Effect of new pre- and post-emergence herbicide molecules in maize on a sandy loam soil of Telangana in India.

ABSTRACT:

Aim: To evaluate the efficacy of new pre and post-emergence herbicides on crop growth, yield attributesand yield in*kharif* maize.
Study Design: Randomized Block Design.
Place and Duration of study: Agriculture Research Station, Karimnagar, during *kharif,* 2023.
Methodology: The experiment involved ten different treatments arranged in a randomized block design, with three replications for each treatment. Treatments were T_1 -Atrazine 50% WP 0.5 kg a.i ha^{-1} as PE *fb* HW at 40 DAS, T_2 -Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* HW at 40 DAS, T_3 - Halosulfuron methyl 5% + atrazine 48% WG (RM) 0.05625 + 0.540 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_4 - Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 0.775 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_5 - Mesotrione 2.27% w/w + atrazine 22.7% w/w SC (RM) 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_6 - Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl 75% WG 0.0675 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_7 - Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione 34.4% SC 0.12 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_8 - Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* topramezone 336 g l^{-1} w/v SC 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_9 - Weedy check, T_{10} - Weed free (HW at 20 and 40 DAS).
Results: The observations are collected on weed control efficiency, various crop growth parameters, yield attributes and yield. It was notableicedthat at 30, 60, 90 days after sowing (DAS) and harvest, the weed-free treatment *i.e.*, hand weeding (HW) at 20 and 40 DAS) recorded the maximumweed control efficiency,plant populationinitial and final plant population, plant height, leaf area, dry matter production, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels cob^{-1}, grain yield, stover yield and harvest indexat both initial and final stages.Among theherbicidale treatments, significantly higher weed control efficiency, plant height, leaf area, dry matter production,cob length, cob girth, number of kernel rows cob^{-1}, and number of kernels cob^{-1} wereas recorded by the application ofpyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS which was found on par with pyroxasulfone @0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, topramezone + atrazine (RM) 0.775 kg a.i ha^{-1} as PoOE at 20 DAS *fb* HW at 40 DAS and pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl @ 0.0675 kg a.i ha^{-1} as PoOE at 20 DAS *fb* HW at 40 DAS. However, significantly lower plant height, leaf area, dry matter production, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels cob^{-1}, grain yield and stover yield were observedunderin the weedy check treatment. Application of pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoOE at 20 DAS *fb* HW at 40 DAS (6875 and 7792 kg ha^{-1}) recorded the significantly maximum grain yield and stover yield which was on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6406 and 7195 kg ha^{-1}), mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6250 and 6944 kg ha^{-1}), topramezone + atrazine (RM) 0.775 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6039 and 6583 kg ha^{-1}) and pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl @ 0.0675 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (5917 and 6806 kg ha^{-1}).
Conclusion: Weed control efficiency, growth parameters, yield attributes and grain yield ofyield in*kharif* maize were significantly higher withthe application ofpyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS which wasis on par withpyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS andmesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS.

Key words: Pyroxasulfone, Tembotrione, Topramezone, mesotrione + atrazine (RM),halosulfuronmethyl,plant height, yield

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1.INTRODUCTION

Maize (*Zea mays* L.) is the world's third leading cereal crop after wheat and rice.It is cultivated in tropical, subtropical, and temperate climates. It is known as the "Queen of Cereals". This title is attributed to maize due to its high yield, versatility, and nutritional value. Maize is a staple food in many parts of the world and is utilized in a wide range of products, including food, animal feed, and industrial raw materials. Its usage pattern is diverse, with 51% used as poultry feed, 20-25% consumed as human food, 10-12% used for cattle feed, and 1% reserved for seed. It has evolved into an industrial crop on a global scale, with 83% of its production worldwide and 76% of its production in India serving the feed, starch, and biofuel industries. It is crucial to increase maize acreage and productivity in the coming years to meet the rising demands for feed, food, and industrial uses, especially considering the rapid growth of the livestock and poultry industries in India.

Maize accounts for 8% and 25% of the world's total area and production under cereal crops. In India, maize covers 10.74 M ha of area, with an average yield of 35.67 million tonnes and productivity of 3321 kg ha^{-1}(E&S Division, DA&FW 2023-24), while in Telangana it is grown in an area of 4.86 lakh hectares with a production of 26.68 lakh tonnes and productivity of 5490 kg ha^{-1} (DA&FW 2023-24).

