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Growth and Productivity Improvement of Chickpea (*Cicer arietinum* L.) through Weed Management by Topramezone

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ABSTRACT

Background: Chickpea (*Cicer arietinum* L.) is the most important pulse crop widely cultivated for its nutritional and economic value. However, weed infestation poses a significant challenge to chickpea production, leading to reduced growth and productivity. Effective weed management strategies are therefore essential to mitigate the losses due to weeds and improve crop productivity. Selective herbicides with low or no phytotoxicity to the crop offer a promising solution for controlling weeds in order to boost up crop productivity. Currently available post emergence herbicides such as imazethapyr, can cause phytotoxic effects on chickpea. Therefore, it is essential to identify new post-emergence herbicides that can effectively control weeds without harming plant health. This study investigates the impact of topramezone, a selective post-emergence herbicide, on weeds as well as growth and productivity of chickpea.

Methods: A field experiment was conducted at Agricultural Farm of Palli Siksha Bhavana, Visva-Bharati, Sriniketan during *rabi* season of 2021-22 and 2022-23. The experiment was laid out in randomized block design with nine treatments and three replications. The treatments were - T_1 - topramezone 15 g ha^{-1} as POE, T_2 - topramezone 17.5 g ha^{-1} as POE, T_3 - topramezone 20 g ha^{-1} as POE, T_4 - topramezone 22.5 g ha^{-1} as POE, T_5 - topramezone 25 g ha^{-1} as POE, T_6 - imazethapyr 60 g ha^{-1} as POE, T_7 - pendimethalin 750 g ha^{-1} as PE, T_8 - weed free and T_9 - unweeded control. The study assessed the density and dry weight of weeds, weed control efficiency, growth and yield parameters as well as yield of chickpea under various application doses of topramezone in comparison with imazethapyr and pendimethalin.

Result: Among all the herbicides, post-emergence application of topramezone 25 g ha^{-1} at 25 days after sowing resulted the lowest density and dry weight of weeds, the highest growth (plant height, LAI) and yield parameters (number of pods plant^{-1}, number of seeds pod^{-1}), seed yield and harvest index. Therefore, post-emergence application of topramezone 25 g ha^{-1} at 25 days after sowing proved to be an effective herbicide for weed control in chickpea in the lateritic belt of West Bengal.

Key words: Chickpea, Herbicide, Imazethapyr, Pendimethalin, Weeds.

INTRODUCTION

Pulses are vital to global nutrition, environmental sustainability and economic stability. Being rich in protein, fibre, vitamins and minerals, they serve as an essential dietary component, particularly in regions where animal protein is scarce. As a resilient crop, pulses are crucial in addressing the challenges posed by climate change and ensuring a sustainable and nutritious food supply for the future. India is the world's largest pulse producing and consuming country contributing one third (34.34%) of total global area and one fourth (25.88%) of total global production under pulses (Anonymous, 2020). Despite being the largest producer, India struggles to produce enough pulses to keep up with its growing population and meet domestic demand, forcing the country to import 0.295 million tonnes in the year 2020-21 at a significant cost in foreign exchange (Murugananthi *et al*., 2024). In India, the area under pulses is 28.90 million hectares with a production of 26.05 million tonnes and productivity of 902 kg ha^{-1} during 2022-23 (Anonymous, 2023a). Though global production and yield of pulses have not raised significantly in recent decades, the world's population has been continuously increasing. As a result, the net availability of pulses per capita has decreased. The per capita availability of pulses has fall down from 60 g capita^{-1} day^{-1} in 1951 to 47.1 g capita^{-1} day^{-1} in 2022 as against World Health Organization recommendation of 80 g capita^{-1} day^{-1} (Anonymous, 2023b). Therefore, it is crucial to boost production to meet the rising demand by effectively enhancing production technologies.

Chickpea (*Cicer arietinum* L.) is the most widely cultivated pulse crop in our country. It is also called as bengal gram or gram. It is an annual legume, said to be

