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EFFECT OF HERBICIDES ON GROWTH AND PRODUCTIVITY OF MAIZE

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ABSTRACT

A field experiment was carried out at College Farm, College of Agriculture, Navsari Agricultural University, Campus Bharuch during *kharif* 2024 to study the effect of herbicides on growth and productivity of maize in a randomized block design (RBD) with ten treatments which included: Weedy check (W_1), Weed free: handweeding and interculturing at 20 and 40 DAS (W_2), Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE fb HW and IC at 30 DAS (W_3), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE fb HW and IC at 30 DAS (W_4), Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE fb 2,4-D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS (W_5), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE fb Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS (W_6), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE fb Halosulfuron-methyl 5 + Atrazine 48 WG 56.25 + 540 kg a.i. ha^{-1} at 30 DAS ready mix (W_7), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE fb Mesotrione 2.27 w/w + Atrazine 22.7 w/w 0.875 kg a.i. ha^{-1} at 30 DAS ready mix (W_8), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE fb Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS ready mix (W_9), Smother crop (Sunhemp) fb 2,4, D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS (W_{10}). Among the different herbicide treatments significantly highest growth attributes (plant height at 60 DAS and at harvest, dry matter plant^{-1} at 30, 60 DAS and harvest, number of leaves plant^{-1} at harvest) yield attributes (number of grains cob^{-1}, cob length, cob girth, shelling percentage, 100 seed weight), grain yield (3580 kg ha^{-1}), straw yield (6308 kg ha^{-1}), crude protein yield (361.58 kg ha^{-1}), net return (₹ 92309 ha^{-1}) and BCR (3.50) was recorded under weed free treatment W_2 : Hand weeding and interculturing at 20 and 40 DAS and found statistically at par with treatment W_9 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix), W_3 (Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS) and W_6 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS).

(Key words: Maize, grain yield, pre and post emergence herbicides, economics)

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in the world s agriculture economy, both as food for human beings and feed for animals. No other cereal on Earth has as immense a potential as maize, which is why it is referred to as the Queen of Cereals. It is cultivated in an area of 4.00 lakh ha with the annual production of 8.57 lakh tonnes, having an average productivity of 2140 kg ha^{-1} (Anonymous, 2022). Among various maize yield-limiting factors, serious infestation of weeds is of immense importance. Weeds inflict more enormous losses in maize production than insect pests and diseases, thus hindering its productivity. Based on the sort of weed species in the standing crop, the magnitude of the decline in maize yield was estimated to be between 33 and 50 per cent (Shantveerayya and Agasimani, 2012). Different weed control methods are used in maize crops, among which chemical weed control is the most economical and effective method to suppress weeds in order to get a healthy and vigorous crop stand. Ali *et al.* (2003) concluded that herbicide application increased biological yield and decreased weed biomass significantly. Herbicide application is not only more effective and cheaper but also an efficient method to check weeds. Usage of chemical herbicides like atrazine and pendimethalin as a pre-emergence spray is effective in controlling broadleaf weeds and certain annual weeds. Post-emergence applications of atrazine and halosulfuron are also operational in regulating the weeds. Repeated use of the same herbicide over time, however, results in the development of weed tolerance to the specific chemical and the development of new biotypes. Therefore, it is important to use tank-mixed blending of various herbicides with various modes of action to extend weed control scope. Hence, a study was carried out to quantify the effect of herbicides in maize on managing weeds and improving productivity economically.