The ~~M~~major maize producing ~~growing~~ states in India include Karnataka (19.4 lakh ha), Madhya Pradesh (15.4 lakh ha) Maharashtra (13.05 lakh ha), Uttar Pradesh (8.91 lakh ha), Rajasthan (8.8 lakh ha), Bihar (7.28 lakh ha) Telangana (4.86 lakh ha) and Tamil Nadu (4.56 lakh ha) (DA&FW 2023-24)~~.~~

In Telangana, during *kharif* 2023, maize wasgrown in an area of 4.86 lakh hectares with a production of 26.68 lakh tonnes and productivity of 5490 kg ha^{-1}(DA&FW 2023-24). The major maize-growing districts in Telangana include Kamareddy (30149 ha), Rangareddy (29022 ha), Vikarabad (26026 ha),Bhadradri (22252 ha), Mahboobabad (22030 ha), Jagitial (18869 ha), Nizamabad (15183 ha), Siddipet (15072 ha), Nagarkurnool (14906 ha) and Mahbubnagar (11678 ha) (Directorate of economics and statistics, 2022-23).

Some of the grassy and broad-leaf weeds observed in maize fields are *Cyperusrotundus*L., *Cynodondactylon*L., *Commelinabenghalensis* L., *Amaranthusretroflexus*L., *Dinebraarabica* L., *Tridax procumbens* L.,*Euphorbia hirta* L., *Euphorbia geniculata* L., *Partheniumhysterophorus* L., *Digeraarvensis* L*., Phyllanthusniruri* L., *Celosia Argentea* L and *Acalypha indica* L. These weeds are among the most problematic globally, infesting maize fields and consequently increasing production costs.

Traditionally, weed control in agriculture involved manual methods such as hoeing and the use of animal-drawn implements. However, the growing shortage of human labour and increasing wage costs have made hand-weeding less practical. Additionally, manual and mechanical weeding methods are costly and often impractical, especially during the monsoon season, when persistent rainfall results in muddy and challenging field conditions. Herbicides present the most viable alternative for weed control in such conditions. Their utilization has transformed farming practices in crops like rice, wheat, and maize in India, demonstrating remarkable effectiveness in managing the diverse weed flora associated with maize cultivation.

Chemical weed management by using pre and post-emergence herbicides can lead to the efficient and cost-effective control of weeds during critical periods of crop weed competition, which may not be possible with~~in~~ manual or mechanical weeding due to ~~its~~ high cost of cultivation (Triveni *et al*., 2017).

Farmers are mostly applying atrazine at 1.0 kg a.i ha^{-1} as a pre-emergence herbicide and 2,4-D at 1.0 kg a.i ha^{-1} as a post-emergence herbicide in maize. However, these herbicides are often

ineffective against a wide range of weed species, and it is well-documented that the persistence of atrazine in the soil can lead to residualeffects.

In the light of this challenging context in agriculture, new generation of pre- and post-emergence herbicides wereare developed for effective control of the weeds control in maize crops. Hence, it is proposed to test the new pre and post-emergence herbicides in the present investigation.

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2. METHODS AND MATERIALS

The field experiment was carried-outat Agriculture Research Station (ARS), Karimnagar during *kharif* (2023). The experimental site is geographically situated inthe Northern Zone of Agro-climatic zone inof Telangana. The soil texture of the experimental site is Sandy loam with neutral pH (6.6), E.C(0.35 dsm^{-1}), low in organic carbon (0.41%), low in available N(267.5 kg ha^{-1})and high in availablePhosphorous (37.4 kg ha^{-1}) and available potassium (287.25 kg ha^{-1}).

The experiment was comprised ofinvolved ten different treatments, arranged in a randomized block design, with three replications for each treatment. The Ttreatments were:T_1 -Atrazine 50% WP 0.5 kg a.i ha^{-1} as PE *fb* HW at 40 DAS, T_2 -Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* HW at 40 DAS, T_3 - Halosulfuron methyl 5% + atrazine 48% WG (RM) 0.05625 + 0.540 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_4 - Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 0.775 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_5 - Mesotrione 2.27% w/w + atrazine 22.7% w/w SC (RM) 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_6 - Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl 75% WG 0.0675 kg a.i ha^{-1} as PoOE at 20 DAS *fb* HW at 40 DAS, T_7 - Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione 34.4% SC 0.12 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS, T_8 - Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* topramezone 336 g l^{-1} w/v SC 0.252 kg a.i ha^{-1} as PoOE at 20 DAS *fb* HW at 40 DAS, T_9 - Weedy check, T_{10} - Weed free (HW at 20 and 40 DAS).

