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IMPACT OF HERBICIDE APPLICATION ON WEED CONTROL EFFICIENCY AND PRODUCTIVITY OF KHARIF MAIZE (*ZEAMAYS L.*), CHANDESWESHER DISTRICT, EASTER UTTAR PRADESH

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ABSTRACT: A field experiment was conducted during Kharif 2023 season at the Agriculture ResearchFarm, Shri Durga Ji Post Graduate College Chandeshwar Azamgarh (U.P.), to evaluate effective weed control measures for improving maize yield. The experiment followed a Randomized Block Design (RBD) with eight treatments, each replicated three times. The treatments included were: T1- Atrazine (1 kg a.i./ha, pre-emergence), T2- Tembotrione (125 g a.i./ha, post-emergence), T3- Alachlor (1 kg a.i./ha, pre-emergence), T4- Alachlor (1 kg a.i./ha) + hand weeding, T5- Dhaincha as a smother crop, T6- Black gram as a smother crop, T7- Weedy check (untreated control), and T8-Weed-free treatment.Among the treatments, T3 (Alachlor, 1 kg a.i./ha, pre-emergence) recorded the highest weed control efficiency and a Benefit-Cost Ratio (B:C) of 2.19. The highest gross and net returns (₹1,41,532/ha) were obtained in T8 (weed-free treatment), supplemented with hand weeding at 20 and 40 DAS. These findings highlight the effectiveness of pre-emergence herbicide application and manual weeding in enhancing maize yield and economic returns.

Keywords: Weed control, herbicides, smother crops, treatment, weed control efficiency, Benefit-Cost B:C Ratio, yield enhancement, hand weeding.

Maize (*Zea mays* L.) is one of the most widely grown cereal crops globally and serves as a staple food in many developing countries (Kumar et al., 2015; Ram et al., 2017). In India, maize ranks as the third most important food crop after rice and wheat. Cereal crops occupy approximately 54% of the total cultivated area in the country, with maize accounting for nearly 36% of the cropped land. As of the 2022-23 agricultural year, maize is cultivated on approximately 9.89 million hectares in India, producing around 31.65 million metric tons, with a productivity of about 3.19 metric tons per hectare. This contributes significantly to the country's total food grain production (ICAR-IIMR, 2023; PIB, 2023).

Despite its importance, maize productivity in India remains significantly lower than in many other countries, primarily due to inadequate weed control. Weeds compete aggressively with maize for essential resources such as water, light, space, and nutrients, leading to yield losses ranging from 30% to 50%. If not managed during critical growth stages, weeds can cause grain yield reductions of up to 100% (Kumawat et al., 2019). The impact of weed competition varies across different growth phases, making it crucial to implement effective agro techniques to enhance maize production. Weed-induced losses in maize yield are estimated to be around 37% globally (Oerke and Dehne, 2004).

Maize's wider row spacing makes mechanical weed control labour-intensive and less effective. Consequently, herbicides are widely adopted in developed countries as a more efficient alternative. Compared to manual weeding, herbicidal treatments are faster, more cost-effective, and provide superior weed control (Chikoye et al., 2005; Kumar et al., 2017). The challenge is even greater in high-rainfall regions where excessive moisture limits the effectiveness of conventional weed management practices. Studies have shown that effective weed control strategies can significantly increase grain yields, with reported gains ranging from 77% to 96.7% compared to unweeded conditions (Tesfay et al., 2014; Yadav et al., 2018).

In India, maize is primarily cultivated during the Kharif season, which is characterized by heavy rainfall and high relative humidity—factors that promote vigorous weed growth. Weeds compete with crops for nutrients, moisture, light, and space, significantly reducing yield potential. The effectiveness of herbicides in managing weeds has been demonstrated through improvements in cob weight, grain yield per cob, 1000-grain weight, and overall productivity. Malik et al. (2006) highlighted the role of plant population and row spacing in

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determining weed density, suggesting that closer row spacing could enhance weed suppression. These findings align with previous studies (Harvey et al., 1997), which showed that higher plant density and herbicide applications lead to increased maize yields.

