Plant Archives Vol. 26, Supplement 2, 2026 pp. 2912-2918 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.371

BIO-EFFICACY OF PRE- AND POST-EMERGENCE HERBICIDES AND THEIR COMBINATIONS AGAINST COMPLEX WEED FLORA OF *KHARIF* MAIZE

Devvart Thakur, Amit Dhankar*, Sonali Sharma, Ruchika and Janak Yadav
Faculty of Agriculture, Maharishi Markandeshwar
(Deemed to be University) Mullana-133207, Ambala (Haryana) India
*Corresponding author E-mail: amitdhankarhau@gmail.com
(Date of Receiving : 08-05-2026; Date of Revision : 27-06-2026; Date of Acceptance : 14-07-2026)

ABSTRACT

A field experiment was conducted to find out the best combinations of pre- and post-emergence herbicides in maize for effective weed control and higher productivity at Maharishi Markandeshwar (Deemed to be University) Mullana, Ambala, Haryana, in *kharif* 2025. The experiment was laid out in a Randomized Block Design with sixteen treatments. Treatments included five pre-emergence (PRE) herbicides comprised T_1: atrazine at 750 g ha^{-1}, T_2: metribuzin at 210 g ha^{-1}, T_3: pendimethalin at 1000 g ha^{-1}, T_4: atrazine at 375 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM), T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) along with six post-emergence herbicides (PoE) T_6: topramezone (7%) + atrazine (63%) at 130 g ha^{-1}(RM), T_7: mesotrione (3.28%) + atrazine (27.6%) at 1000 g ha^{-1} (RM),T_8: halosulfuron-methyl at 67.5 g ha^{-1}, T_9: halosulfuron-methyl at 67.5 g ha^{-1} + atrazine at 750 g ha^{-1} (TM), T_{10}: tembotrione at 100 g ha^{-1},T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione and three pre *fb* post-emergence herbicides (PRE *fb* PoE) T_{12}: atrazine at 750 g ha^{-1} *fb* tembotrione at 120 g ha^{-1}, T_{13}: atrazine at 750 g ha^{-1} *fb* halosulfuron-methy at 67.5 g ha^{-1}, T_{14}: pendimethalin at 1000 g ha^{-1} *fb* 2,4-D amine at 500 g ha^{-1} were be used. Hand weeding thrice at 25, 50 and 75 DAS, T_{15}: weedy check and T_{16}: weed free treatments were also included. Major weed species infesting the experimental field were *Cyperus rotundus*, *Amaranthus viridis*, *Digera arvensis*, *Phyllanthus niruri*, *Cynodon dactylon*, *Echinochloa colona*, *Brachiaria reptans* and *Dactyloctenium aegyptium*. Among herbicide treatments at 30 DAS, T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) as PRE provided the highest weed control efficiency (69.8 %) and at 90 DAS the highest weed control efficiency (83.9 %). Maximum grain yield (6835 kg/ha) and yield attributes of maize were obtained in weed free treatment which was statistically at par with treatment T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE (6732 kg/ha) and also obtained highest B:C ratio (1.83) among all other herbicide treatments.

