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*Research Article*

# New generation pre and post emergence herbicides for weed management in fodder maize cv. African Tall

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## ABSTRACT

*Green and dry fodder play a significant role in reducing the cost of milk and other products in livestock. Among forage crops, maize is one of the most important fodder crops in the world. However, the cost of its green fodder production is comparatively higher than other cereal forage crops. Weeds are known to compete with crops for space, light, and nutrients. Weed management is an important but neglected practice for maximizing quality yield. To determine the best herbicide in fodder maize, five herbicides alone and in combinations were applied as pre- and post-emergence. Among treatments, the application of Topramezon 120g + Atrazine 250g a.i. ha$^{-1}$ at 20 DAS gave the significantly highest yield of green fodder, dry matter, and crude protein. It reduced the weed intensity and gave maximum net returns with a 3.84 benefit-cost ratio. The said treatment has been recommended for higher fodder yield and reduced cost of production.*

***Keywords*:** Weed management, new generation herbicides, green fodder yield and weed index, WCE

The agricultural production systems in India are based upon a mixed farming system in which two major enterprises include the i.e., cultivation of crops and livestock. To meet the demand for green forage of livestock, farmers generally grow seasonal and perennial fodder crops like sorghum, bajra, cowpea, maize, oat, berseem, hybrid Napier, *Desmanthus*, etc. Among the various seasonal fodder crops, maize (*Zea mays* L.) is one of the most important fodders all over the world. In India, also maize variety African tall is grown widely for its higher biomass yield and nutritional quality for many years. In maize, the first 30-60 days after sowing is considered a critical period for crop weed competition (Dass *et al*., 2012). Maize is cultivated by line sowing mainly which allows easy weed proliferation in between lines. Secondly, weeds are known to exude toxic substances from roots e.g., *Parthenium*, leaves that affect the yield of the maize (Rashid *et al*., 2008).

Weeds are the major problem as it reduces crop yield by 20-60% (Shekhawat *et al*., 2017). Due to weed infestation, potential yield losses were high in the case of soybean (50–76%), maize (18-65%), direct seeded rice (15-66%), and groundnut (45–71%) (Gharde *et al.*, 2018). The quantities of nutrients up taken by weeds thus become unavailable to the crop; the extent of nutrient loss varies from 30-40% of the applied nutrients (Mundra *et al*., 2002) Manual removal of weeds is a labour-intensive process which leads to time and economic losses than the application of chemical herbicide. Various herbicides like, atrazine, tembotrione, halosulfuron methyl, 2-4-D amine, pendimethalin, etc. are used to control the weed infestation in maize. The effect of new-generation herbicide and their combinations with recommended herbicides was studied on weed growth and forage yield of fodder maize for three consecutive *kharif* seasons.

## MATERIALS AND METHODS

The experiments were conducted at the BAIF Central Research Station in fodder maize during *kharif* 2017-2019. It was laid in Randomized Block Design with five different herbicides alone and in combination as treatments in three replications with a variety African Tall (Table 1).

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The treatments consisted of $T_1$- Tebotrione @120g *a.i.* $ha^{-1}$ at 20 DAS, $T_2$- Topramezone @ 35g *a.i.* $ha^{-1}$ at 20 DAS, $T_3$- Tembotrione + Atrazine @ 120 g+250 g *a.i.* $ha^{-1}$ at 20 DAS, $T_4$- Topramezone + Atrazine @ 35g+250g *a.i.* $ha^{-1}$ at 20 DAS, $T_5$- Atrazine @1000g a.i $ha^{-1}$ as pre-emergence application, $T_6$- Pendimethalin @1000g *a.i.* $ha^{-1}$as pre-emergence application, $T_7$- Atrazine + Pendimethalin @ 750g+750g *a.i.* $ha^{-1}$as pre-emergence application, $T_8$- 2,4-D @ 500g *a.i.*$ha^{-1}$@ 20 DAS, $T_9$- Hand weeding at 20 DAS and 40 DAS and $T_{10}$- absolute control i.e. Weedy check.