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MATERIALS AND METHODS

A field experiment was carried out at college farm, College of Agriculture, Navsari Agricultural University, Campus Bharuch during *kharif* 2024. The soil of experimental plot was clayey (*Vertisols*) with low in available N (240.42 kg ha^{-1}), medium in P_2O_5 (39.58 kg ha^{-1}) and high in K_2O (338.28 kg ha^{-1}). The soil reaction (pH) was slightly alkaline (7.68). The experiment arranged in a randomized block design, with three replications. Treatments were Weedy check (W_1), Weed free: Hand weeding and inter culturing at 20 and 40 DAS (W_2), Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS (W_3), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS (W_4), Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* 2,4,D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS (W_5), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS (W_6), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Halosulfuron - methyl 5 + Atrazine 48 WG 56.25+540 kg a.i. ha^{-1} at 30 DAS ready mix (W_7), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Mesotrione 2.27 w/w + Atrazine 22.7 w/w 0.875 kg a.i. ha^{-1} at 30 DAS ready mix (W_8), Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS ready mix (W_9), Smother crop (Sunhemp) *fb* 2,4, D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS (W_{10}), each with three replications. The seeds were sown at a spacing of 60 cm × 20 cm. The recommended fertilizer dosage for all the treatments was 100:50:00 kg ha^{-1} of N, P_2O_5 and K_2O, using urea, di-ammonium phosphate (DAP) and single super phosphate (SSP) respectively. In each plot five plants were randomly selected and tagged to record experimental observations on growth attributes (plant height at 30, 60 at DAS and at harvest, dry matter $plant^{-1}$ at 30, 60 DAS and harvest, number of leaves $plant^{-1}$ at harvest, days to 50 % tasseling), yield attributes (number of cobs $plant^{-1}$, number of grains cob^{-1}, number of grain rows cob^{-1}, cob length, cob girth, shelling percentage, 100 seed weight), yield (grain and straw) and quality (crude protein content and crude protein yield).

RESULTS AND DISCUSSION

Effect of herbicide on growth attributes

The data presented in Table-1 indicated that significantly highest plant height at 60 DAS and at harvest (127.68 cm and 198.42 cm, respectively), dry matter $plant^{-1}$ at 30, 60 DAS and harvest (6.83, 60.28, 110.53 g, respectively) and number of leaves $plant^{-1}$ at harvest (13.85) was recorded in treatment W_2 : Weed free (Hand weeding and interculturing at 20 and 40 DAS) which was found superior than rest of the treatments except Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} ready mix at 30 DAS (W_9), Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS (W_3) and Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS (W_6). However, significantly the lowest plant height (98.50 cm) was registered under the treatment W_1 (Weedy check). Different herbicide treatments did not significantly influence to days 50% tasseling and number of leaves $plant^{-1}$ at 30 and 60 DAS. This is due to less weed-crop competition throughout the growth stage of crop and created favorable environment for plant growth. Thus, enhance availability of nutrients, moisture, light and space which might have accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates, resulted in increase in growth characters. These findings are in agreement with those of Yashvanth and Shekara (2023) and Khunghatkar *et al.* (2024). Yashvanth and Shekara (2023) reported that among chemical weed management treatments atrazine (50% WP) @ 1 kg a.i. ha^{-1} as PE followed by topramezone (33.6% SC) @ 50 g a.i. ha^{-1} as PoE recorded significantly higher plant height (195.2 cm), which was on par with atrazine (50% WP) @ 1 kg a.i. ha^{-1} as PE followed by tembotrione (34.4% SC) @ 150 g a.i. ha^{-1} as PoE (193.1 cm) and atrazine (50% WP) @ 1 kg a.i. ha^{-1} as PE followed by 2,4-D (58% SL) @ 2.5 kg a.i. ha^{-1} as PoE (190.1 cm) and superior over rest of the treatments (150.1 cm to 183.1 cm). At harvest, treatment having atrazine (50% WP) @ 1 kg a.i. ha^{-1} as PE followed by topramezone (33.6% SC) @ 50 g a.i. ha^{-1} as PoE recorded significantly higher dry matter production (309.8 g $plant^{-1}$), which was on par with all other combinations of different herbicides (286.0 to 308.4 g $plant^{-1}$) and significantly superior over application of single herbicide alone (248.8 to 260.3 g $plant^{-1}$). Moni *et al.* (2024) reported that the weed free check recorded the significantly highest number of effective tillers (308 m^2) and grains $panicle^{-1}$ (101) of direct-seeded rice amongst all other treatments.

