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Weed Dynamics and Growth and Yield of Maize (*Zea mays* L.) as Influenced by Tembotrione Herbicide

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ABSTRACT

Background: A field experiment was conducted in the Agronomy Research Farm of the School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus, India during the *Kharif* season, 2023 and 2024 to study the weed dynamics and growth and yield of maize as influenced by tembotrione herbicide.

Methods: The experiment was laid out in randomized block design with three replications consisting of 10 treatments. The treatments include *viz*., T_1: Weedy check, T_2: Hand weeding at 20 and 40 DAS, T_3: Tembotrione 100 g ha^{-1} at 15 DAS, T_4: Tembotrione 125 g ha^{-1} at 15 DAS, T_5: Tembotrione 150 g ha^{-1} at 15 DAS, T_6: Tembotrione 100 g ha^{-1} at 30 DAS, T_7: Tembotrione 125 g ha^{-1} at 30 DAS, T_8: Tembotrione 150 g ha^{-1} at 30 DAS,T_9: Atrazine 750 g ha^{-1} at 2 DAS and T_{10}: 2,4-D Na 800 g ha^{-1} at 20 DAS. Surfactant Tween 20 (polyoxyethylene 20 sorbitan monolaurate or polysorbate 20) was used at the rate of 5 ml/litre of water.

Result: The results revealed that hand weeding twice at 20 and 40 DAS resulted in lowest population and biomass of grasses, sedges and broad leaf weeds and among the herbicides application Tembotrione 150 g ha^{-1} at 30 DAS resulted in the lowest values which also resulted in highest weed control efficiency and lowest weed index. The plant height, dry matter accumulation and other yield attributing parameters also showed highest value in application of Tembotrione 150 g ha^{-1} at 30 DAS under herbicides treatments resulting in higher yield. The gross and net return was observed highest in hand weeding treatments. However, with respect to profit, application of Tembotrione 150 g ha^{-1} at 30 DAS resulted in highest benefit cost ratio which indicates beneficial use of this herbicide at 30 DAS.

Key words: Growth, Hand weeding, Maize, Tembotrione, Weed dynamics.

INTRODUCTION

Weed problem in maize has resulted in severe yield loss ranging from 18-65% (Gharde *et al*., 2018). Without any form of weed control, weeds cause higher yield losses than animal pests, pathogens and viruses combined (Oerke, 2006). Average potential maize yield loss due to weed interference in the United States is 50%, threatening a domestic farm gate value of $26.7 billion (Soltani *et al*., 2016). The intensity of weed infestation varies from season to season. However, during *kharif* season due to prolonged exposure to monsoon rains, the competition of weeds and maize is a serious issue which should be controlled using various means. Among the various weed control options, use of herbicides is widely acceptable since it is cost effective and does not require much labour. It provides huge possibility of controlling weeds in all crops while decreasing the costs of weed control. Maize cultivation utilizes herbicides to manage weeds and atrazine is one amongst them which controls weed by disturbing the photosystem II pathway. It is imperative that weed management through herbicides require alternative arrangement between the herbicides with different mode of action to prevent development of herbicides resistance. Therefore, it is necessary to study the other post emergence herbicides for controlling weeds which does not affect the crops as well. The recently introduced tembotrione herbicide has different mode of action compared to the commonly used maize herbicides like atrazine and 2,4-D. Tembotrione herbicide of the β-triketone family inhibits 4-hydroxyphenylpyruvate dioxygenase (4-HPPD) enzyme and the biosynthesis of plastoquinone with subsequent carotenoid pigment formation, membrane structure and chlorophyll disruption in weeds (Zhao *et al*., 2017) and hence it is necessary to study this herbicide in terms of its efficacy and growth and yield of maize as affected by it. Keeping this view, a field experiment was conducted to find out the weed dynamics, growth and yield of maize as influenced by tembotrione herbicide with different doses and application timings.

