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Influence of new-generation herbicide molecules on yield attributes and productivity of *Rabi* maize (*Zea mays* L.)

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Abstract
A field experiment was conducted during the rabi season of 2016 at the College Farm, College of Agriculture, Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, to assess the effectiveness of new-generation herbicide molecules on growth and productivity of rabi maize (*Zea mays* L.). The experiment was laid out in a randomized block design with eight weed management treatments and three replications. The results revealed that weed management practices exerted a pronounced effect on crop growth and yield attributes. Among the treatments, pre-emergence application of atrazine at 1.0 kg a.i. ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 days after sowing (DAS) resulted in superior performance in terms of dry matter accumulation, yield attributes, grain yield, stover yield, and harvest index. Sequential and tank-mix applications involving atrazine and topramezone also improved crop performance but were comparatively less effective than the integrated weed management approach. The unweeded control recorded the lowest values for all growth and yield parameters due to severe crop-weed competition. The study clearly demonstrates that integrated weed management involving both chemical and mechanical methods is more efficient than sole chemical control for enhancing productivity of rabi maize.

Keywords: Maize, dry matter production, yield attributes, harvest index

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops globally, ranking after rice and wheat in terms of area and production. Owing to its wide adaptability, high genetic yield potential, and versatile uses as food, feed, fodder, and industrial raw material, maize occupies a pivotal position in global agriculture. The crop is cultivated successfully under diverse agro-climatic conditions ranging from tropical to temperate regions, thereby contributing substantially to global food and nutritional security.

Globally, maize was cultivated over approximately 179 million hectares during 2016-17, producing more than 1,000 million tonnes with an average productivity of about 5.5 t ha^{-1}. Maize alone accounts for a major share of global coarse grain production and contributes over one-fourth of total cereal output. Continuous progress in hybrid development, genetic enhancement, and adoption of improved agronomic practices has further strengthened the role of maize in world agriculture (Commodity Profile on Maize, 2015; Geofin, 2016).

In India, maize has emerged as a vital component of the cereal economy due to rapid expansion in area and increasing demand from food, feed, and industrial sectors. During 2016, maize was grown on more than 11.5 million hectares with a production exceeding 23 million tonnes. In recent years, the adoption of high-yielding hybrids, improved crop management practices, expansion of irrigation facilities, and growing demand from poultry feed, starch, ethanol, and bio-industrial sectors have driven a substantial increase in maize production. Consequently, national maize production during 2024-25 reached approximately 42.3-43.4 million tonnes, placing India among the leading maize-producing countries globally (Ministry of Agriculture, 2016; IPAD-USDA, 2024-25).

Maize cultivation in India is geographically widespread. Major producing states include Madhya Pradesh, Karnataka, and Maharashtra, while Bihar, Telangana, and Tamil Nadu also contribute significantly. Additional production from West Bengal, Andhra Pradesh, and Uttar Pradesh further highlights the crop's broad adaptability. Telangana alone contributes about 7-7.4% of the national maize output, underscoring its importance in the regional agricultural economy (India Data Map, 2024-25).

Despite its potential, maize productivity in Telangana is constrained by several agronomic factors, among which weed infestation is a major limitation. The crop is particularly vulnerable to weed competition during the initial growth stages due to wider row spacing and relatively slow early growth. Yield losses due to weeds in maize may range from 28 to 100% if not effectively controlled (Patel *et al*., 2006; Nagalakshmi *et al*., 2006) [7, 5]. Hence, timely and effective weed management during the critical period of crop-weed competition is essential to realize optimum yields.

Chemical weed control is an important component of maize production systems, especially under conditions of labour scarcity or unfavourable soil moisture for mechanical operations. Commonly used herbicides in maize include atrazine, simazine, pendimethalin, alachlor, and post-emergence herbicides such as 2,4-D. However, the repeated use of a limited range of herbicides often results in inadequate control of diverse weed flora, persistence issues, and potential residual toxicity to succeeding crops. These limitations necessitate the evaluation of new-generation herbicide molecules and integrated weed management strategies for sustainable weed control in maize cultivation (Singh *et al*., 2012) [10].