***Keywords*:** Tembotrione, Topramezone, Weed control efficiency, pre-and post-emergence herbicides, yield

Introduction

Maize (*Zea mays* L.) is one of the most versatile crops having wider adaptability under diverse soil and climatic conditions. It is an important annual cereal crop belonging to the grass family, Poaceae (gramineae). Globally, maize cultivation covers about 203.47 million hectares (Mha), producing 1163.5 million tonnes (mt) with an average yield of 5.73 t/ha. In India, maize is grown on approximately 9.95 mha, yielding 33.7 mt with a productivity of 3.38 t/ha (FAOSTAT, 2022). Maize occupies importance as a human food (25%), poultry supplement (49%), animal supplement (12%), and industrial products such as starch (12%). Maize also contains maximum genetic yield potential, therefore maize is known as "Queen of cereals" (India Maize Summit, 2018). Maize is infested by a wide range of weed flora, viz. *Panicum spp*., *Echinochloa colona*, *Cyperus rotundus*, *Commelina benghalensis* and *Trianthema portulacastrum* dominate during early crop growth stages, whereas *Dactyloctenium aegyptium* toward the tasseling and crop maturity (Singh *et al*. 2015). The critical period for crop weeds competition in maize is the first six weeks owing to initial slow growth and wider row spacing of maize, coupled with congenial weather conditions allow luxuriant weed growth which may reduce yield by 28–100 % (Pandey *et al*., 1999; Dass *et al*., 2012). In addition, continuous rainfall hinders manual weeding, therefore favoured weed growth which may reduce maize yield by 28–100% (Sharma *et al*., 2018). In addition, weeding by manual and mechanical means is not possible due to continuous rains in the monsoon season (Sepat *et al*., 2017). In maize, the most prevalent pre-emergence herbicide is atrazine used by farmers for weed control. However, several reports indicated that atrazine has developed resistance in certain weeds *Sonchus oleraceus*, *Sisymbrium orientale* and *Rapistvum rugosum* in several countries (Adkins *et al*., 2008). Under such circumstances, there is an urgent need to explore other alternatives to these herbicides through the availability of new post-emergence herbicides such as topramezone and tembotrione. Here, topramezone and tembotrione are selective, post-emergence herbicides that have been recently introduced for use in maize (Zhao *et al*., 2017). These HPPD (4-hydroxyphenylpyruvate dioxygenase) inhibiting herbicides are most effective in weeds control by bleaching of developing tissues. According to (Singh *et al*., 2012), these herbicides demonstrate high effectiveness in rapidly reducing both grass and broad-leaf weeds in maize within a short period of 2–5 DAS. To effectively manage weeds, it is essential to utilize either a combination or sequential application of pre-or post-emergence herbicides. As the critical period of crop-weed competition extends up to 50 days these provide an easy option for herbicidal-based weed management in maize, especially in later seasons. Additionally, in the scenario of no pre-emergence weed management, farmers can have options of suitable post-emergence herbicides for saving their crop from weed losses. Application of tembotrione at 125 and 150 g/ha at 20 DAS effectively reduced the dry weight of *Echinochloa colona*, *Commelina benghalensis*, *Polygonum alatum*, *Ageratum Conyzoides*, and produced higher grain yield of maize at Palampur (Rana *et al*., 2017). Tank mix application of tembotrione at 120 g/ha and topramezone at 25.2 g/ha as early post-emergence at 15 DAS or as a sequential application at 25 DAS with atrazine at 750 g/ha resulted in significantly high weed control and enhanced the yield of the maize (Chhokar *et al*., 2019). Tembotrione application in maize reduced the *rhizomatous Sorghum halepense* by 60 - 82% in Northern Greece. In addition, narrow-leaved weeds (NLWs), viz., *Echinochloa crus-galli*, and *Setaria viridis* were decreased by 90% without affecting the grain yield of maize (Su *et al*., 2020). It has been observed that recently developed herbicides need to be tested at various combinations or in alone to find out the consolidated impact on maize productivity. Therefore, an experiment was initiated to identify suitable pre- and post-emergence herbicide and their combinations against complex weed flora of maize.

