Indian Journal of Weed Science (2026) **58**(2): 171–177
http://dx.doi.org/10.5958/0974-8164.2026.00027.5

RESEARCH ARTICLE

Weed complex in chickpea as influenced by topramezone + methylated seed oil (MSO) adjuvant

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Received: 27 September 2025 | Revised: 18 March 2026 | Accepted: 21 March 2026

ABSTRACT

An experiment was conducted at the Agricultural Research Farm, Banaras Hindu University, Varanasi, Uttar Pradesh, India during the *Rabi* season of 2022-23 and 2023-24 to evaluate the effect of varying rates of topramezone, both alone and in conjunction with methylated seed oil (MSO) adjuvant on complex weed flora and chickpea seed yield. The early post-emergence application (EPoE) of topramezone 20.16 g/ha and 25.20 g/ha with MSO were statistically similar in recording the lowest weed density and biomass, higher weed control efficiency, herbicide efficiency index and lowest weed index. However, all herbicidal treatments tested, except oxyfluorfen 250 g/ha and topramezone 10.08 g/ha, recorded statistically similar chickpea seed yield. In terms of economics, topramezone 20.16 g/ha and 25.20 g/ha with MSO adjuvant recorded statistically similar B:C ratio. Therefore, topramezone 20.16 g/ha is recommended for effective weed control, optimal chickpea seed yield and net profitability in chickpea.

Keywords: Adjuvant, Chickpea, Methylated seed oil (MSO), Topramezone, Weed flora, Weed management.

INTRODUCTION

Chickpea (*Cicer arietinum* L.), a staple pulse crop in India, plays a crucial role in the agricultural economy by enhancing food security and providing a vital source of protein (Malik 2021). India is the largest producer of chickpea with a production of 13.5 million tonnes (World Population Review 2025).

Weed management remains a significant challenge in chickpea cultivation in India. This is largely due to the crop's slow growth rate and insufficient leaf development during its establishment phase, which allows weeds to dominate and hinder chickpea development (Rao and Kumar 2025). Secondly, broad-leaved weeds in chickpea, with about 93% of the weed flora, are detrimental to yield as compared to grasses (Merga and Alemu 2019). In India, weeds like *Chenopodium album*, *Amaranthus viridis*, *Phalaris minor, Anagallis arvensis* and *Solanum nigrum* are prevalent in chickpea fields and can reduce yields by up to 50%, if left uncontrolled (Kashyap *et al.* 2022, Gairola *et al*. 2024). Chickpea must be kept weed free from four leaf stage to beginning of flowering stage (17- 49 days after emergence) (Mohammadi *et al*. 2005). Manual weeding is one of the most effective methods of weed control, however, it is labour-intensive and expensive, making it less sustainable, particularly during peak agricultural seasons when labour shortages are prevalent (Ray *et al.* 2022).

The use of herbicides with broader spectra, such as topramezone, could offer a promising solution by targeting a wider range of weed species. However, there is still limited knowledge on the optimal dosages and application timing for topramezone in chickpea. Topramezone 25.7 g/ha, applied at 21 days after sowing (DAS), was observed to provide effective weed control (Kumar *et al*. 2023). However, the variability in weed species and environmental conditions across different regions in India highlights the need for further research to identify location specific dosage rate of topramezone.

Performance of herbicides can be influenced by the use of adjuvants by enhancing its absorption and overall efficacy. Methylated Seed Oil (MSO) is a refined oil made from methylated fatty acids derived from seeds such as canola, soybean, or other oil crops. MSO adjuvants are particularly beneficial in improving the absorption and penetration of

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herbicides into plant tissues, especially in crops like chickpea, where leaf surfaces are often waxy and resistant to herbicide penetration (Zhang *et al.* 2022). By altering the surface tension of herbicides, MSO allows the active ingredients to spread more evenly on the leaf surface, promoting better adhesion and reducing herbicide runoff (Zhang *et al.* 2013). However, while MSO is known to improve herbicide performance, studies on interaction of MSO with topramezone in chickpea is limited. Therefore, this study was conducted with an objective to evaluate the optimal doses of topramezone, both with and without MSO adjuvants for weed control in chickpea, while comparing it with other weed control options.

