

Effects of applying tank-mix herbicides sequentially and in combination on weed growth and maize (*Zea mays*) production

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Abstract

Wider spacing gives weeds more room to develop and compete for nutrients, sunshine, and water in addition to impeding effective weed control techniques. In India, maize (*Zea mays* L.) is mostly cultivated during the rainy (kharif) season, which is impacted by heavy rain and elevated relative humidity. In India's rice-wheat cropping system, maize is essential because it increases overall farm output, improves soil health (by continuously incorporating residues into the soil), and diversifies crop cycles. More than 47% of India's maize crop is being used for chicken feed, with 14% going toward the manufacture of starch. About 13% is set aside for both human consumption and animal feed, 7% for food processing, while the remaining 6% is either exported or used for other reasons (IIMR 2021). The weedy condition results in a 58.7% decrease in maize grain output when compared to two hand weeding (20 and 40 DAS) (Triveni et al. 2017). Although manual weeding efficiently suppresses weeds, it becomes unfeasible in situations with unpredictable rainfall and damp soil owing to its greater cost and labour-intensive nature. Chemical treatment is an efficient way to manage weeds in these situations.

Introduction

To keep weeds under control during the early phases of crop growth, pre-emergence and post-emergence herbicides must be applied both sequentially and concurrently. Atrazine may be administered both before and after emergence and is often used in maize crops. It successfully suppresses a variety of weeds. However, there are drawbacks to using atrazine in maize, such as residual effects on non-target plants or future crops as weeds become resistant to the herbicide. Atrazine at -1.0 kg a.i./ha as pre-emergence followed by (fb) one hand weeding at 30 DAS yielded the greatest value of weed control efficiency (WCE) in maize (Sunitha et al. 2010). Tembotrione and topramezone are two new post-emergent herbicides that have been released recently. While atrazine may be sprayed right after sowing as a pre-emergence treatment and as a post-emergence herbicide at 30 DAS, topramezone, a highly selective herbicide, eliminates both broadleaf and grassy weeds in maize within 2–5 DAS (Swetha et al. 2018). To suppress a variety of weed species in maize, atrazine may be used as an early post-emergence, i.e., up to 10–15 DAS, when combined with tembotrione and topramezone (Akhtar et al. 2017). In order to effectively and widely control weeds in maize, it is necessary to investigate the usage of novel post-emergence herbicides like tembotrione and topramezone in the best possible combination with atrazine.

During the rainy (kharif) season of 2021–2022, the current research was conducted at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experimental field's soil had a silty clay loam texture, a neutral pH of 7.7, a high organic carbon content of 0.88%, low available nitrogen of 253.1 kg/ha, medium available phosphorus of 16.6 kg/ha, and potassium of 164.0 kg/ha. Nine treatments were included in the study: T1, Weedy; T2, Weed Free; and T3, Atrazine.

- 1 kg a.i./ha PE fb hand weeding at 21 DAS; T₄, Atrazine
- 0.75 kg a.i./ha PE fb Topramezone - 25.2 g a.i./ha; T₅, Atrazine
- 0.75 kg a.i./ha PE fb Tembotrione - 120 g a.i./ha; T₆, Atrazine
- 1.0 kg a.i./ha PE fb Topramezone
- 25.2 g a.i./ha; T₇, Atrazine - 1.0 kg a.i./ha PE fb Tembotrione
- 120 g a.i./ha; T₈, Topramezone - 25.2 g a.i./ha + Atrazine
- 0.75 kg a.i./ha; T₉, Tembotrione - 120 g a.i./ha + Atrazine
- 0.75 kg a.i./ha.

Three replications of the experiment were carried out in RBD. On June 24, 2021, the hybrid variety DKC 9144 was planted with a spacing of 60 cm x 25 cm, and it was harvested on October 12, 2021. A tractor-drawn disc harrow was used for three cross harrowings and one ploughing to prepare the field. The land was levelled using tractor-drawn levellers.

For every acre, 120 kilogram of nitrogen, 60 kg of phosphorus, 40 kg of potassium, and 25 kg of zinc sulphate were sprayed.

