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Bio-efficacy of Different Post Emergent Herbicides on Weed Dynamics and Productivity of Horsegram

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Abstract

Effective weed management is crucial for the successful cultivation of horsegram (*Macrotyloma uniflorum*), a drought-tolerant leguminous crop. This study evaluates the bio-efficacy of various herbicides on weed dynamics and the productivity of horsegram. Field experiments were conducted under AICRP on Arid legumes at ARS Ananthapuramu, where different herbicide treatments were compared with hand weeding and a weedy check during *kharif* 2023. The experiment comprised of eight post emergent treatments which include six herbicides treatments (quizalofop ethyl, haloxyfop-R-methyl, clodinafop propargyl, fenoxaprop-p-ethyl, propaquizafop, imazethapyr sprayed at 15-20 DAS), two hand weedings at 20 and 40 DAS and weedy check replicated thrice in Randomized Block Design. Major weeds were *Rottboellia cochinchinensis* among grasses, *Fimbriocytis* spp. among sedges, *Celosia argentea, Murdania nudiflora* and *Digitaria sanguinalis* among broadleaved weeds. Quizalofop ethyl and Propaquizafop effectively controlled *Rottboellia cochinchinensis* and *Fimbriocytis spp*. Imazethapyr effectively controlled broad leaved weeds. The results demonstrated that hand weeding twice recorded higher seed yield, haulm yield and net returns. Among herbicide treatments, quizalofop ethyl @ 50 g a.i./ha as PoE at 15 - 20 DAS recorded higher seed yield (807 kg/ha), haulm yield (1588 kg/ha) and net returns (15535 Rs/ha) and imazethapyr @ 40 g a.i./ha as PoE at 15 - 20 DAS recorded higher B:C ratio (2.84).

Keywords : Herbicides, Horsegram, Imazethapyr, Quizalofop ethyl, Weed management

Hosegram is one of the important climate resilient indigenous grain legume crops in India (Kiran Kumar *et al.,* 2023). Effective weed management is a critical factor in the successful cultivation of horsegram (*Macrotyloma uniflorum*), a hardy leguminous crop prized for its drought tolerance and nutritional benefits. In regions characterized by semi-arid conditions, horsegram is a vital source of sustenance and income. However, the productivity of this resilient crop is often hindered by the persistent challenge of weed competition. Weeds compete with horse gram for vital resources such as water, nutrients and sunlight, leading to reduced crop yields and compromised quality. In Andhra Pradesh, horse gram is cultivated on approximately 150,000 hectares with annual production of around 90,000 metric tons and average productivity of about 600 kg/ha (https://iipr.icar.gov.in/horsegram/). Traditional weed control methods, such as manual weeding and mechanical cultivation, though effective, are labor-intensive and time-consuming. These methods pose significant challenges for smallholder who often lack the resources and labor necessary for consistent weed management. In response to these challenges, the use of chemical herbicides has emerged as a viable alternative, offering a more efficient and cost-effective solution for weed control in horsegram cultivation. Herbicides, when used appropriately, can significantly reduce weed pressure, thereby enhancing crop growth and yield. The adoption of herbicides in weed management practices has shown promise in increasing agricultural productivity by minimizing the competition between crops and weeds. However, the use of chemical herbicides also raises concerns regarding environmental safety, human health and the potential development of herbicide-resistant weed species.

This manuscript aims to investigate different herbicides for chemical weed management. It will explore the efficacy of various herbicides in controlling different weed species commonly found in horsegram fields, the optimal application rates and timing and the impact of herbicide use on crop yield and quality. Additionally, the manu script will address the potential risks associated with herbicide use and discuss strategies for mitigating these risks to promote sustainable weed management practices. By synthesizing current research and field studies, this work seeks to provide a comprehensive overview of chemical weed management in horsegram. It aims to offer valuable insights for farmers, agronomists and agricultural policymakers to enhance weed control practices, improve crop productivity and ensure the sustainability of horsegram cultivation.

