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Bio-efficacy of Post Emergence Broad Spectrum Herbicides on Weed Dynamics and Productivity of Horsegram

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Abstract

A field experiment was conducted at ARS Anathapuramu under AICRP on Arid Legumes entitled 'Bio-efficacy of post-emergence broad spectrum herbicides on weed dynamics and productivity of horsegram (*Macrotyloma uniflorum* L.)' during *kharif* 2023. The experiment was laid out in Randomized Block Design replicated thrice with eight treatments which include six herbicide treatments, (Imazethapyr + imazamox @ 50 g/ha Imazethapyr + imazamox @ 75 g/ha, Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha, Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha, Clodin of oppropargy l 8% + aciflourfen sodium 16.5 @ 500 ml /ha, Clodinofoppropargy l 8% + aciflourfen sodium 16.5 @ 750 ml / ha), Hand weeding at 15-20 DAS and 35-40 DAS, Weedy check and ATPHG 11 is taken as test variety. Major weeds observed were *Celosia argentia* and *Murdannia nudiflora* among Broad Leaved Weeds; *Rottbellia cochinchinensis and Digitaria sanguinalis* among grasses. The results revealed that hand weeding twice at 15-20 DAS and 35-40 DAS recorded significantly higher seed yield (1153 kg/ha) and bhusa yield (2467 kg/ha) and was statistically comparable to the post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha (1140 kg/ha seed yield and 2333 kg/ha bhusa yield) and 1000 ml/ha (1075 kg/ha seed yield and 2237 kg/ha bhusa yield). However, post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha recorded higher net returns (22265 Rs./ha) and B:C ratio (2.84).

Keywords : Horsegram, Hand weeding, Propaquizafop, Imazethapyr, Yield

Pulses has high protein and amino acids because of which they are playing a very important role in Indian diet mainly to vegetarians. The per capita recommendation of pulses is 60 g day^{-1} as per FAO and WHO, but the availability is 42 g day^{-1} (Rajesh Naik *et al*., 2022). The productivity of pulses has increased by 13 per cent to reach 841 kg ha^{-1} during 2017- 18 from the level of 743 kg ha^{-1} during 2014-15. The production growth has been 43 per cent (Anonymous, 2018). Horsegram is originated from India and considered to be one of the most important legume crop in India. It is being extensively cultivated in Andhra Pradesh, Tamil Nadu and Karnataka. Horsegram is well known for its diverse usage as food, feed, fodder and green manure crop. In India horsegram is being grown in an area of about 5.07 lakh ha with production and with productivity of 2.62 lakh tonnesand 516 kg/ha, respectively (https://iipr.icar.gov.in/horsegram). Horse gram is an excellent source of protein (17.9-25.3%), carbohydrates (51.9-60.9%), essential amino acids, energy, low content of lipid (0.58-2.06%), iron, phosphorus, iron and vitamins such as carotene, thiamine, riboflavin, niacin and vitamin (https://iipr.icar.gov.in/horsegram).

Horsegram subjected to weed competition during critical stages of growth leads to reduction in yields. Eventhough, it is a smothering crop there is need to reduce crop weed competition during early stages until the crop establishment. However, manual weeding is the only way farmers are practicing which is very costly and labour intensive. Migration of labour, high labour wages making it very difficult to manage weeds in horsegram. In order to control the weeds effectively with less cost there is need to identify the best post-emergence herbicides. This study was conducted with an objective to study the bio-efficacy and to identify the best herbicide combination to control the weeds effectively in horsegram.

