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EFFECT OF POST-EMERGENCE HERBICIDES ON WEED DYNAMICS, GROWTH, YIELD AND ECONOMICS OF CLUSTERBEAN (*Cyamopsis tetragonoloba* L.)

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ABSTRACT

A field experiment entitled "Effect of Post-Emergence Herbicides on Growth and Yield of Clusterbean (*Cyamopsis tetragonoloba* L.)" was conducted during the *kharif* seasons of 2023 and 2024 at the Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur, Rajasthan, to evaluate the efficacy of post-emergence herbicides for weed management in clusterbean. The experiment comprised eight treatments arranged in a randomized block design with three replications. The pooled analysis of two years revealed that post-emergence application of Imazethapyr + Imazamox @ 75 g ha^{-1} (T_4) at 15-20 days after sowing was the most effective treatment. It recorded the lowest weed density (7.18 m^{-2}), the highest weed control efficiency (91.80%), and the lowest weed index (8.09%). The same treatment also produced significantly higher grain yield (1333 kg ha^{-1}) and straw yield (2102 kg ha^{-1}) than the control. Moreover, T_4 registered the maximum net returns (Rs. 57,533 ha^{-1}) and benefit ratio (3.29), indicating its superior economic viability of treatment T_4 (Imazethapyr + Imazamox @ 75 g ha^{-1}). Similar trends were observed during both individual years of experimentation.
Keywords **:** Clusterbean, imazethapyr, imazethapyr + imazamox, post-emergence herbicidal control, Weed control efficiency, Weed Index.

Introduction

Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.), commonly known as guar, is an important annual leguminous crop well adapted to the hot arid and semi-arid regions of India, particularly Rajasthan (Choudhary *et al.*, 2025). The crop is valued for its multiple uses as a vegetable, fodder, green manure, and seed crop. Among its various products, guar gum extracted from the endosperm of the seed has immense commercial significance due to its high galactomannan content (Verma *et al.*, 2026). Guar gum is extensively utilized in food processing, pharmaceuticals, textiles, cosmetics, paper manufacturing, mining, and petroleum industries because of its superior thickening, stabilizing, and emulsifying properties (Kumar *et al.*, 2013). India is the world's largest producer and exporter of clusterbean, contributing a major share of global guar production, with Rajasthan accounting for the largest cultivated area owing to its favourable agro-climatic conditions and vast rainfed tracts (Kumar *et al.*, 2026). Despite its considerable economic and industrial importance, the productivity of clusterbean remains relatively low. This is primarily attributed to its cultivation under rainfed conditions, where erratic rainfall, poor soil fertility, and inadequate crop management practices adversely affect crop performance. Adoption of improved agronomic practices has been reported to significantly enhance the growth, productivity, and profitability of clusterbean cultivation (Choudhary *et al.*, 2026).

Among the various production constraints, weed infestation is recognized as one of the most serious factors limiting clusterbean productivity. The crop exhibits slow initial growth and poor canopy development during the early stages, allowing weeds to emerge and establish rapidly. These weeds compete aggressively with the crop for moisture, nutrients, light, and space during the critical period of crop-weed competition, resulting in substantial reductions in plant growth, yield attributes, and seed yield (More *et al*., 2026). Yield losses due to unchecked weed infestation have been reported to be considerable, particularly under rainfed conditions where soil moisture is often the most limiting factor. Although manual weeding remains an effective method of weed control, its dependence on timely labour availability and increasing labour costs have reduced its practicality and economic viability (Maity *et al*., 2026). Consequently, chemical weed management has emerged as a reliable and cost-effective alternative for ensuring timely weed control. Post-emergence herbicides have become an integral component of modern integrated weed management strategies because they effectively suppress weeds after crop establishment while minimizing crop-weed competition during the critical growth stages. Appropriate post-emergence herbicides not only provide broad-spectrum weed control but also improve nutrient and moisture availability to the crop, resulting in enhanced growth, higher yield attributes, increased seed yield, and superior economic returns. Several researchers have reported the effectiveness of different post-emergence herbicides in improving weed control efficiency, reducing weed biomass, and increasing the productivity and profitability of clusterbean under diverse agro-climatic conditions (Choudhary *et al*., 2006; Dhaker *et al*., 2009; Yadav *et al*., 2011). Nevertheless, the performance of post-emergence herbicides is influenced by several factors, including the composition of weed flora, herbicide spectrum, application timing, prevailing environmental conditions, and herbicide combinations. Variations in these factors often result in differences in weed control efficiency and crop response across locations and seasons. Therefore, systematic evaluation of suitable post-emergence herbicides under local agro-climatic conditions is essential for identifying effective, economical, and environmentally sustainable weed management practices. Keeping these considerations in view, the present investigation was undertaken to evaluate the effect of different post-emergence herbicides on weed dynamics, crop growth, yield attributes, yield, and economics of clusterbean under the semi-arid conditions of Rajasthan.