Materials and Methods

The field experiment was conducted during the *kharif* season of 2025 at the Research Farm of Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala, Haryana. The experiment was laid out in a Randomized Block Design with sixteen treatments and three replications. The treatments comprised T_1: atrazine at 750 g ha^{-1} as PRE, T_2: metribuzin at 210 g ha^{-1} as PRE, T_3: pendimethalin at 1000 g ha^{-1} as PRE, T_4: atrazine at 375 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) as PRE, T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) as PRE, T_6: topramezone (7%) + atrazine (63%) at 130 g ha^{-1}(RM) as PoE, T_7: mesotrione (3.28%) + atrazine (27.6%) at 1000 g ha^{-1} (RM) as PoE, T_8: halosulfuron-methyl at 67.5 g ha^{-1} as PoE, T_9: halosulfuron-methyl at 67.5 g ha^{-1} + atrazine at 750 g ha^{-1} (TM) as PoE, T_{10}: tembotrione at 100 g ha^{-1} as PoE, T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) applied as PoE ,T_{12}: atrazine at 750 g ha^{-1} *fb* tembotrione at 120 g ha^{-1} as PPE *fb* PoE, T_{13}: atrazine at 750 g ha^{-1} *fb* halosulfuron-methy at 67.5 g ha^{-1} applied as PPE *fb* PoE, T_{14}: pendimethalin at 1000 g ha^{-1} *fb* 2,4-D amine at 500 g ha^{-1} applied as PE *fb* PoE, T_{15}: weed-free ,T_{16}: weedy check. . Maize variety P-3396 was taken, and sown during the second fortnight of July. The crop was sown on the ridge with a distance of 67.5 cm of row × row and 20 cm of plant × plant using 20 kg/ha seed. Irrigation was applied as per the crop requirement. The recommended dose of 180 kg N, 60 kg P_2O_5 and 40 kg K_2O through urea, di-ammonium phosphate and muriate of potash, respectively was applied in maize. A full amount P_2O_5 and K_2O was applied at sowing time while N was given in three equal splits at sowing, knee height (35 DAS) and tasseling stage (55 DAS). Pre emergence herbicides were sprayed 2 DAS of *kharif* maize, whereas post emergence herbicides were sprayed 27 DAS during the experimental year. Herbicides were sprayed with manually operated knapsack sprayer fitted with electric motor and flat fan nozzle using 300 litres of water per ha. Weed free plots were kept free from weeds by manual hoeing at 25, 50 and 75 DAS during the year. Species wise weed density was recorded using 0.5 m × 0.5 m quadrate at

30 and 90 days after sowing of maize. The weeds taken out to count weed density (No./m^2) species wise were oven dried and weight was expressed as g/m^2. Weed control efficiency (WCE) of each treatment was calculated using the formula (Mani *et al*., 1973). Yield attributes, viz. cob length and numbers of grain/cob were determined from ten randomly selected cob from each net plot and average value was calculated. The grain yield and stover yield were obtained from the net plot area, converted into kg ha^{-1}.

Net return (Rs. ha^{-1}) was calculated by subtracting the cost of cultivation from the gross return of the individual treatments.

Net Returns (Rs. ha^{-1})

= Gross returns – Cost of cultivation

Benefit-cost ratio (Rs. /re-invested) was calculated with gross return dividing by cost of cultivation

$$B:C = \frac{\text{Gross return}\left(ha^{-1}\right)}{\text{Cost of cultivation}\left(ha^{-1}\right)}$$

Data of all the observations are statistical analysis. Data on weed density and weed dry weight was square root transformed before analysis. Where the F test was significant (at 5% level of significance), the critical difference (CD) was used to compare mean (P=0.05).

Results and Discussion

Weed flora

The major weeds appeared in the experimental field at all the stages of observation were *Cyperus rotundus* among sedges, *Amaranthus viridis*, *Digera arvensis*, and *Phyllanthus niruri* among broad leaf weeds, *Cynodon dactylon*, *Echinochloa colona*, *Brachiaria reptans* and *Dactyloctenium aegyptium* as grassy weeds. Sedges constitute (57.55 and 61.38%) of weed flora followed by grassy weeds (31.10 and 34.11%) and broadleaf weeds (7.48 and 8.35%) at 30 and 90 days after sowing.

