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Evaluating the Effects of Herbicide on Growth, Yield and Soil Attributes of Maize Crop in the Trans-Gangetic Region

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ABSTRACT

Background: Pesticides have been used extensively in agriculture to control pests, plants, weeds, insects and other species that can harm crop plants. Pesticides are wide words for substances that are used to eradicate undesired organisms from crops in order to preserve or increase crop yield. Herbicide application requires technical ability in the selection of a specific herbicide, the safe application dose and the application method. The current study aimed to study the effect of pre-emergence and post-emergence herbicides on the growth and soil attributes of maize.

Methods: The experimental site was East which falls under the central plain zone of agro-climatic zones of Punjab. It comprised 10 treatments of different herbicide combinations. The experiment was laid out in a randomized block design with three replications. Maize variety PMH-13 was used as a test crop and sown in July 2022 at a row spacing of 60×20 cm. Results revealed that (T8) Atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS was the most superior herbicide treatment in increasing plant height, Number of leaves, crop dry matter accumulation, stem girth, chlorophyll content, cob length, cob girth, with soil attributes.

Result: The highest grain yield (59.0 q/ha) and stover (117.06 q/ha) of maize were also recorded under Atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb hand weeding at 20 DAS. Atrazine pre-emergence application at a dosage of 1 kg ai/ha resulted in faster growth and lower weed density at 20 DAS. T8, which is atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS, is suggested for increased grain yield in the Trans Gangatic region based on performance.

Key words: Pendimethalin, Post-emergence herbicide, Weed management, Weed monitoring.

INTRODUCTION

Nature has its constant battle for survival among living things. Certain plant species flourish in some areas by benefiting from adjacent plants, which helps them grow. A weed is a plant that is regarded as unwanted in a specific situation and grows where it is not desired (Harlan *et al.*, 1965). Agriculture has used a wide range of pesticides to get rid of unwanted pests, plants, weeds, insects and other organisms that can affect crop plants (Singh *et al.*, 2023; Choudhary *et al.*, 2016). Pesticides are broad terms for compounds used to remove undesirable entities to preserve or boost crop output (Singh *et al.*, 2023a). After rice and wheat, maize is the third most significant cereal crop in India. Maize accounts for roughly 10% of total food grain production in the country. The largest maize-growing states are Andhra Pradesh, Karnataka, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh and Himachal Pradesh, accounting for more than 80% of total maize production. In maize, there is a great pre-emergence herbicidal alternative, but post-emergence herbicides are difficult to find (Singh *et al.*, 2015; Kumari *et al.*, 2018).

Topramezone and tembotrione are two recent selective post-emergence herbicides for maize. These herbicides that inhibit HPPD (4-hydroxyphenylpyruvate dioxygenase) are very effective at controlling weeds by bleaching developing tissues. These provide a straightforward option for herbicidal-based weed management of maize, especially in later seasons when crop-weed competition might extend up to 50 days. Furthermore, the planter looks for adequate post-emergence herbicides to protect his crop from weed losses if there is no pre-emergence weed management. Weed monitoring is required to comprehend key weed issues, grading them based on relative severity and grouping them based on the type of management required in the case of annuals, biennials, perennials, grasses and broadleaves. Weed monitoring gives data that can be used to adapt weed control tactics to reduce

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the impact of weeds. The primary purpose of weed survey and mapping is to properly find and delineate regions with populations of unwanted plants. (Walia *et al.*, 2018).

Herbicides offer tremendous prospects for lowering weed management expenses in every area while also offering quick and effective weed control. Although the pre-emergence insecticide atrazine is recommended, it is ineffective against specific weeds, including *Brachiaria ramose* (Rana *et al.*, 2017). As a result, a new post-emergence herbicide is necessary to successfully control weeds in kharif maize without interfering with crop development or production. Because of the low efficacy of pre-emergence herbicides in low rainfall conditions, the spread of triazine-resistant weeds and the introduction of efficient post-emergence broad-spectrum herbicides, interest in total post-emergence weed control programs in maize has recently increased (Whaley *et al.,* 2006).