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MATERIALS AND METHODS

The experiment was conducted during *Kharif* season of 2023 and 2024 at School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland. The experiment was laid out in randomized block design with three replications consisting of 10 treatments. The soil of the experimental site was sandy loam with low in available N (186 kg/ha), high in P_2O_5 (45.22 kg/ha) and high in K_2O (295.12 kg/ha). Maize variety RCM 76 was sown in the 1st week of July with seed rate of 20 kg ha^{-1} and was fertilized with N-P_2O_5- K_2O at 80-30-20 kg ha^{-1}. All the treatments were applied as per the dose and schedule. Surfactant Tween 20 (polyoxyethylene 20 sorbitan monolaurate) was used at the rate of 5 ml/litre of water. Herbicide treatments were applied as per treatment. The treatments include *viz*., T_1: Weedy check, T_2: Hand weeding at 20 and 40 DAS, T_3: Tembotrione 100 g ha^{-1} at 15 DAS, T_4: Tembotrione 125 g ha^{-1} at 15 DAS, T_5: Tembotrione 150 g ha^{-1} at 15 DAS, T_6: Tembotrione 100 g ha^{-1} at 30 DAS, T_7: Tembotrione 125 g ha^{-1} at 30 DAS, T_8: Tembotrione 150 g ha^{-1} at 30 DAS, T_9: Atrazine 750 g ha^{-1} at 2 DAS and T_{10}: 2,4-D Na 800 g ha^{-1} at 20 DAS. The herbicides were applied through knapsack sprayer fitted with a flood jet nozzle using 500 liters of water per hectare. Observations were recorded on weed parameters and crop parameters and economics were worked out.

Weed control efficiency (%) and weed index was calculated by using the formulae:

$$\text{Weed control efficiency (\%)} = \frac{W_C - W_T}{W_C} \times 100$$

Where,

W_C = Weed dry weight in control (unweeded) plot.

W_T = Weed dry weight in treated plot for which WCE is to be worked out.

$$\text{Weed index (\%)} = \frac{Y_{WF} - Y_T}{Y_{WF}} \times 100$$

Where,

Y_{WF} = Yield of maize in weed free treatment (Hand weeding treatment).

Y_T= Yield of maize in treated plot for which weed index is to be worked out.

The experimental data were statistically analysed with the methods described by (Panse and Sukhatme, 1967). The data involving weed population were transformed by square root transformations for analysis. For, significant results, the critical differences were worked out at 5 per cent probability to draw statistical conclusions.

RESULTS AND DISCUSSION

Major weed found in the experiment

The dominant broad leaf weeds found in the experiment were *Mimosa pudica, Commelina benghalensis, Amaranthus viridis, Sida cordifolia, Ageratum conzyoides, Bidens pilosa, Acmella oleracea, Chromolaena odorata.* Among the sedges *Cyperus rotundus, Kyllinga brevifolia* were dominant. *Eleusine indica, Cynodon dactylon, Seteria glauca, Oplismenus hirtellus, Digitaria sanguinalis* were the dominant grasses found in the experimental field.

Weed dynamics

Population and biomass of grasses

Application of Atrazine 750 g ha^{-1} at 2 DAS recorded significantly lowest population and dry weight of grasses at 20 DAS (Table 1 and 2) as atrazine was applied as pre-mergence herbicide. Atrazine due to inhibition of photosystem II mode of action might have inhibited photosynthesis in germinating weeds which resulted in lowest grasses population. Hirwe *et al*. (2025) also found that application of Atrazine as pre-emergence resulted in lower density of weeds at 20 DAS. Atrazine herbicide causes photosynthesis process to slow down by disturbing photosystem II (Bai *et al.,* 2015) due to which there is inhibition of electro-chemical energy which leads to the production of triplet chlorophyll and singlet oxygen Perez-Jones *et al.* (2009) that destroys proteins, lipids and pigments (Zhu *et al*., 2009). This was followed by tembotrione @150 g ha^{-1} at 15 DAS. Since it was applied at 15 DAS, it could not reduce considerably the population at 20 DAS. However, in the case of biomass it showed statistically at par result with tembotrione 125 g ha^{-1} and tembotrione 100 g ha^{-1} at 15 DAS (Table 2). This may be due to the effect of tembotrione where it starts to knock down the carotenoid pigment affecting the photosynthesis that result in reduced dry matter production. As it reaches 40 DAS, two hand weeding at 20 DAS and 40 DAS treatment gave the lowest weed population and was found to be at par with Tembotrione @ 150 g ha^{-1} at 30 DAS. In the case of biomass, hand weeding gave the lowest weed biomass and was at par with Tembotrione 150 g ha^{-1}, Tembotrione 125 g ha^{-1} at 30 DAS and Atrazine 750 g ha^{-1} at 2 DAS. Hand weeding treatment continued to record the lowest population and biomass of grasses at 60 DAS and among herbicide treatments, Tembotrione @150 g ha^{-1} at 30 DAS recorded the minimum population which was at par with Tembotrione @ 125 g ha^{-1} at 30 DAS. In the case of biomass, application of Tembotrione 150 g ha^{-1} at 30 DAS and Tembotrione 125 g ha^{-1} at 30 DAS was at par with hand weeding at 20 and 40 DAS. Singh *et al*. (2012) also observed superiority of tembotrione in controlling *Echinochloa* species which is a grassy weed.

