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Synergistic effects of Pendimethalin and Imazethapyr with manual weeding on chickpea yield and economics

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Abstract

Chickpea is a crucial *rabi* pulse crop in India, yet its productivity is substantially hindered by weed competition, which can reduce crop yields by up to 90%. To evaluate effective control strategies, a field experiment was conducted during 2018 at SVPUAT in Meerut, Uttar Pradesh. The study utilized a randomized complete block design to test ten weed management treatments, encompassing mechanical, chemical, and integrated approaches. The experimental field was primarily infested with narrow-leaved weeds, including *Phalaris minor* and *Avena ludoviciana*, as well as broad-leaved weeds like *Anagallis arvensis*, *Chenopodium album*, and *Melilotus indica*.

Results demonstrated that the weedy check treatment resulted in the highest weed densities and dry weights across all growth stages. Conversely, the integrated application of Pendimethalin (1 kg a.i./ha as pre-emergence) followed by Imazethapyr (50 g a.i./ha at 20 days after sowing) and one hand weeding (at 40 days after sowing) proved highly effective. This integrated treatment significantly minimized weed density and dry weight, recording the lowest weed index (6.7%) and highest WCE (efficiency of controlling weeds) (up to 71.4%) among the chemical-based methods. Furthermore, this approach generated the highest seed (25.2 q/ha) yield, returns (net) (Rs. 100,579/ha), and Benefit Cost (4.35) ratio among the herbicidal treatments. The findings conclude that combining PE and PoE herbicides with manual weeding offers a highly efficient and economically viable solution for managing weed populations and enhancing chickpea productivity.

Keywords: Chickpea (*cicer arietinum* L.), integrated weed management, pendimethalin, imazethapyr, weed control efficiency, crop yield and economics

Introduction

Pulses are one of the most significant food crops in the India because of their higher protein content, they are the most accessible and affordable source of eatable protein and necessary amino acids for vegetarians. Pulses contain 20 to 25 per cent protein by weight which is double the protein content of wheat and three times that of rice. They include complex carbohydrates, essential vitamins, and minerals in addition to proteins. Pulses not only provide health advantages but also are good for the environment. They contribute significantly to sustainable agriculture because of their nitrogen fixing ability. Pulses can be grown in a variety of cropping systems without interfering with the primary cereal or oilseed crops, which is one of its many advantages. In world, India is the largest producer and consumer of pulses, with an area dedicated to their cultivation exceeding 28 M ha with 31% and 28% of the total area and production, respectively, it takes the top spot. Pulses productivity increased to 885 kg/ha during in 2020-21 as compared to previous years.

Among pulses, Chickpea is a major *rabi* pulse crop in India popularly called as gram being rich in protein makes it an important pulse crop. Chickpea accounts for an area of 98.86 lakh ha, with a production of 107.37 lakh tons and 1086 kg ha⁻¹ with a contribution of 34 % and 45 % in area and production, respectively in India. Madhya Pradesh remained the largest producer in India followed by Maharashtra. Uttar Pradesh is 5th largest in area and production of Chickpea (5.73 lakh ha and 7.09 lakh tons, respectively). Among the agronomic management practices, weed management is the major factor in determining the maximum potential yield of the crop. Inadequate management of weeds is one of the major factors affecting yield of pulses adversely as weeds potentially reduce the pulse crop yield up to 90% (Mishra et al. 2016). The degree

of reduction of yield depends on the density and duration of weed species and fertility status of soil. Major and strong competition weeds species found in gram field were *Asphodelus tenuifolius*, *Chenopodium album*, *Trigonella polycerata*, *C. murale*, *Convolvulus arvensis* and *Euphorbia dracunculoides* (Punia *et al.*, 2009). On an average, weeds lower crop yield by 40% to 87% (Rathod *et al.*, 2017). A thorough understanding of the weed populations present in the field is necessary to choose when to control weeds. Proper weed management operations like timing and ways of weed control can increase the potential of production in the chickpea by minimizing the yield reduction. Among different weed management options, manual and mechanical weed management practices are laborious, time consuming and less efficient. Thus to control weeds efficiently, chemical weed management must be implemented immediately in place of the expensive human mechanical method (Marwat *et al.* 2003). Hence, research was conducted to study the Effect of different weed management practices on growth and yield of Chickpea (*Cicer arietinum* L.).

