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RESEARCH NOTE

Impact of sole and sequential application of herbicides on weeds, nutrients uptake and productivity of maize

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ABSTRACT

A field experiment was carried out during rainy *(Kharif)* season 2019 at agricultural research farm of Trihut College of Agriculture (TCA), Dholi under Rajendra Prasad Central Agricultural University (RPCAU) Pusa, Samastipur, Bihar, (India) to quantify the efficacy of sole and sequential application of herbicides in managing weeds and enhance the productivity of maize (*Zea mays* L.). Eleven treatments were tested in randomised block design with three replications. Atrazine 1.0 kg/ha pre-emergence application (PE) followed by (*fb*) post-emergence application (PoE) of tembotrione 0.120 kg/ha at 25 days after seeding (DAS) significantly reduced weed density, weed biomass, N, P, K removal by weeds and increased the yield attributes, grain yield and benefit-cost ratio of maize compared to sole and tank mixed application of atrazine, topramezone and tembotrione.

Keywords: Atrazine, Maize, Nutrient uptake by weeds, Tembotrione, Topramezone, Weed management

Maize (*Zea mays* L.) is an important cereal crop grown for food, feed and industrial purpose in the world and it occupy third position after rice and wheat in India. The maize productivity is affected by the weeds due to severe competition between the crop and weeds in early growth stage of the crop. The yield loss may extend from 33 to 50%, if weeds are not controlled adequately (Sharma *et al.* 2000). It has been reported that application of herbicides alone was not sufficient to control weeds in the maize crop (Sweta *et al.* 2015, Kumar and Chawla 2019). The use of pre-and post-emergence herbicides or herbicide mixture would be more effective to manage weeds in maize (Kakade *et al.* 2020) as the pre-emergence application of herbicides will control the weeds upto 25 days and later the post-emergence herbicide application further controls weeds. Therefore, an experiment was conducted to quantify the efficacy of sole and sequential application and mixture herbicides on weeds management in maize during rainy (*Kharif*) season.

A field trial was conducted during the rainy (*Kharif*) season 2019 at agricultural research farm of Trihut College of Agriculture (TCA) Dholi under the Rajendra Prasad Central Agricultural University (RPCAU) Pusa, Samastipur Bihar, (India). The soil was alkaline in nature, it has pH 7.9. The soil was low in soil organic carbon (0.46%), medium in available N (238 kg/ha), P (17.4 kg/ha) and available K (126.2 kg/ha). The total rainfall during experimental period was 935.6 mm, which was distributed well during crop growth period and made environment congenial for proper expansion of crop. The highest (250.6 mm) rainfall received in 39 meteorological weeks (24-30 Sep.) (**Figure 1**). During the experimental period, maximum temperature was 35.5^{0}C and the lowest temperature was 21^{0}C in July and October, respectively. The evaporation was high during August and the lowest was in September and it was inversely related to rainfall (**Figure 1**).

The weed management treatments tested included weedy check; post-emergence application (PoE) of topramezone 25.2 g/ha at 25 days after seeding (DAS), tembotrione 0.120 kg/ha PoE at 25 DAS; pre-emergence application (PE) of atrazine 1.0 kg followed by (*fb*) hand weeding (HW) at 25 DAS; atrazine 0.75 kg/ha pre-emergence (PE) followed by (*fb)* topramezone 25.2 g/ha PoE at 25 DAS; atrazine 0.75 kg PE followed by (*fb*) tembotrione 0.120 kg/ha PoE at 25 DAS; atrazine 1.0 kg PE followed by (*fb*) topramezone 25.2 g/ha PoE at 25 DAS; atrazine 1.0 kg/ha PE followed by (*fb*) tembotrione 0.120 kg/ha PoE at 25 DAS; topramezone 25.2 g/ha + atrazine 0.75kg/ha PoE at 15 DAS; tembotrione 0.120 kg/ha + atrazine 0.75kg/ha PoE at 15 DAS and weed free. A randomized block design with three replications was

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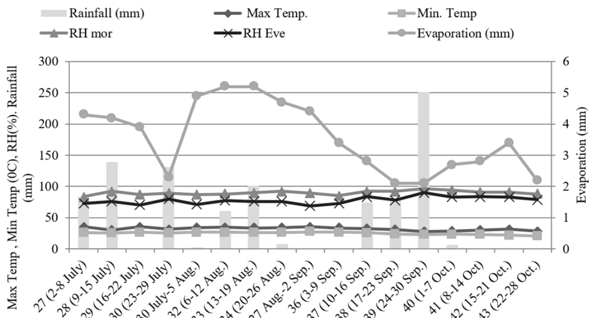