Material and Methods

A field experiment was conducted at Agricultural Research Station, Aanthapuramu under AICRP on Arid legumes during *kharif*, 2023. The experimental site is situated in the Scarce rainfall zone of Andhra Pradesh which is situated between 14.68° N latitude and 77.60° E longitude with an altitude of 335 m above mean sea level. The soil of the experimental site was red sandy loam in its texture. The soil of the site is slightly alkaline in reaction (pH 7.97) with low electrical conductivity (0.07dS m^{-1}) and organic carbon content (0.09%). It has low available nitrogen (212.9 $kgha^{-1}$), phosphorus (12.7 kg ha^{-1}) and medium potassium (294 kg ha^{-1}) and low micronutrients (Copper-0.08 ppm, Manganese-0.59 ppm, iron-0.43 ppm, zinc-0.50 ppm). The experiment was laid out in Randomized Block Design replicated thrice with eight treatments comprised of T1: Imazethapyr + imazamox @ 50 g/ha T2: Imazethapyr + imazamox @ 75 g/ha T3: Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha T4: Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha T5: Clodinofoppropargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha T6: Clodinofoppropargyl 8% + aciflourfen sodium 16.5 @ 750 ml /ha T7: Hand weeding at 15-20 DAS and 35-40 DAS T8: Weedy check. All herbicide treatments were imposed at 15-20 DAS as PoEand hand weeding treatment were imposed as per treatments. ATPHG 11 was taken as test variety. Line sowing was done with 30 cm spacing between rows with tractor drawn seed drill after seed treatment with fungicide. Before sowing crop was supplied with Recommended dose of fertilizers through urea, single super phosphate and Muriate of Potash through broadcastings. During the crop growth period the total rainfall of 284.8 m was recorded with 19 rainy days. Growth and yield parameters like plant height, number of branches/ plant, plant population, number of pods/plant, number of seeds/pod, pod weight, seed weight, pod length were recorded before harvesting. Weed density and weed dry matter were recorded at 60, 75, 90 DAS and harvest in one square meter area. Harvesting was done with sickles to ground level and dried. Threshing was done by trampling with tractor and seed and bhusa yield was recorded separately. Weed Control Efficiency, Weed Index, Harvest Index, Rain Water Use Efficiency, Production Efficiency were calculated by using the specified formulae. Economics were calculated by taking prevailing labour wages and market prices of inputs and outputs into consideration.

Harvest index (%) = Economic yield/ Biological yiel dx100 (Donald, 1962).

Where, Economic yield = Seed yield

Biological yield = Seed yield + bhusa yield

RWUE ($kghamm^{-1}$) = Yield (kg ha^{-1})/ Total water use (mm) (Cheema *et al.,* 1991)

Production efficiency (kg ha^{-1} day^{-1}) = Seed Yield (kg ha^{-1})/ Duration of the crop (days) (Tomar and Tiwari, 1990).

Weed Index (%) = Maximum seed yield -Seed yield from treated plot/ Maximum seed yield x 100 (Gill and Vijaya Kumar, 1966).

Weed Control Efficiency (%) = DWC - DWT/ DWC x 100

Gross return ($Rs.ha^{-1}$) = (Seed yield x price) + (bhusa yield x price)

Net returns ($Rs.ha^{-1}$) = Gross return ($Rs.ha^{-1}$)-Cost of cultivation (Where, WCE = Weed control efficiency

(%) DWC = Dry weight of weeds in weedy check plot (g) DWT = Dry weight of weeds in treated plot (g) (Mani *et al*. 1973) Rs. ha^{-1})

Benefit: cost ratio = Gross returns ($Rs.ha^{-1}$)/ cost of cultivation ($Rs.ha^{-1}$)

The collected data were subjected to statistical analysis using SPSS. Analysis of variance (ANOVA) was performed to determine the significance of treatment effects. Means were compared using the Least Significant Difference (LSD) test at a 5 per cent probability level.

Results and Discussion

Major Weeds Associated with Horsegram

Rottbellia cochinchinensis, Celosia argentea, Andrographis spp., *Cyperus rotundus, Rhyncosia minima, Murdannia nodiflora, Digitaria sanguinalis* were the major weeds associated with horsegram. Fig. 1, clearly shows that most predominant weeds were *Celosia argentea and Murdannia nodiflora* among Broad Leaved Weeds; *Rottbellia cochinchinensis* and *Digitaria sanguinalis* among grasses accounting for 82 per cent of the total weeds observed.