Population and biomass of sedges

In the case of sedges, at 20 DAS Tembotrione 150 g ha^{-1} at 15 DAS recorded lowest population which was at par with Tembotrione 125 g ha^{-1} at 15 DAS followed by Tembotrione 100 g ha^{-1} at 15 DAS. Similar trend was observed in weed biomass at 20 DAS. However, at 40 DAS, hand weeding was seen the lowest weed population which is due to the removal of weeds including the roots. Among the herbicide

Table 1: Effect of treatments on the weed population dynamics (no.m^{-2}) (Pooled data).

Treatments	Grasses			Sedges			Broad leaf weed		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1: Weedy check	7.55 (56.67)	9.67 (93.00)	10.70 (114.17)	6.63 (43.50)	9.42 (88.67)	10.27 (105.33)	5.98 (35.50)	7.60 (57.50)	8.07 (64.67)
T_2: Hand weeding at 20 and 40 DAS	6.73 (45.00)	1.99 (3.50)	2.95 (8.33)	6.37 (40.33)	2.15 (4.17)	2.70 (7.00)	5.88 (34.33)	2.69 (6.83)	2.47 (6.00)
T_3: Tembotrione 100 g ha^{-1} at 15 DAS	6.38 (40.50)	6.53 (42.33)	7.72 (59.17)	3.30 (10.50)	6.28 (39.00)	7.19 (51.33)	4.62 (21.00)	5.31 (27.83)	6.19 (38.00)
T_4: Tembotrione 125 g ha^{-1} at 15 DAS	5.13 (26.17)	6.22 (38.33)	6.93 (47.83)	2.17 (5.00)	5.71 (32.33)	7.06 (49.50)	4.59 (21.00)	5.01 (24.67)	5.78(33.17)
T_5: Tembotrione 150 g ha^{-1} at 15 DAS	3.70 (13.50)	4.61 (20.83)	5.78 (33.00)	1.94 (3.67)	4.38(19.17)	5.27 (27.33)	3.59 (12.83)	4.59(20.67)	5.39(28.83)
T_6: Tembotrione 100 g ha^{-1} at 30 DAS	7.28 (52.67)	3.03 (9.00)	4.44 (19.33)	5.92 (34.83)	2.49 (6.00)	4.04 (16.17)	5.48 (29.83)	4.20(17.17)	4.74 (22.17)
T_7: Tembotrione 125 g ha^{-1} at 30 DAS	6.97 (48.33)	2.72 (7.17)	3.77 (13.83)	6.52 (42.17)	2.49 (5.83)	3.59 (12.83)	5.81 (33.50)	3.91 (14.83)	4.66 (21.50)
T_8: Tembotrione 150 g ha^{-1} at 30 DAS	6.31 (39.50)	2.17 (4.33)	3.47 (11.83)	5.84 (33.83)	2.30 (5.00)	3.31 (10.67)	5.90 (34.50)	3.76 (13.83)	4.41 (19.33)
T_9: Atrazine 750 g ha^{-1} at 2 DAS	2.87 (8.00)	3.40 (11.17)	4.74 (22.67)	3.42 (11.50)	4.47 (20.00)	5.20 (26.67)	2.71(7.00)	4.00 (15.67)	4.84 (23.33)
T_{10}: 2,4-D Na 800 g ha^{-1} at 20 DAS	7.64 (58.00)	7.82 (60.67)	8.09 (65.00)	6.27 (38.83)	7.09 (50.00)	8.18 (66.83)	5.11 (25.83)	3.19 (9.83)	4.06 (16.67)
S.Em(±)	0.186	0.18	0.176	0.180	0.21	0.173	0.145	0.160	0.178
CD (0.05)	0.530	0.52	0.502	0.512	0.63	0.494	0.413	0.455	0.508

The value in the parenthesis is original data which is subjected to square root transformation.