Materials and Methods

The experiment entitled “Synergistic Effects of Pendimethalin and Imazethapyr with Manual Weeding on Chickpea Yield and Economics” was conducted during 2018 at SVPUAT, Meerut (U.P.) located in IGP (Indian Gangetic plains) of Western UP which is located at 29° 40' Northern latitude, 77° 42' Eastern longitude with 237 metres of elevation above the MSL. The soil of experimental site was sandy loam in texture, low in available N (171.1 kg ha⁻¹) and SOC (0.47 %), medium in available P (16.1 kg ha⁻¹), K (225.2 kg ha⁻¹) and pH (7.82). The experiment was laid out in randomised complete block design comprising of 10 weed management practices involving mechanical, chemical and integrated practices to control weeds in chickpea. The treatments are T₁: Control (Weedy check); T₂: Weed free; T₃: One hand weeding 20 DAS; T₄: Two hand weeding at 20 and 40 DAS; T₅: Pendimethalin 1 kg a.i./ha Pre emergence (PE); T₆: Pendimethalin 1 kg a.i./ha PE + one hand weeding at 20 DAS; T₇: Imazethapyr 50 g a.i./ha Post emergence (PoE) (20 DAS); T₈: Imazethapyr 50 g a.i./ha 20 DAS + one hand weeding 40 DAS; T₉: Pendimethalin 1 kg a.i./ha PE + Imazethapyr 50 g a.i./ha 20 DAS; T₁₀: Pendimethalin 1 kg a.i./ha PE + Imazethapyr 50 g a.i./ha 20 DAS + one hand weeding 40 DAS. The various observations recorded on weed flora, growth and yield of chickpea during the course of investigation to study the effectiveness of different treatments are subjected to statistical analysis as given by Gomez and Gomez (1984).

Results

Common weed flora of experimental field during chickpea crop season

The experimental field was infested with both grassy and broad leaved weeds. The major weeds species of chickpea were *A. ludoviciana*, *P. minor* among the monocot weeds. Field was also infested with perennial grass such as *C. dactylon* L. *A. arvensis*, *C. album*, *M. indica*, *F. parviflora*, *L. aphaca*, *M. alba* were among dicot weeds and sedges viz., *C. rotundus* L. etc.

Effect of weed management practices on weed density

The data pertaining to narrow leaved, broad leaved and total weed density in chickpea crop is presented in table 1-3.

Narrow leaved weed density

Narrow leaved weed density (*P. minor* and *A. ludoviciana*) was significantly affected by various weed management practices. Among different weed control treatments, the highest density was contributed by *P. minor* (4.7, 4.9 & 4.3 m⁻²) and *A. ludoviciana* (5.5, 5.8 & 5.0 m⁻²) found in weedy check at 30, 60, and 90 DAS

respectively. However, among the herbicide treatments, significantly lower weed density of *Phalaris minor* (3.5, 3.3 and 2.8 m⁻²) and *A. ludoviciana* (4.6, 3.8 and 3.4 m⁻²) recorded with PE application of Pendimethalin+Imazethapyr (20 DAS)+one hand weeding (40 DAS) and significantly on par with PE application of Pendimethalin+Imazethapyr(20 DAS) at 30, 60, and 90 DAS respectively

Broad leaved weed density

Anagallis arvensis, *Chenopodium album* and *Melilotus indica* were the major broad leaved weeds found in the field. Significantly higher density of *A. arvensis* (5.4, 4.6 & 4.2 m⁻²), *C. album* (5.6, 5.2 & 4.7 m⁻²) and *M. indica* (5.1, 4.7 & 4.2 m⁻²) were found in weedy check at 30, 60 and 90 DAS respectively.

Among the weedicide treatments, density of *A. arvensis* (3.9, 3.1 and 2.9), *C. album* (5.0, 3.2 and 3.0) and *M. indica* (3.9, 3.0 and 2.5) were found significantly lower under the PE application of Pendimethalin+Imazethapyr (20 DAS)+one hand weeding (40 DAS) at 30, 60 and 90 DAS, respectively. Treatment with PE application of Pendimethalin+Imazethapyr (20 DAS) (3.6 m⁻²) remained statistically on par with treatment T₁₀ throughout the stages of crop growth.