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one of the oldest pulses known and cultivated in Asia and Europe. It is a good source of carbohydrates and protein, together constituting about 80% of the total dry seed mass in comparison with other pulses (Jukanti *et al*., 2012). Chickpeas are low in cholesterol and rich in dietary fiber (DF), minerals and vitamins. It is plentiful in unsaturated fatty acids and carotenoids (Marioli Nobile *et al*., 2013). Chickpeas are split and turned into flour (besan), in the Indian subcontinent, which is used to prepare a variety of snacks. On average, 100 g of chickpea contains around 17 g of protein, 4.6 milligrams of iron, 186 mg of folic acid, 202 mg of calcium and 360 calories of energy (Anonymous, 2016). Global production of chickpea in 2022 was estimated to be 18.10 million tonnes. India is a leader in production and consumption of chickpea with a production of 12.26 million tonnes that shares about 70% of global production in the year 2022-23. In India, it is cultivated under 10.47 million hectare area with a productivity of 1172 kg ha^{-1}. The highest area under chickpea was in Maharashtra which shares 28.23 % followed by Madhya Pradesh covering 20.13 % of the total chickpea area of the country (Anonymous, 2023c). In West Bengal, the cultivated area under chickpea was 39770 ha, production is 50070 tonnes and productivity 1259 kg ha^{-1} in the year 2020-21 (Anonymous, 2022). Inappropriate production methods, insufficient biological nitrogen fixation, seed damage from a variety of pathogens and pests as well as cultivar vulnerability to abiotic stresses are major contributors of less production. Out of all these factors, weeds are the major cause of low production of chickpea as unrestricted weed growth drastically reduces the yield of chickpea.

Chickpea is a poor competitor of weeds because of its slow growth rate and limited leaf area development at the early stages of crop growth and establishment (Ratnam Rao and Reddy, 2011). The critical period of crop-weed competition in chickpea is 16 to 48 DAS (Mukherjee, 2007). The reduction in grain yield may be up to 75% depending on the weed species and their densities in various countries (Rashid *et al*., 2019). Weed emergence with chickpea creates severe competition unless controlled timely and effectively. There are several methods to control weeds in chickpea fields *i.e.* preventive methods, cultural methods, physical or manual methods and chemical methods. Physical or manual method is the most common and traditional method. Although, hand weeding is easy, environment friendly and most effective, it is proving difficult because of labour scarcity at critical times of weeding and increasing costs (Dubey *et al*., 2018). Mechanical weeding is very labour intensive and there is possibility of non-availability of labour during some seasons. On the other hand, the chemical method of weed control with the use of herbicides is cheap, effective, time saving and hence, gaining popularity among farmers for controlling weeds.

Effective control of mixed weed flora through a suitable herbicide is crucial for increased adoption by farmers. Herbicides have made it feasible to manage a broad spectrum of weeds in chickpea efficiently and economically. The herbicides, pendimethalin and imazethapyr are used as pre and post-emergence application, respectively in chickpea. Pendimethalin is N-(1-ethyl propyl)-3,4-dimethyl-2,6-dinitro benzenene amine compound that belongs to the dinitroaniline family. Its primary mode of action is to inhibit plant cell division by binding to and inactivating tubulin, a protein essential for cell division. This disruption causes mitotic abnormalities, which prevent the development of lateral roots and hinder seedling germination in susceptible plant species. If pre-emergence herbicide treatment is skipped for any reason, it is necessary to apply post-emergence herbicide to effectively control both grasses and broadleaved weeds. Besides, the pre-emergence herbicides are unable to control later flushes of weeds at later crop growth stages. Imazethapyr is 2- [4,5-dihydro-4-methyl-4-(1-methyl ethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridine carboxylic acid compound from the imidazolinone family and is commonly used herbicide to control the later flushes of weeds in chickpea by suppressing the activity of the enzyme acetohydroxy acid synthase, which catalyses the creation of three branched chain amino acids necessary for protein synthesis and cell growth. Some studies revealed that imazethapyr as post-emergence application in chickpea gives effective weed control but causes phytotoxicity in terms of chlorosis and epinasty that can be extended up to the flowering stage resulting in poor recovery of crop plants and yield reduction (Nath *et al*., 2018).

Hence, there is an urgent need to identify and evaluate an effective post-emergence herbicide for broad spectrum weed control in chickpea which can also control later flushes of weeds. Topramezone is an effective herbicide in maize to control broad and narrow leaved weeds but its efficacy in chickpea is not yet well established. Schonhammer *et al*., 2006 described topramezone as the first selective, systemic, post-emergence herbicide belonging to a chemical class called pyrazolones. Topramezone is an aromatic ketone that is phenyl 1H-pyrazol-4-yl ketone in which the pyrazolyl group is substituted at positions 1 and 5 by methyl and hydroxy groups, respectively and in which the phenyl group is substituted at positions 2, 3 and 4 by methyl, 4,5-dihydro-1,2-oxazol-3-yl and methyl sulfonyl groups, respectively. Topramezone [3-(4,5-Dihydro-3-isoxazolyl) -2-methyl-4- methyl sulfonyl) phenyl] (5-hydroxy-1-methyl-1H-pyrazol-4-yl) methanone] inhibits hydroxyphenyl pyruvate dioxygenase enzyme of carotenoid (pigment) biosynthesis. Consequently, chlorophyll is destroyed by oxidation. This effect is seen as a pronounced bleaching of the growing shoot tissue and subsequent necrosis of the above ground plant matter (Wolf and Rust, 2005). Topramezone is taken up by the shoot and the roots. It is distributed within the plants both acro- and basipetally. Some research works revealed that topramezone as post-emergence herbicide can effectively control weeds in chickpea without any phytotoxicity to chickpea plants and can thereby increase yield (Nath *et al*., 2021).