MATERIALS AND METHODS

The study was conducted during the *Rabi* season of 2022-23 and 2023-24 at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) in randomized block design (RBD) with eleven treatments and three replications. The treatments include early post emergence application (EPoE) of topramezone at 10.08, 15.12, 20.16 and 25.20 g/ha, with 2 mL/L MSO adjuvant; oxyfluorfen 250 g/ha; hand weeding twice at 20 and 40 DAS and untreated control. During the study period, the mean monthly maximum and minimum temperature ranged from 29.91-12.54°C in the first year and 26.37-12.85°C in the second year, and monthly average rainfall of 0.09 and 3.78 mm respectively. Initial soil status of the study site indicates sandy clay loam texture with 0.44% organic carbon, 198 kg/ha available N, 22.18 kg/ha available P and 216 kg/ha available K. *Pusa Kabuli* variety of chickpea was sown on 25.11.2022 and 20.11.2023 in a 4.5 m × 5.0 m plot size with 45 cm × 10 cm spacing. All herbicide applications were done at 2-3 leaf stage of weeds (18 days after sowing) using a knapsack sprayer fitted with flat fan nozzle as per treatment dose. One irrigation at 7-8 days after herbicide application (DAA) was done to get good efficacy. The crop was harvest at physiological maturity on 10.04.2023 and 28.03.2024.

The observations on weed density were recorded using a 1 m × 1 m quadrat placed randomly at five places per plot and cumulative weed density expressed as no./m^2. Weed density was recorded species-wise at 10 and 45 DAA. The weeds were dried separately species-wise in the sun and further in the oven at 70^{o}C to record weed dry weight (weed biomass) as g/m^2. Weed control efficiency (WCE), weed index (WI) and herbicide efficiency index (HEI) were computed using the equation suggested by Mani *et al*. (1973), Gill and Kumar (1969) and Krishnamurthy *et al.* (1975), respectively.

Weed density and weed biomass data were square root transformed ($\sqrt{x + 0.5}$) prior to analysis. ANOVA was performed using *Statistical Tool for Agricultural Research* (STAR), IRRI, version 2.0.1. The same software was used for correlation analysis.

RESULTS AND DISCUSSIONS

Weed flora

The weed flora observed in the experimental site consisted of ten species including broad-leaved weeds and grasses belonging to six families (**Table 1**).

Weed density

At 10 and 45 days after application (DAA), the highest density of *Melilotus officinalis* was observed, followed by *Sonchus oleraceus* and *Chenopodium album* (**Table 2**). The lowest density was of *Solanum nigrum*. At 10 DAA, among the herbicidal treatments, topramezone 20.16 g/ha + MSO adjuvant recorded the lowest density of all weed species, which was statistically at par with

Table 1. Weed flora observed in the experimental site

Scientific name	Common name	Family	EPPO code
Broad-leaved weeds			
Melilotus officinalis	Yellow sweet clover	Fabaceae	MEUOF
Medicago spp.	Burclover	Fabaceae	MEDSS
Chenopodium album	Lambsquarters	Amaranthaceae	CHEAL
Sonchus oleraceus	Common sowthistle	Asteraceae	SONOL
Rumex spp.	Dock	Polygonaceae	RUMSS
Anagallis arvensis	Scarlet pimpernel	Primulaceae	ANGAR
Polygonum plebeium	Small knotweed	Polygonaceae	POLPB
Parthenium hysterophorus	Carrot grass	Asteraceae	PTNHY
Solanum nigrum	Black nightshade	Solanaceae	SOLNI
Grass			
Phalaris minor	Little seed canary grass	Poaceae	PHAMI

Table 2. Species wise weed distribution at various stages after herbicidal application

Species	10 DAA	45 DAA
MEUFO	11%	11%
MEDSS	10%	11%
CHEAL	11%	11%
SONOL	11%	11%
RUMSS	10%	10%
ANGAR	10%	10%
POLPB	9%	10%
PTNHY	9%	9%
SOLNI	8%	8%
PHAMI	11%	9%