Table 2: Effect of treatments on the weed biomass production (g m^{-2}) (Pooled data).

Treatments	Grasses			Sedges			Broad leaf weed		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1: Weedy check	8.68	11.57	29.78	7.77	9.95	25.82	6.35	12.23	23.72
T_2: Hand weeding at 20 and 40 DAS	7.10	1.29	6.95	7.52	2.43	5.75	6.37	0.72	6.53
T_3: Tembotrione 100 g ha^{-1} at 15 DAS	5.72	9.12	17.67	2.73	5.70	14.60	3.70	9.38	17.47
T_4: Tembotrione 125 g ha^{-1} at 15 DAS	2.82	6.83	15.37	2.07	5.65	14.88	3.57	9.00	14.90
T_5: Tembotrione 150 g ha^{-1} at 15 DAS	1.82	5.73	12.27	1.15	3.37	10.65	1.42	7.08	13.42
T_6: Tembotrione 100 g ha^{-1} at 30 DAS	7.72	3.01	12.50	5.73	2.82	10.25	5.43	6.46	10.68
T_7: Tembotrione 125 g ha^{-1} at 30 DAS	6.33	2.70	9.47	6.70	2.82	8.83	6.33	5.14	10.32
T_8: Tembotrione 150 g ha^{-1} at 30 DAS	6.10	1.61	7.80	5.33	2.56	8.33	6.45	4.43	8.60
T_9: Atrazine 750 g ha^{-1} at 2 DAS	1.00	2.72	12.00	2.70	5.02	10.45	0.30	4.57	10.78
T_{10}: 2, 4-D Na 800 g ha^{-1} at 20 DAS	11.72	11.05	27.12	6.47	11.68	14.42	3.17	1.35	7.23
S.Em(±)	0.713	0.57	1.23	0.44	0.48	0.91	0.738	0.628	0.915
CD (0.05)	2.032	1.62	3.49	1.15	1.38	2.59	2.104	1.791	2.608

application, Tembotrione @ 150 g ha^{-1} at 30 DAS observed the least sedges count and was at par with Tembotrione 125 g ha^{-1} at 30 DAS and Tembotrione 100 g ha^{-1} at 30 DAS. As it reaches 60 DAS, application of Tembotrione 150 g ha^{-1} at 30 DAS continued to give best result among the herbicide treatment in terms of population and biomass of weeds. Yadav *et al*. (2018) also reported good control of sedge, *Cyperus rotundus* under the application of tembotrione where they observed better control than atrzaine application.

Population and biomass of broad leaf weeds

Application of atrazine 750 g ha^{-1} at 2 DAS recorded the lowest broad-leaved weed population at 20 DAS (Table 1) which was followed by application of Tembotrione 150 g ha^{-1} at 15 DAS. In the case of biomass, these two treatments were at par with each other. At this stage since no other herbicides were applied except for Tembotrione at 15 DAS, all the other treatments were at par with weedy check. However, at 40 DAS, the lowest population of broad leaf among the herbicide treatment was recorded under 2, 4-D Na 800 g ha^{-1} applied at 20 DAS while two handing treatment at 20 and 40 DAS gave the overall lowest broad leaf weeds which was followed by application of Tembotrione 150 g ha^{-1} at 30 DAS. At 60 DAS, hand weeding continued to record the lowest broad leaf weeds while 2,4-D Na 800 g ha^{-1} was found to record the lowest amongst all the herbicide treatments. Kumar *et al*. (2023) also found good control of broad leaf weeds. 2,4-D affects broadleaf weeds after they emerge through uncontrolled growth (Raghuwanshi *et al*., 2023). Kumar *et al*. (2024) found that 2, 4-D Sodium salt 80% WP 1250 g/ha at 25 DAS recorded lesser weed density and weed dry weight of *Physalis minima, Chenopodium album, Parthenium hysterophorus* and *Cichorium intybus* at 45 DAS. In the case of biomass, hand weeding recorded the lowest value and was par with 2,4-D Na 800 g ha^{-1} at 20 DAS and Tembotrione 150 g ha^{-1} at 30 DAS. The broad spectrum control of tembotrione might have resulted in the killing of broad leaf weeds and also the specific target of broad leaf weeds by 2,4-D might have resulted in at par treatment with handweeding. Rana *et al*. (2018) also found similar results where tembotrione was applied at 120 g ha^{-1} and 150 g ha^{-1} and even performed better than hand weeding in controlling *Ageratum conyzoides.*