At sowing, a third of the nitrogen dosage, all of the phosphorus (in the furrows), potassium, and zinc sulphate (on the side of the furrows) were administered. The remaining nitrogen was sprayed in two equal amounts at knee height and tasseling. While post-emergence herbicides like tembotrione and topramezone were used at 30 DAS, atrazine was sprayed as pre-emergence shortly after planting. Herbicides were applied in a single tank-mix as an early post-emergence treatment at 15 DAS. Manual weeding was done three times at 18, 30, and 42 DAS to control weeds under the weed-free treatment. The herbicides were sprayed at a volume of 500 litres per hectare using a flat fan nozzle. Weed flora observations were made at 50 DAS. Weed samples were gathered using a 1.0 m² quadrat, shade-dried for two to three days, and then dried in a hot air oven at 65±5°C until they reached a consistent weight. The dry weight of the weeds was measured using a digital balance and reported in g/m². Square root transformation was used to normalise the weed data, namely weed density and dry weight, with an extra factor of 1.0. Table 1 contains information on the overall weed density statistics. Compared to the other treatments, the weedy plot had the greatest overall weed density (369.3/m²) at 50 DAS. Similar to previous herbicidal treatments, tank mix application of topramezone + atrazine produced a dramatically reduced overall weed density. This resulted from the early post-emergence tank mix application's effective management of early-emerging weeds (Lavanya et al. 2021). The total weed dry matter accumulation in the weedy treatment was much greater at 50 DAS (441.5 g/m²). The total dry matter accumulated at 50 DAS was statistically equal across all herbicidal treatments, with the highest value (116.9 g/m²) occurring in the sequential application of topramezone (-25.2 g/ha) and atrazine (-1.0 kg a.i./ha). The weed population and overall dry matter buildup decreased as a consequence of the herbicidal treatments, which stopped sensitive weed species from germinating further (Samant et al. 2015).

Depending on the weed management technique, different treatments have different weed control efficiencies (WCE). Both sequential and tank mix treatments exhibited comparable WCE at 50 DAS, with the tank mix application of topramezone - 25.2 g a.i./ha + atrazine -0.75 kg a.i./ha showing the highest value (79.9%) (Table 1). Because of the greater dry weight of weeds in the weedy treatment, the WCE was higher at 50 DAS, whereas it was lower in the herbicidal treatments. The treatment that included atrazine (-1 kg a.i./ha) fb manual weeding had the lowest weed index (3.5%). The weed index was slightly higher for sequential application treatments (atrazine (-0.75 kg a.i./ha) fb topramezone, atrazine (-0.75 kg a.i./ha) fb tembotrione, and atrazine (-1.0 kg a.i./ha) fb topramezone) than for tank mix application treatments (topramezone + atrazine and tembotrione + atrazine, 10.6 and 9.5%, respectively). With a weed score of 51.6%, the weedy crop demonstrated a decrease in weeds.

Table 1 Effect of pre-and post-emergence herbicides on weed growth and yield of *kharif* maize

Treatment	Total weed density (no./m ²)	Total weed dry matter (g/m ²)	Weed control efficiency (%)	Weed index (%)	Grain yield (t/ha)	Stover yield (t/ha)	Cost of cultivation (₹/ha)	Net returns (× 1000 ₹/ha)	Net B:C
T ₁	19.1 (369.3)	20.9 (441.5)	0.0	51.6	3.46	5.98	32,588	32.09	0.98
T ₂	1.0 (0.0)	1.0 (0.0)	100.0	0.0	7.20	9.81	48,338	86.34	1.79
T ₃	15.6 (244.0)	10.2 (104.1)	75.6	3.5	6.94	9.38	39,338	90.52	2.30
T ₄	14.0 (197.3)	9.7 (93.9)	78.1	7.9	6.60	9.01	38,888	84.60	2.18
T ₅	14.3 (205.3)	10.1 (105.6)	74.2	7.6	6.65	9.50	38,888	85.58	2.20
T ₆	16.2 (262.7)	10.6 (116.9)	71.5	7.8	6.67	9.13	39,088	85.56	2.19
T ₇	15.4 (237.3)	9.6 (93.7)	78.9	4.7	6.88	9.25	39,088	89.58	2.29
T ₈	13.9 (197.3)	9.2 (84.7)	79.9	10.6	6.42	8.95	38,188	81.81	2.14
T ₉	14.6 (214.7)	10.0 (102.3)	76.1	9.5	6.50	8.88	38,188	83.50	2.19
SEm ±	0.8	0.9	-	-	0.41	0.37	-	7.81	0.20
LSD (P=0.05)	2.5	2.7	-	-	1.26	1.14	-	23.62	0.62

Data given in parenthesis are original value. Refer to the methodology for treatment details.

grain yield of maize by over 50% as compared to a crop free of weeds.