Material and Methods

The field investigation entitled *"Effect of Post-Emergence Herbicides on Weed Dynamics, Growth, Yield and Economics of* Clusterbean *(Cyamopsis tetragonoloba* (L.) Taub.)*"* was conducted during the *Kharif* seasons of 2023 and 2024 at the Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur, Rajasthan, India. The experimental farm is situated at 26°84′ N latitude and 75.81° E longitude, at an altitude of 390 m above mean sea level (MSL), and falls under the semi-arid eastern plain agro-climatic zone of Rajasthan. The region is characterized by hot summers, low and erratic rainfall, and mild winters, making it representative of the rainfed clusterbean-growing areas of the state.

The experimental field possessed a sandy loam soil texture with a slightly alkaline reaction, having a soil pH ranging from 7.82 to 7.88. The soil was low in organic carbon (0.16-0.29%) and available nitrogen (115-119 kg ha^{-1}), while it contained medium levels of available phosphorus (38-80 kg P_2O_5 ha^{-1}) and available potassium (170-280 kg K_2O ha^{-1}). The initial physico-chemical properties of the experimental soil indicated a moderately fertile condition, which is typical of the cultivated soils of the region. The experiment was laid out in a Randomized Block Design (RBD) comprising eight weed management treatments with three replications. The treatments consisted of T_1: Unweeded check, T_2: Weed-free, T_3: Imazethapyr 10% SL @ 100 g ha^{-1}, T_4: Imazethapyr + Imazamox @ 75 g ha^{-1}, T_5: Propaquizafop 2.5% + Imazethapyr 3.75% ME @ 33.3 + 50 g ha^{-1}, T_6: Acifluorfen sodium 16.5% EC + Clodinafop-propargyl 8% EC @ 750 ml ha^{-1}, T_7: Acifluorfen sodium 16.5% EC + Clodinafop-propargyl 8% EC @ 1000 ml ha^{-1} and T_8: Fomesafen 11.1% + Fluazifop-p-butyl 11.1% SL @ 220 g ha^{-1}. All herbicidal treatments were applied as post-emergence sprays at 15-20 days after sowing (DAS) using a knapsack sprayer fitted with a flat-fan nozzle to ensure uniform coverage of the crop and weed canopy. All recommended agronomic practices for clusterbean cultivation, including land preparation, sowing, fertilizer application, irrigation, and plant protection measures, were followed uniformly in all the treatments throughout the crop-growing period, except for the weed management practices under investigation. Observations on weed dynamics, growth parameters, yield attributes, seed and haulm yield, and economics were recorded at appropriate crop growth stages following standard experimental procedures. The pooled data of two years were subjected to statistical analysis using the analysis of variance (ANOVA) technique appropriate for the Randomized Block Design, and the significance of treatment differences was tested using the critical difference (CD) test at the 5 per cent level of probability.