All the recommended agronomic practices i.e., fertilizers, spacing, irrigation, etc. for the cultivation of maize were followed. The crop was sown in the month of July during each kharif season with line sowing method at 30 cm spacing. The recommended dose of fertilizer 80:40:40 kg NPK/ha was applied to crop. The half dose of the nitrogen and full dose of Phosphorus and Potash were applied at the time of sowing. Remaining 50 percent nitrogen was given 30 days after sowing. The irrigation was given as per the requirement of the crop during kharif season. The crop was harvested at 50% flowering stage. The observations on, maize growth: average plant height, number of leaves, stem girth, yield Parameters: green fodder yield, dry matter yield, and crude protein yield were recorded. In addition, the total number of weeds per square meter was counted before spraying of herbicide and after 30 and 60 DAS for each treatment. The data was compiled and analysed using Opstat software. The principal component Analysis was carried out using PAST software (Hammer *et al*., 2001).

## RESULTS AND DISCUSSION

The experimental field was infested with various weed species, consisting of both dicot and monocot weeds and sedges. In the experimental field the monocot and dicot weeds found predominantly. The most common dicot weeds are *Euphorbia hirta, Digera arvensis, Lagasca mollis, Echinochloa crusgalli, Parthenium hysterophorus* and in monocot *Cynodon dactylon*, whereas in sedges *Cyperus rotundus* were present in less number.

The adopted weed management treatments showed a significant effect on weed control in fodder maize (Table 1). Hand weeding at 20 and 40 DAS significantly minimizes weed infestation in both monocots and dicots in the field. Among chemical weed management treatments, a combination of topramezone 35g + atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS significantly recorded the minimum weed count 27.83 $m^{-2}$ at and 48.50 $m^{-2}$ at 30 DAS and 60 DAS, respectively followed by treatment $T_3$ (tembotrione + atrazine @ 120 g + 250g *a.i.* $ha^{-1}$ at 20 DAS) which recorded weed population of 32.83 $m^{-2}$ at 30 DAS and 52.17 $m^{-2}$ at 60 DAS. Baldaniya *et al.* (2018) reported that the application of atrazine 0.5 kg $ha^{-1}$ + topramezone 0.025 kg $ha^{-1}$ tank mix at 20 DAS effectively decline the monocots and sedge weed population in *Zea mays*. Application of Temobotrone @120 g $ha^{-1}$ at 25 DAS minimizes total weed population in *kharif* maize (Gupta *et al.*, 2018). This was because Topramezone controls the monocot as well as dicot weeds and Atrazine also controls the monocot weed infestation. The maximum weed population was recorded in the weedy check treatment being, 123.33 $m^{-2}$ at 30 DAS and 110 $m^{-2}$ at 60 DAS.
Maximum weed control efficiency (WCE) was recorded in hand weeding with 90.59% and 77.33% at 30 DAS and 60 DAS, respectively (Table 1). The significantly maximum weed control efficiency was recorded in $T_4$ being, 80.15% and 66.40% at 30 and 60 DAS, respectively however, treatment T3 were found at par with WCE 75.18% and 63.16% at 30 and 60 DAS respectively. Application of atrazine 0.5 kg $ha^{-1}$ + topramezone 0.025 kg $ha^{-1}$ at 20 DAS recorded the WCE of 73.9% which was at par with hand weeding at 20 and 40 DAS with 76.50% weed control efficiency (Baldaniya *et al.*, 2013). Lower the weed index better the efficacy of herbicide. A significantly low weed index of 3.05 % was recorded in treatment $T_4$ however, treatment T3 with weed index of 6.30% were found at par with treatment T4.

All the growth parameters were recorded at 50% flowering stage of the crop. Plant height ranged between 211.46-292.54 cm whereas, leaves per plant varied between 11.44 - 19.44 (Table 2). The treatment weedy check showed lower values for growth parameters. The application of herbicide influenced crop growth due to reduction of weed population or suppression of weed growth. A significant maximum plant height of 292.54 cm was recorded in topramezone 35g + atrazine 250g *a.i.* $ha^{-1}$ at 20 das. An increase in plant height leads to an increase in the number of leaves per plant. Kumawat *et al.* (2021) reported the plant height of maize as 249.17 cm in topramizon + atrazine @35g+250g $ha^{-1}$ application. A significantly maximum number of leaves per plant of 19.44 was recorded in treatment $T_3$ (Table 2). Significant maximum stem diameter of 1.91cm was recorded by the treatment of topramezone 35g + atrazine 250g *a.i.* $ha^{-1}$ at 20 das followed by treatment topramezone 35g *a.i.* $ha^{-1}$ at 20 DAS with 1.80 cm stem diameter. The increase in the plant height, the number of leaves per plant, and stem diameter were due to the lower weed intensity. The herbicides minimise the weed intensity which reduces the crop weed competition for nutrients, space, and soil moisture resulting in maximum growth.