Effect on weeds

All the weed control treatments significantly reduced the density of all weeds over weedy check at 30 and 90 DAS. At 30 DAS, among different herbicide treatments, density of sedges showed non-significant and at 90 DAS minimum density of sedges was recorded in treatment T_9: halosulfuron-methyl 67.5 g ha^{-1} + atrazine 750 g ha^{-1} (TM) as PoE at par with T_{11}, T_8 and T_{13}. Pendimethalin (T_3) applied pre-emergence was not effective in controlling sedges in *kharif* maize. The lowest density of grassy weeds was in treatment T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) as PRE at par T_4, T_{14} and T_3 at 30 DAS and at 90 DAS minimum density of grassy weeds was recorded in treatment T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE at par T_{12}, T_{10} and T_{13}. At 30 DAS minimum density of broadleaf weeds was recorded in treatment T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) applied as PRE at par with T_2, T_{12} and T_{13}. At 90 DAS the lowest broadleaf weed density recorded in treatment T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE at par T_7, T_9, and T_{14}.

All the weed control treatments resulted in significantly lower the dry weight of all weeds than weedy check at 30 and 90 DAS. At 30 DAS minimum dry weight of sedges was recorded in treatment T_9: halosulfuron-methyl at 67.5 g ha^{-1} + atrazine at 750 g ha^{-1} (TM) as PoE at par with T_4, and T_5, T_7, T_{10} each recorded same dry weight (3.03 g m^{-2}) and at 90 DAS lowest dry weight of sedge were observed among the treatments T_9: halosulfuron-methyl 67.5 g ha^{-1} + atrazine 750 g ha^{-1} (TM) as PoE at par with T_{11}, T_8 and T_{13}.The lowest dry weight of grassy weeds was in treatment T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) as PRE at par T_4, T_{14} and T_3 at 30 DAS and at 90 DAS minimum dry weight of grassy weeds was recorded in treatment T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE at par T_{13}, T_{12} and T_6. At 30 DAS the lowest dry weight of broadleaf weeds was recorded in treatment T_5: metribuzin at 105 g ha^{-1} + pendimethalin at 500 g ha^{-1} (TM) applied as PRE at par with T_2, T_4 and T_{12}. At 90 DAS the lowest broadleaf weed dry weight recorded in treatment T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE at par T_7, T_9, and T_{14}.

The data indicated that highest weed control efficiency of 100% was in T_{15}: weed free and lowest in T_{16}: weedy check treatment at various stages of crop growth. At 30 DAS the higher weed control efficiency was recorded in T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE (69.8%), at par with T_4 (65.7%), T_{14} (51.9%), and T_3 (49.5%) and at 90 DAS among the herbicide treatments, T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE maintained the highest weed control efficiency (83.9 %) among all herbicide treatments at par with T_{13} (70.8 %) and T_7 (70.1%) during *kharif* 2025, respectively.

Table 1: Effect of pre and post emergence herbicides application on weed density (No. m^{-2}) at different stages of crop growth in *kharif* maize

