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Research Paper

Chemical weed management in chickpea (*Cicer arietinum*) under *Vertisols* of Eastern Plateau Plain zone of India

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ABSTRACT

A field experiment was conducted during the winter seasons of 2020–21 and 2021–22 at Instructional-cum-Research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh to study the effect of various herbicides and their combinations on weed dynamics and performance of chickpea. A total of 14 treatment combinations including hand weeding and unweeded control were laid out in a randomized block design with three replications. The results revealed that significantly lower weed density and dry matter production, weed index and higher weed control efficiency were observed under two hand weedings at 20 and 40 DAS which was found at par to oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). The higher dry matter accumulation, crop growth rate, number of pods/plant, number of seeds/pod, seed index, seed yield (1.78 t/ha) and stover yield (2.70 t/ha) of chickpea were obtained with oxyfluorefen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). Application of oxyfluorefen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) controlled complex weeds flora effectively and fetched maximum net returns (₹63.1 × 10^3/ha) and benefit-cost ratio (3.02).

Key words: Chickpea, Herbicides, Post-emergence, Pre-emergence, Weed flora

Chickpea (*Cicer arietinum* L.) is one of the important pulse crops in the world covering 14.6 M ha area with 14.8 Mt of production (FAO, 2021). Chickpea is valued for its nutritional quality (high protein content 18–22%, carbohydrate 52–70%, fat 4–10%, minerals, calcium, phosphorus and iron; and vitamins) in the vegetarian diet. Also, pulse crops are promoted in cropping system intensification and diversification to ensure the sustainable productivity and prevent soil degradation. Specifically, chickpea plays an important role in conservation agriculture systems because of resource saving and biological N-fixation (Nath *et al.,* 2021). India is the largest chickpea producing country accounting for 64% of the global chickpea production. In India it is cultivated in area of 10.47 M ha with a total production of 11.35 Mt and productivity of 1,116 kg/ha (Agricultural Statistics at a Glance*,* 2020).

One of the major constraints in successful cultivation of chickpea is their poor ability to compete with weeds because of slow growth rate and limited leaf development at early stage of crop growth and establishment (Merga and Alemu, 2019). Crop losses up to 90% are possible due to uncontrolled weeds in chickpea (Bhutada, 2015). Presently, pre-emergence (PE) application of pendimethalin at 1000 g/ha followed by one hand weeding is advocated for weed management in chickpea. However, hand weeding is a cumbersome process because of limited availability of labour at critical period and increasing cost. Also, application of pendimethalin as pre-emergence application does not control the later flush of weeds after one month of sowing. Therefore, post-emergence herbicides are essential, but there is no such herbicide recommended especially for controlling broad-leaved weeds in chickpea. Some studies have suggested the application of imazethapyr in chickpea,

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but lower weed control efficiency and phytotoxicity to crop hinder its wider adoption. Quizalofop-p-ethyl 50 g/ha and fenoxaprop-p-ethyl 100 g/ha are recommended in chickpea to control grassy weeds, but the dominant broad-leaved weeds caused severe yield loss in chickpea (Nath *et al.,* 2021). Hence, the efficacy of new PE and PoE herbicides should be studied, either alone or in combination for efficient weed management in chickpea. Therefore to estimate the appropriate herbicide or herbicide combination the two years investigation was carried out.

