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Research Communication

Growth and productivity of maize (*Zea mays*) as influenced by sequential and combined application of tank mix herbicides

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ABSTRACT

The experiment was conducted during 2021–22 at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand to evaluate the impact of sequential and tank mix application of pre- and post-emergence herbicide on weed dynamics and maize productivity. The study was comprised of 9 treatments viz. Weedy (T_1); Weed free (T_2); Pre-emergence (PE) application of Atrazine -1 kg a.i./ha *fb* hand weeding (T_3); PE application of Atrazine - 0.75 kg a.i./ha *fb* Post Emergence (Post E) application of Topramezone - 25.2 g a.i./ha (T_4); PE application of Atrazine - 0.75 kg a.i./ha *fb* Post E application of Tembotrione - 120 g a.i./ha (T_5); PE application of Atrazine - 1.0 kg a.i./ha *fb* Post E application of Topramezone - 25.2 g a.i./ha (T_6); PE application of Atrazine - 1.0 kg a.i./ha *fb* Post E application of Tembotrione - 120 g a.i./ha (T_7); Early Post E application of Topramezone - 25.2 g a.i./ha + Atrazine - 0.75 kg a.i./ha (T_8) and Early Post E application of Tembotrione - 120 g a.i./ha + Atrazine - 0.75 kg a.i./ha (T_9). *Eleusine indica, Echinochloa colona*, *Digitaria sanguinalis* and *Eragrostis japonica* were dominant among grassy weeds whereas broad leaf weeds included *Cucumis melo, Phyllanthus niruri, Cleome viscosa* and *Commelina benghalensis*. *Cyperus rotundus* was dominant among sedges. Topramezone - 25.2 g a.i./ha + Atrazine - 0.75 kg a.i./ha Early Post E resulted significantly lower total weed density and was similar to other herbicidal treatments. The highest grain yield (7.2 t/ha) was recorded in a weed-free crop that was similar to all herbicide-treated crops and significantly higher than the weedy crop. Tank mix application of atrazine - 0.75 kg a.i./ha with tembotrione 120 g a.i./ha or topramezone 25.2 g a.i./ha at 15 DAS can be suggested owing to higher grain yield and profits for farmers while lowering the dose and expenses involved in manual weeding and spraying atrazine separately.

***Key words*:** Atrazine, Grain yield, Leaf-area index, Tank mix, Tembotrione

Maize (*Zea mays* L.) is a globally significant crop and ranks as one of the most important crops worldwide. In India, it is the third-largest crop in terms of production, following rice and wheat. On a global scale, maize occupies approximately 203.47 million ha (Mha) of land with a production of 1163.5 million tonnes (Mt) along with productivity of 5.73 tonnes per hectare (t/ha) while the area, production, and productivity of maize in India were estimated to be ~ 9.95 Mha, 33.7 Mt and 3.38 t/ha, respectively (FAOSTAT, 2022). In India, cultivation of maize is primarily done during the rainy (*kharif*) season which is characterized by a high degree of relative humidity and heavy precipitation. As maize is a widely spaced crop, it provides ample space for weeds to proliferate and compete with it for nutrients, light and water. Weeds significantly reduced the grain yield of maize by 58.7%, as compared with manual weeding performed at 20 and 40 days after sowing (DAS) (Triveni *et al*., 2017). Albeit, manual weeding can provide satisfactory results, however, it is expensive, laborious and difficult to maintain in wet or impulsive conditions, making it uneconomical for large areas of land. In such conditions, chemical weed control may be an effective tool for timely and economical control. Atrazine is one of the most commonly used herbicides in maize crops can be used both as pre- and post-emergent. Weeds can be effectively controlled with application of atrazine 1.0 kg a.i./ha followed by manual weed control at 30 DAS (Sunitha *et al.*, 2010). Two novel herbicides, viz. Tembotrione and Topramezone have been introduced for effective control of weeds in maize. These are highly effective in reducing both grass and broad-leaf weeds in maize in a short period of time of 2–5 DAS (Singh *et al.,* 2012). In order to

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effectively manage weeds, it is necessary to employ either a combination or sequential application of pre- or post-emergence herbicides. Hence, an experiment was conducted to determine the effects of novel post-emergence herbicides and the optimal combinations of these herbicides with atrazine, as well as the window of application for maize crop.