Density of other weeds and total weed density:

Other weed density

Results revealed that significantly higher density of other weeds (4.8, 4.6 & 4.4 m⁻²) was observed in weedy check treatments at 30, 60 & 90 DAS, respectively. Among the different chemical based weed management treatments, treatment with PE application of Pendimethalin+Imazethapyr (20 DAS) +one hand weeding (40 DAS) significantly controlled the other weeds population (4.0, 2.8 and 2.5) as compared to rest of the treatments except with the treatment, PE application of Pendimethalin+Imazethapyr (20 DAS) (4.0, 3.0 and 2.6) at 30, 60 and 90 DAS, respectively. However, at 90 DAS, Imazethapyr (20 DAS) +one hand weeding (40 DAS) was also remained on par with the T₁₀ (2.7 m⁻²).

Total weed density

Total weed density was significantly affected by different weed management practices. Where weedy check recorded significantly higher total weed density as compared to rest of the treatments. However, treatment with PE application of Pendimethalin+Imazethapyr (20 DAS)+one hand weeding (40 DAS) recorded significantly lower total weed density (7.7, 6.6 and 5.8) as compared to rest of the treatments except being on par with PE application of Pendimethalin+Imazethapyr (20 DAS) (8.3, 7.0 and 6.7) and Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS) (8.7, 7.8 and 7.3) at 30, 60 and 90 DAS, respectively.

Effect of weed management practices on weed dry weight

The data related to dry weight of narrow leaved, broad leaved and total weeds in chickpea crop is presented in table 4-6.

Narrow leaved weed dry weight

P. minor and *A. ludoviciana* dry weight as affected by various treatments inclusive of weed management practices. Among different weed management treatments, weedy check recorded significantly higher weed dry weight (*Phalaris minor* and *Avena ludoviciana*) as compared to rest of the treatments. Whereas, among chemical based weed management practices, integrated weed management practice i.e., PE application of Pendimethalin+Imazethapyr (20 DAS) +one hand weeding (40 DAS) recorded significantly lower weed dry weight as compared to other treatments. However, it remained on par with PE application of Pendimethalin+Imazethapyr (20 DAS) and

Imazethapyr (20 DAS) +one hand weeding (40 DAS) at 30, 60 and 90 DAS, respectively.

Broad leaved dry weight of weed

Similar to narrow leaved weed dry weight, significantly lower dry weight of broad leaved weeds was recorded with the PE application of Pendimethalin+Imazethapyr (20 DAS) +one hand weeding (40 DAS) followed by PE application of Pendimethalin+Imazethapyr (20 DAS) and Imazethapyr (20 DAS) +one hand weeding (40 DAS) at 30, 60 and 90 DAS. However, significantly higher broad leaved weed dry weight was recorded under weedy check and lower was recorded under weed free check.

Other weed dry weight

PE application of Pendimethalin+Imazethapyr (20 DAS) +one hand weeding (40 DAS) successfully controlled the other weed density as compared to other treatments which recorded significantly lower other weed dry weight as compared to rest of the treatments except being statistically on par with PE application of Pendimethalin+Imazethapyr (20 DAS) at 30, 60 and 90 DAS.

Total weed dry weight

Total weed dry weight was significantly lower (5.7, 7.2 and 7.9 g m⁻²) with the application of Pendimethalin as Pre emergence followed by Imazethapyr spray at 20 DAS and one hand weeding at 40 DAS which was followed by PE application of Pendimethalin+Imazethapyr (20 DAS) (6.0, 7.6 and 8.2 g m⁻²) and Imazethapyr(20 DAS)+one hand weeding (40 DAS) at 30, 60 and 90 DAS but significantly higher over rest of the treatments.

Weed index (%) and Weed control efficiency (WCE %)

Weed management practices Significantly affected the weed

index. Among the treatments, significantly the highest weed index (50.7 %) was found in weedy check at harvest. Among the different herbicide treatments, highest weed index (40.3 %) was observed with the Post emergence application of Imazethapyr (20 DAS), which was statistically at par with Pre emergence soil application of Pendimethalin (36.6 %) at harvest, respectively. The significantly lowest weed index (6.7 %) was found with the PE application of Pendimethalin+Imazethapyr (20 DAS)+one hand weeding (40 DAS), which was followed by PE application of Pendimethalin+Imazethapyr(20 DAS) (13.4%) as compared to rest of the herbicide based treatments.

Significantly higher weed control efficiency (100.0 %) was found in weed free treatment at 60, 90 DAS, respectively. Whereas, significantly higher weed control efficiency (69.5 %) and (71.4 %) was recorded with the PE application of Pendimethalin+Imazethapyr (20 DAS)+one hand weeding (40 DAS), which was statistically at par with two hand weeding treatment at 20 and 40 DAS (69.2 and 70.7 %), PE application of Pendimethalin+Imazethapyr(20 DAS) (62.2 and 68.1 %) and Imazethapyr (20 DAS)+one hand weeding (40 DAS) (64.2 and 65.7 %) at 60 and 90 DAS, respectively.