Taking into account the afore-mentioned information, the present experiment was undertaken to find out the effect of topramezone for weed management in chickpea to enhance its growth and productivity under laterite belt of West Bengal.

MATERIALS AND METHODS

The field experiment was carried out at Agricultural Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Birbhum, West Bengal during the *rabi* season of two consecutive years 2021-22 and 2022-23. Geographically, the field was situated at about 23°67′N latitude and 87°65′E longitude with an average altitude of 58.90 m above the mean sea level under sub-humid, semi-arid region and red and laterite zone of West Bengal. The soil in the test field was sandy loam in texture and slightly acidic in reaction. The physico-chemical characteristics of the experimental soil and the chemical examination of the top 15 cm layer revealed that the soil had a low level of organic carbon, low level of nitrogen and medium level of phosphorus and potassium. The experiment was laid out in randomized block design where nine treatments were replicated thrice. The treatments comprised, T_1- topramezone 15 g ha^{-1} as POE, T_2 - topramezone 17.5 g ha^{-1} as POE, T_3- topramezone 20 g ha^{-1} as POE, T_4 - topramezone 22.5 g ha^{-1} as POE, T_5 - topramezone 25 g ha^{-1} as POE, T_6 - imazethapyr 60 g ha^{-1} as POE, T_7 - pendimethalin 750 g ha^{-1} as PE, T_8 - weed free and T_9 - unweeded control. The field was prepared with the help of a tractor drawn cultivator after harvest of the previous crop, rice. The entire quantity of the recommended dose of N, P_2O_5 and K_2O *i.e.*, 20, 60 and 60 kg ha^{-1}, respectively were applied basal during final land preparation. The sources of nutrients were - urea for nitrogen, single super phosphate (SSP) for P_2O_5 and muriate of potash (MOP) for K_2O. The seeds of chickpea variety Anuradha (WBG-39) @ 50 kg ha^{-1} were sown at a spacing of 30 cm × 10 cm in north-south direction. All other recommended package of practices were followed uniformly in all the treatments to raise the crop.

The dose of the herbicides was calculated on the basis of net plot area and the required quantity was measured according to the treatments at the time of preparation of spray solution. The spraying was done by using a knapsack sprayer fitted with a flat fan nozzle using 500 litres of water per hectare. Pendimethalin 750 g ha^{-1} (T_7) was applied as pre-emergence on the next day of sowing whereas topramezone (T_1 to T_5) and imazethapyr (T_6) were applied as post- emergence at 25 days after sowing (DAS). The following formula was used to calculate the doses of herbicides:

$$RQ = \frac{\text{Rate of ai / ha to be applied}}{\text{Active ingredient (\%)}} \times 100$$

In weed free treatment, three hand weedings were done manually at 25, 50 and 75 DAS. Weeds were allowed to grow freely in unweeded control.

The weed density and dry weight of different categories of weeds *viz*., grass, sedge (not present in the experimental field) and broadleaved weeds were recorded separately at 60 DAS and harvest. The category wise weed density was recorded by counting the number of weeds using a quadrate of 0.5 m × 0.5 m and were converted to density m^{-2}. For recording dry weight, these weeds were removed separately category wise, cleaned thoroughly, sun dried initially and then oven dried at 65°C for 72 hours till constant weight was obtained. The weight of the dried weed samples were recorded category wise and expressed in g m^{-2}.

The observation on phytotoxicity of chickpea crop caused by the herbicides was done on the basis of phytotoxicity rating scale (PRS) for the applied herbicides. The observation on the level of phytotoxicity through visual assessment of crop response was graded on a scale of 0-10. Rating "0" indicates no phytotoxicity and "10" indicates100% kill.

Weed control efficiency (WCE) is expressed as the percentage of weed control over untreated control. It denotes the efficiency of the applied herbicide. WCE of different treatments was computed on the basis of weed dry weight by using the following formula:

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

Where,

X= Weed dry weight in unweeded control plot.

Y= Weed dry weight in treated plot.

Weed index is the measure of the efficiency of a particular treatment when compared with a weed free treatment. It is expressed as percentage of yield potential under weed free. Higher weed index means greater loss. Weed Index was calculated using the following formula:

$$\text{Weed index (\%)} = \frac{\text{Yield from weed free plot - Yield from treated plot}}{\text{Yield from weed free plot}} \times 100$$

Plant height from five randomly selected plants from each plot was measured at 60 DAS and harvest with the help of a measuring scale (cm) and the average plant height was calculated for each plot at each observation. LAI is the area of leaf surface per unit of land surface. Leaf area per plant was measured by leaf area meter (LICOR Model LI 3100) at 60 and 90 DAS.