Treatment details		Dose (g ha^{-1})	Time of application	Sedges		Grasses		BLWs	
				30 DAS	90 DAS	30 DAS	90 DAS	30 DAS	90 DAS
T_1	Atrazine	750	PRE	10.60 (111.3)	9.87 (96.5)	8.14 (65.3)	7.16 (50.3)	3.32 (10.0)	3.08 (8.5)
T_2	Metribuzin	210	PRE	10.68 (113.1)	9.75 (94.0)	6.22 (37.7)	6.29 (38.6)	2.89 (7.3)	2.70 (6.3)
T_3	Pendimethalin	1000	PRE	10.46 (108.3)	10.06 (100.3)	5.32 (27.3)	5.59 (30.2)	4.43 (18.7)	3.86 (13.9)
T_4	Atrazine + pendimethalin (TM)	375 + 500	PRE	10.38 (106.8)	9.69 (93.0)	4.93 (23.3)	5.33 (27.4)	2.97 (7.8)	3.13 (8.8)
T_5	Metribuzin + pendimethalin (TM)	105 + 500	PRE	10.40 (107.2)	9.49 (89.0)	4.43 (18.6)	4.48 (19.1)	2.51 (5.3)	2.70 (6.3)
T_6	Toperamezone (7%) + atrazine (63%)-RM	130	PoE	10.83 (116.3)	8.78 (76.0)	9.98 (98.7)	4.29 (17.4)	5.07 (24.7)	2.63 (5.9)
T_7	Mesotrione (3.28%) + atrazine (27.6%)-RM	1000	PoE	10.76 (114.7)	8.44 (70.3)	9.86 (96.3)	4.53 (19.5)	4.90 (23.0)	2.28 (4.2)
T_8	Halosulfuron-methyl	67.5	PoE	10.50 (109.3)	3.62 (12.1)	9.71 (93.3)	7.95 (62.3)	4.62 (20.3)	3.49 (11.2)
T_9	Halosulfuron-methyl + atrazine (TM)	67.5 + 750	PoE	10.38 (106.7)	3.42 (10.7)	9.63 (91.7)	7.58 (56.5)	4.44 (18.7)	2.42 (4.9)
T_{10}	Tembotrione	100	PoE	10.92 (118.3)	8.36 (68.9)	9.81 (95.3)	4.30 (17.5)	5.03 (24.3)	2.67 (6.1)
T_{11}	Halosulfuron-methyl + tembotrione (TM)	67.5 + 120	PoE	10.69 (113.3)	3.56 (11.7)	9.78 (94.7)	3.56 (11.7)	4.83 (22.3)	2.07 (3.3)
T_{12}	Atrazine *fb* tembotrione	750 + 120	PRE *fb* PoE	10.65 (112.5)	8.57 (72.4)	8.00 (63.0)	4.26 (17.2)	3.21 (9.3)	2.79 (6.8)
T_{13}	Atrazine *fb* halosulfuron-methyl	750 + 67.5	PRE *fb* PoE	10.73 (114.2)	4.12 (16.0)	7.98 (62.6)	3.92 (14.4)	3.27 (9.7)	2.83 (7.0)
T_{14}	Pendimethalin *fb* 2,4-D amine	1000 + 500	PRE *fb* PoE	10.54 (110.1)	7.42 (54.0)	5.25 (26.5)	5.37 (27.8)	4.35 (17.9)	2.46 (5.1)
T_{15}	Weed free	-	-	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
T_{16}	Weedy check	-	-	10.73 (114.2)	9.99 (98.8)	10.02 (99.3)	8.90 (78.3)	4.97 (23.7)	4.49 (19.2)
SE(m) ±				0.09	0.07	0.07	0.06	0.04	0.02
CD at 5% level of significance				NS	0.23	0.20	0.17	0.12	0.07

*Original values are in parenthesis and before statistical analysis were subjected to square root transformation (√x+1)

Table 2: Effect of pre and post emergence herbicides application on weed dry weight (g m^{-2}) and weed control efficiency at different stages of crop growth in *kharif* maize

Treatment details		Dose (g ha^{-1})	Time of application	Sedges		Grasses		BLWs		WCE	
				30 DAS	90 DAS	30 DAS	90 DAS	30 DAS	90 DAS	30 DAS	90 DAS
T_1	Atrazine	750	PRE	3.16 (9.0)	4.48 (19.1)	3.67 (12.4)	5.08 (24.8)	2.42 (4.9)	5.73 (31.8)	43.6	35.7
T_2	Metribuzin	210	PRE	3.08 (8.5)	4.40 (18.3)	2.85 (7.1)	4.47 (18.9)	2.12 (3.5)	4.94 (23.4)	59.1	48.4
T_3	Pendimethalin	1000	PRE	3.20 (9.3)	4.62 (20.4)	2.46 (5.1)	3.89 (14.1)	3.19 (9.1)	7.28 (52.0)	49.5	26.5
T_4	Atrazine + pendimethalin (TM)	375 + 500	PRE	3.01 (8.0)	4.32 (17.7)	2.29 (4.2)	3.71 (12.7)	2.17 (3.7)	5.81 (32.7)	65.7	46.4
T_5	Metribuzin + pendimethalin (TM)	105 + 500	PRE	3.03 (8.2)	4.21 (16.7)	2.09 (3.3)	3.14 (8.8)	1.87 (2.5)	4.94 (23.4)	69.8	58.4
T_6	Toperamezone (7%) + atrazine (63%)-RM	130	PoE	3.16 (9.0)	3.72 (12.8)	4.71 (21.2)	2.92 (7.5)	4.06 (15.5)	4.75 (21.6)	1.8	64.4
T_7	Mesotrione (3.28%) + atrazine	1000	PoE	3.03	3.54	4.64	3.05	3.93	4.04	7.1	70.1

