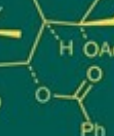
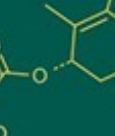


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Effect of chemical weed management practices on growth and yield of Chickpea (*Cicer arietinum* L.)

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ABSTRACT

Chickpea stands out as a vital winter (rabi) pulse crop across India, yet its total yield is severely restricted by heavy weed interference, which can trigger production losses reaching up to 90%. To identify optimal weed suppression measures, researchers conducted a field trial during the 2018 season at the Sardar Vallabhbhai Patel University of Agriculture and Technology (Meerut, Uttar Pradesh). Utilizing a randomized complete block design, the study evaluated ten specific weed control strategies, encompassing mechanical, chemical, and combined (integrated) management techniques. The experimental site experienced significant infestations from narrow-leaved grassy weeds, such as *Phalaris minor* and *Avena ludoviciana*, alongside prominent broad-leaved species including *Anagallis arvensis*, *Chenopodium album*, and *Melilotus indica*.

The findings revealed that the untreated (weedy check) plots consistently exhibited the highest weed populations and dry biomass throughout all measured growth stages. In contrast, integrating a pre-emergence application of Pendimethalin (1 kg a.i./ha) with a post-emergence spray of Imazethapyr (50 g a.i./ha at 20 days after sowing) and a single manual weeding session (at 40 days after sowing) delivered outstanding results. This comprehensive method drastically lowered both weed counts and biomass, achieving the lowest weed index (6.7%) and peak weed control efficiency (71.4%) among all herbicide-based trials. Furthermore, this integrated treatment yielded the maximum grain output (25.2 q/ha), optimal net profit (Rs. 100,579/ha), and the highest Benefit-Cost ratio (4.35). Ultimately, combining pre- and post-emergence chemical applications with targeted hand weeding provides a highly effective, profitable strategy for controlling weeds and maximizing chickpea harvests.

Keywords: Chickpea (*Cicer arietinum* L.), Integrated weed management, Pendimethalin, Imazethapyr, Weed control efficiency, Crop yield and economics

Introduction

Due to their substantial protein profile, pulses represent a crucial food category in India, offering a highly economical and readily available source of essential amino acids for the vegetarian demographic. Comprising approximately 20% to 25% protein by weight, pulses deliver twice the protein of wheat and roughly three times that of rice. Alongside protein, they furnish complex carbohydrates, vital minerals, and vitamins. Beyond human health benefits, pulse crops are environmentally advantageous; their natural nitrogen-fixing capabilities play a major role in promoting sustainable agricultural systems. Furthermore, their adaptability allows them to be seamlessly integrated into diverse cropping sequences without disrupting primary cereal or oilseed production.

Globally, India holds the leading position in both producing and consuming pulses, dedicating over 28 million hectares to their cultivation, which accounts for roughly 31% of the global area and 28% of total production. Pulse productivity saw an upward trend reaching 885 kg/ha during the 2020-21 period. Among these, chickpea (commonly known as gram) serves as a predominant winter pulse crop, highly valued for its nutritional richness. In India, chickpea cultivation spans approximately 98.86 lakh hectares, generating 107.37 lakh tons at a productivity rate of 1086 kg/ha. Madhya Pradesh leads national production, followed by Maharashtra, while Uttar Pradesh ranks fifth in both cultivation area (5.73 lakh ha) and total output (7.09 lakh tons).

A major agronomic constraint severely restricting chickpea yield potential is inadequate weed suppression. Unmanaged weeds aggressively compete for resources, potentially slashing pulse crop yields by up to 90% (Mishra *et al.*, 2016) [1]. Yield losses fluctuate depending on the duration of interference, weed density, and the soil's nutrient profile. Common dominant weed competitors in gram fields include *Asphodelus tenuifolius*, *Chenopodium album*, *Trigonella polycerata*, *C. murale*, *Convolvulus arvensis*, and *Euphorbia dracunculoides* (Punia *et al.*, 2009) [2]. On average, weed competition diminishes overall crop output by 40% to 87% (Rathod *et al.*, 2017) [3]. Implementing timely and precise weed control relies heavily on understanding the specific flora present in the field. While traditional manual or mechanical weeding practices are

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effective, they are highly labor-intensive, costly, and time-consuming. Consequently, chemical intervention offers a necessary, efficient alternative to manual labor for large-scale weed management (Marwat *et al.*, 2003) [4]. Therefore, this study was undertaken to evaluate the efficacy of diverse weed management techniques on the growth and overall productivity of Chickpea (*Cicer arietinum* L.).