The Oobservations were recorded on weed control efficiency at 30 DAS,andinitial and final plant population, plant height, leaf area, dry matter production, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels cob^{-1}, grain yield, stover yield and harvest index in maize at 30, 60, 90 DAS and harvest.Weed control efficiency is calculated as the percentage reduction in weed dry matter yield in the treated plots compared to the untreated control 60days after sowing (DAS)as under on equation 1.;

$$WCE = \frac{\text{Dry weight of weeds in unweeded control (g } m^{-2}) - \text{Dry weight of weeds in treatment plot (g } m^{-2})}{\text{Dry weight of weeds in unweeded control (g } m^{-2})} \times 100 \quad (1)$$

The seeds wereare sown with a spacing of 60×20 cmin between the lines. The recommended dose of fertilizers(RDFs)dosage for all the treatments was 200:60:50 kg ha^{-1} of N, P_2O_5, and K_2O, using urea, di-ammonium phosphate (DAP), and murate of potash (MOP) respectively.A total of 828 mm of rainfall was recorded over 36 rainy days. The weekly mean maximum temperature during the crop growth period ranged from 28.9°C to 42.4°C with an average of 35.8°C. The weekly mean minimum temperature during the crop growth period ranged from 17.1°C to 31.6°C with an average of 25.0°C. The mean weekly sunshine ranged from 1.2 to 8.2 hours and the mean evaporation ranged from 0.9 to 4.3 mm. All recorded data from the study were subjected to statistical analysis using the analysis of variance technique for a randomized block design.

3.RESULTS AND DISCUSSIONS

3.1 Weed control efficiency

At 60 DAS, the highest weed control efficiency was observed underinpyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (92.44%) which was closely followed by hand weeding at 20 and 40 DAS, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (90.57%) and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (86.72%). The increased weed control efficiency observed in these treatments can be attributed to a reduced weed

population and lower weed dry weight. Similar results were obtained by the findings of Sundari *et al.* (2019), Kaur *et al*. (2018) and Lavanya *et al.* (2020). Among all the treatments, the T_9-weedy check provided the lowest weed control efficiency (0.00) (Fig. 1).

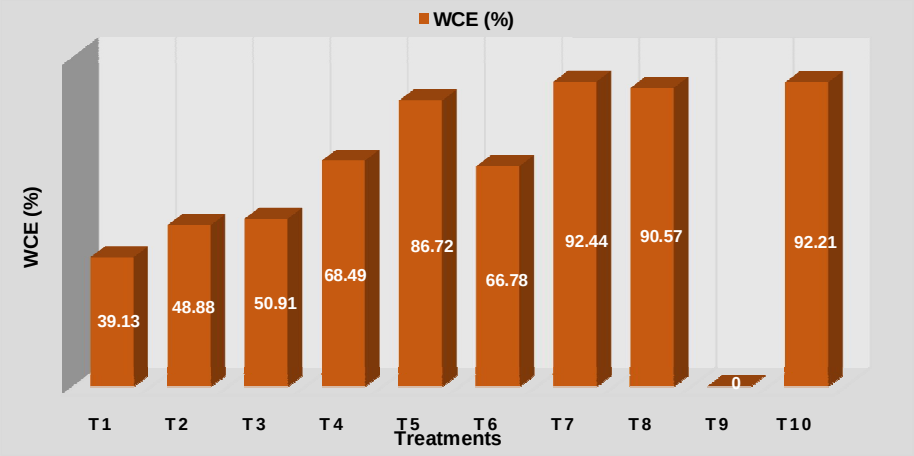

Fig. 1. Effect of different weed control treatments on weed control efficiency (%) in *kharif* maize at 60DAS

3.2Crop growth parameters

3.2.1 Plant population

~~The Fig. 2 presents data on the initial and final plant stands under various weed management treatments.~~ The salient findings on the initial and final plant stands under various weed management ~~indicate~~practices indicated that the initial or final plant standswere ~~these weed management strategies did~~ not significantly affected by weed management practices imposed~~ the initial or final plant stands~~ (Fig. 2), demonstrating consistent emergence and stability throughout the crop growth period. This suggests a uniform plant population across all treatments. These results are similar with the findings of Mali et al. (2017) and Kumar et al. (2019).