Manual weeding, although effective, is labour-intensive, costly, and often hindered by adverse weather conditions. Additionally, many currently available herbicides provide only limited control over diverse weed species in maize fields. Therefore, exploring new herbicide formulations, either individually or in combination, is essential for comprehensive weed management in *Kharif* maize cultivation. Herbicide application must be both safe and efficient to ensure effective weed control without adversely affecting subsequent crops, such as wheat.

The combined application of Alachlore @ 1 kg a.i. ha^{-1} + hand weeding offers a promising weed management approach in maize. Alachlore is particularly effective during early growth stages, while hand weeding at around 40 days after sowing (DAS) helps prevent late stage weed infestations. This sequential weed control strategy ensures economic and effective weed management, ultimately improving maize productivity. Therefore, this study was conducted to evaluate the impact of Alachlore @ 1 kg a.i. ha^{-1} + hand weeding on weed suppression and yield enhancement in maize.

MATERIALS AND METHOD

The experiment was conducted during the Kharif season of 2023 at the Agriculture Research Farm of Shri Durga Ji Post Graduate College, Chandeshwar, Azamgarh (U.P.). The study was laid out in a Randomized Block Design (RBD) with three replications, and the net plot size measured 4.2 m × 3.2 m (13.44 m²).The experimental soil was alluvial and calcareous, with a pH of 8.25, electrical conductivity of 0.34 dS/m, organic matter content of 0.38%, available phosphorus of 16.78 kg ha^{-1}, and extractable potassium of 270.8 kg ha^{-1}.Maize variety Ganga-5 was sown on July 20, 2023, at a seed rate of 25 kg ha^{-1}. Shallow furrows (approximately 5 cm deep) were created using a marker, with a row spacing of 60 cm. Within each furrow, 1–2 seeds were dibbled at 25 cm intervals. Thinning was carried out one week after emergence to regulate plant population, followed by a final thinning session two weeks after emergence. Gap filling was performed 8 and 10 days after sowing (DAS) where necessary. Fertilizer application followed the recommended dose, including urea, DAP, muriate of potash, and zinc oxide. Half of the nitrogen (N) and the total amounts of phosphorus (P), potassium (K), zinc sulphate ($ZnSO_4$), and zinc oxide (ZnO4) were applied as basal fertilization. The remaining nitrogen was split into two equal doses and applied as top dressing at 30 DAS and 50 DAS.

Treatments

The experiment included the following weed management treatments:

- T_1: Pre-emergence application of Atrazine 50 WP @ 1 kg a.i. ha^{-1}
- T_2: post-emergence application of Tembotrione 34.4 SC @ 120–125 g a.i. ha^{-1} (20 DAS)
- T_3: Pre-emergence application of Alachlor 50 EC @ 1 kg a.i. ha^{-1}
- T_4: Alachlor 50 EC @ 1 kg a.i. ha^{-1} + hand weeding (30 DAS)
- T_5: Dhaincha @ 6 kg ha^{-1} as a smother crop (sown at the time of maize sowing)
- T_6: Black gram @ 5 kg ha^{-1} as a smother crop (sown at the time of maize sowing)
- T_7: Weedy check (no weed control measures)
- T_8: Weed-free control.

A knapsack sprayer was used for herbicide application. Pre-emergence herbicides were applied one day after sowing, while post-emergence Tembotrione was applied 20 DAS.

Weed Density and Biomass Measurement

Weed density was recorded species-wise using a 1.0 m × 1.0 m quadrat at three random locations per plot at 30, 60, and 90 DAS, and at harvest. Weed count data were expressed as number of weeds per square meter (no. m^{-2}).

For weed dry matter estimation, collected weeds were:

1. Air-dried in shade for 2–3 days.
2. Oven-dried at 65 ± 5°C until a constant weight was achieved.
3. Weighed using a digital balance and expressed in grams per square meter (g m^{-2}).

Economic Analysis

The cost of cultivation, gross return, net monetary return, and benefit-cost ratio (B:C ratio) were calculated using standard procedures based on total costs incurred and returns obtained. Weed Control Efficiency (WCE) and Weed Index (WI) were calculated using the formulae suggested by Gill and Vijay Kumar (1969).

RESULTS AND DISCUSSION

Weed flora.