MATERIALS AND METHODS

An experiment was conducted during winter seasons of 2021–22 and 2022–23 at Instructional- cum- Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh situated in central part of Chhattisgarh and lies at 21°4'N latitude and 81°35'E longitude with an altitude of 290.20 meters above the mean sea level, receives an annual rainfall of 1,200–1,400 mm. The experimental soil belongs to the order *Vertisols*, medium in organic carbon (0.61%) and low in available nitrogen (222.7 kg/ha), medium in available phosphorus (13.8 kg/ha) and high in available potassium (373.2 kg/ha). The experiment was laid out in a randomized block design with 3 replications. The treatment comprised of 14 weed control options *i.e.,* oxyfluorfen 23.5% EC 150 g/ha as pre-emergence (PE), oxyfluorfen 23.5% EC 250 g/ha (PE), metribuzin 70% WP 350 g/ha (PE), quizalofop-p-ethyl 5% EC 100 g/ha as post-emergence (PoE), propaquizafop 10% EC 100 g/ha (PoE), topramezone 33.6% SC 20.6 g/ha (PoE), oxyfluorfen 23.5% EC 150 g/ha (PE) *fb* quizalofop-p-ethyl 5 % EC 100 g/ha (PoE), oxyfluorfen 23.5% EC 150 g/ha (PE) *fb* propaquizafop 10% EC 100 g/ha (PoE), oxyfluorfen 23.5% EC 150 g/ha (PE) *fb* topramezone 33.6% SC 20.6 g/ha (PoE), metribuzin 70% WP 350 g/ha (PE) *fb* quizalofop-p-ethyl 5% EC 100 g/ha (PoE), metribuzin 70% WP 350 g/ha (PE) *fb* propaquizafop 10% EC 100 g/ha (PoE), metribuzin 70% WP 350 g/ha (PE) *fb* topramezone 33.6% SC 20.6 g/ha (PoE), hand weeding twice at 20 and 40 DAS and un-weeded control. Sowing was done manually in the first fortnight of December and 2nd fortnight of November, during 2021-22 and 2022-23, respectively using 80 kg/ha seeds of 'Indira chana-1' cultivar in rows of 30 cm apart, with plant-to-plant distance of 10 cm. Nitrogen (20 kg/ha), phosphorus (50 kg/ha), potassium (20 kg/ha) and sulfur (20 kg/ha) were applied as starter dose. Weed density and dry matter production were observed from 1 m^2 quadrate placed at two random spots in each plot. Dry-matter accumulation (DMA) was recorded at harvesting by collecting 5 random whole plant samples in each plot. Yield attributes and yields were recorded from each plot at harvesting. Crop-growth rate (CGR) between 30-60, 60-90 and 90 DAS-at harvest were recorded on the basis of dry matter accumulation as per procedure given by Redford (1967). Days to 50% flowering and 90% physiological maturity were recorded from each plot. Seed and straw yield (kg/ha) were calculated based on per plot yield. Economic analysis was done on the basis of prevailing market prices of inputs and output obtained from each treatment. The statistical analysis of the data was done according to the procedure given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Weed population, biomass and weed indices

The major weed species recorded in chickpea field were *Echinocoloa colona* L. (14.4%), *Medicago denticulata* Willd. (35.0%), *Physalis minima* Linn. (13.4%), *Chenopodium album* L (14.4%), *Crisium vulgare* Savi. (5.8%), *Parthenium hyterophorus* L. (6.2%) and others (10.9%). Herbicides treatments significantly influenced the density and dry matter production of weeds in chickpea (Table 1). The minimum total density and dry matter production of weeds was recorded under hand weeding twice at 20 and 40 DAS, but it was found at par to oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). When compared among herbicides, at harvest, oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) recorded significantly minimum density of total weeds and it was at par to metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). Hand weeding twice at 20 and 40 DAS had maximum weed control efficiency and minimum weed index followed by oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). When compared among herbicides, the highest weed control efficiency and lowest weed index was recorded under oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) followed by metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). The maximum weed index of 72.2% was observed in un-weeded control (Table 1). The low weeds population in herbicide-treated plots was due to better control of weeds starting from germination stage to maximum vegetative growth stage of crop, which provide crop in advantageous position to have good suppression effects on weeds. The lower dry matter production of weeds in these treatments can also attributed to better crop competitiveness. The better efficacy and prolonged effectiveness of applied HPPD (4-hydroxy phenyl pyruvate dioxygenase) inhibiting herbicides i.e., topramezone reduced weed growth and resulted in rapid depletion of carbohydrate reserves of already germinated weeds. It also results in rapid respiration, bleaching of leaves, reduction in leaf area and reduced photosynthetic activity (Swetha *et al.*, 2018). Similarly, higher weed dry weight in weedy