The data regarding to the effect of different weed management practices on grain and straw yield are shown in Table 7. Data revealed that significantly highest grain yield (27.0 and 36.7 q ha⁻¹, respectively) was recorded under weed free treatment. Whereas, among different chemical based weed management treatments, significantly higher grain yield and straw yield (23.4 and 35.6 q ha⁻¹, respectively) was recorded with the PE application of Pendimethalin+Imazethapyr (20 DAS)+one hand weeding (40 DAS) which was statistically at par with PE application of Pendimethalin+Imazethapyr (20 DAS) (23.4 and 33.5 q ha⁻¹, respectively). However, harvest index did not differ significantly among the weed management treatments.

Table 1: Effect of weed management practices on density of narrow leaf weeds in chickpea at different stages

Treatments	Density (Number per m ²)					
	<i>Phalaris minor</i>			<i>Avena ludoviciana</i>		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T ₁	4.7(20.6)	4.9(22.8)	4.3(17.6)	5.5(28.8)	5.8(32.8)	5.0(24.4)
T ₂	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
T ₃	2.9(7.5)	4.1(9.6)	3.8(9.1)	3.4(10.7)	4.7(14.7)	4.3(13.3)
T ₄	2.9(7.4)	1.9(7.6)	1.7(6.0)	3.4(10.6)	2.2(9.7)	2.0(8.1)
T ₅	4.3(11.5)	4.0(10.8)	3.7(9.6)	4.9(15.2)	4.5(14.6)	4.2(11.5)
T ₆	4.0(9.1)	3.7(10.6)	3.4(5.4)	4.9(13.7)	4.3(12.9)	3.9(7.6)
T ₇	4.2(11.8)	3.8(9.3)	3.6(8.8)	5.0(13.8)	4.4(13.5)	4.1(10.7)
T ₈	4.0(9.7)	3.6(7.9)	3.2(6.3)	4.8(11.9)	4.2(10.6)	3.8(8.3)
T ₉	3.6(9.3)	3.4(6.3)	2.9(5.7)	4.7(9.8)	3.9(7.6)	3.5(7.0)
T ₁₀	3.5(7.6)	3.3(5.7)	2.8(3.8)	4.6(8.3)	3.8(7.1)	3.4(5.4)
SEm±	0.2	0.1	0.1	0.2	0.1	0.1
CD (P= 0.05)	0.5	0.3	0.3	0.6	0.4	0.3

Original values in parenthesis. Values are square root/(X + 1.0)

T₁: Weedy check, T₂:Weed free, T₃:One hand weeding (20 DAS), T₄:Two hand weeding (20 and 40 DAS), T₅:Pendimethalin 1 kg a.i./ha Pre- emergence, T₆:Pendimethalin 1 kg a.i./ha Pre emergence+one hand weeding (20 DAS), T₇:Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T

₈:Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS), T₉:Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀:Pendimethalin 1 kg a.i./ha Pre emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

Table 2: Effect of weed management practices on density of broad leave weeds in chickpea at different stages

