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Effect of Weed Management Practices on Weed Dynamics, Yield Attributes and Yield of Maize

Suman Kantwa[1]*, C. K. Jadon[1], J. P. Tetarwal[1], Baldev Ram[1], S. R. Kantwa[2] and R. K. Yadav[1]

Dept. of Agronomy, College of Agriculture, Ummedganj (Kota), Rajasthan (324 001), India
[2]ICAR-IGFRI, Jhansi, Uttar Pradesh (284 003), India

Corresponding Author

Suman Kantwa

e-mail: kantwasuman@gmail.com

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Abstract

A field experiment was conducted at Research Farm of Agricultural Research Station, Ummedganj, Kota (Agriculture University, Kota), Rajasthan, India during *kharif* 2019 to find out the most effective herbicide combination for limiting the menace of weeds in maize. Results showed that density of monocot weeds were observed more than dicot weeds during the experimentation. The prominent weeds were *Echinochloa colona, Cyperus rotundus, Digera arvensis, Amaranthus viridis, Acalypha indica and Trianthema portulacastrum* etc. caused about 58.3% reduction in grain yield as over two hand weeding at 20 and 40 DAS. In general, grassy weeds were better controlled by herbicides than broad leaves weeds. Among herbicides, maximum weed control efficiency (72.18%) was achieved with application of atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g *a.i.* ha^{-1} at 20-25 DAS (72.18%) which is very close to two hand weeding at 20 and 40 DAS. Furthermore, this treatment also produced higher grain (3496 kg ha^{-1}) and stover yield (6460 kg ha^{-1}) which was at par with atrazine 500 g *a.i.* ha^{-1} (PE) followed by tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS) and atrazine 500 g a.i. ha^{-1} (PE)+hand weeding 30 DAS with *in-situ* weeds mulching. Thus, pre-emergence application of atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS is recommended for better weed control and yield of maize.

Keywords: Atrazine, maize, mulching, weed control efficiency, weed density

1. Introduction

Maize (*Zea mays* L.) is one of the important cereal crops of the world, known as "Queen of cereals" due to its great importance in human and animal diet, very efficient utilizer of solar energy and has immense potential for higher yield. It is known for its wider adaptability and multipurpose uses as food, fodder and industrial products (Murdia et al., 2016). Currently, nearly 1148 mt of maize is being produced together by over 170 countries from an area of 194 million ha with an average productivity of 5.75 t ha^{-1}. In India, the maize is grown on 9.2 mha area with the production of 27.8 mt (Anonymous, 2020). Maize is also good feed for piggery, poultry and other animals. Its content about 11.2% protein, 8% oil, 70% carbohydrate, 2.3% crude fiber, 10.4% albumins and 1.4% ash. (Raut et al., 2017).

It is also an important source of vitamins and minerals like Ca, P, S and small amounts of Na. Its flour is considered to be a good diet for heart patients due to its low gluten (protein) content (Rasool and Khan, 2016).

Article History

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In general, the productivity of maize in India and Rajasthan in particular is relatively very low compared to developed country of world mainly due to poor nutrition, lack of good quality seed, lack of timely weed control, disease & insect management and post-harvest losses (Choudhary et al., 2012). The major yield reducing factors for maize cultivation in India are weeds (Pandey et al., 2001; Gharde et al., 2018). There are about 100 weed species in 66 genera and 24 plant families known to be problematic for maize in the country. Most of the presently available herbicides provide only a narrow spectrum weed control (Patel et al., 2006). The best results of weed control can only be seen in case of integrated weed management practices. Integrated weed management is the need of the day, because of its sustainability and higher productivity (Sharma et al., 2018; Kumawat et al., 2019). Weed control practices in maize resulted in 65 to 90% higher yield than unweeded (Barla et al., 2016; Kumawat et al., 2019). Topramezone and tembotrione are the new selective, post-emergence herbicides introduced for use in maize that inhibit hydroxy-phenyl pyruvate dioxygenase (4-HPPD) enzyme and the biosynthesis of plastoquinone (Swetha et al., 2015). There is need for some alternate post-emergence herbicide like tembotrione which can provide broad spectrum weed control in *kharif* maize without affecting the growth and yield of crop (Williams et al., 2011; Yadav et al., 2017). Therefore, this study was conducted to find out the most selective and potent herbicide for limiting the menace of weeds in maize. Keeping these facts in mind, the present investigation was conducted with objective to evaluate the weed control efficiency of different weed management practices.