Material and Methods

Field experiment was conducted at Agricultural Research Station, Aanthapuramu under AICRP on Arid legumes during *kharif*, 2023. The experimental site is located in scarce rainfall zone of Andhra Pradesh with average annual rainfall of 550 mm and geographical coordinates of the site are approximately 14.68° N latitude and 77.60° E longitude.The soil at the experimental site is red sandy loam. Soils were slightly alkaline with pH of 7.97, EC of 0.07 with low Organic carbon (0.09%), low nitrogen (212.9 kg/ ha) low phosphorus (12.7 kg/ha), medium in potassium (294 kg/ha) and low micronutrients (Copper-0.08 ppm, Manganese-0.59 ppm, iron-0.43 ppm, zinc-0.50 ppm). Experiment was laid in Randomized Block Design with three replications and eight treatments comprised of T1-quizalofop-p-ethyl @ 50 g a.i./ha, T2-Haloxyfop-R-methyl @ 100 g a.i./ha, T3-clodinafop propargyl @ 60 g a.i./ha, T4-Fenoxaprop-p-ethyl @ 90 g a.i./ha, T5-propaquizafop @ 100 g a.i./ha, + T6-imazethapyr @ 40 g a.i./ha as PoE at 15-20 DAS, T7-Hand weeding at 15-20 DAS and 35-40 DAS, T8-Weedy check. ATPHG 11 was taken as test variety and sowing was done with seed drill. 4 kg of Nitrogen, 10 kg of Phosphorus and 8 kg potash supplying fertilizers were broadcasted before sowing.The average maximum temperature over the recorded period was 32.95°C, and the average minimum temperature was 20.12°C. The average morning relative humidity was 83.08 per cent, while the average evening relative humidity was 46.61 per cent. The average wind speed was 7.50 kmph. The total rainfall recorded was 284.8 mm over 19 rainy days. The average sunshine hours per week were 6.13 hours and the average evaporation rate was 6.75 mm per week.

Growth and yield parameters like plant height, number of branches/plants, plant population, number of pods/plants, number of seeds/pods, pod weight, seed weight, pod length was 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 yield x 100 (Donald, 1962).

Where, Economic yield = Seed yield

Biological yield = Seed yield + bhusa yield

Rain Water use Efficiency (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

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)

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 (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

Species Wise Weed Density

Major Weeds Associated with Horsegram : *Rottboellia cochinchinensis, Fimbriocytis* spp*, Commelina diffusa, Commelina benghalensis, Celosia argentea, Andrographis* spp*, Leucasaspera, Cyperus rotundus, Murdania nudiflora, Digitaria sanguinalis, Rubiat ictorum* were the major weeds associated with horsegram. Fig. 1 clearly shows that most predominant weeds were *Fimbriocytis spp, Murdania nudiflora, Rottboellia cochinchinensis, Digitaria sanguinalis* and *Celosia argentea* accounting for 83 per cent of the total weeds observed.

Growth Parameters

The growth parameters, including plant population, plant height, and the number of branches per plant, varied significantly across different weed management treatments in horsegram (Table 1).The plant population ranged from 30.33 to 35.33 plants per square meter. Treatment T7 recorded the highest plant