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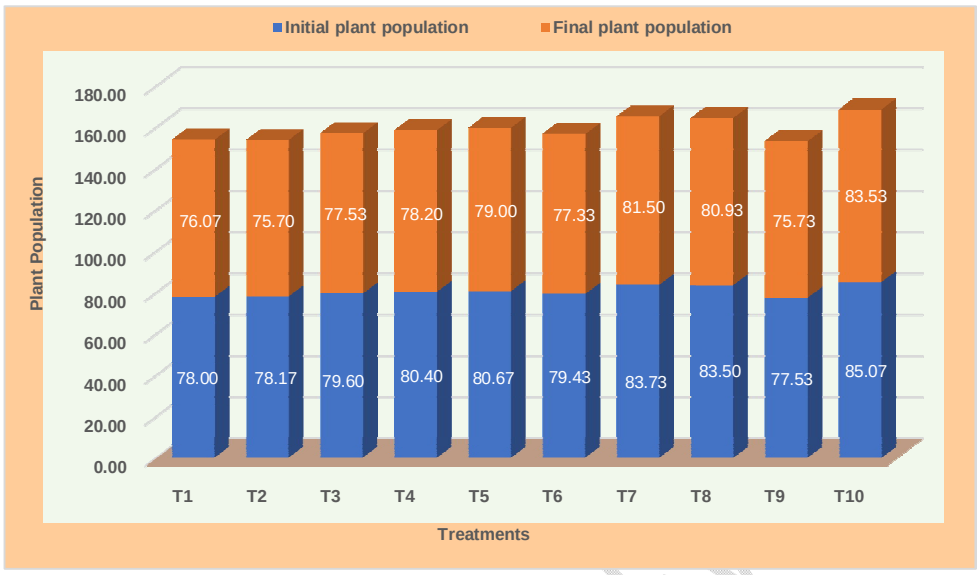

Fig. 2. Effect of different weed control ~~treatments~~ on the initial and final plant population ('000 ha^{-1}) of *kharif* maize

3.1.2 Plant height (cm)

~~Fig 3represents the influence of various weed management treatments on maize plant height (cm) recorded at 30, 60, and 90 DAS and harvest.~~

Weed control ~~treatments~~ significantly influenced the ~~impacted~~ plant height at all growth stages, except at 30 days after sowing (DAS) (Fig. 3). At this stage,weed control treatments had no effect on plant height, and the differences between treatments were statistically non-significant.

At 60 DAS, hand weeding at 20 and 40 DAS (142.6 cm) recorded a significantly higher plant height among all treatments. Among all herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (141.8 cm) resulted in the maximum plant height which was statistically on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (133.3 cm) and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (127.3 cm). This could be attributed to the high weed control efficiency and reduced crop-weed competition in these treatments. The lowest plant height was observed in the weedy check (90.6 cm) as weeds impeded plant growth by competing for soil moisture, nutrients, sunlight, and space during the growth period. These findings are in accordance with the results of Sachan *et al.* (2024), and Bhagat *et al*. (2019).

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At 90 DAS, significantly higher plant height was recorded~~found~~under~~in~~ weed-free treatment (Hand weeding at 20 and 40 DAS) (183.8 cm). Among all the herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (182.3 cm) noticed the taller plants which were statistically on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (178.7 cm) and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (177.2 cm).However weedy check (118.2 cm) showed the lowest plant height.

Hand weeding twice at 20 and 40 DAS resulted in significantly higher plant heights at harvest (196.7 cm). Among the various herbicide treatments, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (193 cm) noticed the higher plant height and it was found statistically on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (187.6 cm) and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (185.6 cm). This increase in plant height could be due to the suppression of weed growth, creating a weed-free environment that facilitated higher vegetative growth of the maize plants. However weedy check (138.0 cm) resulted in

the lowest plant height. Similar results are also stated by Sachan *et al.* (2024), Sundari *et al.* (2019), and Bhagat *et al.* (2019).

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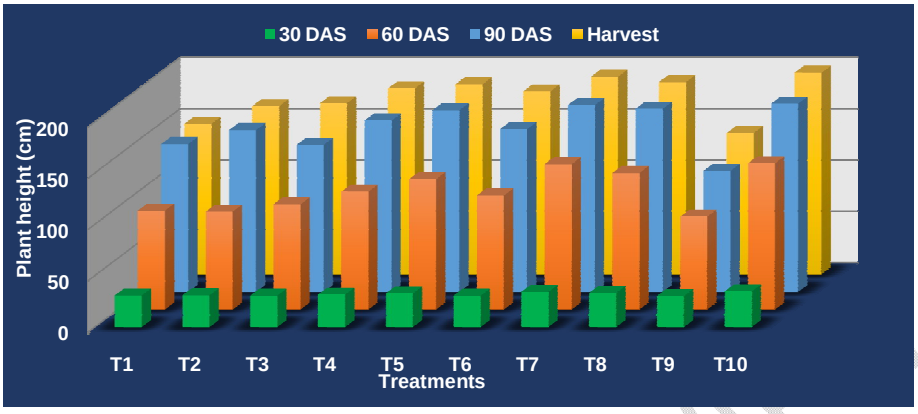