	(27.6%)-RM			(8.2)	(11.5)	(20.5)	(8.3)	(14.5)	(15.3)		
T_8	Halosulfuron-methyl	67.5	PoE	3.19 (9.2)	1.69 (1.9)	4.57 (19.9)	5.29 (27.0)	3.71 (12.8)	6.48 (41.0)	10.0	40.6
T_9	Halosulfuron-methyl + atrazine (TM)	67.5 + 750	PoE	3.00 (8.0)	1.62 (1.6)	4.53 (19.5)	4.98 (23.8)	3.58 (11.8)	4.35 (17.9)	15.6	63.2
T_{10}	Tembotrione	100	PoE	3.03 (8.2)	3.58 (11.9)	4.62 (20.3)	2.94 (7.7)	4.04 (15.3)	4.83 (22.3)	5.9	64.5
T_{11}	Halosulfuron-methyl + tembotrione (TM)	67.5 + 120	PoE	3.03 8.2)	1.67 (1.8)	4.60 (20.2)	2.47 (5.1)	3.88 (14.1)	3.62 (12.1)	8.9	83.9
T_{12}	Atrazine *fb* tembotrione	750 + 120	PRE *fb* PoE	3.11 (8.7)	3.53 (11.4)	3.60 (12.0)	2.89 (7.4)	2.35 (4.5)	5.08 (24.8)	45.9	62.9
T_{13}	Atrazine *fb* halosulfuron-methyl	750 + 67.5	PRE *fb* PoE	3.08 (8.5)	1.86 (2.5)	3.59 (11.9)	2.69 (6.2)	2.39 (4.7)	5.16 (25.7)	46.1	70.8
T_{14}	Pendimethalin *fb* 2,4-D amine	1000 + 500	PRE *fb* PoE	3.11 (8.7)	3.04 (8.2)	2.44 (4.9)	3.64 (12.2)	3.13 (8.8)	4.43 (18.6)	51.9	66.8
T_{15}	Weed free	-	-	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	100.0	100.0
T_{16}	Weedy check	-	-	3.20 (9.3)	5.05 (24.5)	4.78 (21.9)	5.68 (31.3)	4.05 (15.4)	7.93 (61.9)	0.0	0.0
SE(m) ±				0.07	0.03	0.03	0.03	0.02	0.04	-	-
CD at 5% level of significance				0.22	0.09	0.09	0.10	0.07	0.13	-	-

*Original values are in parenthesis and before statistical analysis were subjected to square root transformation ($\sqrt{x+1}$)

Effect on crop growth and yield

However, maximum cob length was recorded in T_{15}: weed free (20.1 cm) and minimum (13.6 cm) in T_{16}: weedy check during the years. Among herbicide treatments, T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as post-emergence, produced the longest cob (19.3 cm), at par with treatment T_{13} (18.7 cm), T_7 (18.3 cm), T_{14} (18.2 cm) and T_{10} (17.9 cm) and cob length was minimum in treatment T_3: pendimethalin at 1000 g ha^{-1} as pre-emergence (14.9 cm) during the *kharif*2025.