Growth Parameters

The study indicated that hand weeding twice at 15-20 days after sowing (DAS) and 35-40 DAS resulted in significantly higher growth parameters. Specifically, it recorded a plant height of 88.33 cm and an average of 10.7 branches per plant (Table 1). When comparing this with post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% at a rate of 1500 ml/ha at 15-20 DAS and Propaquizafop 2.5% + Imazethapyr 3.75% @ 1000 ml/ha at 15-20 DAS, both treatments were found to be on par with hand weeding twice regarding plant height, which measured 85.0 cm and 81.0 cm respectively. However, the weedy check recorded a significantly lower plant height of 51.67 cm and only 8 branches per plant. The findings from the study highlight the effectiveness of hand weeding and the application of herbicides in promoting better growth parameters in crops. These findings align with the research by Dev *et al.* (2020), which highlights the efficiency of chemical herbicides in controlling a broad spectrum of weeds, leading to enhanced crop growth and yield.

Yield Attributes and Yield

The study shows that different treatments significantly impacted yield and yield attributes, as presented in

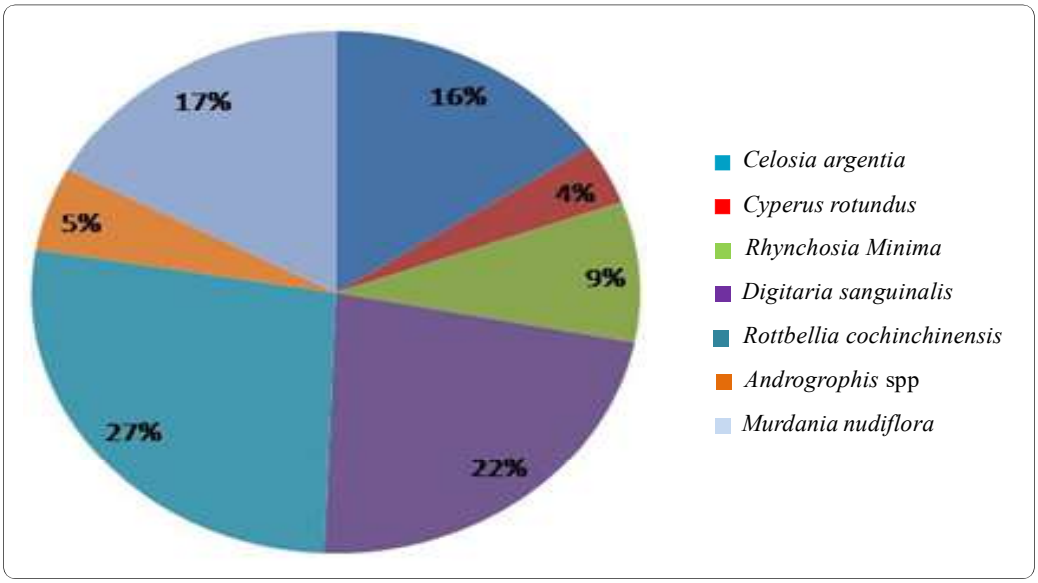

Fig.1. Species wise weed frequency in experimental field (no./sq.m.)