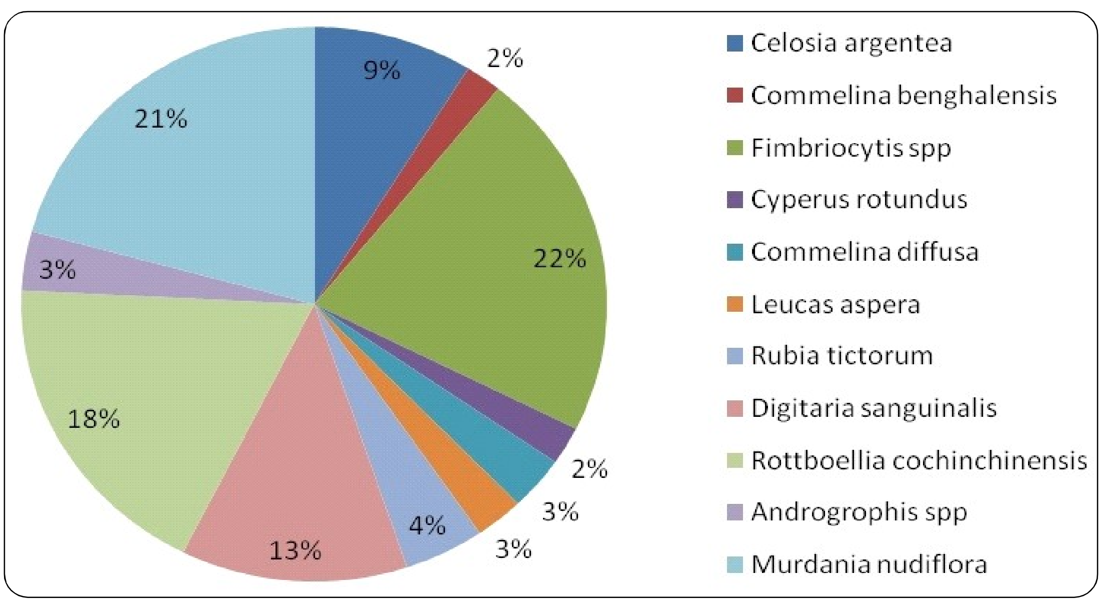

Fig. 1 : Species wise weed frequency in experimental field (no./sq.m.)

Table 1

Influence of different weed management practices on growth and yield 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)
1	34.33	69.67	8.33	4.93	5.3	86.9	51.0	23.0	74.4	42	807	1588
T2	32.33	52.00	6.67	4.43	5.0	71.5	45.0	19.2	68.0	38	663	1451
T3	32.66	57.33	7.33	4.60	5.0	74.6	47.8	21.6	69.2	39	692	1500
T4	32.33	52.00	7.00	4.60	5.0	72.7	46.4	21.3	68.8	38	673	1451
T5	34.00	69.33	8.00	4.83	5.3	86.0	49.5	22.5	71.8	41	799	1582
T6	34.00	68.33	8.00	4.73	5.3	84.4	47.8	22.0	69.2	40	785	1565
T7	35.33	91.00	8.33	4.93	5.3	111.0	52.0	23.5	79.2	44	1125	1900
T8	30.33	49.00	6.33	4.17	5.0	66.3	45.0	18.4	64.4	37.6	615	1246
CD @ 5%	NS	2.34	NS	NS	NS	6.84	NS	2.05	0.33	0.33	70.68	202.66
CV	-	2.11	-	-	-	4.78	-	5.46	2.63	4.66	5.24	7.54

population (35.33 plants/sq.m), while T8 had the lowest (30.33 plants/sq.m). Among herbicide treatments, T1 had the highest plant population (34.33 plants/sq.m), followed closely by T5 and T6 (34.00 plants/sq.m each), The tallest plants were observed in T7 (91.00 cm), significantly higher than the shortest plants in T8 (49.00 cm). Among herbicide treatments, the tallest plants were observed in T1 (69.67 cm) and T5 (69.33 cm). The number of branches per plant varied from 6.33 (T8) to 8.33 (T1 and T7). T1 had the highest number of branches (8.33), followed by T5 and T6 (8.00 each). Treatments T1, T5, T6 and T7, which had higher numbers of branches per plant, likely benefited from reduced weed pressure, which otherwise competes for nutrients and space. It suggests that this treatment provided optimal conditions for horsegram growth by effectively reducing weed competition This observation aligns with findings from Kumar *et al*. (2017), who reported that effective weed management practices can enhance plant growth by minimizing competition for light, nutrients and water.