Material and Method

A field experiment was carried out during the rabi season of 2016 at the College Farm, College of Agriculture, Rajendranagar, Hyderabad, Telangana. The experimental soil was sandy loam in texture, low in available nitrogen, and medium in available phosphorus and potassium. The experiment was laid out in a randomized block design comprising eight weed management treatments with three replications.

Thetreatmentsincluded:

T_1 - Topramezone 33.6% EC @ 25.2 g ha^{-1} + Dimethanamide 72% EC @ 570 g ha^{-1} (early post-emergence);

T_2 - Topramezone 33.6% EC @ 25.2 g ha^{-1} + Atrazine 80% WP @ 0.5 kg ha^{-1} (early post-emergence);

T_3 - Atrazine 50% WP @ 1.0 kg ha^{-1} followed by 2,4-D 50% WP @ 0.5 kg ha^{-1};

T_4 - Atrazine 50% WP @ 1.0 kg ha^{-1} followed by Topramezone 33.6% EC @ 25.2 g ha^{-1} + Dimethanamide 72% EC @ 600 g ha^{-1} at 25 DAS;

T_5 - Atrazine 50% WP @ 1.0 kg ha^{-1} followed by Topramezone 33.6% EC @ 25.2 g ha^{-1} + Atrazine 50% WP @ 0.5 kg ha^{-1} at 25 DAS;

T_6 - Atrazine 50% WP @ 1.0 kg ha^{-1} as pre-emergence followed by Atrazine 50% WP @ 1.0 kg ha^{-1} as post-emergence;

T_7 - Atrazine 50% WP @ 1.0 kg ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS;

T_8 - Unweeded control.

Maize hybrid DHM-117 was sown on 26 October 2016 at a spacing of 60 cm × 20 cm. A uniform recommended fertilizer dose of 180-60-60 kg N-P_2O_5-K_2O ha^{-1} was applied to all treatments using urea, diammonium phosphate (DAP), and muriate of potash (MOP). Observations on plant height, dry matter accumulation at 30, 60, and 90 DAS and at harvest, yield attributes, grain yield, stover yield, and harvest index were recorded following standard procedures.

Result and Discussion

Dry matter production

Dry matter accumulation of *rabi* maize at 30, 60, and 90 DAS and at harvest differed significantly among weed management treatments. The highest dry matter accumulation at all growth stages was consistently recorded under atrazine @ 1.0 kg a.i. ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS (T_7), indicating superior crop growth under effective weed suppression. Enhanced dry matter production under this treatment can be attributed to reduced weed competition, higher weed control efficiency, and improved nutrient uptake, which together created a favorable growth environment for maize.

Dry matter production increased progressively from 30 DAS to harvest across all treatments. Treatment T_7 remained superior throughout the crop growth period and recorded maximum dry matter at harvest, significantly outperforming all herbicidal treatments and the unweeded control. Sequential or tank-mix applications of atrazine with topramezone (T_5 and T_4) also resulted in higher dry matter accumulation due to sustained weed control. In contrast, the unweeded control (T_8) recorded the lowest dry matter at all stages, reflecting severe crop-weed competition. The low standard error values and significant differences at CD (P = 0.05) confirm the reliability of treatment effects. These findings underscore the effectiveness of integrated weed management in enhancing dry matter production of rabi maize (Kumar *et al*., 2017; Singh and Chandra, 2019; Rana *et al*., 2021) [13, 14, 15].