TABLE 1

Effect of broad spectrum post emergence herbicides on growth,yield and yield attributes of horsegram

Treatments	Plant population (No./sq.m)	Plant height (cm)	No. of branches/ plant	Pod length (cm)	No. of seeds/ pod	No. pods/ plant	100 Fresh pod weight (g)	100 dry pod weight (g)	1000 fresh seed weight (g)	1000 dry seed weight (g)	Seed yield (kg/ha)	Bhusa yield (kg/ha)
T1	32.33	78.33	9.3	4.7	5.0	86.33	49.3	22.0	68.4	40.4	803	1564
T2	32.33	79.67	9.3	4.8	5.0	103.00	52.0	22.8	69.2	40.8	1019	1945
T3	33.66	81.00	9.3	4.9	5.0	105.67	52.4	23.0	70.0	42.6	1075	2237
T4	34.33	85.00	10.3	5.0	5.0	112.67	54.6	23.2	72.0	43.0	1140	2333
T5	31.00	66.33	8.0	4.7	4.7	63.00	48.0	20.6	64.0	40.0	586	1154
T6	31.00	67.33	8.0	4.7	4.7	70.67	48.7	20.6	68.0	40.2	657	1306
T7	35.33	88.33	10.7	5.4	5.0	114.00	55.0	23.3	72.4	43.4	1153	2467
T8	30.33	51.67	8.0	4.3	4.3	61.67	47.2	18.2	60.8	40.0	574	1148
CD @ 5%	-	8.27	-	-	-	5.19	-	-	-	-	103.44	198.07
CV	-	6.32	-	-	-	3.31	-	-	-	-	6.75	6.39

T1:Imazethapyr + imazamox @ 50 g/ha T2:Imazethapyr + imazamox @ 75 g/ha T3:Propaquizafop 2.5% + imazethapyr 3.75% @ 1000 ml /ha T4:Propaquizafop 2.5% + imazethapyr 3.75% @ 1500 ml /ha T5:Clodinofoppropargyl 8% + aciflourfen sodium 16.5 @ 500 ml /ha T6:Clodinofoppropargyl 8% + aciflourfen sodium 16.5 @ 750 ml /ha) T7:Hand weeding at 15-20 DAS and 35-40 DAS T8:Weedy check

Table 1. Notable improvements in pod length, number of pods per plant, number of seeds per pod, pod weight, and seed weight were observed in the treatment involving hand weeding twice at 15-20 and 35-40 DAS (Days After Sowing). This treatment was followed by the post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha at 15-20 DAS. The hand weeding treatment recorded the highest seed yield (1153 kg/ha) and bhusa yield (2467 kg/ha) among all treatments. However, this result was statistically comparable to the post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @1500 ml/ha (1140 kg/ ha seed yield and 2333 kg/ha bhusa yield) and 1000 ml/ha (1075 kg/ha seed yield and 2237 kg/ha bhusa yield). In contrast, the lowest seed and bhusa yields were recorded in the weedy check treatment, with yields of 574 kg/ha and 1148 kg/ha, respectively. The observed significant differences in yield and yield attributes among the various treatments can be attributed to the effectiveness of the weed control methods employed. Hand weeding twice at 15-20 and 35-40 DAS and the post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75 per cent demonstrated superior weed control, leading to better crop growth and higher yields. These results align with previous studies that highlight the critical role of timely and effective weed management in enhancing crop productivity. Hand weeding is a traditional yet effective method of weed control, particularly in smaller fields or where labor is readily available. It ensures the complete removal of weeds, reducing competition significantly (Rao and Nagamani, 2010). The results of this study are consistent with those of earlier research that has documented substantial yield increases with timely hand weeding (Singh *et al*., 2012). Chaudhari *et al*., 2017 reported that effective weed control methods, such as hand weeding and the use of post-emergence herbicides, can mitigate this competition, ensuring that crops have better access to nutrients, water and light. Patel *et al*. (2016) observed significant yield improvements with the use of these herbicides in legume crops. Fig. 2 indicates that there is positive correlation between number of pods/plant and seed yield.