Herbicide use necessitates technical skill in the selection of a specific herbicide, the safe application dose and the application method. Certain herbicides have long-lasting effects that limit the alternatives for different crops throughout the crop cycle, which can make a substantial difference in the success or failure of weed management. Herbicides make about 47.5% of the 2 million tonnes of pesticides used each year (Choudhary *et al.,* 2020).

Weed infestation is common in maize, because of its wider row spacing and is a slow-growing crop in its early stages. Wet circumstances during the monsoon time generate even more conducive conditions for weeds to thrive. So quick and effective weed control becomes the priority to save the crop and it can be achieved by application herbicides.

Herbicides applied prior to weed emergence may enable cost-effective weed management from the beginning, which may not be practicable with hand weeding. The goal of the current study was to identify that weed control strategies are both economically viable and successful in increasing *kharif* maize yield and profitability.

MATERIALS AND METHODS

The experiment was carried out at Lovely Professional University's Agricultural Research Farm in Kapurthala district, Punjab, during the *kharif* season of 2022. The experimental location was located at a latitude of 31°22′31.81″North and a longitude of 75°23′03.02″East, in the central plain zone of Punjab's agro-climatic zones, in the trans-Gangetic area of India. The soil of the experimental site comes under the sandy loam. The treatment comprised 10 combinations out of which five combination comprises of individual crops *viz*. (T1) Pendimethalin @ 1 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 30 DAS (T2) Atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha(PoE) 25 DAS (T3) Pendimethalin @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS (T4) Pendimethalin @ 1 kg ai/ha (PE) fb atrazine @ 0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS (T5) Atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS, (T6) Atrazine @ 0.50 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 20 DAS (T7) Atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS, (T8) Atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS (T9) Weed free (T10) Control/ unweeded, with maize (PMH-13) crop having a plot size 5×5 m. The treatments were replicated thrice and laid out under randomized block design (RBD). After thorough field preparation, initial soil samples were taken to analyze the initial soil properties. The initial soil sample was analyzed for available major nutrients; nitrogen (N), phosphorous (P), potassium (K) and organic carbon (OC), pH and soluble salts. The soil has pH (7.56) and organic carbon (0.28%). The Nitrogen status has very low (145.05kg/ha) and the medium in available phosphorus (16.2 kg/ha) while availability of potassium medium K_2O (124.3 kg/ha). Nitrogen, Phosphorus and Potash were applied through Urea, SSP and MOP, respectively. At harvest, seed and straw yields were recorded. Plant samples were collected for chemical analysis of nitrogen in seed and straw samples. In-ground seed and straw samples, N was estimated by micro Kieldahl method (Piper, 1966). For Phosphorus, plant samples were digested (ratio 9:3) in a diacid (HNO_3:$HClO_4$) mixture and P in the extract was determined by (Jackson 2005). Surface soil samples (0-15 cm depth) were collected for chemical analysis after harvesting the crop each year from all plots. For available P, soil samples were extracted with 0.5*M,* NaHCO3 (pH = 8.5) (Olsen *et al.,* 1954) and P content in the extracts was determined as described by Jackson (2005). All the remaining package and practices for the cultivation of experimental crop was made as per recommendation.

Growth attributes like Plant height, number of branches plant^{-1} and weed attributes characters were manually recorded on five randomly selected sample plants from each plot of each replication independently. At the physiological maturity stage, yield characteristics were also recorded. The net plot area of each treatment was used to calculate the seed and straw yield. The data collected from the numerous characters under investigation were evaluated using the analysis of variance (Gomez and Gomez, 1984). Data on growth, yield and weed attributes related characteristics were gathered and statistically analyzed. The maize crop was evaluated based on the effects of herbicide on the different growth attributes.

