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Integrated weed management in horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

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Abstract
The present investigation entitled "Integrated weed management in horsegram [*Macrotyloma uniflorum* (L.) Verdc.]" was carried out during *post-kharif* season 2023 at the Instructional Cum Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.). The experiment was laid out in Randomized Block Design with three replications. The treatments consisted of nine weed management practices *viz.*, weedy check (T_1), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence (T_2), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4), once wheel hoeing at 25 DAS (T_5), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + once wheel hoeing at 25 DAS (T_6), hand weeding at 25 DAS (T_7), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + hand weeding at 25 DAS (T_8) and weed free (T_9). The horsegram variety Chhattisgarh kulthi-3 was grown as test crop on August 28, 2023 and harvesting was done on December 02, 2023. The experiment's findings showed that the following combinations of pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + hand weeding at 25 DAS (T_8) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + once wheel hoeing at 25 DAS (T_6), produced the highest growth characters *viz.*, plant population, plant height, number of branches, dry matter accumulation, crop growth rate, relative growth rate, seed yield, stover yield and harvest index. Below the weedy check (T_1), the minimum values of the aforementioned characters were noted. Throughout the crop growing period, *Cyperus rotundus*, *Parthenium hysterophorus*, *Trianthema* spp., *Phyllanthus* spp., *Cynodon dactylon* and a few other weeds were observed as prevalent in the experimental field. The treatments that reduced weed density, weed dry matter production, weed growth rate and gave the highest weed control efficiency were pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + hand weeding at 25 DAS (T_8), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + once wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). On the other hand, under pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + manual weeding at 25 DAS (T_8), the weed index was recorded as minimum. Additionally, an economic analysis showed that the treatment weed free (T_9) produced the highest net return (61155.66 ₹ ha^{-1}) and gross return (97244.44 ₹ ha^{-1}). Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + hand weeding at 25 DAS (T_8) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + once wheel hoeing at 25 DAS (T_6) were the next two treatments. Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + hand weeding at 25 DAS (T_8) produced the highest B:C ratio, whereas pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre-emergence + once wheel hoeing at 25 DAS (T_6) produced a comparable result.

Keywords: Horsegram, imazethapyr, pendimethalin, economics, yield

Introduction
Horsegram, scientifically known as [*Macrotyloma uniflorum* (L.) Verdc.], is a pulse belonging to the family Fabaceae. Despite its nutritional benefits and versatility, horsegram remains an underexploited legume crop. Its grains are commonly used for human consumption, often prepared as 'dal' in various cuisines, including Indian dishes like rasam. Additionally, horsegram serves as a concentrated feed for cattle, contributing to livestock nutrition. Its versatility extends to agricultural practices, where it can be utilized as green manure, enriching soil fertility. Horsegram goes by various regional names, reflecting its widespread cultivation and usage across different cultures. In Sanskrit, it's known as Kulattha, while in Bengali, it's called Kurti-kalai. In Tamil, it's referred to as Kollu, in Telugu as Ullavallu, in Malayalam as Muthira and in other regions by names like Gahot. This diversity in nomenclature highlights its cultural significance and widespread acceptance