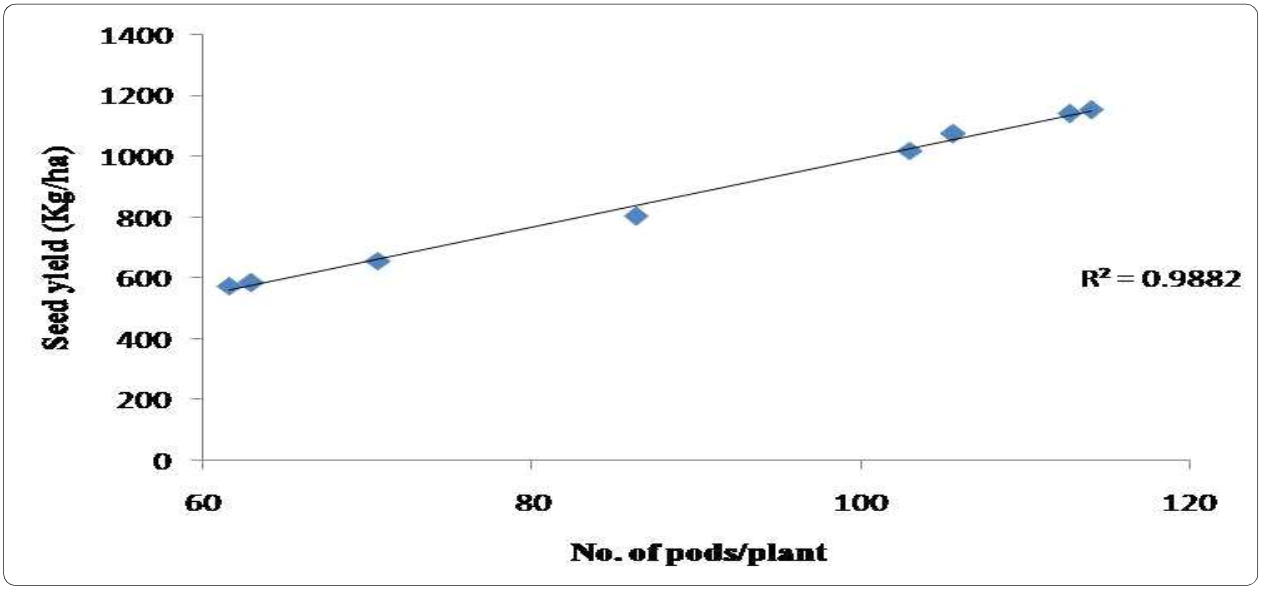

Fig. 2 : Linear regression of no. of pods/plant and seed yield

Economics

Among all treatments, higher gross returns (34982 Rs./ha) were recorded in hand weeding twice at 15-20 DAS and 35-40 DAS. However, post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha recorded higher net returns (22265 Rs./ha) and B:C ratio (2.84). Whereas lower net returns (5924 Rs./ha) and B:C ratio (1.51) were recorded in *Clodinofop propargyl* 8% + aciflourfen sodium 16.5 @ 500 ml /ha as PoE at 15 - 20 DAS. This suggests that while manual hand weeding provides the highest gross returns, the chemical treatment with Propaquizafop and Imazethapyr is more efficient in terms of net returns and overall profitability. Conversely, the combination of *Clodinofop propargyl* and Aciflourfen Sodium yields the lowest economic benefit. While hand weeding offers the highest gross returns, its high labor cost limits its economic viability. According to Chauhan and Johnson (2010), manual weeding, though labor-intensive, can significantly enhance crop yields by maintaining weed-free conditions during critical growth stages. However, the high labor cost associated with hand weeding can reduce net returns,

TABLE 2

Effect of broad spectrum post emergence herbicides on Economicsof horsegram

Treatments	Cost of Cultivation (Rs/ha)	Gross Returns (Rs/ha)	Net Returns (Rs/ha)	Benefit: Cost ratio
T1	11432	23973	12541	2.10
T2	11900	30326	18426	2.55
T3	11550	32471	20921	2.81
T4	12075	34340	22265	2.84
T5	11615	17539	5924	1.51
T6	12170	19685	7515	1.62
T7	15600	34982	19382	2.24
T8	7600	17215	9615	2.27

making it less economically viable despite high gross returns.