Fig. 3. Effect of different weed control treatments on plant height (cm) in *kharif* maize at 30, 60, 90 DAS and harvest

3.1.3 Leaf area (cm^2 plant^{-1})

~~Fig 4. represents T~~the observations on ~~findings of~~ leaf area obtained at 30, 60, and 90 DAS, and harvest due to various weed management practices are presented in Fig. 4.~~ It was observed that~~

~~At 30 DAS,~~ hand weeding at 20, 30 and 40 DAS (1335.7 cm^2 plant^{-1}) revealed a significantly higher leaf area over the rest of the treatments. Among various herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (1298 cm^2 plant^{-1}) noticed the higher leaf area and remained on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (1286.7 cm^2 plant^{-1}), mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (1236 cm^2 plant^{-1}). The minimum leaf area was found in the weedy check (997.3 cm^2 plant^{-1}).

Hand weeding at 20 and 40 DAS (4853.9 cm^2 plant^{-1}) recorded a significantly higher leaf area than the other treatments at 60 DAS. Among various herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (4620 cm^2 plant^{-1}) resulted the higher leaf area and is on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (4477.4 cm^2 plant^{-1}), mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (4386.3 cm^2 plant^{-1}).

Data at 90 DAS revealed that hand weeding at 20 and 40 DAS resulted in significantly more leaf area (4985 cm^2 plant^{-1}) than other treatments. Of the various herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (4732.7 cm^2 plant^{-1}) observed the higher leaf area and it was on par to pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (4630.5 cm^2 plant^{-1}), mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (4523 cm^2 plant^{-1}). The weedy check had the lowest leaf area (3458.3 cm^2 plant^{-1}).

At harvest, hand weeding at 20 and 40 DAS (2584.3 cm^2 plant^{-1}) resulted in a significantly higher leaf area than all the other treatments. Among various herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (2414.7 cm^2 plant^{-1}) recorded the higher leaf area which was on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (2276.0 cm^2 plant^{-1}), mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (2209.3 cm^2 plant^{-1}), topramezone + atrazine (RM) 0.775 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (2178.4 cm^2 plant^{-1}). The lower leaf area was found in the weedy check (1914.0 cm^2 plant^{-1}). These results align with the findings ofEhsas *et al*. (2016) and Negalur*et al.* (2020).

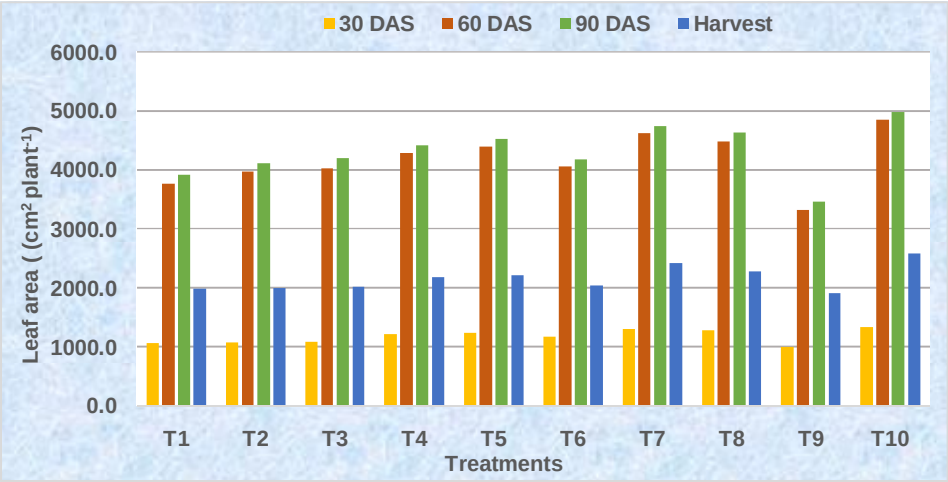

Fig4. Effect of different weed control treatments on leaf area in *kharif* maize at 30, 60, 90 DAS and harvest.

3.1.4 Dry matter production (kg ha^{-1})

The data on weed control efficiency (%) was obtained at 30, 60, and 90 DAS, and harvest. It was based on the total dry weight of weeds in the weedy check, and it differed significantly by various weed management strategies. The results are provided in Table 1.

The production of dry matter was a result of the efficient use of resources in an ideal crop-growing environment. The impact of weed management practices on the dry matter accumulation in maize at 30, 60, and 90 days after sowing (DAS) and at harvest is presented in Table.