Yield and Yield Attributes

The yield and yield attributes were significantly influenced by the different weed management practices (Table 1). Pod length ranged from 4.17 cm (T8) to 4.93 cm (T1 and T7). Among herbicide treatments, T1 recorded higher pod length (4.93 cm) followed by T5 (4.83). The number of seeds per pod was consistently around 5 across treatments, with T1, T5, T6 and T7 showing slightly higher values (5.3 seeds/pod). The number of pods per plant was highest in T7 (111.0) and lowest in T8 (66.3). Among herbicide treatments, T1 recorded higher no. of pods/plant (86.9) followed by T5 (86.0) and T6 (84.4). This indicates that the weed management practice in T7 and T1 significantly enhanced the reproductive capacity of the plants. The 100 fresh pod weight varied from 45 g (T2 and T8) to 52 g (T7) and the 100 dry pod weight ranged from 18.4 g (T8) to 23.5 g (T7). Among herbicide treatments, T1 showed higher 100 fresh and dry pod weight of 51.0 and 23.0 g, respectively. Similarly, the 1000 fresh seed weight and 1000 dry seed weight were highest in T7, indicating that effective weed management can enhance the overall quality and weight of the produce. Among herbicide treatments, higher 1000 fresh and dry seed weight were recorded in T1 with 74.4 and 42.0 g, respectively. Seed yield ranged from 615 kg/ha (T8) to 1125 kg/ha (T7). Higher seed yield was recorded in T1 with 807 kg/ha followed by T5 with 799 kg/ha. Bhusa yield followed a similar trend, with T7 having the highest yield (1900 kg/ha) and T8 the lowest (1246 kg/ha). Among herbicide, treatments T1 recorded higher bhusa yield of 1588 kg/ha followed by T5 with 1582 kg/ha. These results suggest that effective weed control, as seen in T7 and T1, can substantially improve both seed and bhusa yields. The results align with previous studies that emphasize the importance of effective weed management in enhancing crop growth and yield. For instance, Singh *et al*. (2018), found that integrated weed management practices lead to higher yields and better crop performance by maintaining lower weed biomass. Meena *et al*. (2019) observed that effective weed control leads to improved seed quality and higher market value. Fig. 2, shows that no. of pods/ plant and seed yield were positively correlated which indicate that increase in number of pods increases seed yield. Findings are in support with Rajesh Naik *et al.,* 2022.

Economic analysis revealed significant differences in cost of cultivation (COC), gross returns (GR), net returns (NR) and benefit-cost (B: C) ratio among treatments (Table 2). The COC ranged from Rs.7600/ha (T8) to Rs. 15600/ha (T7), indicating that some weed management practices are more cost-intensive than others. T7 had the highest Gross Returns (Rs. 32866/ha) and Net Returns (Rs. 17266/ha), while T8 had the lowest Gross Returns (Rs. 18490/ha) and moderate NR (Rs. 10890/ha). This shows that despite the higher

Table 2

Economics of horsegram as influenced by different weed management practices

Treatment	Cost of Cultivation (Rs/ha)	Gross Returns (Rs/ha)	Net Returns (Rs/a)	Benefit: Cost ratio
T1	8620	24155	15535	2.80
T2	9560	20201	10641	2.11
T3	9798	21046	11248	2.15
T4	9758	20462	10704	2.10
T5	10560	23937	13377	2.27
T6	8280	23532	15252	2.84
T7	15600	32866	17266	2.11
T8	7600	18490	10890	2.43