Table 1. Effect of herbicides on weed biomass, population, weed indices and growth attributes of chickpea (pooled data of 2 years)

Treatment	Dose (g/ha)	Weed density (m^2)	Weed dry matter production (g/m^2)	WCE (%)	WI (%)	DMA (g/plant)	Days to 50% flowering	Days to 90% physiological maturity
Oxyfluorefen (PE)	150	6.2 (37.4)	6.1 (36.8)	58.4	33.4	18.70	53	112
Oxyfluorefen (PE)	250	6.0 (35.0)	6.0 (35.1)	61.1	28.0	18.94	53	111
Metribuzin (PE)	350	6.3 (38.9)	6.2 (37.4)	56.7	35.1	18.54	53	112
Quizalofop-p-ethyl (PoE)	100	7.3 (53.3)	7.0 (48.3)	40.9	48.4	15.84	54	113
Propaquizafop (PoE)	100	7.3 (52.2)	6.9 (47.4)	42.1	47.5	16.08	54	113
Topramezone (PoE)	20.6	5.3 (28.0)	5.4 (29.2)	68.8	17.6	21.88	52	111
Oxyfluorefen (PE) *fb* Quizalofop-p-ethyl (PoE)	150 + 100	5.2 (26.1)	5.3 (27.4)	71.0	12.7	23.25	52	110
Oxyfluorefen (PE) *fb* Propaquizafop (PoE)	150 + 100	5.1 (25.1)	5.2 (26.8)	72.1	11.8	23.59	51	110
Oxyfluorefen (PE) *fb* Topramezone (PoE)	150 + 20.6	3.1 (9.4)	4.1 (16.0)	89.5	1.7	26.91	51	109
Metribuzin (PE) *fb* Quizalofop-p-ethyl (PoE)	350 + 100	5.3 (27.6)	5.4 (28.8)	69.4	16.6	22.27	52	111
Metribuzin (PE) *fb* Propaquizafop (PoE)	350 + 100	5.2 (26.8)	5.4 (28.4)	70.2	15.2	22.67	52	110
Metribuzin (PE) *fb* Topramezone (PoE)	350 + 20.6	3.4 (10.8)	4.1 (16.9)	88.0	3.3	26.40	51	110
Hand weeding twice		2.9 (7.7)	3.8 (13.8)	91.5	0.0	27.55	51	109
Un-weeded control		9.5 (90.0)	8.6 (73.8)	0.0	72.2	13.07	55	114
SEm±		0.10	0.11			0.63	0.62	0.87
CD (P=0.05)		0.29	0.32			1.83	1.81	2.52

DMA, dry-matter accumulation; WCE, weed control efficiency; WI, weed index

*Figures in parenthesis are the original values. †Data transformed to square root transformation $\sqrt{x+1}$

Data on weed density, weed dry matter production, weed control efficiency and dry matter accumulation are of at harvest.

check was obtained due to higher weed density which compete vigorously for nutrients, space, light, water and carbon di-oxide resulting in higher biomass production. These results are in agreement with the findings of Chavada *et al.,* (2018) and Merga and Alemu (2019). The loss of yield (72%) as measured in terms of weed index was recorded maximum under unweeded control due to heavy infestation of weeds. These results were parallel with the findings of Yadav *et al.,* (2018) and Sethi *et al.,* (2021).

