Indian Journal of Weed Science (2023) **55**(1): 32–35
http://dx.doi.org/10.5958/0974-8164.2023.00005.9

RESEARCH ARTICLE

Weed management with pre- and post-emergence herbicides in *Kharif* maize in sub-mountainous area of Punjab, India

Amit Kaul*, Bikramjit Singh and Mandeep Singh

Received: 5 May 2022 | Revised: 6 September 2022 | Accepted: 9 September 2022

ABSTRACT

A field experiment was conducted at Punjab Agricultural University, Krishi Vigyan Kendra, Pathankot, Punjab, India during *Kharif* 2016 and 2017 to identify the best herbicides-based weed management practices in maize (*Zea mays* L.). The treatments consisted of pre-emergence (PE) application of atrazine 1000 g/ha, pendimethalin 750 g/ha, pendimethalin 750 g/ha + atrazine 750 g/ha and post-emergence (PoE) application of tembotrione 110.2 g/ha, tembotrione 110.2 g/ha + atrazine 625 g/ha and 2,4-D amine salt 580 g/ha, hand weeding twice at 15 and 30 days after sowing (DAS) and weedy check. A randomized complete block design with three replications was used. The tembotrione 110.2 g/ha + atrazine 625 g/ha (tank mix) PoE at 25 DAS recorded the highest weed control efficiency (94.2%), maize grain yield (4.43 t/ha), net monetary returns (₹ 28047.3) and B:C (1.77).

Keywords: Atrazine, Economics, Maize, Tembotrione, Weed control efficiency, Weed management

INTRODUCTION

Maize (*Zea mays* L.) is one of the world's most important food crops. It serves as food to the human beings and feed to the cattle. In Punjab, it is grown on an area of 116 thousand hectares with a production of 423 thousand tones and an average grain yield of 3.71 t/ha (Anonymous 2018). The average maize yield is still far below than the achievable potential of hybrids in spite of availability of several high yielding hybrids. The potentiality of maize can be fully exploited by adopting suitable agronomic practices among which, weed management plays a significant role in enhancing the crop yield (Ramesh *et al.* 2017). Maize, being a rainy season and widely spaced crop, gets infested with variety of weeds and subjected to heavy weed competition, which often inflicts huge losses ranging from 28 to 100 per cent (Patel *et al.* 2006). The growth of maize in the first three to four weeks is rather slow and during this period weeds establish rapidly and take competitive advantage (Srividya *et al.* 2011). Management of weeds is considered to be an important factor for achieving higher productivity as weed problem is more severe during *Kharif* season due to continuous rains in early stages of maize growth.

Weeds in maize can be controlled by cultural and chemical measures to attain 77 to 96.7% higher yield than weedy check (Khan *et al.* 1998). Manual weeding is a common practice, but it is labour intensive, time consuming, costly and often not done by most of the farmers at critical period of crop-weed competition. Moreover, the labour problem is becoming acute day by day and it will not be possible and economical to stick the traditional cultural weed control practices (Oerke 2005). Thus, herbicides are preferred by farmers as they control the weeds timely and effectively and offer great scope for minimizing the cost of weed control irrespective of situation.

The use of pre-emergent and post-emergent herbicides would help effective weed management of weeds in maize during the critical period (Rao and Chauhan 2015). Usage of pre-emergence herbicides assumes greater importance in the view of their effectiveness from initial stages. As the weeds interfere during the harvesting of the crop, post-emergence herbicides at about 40-45 DAS may help in avoiding the problem of weeds at later stages. Thus, managing weeds using sequential application of pre- and post-emergence herbicides will be an ideal means for managing the weeds economically and effectively in maize. Hence, a study was carried out to quantify the effect of pre- and post-emergence herbicides in maize in managing weeds and improving the productivity economically.