At 30 days after sowing (DAS), the weed-free treatment (hand weeding at 20 and 40 DAS)(990 kg ha^{-1}) showed a notably higher dry matter production than other treatments. Amongst herbicides, pre-emergence application of pyroxasulfone @ 0.1275 kg a.i ha^{-1}*fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (959 kg ha^{-1}) resulted in a significantly greater dry matter production and was found at par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (938 kg ha^{-1}) and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (914 kg ha^{-1}). The weedy check resulted in a significantly reduced dry matter production (779 kg ha^{-1}) compared to all other treatments.

At 60 DAS, weed-free treatment (6675 kg ha^{-1}) registered the highest dry matter production over the different weed control treatments. Pyroxasulfone @ 0.1275 kg a.i ha^{-1}*fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (6584 kg ha^{-1}) recorded the significantly higher dry matter production among all herbicide treatments which was statistically at par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (6493 kg ha^{-1}) andmesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6419 kg ha^{-1}).However, the weedy check (5591 kg ha^{-1}) treatment showed a markedly lower production of dry matter.

The highest dry matter production was observed in weed-free treatment (hand weeding at 20 and 40 DAS) (9089 kg ha^{-1}) at 90 DAS because of a weed-free environment and was superior over the rest of the treatments. Among herbicidal treatments, pyroxasulfone @ 0.1275 kg a.i ha^{-1}*fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (8959 kg ha^{-1}) recorded the significantly higher dry matter production which was on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (8788 kg ha^{-1})

andmesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (8658 kg ha^{-1}). Whereas lower dry matter production was obtained in the weedy check treatment (7410 kg ha^{-1}) as the vegetative growth was hindered by the competing weeds.

At harvest, dry matter production was significantly higher in the weed-free treatment (hand weeding at 20 and 40 days after sowing) (8129 kg ha^{-1}). Amongst herbicides, pyroxasulfone @ 0.1275 kg a.i ha^{-1}*fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (7902 kg ha^{-1}) noticed the significantly higher dry matter production which was on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (7245 kg ha^{-1}) and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (6944 kg ha^{-1}). Significantly lower dry matter accumulation was found in the weedy check (3096 kg ha^{-1}) over all other treatments. The notable increase in dry matter production was due to improved crop nutrition facilitated by decreased weed competition. This was reflected by significantly lower weed density, reduced weed dry weight, and increased weed control efficiency. These findings are in agreement with the outcomes of Singh *et al.* (2020), and Supriya Gupta (2021).

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Table 1. Effect of different weed control treatments on plant dry matter production (kg ha^{-1}) in *kharif* maize at 30, 60, 90 DAS and harvest

S. No	Treatments	30 DAS	60 DAS	90 DAS	Harvest
T_1	Atrazine 50% WP 0.5 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	801	5670	7697	5686
T_2	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	846	5759	8021	6230
T_3	Halosulfuron methyl 5% + atrazine 48% WG (RM) 0.05625 + 0.540 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	850	5889	8430	6200
T_4	Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 0.775 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	882	6130	8546	6710
T_5	Mesotrione 2.27% w/w + atrazine 22.7% w/w SC (RM) 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	914	6419	8658	6944
T_6	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl 75% WG 0.0675 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	852	5947	8238	6905
T_7	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione 34.4% SC 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	959	6584	8959	7902
T_8	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* topramezone 336 g l^{-1} w/v SC 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	938	6493	8788	7245
T_9	Weedy check	779	5591	7410	3096
T_{10}	Weed-free (HW at 20 and 40 DAS)	990	6675	9089	8129
	SEm (±)	25	198	249	646
	CD (0.05%)	74	416	524	1356

3.1.5 Days to 50% tasseling and silking

Data on~~regarding~~ days to 50% tasseling and silking is~~was~~ presented in Table 2~~.~~ and ~~I~~it was notable~~iced~~ that t~~hese~~ weed control ~~treatments~~ have no significant effect on days to 50% tasseling and silking. The comparable times to achieve 50% tasseling and 50% silking across various treatments indicate that weed competition does not impact the flowering stages of maize. Similar results were noticed by Kumar *et al.* (2019).

Comment [u7]: What was done by these researchers? Elaborate on what they have done under which conditions in order find the similarities and the differences.