The total number of developed pods collected from five plants were counted and average number of pods per plant was worked out for each treatment. The total number of seeds per pod was recorded by counting individual seeds of ten pods which were randomly selected from five plants and the average was calculated for each treatment. The main produce of each net plot was harvested and threshed separately, cleaned and the seed yield was recorded in kilogram per net plot. The seed yield obtained per net plot was converted on a hectare basis in kilogram (kg ha^{-1}).

Cost of cultivation was calculated by summing all expenses incurred in growing the crop. Gross return is the total monetary value of economic products obtained from

the raised crop in the cropping system and was calculated based on the local market prices. Net return from each treatment was calculated separately by subtracting the cost of cultivation from the gross return and expressed as Rs. ha^{-1}. Return per rupee invested was calculated on basis of the gross return to cost of cultivation.

The collected primary data on weed and crop parameters were statistically analyzed using an open-source software R version 4.1.1. The F-test was used to conduct the analysis of variance (ANOVA) and the mean significant differences were evaluated using Tukey's honest significant difference (HSD) test at a significance threshold of 5%. To assess the homogeneity of variances across years, Bartlett's test was applied. If the test indicated that the error variances were not homogeneous, Aitken's transformation was employed for the combined analysis of variance.

RESULTS AND DISCUSSION

Weed flora

The predominant weed flora found in the experimental field were - *Echinochloa colonum*, *Digitaria sanguinalis* and *Cynodon dactylon* among grasses; *Ammannia baccifera*, *Chenopodium album*, *Gomphrena celosioides*, *Polygonum plebeium* and *Vicia hirsuta* among broadleaved weeds. However, there was no sedge in the experimental field.

Density and dry weight of weeds

Weed density, weed dry weight and weed control efficiency at 60 DAS (days after sowing) and at harvest showed significant differences across various weed management treatments (Table 1). At 60 DAS, among the herbicide treatments, T_5 (topramezone 25 g ha^{-1} as POE) and T_7 (pendimethalin 750 g ha^{-1} as PE) were equally effective in reducing grass weed density, while topramezone 25 g ha^{-1} was the most effective against broadleaved weeds (BLW), followed by pendimethalin 750 g ha^{-1}. These outcomes were in line with the findings of Bhosale *et al*. (2023). However, at harvest, pre-emergence application of pendimethalin was the most effective in reducing grass weed density followed by post- emergence application of topramezone 25 g ha^{-1}. For broadleaved weeds, pendimethalin 750 g ha^{-1} was the best, with T_3 (topramezone 20 g ha^{-1}), T_4 (topramezone 22.5 g ha^{-1}) and T_5 (topramezone 25 g ha^{-1}) being equally effective. In terms of weed dry weight, topramezone 25 g ha^{-1} as POE and pendimethalin 750 g ha^{-1} as PE were equally effective for both grass and broadleaved weeds at 60 DAS. At harvest, pendimethalin 750 g ha^{-1} remained the best, followed by topramezone 25 g ha^{-1}, for both categories of weeds. The weed control efficiency (WCE) of topramezone 25 g ha^{-1} as POE and pendimethalin 750 g ha^{-1} was identical at both 60 DAS and at harvest (Table 1). These results corroborated with the findings of Gajanand *et al*. (2023) and Hedayetullah *et al*. (2023).

Phytotoxicity on chickpea crop

No phytotoxicity symptoms were exhibited by pendimethalin 750 g ha^{-1} as pre-emergence (PE) and topramezone at application rates ranging from 15 to 25 g ha^{-1} as post-emergence (POE) treatments on chickpea (Table 2). However, imazethapyr applied at 60 g ha^{-1} as POE caused noticeable phytotoxicity, manifested as chlorosis and stunted growth. These symptoms persisted up to the flowering stage, leading to poor recovery of the crop and a subsequent reduction in yield. Similar findings were observed by Sanketh *et al*. (2023).

Effect on crop growth

The various herbicidal weed control treatments had a significant impact on crop growth parameters such as plant

Table 1: Effect of treatments on density and dry weight of weeds in chickpea.