Crop growth attributes

The crop growth attributes *viz.,* dry-matter accumulation/plant, CGR, 50% flowering and 90% physiological maturity were significantly varied with herbicide treatments (Table 1). Hand weeding twice at 20 and 40 DAS resulted in significantly higher total DMA than other treatment, which was remained at par with oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). When compared among herbicides, significantly higher dry matter accumulation was recorded under oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) as compared to others, but it was found *at par* with metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE), while un-weeded control recorded the lowest. CGR increased with the advancement of crop age up to 90 DAS and it was decreased thereafter (Fig. 1). Treatment hand weeding twice at 20 and 40 DAS was proved to be the best in increasing CGR throughout the crop growth period and it was followed by oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). The increasing trend of CGR from 60-90 DAS was presented by these three treatments whereas, in others, CGR was found to be increased up to 60 DAS and decreased from 60-90 DAS. When compared among herbicidal treatments, oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) was proved to be the best in increasing crop growth rate throughout the period of investigation followed by metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). Significantly minimum days to 50% flowering and days to 90% physiological maturity was taken under hand weeding twice at 20 and 40 DAS which was at par to all the

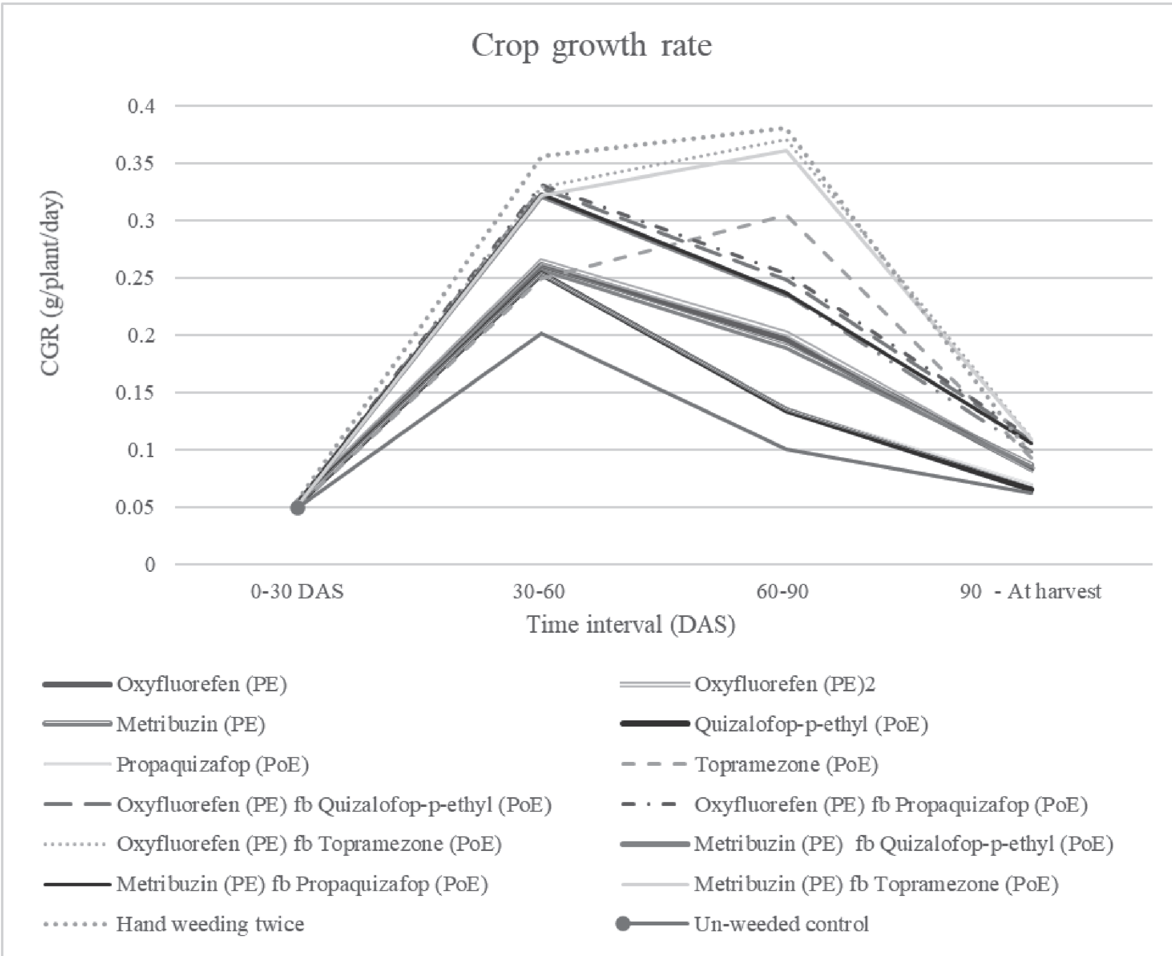

Fig. 1. Effect of different herbicides on crop growth rate of chickpea (pooled data of 2 years)