Present study was carried out during the rainy (*kharif*) season of 2021–22 at the Norman E. Borlaug Crop Research Center, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The soil of experimental field was characterized as silty clay loam, with low available nitrogen (253.1 kg/ha) and medium available phosphorus (16.6 kg/ha) and potassium (164.0 kg/ha). The experiment was conducted in a randomized block design (RBD) comprised of 9 treatments, viz. T_1, Weedy; T_2, Weed free; T_3, Pre-emergence (PE) application of Atrazine - 1 kg a.i./ha followed by hand weeding; T_4, PE application of Atrazine - 0.75 kg a.i./ha followed by post-emergence (Post E) application of Topramezone - 25.2 g a.i./ha; T_5, PE application of Atrazine - 0.75 kg a.i./ha followed by Post E application of Tembotrione - 120 g a.i./ha; T_6, PE application of Atrazine - 1.0 kg a.i./ha followed by Post E application of Topramezone - 25.2 g a.i./ha; T_7, PE application of Atrazine - 1.0 kg a.i./ha followed by Post E application of Tembotrione - 120 g a.i./ha; T_8, Early Post E application of Topramezone - 25.2 g a.i./ha + Atrazine - 0.75 kg a.i./ha; and T_9, Early Post E application of Tembotrione - 120 g a.i./ha + Atrazine - 0.75 kg a.i./ha, with three replications. Field preparation involved one ploughing and three cross harrowing operations using a tractor-drawn disc harrow. Subsequently, the field was leveled using a tractor-drawn leveler. The maize hybrid variety DKC 9144 was sown at a spacing of 60 cm × 25 cm on 24 June 2021 and harvested on 12 October 2021. Pre-emergent application of atrazine (-0.75 kg/ha or -1.0 kg/ha) was done just after sowing on the same day while post-emergence herbicides (topramezone-25.2 g/ha; tembotrione-120 g/ha) were applied at 30 DAS. A single tank mix application of herbicides was performed as an early post-emergence treatment at 15 DAS. In the weed-free treatment, manual weeding was done three times at 18, 30, and 42 DAS to manage the weeds. The herbicides were applied using a flat fan nozzle with a spray volume of 500 litres/ha. Nutrients were applied as nitrogen 120 kg, phosphorus 60 kg, potassium 40 kg and zinc sulfate 25 kg for each hectare. Data were analyzed using the online statistical software OP Stat and analysis of variance (ANOVA) prescribed for randomized block design for testing significance of differences among treatments by 'F' test with 5% level of significance. Weed density and dry matter were subjected to square root transformation.

At 60 DAS the plant height was statistically equal across all herbicidal and weed free treatments. In the weedy plot the plant height was significantly lowest (140.4 cm). The plant height decreased by 29.9% under weedy treatment compared to weed free treatment (Table 1). In weedy conditions, the resources available to the crop were inadequate in comparison to those available to crops treated with herbicides, resulting in poor growth and plant diminution. However, due to the reduced weed growth, the growth factors available to the crop under the herbicidal treatments were increased, resulting in better plant growth and an increase in plant height (Ehsas *et al*., 2016). The leaf-area index (LAI) showed statistically non-significant difference between all weed control treatments at 60 DAS, whereas the maximum value was recorded for weed free treatment (LAI 1.95). There was a significant difference in LAI of the weedy crop at the relevant growth stage with the weed crop having the lowest index at 1.67.

LAI plays an important role in the photosynthesis and the smothering effect on weeds. The better availability of growth factor under herbicidal treatment and weed free treatment due to the reduced weed growth resulted in increased leaf production and development resulting in higher LAI value. Minimum leaf area under weedy treatment was owing to increased weed infestation resulting in poor vegetative growth for the crop (Hassan *et al*., 2010). Cob number varied from 54,321/ha to 62,963/ha but there was no significant difference among the treatments. Cobs number depends on the plant population as there was no significant change in plant population, cobs number remained insignificant (Akhtar *et al.,* 2017). The number of grain rows/cob was significantly influenced by the weed free and herbicidal treatments and weed free treatment recorded significantly higher value than the herbicidal treatments. The lowest number of grain rows/cob in the weedy plot (9.5) was significantly lower (29.6%) than the weed free treatment (13.5). The number of grain rows/cob was directly related to the cob girth as the variations in the cob girth between treatments led to variations in the number of rows (Bhatnagar *et al.*, 2016). In all herbicidal treatments, the number of grains/row was at par value. However, weed free treatment yielded significantly higher numbers per row (37.0) than weedy treatment (32.9).