Table 1: Dry matter production (kg ha^{-1}) as influenced by different weed control treatments in *rabi* maize

Treatment	Dry matter production (kg ha^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 - Topramezone 33.6 EC 25.2 g ha^{-1} + Dimethanamide 72 EC 570 g ha^{-1} (POE)	816	7431	8918	12390
T_2 - Topramezone 33.6 EC 25.2 g ha^{-1} + Atrazine 80 WP 0.5 kg ha^{-1} (POE)	793	7233	8687	12069
T_3 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* 2, 4-D 50 WP 0.5 kg ha^{-1} (POE)	767	7020	8423	11705
T_4 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Topramezone 33.6 EC 25.2 g ha^{-1} + Dimethanamide 72 EC 570 g ha^{-1} (POE)	805	7371	8843	12285
T_5 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Topramezone 33.6 EC 25.2 g. ha^{-1} + Atrazine 50WP 0.5 kg ha^{-1} (POE)	850	7738	9285	12901
T_6 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Atrazine 50 WP 1.0 kg ha^{-1} (POE)	761	6964	8315	11552
T_7 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* intercultural operations and hand weeding at 20 and 40 DAS	1051	9588	11505	15982
T_8 - Unweeded control	649	5902	7083	9842
SEm (±)	27.2	250.4	298.2	413.7
CD (0.05)	82.6	759.6	904.6	1254.8

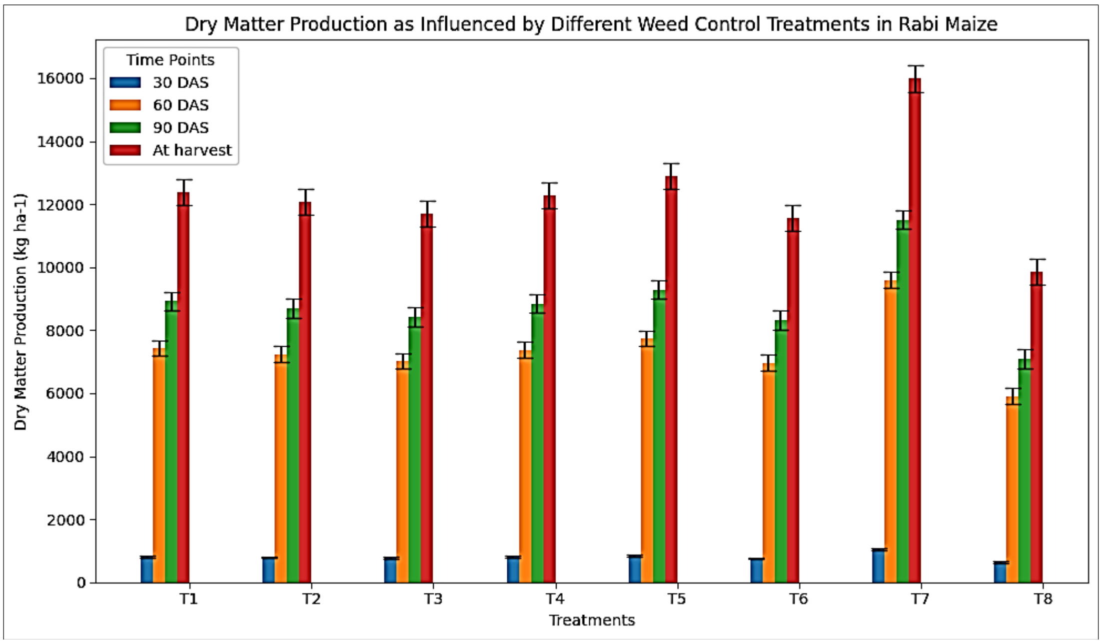

Fig 1: Graph showing the dry matter production (kg ha^{-1}) influenced by different weed control treatments in *rabi* maize, with error bars for each time point (30 DAS, 60 DAS, 90 DAS, and at harvest)

Yield Attributes

The data presented in Table 1 clearly demonstrate that most yield-determining characters of maize were significantly affected by different weed management practices. Parameters such as cob length, cob girth, number of kernel rows per cob, number of kernels per cob, and 100-grain weight exhibited marked variation among treatments. In contrast, the number of cobs per plant did not differ significantly across treatments, indicating that this trait is primarily under genetic control and relatively insensitive to variations in weed management.