MATERIALS AND METHODS

The experiment was carried out at Krishi Vigyan Kendra, Pathankot during 2016 and 2017. The experiment was laid out in randomized complete

Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab 141004, India

* Corresponding author email: amitkaul@pau.edu

block design with three replications having a net plot size of 5 x 3 m. The soil was sandy loam with pH of 7.6, electrical conductivity of 2.5 dS/m, organic matter of soil 0.72%, available phosphorus 9.7 mg/kg and extractable potassium was 139 mg/kg. Maize hybrid PMH-1 was sown on 25th June, 2016 and on 2nd July, 2017 with single row hand drill using a seed rate of 20 kg/ha in 60 cm apart rows. Plant to plant distance of 20 cm was maintained by thinning at an early growth stage. Recommended dose of nitrogen (N), phosphorus (P) and potassium (K) at 160-80-50 kg/ha was applied through urea, di-ammonium phosphate (DAP) and muriate of potash (MOP), respectively. Fertilizers, P and K were applied as basal dose and half of the nitrogen was broadcasted and incorporated into soil at sowing while remaining half of the nitrogen was top dressed at knee high stage.

The treatments comprised of pre-emergence application (PE) of atrazine 1000 g/ha, pendimethalin 750 g/ha, pendimethalin 750 g/ha + atrazine 750 g/ha (tank-mix) and post-emergence application (PoE) of tembotrione 110.2 g/ha, tembotrione 110.2 g/ha + atrazine 625 g/ha and 2,4-D amine salt 580 g/ha, hand weeding twice at 15 and 30 days after sowing (DAS) and weedy check.

A knapsack sprayer fitted with flat-fan nozzle was used for pre-emergence herbicides application within two days after sowing using 500 litre/ha water and for post-emergence herbicides application at 25 DAS using 375 litre/ha water. Phytotoxic effect on crop was recorded at 3rd and 10th day after herbicides application. Weed density was recorded at 20 DAS and 40 DAS by using a quadrat of 100 x 100 cm (1 m^2) size from the center of the plot. The entire weeds inside the quadrat were uprooted and cut close to the transition of root and shoot in each plot and collected for dry matter accumulation (biomass). The samples were first dried in sun and then kept in oven at 70 ± 2°C. The dried samples were weighed and expressed as dry biomass of weed (g/m^2). Cost of cultivation, gross returns, net monetary returns and benefit cost ratio for each treatment were calculated, using standard procedure, by taking into consideration of total costs incurred and returns obtained. Weed control efficiency (WCE) and weed index (WI) were calculated using formulae as suggested by Gill and Vijaya Kumar (1969).

RESULTS AND DISCUSSION

Weed flora

Among the weeds, sedges and broad-leaved weeds were dominant in the experimental site as compared to the grasses (**Table 1**). *Cyperus compressus* L. was the dominant weed followed by *Cyperus rotundus* L., *Trianthema portulacastrum* L. and *Commelina benghalensis* L., during both the years of study.

Effect on weeds

The total weed density was significantly lower with hand weeding done at 15 days after sowing (DAS) in which 82.5 per cent lower weeds were recorded than weedy check. Among the herbicide treatments, total weed density was significantly lower with pendimethalin 750 g/ha + atrazine 750 g/ha (tank mix) than other herbicide-based treatments and it was 18 per cent lesser than weedy check (**Table 1**). The density of *T. portulacastrum* at 20 DAS was significantly reduced by all the pre-emergence herbicides. However, emergence of *C. rotundus*, *C. compressus* and *C. benghalensis* were unaffected by any of the pre-emergence herbicides. *T. portulacastrum* was significantly controlled by pendimethalin 750 g/ha + atrazine 750 g/ha (tank mix) PE followed by atrazine 1000 g/ha PE and hand weeding at 15 DAS with the reduction of 67.5, 38.1 and 58.4 per cent over weedy check during both years, respectively. Similarly, weed biomass of *T. portulacastrum* was also reduced with pendimethalin 750 g/ha + atrazine at 750 g/ha (tank