Effect of herbicide on yield attributes and yield

The data presented in Table 2 indicated that yield attributes of maize *viz*., number of grains cob^{-1} (420), cob length (20.0 cm), cob girth (15.6 cm), shelling percentage (81.4%), 100 seed weight (23.7 g) and grain yield (3580 kg ha^{-1}) and straw yield (6308 kg ha^{-1}) was recorded significantly higher under weed free treatment W_2 : (Hand weeding and interculturing at 20 and 40 DAS) and found statistically at par with treatment W_9 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix), W_3 (Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS) and W_6 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS). While, number of cobs $plant^{-1}$ and number of grain rows cob^{-1} was not significantly influenced by different herbicides treatments. The improved yield attributes under the treatments might be due to periodical removal of weeds by hand weeding as evidenced by a smaller number of weeds and dry weight of weeds, which might have maintained high soil fertility status and moisture content by means of less removal of plant nutrients and water by weeds. This might have increased nutrients and water uptake by the crop leading to increase in rate of photosynthesis. Supply of photosynthates to various metabolic sinks might have favoured yield attributes. Improved yield attributes under the treatment W_9 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone

10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix) might be attributed to better control of weeds from the initial stage by pre-emergence applied Atrazine and post-emergence application of Tembotrione or Topramezone as evidenced by less count and dry weight of weeds which might have resulted in the better utilization of nutrients and moisture available in the soil by the crop leading to production of more photosynthates. These findings are in close conformity with those reported by Vijay *et al.* (2017), Kunghatkar *et al.* (2024), Lunge *et al.* (2023), Twinkle and Kumar (2022), Patel *et al*. (2006), Swetha *et al*. (2015) and Rao *et al*. (2016). Vijay *et al.* (2017) reported that weed free treatment registered significantly higher grain yield (5917.82 kg ha^{-1}) and straw yield (8995.10 kg ha^{-1}), which proved significantly superior to other treatments. The weed free treatment recorded significantly higher number of grains $panicle^{-1}$ (101), test weight (17.73 g), grain yield (4126 kg ha^{-1}), straw yield (5570 kg ha^{-1}) and harvest index (42.55 %) of direct-seeded rice amongst all other treatments reported by Kunghatkar *et al.* (2024). Lunge *et al.* (2023) found that the weed free treatment recorded significantly highest grain and straw yield amongst all other treatments. The highest grain yield and straw yield of wheat was recorded under weed free treatment (55.50 q ha^{-1}) and (72.45 q ha^{-1}) followed by Sulfosulfuron + metsulfuron 32 g ha^{-1} *i.e*. 55.27 q ha^{-1} and 71.07 q ha^{-1}, respectively reported by Twinkle and Kumar (2022). Patel *et al*. (2006) observed hand weeding carried out at 20 and 40 DAS recorded maximum girth and length of cobs followed by atrazine at 0.50 kg ha^{-1} in combination with pendimethalin at 0.25 kg ha^{-1} or atrazine+alachlor. Whereas maximum number of grains cob^{-1} and test weight were recorded with atrazine at 0.50 kg ha^{-1} in combination with pendimethalin at 0.25 kg ha^{-1} followed by twice hand weedings done at 20 and 40 DAS. In general, twice hand weedings and atrazine at 0.50 kg ha^{-1} in combination with pendimethalin at 0.25 kg ha^{-1} were found to be superior and recorded higher grain yield (3658 and 3652 kg ha^{-1}, respectively) as compared to all the treatments of herbicide applied alone, alachlor+metolachlor, alachlor+metribuzin and weedy check. Swetha *et.al*. (2015) observed maximum grain yield (6.58 t ha^{-1}) and stover yield (8.04 t ha^{-1}) in hand weeding at 20 and 40 DAS treatment which was 60.5 % over the unweeded control and on par with topramezone + atrazine at 25.2 + 250 g ha^{-1} + MSO as PoE (6.44 t ha^{-1}) with 59.6 % increase over the unweeded control and tembotrione + atrazine at 105 + 250 g ha^{-1} + stefes mero as PoE (6.28 t ha^{-1}) with 58.7% increase over the control. Rao *et al.* (2016) observed hand weeding at 20 and 40 DAS recorded the highest cob length, grain rows cob^{-1}, grains row^{-1}, total grains cob^{-1}, grain weight cob^{-1}, test weight, grain yield and stover yield. Atrazine @ 1.0 kg a.i ha^{-1} PE fb topramezone spray @ 25 g a.i ha^{-1} at 20 DAS and pendimethalin @ 1.0 kg a.i ha^{-1} PE fb topramezone spray @ 25 g a.i ha^{-1} at 20 DAS were on a par with hand weeding for the yield and yield attributes.