RESULTS AND DISCUSSION

Growth attributes of maize influenced by weed management

Plant height

The data can be recorded and analyzed for growth attributing character of maize (At 20 DAS, the study revealed that there was no significant influence on plant height at an early stage. At 40 DAS, Higher plant height was noted by application of atrazine @ 0.50 kg ai/ha + pendimethalin @

1 kg ai/ha (Tank mix) (PE) *fb* HW at 20DAS which was slightly less than weed free. At 60 DAS, immense growth was recorded in between the growth phase and higher plant height was noted by application of atrazine @ 0.50 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 20 DAS. At 80 DAS, a uniform rate of growth was noted as compared to 60 DAS. Higher plant height was noticed by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS (199.54 cm) which was found to be at par with T1, T9, T4, T7, T3, T5, T2, T6 and T10. Data indicates that integrated weed management has successfully controlled more weed including tank mix application than that of normal or solo herbicide spray (Sivamurugan *et al.,* 2017; Paul *et al*., 2022).

Number of leaves

Observations recorded for a number of leaves state no major variation by application of various weed management techniques at different growth stages of the crop, but severely affected by climate. However, weed-free treatment and atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS noted a higher number of leaves (9.33) plant^{-1}, which was found to be at par with T8, T1, T4, T6, T3, T7, T2, T5 and T10. Some studies have revealed that photoperiod and temperature may affect the final leaf numbers of maize (Ellis *et al.*, 1992).

Stem girth

Data shows (Table 1), A slight variation was noted at 40 DAS. Higher cob girth was noted by application of atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS. At 60 DAS, atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30DAS noted the highest stem girth. At 80 DAS, atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS noted higher stem girth (5.68) which was found to be at par with T9, T1, T4, T2, T3, T5, T7, T6 and T10. It might be Due to drying of crop, girth significantly decreases. But at such stage also, atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS and weed-free treatment noted higher girth than other treatments.

Dry matter accumulation

At 20 DAS, an increase in dry weight was noted when other treatments were compared with the weedy check. Higher dry weight was noted by application of atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS At 60 DAS, application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix)(PE) fb HW at 20DAS noted higher dry weight . At 80 DAS also higher dry weight was noted by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix)(PE) fb HW at 20 DAS (227g) which was found to be at par with T8,T1,T3,T2,T7,T6,T4,T5 and T10 (Table 1). The above results are in accordance with study of Jaybhaye *et al.* (2020).

Cob length

Data having reference to cob length have noted alteration due to treatments (Fig 1). Though weeds have interrupted in between, cob length keeping aside, the yield will have immense fluctuation in them. Keeping all these conditions in mind, the highest length was noted by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS which didn't show much change in comparison to weed free but was way better than the control treatment. Results of pendimethalin @1kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS and pendimethalin @1kg ai/ha (PE) fb atrazine @0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS were nearly similar to each other. as herbicide were same with different dosage, study depicts that change in dosage indirectly affects cob growth due to better nutrient consumption and weed control efficiency. Higher cob length was noted by T8 which was tank mix application of