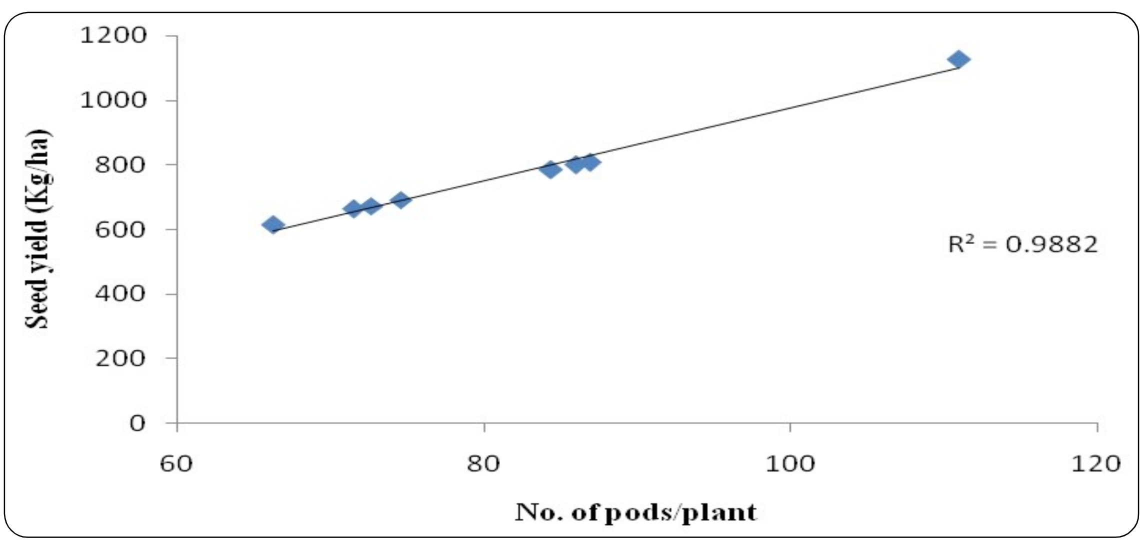

Fig. 2 : Linear regression of no. of pods/plant and seed yield

cost of cultivation, the returns in T7 are substantially higher, making it economically beneficial. Among herbicide treatments, higher gross returns and net returns were recorded in T1 with 24155 and 15535 Rs./ha, respectively. The B:C ratio was highest in T6 (2.84), followed by T1 (2.80) and T7 (2.11), suggesting that these treatments are more profitable. Kumar *et al*. (2017) reported that integrated weed management practices can lead to higher economic returns due to better resource utilization and reduced competition from weeds. This is in line with the study by Patel *et al*. (2016), which showed that integrated weed management practices, although costlier, result in higher economic benefits due to increased yields.

Total Weed Density, Weed Dry Matter and Weed Control Efficiency

Total weed density, dry matter and Weed Control Efficiency is presented in Table 3. Lowest weed density, drymatter and highest weed control efficiency were recorded in T7. Among herbicide treatments, lowest weed density, dry matter and higher weed control efficiency were recorded in T1 followed by T5 at 60, 75, 90 DAS and at harvest. The reduction in weed density and dry matter observed in Treatment T7 (100% weed control efficiency at 60 DAS) aligns with findings from other studies that emphasize the effectiveness of certain herbicides and mechanical methods in reducing weed populations. For example, Ghosh *et al*. (2012) reported that the integration of mechanical weeding and herbicide application can significantly reduce weed biomass in legume crops. The highest weed control efficiency observed in Treatment T7 and T1 indicates the effectiveness of the weed management strategy employed in this treatment. This is consistent with the findings of Chauhan and Johnson (2010), who found that integrated weed management practices, including the

TABLE 3

Weed density, drymatter and Weed Control Efficiency at different growth stages in horsegram as influenced by different weed management practices

Treatments	Weed density (no./m^2)				Weed drymatter (g/m^2)				Weed control efficiency (%)			
	60	75	90	har	60	75	90	har	60	75	90	har
T1	4.18 (17.5)	4.10 (16.8)	3.77 (14.2)	2.20 (4.8)	7.24 (52.4)	7.02 (49.3)	6.69 (44.8)	3.84 (14.7)	33.33	33.33	29.43	53.79
T2	7.25 (52.6)	6.59 (43.4)	5.42 (29.4)	3.87 (!5.0)	10.56 (111.5)	9.98 (99.6)	8.94 (79.9)	8.00 (64.0)	2.76	5.22	5.70	3.73
T3	6.45 (41.6)	5.74 (32.9)	5.11 (26.1)	2.81 (7.9)	9.83 (96.6)	9.63 (92.7)	8.90 (79.2)	6.97 (48.6)	9.48	8.55	6.12	16.13
T4	6.71 (45.0)	5.75 (33.1)	5.28 (27.9)	3.60 (!3.0)	10.56 (111.5)	9.98 (99.6)	8.94 (79.9)	8.00 (64.0)	2.76	5.22	5.70	3.73
T5	5.35 (28.6)	5.28 (27.9)	4.95 (24.5)	2.63 (6.9)	8.37 (70.1)	8.11 (65.8)	7.90 (62.4)	5.74 (32.9)	22.93	22.98	16.67	30.93
T6	5.99 (35.9)	5.46 (29.8)	5.06 (@5.6)	2.63 (6.9)	9.71 (94.3)	9.65 (93.1)	8.74 (76.4)	6.18 (38.2)	10.59	8.36	7.81	25.63
T7	0.00 (0.0)	2.33 (5.4)	3.43 (11.8)	1.14 (1.3)	0.00 (0.0)	4.48 (20.1)	5.48 (30.0)	3.84 (!4.7)	100.00	57.45	42.19	53.79
T8	8.21 (67.4)	6.92 (47.9)	5.84 (34.1)	4.58 (21.0)	10.86 (117.9)	10.53 (110.9)	9.48 (89.9)	8.31 (69.1)	0.00	0.00	0.00	0.00
CD @ 5%	1.62	1.74	1.04	0.74	2.44	2.50	1.96	1.12	-	-	-	-
CV	16.80	18.88	12.27	14.45	16.54	16.44	13.78	10.07	-	-	-	-