herbicidal treatments, except propaquizafop 100 g/ha (PoE) and propaquizafop 100 g/ha (PoE), while, the maximum days were taken by un-weeded control during both the years. Crop dry matter is a net result of photosynthesis which remains in balanced after respiration process. At the same time, growth attributes *i.e.* plant height, number of branches and plant population have the direct effects in contributing the dry matter accumulation, while density and the dry weight of the weeds have a strongly negative correlation. Also, the treatments reduced the density and dry weight of the weeds more effectively, provided a more favourable micro-environment to enhance the crop growth and ultimately having more crop dry weight in the respective treatments. The use of oxyfluorfen in conjunction with topramezone resulted in higher weed control. Oxyfluorfen acts as a contact herbicide, disrupting the photosynthetic processes of emerging weed seeds resulting in the effective control of specific weeds. Similarly, topramezone is effective in managing subsequent weed growth by inhibiting the synthesis of carotenoids, essential compounds for plant growth. This combination of herbicides demonstrates effective control of selective weeds by addressing both initial and later stages of weed growth. Crop dry matter accumulation was increased noticeably due to the different treatments as compared to the weedy check at all the growth stages of crop (Singh *et al.,* 2020). The increase in CGR up to 60 DAS was due to effective source sink relationship, which occurred and translocated photosynthates from vegetative to reproductive parts took place which lead to decrease in vegetative growth and increase in reproductive growth. In un-weeded control, the shading effect of weeds on crop plants might have reduced sunlight interception thus prolonged the vegetative growth resulting in delayed days to flowering. Results are in accordance with Merga and Alemu (2019).

Yield attributes and yield

Hand weeding twice at 20 and 40 DAS resulted in significantly higher number of pods/plant, number of seeds/pod, seed index, seed yield and stover yield as compared to others, but these parameters were remained similar in treatments viz., oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6

g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) with two hand weeding treatment (Table 2). Among the various herbicides, the application of oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) had significantly maximum number of pods/plant, number of seeds/pod, seed index, seed yield and stover yield which was *at par* to metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE). Further, seed index was also *at par* to oxyfluorfen 150 g/ha (PE) *fb* propaquizafop 100 g/ha (PoE), oxyfluorfen 150 g/ha (PE) *fb* quizalofop-p-ethyl 100 g/ha (PoE) and metribuzin 350 g/ha (PE) *fb* propaquizafop 100 g/ha (PoE). All weed management practices were found significantly superior over un-weeded control with respect to yield and yield attributing characteristics of chickpea. The data regarding harvest index showed non-significant differences among herbicidal treatments as well as hand weeding twice at 20 and 40 DAS, while all were significantly higher as compared to treatment un-weeded control (Table 2). The highest number of pods under hand weeding may be due to the less competition at critical periods of crop growth and better suppression of weeds, which allow the crop to grow their potential to absorbing sufficient nutrients, light, moisture and space which facilitate more translocation of photosynthates toward the reproductive parts. Chemical weed management through topramezone (20.6 g a.i./ha) is promising and safe for broad-spectrum weed control as it provided the comparable WCE, WCI and seed yield in chickpea (Nath *et al.,* 2021). In addition, severe weed competition for resources in unweeded control resulting poor growth and yield attributes leading to poor seed yield of chickpea. These findings are in accordance with Kour *et al.* (2014).