2. Materials and Methods

A field experiment was conducted at Research Farm of Agricultural Research Station, Ummedganj, Kota (Agriculture University, Kota) during July-October, 2019. Region falls under the Agro Climatic Zone V of Rajasthan *i.e.* Humid South-Eastern Plain zone. The experiment comprised with the following treatments-T_1: Weedy check, T_2: One hand weeding (30 DAS) with *in situ* mulching with weeds, T_3: Two hand weeding (20 and 40 DAS), T_4: Atrazine 500 g a.i. ha^{-1} (PE), T_5: Atrazine 500 g a.i. ha^{-1} (PE) + hand weeding (30 DAS), T_6: Atrazine 500 g a.i. ha^{-1} (PE)+hand weeding 30 DAS with *in situ* mulching with weeds, T_7: Tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS), T_8: Topramezone 25.2 g a.i. ha^{-1} (20-25 DAS), T_9: Atrazine 500 g a.i. ha^{-1} (PE) followed by Tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS), T_{10}: Atrazine 500 g a.i. ha^{-1} (PE) followed by Topramezone 25.2 g a.i. ha^{-1} (20-25 DAS), T_{11}: Atrazine 500 g a.i. ha^{-1} + Tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS) and T_{12}: Atrazine 500 g a.i. ha^{-1} + Topramezone 25.2 g a.i. ha^{-1} (20-25 DAS) were assigned in a randomized block design with three replication. All the herbicides alone or in combination were applied uniformly in the experimental plots with the help of knapsack sprayer. The maize variety "PHM-3" was sown at a spacing of 60×25 cm^2 between rows and plants. All the recommended agronomic and plant protection measures were adopted to raise crop. Observation recorded on the following aspects- weed density (individual category wise) at 30 and 60 DAS (m^{-2} area), these were subjected to square root transformation to normalize their distribution, weed control efficiency (%) at harvest, yield attributes (number of cobs plant^{-1}, cob weight plant^{-1}, number of grains cob^{-1}, grain weight cob^{-1}, test weight (g), shelling percentage (%)) and yields (grain , and stover yields (kg ha^{-1}) and harvest index (%). The influence of treatment was tested with 'F' test wherever 'F' test shown their significance. The levels of treatment were compared by critical difference at 5% level of probability/ significance.

3. Results and Discussion

The experimental site was mainly infested with monocot, dicot and sedge weeds *viz.*, *Echinochloa colona, Amaranthus viridis, Cyperus rotundus, Digera arvensis, Phyllanthus niruri, Commelina benghalensis, Trianthema portulacastrum* and *Dactyloctenium aegyptium etc,* it was observed that maize crop was majorly infested with monocot followed by dicot during growing season. The data recorded in Table 1 and 2, revealed that significantly lowest total weed density (3.38 weeds m^{-2}) was observed in treatment applying atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS followed by atrazine 500 g a.i. ha^{-1}+topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS (3.53 m^{-2}) and two hand weeding at 20 and 40 DAS (3.71 m^{-2}) and highest weed density was observed in weedy check (10.29 m^{-2}). Respective treatments (atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1}+topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS and two hand weeding at 20 and 40 DAS) being at par with topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS observed significantly lower total weed density over rest of the treatments at 30 DAS and statistically lowest weed density (5.61 weeds m^{-2}) was recorded in treatment practicing two hand weeding at 20 and 40 DAS followed by atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS (5.72 m^{-2}) and atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS (6.39 m^{-2}) compared to rest of the treatments. The highest weed density was observed in weedy check (11.58 m^{-2}). However, two hand weeding at 20 and 40 DAS, atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS and atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS treatments remained at par with each other at 60 DAS. These finding are close conformity with the Stephenson et al. (2015), Rana et al. (2017) and Sundari et al. (2019).