Table 1. Effect of pre- and post-emergence herbicides on weed density at 20 and 40 days after sowing in maize (pooled mean)

Treatment	Weed density at 20 DAS (no./m^2)				Total weed density at 20 DAS (no./m^2)	Weed density at 40 DAS (no./m^2)				Total weed density at 40 DAS (no./m^2)
	TP	*CR*	*CC*	*CB*		*TP*	*CR*	*CC*	*CB*	
Weedy check	4.6(25)	5.5(29)	10.2(104)	3.3(11)	13.0(169)	6.8(47)	5.0(24)	10.0(100)	3.6(12)	13.5 (183)
Hand weeding twice	1.9(3)	1.3(1)	1.0(0)	1.1(1)	2.2(4)	1.5(1)	1.5(1)	1.2(1)	1.5(1)	2.3 (5)
Atrazine 1000 g/ha PE	1.9(3)	4.5(20)	10.0(99)	3.7(14)	11.6(135)	2.5(6)	5.2(27)	9.6(92)	3.4(11)	11.6 (135)
Pendimethalin 750 g/ha PE	2.9(8)	4.8(23)	10.1(102)	3.4(12)	12.0(145)	3.2(10)	5.3(28)	11.5(132)	3.6(13)	13.5 (182)
Pendimethalin + atrazine 750 + 750 g/ha PE	1.5(2)	4.5(20)	9.1(83)	2.8(7)	10.5(111)	2.2(4)	5.1(26)	10.2(104)	4.3(18)	12.3 (152)
Tembotrione 110.2 g/ha PoE	6.3(40)	4.5(19)	9.8(96)	3.8(14)	13.0(168)	1.6(2)	2.6(6)	3.3(11)	1.5(2)	4.5 (20)
Tembotrione+ atrazine 110.2 + 625 g/ha PoE	4.8(28)	5.0(24)	9.7(95)	4.3(18)	12.8(165)	1.7(2)	1.7(2)	1.4(1)	1.4(1)	2.7 (6)
2,4-D amine salt 580 g/ha PoE	6.8(45)	4.9(24)	9.7(95)	3.4(11)	13.2(175)	2.6(6)	3.0(8)	3.3(11)	3.1(9)	6.0 (34)
LSD (p=0.05)	2.54	0.57	1.30	1.13	0.89	0.61	0.47	0.67	0.81	0.61

*Data were square root transformed and values in parenthesis are actual mean values; PE = pre-emergence application; PoE = post-emergence application; *TP*: *T. portulacastrum; CR: C. rotundus; CC: C. compressus; CB: C. benghalensis* mix) PE as compared to other pre-emergence herbicides (**Table 2**). However, total weed biomass was not significantly reduced by any of the herbicide except hand weeding at 15 DAS. Deshmukh *et al.* (2009) also reported that the lowest weed density and biomass at 30 DAS with atrazine 1000 g/ha PE.

At 40 DAS, significantly the lowest weed density and biomass was recorded with tembotrione 110.2 g/ha + atrazine 625 g/ha PoE, followed by tembotrione at 110.2 g/ha PoE at 25 DAS (**Table 1** and **2**). The total weed density was 23.3 and 75.1% lower with tembotrione 110.2 g/ha + atrazine 625 g/ha PoE as compared to pendimethalin 750 g/ha + atrazine 750 g/ha (tank mix) PE and weedy check (**Table 1**). The pre-emergence herbicides were not effective on weeds in maize upto 40 DAS while post-emergence herbicide tembotrione at 110.2 g/ha as well as tembotrione 110.2 g/ha + atrazine 625 g/ha applied at 25 DAS significantly reduced the total weed density and biomass at 40 DAS. Arvadiya (2012) also reported that post-emergence herbicide control weeds very effectively in maize. The weed control efficiency at 40 DAS was significantly higher (94.2%) in tembotrione 110.2 g/ha+ atrazine 625 g/PoE followed by tembotrione at 110.2 g/ha PoE (85.6%) than other treatments and it was closely followed by hand weeding twice at 15 and 30 DAS (94.5%). Williams II *et al.* (2011) and Bollman *et al.* (2008) also reported the efficacy of tembotrione + atrazine 31 + 370 g/ha (tank mix) PoE in managing weeds in maize.