Effect of herbicide on quality parameters

Based on the data provided in Table 3 different herbicides treatments did not result in any significant changes in the crude protein content of maize. However, it is worth nothing that the numerically the highest crude protein content (10.10 %) recorded under the treatment W_2 (Weed free: Hand weeding and interculturing at 20 and 40 DAS)) and lowest protein content (9.34%) was recorded with treatment W_1 (Weedy check). Moreover, significantly higher crude protein yield (361.58 kg ha^{-1}) was registered under treatment W_2 (Weed free: Hand weeding and interculturing at 20 and 40 DAS), which was statistically at par with treatment W_9 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix), W_3 (Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS) and W_6 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS). Significant enhancement in crude protein content and crude protein yield of maize was obtained under weed free treatment (W_2) as compared to weedy check (W_1). The trend of increase in crude protein content and crude protein yield as compared to weedy check was linear. This could be due to higher uptake of nitrogen consequent to higher mineralization of soil nitrogen. Due to higher values of growth attributes, more utilization of nitrogen indirectly helps in crude protein content. The result confirms the findings of Patel *et al*. (2006). Patel *et al*. (2006) observed significantly higher protein content in grain (7.09 %) with hand weeding at 20 and 40 DAS and it was at par with atrazine at 0.50 kg ha^{-1} in combination with pendimethalin at 0.25 kg ha^{-1}.

Economics

The data reflected that maximum net return (₹ 92309 ha^{-1}) was achieved with treatments W_2 (Weed free: Hand weeding and interculturing at 20 and 40 DAS) along with BCR of 3.50 which was statistically at par with treatment W_3 (Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS) and W_9 (Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS ready mix). The increase in net return might be due to higher grain yield obtained under these treatment as compared to cost involved under these treatments. This might be due to effective and efficient control of weeds by hand weeding and pre-emergence herbicide atrazine and post-emergence herbicides Tembotrione and Topramezone. The highest B:C ratio under these treatments might have been due to less cost of herbicides and higher production of grain as well as fodder. These findings are in close vicinity with those reported by Dobariya *et al.* (2014), Swetha *et al*. (2015), Srinivasulu *et al*. (2016), Mandi *et al*. (2019) and Sabiry and Babu (2019). Dobariya *et al.* (2014) recorded maximum net realization of ₹ 77,926 ha^{-1} and BCR of 3.14 with weed free treatment followed by HW and IC at 15 and 30 DAS and atrazine 0.5 kg ha^{-1} as PE + 1 HW and IC at 30 DAS. Swetha *et al*. (2015) reported higher net return (₹62610 ha^{-1}) and benefit: cost ratio (3.17) in tank mix of topramezone + atrazine at 25.2 + 250 g ha^{-1} + MSO as PoE treatment followed by atrazine as PE followed by intercultivation at 30 DAS. Srinivasulu *et al*. (2016) observed the treatment received paraquat spray immediately after dibbling maize