Effect on Weed Growth

Fig. 3 and Fig. 4, shows that *Rottbellia cochinchinensis, Celosia argentea, Andrographis spp , Cyperus rotundus, Rhyncosia minima, Murdannia nodiflora, Digitaria sanguinalis* were the major weeds associated with horsegram which were effectively controlled in hand weeding twice at 15-20 DAS and 35-40 DAS. Hand weeding twice recorded lower weed density and weed dry matter at

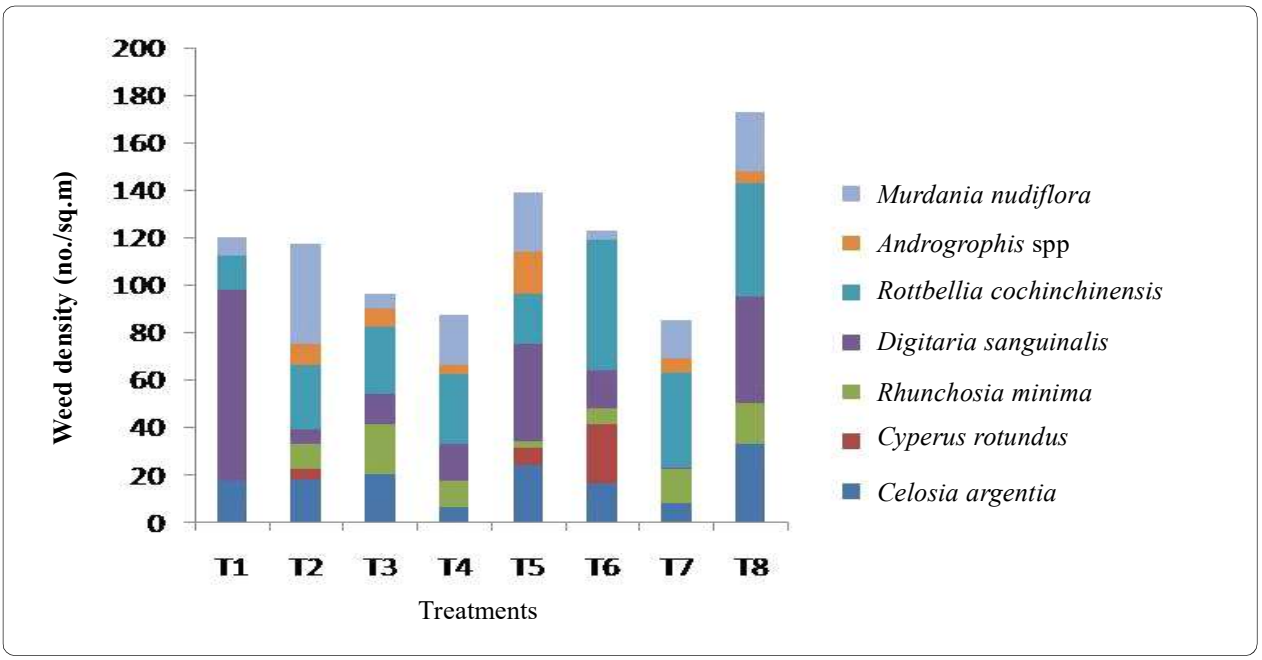

Fig. 3 : Species wise weed density in horsegram in different treatments

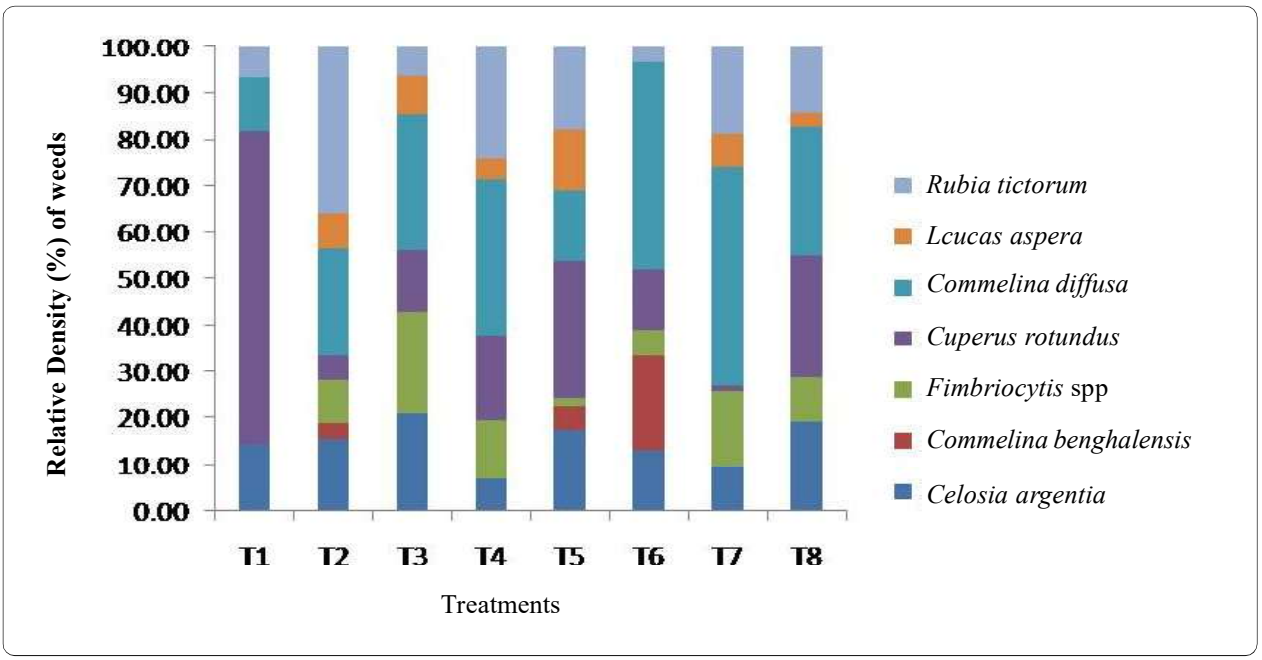

Fig. 4 : Relative density (%) of weeds in horsegram in different treatments

TABLE 3

Effect of broad spectrum post emergence herbicides on Weed density, drymatter and Weed Control Efficiency in horsegram

Treatment	Weed density (no./m^2)				Weed drymatter (g/m^2)				Weed control efficiency (%)				Weed Index (%)