Materials and methods

A field trial investigating the impact of chemical weed management on chickpea growth and yield was executed during the 2018 cropping season at the Sardar Vallabhbhai Patel University of Agriculture and Technology, situated in Meerut, Uttar Pradesh. This region falls within the Indo-Gangetic plains of Western UP (29° 40' N latitude, 77° 42' E longitude, elevation 237 m). The site's soil was categorized as sandy loam with a slightly alkaline pH (7.82). It contained low available nitrogen (171.1 kg/ha), low organic carbon (0.47%), medium available phosphorus (16.1 kg/ha), and medium potassium (225.2 kg/ha).

The experimental setup utilized a randomized complete block design featuring ten specific weed control strategies, encompassing physical, chemical, and integrated methodologies. The tested treatments were: T_1 : Control (Weedy check); T_2 : Weed free; T_3 : One hand weeding at 20 Days After Sowing (DAS); T_4 : Two hand weeding at 20 and 40 DAS; T_5 : Pendimethalin 1 kg a.i./ha Pre-emergence (PE); T_6 : Pendimethalin 1 kg a.i./ha PE + one hand weeding at 20 DAS; T_7 : Imazethapyr 50 g a.i./ha Post-emergence (PoE) at 20 DAS; T_8 : Imazethapyr 50 g a.i./ha at 20 DAS + one hand weeding at 40 DAS; T_9 : Pendimethalin 1 kg a.i./ha PE + Imazethapyr 50 g a.i./ha at 20 DAS; T_{10} : Pendimethalin 1 kg a.i./ha PE + Imazethapyr 50 g a.i./ha at 20 DAS + one hand weeding at 40 DAS.

Throughout the study, systematic observations were recorded concerning weed populations, crop growth parameters, and final yield metrics. All gathered data underwent standard statistical variance analysis procedures outlined by Gomez *et al.* (1984) [5].

Results

3.1 Common weed flora of experimental field during chick-pea crop season

The test plots faced severe infestations from both grassy (monocot) and broad-leaved (dicot) weeds. Prominent monocot species included *Avena ludoviciana* and *Phalaris minor*, alongside perennial grasses like *Cynodon dactylon* L. Dicot weeds present in the field consisted of *Anagallis arvensis*, *Chenopodium album*, *Melilotus indica*, *Fumaria parviflora*, *Lathyrus aphaca*, and *Melilotus alba*, supplemented by sedges such as *Cyperus rotundus* L.

3.2 Effect of weed management practices on weed density

Tables 1 through 3 display the documented populations of narrow-leaved, broad-leaved, and total weeds within the chickpea plots under various treatments.

3.3 Narrow leaved weed density

Different control strategies drastically altered the population density of narrow-leaved weeds (*Phalaris minor* and *Avena ludoviciana*). The unmanaged weedy check (T_1) exhibited the highest concentrations of *Phalaris minor* (4.7, 4.9, and 4.3 m²) and *Avena ludoviciana* (5.5, 5.8, and 5.0 m²) at 30, 60, and 90 DAS, respectively. In contrast, among the herbicidal approaches, applying pre-emergence Pendimethalin (1 kg a.i./ha) combined with post-emergence Imazethapyr (50 g a.i./ha at 20 DAS) and a manual weeding (at 40 DAS) successfully restricted *Phalaris minor* density to 3.5, 3.3, and 2.8 m², and *Avena ludoviciana* to 4.6, 3.8, and 3.4 m² at the respective time intervals. This integrated treatment performed comparably to the combination of solely Pendimethalin PE and Imazethapyr at 20 DAS across all intervals.