Weed control efficiency

At 20 DAS, the highest wed control efficiency was observed in application of Atrazine 750 g ha^{-1} at 2 DAS followed by the application of Tembotrione 150 g ha^{-1} at 15 DAS. However, at 40 DAS and 60 DAS, the trend changed where hand weeding at 20 and 40 DAS recorded the highest weed control efficiency. Among the herbicide treatments, Tembotrione 150 g ha^{-1} at 30 DAS recorded the highest which was followed by application of Tembotrione 125 g ha^{-1}. It was also observed that application of tembotrione at 30 DAS showed higher weed control efficiency than when applied at 15 DAS. At 40 DAS, the highest weed control efficiency (86.82%) was recorded under T_2 (Hand weeding at 20 and 40 DAS), which was significantly superior to all other treatments. It was followed by T_8 (Tembotrione 150 g ha^{-1} at 30 DAS and Tembotrione 125 g ha^{-1} at 30 DAS, which recorded 74.43% and 68.32% WCE respectively. The same trend of observation was recorded at 60 DAS. Rana *et al*. (2017) also found similar result when tembotrione was applied at 30 DAS at the rate 125 g ha^{-1} and 150 g ha^{-1}. The lowest among herbicides was recorded in 2,4-D Na 800 g ha^{-1}. This might be due to the control of only broad leaf weeds by 2,4-D herbicide.

Weed index

Weed index presented in Table 3, showed that the highest weed index was observed in control which indicated that there was 69% yield loss when weeds were not managed while application of Tembotrione 150 g ha^{-1} at 30 DAS recorded that lowest weed index indicating that this treatment recorded the lowest yield reduction (14.98%). This was followed by the same dose of tembotrione applied at 15 DAS. Sharma *et al*. (2023) found that weed index was significantly lower in treatments receiving post-emergence herbicides like Tembotrione 120 g ha^{-1} combined with other herbicides such as atrazine 1000 g ha^{-1} compared to unweeded control. They attributed the reduced weed index to enhanced weed control efficiency, lower weed biomass accumulation and improved crop competitiveness.

Plant height

The highest plant height (111.83 cm) at 60 DAS was recorded in hand weeding at 20 and 40 DAS. Among the herbicide treatments application of Tembotrione 150 g ha^{-1} recorded the highest maize height which was at par with Tembotrione 150 g ha^{-1} at 15 DAS recording 106.50 cm and 102.67 cm respectively. The lowest plant height (81.63 cm) was recorded in weedy check. Rana *et al*. (2018) also reported similar increase in maize plant height with Tembotrione 150 g ha^{-1}, attributing it to effective weed suppression that reduced competition for nutrients, light and moisture. Similar trends were documented by Sharma *et al*. (2017), who found that Tembotrione treatments significantly reduced weed biomass and improved maize yield and growth parameters.

Dry matter accumulation

At 60 DAS, the highest dry matter accumulation (57.84 g $plant^{-1}$) was recorded in hand weeding at 20 and 40 DAS. Application of Tembotrione 150 g ha^{-1} at 30 DAS recorded the highest value among herbicide treatments and was statistically at par with Tembotrione 150 g ha^{-1} at 15 DAS and application of Atrazine 750 g ha^{-1} at 2 DAS. The lowest dry matter (30.78 g $plant^{-1}$) was recorded under weedy check. These observations are consistent with Rana *et al.* (2018), who reported that application of Tembotrione at 150 g ha^{-1} with surfactant at 20 and 30 DAS in maize significantly enhanced biomass accumulation by effectively controlling mixed weed flora such as *Echinochloa colona*, *Commelina benghalensis*.

Table 3: Effect of treatments on weed control efficiency, weed index, plant height, dry matter accumulation, stem girth, length of cob, girth of cob, grain yield and stover yield (Pooled data).