	60 DAS	75 DAS	90 DAS	At harvest	60 DAS	75 DAS	90 DAS	At harvest	60 DAS	75 DAS	90 DAS	At harvest	
T1	3.89	4.92	3.45	2.81	8.91	10.61	9.82	5.8	2.84	4.76	9.24	32.56	29.6
T2	3.54	4.60	2.97	2.63	8.19	10.33	9.82	5.8	10.69	7.27	9.24	32.56	11.5
T3	2.75	4.16	2.60	2.43	7.89	10.04	8.68	3.5	13.96	9.87	19.78	59.30	6.7
T4	2.55	3.77	2.60	2.20	7.46	9.91	7.29	3.5	18.65	11.04	32.62	59.30	1.1
T5	5.22	5.41	4.11	3.15	9.17	10.95	10.80	7.7	0.00	1.71	0.18	10.47	49.6
T6	4.44	5.25	3.73	2.99	8.93	10.85	9.92	6.3	2.62	2.60	8.32	26.74	43.5
T7	0.00	2.64	2.58	1.95	0.00	6.92	5.74	3.0	100.00	37.88	46.95	65.12	0.0
T8	5.35	5.96	4.23	3.31	9.17	11.14	10.82	8.6	0.00	0.00	0.00	0.00	50.6
CD @ 5%	0.68	1.38	0.28	0.13	1.19	1.92	0.83	0.82	-	-	-	-	
CV	11.18	16.71	4.97	2.78	7.91	10.84	5.21	8.45	-	-	-	-	