Table 2. Effect of different weed control treatments on days to 50 % tasseling and silking in *kharif* maize

S No	Treatments	Days to 50 % tasseling	Days to 50 % silking
T_1	Atrazine 50% WP 0.5 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	62	64
T_2	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	60	65
T_3	Halosulfuron methyl 5% + atrazine 48% WG (RM) 0.05625 + 0.540 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	61	63
T_4	Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 0.775 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	61	64
T_5	Mesotrione 2.27% w/w + atrazine 22.7% w/w SC (RM) 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	60	63
T_6	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl 75% WG 0.0675 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	61	63
T_7	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione 34.4% SC 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	60	62
T_8	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* topramezone 336 g l^{-1} w/v SC 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	60	63
T_9	Weedy check	63	65
T10	Weed-free (HW at 20 and 40 DAS)	59	61
	SEm (±)	1.51	1.59
	CD (0.05%)	NS	NS

3.2 Yield Attributes and Yield

3.2.1 Cob length (cm)

~~Data in Table3. revealed that~~ The weed-free treatment (hand weeding at 20 and 40 days after sowing) (17.87 cm) was observed with ~~noticed~~ a significantly higher cob length relative to~~over the~~ other weed management practices~~practices~~ (Table 3). Among all herbicide treatments, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (17.27 cm) resulted in the significantly higher cob length which remains on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (16.6 cm) andmesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (16.17 cm).

3.2.2 Cob girth (mm)

The data on cob girth revealed ~~there was~~ no significant effect by~~of~~ various weed management practices ~~on cob girth~~ (Table 3). However, higher cob girth was~~is~~ obtained under~~in~~ weed-free (44.83 mm) followed by pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (43.14 mm). However, ~~and the~~the lowest was recorded under the~~in~~ weedy check (36.20 mm).

3.2.3 Number of kernel rows cob^{-1}

The data pertaining to the ~~on the~~ effect of various weed management practices on the number of kernel rows per cob is ~~was~~presented~~shown~~ in Table 3. The

Distinct ~~D~~ifferent weed management tactics~~practices~~ significantly influenced the number of kernel rows per cob in maize. The number of kernel rows per cob was significantly higher under the~~in~~ weed-free treatment (15.30). Among herbicide treatments, maximum number of kernel rows per cob observed in pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (14.67) and found on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (14.43), mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (14.13), topramezone + atrazine (RM) 0.775 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (13.80) and pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl @ 0.0675 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (13.77). A minimum number of kernel rows per cob was recorded in the weedy check (11.43).

3.2.4 Number of kernels cob^{-1}

Data regarding the number of kernels per cob in Table 3. revealed that weed-free treatment (578.17) recorded a significantly higher number of kernels per cob over other treatments. Pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (521.33) resulted maximum number of kernels per cob which was on par with the pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (481.27), and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS (457.17). All the other treatments are significantly superior to the weedy check (184.47). The findings of Harisha *et al.* (2023) indicate similar results.

3.2.5 Grain yield (kg ha^{-1})

Grain yield represents the ultimate result of crop growth and the combined effect of growth and yield-contributing factors. A notable increase in maize grain yield was observed with the implementation of various weed management practices. The data on ~~concerning~~ grain yield is~~are~~ presented in Table 4.

Hand weeding twice at 20 and 40 days after sowing had ~~has~~ the maximum grain yield (7083 kg ha^{-1}) among all weed management practices. Due to improved aeration and increased access to space, water, light, and nutrients provided by the removal of weeds in between and within rows, the weed-free plots showed significant growth. The best conditions for growth and development resulted in improved yield qualities and, eventually, the highest yields. These results align with the findings of Sairam *et al.* (2023). Amongst the herbicide treatments, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6875 kg ha^{-1}) recorded the significantly maximum grain yield which remains on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6406 kg ha^{-1})

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andmesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6250 kg ha^{-1}). These results were consistent with the findings presented by Shukla *et al.* (2023), Janak and Grichar (2016), and Bhalse*et al*. (2023).

The grain yield in the weedy check (2570 kg ha^{-1}) was significantly less compared to other treatments. The high levels of weed density and low weed control efficiency in the unweeded control caused a decrease in grain yield due to severe competition from weeds. These observations are consistent with findings from several studies that have recorded yield losses as a result of weed competition (Janak and Grichar, (2016; Nthebere*et al*., 2024;) and Bhalse *et al.* (2023).

3.2.6 Stover yield (kg ha^{-1})

The stover yield of maize Various weed management treatments examined in the present investigation highlighted asignificant influence by imposed weed management practices (Table 4) significantly affected the stover yield of maize, as shown in Table 4.