The weed-free treatment produced the greatest grain yield (7.2 t/ha), which was much greater than the weedy crop and comparable to other herbicide-treated crops. Grain yield results from tank mix and sequential herbicide treatments were comparable. The weedy crop produced 3.4 t/ha of grain, which was 51.9% less than the weed-free crop. In comparison to the weedy treatment, the sequential application of atrazine (-0.75 kg a.i./ha) fb topramezone, atrazine (-0.75 kg a.i./ha) fb tembotrione, atrazine (-1.0 kg a.i./ha) fb topramezone, and atrazine (-1.0 kg a.i./ha) fb tembotrione produced higher grain yields (90.9%, 92.4%, 92.7%, and 98.8%, respectively). Comparing tank mix applications of tembotrione + atrazine and topramezone + atrazine to the weedy treatment, the yield rose by 85.5% and 88.1%, respectively. The ideal circumstances for crop development were supported by the decreased weed competition, which eventually led to a better grain production. For sequential and tank mix atrazine treatments, there was no discernible difference in maize grain production between tembotrione and topramezone (Sundari et al. 2019). In compared to weed-free treatment, the stover production under weedy treatment was substantially lower (5.98 t/ha), showing a significant drop of 38.9%. Among the herbicidal treatments, atrazine (-1 kg a.i./ha) fb manual weeding had the greatest stover output (9.38 t/ha). The greatest net return (₹90,527/ha) was obtained from the atrazine (-1 kg a.i./ha) fb manual weeding treatment, which was comparable to all other treatments except the weedy treatment. The weedy crop had the noticeably lowest net return. The weed-free treatment performed on par with tank mix and sequential treatments.

The greatest cultivation cost (₹48338/ha) was caused by three times manual weeding under weed-free treatment, which was statistically comparable to atrazine (-1 kg a.i./ha) fb hand weeding because of the combined cost of herbicide application and one time manual weeding. Atrazine (-0.75 kg a.i./ha) fb topramezone and atrazine (-0.75 kg a.i./ha) fb tembotrione demonstrated lower cultivation costs among sequential application treatments because 25% less atrazine was used in these treatments. In contrast, tank mix application—that is, topramezone + atrazine and tembotrione + atrazine—showed the lowest cultivation costs. This may have been accomplished by simultaneously using two herbicides and reducing the atrazine dose by 25%.

Atrazine (-1 kg a.i./ha) fb manual weeding had the greatest net B:C (benefit-to-cost) ratio of 2.3, which was considerably better than the weedy treatment but statistically comparable to other herbicidal treatments and the weed-free treatment (Mitra et al. 2018). At 0.98, the weedy treatment's net B:C ratio was noticeably lower. The net B:C ratio was calculated using the net return and the cultivation cost. The stated net B:C ratio varied across the treatments because to variations in net return and cultivation costs (Kakade et al. 2020).

SUMMARY

During the kharif season of 2021–2022, a field experiment was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, to assess the effects of tank-mix herbicides on weeds and maize (*Zea mays* L.) in order to ascertain the ideal dosage, application time, and combinations of herbicides for maize. According to the results, weed-free conditions may successfully reduce weeds and increase grain production just as well as atrazine treated with tembotrione or topramezone by sequential or tank mix treatment. Farmers should use tank mix treatments of topramezone (25.2 g a.i./ha) and tembotrione (120 g a.i./ha) with a lower dosage of atrazine (0.75 kg a.i./ha) since they not only successfully eradicate weeds but also provide a better environment for maize to develop, resulting in significant earnings for farmers. Additionally, it reduces the dosage and costs associated with manually weeding and spraying atrazine separately.

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