Please refer to Table 1 for full form of weed species

topramezone 25.20 g/ha + MSO adjuvant. All the herbicide treatments were found to be equally effective to minimize *P. minor* density at 10 DAA. Topramezone 20.16 g/ha + MSO adjuvant recorded a decrease of 18.55% and 5.75% in total weed density as compared to oxyfluorfen 250 g/ha and topramezone 20.16 g/ha respectively. AT 45 DAS, topramezone 20.16 and 25.20 g/ha both recorded almost similar values of weed density across different species, except for *Phalaris minor*, which was statistically lower with 20.16 g/ha dose. Nonetheless, there was no statistical difference between the two treatments (**Table 3** and **4**). Throughout the study period, the highest weed density was with oxyfluorfen 250 g/ha. Oxyfluorfen being a contact herbicide, do not have the same systemic action as topramezone and likely limited the effectiveness over time (Patel *et al.* 2024). Topramezone's mechanism involves inhibiting the 4-hydroxyphenylpyruvate dioxygenase (HPPD) enzyme, which disrupts carotenoid biosynthesis, leading to bleaching and death of the weed. MSO enhances this effect by improving the penetration of topramezone into the plant tissues, thereby increasing its herbicidal activity (Boyd *et al.* 2020). Moreover, the efficacy of weed control may be attributed to the interaction between the chemical properties of the herbicide and the surfactant nature of MSO. In terms of application, addition of MSO with topramezone ensures that the herbicide adheres more effectively to the leaf surface, allowing for a more uniform distribution and maximized exposure time (Idziak *et al.* 2023). Overall, the combination led to significant reductions in weed density as compared to other herbicides (Nguyen and Liebman 2022).

Weed biomass

The weed biomass at 45 DAA was significant effected by weed control treatments. Topramezone (20.16 and 25.20 g/ha) + MSO adjuvant recorded the lowest weed biomass compared to the rest of the herbicidal treatments (**Table 5**). However, statistically, all topramezone treatments (alone or in combination with MSO adjuvant) were at par with each other and significantly more effective than oxyfluorfen 250 g/ha treatment and untreated control. The highest weed biomass was recorded with oxyfluorfen 250 g/ha among herbicide treatments. Similar effect of topramezone on chickpea was also reported by Gajanand *et al.* (2023). Moreover, the

Table 3. Weed species density (no./m^2) at 10 DAA as influenced by weed control treatments (pooled data of two years)

Treatment	MEUFO	MEDSS	CHEAL	SONOL	RUMSS	ANGAR	POLPB	PTNHY	SOLNI	PHAMI
Topramezone 10.08 g/ha	2.31 (4.84)	2.27 (4.63)	2.18 (4.25)	2.26 (4.59)	2.13 (4.04)	2.03 (3.62)	1.92 (3.17)	1.73 (2.49)	1.60 (2.04)	2.13 (4.04)
Topramezone 15.12 g/ha	2.23 (4.47)	2.19 (4.27)	2.11 (3.95)	2.18 (4.23)	2.06 (3.74)	1.97 (3.36)	1.86 (2.94)	1.68 (2.31)	1.55 (1.89)	2.15 (4.10)
Topramezone 20.16 g/ha	2.13 (4.02)	2.09 (3.85)	2.01 (3.54)	2.08 (3.81)	1.96 (3.34)	1.88 (3.02)	1.77 (2.62)	1.60 (2.06)	1.48 (1.69)	2.16 (4.14)
Topramezone 25.20 g/ha	2.11 (3.95)	2.07 (3.78)	2.00 (3.50)	2.06 (3.74)	1.96 (3.32)	1.86 (2.96)	1.76 (2.58)	1.59 (2.03)	1.47 (1.66)	2.21 (4.36)
Topramezone 10.08 g/ha + MSO adjuvant 2 ml/l of water	2.30 (4.79)	2.25 (4.56)	2.17 (4.21)	2.24 (4.50)	2.13 (4.04)	2.02 (3.56)	1.91 (3.13)	1.72 (2.46)	1.59 (2.01)	2.25 (4.56)
Topramezone 15.12 g/ha + MSO adjuvant 2 ml/l of water	2.12 (3.99)	2.08 (3.81)	2.00 (3.50)	2.07 (3.76)	1.96 (3.34)	1.87 (2.98)	1.76 (2.60)	1.60 (2.04)	1.48 (1.68)	2.19 (4.30)
Topramezone 20.16 g/ha + MSO adjuvant 2 ml/l of water	1.98 (3.42)	1.94 (3.26)	1.87 (3.00)	1.93 (3.22)	1.83 (2.83)	1.75 (2.55)	1.65 (2.22)	1.50 (1.75)	1.39 (1.43)	2.13 (4.02)
Topramezone 25.20 g/ha + MSO adjuvant 2 ml/l of water	2.06 (3.74)	2.02 (3.58)	1.95 (3.30)	2.01 (3.52)	1.92 (3.19)	1.82 (2.79)	1.72 (2.44)	1.56 (1.93)	1.44 (1.57)	2.38 (5.14)
Oxyfluorfen 250 g/ha	2.50 (5.75)	2.45 (5.50)	2.36 (5.07)	2.44 (5.45)	2.31 (4.84)	2.20 (4.32)	2.07 (3.76)	1.86 (2.96)	1.71 (2.41)	2.19 (4.30)
Hand weeding twice 20 and 40 DAS	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Untreated control	3.34 (10.62)	2.02 (3.56)	3.15 (9.39)	3.25 (10.06)	3.07 (8.89)	2.91 (7.97)	2.73 (6.95)	2.44 (5.45)	2.24 (4.50)	2.18 (4.23)
LSD (p=0.05)	0.24	0.24	0.24	0.23	0.26	0.26	0.28	0.24	0.25	0.25