Treatment	Weed density (No. m^{-2})				Weed dry weight (g m^{-2})				WCE (%)	
	60 DAS		Harvest		60 DAS		Harvest		60 DAS	Harvest
	Grass	BLW	Grass	BLW	Grass	BLW	Grass	BLW		
T_1	15.25(11.79)^{a}	11.15^{b}	12.60^{ab}	10.96^{ab}	4.59^{b}	7.03^{b}	7.81^{b}	8.75^{b}	34.34^{e}	43.64^{e}
T_2	14.54(11.22)^{a}	10.66^{bc}	12.00^{abc}	10.28^{b}	4.13^{bc}	6.38^{bc}	6.99^{bc}	8.13^{bc}	46.46^{de}	52.88^{de}
T_3	13.65(10.57)^{a}	10.23^{bcd}	11.31^{bc}	9.72^{bc}	3.51^{cde}	5.88^{bc}	6.50^{cd}	7.38^{cd}	55.64^{cd}	60.40^{cd}
T_4	11.81(9.12)^{a}	9.43^{bcd}	10.44^{cd}	9.47^{bc}	3.18^{de}	5.23^{c}	5.73^{de}	6.90^{de}	64.63^{c}	66.70^{bc}
T_5	10.56(8.15)^{ab}	8.63^{d}	9.44^{de}	9.29^{bc}	2.73^{e}	3.58^{d}	4.88^{ef}	5.81^{ef}	81.12^{b}	76.29^{b}
T_6	14.60(11.29)^{a}	10.71^{bc}	12.08^{abc}	10.34^{ab}	3.67^{cd}	6.14^{bc}	7.05^{bc}	7.85^{bcd}	52.87^{cd}	54.24^{de}
T_7	7.60(5.96)^{ab}	9.12^{cd}	8.12^{e}	8.35^{c}	2.68^{e}	3.28^{d}	4.61^{f}	5.57^{f}	82.85^{b}	77.78^{b}
T_8	0.92(0.71)^{b}	0.71^{f}	0.71^{f}	0.71^{d}	0.71^{f}	0.71^{e}	0.71^{g}	0.71^{g}	100.08^{a}	100^{a}
T_9	16.19(12.52)^{a}	13.82^{a}	13.37^{a}	12.1^{a}	6.53^{a}	8.29^{a}	11.37^{a}	10.89^{a}	00^{f}	00^{f}
CV(%)	8.56(10.37)	9.67	9.46	10.37	12.90	12.59	8.83	8.94	11.29	10.83
SE	0.58(0.54)	0.52	0.55	0.54	0.26	0.38	0.32	0.36	3.75	3.70

*According to Tukey's HSD test (with p = 0.05), means having the same letter does not differ significantly.

**From Bartlett's test of homogeneity of variances, it is observed that error variances across years are not homogenous. So, Aitken's transformation is applied for performing combined analysis of variance. (Figures in parentheses are parameters of original value).

height and LAI (Table 2), primarily due to their effectiveness in reducing weed density and suppressing weed growth compared to the unweeded control (T_9). Among the treatments, the tallest plants were observed in the plots treated with topramezone 25 g ha^{-1} (T_5) and pendimethalin 750 g ha^{-1} (T_7), which showed identical plant heights both at 60 DAS and harvest. T_4 (topramezone 22.5 g ha^{-1} as POE) also resulted in relatively tall plants, though slightly shorter than T_5 and T_7. These outcomes echo the findings of Nath *et al*. (2018). A similar trend was observed in the leaf area index (LAI), where treatments T_5 and T_7 exhibited the highest LAI values at both 60 DAS and 90 DAS, indicating a consistent positive effect of these herbicides on plant canopy development.

Effect on yield parameters and yield

The highest number of pods per plant (Table 3) was observed in treatments receiving topramezone 25 g ha^{-1} (T_5) and pendimethalin 750 g ha^{-1} as PE (T_7) among the herbicidal treatments. Additionally, the highest number of seeds per pod was recorded in treatments T_4 (topramezone 22.5 g ha^{-1} as POE), T_5 and T_7. Regarding 100-seed weight, treatment T_9 (unweeded control), the lowest, was significantly different from all other treatments; notably, the other treatments, including T_8 (weed free), were at par.

The lowest seed yield measuring 448.46 kg ha^{-1}, was observed in the unweeded control treatment, highlighting the detrimental impact of uncontrolled weed growth on crop productivity. In contrast, the highest seed yield was recorded in the weed free treatment, with a yield of 1567.57 kg ha^{-1}. This yield was not significantly different from the yield obtained under the herbicide treatment T_5 (topramezone 25 g ha^{-1}), which produced 1402.58 kg ha^{-1}, demonstrating its effectiveness in weed management. Similar findings have been reported by Banjara *et al*., 2022. The highest harvest index (HI), a measure of the efficiency with which plants convert dry matter into economic yield, was observed in the herbicide treatments T_5 and T_7, indicating their superior performance in enhancing crop yield. Patel *et al*. (2022) also reported similar observations.

Table 2: Effect of treatments on phytotoxicity, plant height and LAI of chickpea.

