Efficacy of different herbicides on weed suppression and productivity of chickpea (*Cicer arietinum* L.)

Abstract

A field experiment was conducted during the rabi season of 2023-24 at the Agronomy Research Farm, Nirwan University, Jaipur, Rajasthan, to evaluate the efficacy of different weed management treatments on weed suppression and chickpea productivity. The experiment, laid out in a randomized block design with ten treatments and three replications, included chemical and manual weed control methods. Treatments included Imazethapyr @ 50 g/ha at 20 DAS, Propaquizafop + Imazethapyr @ 50 g/ha at 20 DAS, Sodium Acifluorfen + Clodinafop Propargyl @ 200 g/ha at 20 DAS, Fomesafen + Fluazifop-p-butyl @ 200 g/ha at 20 DAS, Bentazon @ 750 g/ha at 30 DAS, Pendimethalin + Imazethapyr @ 750 g/ha as pre-emergence, Pendimethalin @ 750 g/ha as pre-emergence, Sulfentrazone @ 75 g/ha as pre-emergence, a weed-free control, and a weedy check. The dominant weeds identified included Chenopodium murale, Chenopodium album, Rumex dentatus, and Cynodon dactylon, reflecting the diverse weed flora. Results showed that the weed-free control achieved the lowest weed density and dry matter, yielding 2033 kg/ha of seed, closely followed by Pendimethalin + Imazethapyr @ 750 g/ha as pre-emergence at 2010 kg/ha. The weedy check had the highest weed density and dry matter, resulting in the lowest yield (633 kg/ha). Pendimethalin + Imazethapyr demonstrated superior weed control efficiency, comparable to the weed-free treatment, and achieved the highest harvest index (38.1%).

Keywords: Productivity, weed management, herbicide efficacy, weed index (WI), grassy weeds, weed control efficiency (WCE), broadleaf weeds.

Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops cultivated in semi-arid and tropical climates. It is valued for its short growth duration, high yield potential, and exceptional nutritional profile as food, feed, and forage (Singh et al., 2012). Commonly known as gram or Bengal gram and locally referred to as chana, chickpea is an essential food legume and an excellent source of animal feed. It is typically consumed in various forms: whole seeds (boiled, fried, roasted, parched, steamed, or sprouted) or as dal flour (besan). Fresh green seeds are also eaten as vegetables. Nutritionally, chickpeas are rich in protein (21.1%), carbohydrates (61.5%), fat (4.5%), vitamins, and minerals such as phosphorus (340 mg), iron (7 mg), and zinc (3 mg per100g)(Singhetal.,2012).However, its cultivation faces substantial challenges, particularly from weed competition, which can lead to severe yield losses. Globally,chickpeasrankasthethirdmostimportant legume crop after dry beans and dry peas (Kaur et al., 2020). Estimates suggest that yield reductions due to weed interference can range from 24% to as high as 88%, depending on the species and density of the weeds present during critical growth phases (35-60 days after emergence) (Sethi et al. 2021; Khan et al. 2023). Weeds are recognized as a primary biotic factor negatively affecting chickpea yield and quality. The slow early growth and short stature of chickpea plants make them particularly vulnerable to competition from weeds such as *Rumex dentatus*, *Chenopodium album*, and *Cynodon dactylon*. These species not only compete for resources but also harbour pests and diseases that can further compromise crop health. Effective weed management strategies are essential to mitigate these issues, ensuring optimal growth conditions for chickpeas. The use of post-emergence herbicides has gained traction as a preferred method for controlling weeds in chickpea fields. Unlike pre-emergence herbicides, which may not provide adequate control due to the rapid growth of weeds, post-emergence applications allow for targeted intervention after both the crop and weeds have emerged. Recent studies indicate that post-emergence herbicides, such as imazethapyr and pendimethalin, can significantly enhance weed control efficiency, with some treatments achieving efficiencies above 97% (Sethi et al. 2021).

2. MATERIAL AND METHODS

The present study was conducted during the *rabi* season of 2023-24 at Agronomy Research Farm of School of Agricultural Sciences, Nirwan University, Jaipur, Rajasthan. The farm is situated at an altitude of 231 meters above mean sea level at $26^{o}15"$ N latitude and $73^{o}00"$ E longitude. The experimental site falls under zone-IIIa of agroclimatic zone of Rajasthan characterized by alkaline soil (pH 8.2). The soil of the experimental field was low in available nitrogen (165.0 kg ha^{-1})(Subia and Asija, 1956), medium in available phosphorus (22.0 kg ha^{-1}) (Olsen *et al*. 1954) and high in available potassium (329.0 kg ha^{-1}) (Jackson, 1973). The experiment was laid out in a randomized block design with ten treatments and replicated thrice (Table 1). The variety under observation was GNG 2144. The data recorded wassubjected to analysis as prescribed by Gomez and Gomez. The statistical significance of data was assessed at 5% using F-test and means were subsequently reported (Fisher, R.A. 1950).