Weed index was lower with tembotrione 110.2 g/ha + atrazine 625 g/ha and tembotrione 110.2 g/ha (tank mix) PoE alone (**Table 3**) and was comparable to hand weeding as it gave complete control of all weeds till 40 DAS. Higher weed density and biomass in 2,4-D amine salt PoE at 25 DAS caused 28.8 per cent yield penalty compared to hand weeding.

Effect on crop

Maize plant height, cob length, grain and stover yields were significantly higher with hand weeding twice at 15 and 30 DAS (**Table 3**). Among the herbicides tested, tembotrione 110.2 g/ha + atrazine 625 g/ha (tank mix) PoE, significantly increased plant height and cob length during both the years, and it was statistically at par with tembotrione 110.2 g/ha alone as reported earlier by Williams II *et al.* (2011), Swetha (2015), Triveni *et al.* (2017). The increased plant height, cob length in effective treatments might be due to less degree of crop weed competition which increased the growth of maize. The stunted growth of crop in weedy check was due to higher weed density and competition (Shinde *et al.* 2018).

Grain yield and stover yield were significantly higher in hand weeding but it was at par with tembotrione 110.2 g/ha + atrazine 625 g/ha PoE and tembotrione 110.2 g/ha PoE. Sabiry and Babu (2019) also reported that the post-emergence herbicide mixtures were at par with hand weeding. The increase in grain yield was 88.5 per cent when tembotrione 110.2 g/ha + atrazine 625 g/ha was applied as compared to weedy check. After the first irrigation the re-emerged weeds in maize cannot be controlled with the pre-emergence herbicides resulting in yield reduction due to occurrence of higher weed density. There was a significant negative linear relationship between grain yield and weed biomass at 40 DAS (**Figure 1**). The least grain yield was recorded under control (weedy check) as reported by Rao *et al.* (2009).

Economics

The gross monetary returns, net monetary returns and benefit cost ration (B:C) in maize were significantly higher with tembotrione 110.2 g/ha + atrazine 625 g/ha PoE at 25 DAS (**Table 3**). The

Table 2. Effect of pre- and post-emergence herbicides on weed biomass at 20 and 40 days after sowing in maize (pooled mean)

Treatment	Weed biomass at 20 DAS (g/m^2)				Total weed biomass at 20 DAS (g/m^2)	Weed biomass at 40 DAS (g/m^2)				Total Weed biomass at 40 DAS (g/m^2)
	TP	*CR*	*CC*	*CB*		*TP*	*CR*	*CC*	*CB*	
Weedy check	5.4 (34)	6.2 (39)	3.4 (11)	4.7 (23)	10.2 (106)	8.8 (78)	6.3 (40)	4.2 (17)	3.8 (14)	12.2 (149)
Hand weeding twice	2.2 (4)	1.4 (1)	1.0 (0)	1.2 (1)	2.6 (6)	1.5 (2)	2.1 (3)	1.4 (1)	1.6 (2)	3.0 (8)
Atrazine 1000 g/ha PE	2.2 (4)	5.1 (26)	3.2 (10)	5.4 (30)	8.3 (69)	2.8 (7)	6.9 (48)	4.0 (15)	3.6 (12)	9.1 (83)
Pendimethalin 750 g/ha PE	3.3 (10)	5.6 (31)	3.3 (10)	4.7 (24)	8.7 (76)	3.7 (13)	7.1 (50)	4.8 (22)	3.9 (15)	10.0 (100)
Pendimethalin + atrazine 750 + 750 g/ha PE	1.6 (2)	5.4 (29)	3.0 (8)	3.0 (9)	6.9 (48)	2.6 (6)	6.8 (46)	4.3 (17)	4.6 (21)	9.5 (90)
Tembotrione 110.2 g/ha PoE	7.4 (54)	5.0 (24)	3.1 (9)	5.5 (30)	10.8 (117)	2.0 (3)	3.7 (13)	2.0 (3)	1.5 (2)	4.6 (21)
Tembotrione + atrazine 110.2 + 625 g/ha PoE	5.6 (39)	5.6 (31)	3.2 (10)	6.1 (37)	11.0 (118)	1.7 (2)	2.2 (4)	1.5 (1)	1.3 (1)	3.1 (9)
2,4-D amine salt 580 g/ha PoE	7.9 (62)	5.4 (29)	3.2 (9)	4.8 (23)	11.1 (123)	2.8 (9)	5.1 (25)	2.2 (4)	3.3 (10)	7.0 (49)
LSD (p=0.05)	3.04	0.89	0.46	1.74	1.70	0.71	0.61	0.47	0.85	0.69