Treatment	Phytotoxicity rating scale			Plant height (cm)		LAI	
	7 DAA	21 DAA	35 DAA	60 DAS	Harvest	60 DAS	90 DAS
T_1	0	0	0	11.45(25.38)^{d}	14.01(43.46)^{e}	0.73^{cd}	0.75^{c}
T_2	0	0	0	11.62(25.81)^{cd}	14.39(44.88)^{de}	0.75^{cd}	0.78^{bc}
T_3	0	0	0	12.25(27.80)^{bcd}	14.84(46.51)^{cd}	0.80^{c}	0.81^{bc}
T_4	0	0	0	12.55(28.63)^{abc}	15.41(48.53)^{bc}	0.85^{bc}	0.86^{abc}
T_5	0	0	0	13.03(29.72)^{ab}	15.77(49.98)^{ab}	1.00^{a}	1.02^{ab}
T_6	3	2	1	11.57(25.75)^{cd}	14.36(44.78)^{de}	0.75^{cd}	0.77^{bc}
T_7	0	0	0	12.92(29.35)^{ab}	15.89(50.20)^{ab}	0.99^{a}	1.02^{ab}
T_8	0	0	0	13.46(30.73)^{a}	16.23(51.32)^{a}	1.05^{a}	1.11^{a}
T_9	0	0	0	9.68(21.16)^{e}	12.22(37.52)^{f}	0.62^{d}	0.64^{c}
CV(%)	-	-	-	8.29 (10.19)	6.76(7.92)	9.23	15.92
SE	-	-	-	0.58(1.60)	0.58(2.12)	0.04	0.08

*According to Tukey's HSD test (with p = 0.05), means having the same letter does not differ significantly.

**From Bartlett's test of homogeneity of variances, it is observed that error variances across years are not homogenous. So, Aitken's transformation is applied for performing combined analysis of variance. (Figures in parentheses are parameters of original value).

Note: DAA- Days after application.

Table 3: Effect of treatments on different yield parameters and yield of chickpea.

Treatment	Pods plant^{-1}	Seeds pod^{-1}	100 seed wt (g)	Seed yield (kg ha^{-1})	HI (%)	WI (%)
T_1	17.05^{de}	1.10^{ab}	12.17^{a}	628.29^{ef}	31.29^{cd}	59.13^{b}
T_2	22.06^{c}	1.14^{ab}	12.31^{a}	785.15^{de}	33.25^{bcd}	49.88^{bc}
T_3	24.30^{bc}	1.18^{ab}	12.34^{a}	972.43^{cd}	34.53^{abc}	37.21^{d}
T_4	27.69^{ab}	1.23^{a}	12.52^{a}	1147.93^{bc}	35.33^{ab}	25.99^{e}
T_5	29.74^{a}	1.24^{a}	12.82^{a}	1402.58^{a}	36.37^{ab}	9.82^{fg}
T_6	20.20^{cd}	1.16^{ab}	12.36^{a}	919.53^{cd}	33.26^{bcd}	40.10^{cd}
T_7	29.36^{a}	1.21^{a}	12.83^{a}	1348.47^{ab}	36.26^{ab}	12.26^{f}
T_8	31.89^{a}	1.27^{a}	13.03^{a}	1567.57^{a}	37.47^{a}	00^{g}
T_9	13.66^{e}	1.00^{b}	10.26^{b}	448.46^{f}	30.28^{d}	70.53^{a}
CV(%)	10.12	8.67	7.74	12.42	5.36	18.05
SE	1.40	0.06	0.55	73.49	1.06	3.53

*According to Tukey's HSD test (with p = 0.05), means having the same letter does not differ significantly.

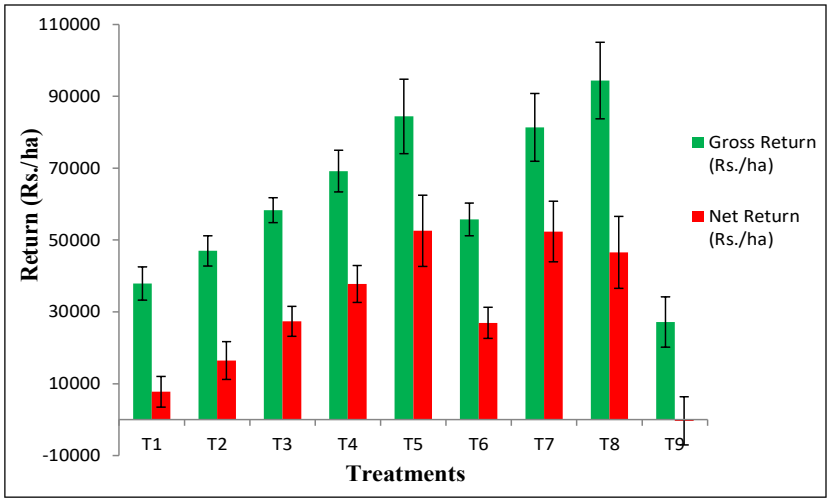


Fig 1: Effect of treatments on gross and net return from the treatments.