Table 1. Effect of different herbicides on growth attributes of maize

Treatments	Plant height (cm)			Days to 50% tasseling	Dry matter accumulation (g plant^{-1})			No. of leaves plant^{-1}		
	30 DAS	60 DAS	At harvest		30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
W_1 : Weedy check	39.6	98.5	150.3	48.3	5.60	46.50	90.86	6.20	8.28	11.20
W_2 : Weed free (Hand weeding and interculturing at 20 and 40 DAS)	44.8	127.6	198.4	52.6	6.83	60.28	110.53	7.01	10.35	13.85
W_3 : Atrazine 50 WP 1.0 kg a.i. ha $^{-1}$ as PE *fb* HW and IC at 30 DAS	42.0	122.6	185.6	51.6	6.35	55.92	103.67	7.25	10.05	13.05
W_4 : Pendimethalin 30 EC 1.0 k a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS	41.9	110.9	176.1	51.0	6.00	53.00	99.15	6.87	9.75	12.20
W_5 : Atrazine 50 WP 1.0 kg a.i. ha $^{-1}$ as PE *fb* 2,4-D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS	41.3	107.0	172.8	50.0	5.96	51.07	97.06	6.30	8.87	11.51
W_6 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS	42.0	120.0	182.6	51.3	6.30	55.78	102.35	6.98	9.51	12.50
W_7 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Halosulfuron –methyl 5 + Atrazine 48 WG 56.25+540 kg a.i. ha $^{-1}$ at 30 DAS (Ready mix)	41.6	107.8	173.9	50.3	5.73	52.95	96.20	6.92	8.98	11.98
W_8 : Pendimethalin 30 EC 1.0 kg a.i. ha $^{-1}$ as PE *fb* Mesotrione 2.27 w/w + Atrazine 22.7 w/w 0.875 kg a.i. ha^{-1} at 30 DAS (Ready mix)	40.8	108.8	174.5	50.6	6.00	53.20	98.72	6.97	9.13	12.03
W_9 : Pendimethalin 30 EC 1.0 k a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix)	43.5	123.6	187.9	52.0	6.39	56.68	103.90	7.01	9.80	12.90
W_{10} : Smother crop (Sunhemp) fb 2,4, D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS	40.0	104.2	165.8	49.6	5.90	51.02	93.07	6.45	9.00	11.53
SE (m) $\pm$	1.75	4.67	6.67	1.93	0.21	2.21	3.54	0.31	0.43	0.51
CD at 5 %	-	14.01	20.01	-	0.63	6.63	10.62	-	-	1.53

Table 2. Effect of different herbicides on yield attributes and yield of maize

Treatments	No. of cobs plant^{-1}	No. of grains cob^{-1}	No. of grain rows cob^{-1}	Cob length (cm)	Cob girth (cm)	Shelling (%)	100 seed weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1}
W_1 : Weedy check	1.23	290.0	13.2	14.9	11.9	59.9	20.2	2612	3573
W_2 : Weed free (Hand weeding and interculturing at 20 and 40 DAS)	1.87	420.0	14.0	20.0	15.6	81.4	23.7	3580	6308
W_3 : Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS	1.80	395.3	13.8	19.0	15.0	76.9	22.9	3395	5758
W_4 : Pendimethalin 30 EC 1.0 k a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS	1.53	370.0	13.7	17.8	14.0	73.3	21.5	3015	4974
W_5 : Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* 2,4-D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS	1.40	345.7	13.4	17.0	13.3	69.6	20.7	2967	4789
W_6 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS	1.73	388.0	13.8	18.6	14.9	75.2	22.0	3280	5381
W_7 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Halosulfuron –methyl 5 + Atrazine 48 WG 56.25+540 kg a.i. ha^{-1} at 30 DAS (Ready mix)	1.48	365.9	13.6	17.2	13.2	70.0	21.1	2995	4845
W_8 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Mesotrione 2.27 w/w + Atrazine 22.7 w/w 0.875 kg a.i. ha^{-1} at 30 DAS (Ready mix)	1.50	369.7	13.6	17.6	13.8	72.6	21.2	3000	4926
W_9 : Pendimethalin 30 EC 1.0 k a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix)	1.83	406.3	13.9	19.2	15.3	78.1	22.3	3409	5987
W_{10} : Smother crop (Sunhemp) *fb* 2,4-D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS	1.47	340.8	13.5	16.9	12.8	67.3	20.8	2750	4656
SE (m) $\pm$	0.15	16.0	0.49	0.7	0.5	2.3	0.66	186	337
CD at 5 %	-	48.0	-	2.1	1.5	6.8	1.98	558	1011