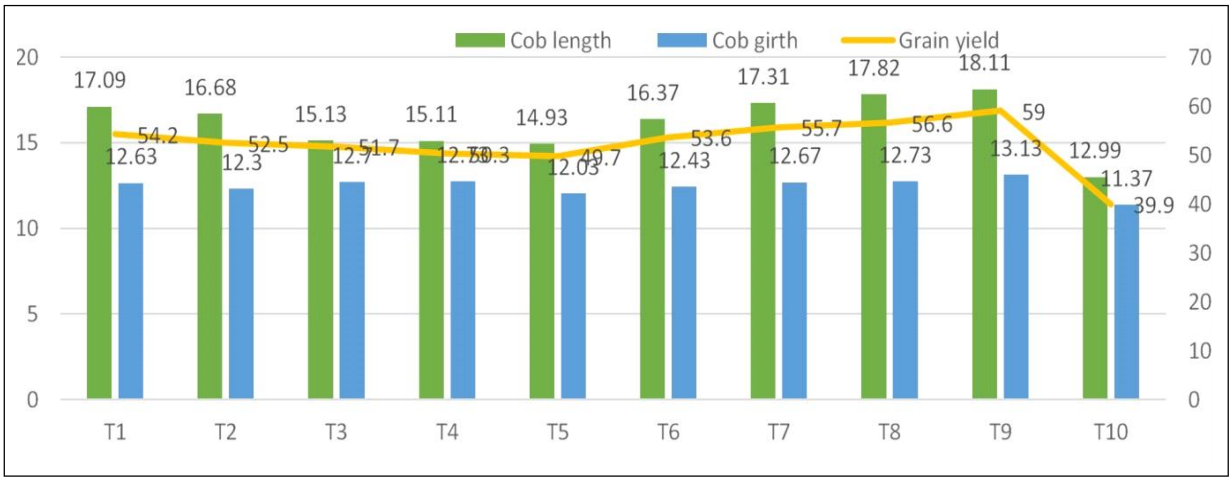

Fig 1: Effects of herbicide on cob length (cm), cob girth (cm), grain yield (q/ha) of maize crop.

Table 1: Effects of herbicide on plant height, stem girth, No. of leaves of maize crop.

Treatment	Plant height (cm)				Stem girth (mm)				No. of leave (plant^{-1})				Dry weight accumulation (g)				Chlorophyll content (mg L^{-1})			
	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS
T1- Pendimethalin @ 1 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 30 DAS	19.33	46.95	174.4	198.08	1.83	2.31	4.29	5.74	7.27	7	10.4	8.27	8.6	58.1	142.7	211.2	28.27	31.88	35.12	43.12
T2- Atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS	19.27	44.59	165.53	184.67	1.84	2.23	4.15	5.37	7.13	6.13	8.33	7.87	9.9	55.4	140.8	209.1	27.47	32.79	33.51	34.25
T3- Pendimethalin @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS	19.22	43.21	166.63	189.23	1.87	2.19	4.14	5.29	6.8	5.87	9.67	8	9.4	47.6	139.7	210.5	27.6	31.16	32.61	34.09
T4- Pendimethalin @ 1 kg ai/ha (PE) fb atrazine @ 0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha(PoE) 25 DAS	19.43	43.26	173.97	193.32	1.81	2.26	4.24	5.44	7.47	6.6	9.4	8.2	8.9	45.5	129.1	195.7	26.93	31.49	31.6	52.37
T5- Atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS	19.01	42.32	163.15	188.55	1.91	2.28	4.27	5.29	6.87	6.47	10.47	7.73	9.1	41.5	124.8	192.4	26.27	32.82	29.27	45.81
T6- Atrazine @ 0.50 kg ai/ha (PE) fbtembotrione @ 120 g ai/ha (PoE) 20 DAS	18.94	46.58	177.9	182.63	1.85	2.25	4.23	5.04	6.8	6.4	10.67	8.13	8.8	54.5	137.7	201.7	26.87	30.79	29.71	54.06
T7- Atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS	18.95	46.99	171.93	192.89	1.91	2.2	4.19	5.08	7.2	6.13	8.47	8	8.4	58.9	145.3	208.4	27.27	32.63	35.12	46.78
T8- Atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS	18.69	47.67	174.03	199.54	1.85	2.24	4.17	5.68	7.07	6.2	9.8	8.33	9.6	63.2	150.3	214.2	27.57	33.27	35.09	42.89
T9- Weed free	19.79	50.25	180.3	196.23	1.86	2.26	4.27	5.64	7	6.33	9.8	9.33	10.6	64.8	156.1	227.0	2.98	4.38	4.13	6.30
T10 - Control	18.03	38.23	153.47	174.55	1.82	2.09	3.93	4.78	7.53	5.53	8.13	7.67	6.7	40.3	113.8	170.4	1.00	1.47	1.39	2.12
C.D. (0.05)	0.75	4.56	12.02	12.32	0.11	0.23	0.28	0.22	0.99	0.73	1.06	0.78	0.79	5.18	3.54	4.66	1.42	2.08	1.97	3.00
SEm(±)	0.25	1.54	4.05	4.15	0.04	0.08	0.09	0.07	0.33	0.25	0.36	0.26	0.27	1.74	1.19	1.57	2.98	4.38	4.13	6.30
SE(d)	0.36	2.17	5.72	5.86	0.05	0.11	0.13	0.10	0.47	0.35	0.51	0.37	0.38	2.47	1.69	2.22	1.00	1.47	1.39	2.12

atrazine and pendimethalin fb hand weeding. The results noted were in accordance with a study by Lavanya *et al.* (2021).