Table 1. Treatment details

Treatments	**Symbols**
Imazethapyr @ 50 g/ha at 20 DAS	T1
Propaquizafop + Imazethapyr @ 50 g/ha at 20 DAS	T2
Sodium acifluorfen + clodinafop propargyl @ 200 g/ha at 20 DAS	T3
Fomesafen + fluazifop-p-butyl @ 200 g/ha at 20 DAS	T4
Bentazon @ 750 g/ha at 30 DAS	T5
Pendimethalin + Imazethapyr @ 750 g/ha .as pre-emergence	T6
Pendimethalin @ 750 g/ha as pre-emergence	T7
Sulfentrazone @ 75 g/ha as pre-emergence	T8
Weed free	T9
Weedy check	T10

Weed density (No./m^2)

In each plot, species wise weed counts were recorded at 30, 60, 90 DAS and at harvest. Forestimating weed density, a quadrat (0.50 m × 0.50 m) was placed randomly at two spots ineach plot. Individual species wise counts were taken and expressed as number/m^2. The mean data were subjected to square root transformation $\sqrt{(x + 0.5)}$ to normalize their distribution(Gomez and Gomez, 1984), where ‘x’ is the original data.

Total weeds dry matter (g/m^2)

The dry weight of weeds was recorded. species wise as g/m2 at the time of removal ofweeds under 0.25 m^2 area (quadrat of 0.50 m × 0.50 m) at 30, 60, 90 DAS and at harvest.All the weeds falling within quadrate were cut close to the ground and were collected spiceswise in paper bags, then these weed samples were weighed after drying them in oven at 70^{o}C for 8 hours and data on dry matter were analyzed as per the standard procedure.

Weed control efficiency (%)

Weed control efficiency (WCE) was calculated by using the following formulasuggested by Mani *et al.* (1973):

$$WCE = \frac{DMC - DMT}{DMC} * 100$$

DMC = Dry matter weight of weeds in weedy check plot
DMT = Dry matter weight of weeds in treated plot

Weed index (%)

Weed index indicates per cent reduction in grain yield due to presence of weeds in thatparticular treatment as compared to total yield of weed free treatment and it is expressed inpercentage. Weed index was calculated by using the formula as followed given by Yadavand Mishra (1982):

$$WI(\%) = \frac{X - Y}{X} * 100$$

X = Grain yield from weed free plot (kg/ha)

Y = Grain yield from treatment for which weed index is to be worked out (kg/ha)

Result & Discussion

Weed density

Table 2. List of weed present in experimental field

Category ofweeds	BotanicalName	Family	CommonName	Local Name
BLWs	*Chenopodiummurale*L.	Chenopodiaceae	Goosefoot	Khartua
	*Chenopodiumalbum*L.	Chenopodiace.ae	Lamb’squarters	Bathua
	Rumexdentatus L.	Polygonaceae	Tootheddock	Jungalipalak

	*Melilotusalba*L.	Fabaceae	Whitesweetclover	Senji(Safed)
	*Melilotusindica*L.	Fabaceae	Yellowsweet clover	Senji(pili)
	*Convolvulusarvensis*L.	Convolvulaceae	Fieldbindweed	Hirankhuri
Grasses	*Asphodelustenuifolius*L.	Liliaceae	Wildonion	Pyaji
	*Cynodondactylon*L.	Poaceae	Bermundagrass	Dhoob

The Table 2 shows the weeds observed in the experimental field during the research, categorized into broadleaf weeds (BLWs) and grasses. The broadleaf weeds identified include *Chenopodium murale* L. and *Chenopodium album* L. both from the family Chenopodiaceae. Other BLWs include *Rumex dentatus* L., *Melilotus alba* L. and *Melilotus indica* L. and *Convolvulus arvensis* L. Among the grasses, *Asphodelus tenuifolius* L. and *Cynodon dactylon* L. were recorded. This diverse weed population reflects the ecological variability of the experimental site and provides insights into the management challenges faced during the research.