as a valuable crop across various regions. (Naik *et al.*, 2022) [23]. In India, horsegram is grown as a pulse crop and accounts for about 0.33 percent of all grain production. In India, horsegram was planted on 0.458 million hectares in 2019–2020, yielding 0.297 million tonnes of product and 6.48 q ha^{-1} of productivity (Anonymous, 2020) [2]. Horsegram's adaptability to diverse soil and climatic conditions makes it a resilient crop, particularly suited to regions experiencing limited rainfall and fluctuating temperatures. It thrives in environments with rainfall ranging from 200-700 mm and temperatures between 20-35°C, earning it the reputation of being drought-hardy. Regarding soil preferences, horsegram exhibits versatility, growing well in various soil types such as loams, black cotton soils, clayey paddy soils, sandy and shallow soils, stony uplands, and cleaned rough forests. This adaptability allows for widespread cultivation across different agro-ecological zones in India. Horsegram is cultivated both as a sole crop and in various combinations with other crops. Its wide adaptability extends its cultivation across almost all states of India. However, the majority of its cultivation, approximately 90-95%, is concentrated in five major states: Orissa, Tamil Nadu, Karnataka, Maharashtra, and Andhra Pradesh. In specific regions like the Northern hill zone and Bastar plateau of Chhattisgarh, horsegram cultivation is significant, particularly among tribal farmers. In Chhattisgarh, for instance, the total cultivated area, crop production, and productivity of horsegram are reported to be 0.026 million hectares, 0.010 million tones and 3.90 quintals ha^{-1}, respectively. (Anonymous, 2019) [1]. A weed-free environment is crucial for maximizing yield and income security in horsegram cultivation. Effective weed management strategies are essential for minimizing yield losses and ensuring the success of the crop. These strategies may include cultural practices like crop rotation, mulching, and intercropping, as well as mechanical methods such as manual weeding and the use of weed control implements. Moreover, the judicious use of herbicides can also play a significant role in weed control, provided they are used responsibly and in accordance with recommended practices to minimize environmental impact. Addressing the challenge of weed infestation in horsegram cultivation requires a holistic approach that integrates various weed management techniques tailored to the specific agroecological conditions and weed spectrum prevalent in the cultivation area. By effectively managing weeds, farmers can mitigate one of the major factors contributing to low production and productivity in horsegram cultivation, thereby enhancing overall crop yields and farmer livelihoods. (Yassin *et al*., 2023) [44]. The traditional method of weed control, such as hand weeding, indeed remains effective but can be expensive and time-consuming, especially in regions experiencing continuous rainfall and labor shortages during critical stages of crop-weed competition, particularly in the *kharif* season. Mechanical weeding also faces similar challenges and may not always be feasible or cost-effective. In such scenarios, the judicious use of herbicides offers a viable alternative for weed management in horsegram cultivation. Herbicides can effectively control weeds, improving crop yield by minimizing competition for essential resources like water, nutrients and sunlight. Additionally, by reducing the need for manual labor in weed control, herbicide use frees up significant labor resources that can be redirected towards other productive activities, thereby enhancing overall farm efficiency and productivity.

Materials and Methods

In the *kharif* season of 2023, a field experiment was carried out at the Instructional Cum Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.). The crop was sown using 20 kg of seed ha^{-1} at a depth of 30 cm and it was fertilised with the required amount of nutrients (20:50:20 kg ha^{-1}). Before being sown, horsegram seeds were treated with rhizobium culture and bavistin. From the moment of sowing, the crop was irrigated to ensure uniform germination. The day after the seeds were sown, the soil was treated with pre-emergence herbicides and at 25 DAS, post-emergence spraying was done. For the crop, all herbicides were applied with a knapsack sprayer fitted with a flat fan nozzle and 500 litres of water ha^{-1}. The treatment strategy was followed during hand weeding. The horsegram recommended cultural practices were followed during the crop-growing stage. We conducted the statistical analysis using the Gomez and Gomez approach. Whenever a statistically significant result was seen, the critical difference (CD) at the 5% probability level was determined.

Results and Discussion

Effect on crop

At 20 DAS, significantly the highest plant height, number of branches and dry matter accumulation were registered under the treatment weed free (T_9) followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre – emergence (T_2). The next best performing treatment was hand weeding at 25 DAS (T_7) which was at par with once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and weedy check (T_1). These results are in accordance with the findings of Jagadesh *et al*. (2019) and Reddy *et al.* (2020) [29]. At 40, 60 DAS & at harvest highest plant height, number of branches and dry matter accumulation were under weed free (T_9) followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS (T_6), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Next the best performing treatment was pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2) which was similar to once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and hand weeding at 25 DAS (T_7). Weedy check (T_1) had the lowest throughout all observational intervals.

Different weed management practices significantly affected the number of pods $plant^{-1}$, Pod length (cm), number of seeds pod^{-1} and test weight (g). With regards to weed management practices, highest number of pods $plant^{-1}$, Pod length (cm), number of seeds pod^{-1} and test weight (g) under weed free (T_9), followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i.

ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Next the best performing treatment was pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2) which was at par with hand weeding at 25 DAS (T_7)**,** once wheel hoeing at 25 DAS (T_5) and imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3). All the above treatments were significantly superior over the treatments of weedy check (T_1).The minimum were observed under weedy check plot (T_1). Similar findings also reported by Reddy *et al*. (2022) [25].

Data related to grain yield, stover yield, biological yield and harvest index as affected by various weed management practices on horse gram are presented in Table 4 reveals that amongst weed management practices, highest grain yield, stover yield, biological yield and harvest index were recorded under weed free (T_9) followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Treatment pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2) were at par to each other once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and hand weeding at 25 DAS (T_7). All weed management treatments were significantly superior over the treatments of weedy check (T_1). The increase in yield might be attributed due to better plant growth, higher translocation of photosynthates, better yield attributing characters are higher weed control efficiency. All these parameters are reflecting in higher yield. These results in conformity with the findings of Singh and Mohinderlal (2022) [35] and Reddy *el at*. (2022) [25].

Table 1: Effect of integrated weed management on plant height and number of branches of horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

Treatments	Plant height (cm)				Number of branches plant^{-1}			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
T_1: Weedy check	17.02	34.76	51.21	65.02	2.23	4.12	6.54	6.38
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	18.09	37.35	56.23	71.19	2.52	5.39	8.07	7.95
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	17.11	36.28	54.29	68.92	2.27	5.27	7.84	7.72
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	18.36	38.89	58.24	74.26	2.59	5.74	8.71	8.59
T_5: Once wheel hoeing at 25 DAS	17.19	36.79	55.25	69.56	2.26	5.22	7.72	7.59
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	18.65	39.42	59.56	75.03	2.55	5.65	8.54	8.44
T_7: Hand weeding at 25 DAS	17.24	37.02	55.78	70.12	2.29	5.32	7.95	7.84
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Hand weeding 25 DAS	18.94	39.94	60.13	75.98	2.62	5.81	8.92	8.81
T_9: Weed free	19.96	41.23	63.46	78.56	2.80	6.05	9.39	9.31
SEm (±)	0.27	0.41	0.64	0.78	0.06	0.08	0.13	0.12
CD (5%)	0.81	1.22	1.92	2.34	0.18	0.23	0.39	0.37

Table 2: Effect of integrated weed management on plant dry weight of horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

Treatments	Plant dry weight (g plant^{-1})			
	20 DAS	40 DAS	60 DAS	At harvest
T_1: Weedy check	1.51	3.32	11.45	14.02
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	2.59	6.76	17.32	26.98
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	1.63	5.99	16.22	25.54
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	2.75	9.43	23.66	33.45
T_5: Once wheel hoeing at 25 DAS	1.56	5.73	15.78	24.32
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	2.67	9.05	22.87	32.78
T_7: Hand weeding at 25 DAS	1.75	6.32	16.86	26.19
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Hand weeding 25 DAS	2.84	9.85	24.35	34.24
T_9: Weed free	3.31	12.23	29.24	39.56
SEm (±)	0.14	0.43	0.99	1.24
CD (5%)	0.43	1.29	2.96	3.72

Table 3: Effect of integrated weed management on number of pods, pod length, number of seeds and test weight of horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

Treatments	Number of Pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Test Weight (g)
T_1: Weedy check	13.98	4.45	4.11	28.56
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	21.43	5.15	4.76	29.78
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	19.76	4.94	4.58	29.26
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	25.47	5.85	5.32	30.02
T_5: Once wheel hoeing at 25 DAS	18.98	4.86	4.47	29.07
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	24.95	5.73	5.13	30.15
T_7: Hand weeding at 25 DAS	20.65	5.03	4.69	29.53
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Hand weeding 25 DAS	26.02	5.97	5.44	30.32
T_9: Weed free	29.05	6.45	6.38	30.70
SEm (±)	0.89	0.12	0.11	0.60
CD (5%)	2.68	0.35	0.32	1.74

Table 4: Effect of integrated weed management on grain yield, stover yield, biological yield and harvest index of horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