Among the herbicidal treatments, T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE, produced the highest number of grains (438 grains cob^{-1}), which was statistically at par with treatment T_{13} (418 grains cob^{-1}), T_7 (414 grains cob^{-1}), T_{14} (408 grains cob^{-1}) and lowest number of grains were recorded in treatment, T_3: pendimethalin at 1000 g ha^{-1} as pre-emergence (344 grains cob^{-1}), during *kharif*2025, respectively.

Difference in grain yield due to different weed control treatments was found to be significant during the year. The highest grain yield (6835 kg ha^{-1}) was recorded under T_{15}: weed free treatment and lowest (3879 kg ha^{-1}) under T_{16}: weedy check during *kharif*2025, respectively. The treatments, T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE, produced the maximum grain yield (6,732 kg ha^{-1}) was statistically at par with T_{12} (6,551 kg ha^{-1}), T_{13} (6,438 kg ha^{-1}), and T_7 (6,367 kg ha^{-1}).

Differences in stover yield due to different weed control treatments were also significant. In general, all herbicidal treatments exhibited significantly higher stover yield than weedy check. The highest stover yield (16,630 kg ha^{-1}) was recorded under T_{15}: weed free treatment and lowest (10,685 kg ha^{-1}) under T_{16}: weedy check during the year. Among herbicidal treatments, higher stover yield in treatment T_{12}: atrazine at 750 g ha^{-1} *fb* tembotrione at 120 g ha^{-1} as PPE *fb* PoE (16,543 kg ha^{-1}) followed by T_{11} (16,499 kg ha^{-1}), T_7 (16,077 kg ha^{-1}), and T_{13} (16,055 kg ha^{-1}).

The harvest index was not significantly influenced by the different weed management treatments, as indicated by the non-significant differences among treatments. Numerically, the highest harvest index (41.1%) was recorded under $T_{15:\ weed}$-free and the lowest and lowest in T_{16}: weedy check (36.3). Among the herbicides treatments, T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE, obtained the highest harvest index (40.8%) was statistically at par with T_{13} (40.1%), and T_{12} (39.6%).

Economics

Highest net returns and benefit-cost ratio (Rs. 95,771 ha^{-1} and 1.83) were recorded in plots treated with T_{11}: halosulfuron-methyl at 67.5 g ha^{-1} + tembotrione at 120 g ha^{-1} (TM) as PoE, followed by T_{12} (Rs. 93,547 ha^{-1} and 1.83), T_{13} (Rs. 88,763 ha^{-1} and 1.78) and T_7 (Rs. 85,468 ha^{-1} and 1.74). Among herbicide treatments, T_3: pendimethalin at 1000 g ha^{-1} as pre-emergence recorded lower net returns and B:C ratio (21,057 ha^{-1} and 1.19) respectively

Table 3: Effect of pre and post emergence herbicides application on cob length, numbers of grains cob $^{-1}$, grain yield, stover yield of *kharif* maize