Table 3. Effect of different herbicides on quality parameters and economics of maize

Treatments	Crude protein Content (%)	Crude protein Yield (kg ha^{-1})	Net return (₹ ha^{-1})	BCR
W_1 : Weedy check	9.34	243.96	53213	2.62
W_2 : Weed free (Hand weeding and interculturing at 20 and 40 DAS)	10.10	361.58	92309	3.50
W_3 : Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS	9.95	337.80	84899	3.37
W_4 : Pendimethalin 30 EC 1.0 k a.i. ha^{-1} as PE *fb* HW and IC at 30 DAS	9.90	298.49	69911	2.93
W_5 : Atrazine 50 WP 1.0 kg a.i. ha^{-1} as PE *fb* 2,4-D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS	9.77	289.88	69384	3.02
W_6 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Tembotrione 34.4 SC 0.12 kg a.i. ha^{-1} at 30 DAS	9.93	325.70	77406	3.05
W_7 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Halosulfuron –methyl 5 + Atrazine 48 WG 56.25+540 kg a.i. ha^{-1} at 30 DAS (Ready mix)	9.87	295.61	69579	2.98
W_8 : Pendimethalin 30 EC 1.0 kg a.i. ha^{-1} as PE *fb* Mesotrione 2.27 w/w + Atrazine 22.7 w/w 0.875 kg a.i. ha^{-1} at 30 DAS (Ready mix)	9.90	297.00	67347	2.77
W_9 : Pendimethalin 30 EC 1.0 k a.i. ha^{-1} as PE *fb* Topramezone 10 g l^{-1} + Atrazine 300 g l^{-1} SC 0.775 kg a.i. ha^{-1} at 30 DAS (Ready mix)	9.99	340.56	84682	3.22
W_{10} : Smother crop (Sunhemp) *fb* 2,4-D amine salt 58 SL 0.5 kg a.i. ha^{-1} at 30 DAS	9.75	268.13	61525	2.70
SE (m) ±	0.25	17.87	-	-
CD at 5 %	-	53.61	-	-

seeds fb Topramezone @ 25 g a.i. ha^{-1} + Atrazine @ 0.625 kg a.i. ha^{-1} as post at 20 DAS resulted in higher net returns (₹ 29098 ha^{-1}) and benefit cost ratio (1.75). Mandi *et al*. (2019) reported weed-free check recorded significantly higher gross returns, being at par with atrazine + pendimethalin + HW. The highest net returns was recorded under atrazine + pendimethalin + 2, 4-D treatment, being at par with atrazine + 2,4-D and pendimethalin + 2, 4-D. Treatment of atrazine + pendimethalin + 2, 4-D resulted in 1.99 times more net returns than weed-free check. With respect to benefit: cost ratio (B:C) the highest B:C was recorded in atrazine + pendimethalin + 2, 4-D (0.54). Sabiry and Babu (2019) reported that pre-emergence application of atrazine 1.25 kg ha^{-1} at sowing + one intercultivation at 30 DAS + one hand weeding at 45 DAS recorded maximum net return (₹ 99535 ha^{-1}) followed by weed free (₹ 97584 ha^{-1}) and Tank mixture Topramezon 12.5 g ha^{-1} + Atrazine 625 g ha^{-1} at 20 DAS (Early PoE) (₹ 97259 ha^{-1}).

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