The significantly highest maize stover yield inmaize was obtained recordedunder inthea weed-free plot (hand weeding at 20 and 40 DAS) (8042 kg ha^{-1}) compared to over other weed control practicestreatments. Among various herbicide treatments, pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione @ 0.12 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (7792 kg ha^{-1}) was significantly superior and resulted in the highest stover yield which was on par with pyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (7195 kg ha^{-1}) andmesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (6944 kg ha^{-1}). This outcome might be due to maintaining a weed-free environment throughout the critical stages of crop growth, which allows high uptake of nutrients by crop. Similar kind of results are confirmed by the findings of Bhalse*et al*. (2023), and Shukla *et al.* (2023). The weedy check treatment noticed the lowest stover yield (3069 kg ha^{-1}).

3.2.7 Harvest index

The data presented in Table4, illustrated that the various weed control practices had no significant effect on the harvest index. However, the highest harvest index was with the application of topramezone + atrazine (RM) 0.775 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS (47.7%) and the lowest harvest index in weedy check (45.6%). The high harvest index might be attributed to the greater translocation of photosynthates, as reflected by the higher yields. These findings are consistent with the results reported by Mali *et al.* (2020).

Table 3. Effect of different weed control treatments on yield attributes in *kharif* maize

S No	Treatments	Cob length (cm)	Cob girth (mm)	No. of kernel rows cob^{-1}	Number of kernels cob^{-1}
T_1	Atrazine 50% WP 0.5 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	13.10	38.28	12.47	315.27
T_2	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	14.37	39.49	13.07	374.80
T_3	Halosulfuron methyl 5% + atrazine 48% WG (RM) 0.05625 + 0.540 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	14.60	40.42	13.20	392.00
T_4	Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 0.775 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	15.93	41.72	13.80	432.53
T_5	Mesotrione 2.27% w/w + atrazine 22.7% w/w SC (RM) 0.875 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	16.17	41.97	14.13	457.17
T_6	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*halosulfuron methyl 75% WG 0.0675 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	15.00	41.35	13.77	422.50
T_7	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb*tembotrione 34.4% SC 0.12 kg a.i ha^{-1} as	17.27	43.14	14.67	521.33

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	PoE at 20 DAS *fb* HW at 40 DAS				
T_8	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* topramezone 336 g l^{-1} w/v SC 0.252 kg a.i ha^{-1} as PoE at 20 DAS *fb* HW at 40 DAS	16.60	42.69	14.43	481.27
T_9	Weedy check	9.80	36.20	11.43	184.47
T_{10}	Weed-free (HW at 20 and 40 DAS)	17.87	44.83	15.30	578.17
	SEm (±)	0.60	1.65	0.50	24.67
	CD (0.05%)	1.78	NS	1.48	73.88

Table4. Effect of different weed control treatments on grain yield (kg ha^{-1}), stover yield (kg ha^{-1}), and harvest index (%) in *kharif* maize

S No	Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
T_1	Atrazine 50% WP 0.5 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	5013	5625	47.2
T_2	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE *fb* HW at 40 DAS	5363	5958	47.4
T_3	Halosulfuron methyl 5% + atrazine 48% WG (RM) 0.05625 + 0.540 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS	5401	6167	46.7
T_4	Topramezone 10 g l^{-1} + atrazine 300 g l^{-1} SC (RM) 0.775 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS	6039	6583	47.7
T_5	Mesotrione 2.27% w/w + atrazine 22.7% w/w SC (RM) 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS	6250	6944	47.4
T_6	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE fb halosulfuron methyl 75% WG 0.0675 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS	5917	6806	46.5
T_7	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE fb tembotrione 34.4% SC 0.12 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS	6875	7792	46.9
T_8	Pyroxasulfone 85% w/w WG 0.1275 kg a.i ha^{-1} as PE fb topramezone 336 g l^{-1} w/v SC 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS	6406	7195	47.1
T_9	Weedy check	2570	3069	45
T_{10}	Weed-free (HW at 20 and 40 DAS)	7083	8042	47
	SEm (±)	345	464	0.50
	CD (0.05%)	725	974	NS

4. CONCLUSION

Based on the results of the present investigation to assess the impact of new pre- and post emergence herbicide molecules in maize, it can be deduced ~~concluded~~ that among distinct~~fferent~~ weed control tactics~~treatments~~;~~,~~ pre-emergence application of pyroxasulfone @ 0.1275 kg a.i ha^{-1} *fb* post-emergence application of tembotrione @ 0.12 kg a.i ha^{-1} at 20 DAS *fb* HW at 40 DAS~~which is~~ on par withpyroxasulfone @ 0.1275 kg a.i ha^{-1} as PE *fb* topramezone @ 0.252 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS and mesotrione + atrazine (RM) @ 0.875 kg a.i ha^{-1} as POE at 20 DAS *fb* HW at 40 DAS~~shows~~ significantly higher weed control efficiency, growth, yield attributesand yield in maize. These suggest.....

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