Among the treatments, application of atrazine at 1.0 kg a.i. ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS (T_7) produced significantly higher cob length, cob girth, and number of kernel rows per cob. This treatment was statistically comparable with T_5, T_1, T_4, and T_2, while the remaining treatments recorded comparatively lower values. Treatment T_7 also resulted in the highest number of kernels per cob and maximum 100-grain weight, reflecting superior sink development and grain filling efficiency.

The improved performance of integrated weed management treatments over the unweeded control can be attributed to effective suppression of weed flora, which reduced competition for nutrients, moisture, light, and space during critical growth stages. Enhanced dry matter accumulation and nutrient uptake under these treatments likely promoted efficient partitioning of assimilates from vegetative tissues to reproductive organs, resulting in improved yield attributes. Similar improvements in yield-attributing characters of maize under effective weed control have been reported earlier by Fathi (2005) [3], Patel *et al*. (2006) [7], Hussein *et al*. (2008) [4], Deshmukh *et al*. (2008) [2], Srividya (2010) [12], and Aleem Ahmed *et al*. (2012) [1].

The superiority of T_7 was further confirmed by graphical representation of yield attributes (Fig. 2a-e), wherein this treatment recorded the highest values for cob length, cob girth, kernel rows per cob, kernels per cob, and 100-grain weight. Sequential or tank-mix herbicide applications, particularly T_5 and T_4, also performed better than sole atrazine treatments, indicating the advantage of sustained and broad-spectrum weed control. In contrast, the unweeded control (T_8) consistently registered the lowest values for all yield-attributing parameters due to intense crop-weed competition. The observed treatment differences were statistically significant at CD (P = 0.05), confirming the reliability of the results (Pandey *et al*., 2016; Kumar and Singh, 2019; Rana *et al*., 2021) [16, 17, 15].

Table 2: Yield attributes as influenced by different weed control treatments in *rabi* maize

Treatments	Cob length (cm)	Cob girth (cm)	No. of rows/cob	Total Number of kernels per cob	100 grain weight (g)
T_1 - Topramezone 33.6 EC 25.2 g ha^{-1} + Dimethanamide 72 EC 570 g ha^{-1} (POE)	20.0	17.0	14.0	282	20.5
T_2 - Topramezone 33.6 EC 25.2 g ha^{-1} + Atrazine 80 WP 0.5 kg ha^{-1} (POE)	19.0	16.3	13.7	270	19.6
T_3 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* 2, 4-D 50 WP 0.5 kg ha^{-1} (POE)	18.7	16.0	13.3	260	18.9.
T_4 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Topramezone 33.6 EC 25.2 g ha^{-1} +Dimethanamide 72 EC 570 g ha^{-1} (POE)	19.3	16.7	14.0	280	21.5
T_5 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Topramezone 33.6 EC 25.2 g. ha^{-1} + Atrazine 50WP 0.5 kg ha^{-1} (POE)	21.0	17.0	14.3	298	20.3
T_6 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Atrazine 50 WP 1.0 kg ha^{-1} (POE)	18.7	15.7	13.3	254	18.4
T_7 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* intercultural operations and hand weeding at 20 and 40 DAS	23.7	17.7	14.7	375	24.5
T_8 - Unweeded control	15.7	15.3	12.7	235	15.3
SEm (±)	0.8	0.3	0.4	12.9	0.9
CD (0.05)	2.5	0.9	1.1	39.1	2.8