Treatments	Density (Number per m ²)								
	<i>Anagallis arvensis</i>			<i>Chenopodium album</i>			<i>Melilotus indica</i>		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T ₁	5.4(28.5)	4.6(20.4)	4.2(16.7)	5.6(30.4)	5.2(25.6)	4.7(20.8)	5.1(24.7)	4.7(20.8)	4.2(16.8)
T ₂	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
T ₃	3.6(11.7)	4.2(16.7)	3.7(14.4)	3.8(13.6)	4.2(17.4)	3.9(15.3)	3.1(8.9)	3.9(11.6)	3.4(10.8)
T ₄	3.6(11.8)	2.2(10.8)	2.0(10.1)	3.8(13.7)	2.3(13.2)	2.0(15.9)	3.1(8.8)	2.1(8.5)	1.8(7.1)
T ₅	4.8(18.3)	3.9(15.1)	3.5(12.6)	5.4(20.1)	4.1(16.6)	3.7(13.0)	4.5(12.4)	3.8(11.8)	3.3(10.9)
T ₆	4.6(15.4)	3.6(13.3)	3.3(10.0)	5.1(17.4)	3.8(14.3)	3.5(14.4)	4.3(11.8)	3.6(10.7)	2.9(6.5)
T ₇	4.8(16.7)	3.8(14.2)	3.4(11.7)	5.3(21.6)	3.9(17.5)	3.6(12.3)	4.4(12.6)	3.6(10.3)	3.1(9.6)
T ₈	4.4(13.6)	3.5(10.6)	3.2(10.3)	5.1(15.8)	3.7(12.7)	3.4(13.7)	4.1(12.7)	3.4(8.9)	2.6(7.0)
T ₉	4.1(11.5)	3.4(8.7)	3.1(8.0)	5.0(14.2)	3.6(10.8)	3.2(10.4)	4.0(11.1)	3.2(6.8)	2.6(5.9)
T ₁₀	3.9(10.3)	3.1(8.2)	2.9(6.2)	5.0(12.6)	3.2(9.3)	3.0(8.9)	3.9(9.4)	3.0(6.3)	2.5(4.2)
SEm±	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1
CD (P= 0.05)	0.5	0.3	0.3	0.6	0.4	0.3	0.6	0.3	0.3

Original values in parenthesis. Values are square root $\sqrt{X + 1.0}$

T₁: Weedy check, T₂:Weed free, T₃:One hand weeding (20 DAS), T₄:Two hand weeding (20 and 40 DAS), T₅:Pendimethalin 1 kg a.i./ha Pre- emergence, T₆:Pendimethalin 1 kg a.i./ha Pre emergence+one hand weeding (20 DAS), T₇:Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T₈:Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS), T₉:Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀:Pendimethalin 1 kg a.i./ha Pre emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

Table 3: Effect of weed management practices on density of other weeds, total weeds (m⁻²) and weed index in chickpea at different stages

Treatments	Density (Number per m ²)						Weed index (%)
	Other weed			Total weed			
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	At harvest
T ₁	4.8(22.4)	4.6(20.6)	4.4(18.6)	12.5(155.4)	12.0(143.0)	10.7(114.9)	50.7
T ₂	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	0.0
T ₃	3.3(9.9)	3.7(13.4)	3.4(11.4)	7.9(62.3)	9.2(83.4)	8.7(74.3)	47.7
T ₄	3.3(9.8)	2.0(9.0)	1.8(7.4)	7.9(62.1)	7.7(58.8)	7.5(54.6)	41.0
T ₅	4.6(13.0)	3.5(13.6)	3.2(10.5)	9.6(90.5)	9.1(82.5)	8.3(68.1)	36.6
T ₆	4.3(12.2)	3.3(11.0)	2.9(6.4)	9.0(79.6)	8.6(72.8)	7.2(50.3)	19.4
T ₇	4.3(11.9)	3.4(11.8)	3.0(10.2)	9.5(88.4)	8.8(76.6)	8.0(63.3)	40.3
T ₈	4.2(11.5)	3.1(9.7)	2.7(7.2)	8.7(75.2)	7.8(60.4)	7.3(52.8)	23.1
T ₉	4.0(11.4)	3.0(7.8)	2.6(6.7)	8.3(67.3)	7.0(48.0)	6.7(43.7)	13.4
T ₁₀	4.0(10.8)	2.8(7.1)	2.5(4.1)	7.7(59.0)	6.6(43.7)	5.8(32.6)	6.7
SEm±	0.1	0.1	0.1	0.9	0.7	0.6	1.3
CD (P= 0.05)	0.4	0.3	0.3	2.4	1.9	1.7	3.8

Original values in parenthesis. Values are square root $\sqrt{X + 1.0}$

T₁: Weedy check, T₂:Weed free, T₃:One hand weeding (20 DAS), T₄:Two hand weeding (20 and 40 DAS), T₅:Pendimethalin 1 kg a.i./ha Pre- emergence, T₆:Pendimethalin 1 kg a.i./ha Pre emergence+one hand weeding (20 DAS), T₇:Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T₈:Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS), T₉:Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀:Pendimethalin 1 kg a.i./ha Pre emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

Table 4: Effect of weed management practices on dry weight of narrow leaf weeds (g m⁻²) in chickpea at different stages