Yield and yield attributes

Cob girth

Data concerned to cob girth noted slight non-uniform variation (Fig 1). Highest cob girth was noted by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS which was at par with pendimethalin @1kg ai/ha (PE) fb atrazine @0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS. It is precise from the data that significant increase in cob girth was noted by all treatments in comparison to weedy check. In comparison to solo pre-emergence spray tank mix application of atrazine and pendimethalin followed by hand weeding have performed well. However, these results are not enough to study cob growth as changes noted are not enough to compare and identify best combination of herbicide. Keeping all these conditions in mind atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS noted higher cob girth, result was supported by Barua *et al.* (2019).

Grain yield

Increase in maize grain yield was noted in weed free (Umesh *et al*., 2024). Significant yield enhancement was seen after application of herbicide either solo or tank mix (Fig 1). Higher grain yield was noted by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS and atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30DAS was lowest and was inferior in comparison to other treatments. Weed control directly affected weed density gradually reducing competition for crop and nutrient uptake is enhanced by crop indirectly increasing grain yield for particular treatment used, findings are supported by Sivamurugan *et al.* (2017).

Stover yield

Distinct results were noticed in case of stover yield as according to other parameters atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS and weed free were nearby to each other (Table 2). But due to differences in early growth stage treatments, visible results can't be unseen. The increment was noticed in treatments in which hand weeding was performed in comparison to chemical treatment used at post-emergence. Alike stats were noticed by application of atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS and atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS with a slight change in weight result was followed by Karde *et al.* (2020).

Biological yield

Weed free situation (176.06 q ha^{-1}) noted more biological yield in comparison to other treatments and way better than the control (116.16q ha^{-1}) (Table 2). The slight decrease in biological yield was noticed by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS which was similar to atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS with slight change, but was higher when compared to other treatments. which was found to be at par with T8, T7, T1, T6, T2, T3, T4, T5 and T10. The effect of weed control treatment can be noticed directly from the evidence from the field.

Harvest index

The data pertaining to harvest index of maize as influenced by different treatments are presented (Table 2). Data stating

Table 2: Effects of herbicide on Stover yield, Biological yield, Harvest index maize crop.

Treatment	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (q ha^{-1})
T1- Pendimethalin @ 1 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 30 DAS	102.54	156.77	34.6
T2- Atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS	100.21	152.74	34.39
T3- Pendimethalin @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS	97.25	148.96	34.71
T4- Pendimethalin @ 1 kg ai/ha (PE) fb atrazine @ 0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS	94.36	144.66	34.78
T5- Atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS	93.89	143.59	34.64
T6- Atrazine @ 0.50 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 20 DAS	101.34	154.97	34.61
T7- Atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS	106.21	161.87	34.4
T8- Atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS	107.1	163.66	34.57
T9- Weed free	117.06	176.06	33.51
T10- Control	76.75	116.61	34.2
C.D. (0.05)	6.17	5.89	1.87
SEm(±)	2.06	1.97	0.63
SE(d)	2.92	2.78	0.89

to harvest index reveals that no significant change was noticed in harvest index despite of various treatments. Still slight change was seen as higher harvest index was noted by application of pendimethalin @1kg ai/ha (PE) fb atrazine @0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS and lowest was noted in atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS.