Data was square root transformed ($\sqrt{x+0.5}$), original data within parenthesis, DAA- days after application, DAS- days after sowing, *Please refer to Table 1 for full form of weed EPPO code.

adjuvant ensured that the herbicide remains effective even under conditions where weed density might typically challenge the efficacy of standalone herbicide applications. This synergy between topramezone and MSO adjuvant contributes to the lower weed biomass, thus providing better growth conditions for chickpea (Zhang *et al.* 2022).

Weed control efficiency, herbicide efficiency index and weed index

Among the herbicidal treatments, the highest weed control efficiency (WCE) was recorded with topramezone 20.16 g/ha, closely followed by topramezone 25.20 g/ha and topramezone 25.20 g/ha (**Figure 1**). The lowest WCE was observed with oxyfluorfen 250 g/ha. Compared to topramezone 20.16 g/ha, oxyfluorfen 250 g/ha recorded approximately 30% lesser WCE. Since WCE is directly influenced by weed biomass, the lower weed biomass observed with topramezone 20.16 and 25.20 g/ha reflected in the WCE, making these treatments the highest WCE. Nath *et al.* (2021) also made similar observations. Topramezone 25.20 g/ha + MSO adjuvant recorded the highest value of herbicidal efficiency index (HEI), among all herbicidal treatments. HEI being a factor of yield, the highest yield and lower weed biomass were observed with this treatment reflected in the HEI. The lowest HEI was again recorded with oxyfluorfen 250 g/ha treatment.

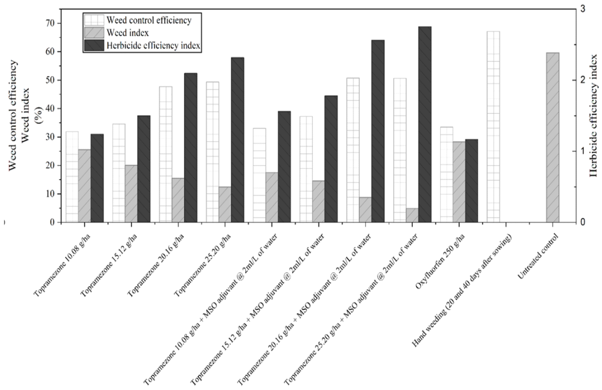

Figure 1. Weed control efficiency and herbicidal efficiency index at 45 DAA, and weed index under different weed control treatments (pooled data of two years)

The highest and lowest weed index was observed under oxyfluorfen 250 g/ha and topramezone 25.20 g/ha + MSO adjuvant respectively (**Figure 1**). Weed index reflects the percent loss in yield with treatment as compared to weed free plot. As observed in the study, oxyfluorfen 250 g/ha consistently recorded the highest weed density and biomass, this may be likely created an environment where chickpea crop was under constant competition with the weeds which likely led to yield penalty. Higher weed density under oxyfluorfen compared to topramezone was also reported by Patel *et al.* (2024).

