield as compared to the atrazine 1.5 kg/ha as PE *fb* power weeder at 25 DAS during 2016-17 and 2017-18 respectively (**Table 3**). Similar findings were reported by Chandrapala *et al.* (2010), Mathukia *et al.* (2014) and Sunitha *et al.* (2010).

Higher economic return is an important consideration in selection of weed management practices as farmers are mostly concerned with higher return per unit area, time and investment. The highest value of net return (₹ 99887 and ₹ 100333/ha) was scored atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS which was 10.99% and 9.30% higher as compared to weed free during 2016-17 and 2017-18, respectively. Benefit: cost ratio followed the similar trend. Higher net income recorded with atrazine under zero till conditions confirmed the findings of Barad *et al.* (2016), Parameswari (2013) and Reddy *et al.* (2012).

Weed free (3 hand weeding) and atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS recorded higher growth and yield of winter maize during both of years. However, from economic point of view, integrated weed management involving atrazine 1.5 kg/ha PE *fb* power weeder at 25 DAS was superior over all other treatments including weed free and hence is the most appropriate and adoptable integrated weed management strategy to achieve higher weed control efficiency, growth, yield and income of *winter* maize under zero tillage condition.

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