Weed control efficiency and weed index is calculated with the help of following formulas

$$\text{WCE}(\%) = \frac{\text{Weed dry matter in weedy check plot} \\ \text{- Weed dry matter in treated plot}}{\text{Weed dry matter in weedy check plot}} \times 100$$

Weed index is a derived parameter to measure crop yield loss accrued across treatments in comparison to a weed free plot and calculated with following formula:-

$$\text{Weed Index} = \frac{\text{Crop yield in weed free plots} \\ \text{- Crop yield in the treated plot}}{\text{Crop yield in weed free plots}} \times 100$$

The economics was calculated as gross income based on prevailing market prices grain and stover and net returns were computed by deducting total cost from gross returns. B:C ratio was calculated for each treatment by dividing net return with cost.

Results and Discussion

Effect on weed dynamics

Post-emergence herbicides exerted a significant influence on weed density, weed dry matter accumulation, weed control efficiency (WCE) and weed index of clusterbean. The weed-free treatment (T_2) effectively eliminated weed infestation throughout the crop growth period and consequently recorded zero weed density, the highest weed control efficiency (99.52%) and a weed index of zero. Among the herbicidal treatments, T_4 [imazethapyr + imazamox @ 75 g ha^{-1}] proved to be the most effective, recording the lowest weed density (7.18 weeds m^{-2}), minimum weed dry matter accumulation (83.02 g m^{-2}), highest weed control efficiency (91.80%) and the lowest weed index (8.18%). Treatment T_5 [propaquizafop 2.5% + imazethapyr 3.75% ME @ 33.3 + 50 g ha^{-1}] ranked next in effectiveness, recording 87.33 per cent weed control efficiency with appreciably lower weed density and dry matter than the remaining herbicidal treatments. In contrast, the unweeded check (T_1) recorded the highest weed density (78.52 weeds m^{-2}), maximum weed dry matter accumulation and the highest weed index (53.50%), reflecting severe weed infestation throughout the crop growth period.

The superior weed suppression observed under T_4 may be attributed to the complementary mode of action of imazethapyr and imazamox, which effectively controlled a broad spectrum of grassy and broad-leaved weeds during the critical period of crop-weed competition. Reduced weed density and biomass minimized competition for moisture, nutrients, light and space, thereby improving crop vigour and resource-use efficiency. The comparatively lower weed control efficiency under the remaining herbicidal treatments could be attributed to their relatively narrow weed control spectrum or lower effectiveness against the prevailing weed flora. Similar findings were reported by Yadav *et al.* (2021), who observed significantly lower weed density and higher weed control efficiency with imazethapyr + imazamox and pendimethalin + imazethapyr in clusterbean. Jain and Jain (2025) also reported that propaquizafop + imazethapyr provided superior weed control efficiency and significantly reduced weed biomass compared with other post-emergence herbicides. Earlier, Yadav *et al.* (2011) and Kaur *et al*. (2026) reported that imazethapyr, either alone or integrated with hand weeding, effectively minimized weed dry matter accumulation and enhanced weed control efficiency under rainfed clusterbean conditions.

Effect on growth and yield attributes

Growth and yield attributes of clusterbean were significantly influenced by different post-emergence herbicide treatments. The weed-free treatment (T_2) recorded the tallest plants (96.80 cm), reflecting complete elimination of crop-weed competition throughout the growing season. Among the herbicidal treatments, T_4 produced significantly taller plants (92.62 cm), which remained statistically at par with the weed-free treatment. The same treatment also recorded the highest number of branches per plant (9.51), maximum number of pods per plant (73.04) and the highest harvest index (37.26%) among all herbicidal treatments. In contrast, the unweeded check (T_1) registered the lowest values for all growth and yield attributes owing to severe and prolonged weed competition during the critical stages of crop growth.