Figure1. Weather parameter during experimental period (July to October 2019)

used. The maize crop variety '*Shaktiman 5'* was grown with recommended package and practices and need based irrigation except the weed control practices. All the herbicides were applied as per treatment by using knap sack sprayer with flat fan nozzle using 500 l/ha of water as per treatments. Weeds were sampled by randomly placing a quadrate of 0.25 m^2 (0.5 × 0.5 m^2) in each plot at two spots. The weeds within the quadrat were counted, identified and classified into groups of sedges, grasses and broad-leaved weeds (BLW) and the density presented as number/ m^2. Later, weeds were uprooted sun dried before keeping in oven at 60-65^{0}C temperature for 48 hrs for complete dry and then weighed for determined its dry weight (weed biomass).

The five plants were selected randomly from each plot to determine the yield attributes. Net plot area was harvested for estimating grain and straw yield of crop. Plant analysis for N, P and K was done as per methods describe in Jackson (1973). Economics of different treatments was calculated as per prevailing market price. The data for different weed and crop parameters was analyzed with the help of ANOVA technique for randomized block design. To normalize the data of weed density and biomass, values were transformed by square root transformed $\sqrt{x+0.5}$ before analysis. The least square difference (LSD) post hoc was applied for pair wise comparison at $p<0.05$.

Weed flora

A total of twelve weed species were observed in the experimental field, of which four were grasses, *viz.*, *Digitaria sanguinalis* (L.) Scop., *Sorghum helepense* (L.) Pers, *Brachiaria reptans* (L.) C.A.Gardner and C.E.Hubb., *Dactyloctenium aegyptium* (L.) Willd., seven were broad-leaved weeds (BLW), *viz. Digera arvensis* Forssk., *Commelina benghalensis* L., *Cleome viscose* L., *Euphorbia hirta* L., *Boerhavia erecta* L. and *Celosia argentea* L., *Ipomea pes-tigradis* and a sedge, *viz. Cyperus rotundus* L. The grass weeds were dominant with relative density (RD) of 42% followed by BLW with RD of 33% and sedge with RD of 25% in the control plot of experimental field.

Effect on weeds

Application of atrazine 1.0 kg/ha PE followed by (*fb*) tembotrione 0.120 kg/ha PoE significantly reduced the sedge density (3.01 plants/m^2) than the unweeded and topramezone 25.2 g/ha PoE (4.76 plants/m^2) and tembotrione 0.120 kg/ha PoE (4.37 plants/m^2) alone, (**Table 1**). This result was corroborated with the results of Kakade *et al.* (2020). However, it was statistically at par with atrazine 1.0 kg/ha PE followed by (*fb*) topramezone 25.2 g/ha (3.28 plant /m^2) and atrazine 1.0 kg/ha PE *fb* hand weeding at 25 DAS (3.18/m^2). Tank mixing application of tembotrione 0.120 kg/ha + atrazine 0.75 kg/ha PoE and topramezone 25.2 g/ha + atrazine

Table 1. Effect of weed management treatments on weed density, weed biomass, weed control efficiency (WCE) and weed index (WI) at 50 days after seeding (DAS)

Treatment	Weed density (no./m^2)				Weed biomass (g/m^2)	WCE (%)	Weed index
	Sedges	Broad-leaved	Grasses	Total weeds			
Weedy check	8.04(64.3)	8.16(66.3)	9.26(85.3)	14.69(216.0)	12.44(154.6)	0	57.5
Topramezone 25.2 g/ha at 25 DAS	4.76(22.3)	4.0(15.6)	5.88(34.3)	8.51(72.3)	6.85(46.6)	69.7	38.3
Tembotrione 0.120 kg/ha at 25 DAS	4.37(18.6)	3.57(12.3)	5.29(27.6)	7.67(58.6)	6.21(38.3)	75.2	23.1
Atrazine 1.0 kg/ha PE *fb* HW at 25 DAS	3.18(9.6)	2.75(7.3)	4.31(18.3)	5.97(35.3)	4.79(22.6)	85.3	10.0
Atrazine 0.75 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS	3.71(13.3)	3.43(11.3)	5.03(25.3)	7.09(50.0)	5.75(32.6)	78.8	29.2
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS	3.43(11.3)	3.11(9.3)	4.76(22.3)	6.57(43.0)	5.29(27.6)	81.9	10.6
Atrazine 1.0 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS	3.28(10.3)	2.74(7.33)	4.66(21.33)	6.27(39.0)	5.07(25.3)	83.6	12.8
Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS	3.01(8.6)	2.43(5.6)	4.12(16.6)	5.60(31.0)	4.54(20.3)	86.8	2.7
Topramezone 25.2 g/ha + atrazine 0.75 kg/ha at 15 DAS	4.36(18.6)	3.32(10.6)	6.13(37.3)	8.18(66.6)	6.56(42.66)	72.2	31.2
Tembotrione 0.120 kg/ha + atrazine 0.75 kg/ha at 15 DAS	3.69(14.6)	3.01(8.6)	5.83(33.6)	7.55(57.0)	6.14(37.3)	75.8	20.5
Weed free check	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	0.71(0.0)	100	00.0
LSD (p=0.05)	0.28	0.28	0.40	0.66	0.35	-	--