3.4 Broad leaved weed density

The major broad-leaved competitors documented were *Anagallis arvensis*, *Chenopodium album*, and *Melilotus indica*. Their densities were strongly influenced by the implemented control measures. As expected, the control group (weedy check) harbored the highest counts of *Anagallis arvensis* (5.4, 4.6, and 4.2 m²), *Chenopodium album* (5.6, 5.2, and 4.7 m²), and *Melilotus indica* (5.1, 4.7, and 4.2 m²) at 30, 60, and 90 DAS, respectively. Alternatively, the integrated application of Pendimethalin (1 kg a.i./ha PE) + Imazethapyr (50 g a.i./ha at 20 DAS) + one hand weeding (40 DAS) secured significantly lower weed counts for *A. arvensis* (3.9, 3.1, 2.9), *C. album* (5.0, 3.2, 3.0), and *M. indica* (3.9, 3.0, 2.5) at the matching growth stages. The dual herbicide treatment without hand weeding (T_9) demonstrated statistically similar broad-leaved suppression capabilities to the fully integrated T_{10} approach.

3.5 Density of other weeds and total weed density

3.5.1 Other weed density

The weedy check plots maintained the most robust population of miscellaneous weeds (4.8, 4.6, and 4.4 m²) at 30, 60, and 90 DAS. Meanwhile, the integrated T_{10} strategy (Pendimethalin PE + Imazethapyr at 20 DAS + manual weeding at 40 DAS) proved exceptional at suppressing other weed types (4.0, 2.8, and 2.5 m²), significantly outperforming most alternatives. It remained statistically equivalent to the T_9 treatment (Pendimethalin PE + Imazethapyr at 20 DAS) at 30, 60, and 90 DAS. By the 90 DAS mark, the T_8 approach (Imazethapyr at 20 DAS + hand weeding at 40 DAS) also matched the suppression efficacy of T_{10} .

3.5.2 Total weed density

Overall weed concentration was heavily dependent on the chosen intervention. While the untreated check predictably hosted the densest weed coverage, the T_{10} integrated package (Pendimethalin PE + Imazethapyr at 20 DAS + manual weeding at 40 DAS) achieved the lowest total weed densities (7.7, 6.6, and 5.8 m²) across the 30, 60, and 90 DAS intervals. This performance was statistically on par with T_9 (Pendimethalin PE + Imazethapyr at 20 DAS) and T_8 (Imazethapyr at 20 DAS + hand weeding at 40 DAS).

3.6 Effect of weed management practices on weed dry weight

Detailed records concerning the accumulated dry biomass of narrow-leaved, broad-leaved, and total weeds are outlined in Tables 4 through 6.

3.6.1 Narrow leaved weed dry weight

The biomass accumulation of *Phalaris minor* and *Avena ludoviciana* varied significantly based on the treatment. The unmanaged control plot yielded the heaviest weed dry weights. Conversely, among the chemically assisted plots, the complete integrated strategy (Pendimethalin 1 kg a.i./ha PE + Imazethapyr 50 g a.i./ha at 20 DAS + hand weeding at 40 DAS) successfully restricted biomass accumulation to the lowest levels. This treatment's efficacy was statistically equivalent to both T_9 (Pendimethalin PE + Imazethapyr at 20 DAS) and T_8 (Imazethapyr at 20 DAS + hand weeding at 40 DAS) at the 30, 60, and 90 DAS marks.

3.6.2 Broad leaved weed dry weight

Reflecting the trends observed in grassy weeds, broad-leaved dry weight was most effectively minimized by the integrated T_{10} treatment (Pendimethalin PE + Imazethapyr at 20 DAS + hand weeding at 40 DAS), closely followed by the T_9 and T_8 treatments. The weedy check produced the highest broad-leaved biomass, while the absolute weed-free control maintained zero biomass.