Gross returns, net returns and B:C

Treatment hand weeding twice at 20 and 40 DAS had the highest gross returns (96.09 × 10^3/ha), while net returns (63.11 × 10^3/ha) and Benefit: cost ratio (3.02) were maximum under oxyfluorfen 150 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) closely followed by metribuzin 350 g/ha (PE) *fb* topramezone 20.6 g/ha (PoE) (Table 2). The higher gross returns under hand weeding twice were because of higher seed and stover yield. The higher gross returns, net returns and B: C under above herbicidal treatments was due to the fact that higher seed and stover yields associated with lower cost of cultivation. Although higher cost of herbicides increased the cost of cultivation, if a herbicide found appropriate and effective for control of weeds, then increased yield due to less crop-weed competition meet the gap caused by costly herbicides. Dixit *et al.* (2015) also stated that twice manual weeding gave 11.2% higher chickpea equivalent yield than herbicidal weed management but due to higher cost of cultivation under manual

Table 2. Effect of herbicides on yield attributes, yield and economics of chickpea (pooled data of 2 years)

Treatments	Dose (g/ha)	Pods/ plant	Seeds/ pod	Seed index (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Gross returns (× 10^3/ha)	Net returns (× 10^3/ha)	Benefit-cost ratio
Oxyfluorefen (PE)	150	30.4	1.37	23.8	1204	1979	37.8	64.11	37.09	2.38
Oxyfluorefen (PE)	250	31.0	1.37	23.9	1300	2021	39.1	69.12	41.48	2.50
Metribuzin (PE)	350	29.7	1.37	23.3	1170	1922	37.8	62.30	35.39	2.32
Quizalofop-p-ethyl (PoE)	100	26.0	1.30	23.0	931	1673	35.7	49.73	19.80	1.67
Propaquizafop (PoE)	100	26.6	1.30	23.1	950	1702	35.7	50.73	22.46	1.80
Topramezone (PoE)	20.6	34.6	1.47	24.7	1489	2257	39.7	79.14	49.43	2.67
Oxyfluorefen (PE) *fb* Quizalofop-p-ethyl (PoE)	150 +100	36.7	1.53	25.5	1579	2396	39.7	83.90	52.37	2.66
Oxyfluorefen (PE) *fb* Propaquizafop (PoE)	150 +100	37.3	1.57	25.7	1593	2410	39.7	84.66	54.78	2.84
Oxyfluorefen (PE) *fb* Topramezone (PoE)	150 + 20.6	39.6	1.67	26.1	1776	2704	39.7	94.42	63.11	3.02
Metribuzin (PE) *fb* Quizalofop-p-ethyl (PoE)	350 + 100	35.4	1.50	25.0	1507	2303	39.6	80.14	48.71	2.55
Metribuzin (PE) *fb* Propaquizafop (PoE)	350 + 100	35.8	1.50	25.2	1532	2347	39.5	81.47	51.70	2.74
Metribuzin (PE) *fb* Topramezone (PoE)	350 + 20.6	39.2	1.63	26.0	1746	2670	39.5	92.85	61.65	2.98
Hand weeding twice		41.2	1.77	26.2	1807	2752	39.8	96.09	60.69	2.72
Un-weeded control		23.0	1.23	22.7	501	1462	25.6	27.33	1.92	1.08
SEm±		0.8	0.04	0.33	30.0	53.6	0.8			
CD (P=0.05)		2.3	0.17	0.95	87	156	2.2			

Based on price of seed, ₹51,000/t in 2021–22 and ₹52,300/t in 2022–23 and stover, ₹1,000/t weeding, application of recommended herbicide in chickpea-fodder sorghum system was profitable, giving higher net return and B:C ratio. These results confirm the findings of Dewangan *et al.,* (2016) and Dubey *et al.,* (2018).

Thus, it can be concluded that the sequential application of oxyfluorefen at 150 g/ha (PE) followed by topramezone at 20.6 g/ha (PoE) was the most effective in reducing weed density, weed dry matter, and weed index. Additionally, it exhibited higher weed control efficiency and led to increased growth, yield, and profitability of chickpea.

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