#Weed data was transformed by square root transformed $\sqrt{x+0.5}$. The value in parentheses is original value; PE: Pre-emergence; DAS: Days after seeding

0.75 kg/ha PoE have recorded significantly lower sedge density than all except atrazine 1.0 kg/ha PE *fb* topramezone 25.2 g/ha PoE and atrazine PE *fb* hand weeding (HW). Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE and atrazine 1.0 kg/ha PE *fb* topramezone 25.2 g/ha PoE recorded significantly lower BLW density than sequential application of lower dose of atrazine 0.75 kg/ha PE with either with topramezone 25.2 g/ha or tembotrione 0.120 kg/ha PoE. Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE significantly reduced the grasses weed density (4.12/m^2), compared to all other practices but it was at par with atrazine 1.0 kg/ha PE *fb* HW at 25 DAS (4.31/m^2).

Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE significantly decreased the total weed density and its biomass compared from all treatments except atrazine 1.0 kg/ha *fb* HW. The atrazine as PE controlled the initial weed population and then sequential application of tembotrione 0.120 kg/ha as PoE controlled the second flushes of weeds. This result was corroborated with the results of Dey and Pratap (2018) and Verma *et al.* (2018).

It was corroborated with the results of Kakade *et al.* (2020). The highest WI (57.6) was recorded with weedy check and the lowest (2.7) with atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE at 25 DAS.

Nutrient uptake by weeds and maize

The highest N (40.35 kg/ha), P (10.2 kg/ha), and K (11.9 kg/ha) removal by weeds was recorded in weedy check. Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS significantly reduced N, P and K removal by weeds compared to all other treatments (**Table 2**). This treatment effectively controlled the weeds in field thereby reduced the removal of nutrients. The highest N, P and K uptake through crop (grain and straw) recorded with weed free and the lowest uptake of those nutrients by crop in weedy check. Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE significantly increased N, P and K uptake by grain and straw compared from other practices and it was at par on weed free check.

Effect on maize

Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE recorded significantly higher seed weight (23.3 g) than other treatments and was at par with weed free (24.2 g) (**Table 3**). The weed free obtained the highest grain yield (6.42 t/ha) and weedy check recorded lowest (2.72 t/ha). Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE at 25 DAS recorded significantly higher maize grain yield (6.24 t/ha) and straw yield (8.61 t/ha) than all other herbicides treatments. This treatment effectively controlled the weeds and provided completive free microclimate to the maize crop resulted in higher yield. Similar results were recorded by Verma *et al.* (2018), Nazreen *et al.* (2018), Mitra *et al.* (2018), Singh *et al.* (2012), Chhokar *et al.* (2019)

Maize cob length, grains/cob and 1000-grain weight and grain yield increased with better weed control in the field resulting in greater nutrients uptake compare to the unweeded plot, as also reported by Nazreen *et al.* (2017), Yakadri *et al.* (2015) and Singh *et al.* (2017).

Economics

The highest gross returns was recorded with the weed free but net returns was found with the application of atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE compared to the other all treatments due to lesser cost of cultivation involved in this treatment (₹ 34445/ha) **(Figure 2)** than normal manually weeding practice (₹ 42786/ha.).