The marked improvement in growth parameters under T_4 was primarily due to efficient weed suppression, which enhanced the availability of essential growth resources, including soil moisture, nutrients, sunlight and growing space. Reduced competition during the early stages of crop development promoted better vegetative growth, improved photosynthetic activity and greater assimilate production, resulting in increased branching, pod formation and partitioning of dry matter towards economic yield. Similar results were reported by Jain and Jain (2025), who observed significant improvements in plant height, number of branches and pods per plant with propaquizafop + imazethapyr over other herbicidal treatments. Likewise, Yadav *et al.* (2021) reported significantly higher numbers of pods per plant and seeds per pod under imazethapyr + imazamox and pendimethalin + imazethapyr owing to effective weed management. Earlier, Yadav *et al.* (2011) and Kaur *et al*. (2026) also observed that imazethapyr integrated with hand weeding significantly improved crop growth, nutrient uptake and yield-contributing characters in clusterbean.

Effect on Grain and Straw Yield

Grain yield and straw yield of clusterbean were significantly influenced by the different post-emergence herbicide treatments, highlighting the importance of effective weed management in realizing the productive potential of the crop. Timely suppression of weeds during the critical crop-weed competition period minimized competition for nutrients, moisture, light, and space, thereby creating favourable conditions for crop growth, dry matter accumulation, and reproductive development. As a result, herbicide-treated plots produced substantially higher grain and straw yields than the unweeded control.

The weed-free treatment (T_2) recorded the highest grain yield (1398 kg ha^{-1}) and straw yield (2361.5 kg ha^{-1}), reflecting the complete elimination of weed competition throughout the crop growth period. Among the herbicidal treatments, Imazethapyr + Imazamox @ 75 g ha^{-1} (T_4) produced the highest grain yield (1333 kg ha^{-1}) and straw yield (2102 kg ha^{-1}), remaining statistically comparable with the weed-free treatment. This treatment was followed by Propaquizafop + Imazethapyr (T_5), which also recorded appreciably higher grain (1208 kg ha^{-1}) and straw yield (1981.5 kg ha^{-1}) than the remaining herbicidal treatments. In contrast, the unweeded control (T_1) registered the lowest grain yield (648 kg ha^{-1}) and straw yield (972.5 kg ha^{-1}), indicating severe yield reduction due to uncontrolled weed infestation. The higher grain and straw yields obtained under T_4 can be attributed to its superior weed control efficiency, which effectively reduced weed density and weed biomass during the early growth stages of clusterbean. Efficient suppression of both grassy and broad-leaved weeds ensured greater availability of soil moisture, nutrients, and solar radiation, resulting in enhanced photosynthetic efficiency, greater dry matter production, and improved translocation of assimilates towards reproductive organs (Choudhary *et al.*, 2026). The increase in grain yield was associated with better reproductive development, while the higher straw yield reflected enhanced vegetative growth resulting from reduced crop stress throughout the growing season. Conversely, poor yields under the unweeded control were primarily due to intense crop-weed competition, which restricted nutrient uptake, depleted soil moisture, intercepted incoming light, and reduced photosynthetic activity. Continuous competition during the critical stages of crop growth adversely affected biomass accumulation, flower retention, pod development, and seed filling, ultimately resulting in substantial reductions in both grain and straw yield. The findings clearly demonstrate that uncontrolled weed growth remains one of the major constraints limiting the productivity of clusterbean under semi-arid conditions (Kumar *et al.*, 2023).

The superior performance of Imazethapyr + Imazamox may also be attributed to its broad-spectrum herbicidal activity through inhibition of the acetolactate synthase (ALS) enzyme, leading to effective suppression of susceptible weed species soon after application. The resultant weed-free environment improved crop vigour, nutrient-use efficiency, and physiological efficiency, thereby maximizing biomass production and economic yield. These findings are in close agreement with those of Yadav *et al.* (2021), who reported significantly higher seed yield under post-emergence application of imazethapyr + imazamox owing to efficient weed control and improved crop growth. Jain and Jain (2025) similarly observed that propaquizafop + imazethapyr significantly enhanced seed yield by minimizing weed competition throughout the crop growth period. Earlier, Yadav *et al*. (2011) and Ghosh *et al.* (2022) also reported that effective post-emergence weed management substantially increased seed and straw yields through improved nutrient uptake and greater resource-use efficiency under rainfed clusterbean cultivation. The present study confirms that effective post-emergence herbicide application, particularly Imazethapyr + Imazamox @ 75 g ha^{-1}, is an efficient strategy for enhancing the productivity of clusterbean by minimizing weed interference and improving crop resource utilization