**Table 1: Effect of different weed management treatment on weeds count, weed index and weed control efficiency of forage Maize (pooled)**

| Treatments | Total weed count per m sq. at 30 DAS | Total weed count per m sq. at 60 DAS | Weed index (%) | WCE at 30 DAS (%) | WCE at 60 DAS (%) |
|---|---|---|---|---|---|
| $T_1$-Tebotrione 120g *a.i.* $ha^{-1}$ at 20 DAS | 46.33 | 58.83 | 16.68 | 70.97 | 58.34 |
| $T_2$-Topramezone 35g *a.i.* $ha^{-1}$ at 20 DAS | 44.33 | 62.33 | 14.10 | 73.04 | 58.68 |
| $T_3$-Tembotrione 120g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 32.83 | 52.17 | 6.30 | 75.18 | 63.16 |
| $T_4$-Topramezone 35g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 27.83 | 48.50 | 3.05 | 80.15 | 66.40 |
| $T_5$-Atrazine 1000g *a.i.* $ha^{-1}$ as pre-emergence | 68.83 | 83.33 | 21.64 | 66.15 | 44.99 |
| $T_6$ -Pendimethalin 1000g *a.i.* $ha^{-1}$ as pre-emergence | 56.50 | 79.33 | 19.64 | 66.52 | 49.65 |
| $T_7$-Atrazine 750g + Pendimethalin750g *a.i.* $ha^{-1}$ as pre-emergence | 58.67 | 73.33 | 18.85 | 68.15 | 50.59 |
| $T_8$- 2,4-D 500g *a.i.* $ha^{-1}$ at 20 DAS | 75.67 | 87.33 | 30.09 | 60.34 | 47.35 |
| $T_9$-Hand weeding at 20 and 40 DAS | 26.33 | 39.33 | - | 90.59 | 77.33 |
| $T_{10}$-Weedy check | 123.33 | 110.00 | - | - | - |
| **SEm (±)** | **3.69** | **2.59** | **2.68** | **3.12** | **4.10** |
| **LSD (0.05)** | **11.06** | **7.75** | **8.01** | **9.43** | **12.41** |
| **CV (%)** | **11.42** | **6.45** | **27.68** | **7.47** | **12.39** |

*Note: WCE= weed control efficiency*

**Table 2: Effect of different weed management treatment on growth parameters at 50% flowering stage (pooled)**

| Treatments | Plant height (cm) | No. of leaves per plant | Stem girth (cm) |
|---|---|---|---|
| $T_1$-Tebotrione 120g *a.i.* $ha^{-1}$ at 20 DAS | 259.27 | 17.00 | 1.66 |
| $T_2$-Topramezone 35g *a.i.* $ha^{-1}$ at 20 DAS | 269.65 | 18.00 | 1.80 |
| $T_3$-Tembotrione 120g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 280.14 | 19.44 | 1.79 |
| $T_4$-Topramezone 35g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 292.54 | 19.33 | 1.91 |
| $T_5$-Atrazine 1000g *a.i.* $ha^{-1}$ as pre-emergence | 211.46 | 15.56 | 1.36 |
| $T_6$ -Pendimethalin 1000g *a.i.* $ha^{-1}$ as pre-emergence | 254.35 | 14.11 | 1.33 |
| $T_7$-Atrazine 750g + Pendimethalin750g *a.i.* $ha^{-1}$ as pre-emergence | 243.18 | 12.22 | 1.36 |
| $T_8$- 2,4-D 500g *a.i.* $ha^{-1}$ at 20 DAS | 217.92 | 11.44 | 1.23 |
| $T_9$-Hand weeding at 20 and 40 DAS | 239.88 | 15.22 | 1.13 |
| $T_{10}$-Weedy check | 211.95 | 12.89 | 1.19 |
| **SEm (±)** | **7.73** | **0.56** | **0.12** |
| **LSD (0.05)** | **23.13** | **1.68** | **0.12** |
| **CV (%)** | **5.40** | **6.28** | **13.81** |