Weed density and weed dry matter values are transformed through square root transformation.
Values in paranthesis are original alues

use of pre-emergence herbicides, can achieve high weed control efficiency in legume crops.

Species Wise Weed Density and Relative Density of Weeds

The species wise weed density varied significantly across treatments, with some species like *Celosia argentia* and *Digitaria sanguinalis* showing high densities in multiple treatments, while others like C*ommelina benghalensis* and *Cyperus rotundus* were less prevalent (Fig. 2 and Fig. 3). The relative density of weed species depicted in Fig. 4, showed that weed management practices had a remarkable effect. In major treatments, *Fimbriocytis* spp and *Murdania nudiflora* contributed major relative density. *Rottboellia cochinchinensis* among grasses, *Fimbriocytis* spp among sedges, *Celosia argentea, Murdania nudiflora Digitaria sanguinalis* among broadleaved weeds were the major weeds in experimental fields. This differential response to weed management practices can be explained by the selective efficacy of herbicides and mechanical

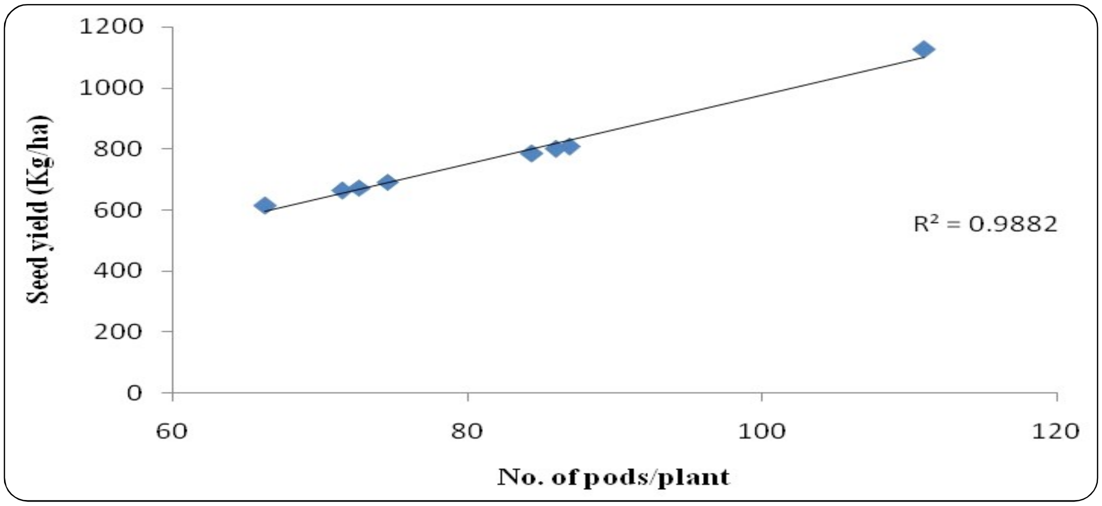

Fig. 2 : Linear regression of no. of pods/plant and seed yield

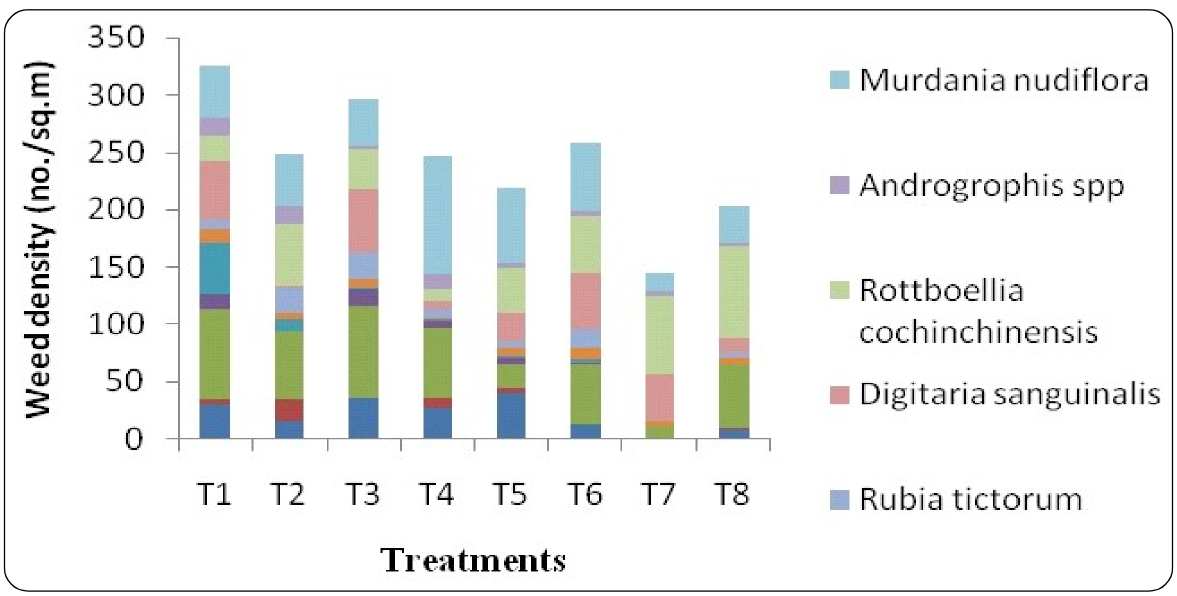

Fig. 3 : Species wise weed density in horsegram in different treatments

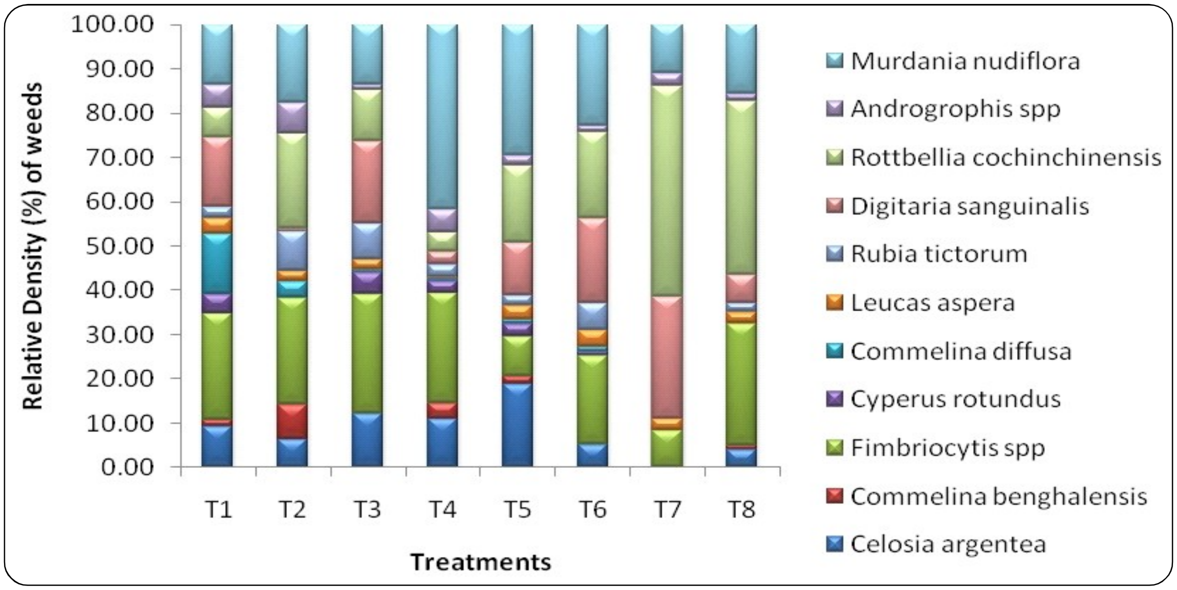

Fig. 4 : Relative density (%) of weeds in horsegram in different treatments