*Data were square root transformed and values in parenthesis are actual mean values; PE = pre-emergence application; PoE = post-emergence application; *TP*: *T. portulacastrum; CR: C. rotundus; CC: C. compressus; CB: C. benghalensis*

Table 3. Effect of pre- and post-emergence herbicides on growth, yield attributes and yield of maize (pooled mean)

Treatment	Plant height (cm)	Cob length (cm)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Weed index (%)	Weed control efficiency (%)	Net returns (Rs/ha)
Weedy check	170.3	14.3	2.35	3.44	40.6	46.0	-	2926.5
Hand weeding twice	211.0	15.2	4.47	5.81	43.5	-	94.52	24526.3
Atrazine 1000 g/ha PE	179.7	14.7	2.86	3.79	43.1	35.7	44.12	9287.7
Pendimethalin 750 g/ha PE	175.3	14.7	2.43	3.35	42.0	45.8	32.40	2624.5
Pendimethalin + atrazine 750 + 750 g/ha PE	182.0	14.8	3.24	4.42	42.4	27.8	38.87	13734.8
Tembotrione 110.2 g/ha PoE	209.6	15.1	4.26	5.68	42.9	4.6	85.65	26318.3
Tembotrione+ atrazine 110.2 + 625 g/ha PoE	210.6	15.0	4.43	5.85	43.0	1.7	94.24	28047.8
2,4-D amine salt 580 g/ha as PoE	181.0	15.0	3.18	4.24	43.1	27.4	66.90	14326.8
LSD (p=0.05)	8.4	0.5	1.03	1.50	1.4	24.6	-	-

PE = Pre-emergence application; PoE = Post-emergence application

highest B:C was obtained with tembotrione 110.2 g/ha + atrazine 625 g/ha (1.77) followed by tembotrione 110.2 g/ha (1.74). The weedy check and pendimethalin 750 g/ha PE recorded the lowest B: C (1.08 and 1.09, respectively). The results are in accordance with those reported by Triveni *et al* (2017).

It was concluded that the tembotrione 110.2 g/ha + atrazine 625 g/ha (tank mix) as PoE significantly decreased the weed density, weed biomass and enhanced the weed control efficiency up to 94% and hence it may be recommended to the maize growers to effectively and economically managing weeds and improve maize grain yield with higher net returns.