Effect on Economics

The economic analysis revealed that weed management practices exerted a significant influence on the profitability of clusterbean cultivation by affecting both crop yield and the cost of weed control. Although complete weed removal maximized crop productivity, the associated labour requirement substantially increased the cost of cultivation. Consequently, herbicide-based weed management emerged as a more economically viable alternative by providing effective weed control with lower input costs and higher net returns.

The weed-free treatment (T_2) recorded the highest gross returns (Rs. 87,113 ha^{-1}) owing to its maximum grain and straw yields. However, the higher expenditure incurred on repeated manual weeding reduced its overall economic efficiency. Among the herbicidal treatments, Imazethapyr + Imazamox @ 75 g ha^{-1} (T_4) proved to be the most profitable, registering the highest net returns (Rs. 57,533 ha^{-1}) and benefit:cost ratio (3.29). This treatment was followed by Propaquizafop + Imazethapyr (T_5), which also recorded favourable economic returns with a benefit:cost ratio of 3.09. In contrast, the unweeded control (T_1) resulted in the lowest economic returns due to severe yield losses caused by uncontrolled weed infestation. The superior economic performance of T_4 can be attributed to its excellent weed control efficiency, which effectively minimized crop-weed competition and substantially increased grain and straw yields without incurring the high labour costs associated with manual weed management. The broad-spectrum activity of imazethapyr + imazamox ensured effective suppression of both grassy and broad-leaved weeds during the critical crop growth period, resulting in improved resource-use efficiency, enhanced crop productivity, and ultimately higher profitability. The lower cost of herbicide application relative to repeated hand weeding further contributed to increased net returns and a superior benefit : cost ratio.

Conversely, despite recording the highest biological and economic yields, the weed-free treatment generated comparatively lower net returns than T_4 because of the substantially higher labour requirement for maintaining weed-free conditions throughout the crop season. This finding highlights that maximum yield does not necessarily translate into maximum profit, emphasizing the importance of considering both productivity and production costs while selecting weed management practices. The poor economic performance of the unweeded control was primarily a consequence of severe weed competition, which significantly reduced grain and straw yields, thereby lowering gross returns and overall profitability (Sepat *et al*., 2017). These results clearly demonstrate that failure to control weeds not only decreases crop productivity but also adversely affects farm income.

The present findings are in close agreement with those of Yadav *et al*. (2021), who reported significantly higher net returns and B:C ratio with post-emergence application of imazethapyr + imazamox due to superior weed control and increased seed yield. Jain and Jain (2025) also observed that propaquizafop + imazethapyr produced higher profitability than other herbicidal treatments because of its effective weed suppression and lower weed management cost. Earlier, Yadav *et al*. (2011) and Kaur *et al*. (2025) reported that effective post-emergence weed control significantly improved economic returns by increasing crop productivity while reducing losses caused by weed competition. Therefore, the present investigation clearly establishes that post-emergence application of Imazethapyr + Imazamox @ 75 g ha^{-1} is not only an effective weed management strategy but also the most economically viable option for clusterbean cultivation under the semi-arid conditions of Rajasthan.

Conclusion

The present investigation demonstrated that post-emergence herbicides significantly improved weed management, crop growth, productivity and profitability of clusterbean compared with the untreated control. Among the evaluated treatments, T_4 proved to be the most effective herbicidal treatment, recording the lowest weed density (7.18 weeds m^{-2}), highest weed control efficiency (91.80%), minimum weed index (8.18%), significantly higher growth attributes, grain yield (1333 kg ha^{-1}), stover yield (2102 kg ha^{-1}), maximum net returns (57,533 ha^{-1}) and the highest benefit:cost ratio (3.29). Although the weed-free treatment (T_2) produced the highest grain and stover yields, it involved higher cultivation costs and was therefore less economical than T_4. The superior performance of T_4 may be attributed to its effective suppression of both grassy and broad-leaved weeds during the critical crop-weed competition period, resulting in improved resource utilization and enhanced crop productivity.