Treatments	Dry weight (g m ²)					
	<i>Phalaris minor</i>			<i>Avena ludoviciana</i>		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T ₁	3.2(9.4)	4.2(17.4)	4.3(18.6)	3.9(14.4)	5.6(30.6)	5.8(32.8)
T ₂	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
T ₃	2.3(4.5)	3.2(10.5)	3.5(11.3)	2.8(6.9)	3.9(14.4)	4.2(16.3)
T ₄	2.3(4.4)	2.5(5.4)	2.8(6.7)	2.8(7.0)	3.1(8.9)	3.4(10.3)
T ₅	2.7(6.2)	3.1(8.8)	3.3(9.8)	3.0(8.2)	4.1(15.8)	4.3(17.5)
T ₆	2.5(5.1)	2.9(7.6)	3.1(8.9)	2.9(7.6)	3.8(13.4)	4.0(15.4)
T ₇	2.6(5.8)	3.0(8.2)	3.2(9.6)	3.0(7.8)	3.9(14.6)	4.2(16.7)
T ₈	2.4(4.8)	2.8(7.1)	3.0(8.5)	2.9(7.2)	3.7(12.9)	3.9(14.6)
T ₉	2.3(4.1)	2.8(6.8)	2.9(7.6)	2.8(6.7)	3.6(12.3)	3.9(14.3)
T ₁₀	2.2(3.9)	2.7(6.2)	2.8(7.4)	2.7(6.3)	3.4(10.7)	3.5(12.4)
SEm±	0.1	0.1	0.2	0.1	0.2	0.2
CD (P= 0.05)	0.3	0.4	0.5	0.3	0.5	0.6

Original values in parenthesis. Values are square root $\sqrt{X + 1.0}$

T₁: Weedy check, T₂:Weed free, T₃:One hand weeding (20 DAS), T₄:Two hand weeding (20 and 40 DAS),

T₅:Pendimethalin 1 kg a.i./ha Pre- emergence, T₆:Pendimethalin 1 kg a.i./ha Pre emergence+one hand weeding (20 DAS), T₇:Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T₈:Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40

DAS), T₉:Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀:Pendimethalin 1 kg a.i./ha Pre emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

Table 5: Effect of weed management practices on dry weight of broad leaf weeds (g m⁻²) in chickpea at different stages

Treatments	Dry weight (g m ⁻²)								
	<i>Anagallis arvensis</i>			<i>Chenopodium album</i>			<i>Melilotus indica</i>		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T ₁	4.1(15.8)	5.7(31.6)	5.8(33.4)	4.5(19.8)	5.9(34.8)	6.1(36.4)	3.6(11.9)	5.2(26.7)	5.4(28.4)
T ₂	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
T ₃	3.1(8.8)	3.9(14.7)	4.2(16.8)	3.4(10.8)	4.6(20.7)	4.8(22.6)	2.4(5.1)	3.6(11.8)	3.8(13.5)
T ₄	3.1(8.7)	3.3(10.2)	3.7(12.4)	3.4(10.9)	3.8(13.8)	4.1(15.7)	2.4(5.0)	2.7(6.3)	3.1(8.6)
T ₅	3.0(8.2)	4.0(14.8)	4.2(16.8)	3.0(8.2)	3.9(14.3)	4.2(16.5)	2.8(6.8)	3.7(12.6)	3.9(14.9)
T ₆	3.0(7.9)	3.6(12.2)	3.9(14.3)	2.9(7.4)	3.7(12.5)	3.9(14.9)	2.6(5.9)	3.4(10.7)	3.7(12.4)
T ₇	2.9(7.7)	3.8(13.4)	4.1(15.9)	3.0(7.9)	3.8(13.7)	4.1(15.6)	2.7(6.2)	3.5(11.3)	3.8(13.2)
T ₈	2.8(6.9)	3.5(11.3)	3.8(13.4)	2.8(6.8)	3.6(12.0)	3.9(14.3)	2.6(5.6)	3.2(9.2)	3.6(11.7)
T ₉	2.7(6.4)	3.4(10.5)	3.7(12.4)	2.7(6.3)	3.6(11.8)	3.8(13.5)	2.5(5.2)	3.1(8.6)	3.4(10.7)
T ₁₀	2.6(6.0)	3.3(9.7)	3.5(11.5)	2.6(5.7)	3.5(11.2)	3.8(13.4)	2.4(4.8)	2.8(7.1)	3.2(9.6)
SEm±	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1
CD (P= 0.05)	0.4	0.3	0.4	0.6	0.5	0.4	0.3	0.4	0.3