Treatments	Weed control efficiency (%)			Weed index (%)	Plant height (cm)	Dry matter accumulation (g plant^{-1})	Stem girth (cm)	Length of cob (cm)	Girth of cob (cm)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
	20 DAS	40 DAS	60 DAS								
T_1: Weedy check	-	-	-	69.23	8.68	11.57	29.78	7.77	9.95	1126	2364
T_2: Hand weeding at 20 and 40 DAS	7.99	86.82	89.03	0.00	7.10	1.29	6.95	7.52	2.43	3663	7110
T_3: Tembotrione 100 g ha^{-1} at 15 DAS	46.74	28.24	30.43	23.85	5.72	9.12	17.67	2.73	5.70	2786	5581
T_4: Tembotrione 125 g ha^{-1} at 15 DAS	62.85	36.19	37.55	22.27	2.82	6.83	15.37	2.07	5.65	2845	5828
T_5: Tembotrione 150 g ha^{-1} at 15 DAS	80.84	51.92	51.27	18.55	1.82	5.73	12.27	1.15	3.37	2980	6104
T_6: Tembotrione 100 g ha^{-1} at 30 DAS	17.18	63.48	58.88	22.34	7.72	3.01	12.50	5.73	2.82	2843	5724
T_7:Tembotrione 125 g ha^{-1} at 30 DAS	15.11	68.32	66.38	21.08	6.33	2.70	9.47	6.70	2.82	2890	5860
T_8: Tembotrione 150 g ha^{-1} at 30 DAS	21.65	74.43	72.41	14.98	6.10	1.61	7.80	5.33	2.56	3113	6381
T_9: Atrazine 750 g ha^{-1} at 2 DAS	82.46	63.43	59.19	26.86	1.00	2.72	12.00	2.70	5.02	2676	5480
T_{10}: 2,4-D Na 800 g ha^{-1} at 20 DAS	6.36	28.53	35.04	29.31	11.72	11.05	27.12	6.47	11.68	2586	5297
S.Em(±)	-			-	0.71	0.57	1.23	0.44	0.48	36	70
CD (p=0.05)	-			-	2.03	1.62	3.49	1.15	1.38	104	199

Stem girth of maize

The highest stem girth (4.92 cm) was recorded in hand weeding at 20 and 40 DAS which was at par with application of Tembotrione 150 g ha^{-1} at 30 DAS and Tembotrione 150 g ha^{-1} at 15 DAS, recording 4.65 and 4.61 cm respectively. These findings are in line with the work of Kumar *et al*. (2020), who reported increased stem girth in maize under effective weed control through tembotrione application with dosage ranging from 120-150 g ha^{-1} and manual weeding. Their results indicated that better weed suppression improved soil moisture and nutrient availability, enhancing stem diameter.

Length and girth of cob

The maximum length (24.07 cm) and girth of cob (6.30 cm) was recorded in T_2 (Hand weeding at 20 and 40 DAS), which was followed by Tembotrione 150 g ha^{-1} at 30 DAS while in the case of cob girth it was statistically at par with each other. In both the cases the minimum cob length (13.42 cm) and cob girth was recorded in Weedy check. These findings are in close agreement with those of Yadav *et al*. (2017), who reported a significantly longer cob length (22.7 cm) in maize under two-hand weeding treatments compared to weedy check (14.1 cm). Their study highlighted that a weed-free environment during early and mid-vegetative stages promoted better nutrient uptake and assimilate partitioning to reproductive organs. Similarly, Raghav *et al*. (2021) observed a cob length of 23.4 cm under tembotrione application at 120 g ha^{-1}, which was significantly higher than the untreated control.

Grain yield

The maximum grain yield (3663 kg ha^{-1}) was recorded in Hand weeding at 20 and 40 DAS), which was found to be significantly superior over all other treatments. Kumar *et al*. (2020) observed that two hand weedings (at 20 and 40 DAS) produced the highest grain yield (3655 kg ha^{-1}) in maize, significantly out performing herbicidal and untreated plots. It was then followed by application of tembotrione 150 g ha^{-1} at 30 DAS recording 3113 kg ha^{-1} followed by tembotrione 125 g ha^{-1} 30 DAS, while the lowest grain yield (1126 kg ha^{-1}) was recorded under weedy check. Yadav *et al*. (2018) also reported similar findings where tembotrione application was significantly superior to other herbicides. The control of weeds in tembotrione application at 150 g ha^{-1} at 30 DAS might have allowed the crop to physiologically perform better resulting in highest grain yield among the herbicides and doses tested.