3.6.3 Other weed dry weight

Applying pre-emergence Pendimethalin, followed by a post-emergence Imazethapyr spray at 20 DAS, and a single hand weeding event at 40 DAS reliably curbed the dry weight of other weed varieties. This specific strategy yielded remarkably lower biomass compared to

the majority of other treatments, remaining statistically parallel only to the T_9 treatment (Pendimethalin PE + Imazethapyr at 20 DAS) across all evaluated timelines.

3.6.4 Total weed dry weight

The fully integrated T_{10} management plan yielded the smallest total weed dry weight footprint (5.7, 7.2, and 7.9 g/m²) at 30, 60, and 90 DAS, respectively. This was closely followed by T_9 (6.0, 7.6, and 8.2 g/m²) and T_8 . All these chemically supported methods provided superior biomass suppression compared to the remaining physical and partial chemical methods.

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

Weed index metrics were notably altered by the specific control methods applied. Predictably, the unmanaged control plot demonstrated the highest weed index at harvest (50.7%). Among the herbicide-centric regimens, solely utilizing Imazethapyr as a post-emergence spray at 20 DAS resulted in a high weed index (40.3%), which was statistically comparable to relying only on pre-emergence Pendimethalin (36.6%). By stark contrast, the fully integrated T_{10} regimen (Pendimethalin PE + Imazethapyr at 20 DAS + hand weeding at 40 DAS) achieved the most favorable, lowest weed index (6.7%), followed by the dual-herbicide T_9 strategy (13.4%).

Maximum weed control efficiency (100%) was strictly maintained in the weed-free plots. However, within practical management applications, the integrated T_{10} approach provided stellar WCE ratings (69.5% at 60 DAS and 71.4% at 90 DAS). This outcome was statistically competitive with dual manual weeding at 20 and 40 DAS (69.2% and 70.7%), the dual herbicide T_9 approach (62.2% and 68.1%), and the T_8 strategy (64.2% and 65.7%).

Crop yield and economics

Data highlighting grain yield, straw yield, and economic returns are consolidated in Table 7. As expected, maintaining a completely weed-free environment facilitated the highest grain (27.0 q/ha) and straw (36.7 q/ha) yields. Nevertheless, evaluating the practical chemical interventions revealed that the integrated T_{10} approach (Pendimethalin PE + Imazethapyr at 20 DAS + hand weeding at 40 DAS) generated exceptional grain and straw returns (25.2 and 35.6 q/ha, respectively), marginally outperforming the dual herbicide T_9 strategy (23.4 and 33.5 q/ha, respectively). The harvest index remained statistically uniform across all testing blocks.

From a financial perspective, the completely weed-free regimen provided maximum gross returns (Rs. 138,540/ha), net returns (Rs. 106,796/ha), and Benefit-Cost (BC) ratio (4.36). However, among the practical applied treatments, the integrated T_{10} strategy (Pendimethalin PE + Imazethapyr at 20 DAS + hand weeding at 40 DAS) led the pack with massive gross returns (Rs. 130,600/ha), peak net returns (Rs. 100,579/ha), and an exceptional BC ratio of 4.35. This economic performance was statistically matched by the T_9 dual-herbicide approach (Rs. 121,660/ha gross, Rs. 93,459/ha net, and 4.31 BC ratio) and the T_6 method (Pendimethalin PE + one hand weeding at 20 DAS).

Discussion

Analysis of overall weed populations and accumulated dry biomass revealed a general pattern: weed growth escalated until roughly 60 DAS, after which it began to decline. This phenomenon occurs because weeds naturally undergo leaf senescence during later growth phases, reducing their active dry matter accumulation. The severe weed pressure observed in the unmanaged control plots aligns with similar findings previously documented by Singh *et al.* (2017) [6].