Original values in parenthesis. Values are square root $\sqrt{(X + 1.0)}$

T₁: Weedy check, T₂:Weed free, T₃:One hand weeding (20 DAS), T₄:Two hand weeding (20 and 40 DAS), T₅:Pendimethalin 1 kg a.i./ha Pre- emergence, T₆:Pendimethalin 1 kg a.i./ha Pre emergence+one hand weeding (20 DAS), T₇:Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T

₈:Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS), T₉:Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀:Pendimethalin 1 kg a.i./ha Pre emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

Table 6: Effect of weed management practices on dry weight of other weeds, total weed (g m⁻²) and weed control efficiency in chickpea

Treatments	Dry weight (g m ⁻²)						Weed control efficiency (%)	
	Other weed			Total weed			60 DAS	90 DAS
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS		
T ₁	3.8(13.7)	5.4(28.8)	5.6(30.2)	7.7 (85.0)	12.5 (169.9)	13.4 (179.8)	0.0	0.0
T ₂	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100.0	100.0
T ₃	2.6(5.7)	3.8(13.6)	4.1(15.4)	6.5 (41.8)	9.3 (85.7)	9.8 (95.9)	49.5	48.6
T ₄	2.6(5.6)	2.9(7.7)	3.3(9.7)	6.5 (41.6)	4.2 (52.3)	7.9 (63.4)	69.2	70.7
T ₅	3.1(8.4)	3.4(10.9)	3.7(12.7)	6.8 (46.0)	8.8 (77.2)	9.4 (88.2)	54.5	55.6
T ₆	2.9(7.5)	3.1(8.9)	3.4(10.6)	6.4 (41.4)	8.1 (65.3)	8.7 (76.5)	61.5	63.3
T ₇	3.0(7.9)	3.3(9.7)	3.5(11.4)	6.6 (43.3)	8.4 (70.9)	9.1 (82.4)	58.3	59.5
T ₈	2.8(7.1)	3.0(8.3)	3.3(10.1)	6.2 (38.4)	7.8 (60.8)	8.5 (72.6)	64.2	65.7
T ₉	2.8(6.8)	2.9(7.5)	3.2(9.5)	6.0 (35.5)	7.6 (57.5)	8.2 (68.0)	66.2	68.1
T ₁₀	2.7(6.2)	2.8(6.8)	3.1(8.4)	5.7 (32.9)	7.2 (51.7)	7.9 (62.7)	69.5	71.4
SEm±	0.1	0.1	0.1	0.5	0.7	0.8	1.9	2.1
CD (P= 0.05)	0.3	0.4	0.3	1.5	2.2	2.5	5.7	6.1

Original values in parenthesis. Values are square root $\sqrt{(X + 1.0)}$

T₁: Weedy check, T₂:Weed free, T₃:One hand weeding (20 DAS), T₄:Two hand weeding (20 and 40 DAS), T₅:Pendimethalin 1 kg a.i./ha Pre- emergence, T₆:Pendimethalin 1 kg a.i./ha Pre emergence+one hand weeding (20 DAS), T₇:Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T

₈:Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS), T₉:Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀:Pendimethalin 1 kg a.i./ha Pre emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

Table 7: Effect of weed management practices on grain, straw yield (q ha⁻¹) and economics of chickpea

Treatments	Yield (q ha ⁻¹)		Harvest Index	Gross return (Rs. ha ⁻¹)	Net return (Rs. ha ⁻¹)	B: C ratio
	Grain	Straw				
T ₁	13.4	22.6	37.2	72760	47386	2.87
T ₂	27.0	36.7	42.4	138540	106796	4.36
T ₃	14.2	22.8	38.4	76000	48806	2.79
T ₄	16.0	24.6	39.4	84640	55626	2.92
T ₅	17.2	26.4	39.4	91000	63843	3.35
T ₆	21.8	31.7	40.8	113780	84803	3.93
T ₇	16.2	25.4	38.9	86200	59782	3.26
T ₈	20.8	31.0	40.1	109280	81042	3.87
T ₉	23.4	33.5	41.1	121660	93459	4.31
T ₁₀	25.2	35.6	41.4	130600	100579	4.35
SEm±	0.7	1.1	1.4	3753	2763	0.21
CD (P= 0.05)	2.1	3.0	NS	10856	7994	0.63