Chlorophyll content

The data pertaining to plant chlorophyll of maize as influenced by different treatments are presented in (Table 1). Study of effect of weed management on chlorophyll content states that no significant variation was noted. Slight variation was noted in weedy check and other treatments. In such cases nutrient management techniques can play an important role in chlorophyll fluctuation, but weed management won't have such effect as application of nutrients was given according to the recommended dose of fertilizer. On the other hand, an increase in chlorophyll was noted at 80 DAS, which can be due to climate change or may be because of a decrease in the weed population.

Soil attributes influenced by weed management

pH

The data about soil pH of maize as influenced by different treatments are presented in (Fig 2). Observations recorded for soil pH revealed that there is no such high impact observed and recorded on field. Similar results were noted by Pennsylvania state university when they studied persistence of herbicides in soil and noted that higher pH soils frequently digest herbicides more slowly through chemical and microbiological breakdown than lower-pH soils. As the soil pH rises, especially above pH 7.0, the chemical breakdown rate of the triazine and sulfonylurea herbicide families slows.

EC

Observations recorded for soil EC reveal that no noteworthy change was recorded during the Analysis (Fig 2). The study says that salinity has a profound impact on the biochemistry, physiology and growth of weeds as each species will react to salt stress differently. In fact, the positively charged hard water cations will bond to the negatively charged herbicide molecule and hinder the herbicide's ability to penetrate the plant. Although, lowest EC was recorded by pendimethalin @ 1kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 30DAS and highest was recorded by atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS and was tantamount to atrazine @ 0.50 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 20 DAS and atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS.

Organic carbon (%)

The data pertaining to soil organic carbon of maize, as influenced by different treatments, are presented in (Fig 2). Observations recorded for organic carbon have noted desirable changes while analysis as high organic carbon was noted by application of pendimethalin @ 1 kg ai/ha (PE) fb atrazine @0.75 kg ai/ha + 2,4-D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS and lowest by application of pendimethalin @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS, by keeping one condition in mind that soil carbon levels are also influenced by climate conditions such as temperature and rainfall.

Available nitrogen (kg/ha)

Study and analysis of soil nitrogen levels revealed that highest nitrogen status was noted by application of atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS which might be due to low growth rate in that

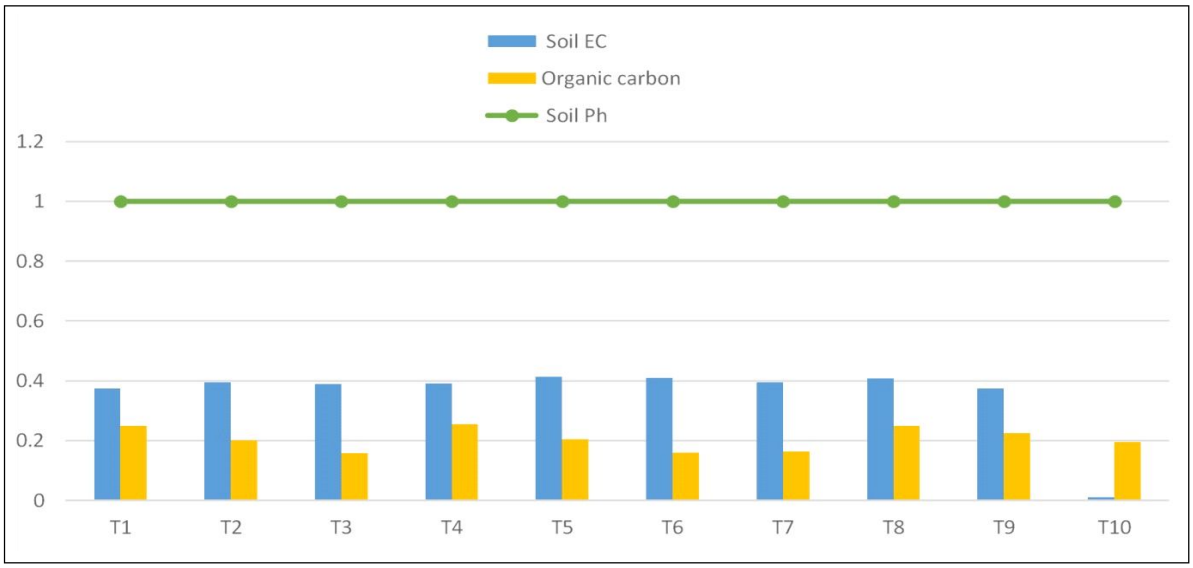

Fig 2: Effects of herbicide on EC (dSm^{-1}), pH and soil organic carbon (%).