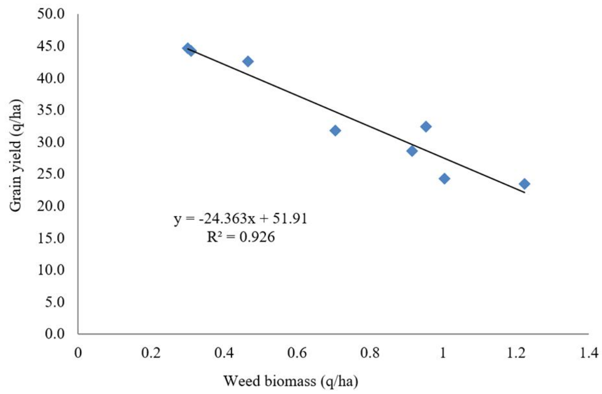

Figure 1. Relationship between weed biomass at 40 days after sowing and grain yield of maize

REFERENCES

Anonymous. 2018. Package and practices of Punjab Agricultural University Ludhiana pp 23.

Arvadiya LK, Raj VC, Patel TU, Arvadiya MK and Patel AM. 2012. Effect of plant population and weed management practices on productivity of sweet corn. *Indian Journal of Weed Science* **44**(3): 167–171.

Bollman JD, Boerboom BH, Becker RL and Fritz VA. 2008. Efficacy and tolerance to HPPD-inhibiting herbicides in sweet corn. *Weed Technology* **22**: 666–674.

Deshmukh LS, Jadhav AS, Jathure RS and Raskar SK. 2009. Effect of nutrient and weed management on weed growthand productivity of kharif maize under rainfed condition. *Karnataka Journal of Agricultural Sciences* **22**(4): 889–891.

Gill GS and K Vijaya. 1969. “Weed index” A new method for reporting weed control trials. *Indian Journal of Agronomy* **16**: 96–98.

Khan SA, Hussain N, Khan IA, Khan M and Iqbal M. 1998. Study on weed control in maize. *Sarhad Journal of Agriculture* **14**(6): 581–586.

Oerke E C. 2005. Crop losses to pest. *Journal of Agriculture Science* **143**: 1–13.

Patel VJ, Upadhyay PN, Patel JB and Meisuriya MI. 2006 Effect of herbicide mixture on weeds in *Kharif* maize (*Zea mays* L.) under middle Gujarat conditions. *Indian Journal of Weed science* **38**(1&2): 54–57.

Ramesh K, Rao AN and Chauhan BS. 2017. Role of crop competition in managing weeds in rice, wheat, and maize in India: A review. *Crop Protection* **97**: 14–21

Rao AN and Chauhan BS. 2015. Weeds and Weed Management in India - A Review. In: Weed Science in the Asian Pacific Region. Indian Society of Weed Science, Hyderabad, pp. 87–118.

Rao AS, Ratnam M and Reddy TY. 2009. Weed management in zero-till sown maize. *Indian Journal of Weed Science* **41**(1&2): 46–49.

Sabiry B and Babu R. 2019. Influence of early post emergent herbicide mixtures on weed control and gain yield of maize (Zea mays L.). *Acta Scientific Agriculture* **3**(5): 26–28.

Shinde SS, Pawar SU, Awasarmal VB and Narkhede WN. 2018. Studies on effect of different herbicides on weed control, yield and economics of maize. *International Journal of Current Microbiology and Applied Sciences* **6**: 951–955.

Srividya S, Chandrasekhar K and Veeraraghavaiah R. 2011. Effect of tillage and herbicide use on weed management in maize. *The Andhra Agricultural Journal* **58**(2): 123–126.

Swetha K. 2015.Weed management with new generation herbicides in *Kharif* maize *(Zea mays l.).* M.Sc. thesis, Department of Agronomy, Professor Jayashankar Telangana State Agricultural University, Rajendranagar,

Triveni U, Rani Sandhya Y, Patro TSSK and Bharathalakshmi M. 2017. Effect of different pre- and post-emergence herbicides on weed control, productivity and economics of maize. *Indian Journal of Weed Science* **49**(3): 231–235.

Williams II MM, Boydston RA, Peachy R Ed and Robinson D. 2011. Significance of atrazine as a tank-mix partner with tembotrione. *Weed Technology* **25**: 299–302.