The maximum weed control efficiency of total weeds was recorded under treatment hand weeding twice at 20 and 40 DAS (76.05%) followed by atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS (72.18%) and atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75

Table 1: Effect of weed management practices on weed density (weeds m^{-2}) at 30 DAS (Individual category wise)

Treatments	Weed density (weeds m^{-2})							
	At 30 DAS				At 60 DAS			
	Grassy	BLW	Sedge	Total	Grassy	BLW	Sedge	Total
T_1	5.87 (34.00)*	6.81 (46.00)	5.06 (25.33)	10.29 (105.33)	7.23 (52.00)	6.84 (46.33)	5.97 (35.33)	11.58 (133.67)
T_2	5.72 (32.33)	5.63 (31.33)	4.94 (24.00)	9.38 (87.67)	5.33 (28.00)	5.26 (27.33)	4.71 (22.00)	8.81 (77.33)
T_3	1.72 (2.67)	2.96 (8.33)	1.68 (2.33)	3.71 (13.33)	3.71 (13.33)	3.41 (11.33)	2.56 (6.33)	5.61 (31.00)
T_4	3.38 (11.00)	4.20 (17.33)	3.81 (14.33)	6.54 (42.67)	5.56 (30.67)	5.79 (33.33)	4.85 (23.33)	9.37 (87.33)
T_5	3.33 (10.67)	4.56 (20.33)	3.75 (13.67)	6.72 (44.67)	4.44 (19.33)	4.76 (22.67)	4.18 (17.00)	7.69 (59.00)
T_6	3.27 (10.33)	4.52 (20.00)	3.62 (12.67)	6.59 (43.00)	4.04 (16.00)	4.63 (21.00)	3.98 (15.67)	7.29 (52.67)
T_7	2.16 (4.33)	2.39 (5.67)	3.12 (9.33)	4.44 (19.33)	3.10 (9.33)	5.30 (27.67)	4.54 (20.33)	7.60 (57.33)
T_8	1.46 (1.67)	2.08 (4.00)	3.06 (9.00)	3.85 (14.67)	2.54 (6.00)	4.98 (25.00)	4.45 (19.67)	7.10 (50.67)
T_9	2.03 (3.67)	2.53 (6.00)	2.65 (6.67)	4.10 (16.33)	2.96 (8.33)	4.40 (19.00)	3.69 (13.33)	6.39 (40.67)
T_{10}	1.34 (1.33)	2.24 (4.67)	2.34 (5.00)	3.38 (11.00)	2.34 (5.00)	4.07 (16.33)	3.36 (11.00)	5.72 (32.33)
T_{11}	2.11 (4.00)	2.52 (6.00)	3.00 (8.87)	4.37 (18.67)	3.07 (9.00)	5.01 (24.67)	4.40 (19.00)	7.29 (52.67)
T_{12}	1.46 (1.67)	2.02 (3.67)	2.67 (6.67)	3.53 (12.00)	2.71 (7.00)	4.89 (23.67)	4.27 (18.00)	6.99 (48.67)
SEm±	0.22	0.25	0.25	0.24	0.24	0.35	0.34	0.33
CD (p=0.05)	0.63	0.73	0.73	0.70	0.72	1.02	1.01	0.95

T_1: Weedy check, T_2: One hand weeding (30 DAS) with *in situ* mulching with weeds, T_3: Two hand weeding (20 & 40 DAS), T_4: Atrazine 500 g a.i. ha^{-1} (PE), T_5: Atrazine 500 g a.i. ha^{-1} (PE) + hand weeding (30 DAS), T_6: Atrazine 500 g a.i. ha^{-1} (PE) + hand weeding 30 DAS with *in situ* mulching with weeds, T_7: Tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS), T_8: Topramezone 25.2 g a.i. ha^{-1} (20-25 DAS), T_9: Atrazine 500 g a.i. ha^{-1} (PE) followed by Tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS), T_{10}: Atrazine 500 g a.i. ha^{-1} (PE) followed by Topramezone 25.2 g a.i. ha^{-1} (20-25 DAS), T_{11}: Atrazine 500 g a.i. ha^{-1}+Tembotrione 120.75 g a.i. ha^{-1} (20-25 DAS) and T_{12}: Atrazine 500 g a.i. ha^{-1}+Topramezone 25.2 g a.i. ha^{-1} (20-25 DAS); *: √x+0.05 Transformed values and data in parenthesis are original values; **: Weed observations at 30 DAS were taken prior to hand weeding at 30 DAS