Original values in parenthesis. Values are square root $\sqrt{(X + 1.0)}$

T₁: Weedy check, T₂: Weed free, T₃: One hand weeding (20 DAS), T₄: Two hand weeding (20 and 40 DAS), T₅: Pendimethalin 1 kg a.i./ha Pre-emergence, T₆: Pendimethalin 1 kg a.i./ha Pre-emergence+one hand weeding (20 DAS), T₇: Imazethapyr 50 g a.i./ha Post-emergence (20 DAS), T₈: Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS), T₉: Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS), T₁₀: Pendimethalin 1 kg a.i./ha Pre-emergence+Imazethapyr 50 g a.i./ha (20 DAS)+one hand weeding (40 DAS)

The highest gross return (Rs. 138540 ha⁻¹), net returns (Rs. 106796 ha⁻¹) and BC ratio (4.36) were found in weed free treatment which was higher than other treatments. Among the herbicidal treatments, the highest gross return (130600 Rs. ha⁻¹), net returns (100579 Rs. ha⁻¹) and BC ratio (4.35) was recorded with the application of Pendimethalin 1 kg a.i./ha Pre-emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS) which was statistically at par (121660, 93459 Rs. ha⁻¹ and 4.31, respectively) with Pendimethalin 1 kg a.i./ha Pre-emergence + Imazethapyr 50 g a.i./ha (20 DAS) and Pendimethalin 1 kg a.i./ha Pre-emergence+ one hand weeding (20 DAS) (113780, 84803 Rs. ha⁻¹ and 3.93, respectively).

Discussion

The data on total weed density and their dry weight as affected by different treatments indicated that in general, weed population and dry weight increased up to 60 DAS, and thereafter showed decreasing trend. This was due to the fact that at later stage most of the weed growth ceased because of leaf senescence, and thereby resulted in reduction in dry matter accumulation of weeds. Higher infestation of weeds under weedy check were also reported by Singh *et al.* (2017).

Weed density

The data clearly indicate that the weedy check treatment resulted in the highest weed densities across all categories (narrow-leaved, broad-leaved, and total weeds) at 30, 60, and 90 DAS. This underscores the necessity of effective weed management practices to reduce weed competition and enhance crop performance. Among the herbicide treatments, the combination of Pendimethalin (1 kg a.i./ha) as a pre-emergence herbicide, followed by Imazethapyr (50 g a.i./ha) at 20 DAS and one hand weeding at 40 DAS, consistently resulted in significantly lower weed densities. This integrated approach proved to be the most effective in managing both narrow-leaved and broad-leaved weeds, maintaining weed densities at manageable levels throughout the crop growth stages.

Weed dry weight

The dry weight of weeds followed a similar trend to weed density, with the weedy check treatment showing the highest values. The integrated weed management practice (Pendimethalin+Imazethapyr+hand weeding) again demonstrated superior efficacy in reducing weed biomass. This reduction in weed dry weight is crucial as it directly correlates with reduced competition for resources such as nutrients, water, and light, thereby promoting better crop growth and yield.

Weed index and weed control efficiency

The weed index and weed control efficiency (WCE) metrics further validate the effectiveness of the integrated weed management approach. The lowest weed index and highest WCE were observed in the Pendimethalin + Imazethapyr + hand weeding treatment, indicating its superior ability to suppress weed

growth and enhance crop productivity. The weed-free treatment, while showing the highest WCE, is not always practical or cost-effective for farmers. Therefore, the integrated approach offers a balanced solution, combining chemical and manual methods to achieve optimal weed control.

Crop yield and economics

The impact of weed management on crop yield was evident, with the highest grain and straw yields recorded under the weed-free treatment. However, among the chemical-based treatments, the integrated approach (Pendimethalin+Imazethapyr+hand weeding) resulted in significantly higher yields compared to other treatments. This suggests that effective weed management not only reduces weed pressure but also translates into tangible yield benefits. The harvest index, which did not differ significantly among treatments, indicates that the proportion of grain to total biomass remained consistent, further emphasizing that yield improvements were primarily due to better weed control.

In weed management practices the highest cost of cultivation (₹ 31744 ha⁻¹) was recorded under weed free treatment due to higher labor charge and lowest cost of cultivation (₹ 25374 ha⁻¹) was observed in weedy check treatment.

Conclusion

In conclusion, the study demonstrates that an integrated weed management strategy, combining pre-emergence and post-emergence herbicides with manual weeding, is highly effective in controlling weed populations in chickpea fields. This approach not only reduces weed density and biomass but also enhances crop yield, offering a practical and efficient solution for farmers. Future research could explore the long-term sustainability of such integrated practices and their economic viability under different agro-ecological conditions.

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