The major weed species observed during the experiment included both grassy and broadleaf weeds, along with a single sedge species. Among the grassy weeds, *Cynodondactylon* and *Echinochloacolonum* were predominant, while *Solanum nigrum, Digera arvensis, Phyllanthus niruri,* and *Commelina benghalensis* were the major broadleaf weeds. *Cyperus rotundus* was the only sedge species present. The complete details of the weed flora infesting the maize crop are presented in Table 1.

Effect on weed density.

The lowest total weed density was recorded in the weed-free treatment (T8), followed by hand weeding at 20 and 40 DAS. Among chemical weed management practices, alachlor at 1 kg a.i. ha^{-1} (PE) + hand weeding (T4) was significantly superior to other treatments at 30, 60, and 90 DAS, as well as at harvest. At 30 DAS, the application of alachlor at 1 kg a.i. ha^{-1} (PE) alone showed considerable weed suppression, while at later stages, tembotrione at 125 g a.i. ha^{-1} (POE) provided effective control, particularly when used in combination with alachlor at 1 kg a.i. ha^{-1} (PE). In contrast, the highest weed density was recorded in the weedy check (T7).

The superior weed control observed with alachlor + hand weeding (T4) can be attributed to the combination of pre-emergence (PE) and post-emergence (POE) herbicide action alongside physical removal of weeds. Tembotrione, a selective HPPD inhibitor, disrupted carotenoid biosynthesis, leaving chlorophyll unprotected against oxidative damage. This resulted in bleaching of sensitive weeds, ultimately leading to their mortality. Similar findings were reported by Pandey et al. (2002). The total weed density at different growth stages under various treatments is summarized in Table 2.

The lowest total weed dry weight was observed in the weed-free treatment (T8), followed by alachlor + hand weeding (T4) at all growth stages. Among chemical treatments, alachlor at 1 kg a.i. ha^{-1} (PE) consistently reduced weed dry weight, and its efficacy was further enhanced when combined with a single hand weeding at 30 DAS. The weedy check (T7) recorded the highest total weed dry weight. These results align with the findings of Pandey et al. (2001), which demonstrated the dominance of alachlor over other pre-emergence herbicides in controlling weed populations.

Effect on weed dry weight.

The lowest total weed dry weight was recorded under hand weeding at 20 & 40 DAS (T8). Among chemical weed management practices, alachlor @1 kg a.i. ha^{-1} + hand weeding showed superior weed suppression at 30, 60, 90 DAS, and at harvest, compared to other treatments. At 30 DAS, alachlor @1 kg a.i. ha^{-1} (PE), and at later stages tembotrione @125 g a.i. ha^{-1} (POE) and alachlor @1 kg a.i. ha^{-1} (PE), were at par with alachlor @1 kg a.i. ha^{-1} + hand weeding. The highest weed dry weight (53.16, 361.2, 320.96, and 349.50 g) was recorded in the weedy check (T7). Among pre-emergence herbicides, alachlor was the most effective in reducing weed population and dry weight, followed by pendimethalin and atrazine. This trend remained consistent when these herbicides were applied in combination with single hand weeding at 30 DAS. Similar findings were reported by Pandey et al. (2001).

The highest weed control efficiency (100% at all stages) was observed in hand weeding (T8). Among chemical weed management practices, the highest weed control efficiency at 30, 60, 90 DAS, and at harvest was recorded under alachlor @1 kg a.i. ha^{-1} + hand weeding. The lowest weed control efficiency was observed in the weedy check (T7). The weed control efficiency of different treatments ranged from 26.37% to 60.74% at early stages and 47.03% to 71.78% at later stages.

The lowest weed index was recorded under hand weeding at 20 & 40 DAS (T8). Among herbicide treatments, the minimum weed index (3.04%) was observed under alachlor @1 kg a.i. ha^{-1} + hand weeding, while the highest weed index (13.39%) was recorded in the black gram smother crop treatment.

Effect on Crop

Maize plant height, cob length, grain yield, and stover yield were significantly higher with hand weeding twice at 20 and 40 DAS. Among the herbicide treatments, *Alachlore @ 1 kg a.i.* ha^{-1} + *hand weeding (T4)* and *Tembotrione @ 125 g a.i.* ha^{-1} *(POE)* significantly increased plant height and cob length. These results were statistically at par with *Alachlore @ 1 kg a.i.* ha^{-1} + *hand weeding*, as reported by Ehsas et al. (2016) and Sunitha et al. (2010). The increase in plant height and cob length in effective treatments might be attributed to reduced crop-weed competition, allowing better maize growth. In contrast, the weedy check showed stunted crop growth due to higher weed density and competition.