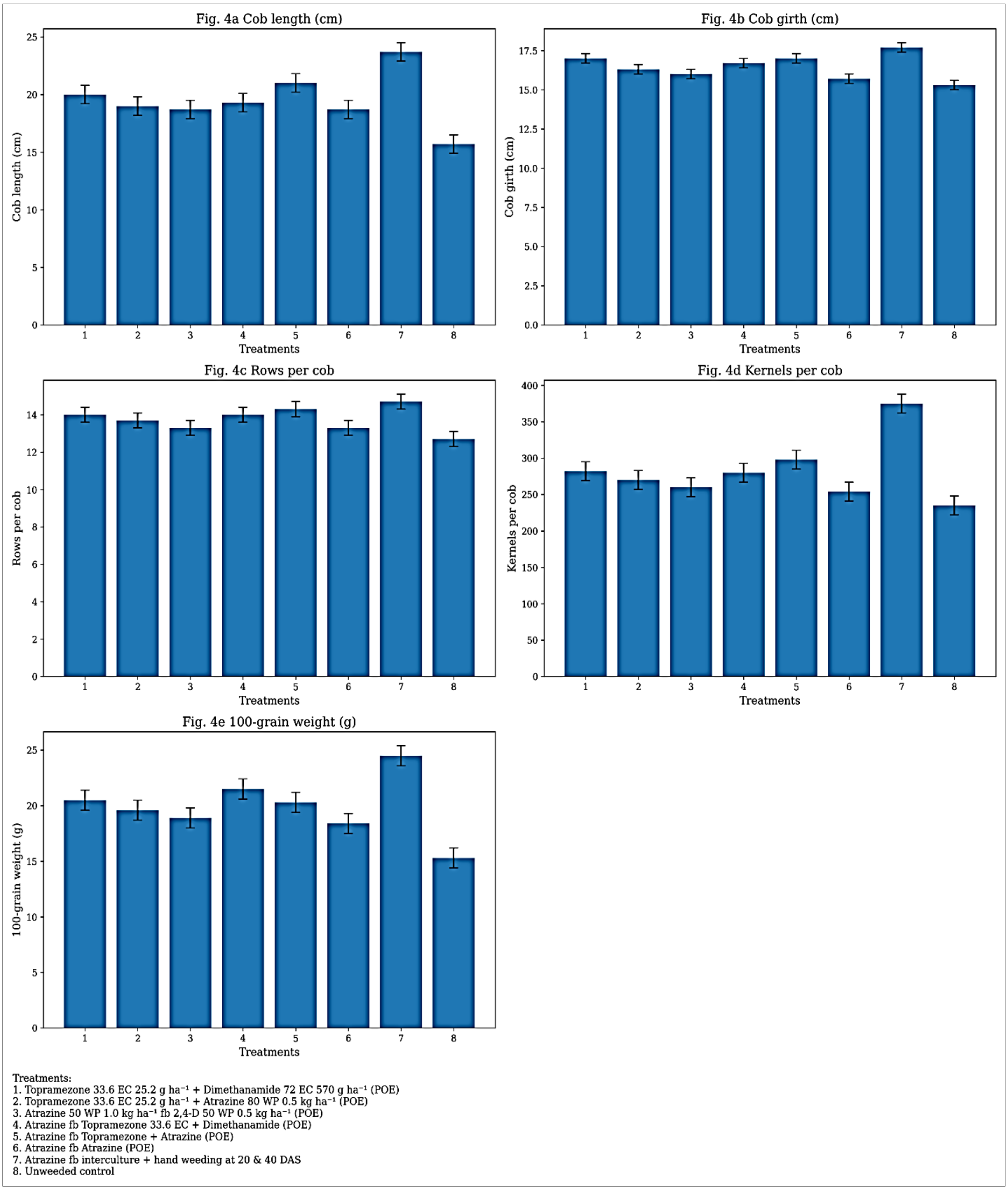

Fig 2a-e: Effect of different weed management treatments on cob length, cob girth, number of kernel rows cob^{-1}, kernels cob^{-1}, and 100-grain weight of rabi maize. Vertical bars represent ± SEm; differences exceeding CD at P = 0.05 are statistically significant

Grain and Stover Yields

Grain and stover yields of maize were significantly affected by the different weed management treatments, as presented in Table 3. Among the treatments, pre-emergence application of atrazine at 1.0 kg a.i. ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS (T_7) resulted in the highest grain and stover yields and proved to be statistically superior to all other treatments. The yield enhancement observed under T_7 can be primarily attributed to effective suppression of weed density and biomass, which substantially reduced competition for essential growth resources during critical stages of crop development.