Table 2: Effect of weed management practices on weed control efficiency (%) at harvest (Individual category wise)

Treatments	Weed control efficiency (%) at harvest				Weed index (%)
	Grassy	BLW	Sedge	Total	
T_1	-	-	-	-	58.53
T_2	54.21	46.72	36.87	46.44	32.63
T_3	81.35	73.68	72.88	76.05	-
T_4	51.55	40.64	35.78	42.92	35.08
T_5	74.97	58.92	57.50	63.91	14.46
T_6	75.93	60.75	58.53	65.35	6.98
T_7	70.33	55.28	54.47	60.13	30.17
T_8	73.25	58.49	55.39	62.44	26.19
T_9	78.67	65.97	65.98	70.28	4.52
T_{10}	80.12	67.81	68.65	72.18	1.24
T_{11}	73.74	58.64	55.79	62.74	19.55
T_{12}	74.11	59.70	56.30	63.50	15.45
SEm±	1.97	3.72	2.45	1.37	-
CD (p=0.05)	5.77	10.92	7.19	4.03	-

g a.i. ha^{-1} at 20-25 DAS (70.28%) and minimum weed control efficiency was recorded under treatment weedy check (0.0%). Weed management practice two hand weeding at 20 and 40 DAS being at par with atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, showed superiority in terms of total WCE over rest of the treatments under investigation. Application of atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS recorded lowest weed index (1.24%). Hand weeding twice removed the weeds completely and created condition which were more favourable for growth and ultimately resulted in the lowest density of later emerged weeds and their lowest dry biomass with higher weed control efficiency during the crop growth period. Manual weeding maintained its supremacy over chemical control in limiting the weed load (weed density as well as their biomass) in maize crop reported by Barla et al., 2016. Among all the herbicidal weed control treatments, alone and combined application (with atrazine) of topramezone and tembotrione was found the most effective in order to reduce the density and dry matter of weeds at all stages compared to other treatments. This might be due to post-emergence application of topramezone and tembotrione controlled majority of weeds. The results are in close agreement with the findings of Swetha et al., 2015 and Damalas et al. (2018).

Mulching practice was also proved effective for controlling the weeds reported by Kumar and Angadi, 2014.

A perusal of data presented in Table 3 reveals that all weed management practices significantly affected the yield attributes over weedy check except no. of cob plant^{-1}. Number of cobs plant^{-1} was did not differed significantly by adoption of different weed management practices in maize crop. Practicing of two hand weeding at 20 and 40 recorded significantly higher cob weight plant^{-1} (95.12 g), number of grains cob^{-1} (313.67), grain weight cob^{-1} (72.29 g), test weight (223.83 g), shelling percentage (76.13%) being at par with atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS (94.43 g, 306.00, 70.44 g, 222.85 g, 74.59%, respectively) over weedy check. While minimum values of yield attributes recorded under weedy check. The better expression of yield attributes in herbicide treated and hand weeded plots might be due to minimum crop weed competition during critical phases of crop growth either manually or chemically, exerts an important regulation function on complex processes of yield formation, due to better availability of growth inputs *viz*., water, space and nutrients.

3.1. Effect on yields and harvest index

The various weed management practices significantly affected grain yield and data are presented in Table 3. Practicing of two hand weeding at 20 and 40 DAS being at par with atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS (3496 kg ha^{-1}), atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS (3380 kg ha^{-1}) and atrazine 500 g a.i. ha^{-1} (PE)+hand weeding at 30 DAS with *in situ* mulching with weeds (3293 kg ha^{-1}) recorded significantly highest grain yield (3540 kg ha^{-1}) over rest of the treatments. Two hand weeding at 20 & 40 DAS treatment recorded 141.1, 48.43, 54.02, 16.90, 7.49, 43.22, 35.46, 4.74, 1.25, 24.31 and 18.26 per cent more grain yield over weedy check, one hand weeding at 30 DAS with *in situ* mulching with weeds, atrazine 500 g a.i. ha^{-1} (PE), atrazine 500 g a.i. ha^{-1} (PE) + hand weeding at 30 DAS, atrazine 500 g a.i. ha^{-1} (PE) + hand weeding at 30 DAS with *in situ* mulching with weeds, tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS, topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1} + tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS and atrazine 500 g a.i. ha^{-1}+topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, respectively. The data presented in Table 3 shows that stover yield (kg ha^{-1}) of maize was significantly affected by various weed management practices. Implementation of two hand weeding at 20 and 40 DAS being at par with atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS (6460 kg ha^{-1}), atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75 g *a.i.* ha^{-1} at 20-25 DAS (6247 kg ha^{-1}), atrazine 500 g a.i. ha^{-1} (PE)+hand weeding at 30 DAS with *in situ* mulching with weeds (6103 kg ha^{-1}) recorded significantly highest stover yield (6530 kg ha^{-1}) over rest of the treatments. Respective treatment (two hand weeding at 20 and 40 DAS) recorded 138.76, 47.18, 52.63, 15.86, 6.99, 38.35, 31.08, 4.54,