Table 4. Weed species density (no./m^2) at 45 DAA as influenced by weed control treatments (pooled data of two years)

Treatment	MEUFO	MEDSS	CHEAL	SONOL	RUMSS	ANGAR	POLPB	PTNHY	SOLNI	PHAMI
Topramezone 10.08 g/ha	1.77 (2.63)	1.74 (2.51)	1.68 (2.32)	1.73 (2.49)	1.64 (2.19)	1.57 (1.96)	1.49 (1.72)	1.36 (1.35)	1.27 (1.10)	1.34 (1.28)
Topramezone 15.12 g/ha	1.66 (2.24)	1.63 (2.14)	1.57 (1.96)	1.62 (2.11)	1.54 (1.86)	1.48 (1.68)	1.40 (1.45)	1.29 (1.15)	1.20 (0.94)	1.27 (1.10)
Topramezone 20.16 g/ha	1.53 (1.83)	1.50 (1.75)	1.45 (1.60)	1.49 (1.72)	1.43 (1.53)	1.37 (1.36)	1.30 (1.19)	1.20 (0.94)	1.13 (0.77)	1.19 (0.90)
Topramezone 25.20 g/ha	1.47 (1.65)	1.44 (1.57)	1.40 (1.45)	1.43 (1.54)	1.37 (1.36)	1.32 (1.23)	1.25 (1.06)	1.16 (0.83)	1.09 (0.69)	1.15 (0.82)
Topramezone 10.08 g/ha + MSO adjuvant 2 ml/l of water	1.73 (2.49)	1.70 (2.37)	1.65 (2.21)	1.69 (2.36)	1.62 (2.11)	1.54 (1.86)	1.46 (1.63)	1.34 (1.28)	1.25 (1.05)	1.33 (1.27)
Topramezone 15.12 g/ha + MSO adjuvant 2 ml/l of water	1.56 (1.92)	1.53 (1.83)	1.48 (1.69)	1.52 (1.81)	1.45 (1.60)	1.39 (1.43)	1.33 (1.26)	1.22 (0.99)	1.14 (0.80)	1.21 (0.96)
Topramezone 20.16 g/ha + MSO adjuvant 2 ml/l of water	1.42 (1.50)	1.39 (1.43)	1.35 (1.31)	1.38 (1.40)	1.32 (1.23)	1.27 (1.11)	1.22 (0.98)	1.13 (0.77)	1.06 (0.62)	1.11 (0.73)
Topramezone 25.20 g/ha + MSO adjuvant 2 ml/l of water	1.41 (1.47)	1.39 (1.42)	1.35 (1.31)	1.38 (1.40)	1.33 (1.26)	1.27 (1.11)	1.22 (0.98)	1.13 (0.77)	1.06 (0.62)	1.14 (0.79)
Oxyfluorfen 250 g/ha	2.05 (3.70)	2.01 (3.54)	1.94 (3.26)	2.00 (3.50)	1.90 (3.11)	1.81 (2.76)	1.71 (2.42)	1.55 (1.90)	1.43 (1.54)	1.53 (1.84)
Hand weeding twice 20 and 40 DAS	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Untreated control	4.29 (17.86)	2.50 (5.73)	4.05 (15.86)	4.19 (17.06)	3.95 (15.06)	3.74 (13.49)	3.50 (11.75)	3.13 (9.27)	2.85 (7.59)	3.08 (8.96)
LSD (p=0.05)	0.36	0.37	0.37	0.35	0.23	0.30	0.24	0.36	0.37	0.37

Data was square root transformed ($\sqrt{x + 0.5}$), original data within parenthesis, DAA- days after application, DAS- days after sowing. *Please refer to Table 1 for full form of weed EPPO code.

Chickpea seed yield

The highest chickpea seed yield was recorded with hand weeding twice at 20 and 40 DAS, while the lowest chickpea seed yield was recorded under weedy check among all treatments (**Figure 2**). Topramezone 25.20 g/ha + MSO adjuvant recorded the highest chickpea seed yield, during both the years, (**Figure 2**) which was 24% and 7.8% higher compared to oxyfluorfen 250 g/ha and topramezone 20.16 g/ha, respectively and was 4.9% lower than hand weeding twice treatment. All herbicidal treatments except topramezone 10.08 g/ha and oxyfluorfen 250 g/ha were statistically at par with topramezone 25.20 g/ha treatment. The higher seed yield observed with topramezone 25.20 g/ha may be due to combined effects of weed suppression and improved plant growth. Reduced weed density likely favoured growing environment for the chickpea, allowing the crop to achieve higher yield (Kumar *et al*. 2025). Higher chickpea seed yield with topramezone application was also reported by Nath *et al.* (2018).