In addition to weed control, the intercultural operations and hand weeding practices likely improved soil physical conditions by enhancing aeration and reducing surface compaction, thereby promoting better root development and nutrient uptake. These factors collectively contributed to improved crop growth, superior yield attributes, and ultimately higher grain and stover yields.

In contrast, the unweeded control treatment recorded the lowest grain and stover yields due to continuous weed pressure throughout the crop growth period. Elevated weed biomass under this treatment resulted in intense competition for nutrients, moisture, light, and space, leading to reduced dry matter accumulation, restricted plant growth, and poor development of yield components. The present findings are consistent with earlier reports highlighting the adverse effects of uncontrolled weed infestation on maize productivity (Pandey *et al*., 2001; Patel *et al*., 2006; Rao *et al*., 2009; Sandhyarani and Karunasagar, 2013; Aleem Ahmed *et al*., 2012; Sonawane *et al*., 2014) [6, 1, 7, 8, 9, 1, 11].

Harvest Index

Harvest index values varied significantly among the different weed management treatments, as shown in Table 2. The maximum harvest index (45.26%) was achieved under the treatment involving atrazine application at 1.0 kg a.i. ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS (T_7), whereas the unweeded control (T_8) registered the lowest harvest index (39.40%). The superior harvest index observed under T_7 indicates more efficient partitioning of assimilates towards grain formation, which was facilitated by effective weed suppression and reduced competition during critical growth stages. Enhanced grain yield under this treatment suggests improved translocation of photosynthates from vegetative tissues to reproductive sinks. Similar improvements in harvest index under effective weed management in maize have been reported earlier by Nagalakshmi *et al*. (2006) [5] and Srividya (2010) [12].

Table 3: Grain yield, Stover yield and harvest index of *rabi* maize as influenced by different weed control treatments

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1 - Topramezone 33.6 EC 25.2 g ha^{-1} + Dimethanamide 72 EC 570 g ha^{-1} (POE)	5127	6561	43.9
T_2 - Topramezone 33.6 EC 25.2 g ha^{-1} + Atrazine 80 WP 0.5 kg ha^{-1} (POE)	4902	6483	43.1
T_3 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* 2, 4-D 50 WP 0.5 kg ha^{-1} (POE)	4726	6318	42.8
T_4 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Topramezone 33.6 EC 25.2 g ha^{-1} +Dimethanamide 72 EC 570 g ha^{-1} (POE)	5097	6492	43.95
T_5 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Topramezone 33.6 EC 25.2 g. ha^{-1} + Atrazine 50WP 0.5 kg ha^{-1} (POE)	5403	6766	44.4
T_6 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* Atrazine 50 WP 1.0 kg ha^{-1} (POE)	4615	6284	42.3
T_7 - Atrazine 50 WP 1.0 kg ha^{-1} *fb* intercultural operations and hand weeding at 20 and 40 DAS	6821	8249	45.26
T_8 - Unweeded control	3665	5622	39.4
SEm (±)	187.02	203.33	0.45
CD (0.05)	567.24	616.71	1.38