Stover yield

The highest stover yield (7110 kg ha^{-1}) was recorded in hand weeding at 20 and 40 DAS, followed by Tembotrione 150 g ha^{-1} at 30 DAS which recorded 6381 kg ha^{-1}. The lowest straw yield (2364 kg ha^{-1}) was observed in weedy check. Similar results were reported by Meena *et al*. (2017), who observed significantly higher straw yield in maize with tembotrione application at 150 g ha^{-1} attributing it to better

Table 4: Effect of treatments economics of the treatment.

Treatments	Cost of cultivation (` ha^{-1})	Gross return (` ha^{-1})		Net return (` ha^{-1})		B C ratio	
		2023	2024	2023	2024	2023	2024
T_1: Weedy check	34678.73	84549.20	86170.70	49870.50	51492.00	0.44	0.49
T_2: Hand weeding at 20 and 40 DAS	51078.73	210269.00	221549.00	159190.35	170469.90	2.12	2.34
T_3: Tembotrione 100 g ha^{-1} at 15 DAS	36396.73	160976.00	162597.00	124579.50	126199.95	2.43	2.47
T_4: Tembotrione 125 g ha^{-1} at 15 DAS	36763.73	162831.00	166784.00	126066.90	130020.75	2.42	2.54
T_5: Tembotrione 150 g ha^{-1} at 15 DAS	37130.73	170617.00	171886.00	133486.50	134755.50	2.60	2.63
T_6: Tembotrione 100 g ha^{-1} at 30 DAS	36396.73	162368.00	166260.00	125971.20	129863.70	2.46	2.57
T_7: Tembotrione 125 g ha^{-1} at 30 DAS,	36763.73	163787.00	169799.00	127023.60	133035.15	2.45	2.62
T_8: Tembotrione 150 g ha^{-1} at 30 DAS	37130.73	173269.00	181194.00	136137.90	144063.00	2.67	2.88
T_9: Atrazine 750 g ha^{-1} at 2 DAS	35828.73	155239.00	157262.00	119410.35	121432.95	2.34	2.39
T_{10}	35728.73	151805.00	152418.00	116076.30	116689.05	2.25	2.27

The fixed cost of cultivation was `34678.73/- (Indian currency). The total cost of cultivation was calculated by the addition of fixed cost of cultivation with the cost involved in each respective treatment. The price of the maize was `75.00/- per kg based on market price which was used for calculating the gross return. The net return was calculated by subtracting cost of cultivation from the gross return of each treatment and benefit cost ratio was calculated by taking the ratio of net return to cost of cultivation.

weed control and higher dry matter production. Likewise, Singh *et al*. (2020) noted that two hand weedings (20 and 40 DAS) significantly increased straw yield (above 7000 kg ha^{-1}) in maize, due to effective weed elimination and improved nutrient uptake by the crop.

Economics

The highest gross return and net return in both the years were recorded in twice hand weeding which was followed by application of tembotrione 150 g ha^{-1} at 30 DAS (Table 4). However, when the benefit cost ratio was calculated, the hand weeding treatment could not give the highest profit due to the high cost of cultivation involved. Sahoo *et al*. (2024) also reported that though the hand weeding performed well in terms of less weed density and dry matter, it was not cost effective. Triveni *et al*. (2017) was also of the opinion that hand weeding is laborious, time consuming, costly and tedious job. It was found that among all the treatments, tembotrione 150 g ha^{-1} at 30 DAS recorded the highest benefit cost ratio. It is interesting to note that since the treatments were focused on chemical herbicides, the cost of cultivation involved was lesser and therefore there was profit in all the herbicide treatments. However, from the point of highest benefit, application of tembotrione 150 g ha^{-1} at 30 DAS is beneficial for the profit of the farmers.

CONCLUSION

Based on the findings of the experiment, it can be concluded that tembotrione application could result in effective weed control in maize and resulted in better growth, higher yield and profits to the maize growers. Among the herbicides treated it was observed that tembotrione 150 g ha^{-1} when applied at 30 DAS resulted in higher weed control efficiency and better economics of the crop compared to application at 15 DAS. Therefore, this herbicide holds promising results and when rotated with other herbicides may help in preventing development of weed resistance in future which is a common phenomenon in every herbicide managed weed management.

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Conflict of interest

The authors have no conflict of interest.

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