Treatment details		Dose (g ha^{-1})	Time of application	Cob length	No. of grains cob $^{-1}$	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1	Atrazine	750	PRE	15.3	348	4,381	11,682	37.5
T_2	Metribuzin	210	PRE	15.7	370	5,283	13,829	38.2
T_3	Pendimethalin	1000	PRE	14.9	344	4,149	11,122	37.3
T_4	Atrazine + pendimethalin (TM)	375 + 500	PRE	15.5	367	5,005	13,138	38.1
T_5	Metribuzin + pendimethalin (TM)	105 + 500	PRE	17.2	387	5,437	13,977	38.9
T_6	Toperamezone (7%) + atrazine (63%)-RM	130	PoE	17.7	401	6,070	15,525	39.1
T_7	Mesotrione (3.28%) + atrazine (27.6%)-RM	1000	PoE	18.3	414	6,367	16,077	39.6
T_8	Halosulfuron-methyl	67.5	PoE	16.0	372	4,821	12,555	38.4
T_9	Halosulfuron-methyl + atrazine (TM)	67.5 + 750	PoE	17.5	403	6,245	15,889	39.3
T_{10}	Tembotrione	100	PoE	17.9	404	5,892	14,992	39.3
T_{11}	Halosulfuron-methyl + tembotrione (TM)	67.5 + 120	PoE	19.3	438	6,732	16,499	40.8
T_{12}	Atrazine *fb* tembotrione	750 + 120	PRE *fb* PoE	17.2	406	6,551	16,543	39.6
T_{13}	Atrazine *fb* halosulfuron-methyl	750 + 67.5	PRE *fb* PoE	18.7	418	6,438	16,055	40.1
T_{14}	Pendimethalin *fb* 2,4-D amine	1000 + 500	PRE *fb* PoE	18.2	408	5,738	14,527	39.5
T_{15}	Weed free	-	-	20.1	443	6,835	16,630	41.1
T_{16}	Weedy check	-	-	13.6	327	3,879	10,685	36.3
SE(m) ±				0.33	8.97	119	298	0.69
CD at 5% level of significance				0.97	26.05	346	864	2.02

Table 4: Effect of pre and post emergence herbicides application on economic of *kharif* maize

Treatment details		Dose (g ha^{-1})	Time of application	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1	Atrazine	750	PRE	111289	140190	28901	1.26
T_2	Metribuzin	210	PRE	111222	168279	57057	1.51
T_3	Pendimethalin	1000	PRE	111885	132942	21057	1.19
T_4	Atrazine + pendimethalin (TM)	375 + 500	PRE	111587	159534	47947	1.43
T_5	Metribuzin + pendimethalin (TM)	105 + 500	PRE	111553	172419	60866	1.55
T_6	Toperamezone (7%) + atrazine (63%)-RM	130	PoE	114652	192255	77603	1.68
T_7	Mesotrione (3.28%) + atrazine (27.6%)-RM	1000	PoE	115571	201039	85468	1.74
T_8	Halosulfuron-methyl	67.5	PoE	113277	153369	40092	1.35
T_9	Halosulfuron-methyl + atrazine (TM)	67.5 + 750	PoE	113914	197547	83633	1.73
T_{10}	Tembotrione	100	PoE	112669	186384	73715	1.65
T_{11}	Halosulfuron-methyl + tembotrione (TM)	67.5 + 120	PoE	115294	211065	95771	1.83
T_{12}	Atrazine *fb* tembotrione	750 + 120	PRE *fb* PoE	113306	206853	93547	1.83
T_{13}	Atrazine *fb* halosulfuron-methyl	750 + 67.5	PRE *fb* PoE	113914	202677	88763	1.78
T_{14}	Pendimethalin *fb* 2,4-D amine	1000 + 500	PRE *fb* PoE	112298	181293	68995	1.61
T_{15}	Weed free	-	-	134252	213930	79678	1.59
T_{16}	Weedy check	-	-	110252	125151	14899	1.14

Conclusions

Based on one year of field study, it can be concluded that application of halosulfuron methyl + tembotrione (T_{11}) (TM) at 67.5 +100 g ha^{-1} found best treatment in order to control different weed flora, increasing yield attributes and yield of maize closely followed by, tank mix application of atrazine *fb* tembotrione (T_{12}) and atrazine *fb* halosulfuron-methyl (T_{13}). The highest benefit-cost ratio (1.83) was recorded under the treatment with T_{11}: halosulfuron methyl + tembotrione (TM) at 67.5 +100 g ha^{-1} and T_{12}: atrazine *fb* tembotrione (1.83) closely followed by T_{13}: atrazine *fb* halosulfuron-methyl (1.78). In contrast, the lowest B-C ratio (1.14) was recorded with T_{16}: weedy check treatment.

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