Grain yield, stover yield, and harvest index of rabi maize were significantly affected by the different weed management practices employed during the study (Table 3). Among the treatments, T_7, which involved application of atrazine at 1.0 kg ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS, produced the highest grain and stover yields along with the maximum harvest index. This clearly reflects enhanced biomass accumulation and more efficient allocation of assimilates towards grain production under conditions of effective weed control. The yield advantage observed under T_7 can be attributed to substantial reduction in crop-weed competition, improved availability and uptake of nutrients, enhanced photosynthetic activity, and better translocation of photosynthates from source to sink. Sequential and tank-mix herbicide treatments, particularly T_5 and T_4, also resulted in significantly higher yields compared to sole atrazine application, highlighting the importance of prolonged and broad-spectrum weed suppression for sustaining crop growth. In contrast, the unweeded control (T_8) recorded the lowest grain yield, stover yield, and harvest index due to intense weed interference throughout the crop growth period. The low standard error of mean (SEm) values and treatment differences exceeding the critical difference at P = 0.05 indicate the robustness and reliability of the experimental results, thereby confirming the effectiveness of integrated weed management practices in enhancing yield and harvest efficiency of rabi maize (Pandey *et al*., 2016; Kumar and Singh, 2019; Rana *et al*., 2021) [16, 17, 15].

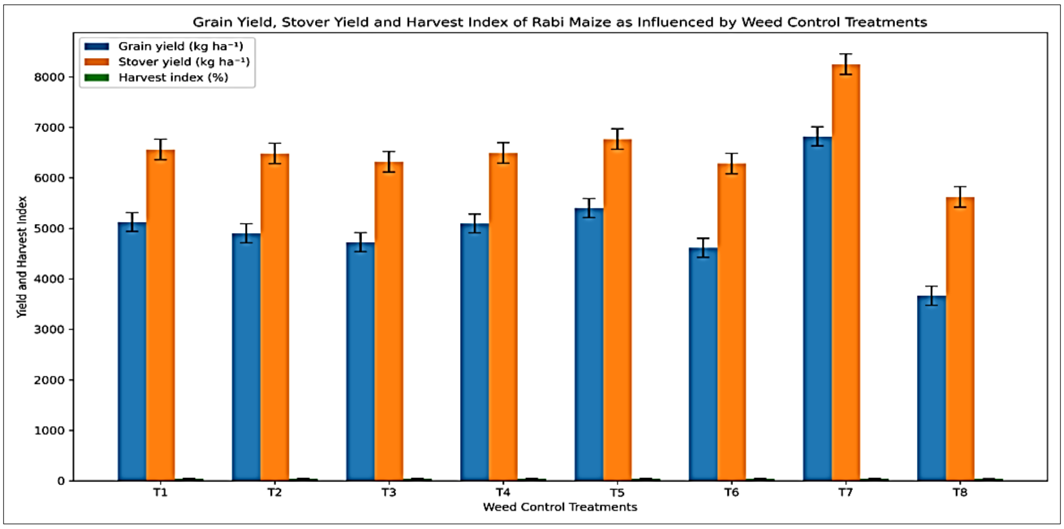

Fig 3: Grain Yield, Stover Yield Harvest Index of Rabi Maize as Influenced by Weed Control Treatments

Conclusion

Weed management strategies exerted a significant influence on crop growth, dry matter accumulation, yield attributes, grain yield, stover yield, and harvest index of rabi maize. Among the treatments evaluated, application of atrazine at 1.0 kg a.i. ha^{-1} followed by intercultural operations and hand weeding at 20 and 40 DAS (T_7) consistently resulted in the highest dry matter production across all growth stages, superior yield components, maximum grain and stover yields, and the highest harvest index (45.26%). These outcomes indicate enhanced biomass production and more efficient partitioning of assimilates under conditions of effective weed suppression. Sequential and tank-mix herbicide treatments (T_5 and T_4) also improved crop performance compared to sole atrazine application; however, their effectiveness was comparatively lower than that of the integrated weed management approach. In contrast, the unweeded control (T_8) exhibited the poorest growth and yield performance due to intense crop-weed competition, as evidenced by a reduced harvest index (39.40%). Overall, the results clearly demonstrate that integrated weed management combining chemical and mechanical control measures is more effective than sole chemical methods in improving productivity and harvest efficiency of rabi maize under the prevailing experimental conditions.

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