Weed density and weed dry matter values are transformed through square root transformation

60, 75, 90 DAS and at harvest. Among herbicide combinations, post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha recorded lower weed density and weed dry matter at 60, 75, 90 DAS and at harvest. Lowest weed growth in this treatment is due to better control of weeds during critical stages of crop growth. Whereas, higher weed density and weed dry matter were recorded in weedy check at all growth stages. These findings are supported by Tiwari *et al*., 2016 and Pandey *et al*., 2017 in pulses.

Weed Control Efficiency and Weed Index

Table 3 clearly shows that higher weed control efficiency at all growth stages was observed in hand weedng twice at 15-20 and 35-40 DAS. This treatment was followed by the post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha at 15-20 DAS. Higher the weed control efficiency, higher the seed yield which indicates the direct proportion of WCE and yield. Higher Weed Control Efficiency was due to lower weed density and weed dry matter in certain treatments. Whereas, lower Weed Control Efficiency was observed in weedy check. Weed index indicates the reduction in yields due to competition from weeds. Weed Index was higher in weedy check (50.6%), lower in hand weeding twice (0.0) and closely followed by post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha (1.1) which shows the effectiveness of treatments in controlling weeds. Lower WCE and higher Weed Index were due to good control of weeds during critical periods of crop growth and higher yields due to reduced competition of weeds for resources with crop. These results are similar to findings of Raj*et al*. (2012), Gupta *et al*. (2013) and Kewat *et al*. (2014) in pulses.

Harvest Index, Weed Index, Rain Water use Efficiency and Production Efficiency

The efficacy of different weed control methods significantly influences crop performance metrics such as the harvest index, rainwater use efficiency and production efficiency (Table 4). Higher harvest

Table 4

Effect of broad spectrum post emergence herbicides on Harvest Index, Weed Index, Rain Water Use Efficiency Production in horsegram

Treatments	Harvest Index (%)	Rain Water Use Efficiency (kg/ha.mm)	Production Efficiency (kg/ha/day)
T1	32.02	3.67	6.69
T2	32.36	4.66	8.49
T3	34.50	4.92	8.96
T4	34.83	5.22	9.50
T5	33.55	2.68	4.88
T6	33.39	3.01	5.47
T7	34.92	5.28	9.61
T8	31.10	2.63	4.78

index of 34.92%, rain water use efficiency of 5.28 kg/ha.mm, production efficiency of 9.61 k/ha/day were recorded in hand weeding at 15-20 DAS and 35-40 DAS. Among herbicide treatments, Post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha recorded higher harvest index, rain water use efficiency and production efficiency (34.83 5.22, 9.50; respectively). Lower harvest index of 31.1 per cent, rain water use efficiency of 2.63 kg/ha.mm and production efficiency of 4.78 k/ha/day were observed in weedy check. These results suggest that manual weed control is highly effective in optimizing crop performance. Similar findings were reported by [Singh *et al*. (2016)], where hand weeding significantly improved the growth and yield of crops by reducing weed competition and enhancing nutrient availability. Although Post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha slightly less effective than hand weeding, this treatment provides a practical alternative for weed management, especially in large-scale operations where manual weeding is labor-intensive and costly. Chauhan *et al*. (2012) and Kiran Kumar *et al.,* 2023 found that the application of herbicides can effectively reduce weed density and biomass, leading to improved crop yields and resource use efficiency.

Post-emergence application of Propaquizafop 2.5% + Imazethapyr 3.75% @ 1500 ml/ha ad 1000 ml/ha appear to be the most effective in controlling weeds based on the criteria of weed density, dry matter reduction and overall control efficiency. Hand weeding twice also stands out for its exceptionally high initial control efficiency. Further field trials and specific environmental considerations may be needed to optimize weed management strategies based on these findings.

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