Grain and stover yields were significantly higher in hand-weeding treatments but were statistically at par with *Alachlore @ 1 kg a.i.* ha^{-1} + *hand weeding (T4)* and *Tembotrione @ 125 g a.i.* ha^{-1} *(POE)*. The increase in grain yield was 3.95 tons ha^{-1} when hand weeding was applied compared to the weedy check. The lowest grain yield was recorded under the

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control (weedy check), consistent with findings by Khan et al.

Economics

Gross income, cost of cultivation, net return, and benefit-cost ratio (B:C) in maize were significantly higher with hand weeding at 20 and 40 DAS (T8), followed by *Tembotrione @ 125 g a.i. ha⁻¹ (POE) (T2)* (Table 4).

The highest B:C ratio was obtained with *Alachlore @ 1 kg a.i. ha⁻¹ (PE) (T3)*, followed by *Atrazine @ 1 kg a.i. ha⁻¹ (PE) (T1)*. The lowest B:C ratio (1.47 Rs. Rs⁻¹) was recorded in the weedy check (T7).

Table -1: Weed flora infested experimental maize crop during kharif season.

S.No.	Botanical Name	English name	Local name	Family	Group
1.	*Solenum nigrum*	Black nightshade	Makai	Solanaceae	Broad leaf
2.	*Digra arvensis*	-	Lahasua	Amaranthaceae	Broad leaf
3.	*Phyllanthus niruri*	-	Hazardana	Euphorbiaceae	Broad leaf
4.	*Commelina benghalensis*	Day flower	-	Commelinaceae	Broad leaf
5.	*Eclipta alba*	False Daisy	Bhangra	Compositae	Broad leaf
6.	*Cyprus rotundus*	Purple nut grass	Montha	Cyperaceae	Sedge
7.	*Cynodondactylon*	Bermuda grass	Doop grass	Poaceae	Grassy
8.	*Echinochloacolonum*	Jangli rice	Jangli Rice	Poaceae	Grassy

Table -2: Total weed density at successive growth stage as influenced by weed management practices in kharif Maize.

Treatment		Total weed densities (no. m^{-2})			
		30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T1	Atrazine @1 kg a.i. ha^{-1} (PE)	16.37 (268)	18.08 (327)	15.76 (233)	15.5 (225)
T2	Tembotrione @125 g a.i. ha^{-1} (POE)	20.24 (390)	17.02 (273)	13.99 (182)	13.50 (169)
T3	Alachlore @1 kg a.i. ha^{-1} (PE)	16.27 (249)	17.79 (299)	14.78 (204)	14.17 (187)
T4	Alachlore @1 kg a.i. ha^{-1} + Hand weeding	15.06 (212)	16.62 (260)	13.72 (175)	13.18 (161)
T5	Dhaincha as a smoother crop	17.26 (281)	18.85 (337)	17.99 (306)	17.82 (300)
T6	Black gram as a smoother crop	17.61 (293)	19.20 (350)	18.38 (320)	18.22 (314)
T7	Weedy check	21.54 (443)	25.89 (645)	22.22 (472)	22.08 (466)
T8	Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±		**0.40**	**0.45**	**0.48**	**0.13**
C.D. (at 5%)		**1.21**	**1.36**	**1.17**	**0.39**

**Figure in parenthesis is original value.*
**Original data of weed density was transformed by* $\sqrt{x + 0.5}$

Table- 3: Weed control efficiency (%) and weed index (%) at successive growth stage as influenced by weed management practices in kharif Maize.