Weed Density: The unmanaged control plots unequivocally hosted the densest weed populations across all classifications (narrow-leaved, broad-leaved, and total) at every measurement interval. This explicitly highlights the critical need for proactive weed suppression to mitigate resource competition. Among the diverse herbicide trials, integrating pre-emergence Pendimethalin (1 kg a.i./ha) with a post-emergence Imazethapyr application (50 g a.i./ha at 20 DAS) and a targeted manual weeding session (at 40 DAS) proved exceptionally capable of keeping both grass and broadleaf weed counts at minimal levels.

Weed Dry Weight: Biomass accumulation mirrored the density metrics, peaking aggressively in the untreated check plots. The T_{10} integrated management protocol once again exhibited unparalleled effectiveness in slashing weed biomass. Lowering weed dry weight is essential, as it directly translates to decreased weed-crop competition for vital sunlight, moisture, and soil nutrients, thereby fostering a healthier crop canopy.

Weed Index and Weed Control Efficiency: Both weed index and WCE parameters firmly validated the superiority of the integrated management tactic. The Pendimethalin + Imazethapyr + manual weeding package achieved a highly desirable low weed index paired with a top-tier WCE, confirming its robust capacity to arrest weed development. While a completely weed-free environment generates a perfect WCE, it is rarely feasible or economically viable for commercial farming. Thus, the integrated strategy strikes a perfect balance between chemical reliability and manual precision.

Crop Yield and Economics: Weed interference drastically dictated harvest outcomes. Though absolute weed-free plots secured top yields, the integrated chemical and physical approach (Pendimethalin + Imazethapyr + manual weeding) delivered immense, statistically comparable yield improvements over less intensive treatments. The uniform harvest index across the board confirms that yield boosts resulted directly from diminished weed pressure, not physiological alterations in the crop. Financially, maintaining weed-free conditions was the most expensive endeavor (Rs. 31,744/ha) due to intensive labor demands, whereas the untreated plot was the cheapest (Rs. 25,374/ha). The integrated approach maximized profit margins efficiently.

Conclusion

Adopting a holistic integrated weed management plan incorporating pre-emergence and post-emergence herbicide applications followed by a single physical weeding serves as an exceptionally effective method for eliminating competitive flora in chickpea cultivation. This strategy drastically curtails weed presence and biomass while simultaneously driving up crop output, providing a highly profitable and pragmatic framework for growers. Subsequent investigations should evaluate the enduring ecological sustainability and localized financial viability of these integrated protocols across diverse farming zones.

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
Weedy check	4.7(20.6)	4.9(22.8)	4.3(17.6)	5.5(28.8)	5.8(32.8)	5.0(24.4)
Weed free	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
One hand weeding (20 DAS)	2.9(7.5)	4.1(9.6)	3.8(9.1)	3.4(10.7)	4.7(14.7)	4.3(13.3)

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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
Two hand weeding (20 and 40 DAS)	2.9(7.4)	1.9(7.6)	1.7(6.0)	3.4(10.6)	2.2(9.7)	2.0(8.1)
Pendimethalin 1 kg a.i./ha Pre emergence	4.3(11.5)	4.0(10.8)	3.7(9.6)	4.9(15.2)	4.5(14.6)	4.2(11.5)
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	4.0(9.1)	3.7(10.6)	3.4(5.4)	4.9(13.7)	4.3(12.9)	3.9(7.6)
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	4.2(11.8)	3.8(9.3)	3.6(8.8)	5.0(13.8)	4.4(13.5)	4.1(10.7)
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	4.0(9.7)	3.6(7.9)	3.2(6.3)	4.8(11.9)	4.2(10.6)	3.8(8.3)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	3.6(9.3)	3.4(6.3)	2.9(5.7)	4.7(9.8)	3.9(7.6)	3.5(7.0)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	3.5(7.6)	3.3(5.7)	2.8(3.8)	4.6(8.3)	3.8(7.1)	3.4(5.4)

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
Weedy check	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)
Weed free	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)
One hand weeding (20 DAS)	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)
Two hand weeding (20 and 40 DAS)	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)
Pendimethalin 1 kg a.i./ha Pre emergence	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)
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	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)
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	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)
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	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)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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)

Table 3. Effect of weed management practices on density of other weeds, total weeds (m²) and weed index in chickpea at different stages