Table 1 : Effect of post emergence herbicides weed dynamics & dry matter of Cluster bean (Two year pooled data)

Treatments	Weed density/weed sq. meter	Weed Control Efficiency (%)	Weed Index (%)	Dry matter accumulation (g/m^2)
T_1	78.52	0.00	53.50	62.65
T_2	**0.00**	**99.52**	0.00	**87.37**
T_3	12.07	84.64	21.26	78.29
T_4	**7.18**	91.80	**8.18**	**83.02**
T_5	10.00	87.33	13.63	81.20
T_6	15.64	79.99	37.76	77.13

T_7	15.97	79.56	44.03	76.64
T_8	19.39	73.10	41.72	76.01
S.E.(m)±	1.18	-	-	3.87
CD 5%	3.57	-	-	11.74
CV	10.28	-	-	8.62

Table 2: Effect of post emergence herbicides on yield attributes & Harvest index of Clusterbean (Two year pooled data)

Treatments	Plant height (cm)	No branches/ per plant	No of pods /per plant	Harvest index (%)
T_1	**69.85**	**6.10**	**54.99**	**24.47**
T_2	96.80	9.38	73.96	31.56
T_3	86.06	8.57	67.06	33.92
T_4	**92.62**	**9.51**	**73.04**	**37.26**
T_5	83.18	8.13	63.16	32.37
T_6	81.30	7.88	62.52	32.34
T_7	78.81	7.59	57.23	28.56
T_8	78.12	7.28	58.11	28.04
S.E.(m)±	3.59	0.37	2.71	1.54
CD 5%	10.89	1.10	8.21	4.7
CV	7.59	7.85	8.19	8.64

Table 2 : Effect of post emergence herbicides on Grain yield, Stover yield & B:C ratio of Clusterbean (Two year pooled data)

Treatments	Grain yield (kg/ha)	Stover yield (kg/ha)	Gross returns (Rs./ha^{-1})	Net returns (Rs./ha^{-1})	B:C ratio
T_1	648	972.50	40194	17354	1.76
T_2	1398	2361.50	87113	49223	2.30
T_3	1101	1685.00	68116	43996	2.83
T_4	**1333**	**2102.00**	**82658**	**57533**	**3.29**
T_5	1208	1981.50	75018	50728	3.09
T_6	870	1481.50	54379	30415	2.27
T_7	783	1537.00	49544	25205	2.04
T_8	813	1416.50	50977	26342	2.07
S.E.(m)±	59.21	127.22	-		
CD 5%	179.56	385.82			
CV	10.06	13.02			