The data on forage maize green fodder, dry matter, and crude protein yield was recorded at 50% flowering stage, and pooled data was presented in table 3. All the weed management treatments showed a significant influence on green fodder yield, dry matter yield, and crude protein yield. An increase in green fodder yield was observed because of different weed management treatments which suppress the weed growth and hence break the competition for the nutrient, space, soil moisture, and light. Among chemical weed management treatments, $T_4$ recorded significantly higher green fodder yield, dry matter yield, and crude protein yield which was at par with the treatment $T_3$. The lowest yield was recorded in weedy check treatment. Kumar *et al*. (2019) reported similar results. Baldaniya *et al*. (2013) also reported that an application of atrazine 0.5 kg $ha^{-1}$ + topramezone 0.025 kg $ha^{-1}$ at 20 DAS gave 748 q $ha^{-1}$ and 249 q $ha^{-1}$ green fodder yield and dry matter yield, respectively.

**Table 3: Effect of different weed management treatment on green forage yield, dry matter yield and crude protein yield of forage Maize (pooled)**

| Treatments | Green forage yield (q $ha^{-1}$) | Dry matter yield (q $ha^{-1}$) | Crude Protein Yield (q $ha^{-1}$) |
|---|---|---|---|
| $T_1$-Tebotrione 120g *a.i.* $ha^{-1}$ at 20 DAS | 732.41 | 139.50 | 11.01 |
| $T_2$-Topramezone 35g *a.i.* $ha^{-1}$ at 20 DAS | 761.38 | 154.53 | 12.55 |
| $T_3$-Tembotrione 120g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 812.16 | 167.42 | 13.28 |
| $T_4$-Topramezone 35g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 843.17 | 171.41 | 13.31 |
| $T_5$-Atrazine 1000g *a.i.* $ha^{-1}$ as pre-emergence | 654.54 | 133.56 | 9.92 |
| $T_6$ -Pendimethalin 1000g *a.i.* $ha^{-1}$ as pre-emergence | 706.78 | 142.09 | 11.59 |
| $T_7$-Atrazine 750g + Pendimethalin750g *a.i.* $ha^{-1}$ as pre-emergence | 704.51 | 126.56 | 9.37 |
| $T_8$- 2,4-D 500g *a.i.* $ha^{-1}$ at 20 DAS | 606.89 | 125.71 | 9.98 |
| $T_9$-Hand weeding at 20 and 40 DAS | 783.37 | 147.87 | 10.91 |
| $T_{10}$-Weedy check | 532.34 | 105.84 | 7.93 |
| **SEm (±)** | **19.04** | **3.75** | **0.28** |
| **LSD (0.05)** | **57.00** | **11.23** | **0.85** |
| **CV (%)** | **4.62** | **4.59** | **4.47** |

PCA has been calculated to study correlation and effectiveness among various factors recorded. The control ($T_{10}$) was found to be out-grouped also showing the influence of vector weed count suggesting a higher weed number. Fodder yield influencing factors such as plant height, green fodder yield, and dry matter yield mainly by $T_4$ followed by $T_3$ treatment where two herbicides have been applied whereas, relatively less influence was observed on single herbicides treatments $T_1$ and $T_2$. Treatment $T_9$ showed a higher influence of only one factor i.e., green fodder yield. The lower influence was observed in $T_5$, $T_7$, and $T_8$ treatments as compared to $T_4$ and $T_3$. The PCA also demonstrated T4 as the best treatment followed by $T_3$ in both cases application of two herbicides was carried out (Fig 1). The use of the combination of two herbicides was also reported to yield higher seed yield in maize than a single herbicide (Kakade *et al.* 2020, Sweta *et al.* 2020).