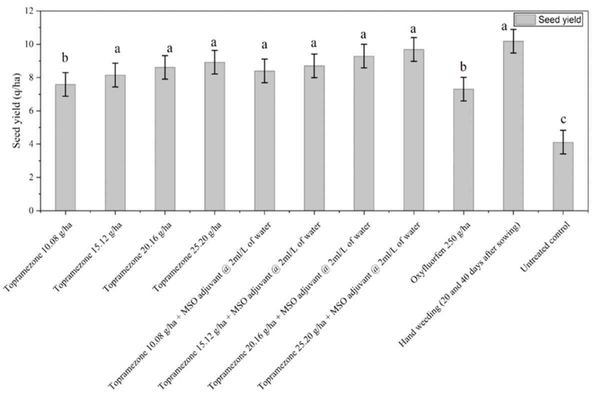

Figure 2. Seed yield of chickpea as affected by different weed control treatments (pooled data of two years)
(Similar letters across bar indicate non-significance at p=0.05 as per LSD)

Correlation analysis

Correlation analysis among seed yield and various weed efficiency indices indicate that there was a strong positive correlation between seed yield and WCE at 45 DAS, moderately positive relation between seed yield and HEI at 45 DAA, and a perfect negative correlation between seed yield and weed index (**Figure 3**). The improved higher yield with reduced weed competition was reported earlier by Bhosale *et al.* (2023), Nath *et al.* (2021) and Nath *et al.* (2018). The perfect negative correlation between seed yield and yield index indicates that as weed density increases, seed yield decreases (Choudhary *et al.* 2025).

Economics

Economic analysis indicated that weed management treatments significantly affected cost of cultivation, returns, and benefit-cost (B:C) ratio

Table 5. Weed species* biomass (g/m^2) at 45 DAA as influenced by weed control treatments (pooled data of two years)

Treatment	MEUOF	MEDSS	CHEAL	SONOL	RUMSS	ANGAR	POLPB	PTNHY	SOLNI	PHAMI
Topramezone 10.08 g/ha	1.69 (2.36)	1.67 (2.26)	1.61 (2.09)	1.65 (2.24)	1.57 (1.97)	1.51 (1.77)	1.43 (1.55)	1.31 (1.22)	1.23 (1.00)	1.29 (1.16)
Topramezone 15.12 g/ha	1.61 (2.12)	1.59 (2.03)	1.54 (1.87)	1.58 (2.00)	1.51 (1.77)	1.45 (1.58)	1.38 (1.39)	1.26 (1.09)	1.18 (0.89)	1.25 (1.05)
Topramezone 20.16 g/ha	1.26 (1.09)	1.25 (1.05)	1.21 (0.96)	1.24 (1.04)	1.19 (0.91)	1.15 (0.82)	1.10 (0.72)	1.04 (0.56)	0.98 (0.46)	1.02 (0.54)
Topramezone 25.20 g/ha	1.21 (0.98)	1.20 (0.94)	1.17 (0.86)	1.20 (0.93)	1.15 (0.82)	1.11 (0.74)	1.07 (0.64)	1.01 (0.50)	0.96 (0.42)	1.00 (0.50)
Topramezone 10.08 g/ha + MSO adjuvant 2 ml/l of water	1.65 (2.25)	1.63 (2.15)	1.58 (1.98)	1.62 (2.13)	1.55 (1.89)	1.48 (1.68)	1.41 (1.47)	1.29 (1.15)	1.21 (0.95)	1.28 (1.15)
Topramezone 15.12 g/ha + MSO adjuvant 2 ml/l of water	1.54 (1.89)	1.52 (1.81)	1.48 (1.67)	1.51 (1.79)	1.45 (1.59)	1.39 (1.41)	1.32 (1.24)	1.22 (0.98)	1.14 (0.80)	1.20 (0.95)
Topramezone 20.16 g/ha + MSO adjuvant 2 ml/l of water	1.18 (0.89)	1.17 (0.86)	1.14 (0.79)	1.16 (0.85)	1.12 (0.75)	1.08 (0.67)	1.04 (0.59)	0.98 (0.46)	0.94 (0.38)	0.97 (0.44)
Topramezone 25.20 g/ha + MSO adjuvant 2 ml/l of water	1.18 (0.89)	1.17 (0.85)	1.14 (0.79)	1.16 (0.85)	1.13 (0.76)	1.08 (0.67)	1.04 (0.59)	0.98 (0.46)	0.94 (0.38)	0.99 (0.47)
Oxyfluorfen 250 g/ha	1.65 (2.22)	1.62 (2.12)	1.57 (1.96)	1.61 (2.10)	1.54 (1.86)	1.47 (1.66)	1.40 (1.45)	1.28 (1.14)	1.20 (0.94)	1.27 (1.11)
Hand weeding twice 20 and 40 DAS	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Untreated control	2.6 (6.25)	2.51 (5.78)	2.37 (5.10)	2.51 (5.80)	2.32 (4.87)	2.19 (4.28)	2.09 (3.88)	1.87 (2.99)	1.72 (2.44)	1.85 (2.91)
LSD (p =0.05)	0.15	0.26	0.25	0.22	0.14	0.18	0.18	0.14	0.16	0.18