Table 2. Effect of weed management treatments on nutrients uptake by weeds and maize

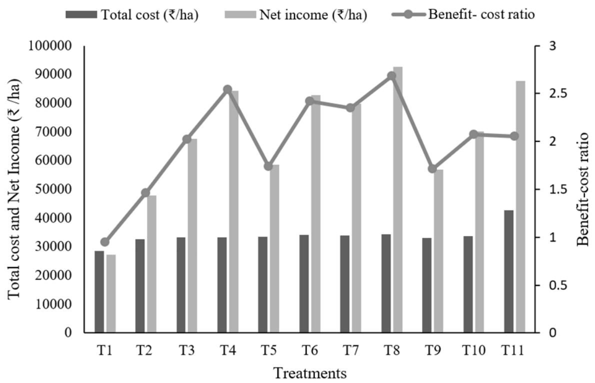
Treatment	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Weeds	Maize		Weeds	Maize		Weeds	Maize	
		Grain	Straw		Grain	Straw		Grain	Straw
Topramezone 25.2 g/ha at 25 DAS	20.5	76.3	23.1	4.3	16.6	3.95	5.3	12.2	48.9
Tembotrione 0.120 kg/ha at 25 DAS	15.9	94.7	28.5	3.4	22.2	5.08	3.4	16.2	66.1
Atrazine 1.0 kg/ha PE *fb* HW at 25 DAS	10.9	111.4	34.2	2.1	28.2	5.65	3.1	19.1	72.5
Atrazine 0.75 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS	12.5	86.6	25.5	2.6	21.3	4.49	3.1	14.9	56.5
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS	11.7	110.6	34.2	2.4	27.5	5.89	2.8	17.7	74.8
Atrazine 1.0 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS	14.6	108.9	31.1	3.0	27.3	5.46	3.5	17.8	67.6
Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS	9.2	121.6	36.9	1.6	31.8	6.44	1.6	21.8	87.6
Topramezone 25.2 g/ha + atrazine 0.75 kg/ha at 15 DAS	16.4	84.1	25.4	3.5	21.1	4.41	4.1	14.9	56.5
Tembotrione 0.120 kg/ha + atrazine 0.75 kg/ha at 15 DAS	15.8	98.3	29.7	2.8	24.9	5.02	3.5	16.8	63.1
Weedy check	40.3	49.3	15.5	10.2	13.1	2.72	11.9	8.1	31.1
Weed free check	0.0	124.4	36.0	0.0	35.9	6.93	0.0	24.3	90.5
LSD (p= 0.05)	1.33	2.81	0.68	0.21	0.71	0.12	0.24	0.48	1.6

PE: Pre-emergence; DAS: Days after seeding; *fb*: followed by

Table 3. Effect of weed management treatments on yield attributes, yield and harvest index of maize

Treatment	100 seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
Topramezone 25.2 g/ha at 25 DAS	19.1	3.95	5.55	0.41
Tembotrione 0.120 kg/ha at 25 DAS	20.2	4.94	6.96	0.41
Atrazine 1.0 kg/ha PE *fb* HW at 25 DAS	21.3	5.77	7.97	0.42
Atrazine 0.75 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS	19.7	4.54	6.08	0.42
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS	21.2	5.73	7.97	0.41
Atrazine 1.0 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS	20.8	5.69	7.60	0.42
Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS	23.3	6.24	8.61	0.42
Topramezone 25.2 g/ha + atrazine 0.75 kg/ha at 15 DAS	19.0	4.41	6.21	0.41
Tembotrione 0.120 kg/ha + atrazine 0.75 kg/ha at 15 DAS	19.9	5.09	7.08	0.41
Weedy check	16.9	2.72	3.90	0.41
Weed free check	24.2	6.42	8.79	0.42
LSD (p=0.05)	1.61	0.15	0.16	NS

PE: Pre-emergence; DAS: Days after seeding; *fb*: followed by



T1: Weedy check; **T2**: Topramezone 25.2 g/ha at 25 DAS; **T3:** Tembotrione 0.120 kg/ha at 25 DAS; **T4**: Atrazine 1.0 kg/ha PE *fb* HW at 25 DAS; **T5**: Atrazine 0.75 kg/ha PE *fb* topramezone 25.2 g/ha at 25 DAS; **T6**: Atrazine 0.75 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS;**T7**: Atrazine 1.0 kg/ ha PE *fb* topramezone 25.2 g/ha at 25 DAS; **T8**: Atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha at 25 DAS; **T9:** Topramezone 25.2 g/ha + atrazine 0.75 kg/ha at 15 DAS; **T10**: Tembotrione 0.120 kg/ha + atrazine 0.75 kg/ha at 15 DAS; **T11**: Weed free check

Figure 2. Cost of cultivation, net return and benefit-cost ration of different treatments

Based on this study, it was concluded that atrazine 1.0 kg/ha PE *fb* tembotrione 0.120 kg/ha PoE effectively controls the weeds resulting in higher grain yield of maize, net return and benefit-cost ratio of maize crop compare to manual weeding and other treatments.

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