PE application of Atrazine - 1.0 kg a.i./ha followed by Post E application of Topramezone - 25.2 g a.i./ha resulted in significantly higher no. of grain/cob (494). Weed free crop had the maximum no. of grains/cob value (514) which can be calculated by multiplying the number of rows per row by the number of cob. The higher grain rows per row and number of cob were obtained in herbicidal treatments resulted more number of grains/cob (Ghrasiram *et al.*, 2020).

Table 1. Effect of herbicidal treatments on growth and productivity of maize

Treatment	Plant height (cm) (60 DAS)	Leaf area index (60 DAS)	No. of cobs (/ha)	No. of grain rows/cob	No. of grains/ row	No. of grains/ cob	Grain yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T_1	140.4	1.67	54,321	9.5	27.9	266	3.45	11.66	29.54
T_2	200.2	2.78	62,346	13.5	37.9	514	7.20	20.09	35.88
T_3	182.4	2.65	62,963	13.1	37.4	490	6.94	19.10	36.37
T_4	186.2	2.48	62,963	13.1	37.0	484	6.60	18.23	36.25
T_5	185.2	2.55	62,346	13.1	37.2	488	6.65	19.06	34.86
T_6	184.7	2.63	61,111	13.1	37.8	494	6.66	18.85	35.26
T_7	187.3	2.79	61,728	13.1	37.6	492	6.88	18.86	36.43
T_8	188.2	2.72	62,346	12.7	37.3	472	6.41	18.04	35.55
T_9	191.8	2.77	61,728	12.9	37.0	478	6.50	18.18	35.73
SEm±	8.1	0.12	2268	0.3	1.6	19	4.17	6.37	1.70
CD (P=0.05)	24.6	0.37	NS	0.8	4.7	56	12.63	19.8	NS

Refer to the methodology for treatment details. DAS, Days after sowing.

Weed-free crops recorded the highest grain yield (7.2 t/ha). Both the herbicide treatments and the tank mix had similar results. The weedy crop recorded the lowest grain yield (3.4 t/ha), which was significantly lower than the weed-free crop. The herbicides applied sequentially in the treatments, viz. Atrazine - 0.75 kg a.i./ha followed by Topramezone; Atrazine - 0.75 kg a.i./ha followed by Tembotrione; Atrazine - 1.0 kg a.i./ha followed by Topramezone; Atrazine - 1.0 kg a.i./ha followed by Tembotrione resulted in 90.9, 92.4, 92.7 and 98.8%, respectively more grain than the weedy treatment. The tank mix application of herbicides under the treatments, viz. Topramezone + Atrazine - 0.75 kg a.i./ha and Tembotrione + Atrazine - 0.75 kg a.i./ha also led to increased grain yield by 85.5 and 88.1%, respectively in comparison to weedy treatment. The higher yield attributing characters, like number of grains per row and number of grains per cob contributed to the higher grain yield. There was no difference in the yield of maize grain between sequentially applied herbicides and in a tank mix application (Sundari *et al.*, 2019). The weed-free crop yielded the highest biological yield of 20.09 t/ha which was statistically on par with other herbicidal treatments with the exception of treatment Topramezone + Atrazine - 0.75 kg a.i./ha. Conversely, the weedy treatment yielded 11.66 t/ha which was significantly lower (41.9%) than the weed-free treatment. The biological yield is the sum of the yield of cobs, husk, and stover (Khan *et al*., 2016). The harvest index of maize showed a non-significant range of 29.54% for the weedy treatment and 36.43% for the Atrazine - 1.0 kg a.i./ha followed by Tembotrione treatment (Stanzen *et al.*, 2017). A difference in the harvest index was ascribed to the difference between the grain yield and the biological yield.

Based on the results, tank mix application with Atrazine at reduced dose (0.75 kg/ha) in combination with Tembotrione (120 g/ha) or Topramezone (25.2 g/ha) should be applied at 15 DAS (days after sowing), which is not only single application but also convenient and cost effective application in addition to maintaining the desired weed control in maize.

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