Data was square root transformed ($\sqrt{x + 0.5}$), original data within parenthesis, DAA- days after application, DAS- days after sowing, *Please refer to Table 1 for full form of weed EPPO code.

Table 6. Economic of chickpea cultivation under various weed control treatments

Treatment	Total cost (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
Topramezone 10.08 g/ha	27177	42855	40864	1.5
Topramezone 15.12 g/ha	28006	46019	45074	1.61
Topramezone 20.16 g/ha	28836	48647	48474	1.68
Topramezone 25.20 g/ha	29666	50398	50524	1.7
Topramezone 10.08 g/ha + MSO adjuvant 2 ml/l of water	29223	47460	46287	1.58
Topramezone 15.12 g/ha + MSO adjuvant 2 ml/l of water	30053	49183	48067	1.6
Topramezone 20.16 g/ha + MSO adjuvant 2 ml/l of water	30883	52489	52187	1.69
Topramezone 25.20 g/ha + MSO adjuvant 2 ml/l of water	31713	54720	54867	1.73
Oxyfluorfen 250 g/ha	26147	41273	41083	1.57
Hand weeding twice 20 and 40 DAS	39917	57545	51523	1.29
Untreated control	25517	23250	11523	0.45
LSD (p= 0.05)	1281	2113	1746	0.09

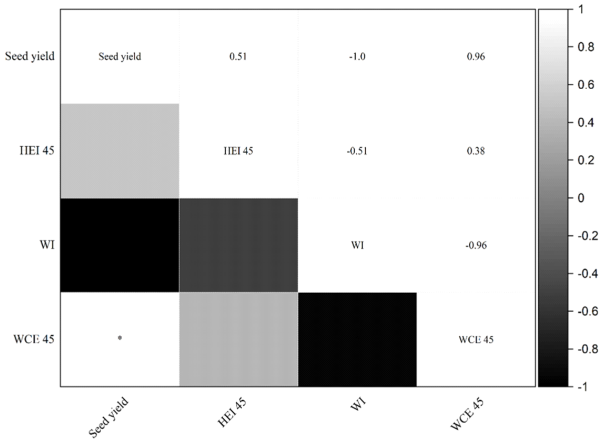

Figure 3. Correlation analysis between chickpea's seed yield and weed control indices

(*Significant at *pd" 0.05,* HEI 45: herbicide efficiency index at 45 DAA, WI: weed index, WCE 45: weed control efficiency index at 45 DAA)

(**Table 6**). Among the treatments, topramezone at 25.20 g/ha + MSO adjuvant recorded the highest gross return, net return, and B:C ratio. However, this treatment was statistically at par with topramezone at 20.16 g/ha + MSO adjuvant and topramezone at 25.20 g/ha alone. Although hand weeding twice at 20 and 40 DAS recorded the highest gross return, its higher cost of cultivation resulted in a lower B-C ratio compared to herbicidal treatments. The untreated control recorded the lowest gross and net returns and a B:C ratio.

Conclusion

It can be concluded that topramezone 20.16 g/ha + MSO adjuvant (2 ml/l of water) effectively controlled both broad-leaved and grassy weeds in chickpea resulting in higher chickpea seed yield and profitability.

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