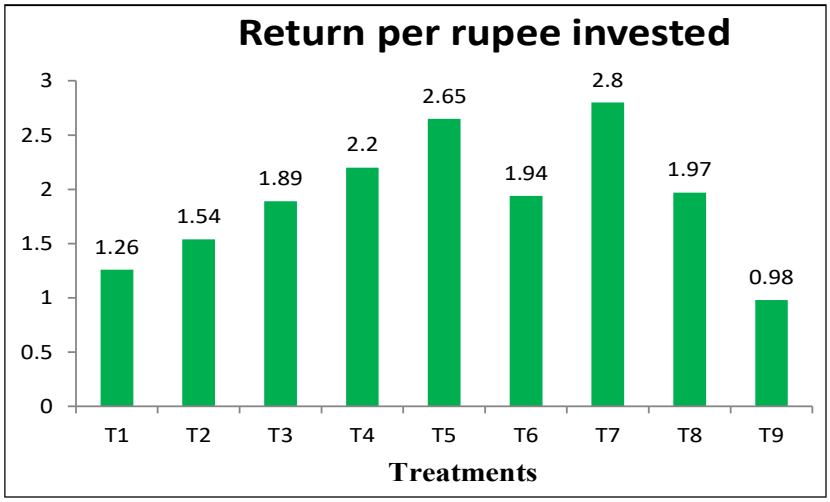


Fig 2: Effect of treatments on return per rupee invested from the treatments.

The unweeded control recorded the highest weed index (70.53%), reflecting the severe weed infestation in this treatment, which ultimately led to a substantial reduction in seed yield compared to the weed free treatment (T_8). These results agree with the findings of Patel *et al*. (2024). Among the herbicidal treatments, topramezone 25 g ha^{-1} as POE emerged as the most effective herbicide, with a relatively low weed index of 9.82%, underscoring its potential as the best herbicidal option for managing weeds and optimizing yield. Similar results were obtained by Kumari *et al*. (2021).

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The highest gross return was observed under weed free conditions (T_8) and with topramezone 25 g ha^{-1} as post-emergence (POE) treatment (T_5), both showing similar results. They were followed by pendimethalin 750 g ha^{-1} as pre-emergence (PE) treatment (T_7), which also performed well in terms of gross return (Fig 1). However, for net return, T_5 was the most profitable, followed by T_7 and T_8. In terms of return per rupee invested (RRI), both T_5 and T_7 showed the highest efficiency, with RRI values of 2.65 and 2.80 (Fig 2), respectively, indicating the best return on investment. In contrast, the unweeded control (T_9) had the lowest RRI, emphasizing the economic disadvantage of not controlling weeds. Overall, T_5 and T_7 offered the best balance of returns and investment efficiency.

CONCLUSION

Post-emergence application of topramezone 25 g ha^{-1} at 25 days after sowing significantly reduced the density and dry weight of weeds (grasses and broadleaved weeds) and increased crop growth and productivity than post-emergence application of imazethapyr 60 g ha^{-1} in chickpea. However, it was comparable with pre-emergence application of pendimethalin 750 g ha^{-1}. Topramezone 25 g ha^{-1} registered the lowest weed index and was superior to its

lower doses (from 15 to 22.5 g ha^{-1}) in recording higher weed control efficiency, crop growth and productivity. Hence, topramezone 25 g ha^{-1} at 25 days after sowing can be recommended as a post-emergence herbicide for effective weed management in chickpea resulting higher growth and productivity of the crop under laterite belt of West Bengal.

Conflict of interest

The authors declare that there are no conflicts of interest regarding authorship and/or publication of this article.

REFERENCES

Anonymous, (2016). Foundation for Agrarian Studies. https://fas.org.in/pulse-consumption-in-india.

Anonymous, (2020). Agricultural statistics at a glance. Directorate of Economics and Statistics. 81.

Anonymous, (2022). Project Coordinator's Report of All India Coordinated Research Project on Chickpea, ICAR-Indian Institute of Pulses Research, Kanpur.

Anonymous, (2023a). Indiastat.com. https://www.indiastat.com/table/agriculture/selected-state-season-wise-area-production-product/775293.

Anonymous, (2023b). Economic Survey of India. Ministry of Finance, Government of India.

Anonymous, (2023c). Indiastat.com. https://www.indiastat.com/table/agriculture/selected-state-wise-area-production-productivity-g/1456848.

Banjara, G.P., Porte, P. and Bhumika, B. (2022). Impact of different broad spectrum herbicides on yield and economics of chickpea crop (*Cicer arietinum* L.). *The Pharma Innovation Journal.* **11(11):** 617-620.