methods against specific weed species. According to Chauhan *et al*. (2011), certain herbicides are more effective against broadleaf weeds, while others target grass species more effectively. This specificity can influence the composition of weed species in the field.

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

Harvest index was highest (37.17%) in T7 treatment, indicating a greater proportion of economic yield relative to the total biomass produced (Table 4). The low weed index in T7 signifies effective weed suppression, leading to better crop performance. High rain water use efficiency (5.15 kg/ha.mm) and production efficiency (9.37 kg/ha/day) in T7 demonstrate the treatment's effectiveness in utilizing available resources for optimal crop production. Among herbicide treatments higher harvest index (34.02%), weed index (28.1%), Rain Water Use Efficiency (3.70 kg/ha.mm) and Production Efficiency (6.73 kg/ha/day) was recorded in quizalofop-p-ethyl @ 50 g a.i./ha followed by propaquizafop @ 100 g a.i./ha. These findings are consistent with Sharma *et al*. (2015), who reported that efficient weed management enhances resource use efficiency, resulting in higher productivity.

TABLE 4

Harvest Index, Weed Index, Rain Water Use Efficiency and Production Efficiency as influenced by different weed management practices in horsegram

Treatment	Harvest Index (%)	Weed Index (%)	Rain Water Use Efficiency (Kg/ha.mm)	Production Efficiency (kg/ha/day)
T1	34.02	28.1	3.70	6.73
T2	31.35	40.7	3.04	5.52
T3	31.56	38.2	3.17	5.77
T4	31.68	39.9	3.08	5.61
T5	33.55	28.8	3.66	6.66
T6	33.39	30.1	3.59	6.54
T7	37.17	0.0	5.15	9.37
T8	33.10	45.3	2.82	5.13

Marginal Cost, Returns and Savings over Hand Weeding