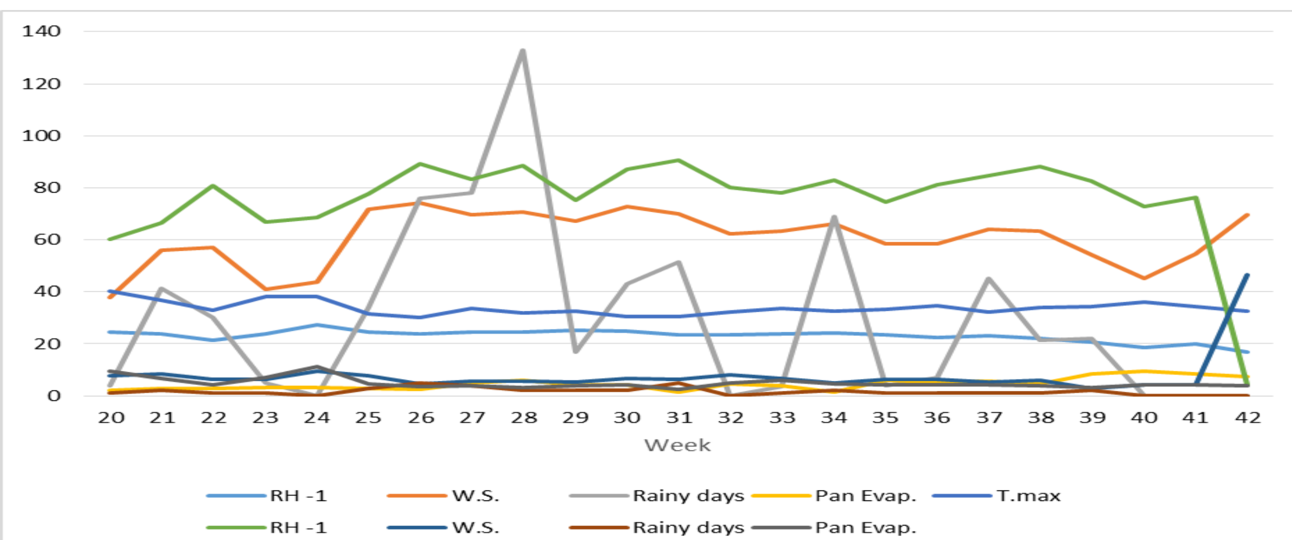

Fig. 1: Weekly weather data for *kharif* season (2023) at RARI, Durgapura, Jaipur, Rajasthan.

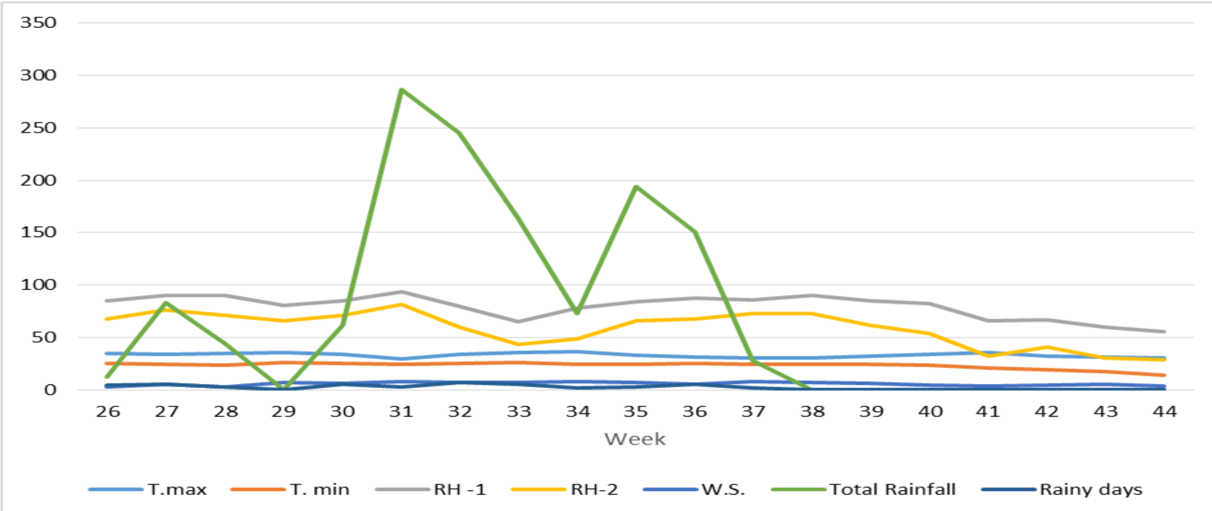

Fig. 2 : Weekly weather data for *kharif* season (2024) at RARI, Durgapura, Jaipur, Rajasthan.