treatment and lowest was noted by application of pendimethalin @ 1 kg ai/ha (PE) *fb* tembotrione @ 120 g ai/ha (PoE) 30 DAS (Fig 3), which can be due to leaching of excess water removes water-soluble nutrients out of the soil, by runoff or drainage. Also nitrogen uptake rate not only depends on weed infestation but also on weeds species affecting certain area. High nutrient uptake is seen where weeds are controlled satisfactorily. The results noted were in accordance with study done by Oyeogbe *et al.* (2018) who noted lower. Nitrogen level in plots with herbicidal combinations as compared to the weedy check.

Available phosphorus(kg/ha)

Data about the study of available phosphorus in soil and the effect of herbicide on it states that (Fig 3), variation was recorded in a view of the fact that non-identical nutrient uptake was observed according to treatments in which the highest phosphorus availability was noted by application of atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS and lowest in atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS and was at par with atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS. Results noted were under study done by Oyeogbe*et al.* (2018) who noted lower phosphorus level in plots with herbicidal combinations as compared to weedy check.

Available potassium(kg/ha)

Study and analysis of data concerning to nutrient called potassium revealed that variation was noted weed free and weedy check treatments were compared to other treatments. However, the minimum alteration was noted when data was observed carefully (Fig 3). Application of atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30DAS and atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS noted nearly similar results and also recorded high potassium content in the soil. Lower potassium level in soil was noted by application of pendimethalin @ 1 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 30DAS and was slightly low to atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS. Here, weed free also noted lowest potassium level in soil. The findings were consistent with the findings of Oyeogbe *et al.* (2018), who discovered decreased potassium levels in herbicidal combination plots compared to weedy control plots.

Weed attributes in maize influenced by weed management

Weed density (No of weed m^{-2})

The data about weed density in maize as influenced by different treatments (Table 3). It is expressed that, 20 DAS variation was noted as different dosages of varied herbicides were incorporated in the field. The lowest weed density was recorded by atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS and higher weed infestation was observed by application of atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS and At 40 DAS, due to change in post-emergence treatments and dosage, lowest weed density was noted by atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS and At 60 DAS higher weed density was noted by application of atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30DAS, which was similar to performance at 40 DAS due to the less effective nature of herbicide. At 80 DAS significant reduction in density was noted due to the completion of the weed's lifecycle. As herbicide action was already done, there's no way for other treatments to perform better than atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS. At harvest, atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS gave significant results by controlling weed infestation, as atrazine is absorbed by the roots before being transferred

Fig 3: Effects of herbicide on available nitrogen (kg/ha), available phosphorus (kg/ha) and available potash (kg/ha) in soil.

Table 3: Effects of herbicide on weed density, weed control efficiency and weed index.