Treatments	Grain Yield (kg ha^{-1})	Stover Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harves Index (%)
T_1: Weedy check	516.70	902.12	1418.82	36.42
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	736.35	1189.12	1925.47	38.24
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	665.71	1090.78	1756.49	37.90
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	975.73	1371.45	2347.18	41.57
T_5: Once wheel hoeing at 25 DAS	684.68	1120.12	1804.80	37.94
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	988.37	1397.45	2385.83	41.43
T_7: Hand weeding at 25 DAS	698.34	1155.45	1853.80	37.67
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Hand weeding 25 DAS	1005.37	1421.12	2426.49	41.43
T_9: Weed free	1165.71	1595.12	2760.83	42.22
SEm (±)	42.39	56.48	106.32	1.65
CD (5%)	127.10	169.34	318.76	NS

Effect on weeds

At 20, 40, 60 DAS and at harvest the percentage composition of *Cynodon dactylon* (56.28%, 42.45%, 42.51% and 40.92%, respectively) was recorded highest followed by *Cyperus* spp. (30.71%, 23.44%, 23.24% and 23.69%, respectively) and *Parthenium hysterophorus* (2.06%, 1.97%, 6.24% and 5.09%, respectively). Other weed species like *Trianthema*s pp., *Phyllanthus* spp. etc. were also observed in the experiment field in negligible quantum. The weed density and dry matter production of weeds were significantly influenced by different weed management practices during all the stages of observations. At 20 DAS, minimum weed density and dry matter production of weeds was observed under the treatment of under pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), however, it was at par to the treatment of pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2). Next superior were once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and hand weeding at 25 DAS (T_7). This might be due to effective control of first flush of weeds, which affects the plants at emergence. Similarly, at later time interval of observations *i.e.* at 40, 60 DAS and at harvest, significantly lowest weed density and dry matter production of weeds was recorded under pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Treatment pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2) next superior treatment and which was at par with once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and hand weeding at 25 DAS (T_7). Weed density and dry matter production of weeds were higher under weedy check (T_1) as compared to rest of the treatments. These results were in accordance to the findings of Sai *et al.* (2019) [33]. Weed control efficiency of different treatments at 20, 40, 60 DAS and at harvest are presented in Table 6. The results show that the treatment weed free (T_9) had the significantly highest weed control efficiency at 20 DAS, followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), however, it was at par to the treatment of pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2). Next superior were once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and hand weeding at 25 DAS (T_7). Minimum under weedy check (T_1). However, weed free (T_2) had by far the highest weed control efficiency at 40, 60, and at harvest. Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Treatment pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence (T_2) next superior treatment and which was at par with once wheel hoeing at 25 DAS (T_5), imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_3) and hand weeding at 25 DAS (T_7). Minimum was under weedy check (T_1) as compared to rest of the treatments. These results were in accordance to the findings of Sai *et al.* (2019) [33]. This might be owing to less dry matter production and population of weeds in the above treatments. The findings of Singh and Khanna (2018) [34] and Singh *et al.* (2016) are consistent with these results.

Weed index is the extent of yield reduction due to competition from weeds. Data on weed index are presented in Table 6. Weed index had remarkably influenced by weed management practices. Maximum weed index was noticed under weedy check (T_1), which was 55.67%. Similar results confirm the findings of Tiwari *et al.* (2017) [40], Sai *et al.* (2019) [33] and Yassin *et al.* (2023) [44]. Whereas, minimum weed index was registered under pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), which was at par with pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Weed index indicate the reduction in yield due to weed competition as compare to the maximum attained grain yield. The maximum weed index under control plot was due to the fact, that there was minimum grain yield reported under control plot due to high infestation of weeds at critical period of crop-weed competition, which reduces the availability of yield components.

Effect on crop economics

The data on cost of cultivation, gross return, net return and benefit: cost ratio from horse gram as affected by different weed management treatments are presented in Table 7. The highest cost of cultivation (36088.78 ₹ ha^{-1}) was recorded under weed free (T_9) due to higher cost involved in labour wages, followed by the treatment of followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8) and minimum was noted under weedy check (T_1). The highest gross return (97244.44 ₹ ha^{-1}) and net return (61155.66 ₹ ha^{-1}) were obtained under weed free (T_9), followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). The highest benefit: cost ratio (1.76) recorded under the treatment of pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). However, minimum gross return, net returns and benefit: cost ratio was obtained under weedy check (T_1). The higher benefit: cost ratio under above treatments might be due to higher seed yield coupled with lower cost of chemical treatments.