T1 and T6 offer the highest total savings, indicating they are financially advantageous compared to hand weeding. T2, T3 and T4 result in negative total savings, meaning they are more costly compared to hand weeding. T8 has the highest cost savings, but its total savings are lower than T1 and T6 due to its higher marginal returns. Overall, T1 and T6 stand out as the most beneficial treatments in terms of net savings, while T2, T3, and T4 are less cost-effective (Table 5).

TABLE 5

Marginal returns, Marginal cost and savings over hand weeding

Treatment	Marginal cost (Rs/ha)	Marginal Returns (Rs/ha)	Cost Savings over hand weeding (Rs/ha)	Total savings over hand weeding (Rs/ha)
T1	-6980	-1731	6980	5249
T2	-6040	-6625	6040	-585
T3	-5802	-6018	5802	-216
T4	-5842	-6562	5842	-720
T5	-5040	-3889	5040	1151
T6	-7320	-2014	7320	5306
T7	-	-	-	-
T8	-8000	-6376	8000	1624

This study demonstrates that effective weed management practices significantly improve the growth, yield and economic returns of horsegram cultivation. Treatment T7 emerged as the most effective strategy, providing the highest plant height, number of branches, yield attributes and economic returns. However, other treatments like T6 and T1 also offered substantial benefits, making them viable alternatives. Implementing effective weed management strategies is crucial for optimizing horsegram production and ensuring sustainable agricultural practices. Future research could explore the long-term impacts of these practices on soil health and crop performance.

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