Table 3: Effect of weed management practices on yield attributes of maize

Treatments	Yield attributes						Yield (kg ha^{-1})		Harvest index (%)	Net return (₹ ha^{-1})
	No. of cobs plant^{-1}	Cob weight plant^{-1} (g)	No. of grains cob^{-1}	Grain weight cob^{-1} (g)	Test weight (g)	Shelling percentage (%)	Grain	Stover		
T_1	0.93	63.64	181.33	38.77	213.46	60.91	1468	2735	34.93	15267
T_2	1.00	86.11	273.00	62.65	221.17	73.10	2385	4437	34.98	30542
T_3	1.00	95.12	313.67	72.29	223.83	76.13	3540	6530	35.16	50992
T_4	1.00	86.26	264.00	60.49	221.01	70.26	2298	4278	34.95	33172
T_5	1.00	93.59	289.00	66.59	222.44	71.21	3028	5636	34.97	44301
T_6	1.00	93.34	294.33	67.99	222.73	72.88	3293	6103	35.05	50134
T_7	1.00	87.13	260.33	59.92	221.31	68.73	2472	4720	34.37	33052
T_8	1.00	87.09	269.67	62.20	222.07	71.43	2613	4982	34.43	36098
T_9	1.00	93.83	295.33	68.64	222.75	73.15	3380	6247	35.11	52500
T_{10}	1.00	94.43	306.00	70.44	222.85	74.59	3496	6460	35.13	54984
T_{11}	1.00	91.62	284.00	64.47	222.07	70.27	2848	5290	34.90	40746
T_{12}	1.00	93.55	284.33	65.55	222.37	70.10	2993	5480	35.01	42978
SEm±	0.02	2.99	10.21	2.66	1.74	2.52	163	295	0.27	3595
CD (*p*=0.05)	NS	8.77	29.94	7.79	5.10	7.39	478	865	NS	10544

1.08, 23.44 and 19.16% more stover yield over weedy check, one hand weeding at 30 DAS with *in situ* mulching with weeds, atrazine 500 g a.i. ha^{-1} (PE), atrazine 500 g a.i. ha^{-1} (PE)+hand weeding at 30 DAS, atrazine 500 g a.i. ha^{-1} (PE)+hand weeding at 30 DAS with *in situ* mulching with weeds, tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS, topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1} (PE) followed by tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS, atrazine 500 g a.i. ha^{-1}+tembotrione 120.75 g a.i. ha^{-1} at 20-25 DAS and atrazine 500 g a.i. ha^{-1}+topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS respectively. Whereas, application of atrazine 500 g a.i. ha-1 (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS in maize fetched highest net returns of ₹ 54984 ha^{-1}. The yield was also significantly improved by individually application of atrazine and one hand weeding at 30 DAS over weedy check. Weed management practices did not affected significantly the harvest index of maize. Weed management practices brought down competition and created favourable micro-environment for better establishment, growth and development of maize crop.Weed control treatments also increased CGR, compared to weedy check that facilitated higher photosynthate production and translocation from source to sink, resulting in overall improvement in yield attributing traits and consequently the yields. Kumar and Angadi (2014), Samant et al. (2015) Teame et al. (2017) and Patel et al. (2018) also observed significant effect of weed control in increasing yield of maize.

4. Conclusion

Application of atrazine 500 g a.i. ha^{-1} (PE) followed by topramezone 25.2 g a.i. ha^{-1} at 20-25 DAS reduced weed infestation, improved grain yield of maize and fetched higher economic returns.

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