Treatment	Weed density (No. of weed m^{-2})					Weed control efficiency (%)					Weed index
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	At harvest
T1- Pendimethalin @ 1 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 30 DAS	16.67 (4.14)	22.33 (4.78)	36.67 (6.10)	35.00 (5.96)	28.33 (5.37)	75.98	86.89	77.78	81.73	82.05	8.08
T2- Atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS	12.67 (3.63)	29.00 (5.43)	47.67 (6.94)	48.67 (7.01)	41.33 (6.47)	83.39	75.36	69.84	72.95	74.04	10.97
T3- Pendimethalin @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha (PoE) 25 DAS	18.33 (4.34)	31.33 (5.64)	56.33 (7.54)	53.67 (7.36)	45.33 (6.77)	76.83	69.62	64.34	67.69	70.19	12.38
T4- Pendimethalin @ 1 kg ai/ha (PE) fb atrazine @ 0.75 kg ai/ha + 2,4 D amine salt @ 0.4 kg ai/ha (PoE) 25 DAS	17.33 (4.22)	34.33 (5.90)	62.67 (7.95)	59.33 (7.74)	50.33 (7.13)	73.82	79.66	61.31	64.64	66.70	14.74
T5- Atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS	39.67 (6.34)	38.33 (6.23)	71.33 (8.48)	66.67 (8.20)	58.67 (7.69)	34.13	72.30	57.49	61.27	60.80	15.78
T6- Atrazine @ 0.50 kg ai/ha (PE) fb tembotrione @ 120 g ai/ha (PoE) 20 DAS	39.00 (6.28)	26.00 (5.15)	44.00 (6.67)	40.67 (6.42)	31.33 (5.64)	65.52	86.06	73.50	77.15	81.28	9.05
T7- Atrazine @ 0.50 kg ai/ha (PE) fb HW at 20 DAS	42.00 (6.52)	18.67 (4.38)	31.00 (5.61)	28.33 (5.37)	21.33 (4.67)	66.93	87.39	78.67	85.30	86.68	5.60
T8- Atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS	14.67 (3.89)	16.33 (4.10)	30.33 (5.55)	27.67 (5.31)	20.33 (4.56)	81.54	97.38	86.96	89.08	90.87	4.10
T9- Weed free	1.67 (1.47)	1.33 (1.35)	2.67 (1.78)	1.33 (1.35)	1.33 (1.35)	98.33	98.47	97.53	99.31	99.13	0.00
T10- Control	77.67 (8.84)	107.00 (10.37)	184.00 (13.58)	185.00 (13.62)	163.67 (12.81)	0.00	0.00	0.00	0.00	0.00	32.43
C.D. (0.05)	3.66	4.09	4.92	6.36	6.97	4.55	3.58	1.73	4.36	3.59	3.52
SEm (±)	1.22	1.37	1.64	2.12	2.33	1.52	1.20	0.58	1.46	1.20	1.18
SE (d)	1.73	1.93	2.32	3.00	3.29	2.15	1.69	0.82	2.06	1.70	1.66

to the aerial portions. The results noted were following a study done by Barua *et al.* (2019).

Weed control efficiency (%)

At 20 DAS, the highest weed control efficiency (Table-3) was noted by atrazine @ 1 kg ai/ha (PE) fb 2,4-D amine salt @ 1 kg ai/ha(PoE) 25 DAS against all treatments. At 40 DAS, highest weed control efficiency was noted by atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS and has performed excellent against all treatments. At 60 DAS, decrease in weed control efficiency was observed. Implementation of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS recorded higher weed control efficiency. At 80 DAS, an increase in weed control efforts was noticed. Higher weed control efficiency was noted by application of atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS and At harvest, atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20DAS and atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30DAS have recorded highest and lowest weed control efficiency as noted on the field. The results noted were from a study done by Barua *et al.* (2019) and Sahoo *et al.* (2024).

Weed index

Weed index observations are calculated by using yield data of certain treatments to judge the performance of treatment implementation. The weed index is inversely proportional to the yield parameters. Using weed index as a parameter to understand weed destruction on the field, has shown better results according to the treatments. The highest weed index was noted (Table 3) by atrazine @ 0.50 kg ai/ha (PE) fb 2,4-D sodium salt @ 0.50 kg ai/ha (PoE) 30 DAS.

CONCLUSION

Application of atrazine as pre-emergence at a dosage of 1 kg ai/ha recorded higher growth and lower weed density at 20 DAS. Application of hand weeding performs better than any other herbicide combination but with one issue that is higher cost input. In that case tembotrione gave best results. Based on performance, T8 which is atrazine @ 0.50 kg ai/ha + pendimethalin @ 1 kg ai/ha (Tank mix) (PE) fb HW at 20 DAS is recommended for higher grain yield in the Trans Gangetic region.

Conflict of interest

The authors declare no conflict of interest.

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