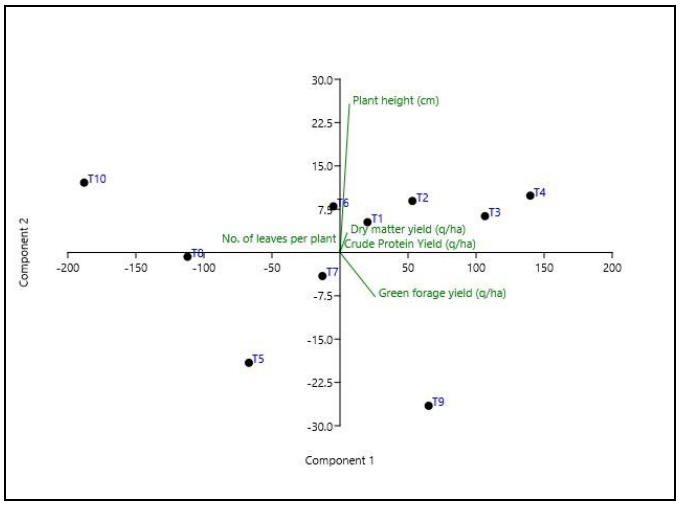


**Fig. 1: PCA for weed management treatments for morphological and yield attributing characters**

A significant difference in gross monetary returns, net monetary returns, and B: C ratio of fodder maize was observed among the treatments (Table 4). Maximum gross monetary return, net monetary return, and benefit-cost ratio of Rs. 227601 $ha^{-1}$, Rs. 168266 $ha^{-1}$ and 1:3.84 was recorded by the treatment combination of topramezone 35g + atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS which was found at par with the application of tembotrione120g + atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS with Rs. 219229 $ha^{-1}$, Rs. 159945 $ha^{-1}$ and 1: 3.70 of gross monetary returns, net monetary return, and benefit-cost ratio, respectively. Kumawat *et al*., 2021 also reported that the treatment of topramizon + atrazine @35g+250g $ha^{-1}$ recorded a significant difference in gross monetary returns, net monetary returns, and B: C ratio of fodder maize was observed among the

treatments (Table 4). maximum benefit cost ratio and net monetary return of 1.56 and Rs. 42398.85 $ha^{-1}$, respectively over the hand weeding treatment. The treatment $T_4$ significantly minimise the weed intensity which helps to increase plant growth and fertilizer use efficiency by the maize crop. The maximum fodder yield was also recorded by similar treatments lead to achieve the maximum net monetary returns and higher benefit cost ratio.

**Table 4: Effect of different weed management treatment on crop economics (pooled mean 2017-2019)**

| Treatments | Gross monetary returns (Rs /ha) | Net monetary return (Rs. /ha) | B: C Ratio |
|---|---|---|---|
| $T_1$-Tebotrione 120g *a.i.* $ha^{-1}$ at 20 DAS | 197703 | 142229 | 3.56 |
| $T_2$-Topramezone 35g *a.i.* $ha^{-1}$ at 20 DAS | 205521 | 149996 | 3.70 |
| $T_3$-Tembotrione 120g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 219229 | 159945 | 3.70 |
| $T_4$-Topramezone 35g + Atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS | 227601 | 168266 | 3.84 |
| $T_5$-Atrazine 1000g *a.i.* $ha^{-1}$ as pre-emergence | 176682 | 121382 | 3.19 |
| $T_6$ -Pendimethalin 1000g *a.i.* $ha^{-1}$ as pre-emergence | 190784 | 135109 | 3.43 |
| $T_7$-Atrazine 750g + Pendimethalin750g *a.i.* $ha^{-1}$ as pre-emergence | 190172 | 134197 | 3.40 |
| $T_8$- 2,4-D 500g *a.i.* $ha^{-1}$ at 20 DAS | 163820 | 107611 | 2.91 |
| $T_9$-Hand weeding at 20 and 40 DAS | 211457 | 147307 | 3.30 |
| $T_{10}$-Weedy check | 143518 | 90401 | 2.69 |
| **SEm (±)** | **5139.23** | **4924.13** | **0.11** |
| **LSD (0.05)** | **15387.73** | **14743.69** | **0.33** |
| **CV (%)** | **4.62** | **6.18** | **4.89** |

## CONCLUSION

Huge infestation of weed in forage crops, high cost of mechanical weed management and its laborious nature necessitate the application of chemical herbicides for the control of weeds. It can be inferred from the study that the combined application of topramezone 35g + atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS or tembotrione1 20g + atrazine 250g *a.i.* $ha^{-1}$ at 20 DAS in forage maize may suitably reduce weed infestation and secure high forage yield as well as economic returns.

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