Treatments	Density (Number per m²)						Weed index (%) At harvest
	Other weed			Total weed			
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	
Weedy check	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
Weed free	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
One hand weeding (20 DAS)	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

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Treatments	Density (Number per m²)						Weed index (%) At harvest
	Other weed			Total weed			
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	
Two hand weeding (20 and 40 DAS)	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
Pendimethalin 1 kg a.i./ha Pre emergence	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
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	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
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	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
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	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
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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

Table 4. Effect of weed management practices on dry weight of narrow leaf weeds (g m²) 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
Weedy check	3.2(9.4)	4.2(17.4)	4.3(18.6)	3.9(14.4)	5.6(30.6)	5.8(32.8)
Weed free	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
One hand weeding (20 DAS)	2.3(4.5)	3.2(10.5)	3.5(11.3)	2.8(6.9)	3.9(14.4)	4.2(16.3)
Two hand weeding (20 and 40 DAS)	2.3(4.4)	2.5(5.4)	2.8(6.7)	2.8(7.0)	3.1(8.9)	3.4(10.3)
Pendimethalin 1 kg a.i./ha Pre emergence	2.7(6.2)	3.1(8.8)	3.3(9.8)	3.0(8.2)	4.1(15.8)	4.3(17.5)
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	2.5(5.1)	2.9(7.6)	3.1(8.9)	2.9(7.6)	3.8(13.4)	4.0(15.4)
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	2.6(5.8)	3.0(8.2)	3.2(9.6)	3.0(7.8)	3.9(14.6)	4.2(16.7)
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	2.4(4.8)	2.8(7.1)	3.0(8.5)	2.9(7.2)	3.7(12.9)	3.9(14.6)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	2.3(4.1)	2.8(6.8)	2.9(7.6)	2.8(6.7)	3.6(12.3)	3.9(14.3)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	2.2(3.9)	2.7(6.2)	2.8(7.4)	2.7(6.3)	3.4(10.7)	3.5(12.4)

Table 5. Effect of weed management practices on dry weight of broad leaf weeds (g m²) 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
Weedy check	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)
Weed free	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)
One hand weeding (20 DAS)	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)
Two hand weeding (20 and 40 DAS)	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)
Pendimethalin 1 kg a.i./ha Pre emergence	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)

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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
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	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)
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	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)
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	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)
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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)

Table 6. Effect of weed management practices on dry weight of other weeds, total weed (g m²) 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		
Weedy check	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
Weed free	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
One hand weeding (20 DAS)	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
Two hand weeding (20 and 40 DAS)	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
Pendimethalin 1 kg a.i./ha Pre emergence	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
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	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
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	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
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	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
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	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

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				
Weedy check	13.4	22.6	37.2	72760	47386	2.87
Weed free	27.0	36.7	42.4	138540	106796	4.36
One hand weeding (20 DAS)	14.2	22.8	38.4	76000	48806	2.79
Two hand weeding (20 and 40 DAS)	16.0	24.6	39.4	84640	55626	2.92

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Treatments	Yield (q ha ⁻¹)		Harvest Index	Gross return (Rs. ha ⁻¹)	Net return (Rs. ha ⁻¹)	B:C ratio
	Grain	Straw				
Pendimethalin 1 kg a.i./ha Pre emergence	17.2	26.4	39.4	91000	63843	3.35
Pendimethalin 1 kg a.i./ha Pre emergence + one hand weeding (20 DAS)	21.8	31.7	40.8	113780	84803	3.93
Imazethapyr 50 g a.i./ha Post emergence (20 DAS)	16.2	25.4	38.9	86200	59782	3.26
Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	20.8	31.0	40.1	109280	81042	3.87
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS)	23.4	33.5	41.1	121660	93459	4.31
Pendimethalin 1 kg a.i./ha Pre emergence + Imazethapyr 50 g a.i./ha (20 DAS) + one hand weeding (40 DAS)	25.2	35.6	41.4	130600	100579	4.35

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