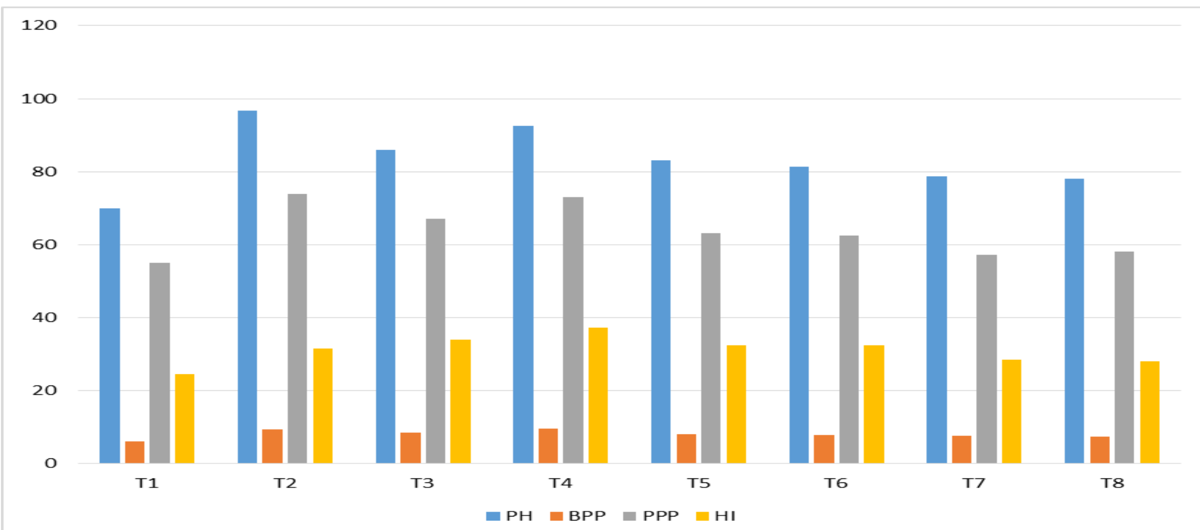

Fig. 3 : Effect of post emergence herbicides on yield attributes & Harvest index of Clusterbean (Two year pooled data)

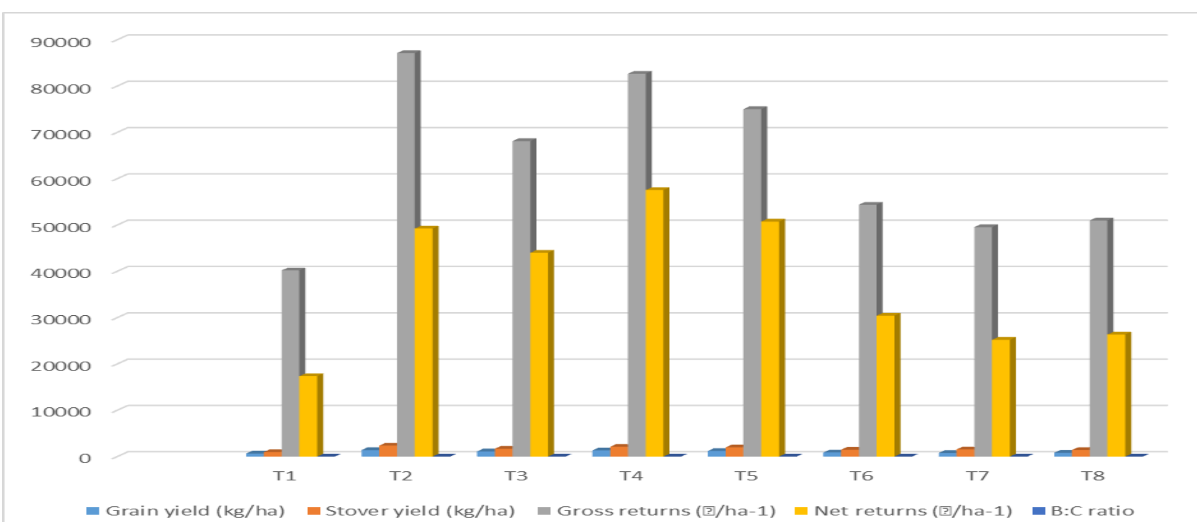

Fig. 4 : Effect of post emergence herbicides on grain yield, stover yield & B:C ratio of clusterbean (Two year pooled data)

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