Treatment		**Weed control efficiency (%)**				
		30 Day	**60 Day**	**90 Day**	**At harvest**	**Weed index (%)**
T1	Atrazine @1 kg a.i. ha^{-1} (PE)	37.23	51.16	51.06	51.75	8.70
T2	Tembotrione @125 g a.i. ha^{-1} (POE)	9.27	57.98	57.84	58.12	5.11
T3	Alachlore @1 kg a.i. ha^{-1} (PE)	49.49	57.78	54.69	54.02	8.30
T4	Alachlore @1 kg a.i. ha^{-1} + hand weeding	51.24	59.69	62.92	63.35	3.04
T5	Dhaincha as a smoother crop	36.79	48.22	35.17	31.71	11.79
T6	Blackgram as a smoother crop	33.86	45.74	32.20	28.53	13.39
T7	Weedy check	**0.00**	**0.00**	**0.00**	**0.00**	**43.47**
T8	Weed free	**100.00**	**100.00**	**100.00**	**100.00**	**0.00**

Table 4: Effect of weed management practices on, Cost of cultivation, gross return, net return, and B:C ratio on maize crop

Treatment		**Economics**			
		Total cost of cultivation (`ha^{-1})	**Gross return (` ha^{-1})**	**Net return (` ha^{-1})**	**B:C Ratio (` `$^{-1}$invested)**
T1	Atrazine @1 kg a.i. ha^{-1} (PE)	39708	125787	86079	2.17
T2	Tembotrione @125 g a.i. ha^{-1} (POE)	42526	133314	89205	2.12
T3	Alachlore @1 kg a.i. ha^{-1} (PE)	39508	126025	86517	2.19
T4	Alachlore @1 kg a.i. ha^{-1} + hand weeding	44109	133474	90948	2.06
T5	Dhaincha as a smoother crop	43490	126771	83281	1.91
T6	Blackgram as a smoother crop	44036	125974	81938	1.86
T7	Weedy check	38006	93984	55978	1.47
T8	Weed free	48056	141532	93476	1.95

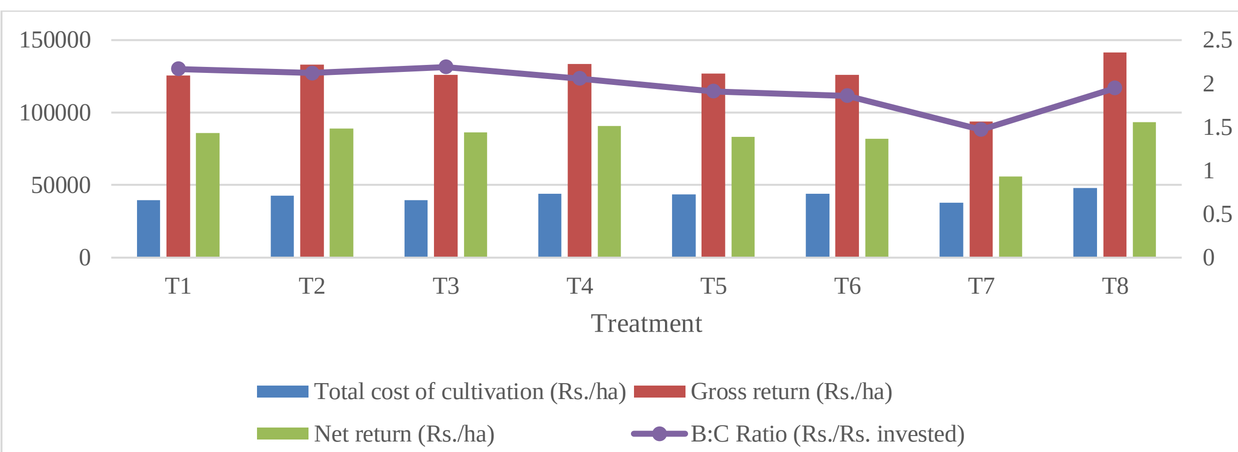

Fig. 1: **Effect of weed management practices on, Cost of cultivation, gross return, net return and B:C ratio on maize crop grown under eastern Uttar Pradesh.**

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CONCLUSIONS

This study underscores the importance of effective weed management in maize production, with hand weeding at 20 and 40 DAS proving to be the most effective strategy for minimizing weed density and dry weight, leading to significantly higher yield and economic returns. Among chemical control methods, Alachlore @ 1 kg a.i. ha^{-1} + hand weeding and Tembotrione @ 125 g a.i. ha^{-1} (POE) demonstrated superior weed suppression and crop performance. While these findings provide practical recommendations for maize growers, further research is needed to explore long-term sustainability, herbicide resistance development, and the environmental impact of repeated chemical applications. Additionally, integrating precision agriculture technologies and bioherbicides could offer innovative, eco-friendly solutions for sustainable weed managementing in maize crop.

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