Bhosale, N., Jadhav, K., Choudhari, B., Shinde, L. and Bhosale, A. (2023). Studies on economics of various herbicides for controlling weeds in chickpea (*Cicer arietinum* L.). *The Pharma Innovation Journal.* **12(8):** 2461-2464.

Dubey, S.K., Kumar, A., Singh, D., Pratap, T. and Chaurasiya, A. (2018). Effect of different weed control measures on performance of chickpea under irrigated condition. *International Journal of Current Microbiology and Applied Sciences*. **7(5):** 3103-3111.

Gajanand, Kumar, S., Kumar, M., Birla, D., Choudhary, S. and Singh, D. (2023). Evaluation of dose and application time of topramezone for weed management in chickpea. *Indian Journal of Weed Science*. **55(3):** 324-327.

Hedayetullah, M. and Kumar, N. (2023). Bio-efficacy of different POE herbicides for broad spectrum weeds management in chickpea (*Cicer arietinum* L.). *Journal of Food Legumes*. **36(1):** 43-46.

Jukanti, A.K., Gaur, P.M., Gowda, C.L.L. and Chibbar, R.N. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. *British Journal of Nutrition.* **108(S1):** S11-S26.

Kumari, S., Kumar, B., Seema, K.L. and Kumar, D. (2021). Investigation on efficacy of pre and post emergence herbicides of chickpea (*Cicer arietinum*): Productivity, weed dynamics and economics. *The Pharma Innovation Journal.* **10(9):** 622-626.

Marioli Nobile, C.G., Carreras, J., Grosso, R., Inga, C.M., Silva, M.P., Aguilar, R. and Martinez, M. J. (2013). Proximate composition and seed lipid components of "kabuli"- type chickpea (*Cicer arietinum* L.) from Argentina. *Agricultural Sciences.* **4(12):** 729-737.

Mukherjee, D. (2007). Techniques of weed management in chickpea-A review. *Agricultural Reviews*. **28(1):** 34-41.

Murugananthi, D., Shivakumar, K.M., Palanichamy, N.V., Prabha, S.A., Somasundaram, E., Rohini, A., Devi, R.P., Selvanayaki, S. and Kavitha, P.G. (2024). Demand and supply projections for pulses in India. *Legume Research*. doi: 10.18805/LR-5346.

Nath, C.P., Dubey, R.P., Sharma, A.R., Hazra, K.K., Kumar, N. and Singh, S.S. (2018). Evaluation of new generation post-emergence herbicides in chickpea (*Cicer arietinum* L.). *National Academy Science Letters.* **41(1):** 1-5.

Nath, C.P., Kumar, N., Hazra, K.K., Praharaj, C.S., Singh, S.S., Dubey, R.P. and Sharma, A.R. (2021). Topramezone: A selective post-emergence herbicide in chickpea for higher weed control efficiency and crop productivity. *Crop Protection.* **150:** 105-814.

Patel, A., Banjara, G., Shrivastava, G., Rathore, S., Shekhawat, K., Painkara, S.K. and Mishra, R.K. (2024). Chemical weed management in chickpea (*Cicer arietinum* L.) under vertisols of eastern plateau plain zone of India. *Indian Journal of Agronomy.* **69(2):** 166-171.

Patel, D., Tiwari, N., Savu, R. M. and Rajwade, O. (2022). Effect of pre and post emergence herbicides on yield and economics of chickpea (*Cicer arietinum* L.). *The Pharma Innovation Journal.* **11(9):** 1754-1757.

Rashid, A., Khan, R. and Marwat, S. (2019). Importance of weed control in chickpea under rainfed condition. *American-Eurasian Journal of Agriculture and Environment Science.* **5(4):** 456-459.

Ratnam, M., Rao, A.S. and Reddy, T.Y. (2011). Integrated weed management in chickpea (*Cicer arietinum* L.). *Indian Journal of Weed Science*. **43(2):** 70-72.

Sanketh, G.D., Rekha, K.B., Shekhawat, K., Chaithanya, Y., Ramprakash, T. and Sudhakar, K.S. (2023). Elucidating the impact of new-generation herbicides on productivity and phytotoxicity on chickpea (*Cicer arietinum*) and their residual effects. *Indian Journal of Agricultural Sciences.* **93(10):** 1149-1152.

Schonhammer, A., Koch, H. and Freitag, J. (2006). Topramazone-A new highly selective herbicide compound for control of warm season grasses and dicotyledoneous weeds in maize. *Journal of Plant Diseases and Protection.* **20(2):** 1023-1031.

Wolf, J.K. and Rust, M.C. (2005). Topramezone Herbicide. Tier II drinking water assessment. US Environmental Protection Agency.