Table 5: Effect of integrated weed management on weed density and weed dry matter production of horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

Treatments	Weed density (m^{-2})				Weed dry matter production (g m^2)			
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
T_1: Weedy check	16.34	18.22	19.05	20.83	64.93	92.10	122.55	134.23
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	9.10	9.62	8.35	5.72	36.52	40.48	52.02	61.57
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	15.51	10.84	9.29	6.12	62.03	45.67	56.67	66.02
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	9.60	8.17	7.09	4.83	34.54	12.34	13.54	15.04
T_5: Once wheel hoeing at 25 DAS	14.64	10.83	8.28	5.69	63.24	46.34	58.34	68.23
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	9.26	8.03	6.34	4.11	35.05	14.04	15.91	17.81
T_7: Hand weeding at 25 DAS	14.60	10.67	8.14	5.65	61.22	43.56	54.56	63.85
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Hand weeding 25 DAS	9.25	7.51	6.02	4.06	33.92	10.06	11.23	13.43
T_9: Weed free	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEm (±)	0.38	0.31	0.24	0.18	2.21	2.45	2.68	2.82
CD (5%)	1.15	0.93	0.74	0.55	6.64	7.34	8.02	8.46

Table 6: Effect of integrated weed management on weed control efficiency and weed index of horsegram [*Macrotyloma uniflorum* (L.) Verdc.]

Treatments	Weed control efficiency (%)				Weed index (%)
	20 DAS	40 DAS	60 DAS	At harvest	
T_1: Weedy check	0.00	0.00	0.00	0.00	55.67
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	43.75	56.05	57.55	54.13	36.83
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	4.47	50.41	53.76	50.82	42.89
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	46.80	86.60	88.95	88.80	16.30
T_5: Once wheel hoeing at 25 DAS	2.60	49.69	52.39	49.17	41.27
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	46.02	84.76	87.02	86.73	15.21
T_7: Hand weeding at 25 DAS	5.71	52.70	55.48	52.43	40.09
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Hand weeding 25 DAS	47.76	89.08	90.84	89.99	13.75
T_9: Weed free	100.00	100.00	100.00	100.00	0.00
SEm (±)	2.01	2.71	2.66	2.58	-
CD (5%)	6.03	8.12	7.98	7.74	-

Table 7: Economics of horsegram [*Macrotyloma uniflorum* (L.) Verdc.] cultivation

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C ratio
T_1: Weedy check	25297.78	43591.68	18293.90	0.72
T_2: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence	27651.78	61881.11	34229.33	1.24
T_3: Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	27151.78	55983.54	28831.76	1.05
T_4: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS	29505.78	81487.02	51981.24	1.76
T_5: Once wheel hoeing at 25 DAS	28240.78	57574.47	29333.69	1.04
T_6: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + Wheel hoeing at 25 DAS	30594.78	82563.57	51968.79	1.70
T_7: Hand weeding at 25 DAS	28567.78	58756.13	30188.35	1.06
T_8: Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre – emergence + Hand weeding 25 DAS	30921.78	83982.76	53060.98	1.72
T_9: Weed free	36088.78	97244.44	61155.66	1.69

Conclusion

Weed free plot (T_9) have registered higher growth, yield attributes and yield as well as gross return followed by pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4) of *post-kharif* horsegram as compared to other weed management practices. Pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8), pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + wheel hoeing at 25 DAS (T_6) and pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4) were next best performing treatments, it had the potential to control broad spectrum of weeds *i.e.* broad, narrow leaved weeds and sedges. Weed control efficiency at harvest also recorded higher values in both the treatments. The benefit:cost ratio was higher under pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + imezathypr 10 SL @ 100 g a.i. ha^{-1} at 25 DAS (T_4). Minimum weed index was recorded under pendimethalin 30 EC @ 1000 ml a.i. ha^{-1} as pre - emergence + hand weeding 25 DAS (T_8).

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