Density of dominated weed species

The density of different dominated weeds at 60 days after sowing (DAS) and at harvest was significantly influenced by various weed management treatments(Table 3). In case of *Chenopodium murale* L, the weed-free treatment (T9) consistently recorded the lowest weed density (0.71, no weed presence) at both 60 DAS and harvest, significantly differing from all other treatments. The highest density was observed in the weedy check (T10) with values of 10.73 at 60 DAS and 10.84 at harvest. Among herbicide treatments, Pendimethalin + Imazethapyr (T6) performed best, with weed densities at par with T9 at both stages (1.31 at both intervals), indicating its strong efficacy. In *Chenopodium album* L., Similarly, T9 recorded the least density (0.71) throughout, while T10 had the highest densities of 4.67 at 60 DAS and 5.79 at harvest. Among the treatments, Imazethapyr (T1) and Pendimethalin + Imazethapyr (T6) showed comparable control, (1.26 at 60 DAS in T6). In case of *Rumex dentatus*, Weed-free conditions (T9) again achieved the lowest density (0.71), while the weedy check (T10) recorded the highest (2.65 at 60 DAS and 2.93 at harvest). Among herbicidal treatments, T6 stood out with the lowest density (0.71 at 60 DAS) within the effective treatments, suggesting its superior performance. This is because, Pendimethalin, a pre-emergence herbicide, inhibits cell division and root growth in weed seeds, while

Imazethapyr, an ALS inhibitor, disrupts amino acid synthesis, effectively controlling both broadleaf and grassy weeds in fields (Bagale, 2024).

Total density of weeds

The total density of weeds at various growth stages (30 DAS, 60 DAS, 90 DAS, and at harvest) was significantly influenced by weed management treatments (Table 4). The weed-free treatment (T9) consistently recorded the lowest total weed density across all growth stages, demonstrating effective control. Among the herbicide treatments, Pendimethalin + Imazethapyr (T6) was the most effective, recording weed densities of 1.17 (1.00 weeds/m²) at 30 DAS, 1.68 (2.33 weeds/m²) at 60 DAS, and maintaining low levels of 2.11 (4.00 weeds/m²) at harvest. These values were statistically at par with T9 and significantly lower than other treatments. The weedy check (T10) showed the highest weed density across all stages, with 4.29 (18.00 weeds/m²) at 30 DAS, increasing drastically to 12.60 (158.33 weeds/m²) at harvest. Treatments such as Sodium Acetate + Clodinagan (T3) and Sulfentrazone (T8) recorded higher weed densities (e.g., T3 at 6.03 (35.88 weeds/m²) and T8 at 5.48 (29.53 weeds/m²) at harvest) and were significantly less effective compared to T6 and T9. The results indicate that Pendimethalin + Imazethapyr (T6) provides the most effective chemical weed control, with densities at par with the weed-free treatment across all stages. This combination likely leverages the pre-emergence efficacy of Pendimethalin, inhibiting weed germination, and the post-emergence action of Imazethapyr, disrupting amino acid synthesis in established weeds. In contrast, other herbicides exhibited varying degrees of efficacy, with treatments like T3 and T8 failing to suppress weed growth effectively.

Total dry matter of weeds

The results of the study on total dry matter of weeds at various growth stages influenced by weed management treatments indicate significant differences among treatments (Table 5). The highest weed dry matter was consistently observed in the weedy check (T10) across all stages, with values of 13.80 g/m² at 30 DAS, 33.25 g/m² at 60 DAS, 40.83 g/m² at 90 DAS, and 45.87 g/m² at harvest. The lowest weed dry matter was recorded in the weed-free treatment (T9), which maintained a consistent value of 0.71 g/m² across all stages. Treatments such as Pendimethalin + Imazethapyr (T6) and Imazethapyr (T1) showed relatively low weed dry matter values, which were statistically at par with each other and significantly lower than other chemical treatments. For example, at harvest, T6 recorded 3.71 g/m², while T1 recorded 5.32 g/m². The findings highlight the effectiveness of integrated or pre-emergence herbicide treatments in reducing weed biomass compared to post-emergence treatments or untreated plots. The weed-free treatment (T9) demonstrated the best control by completely suppressing weed growth, as expected. Among chemical treatments, Pendimethalin + Imazethapyr (T6) and Imazethapyr alone (T1) were highly effective in minimizing weed dry matter, likely due to their pre-emergence application and broad-spectrum activity against weeds during early growth stages.

Yield

The analysis of the yield, stover yield, and harvest index of chickpea as influenced by various weed management treatments reveals significant differences among the treatments (Table 6). The highest seed yield was achieved in the weed-free treatment (T9), with a remarkable 2033 kg/ha, closely followed by Pendimethalin + Imazethapyr (T6) at 2010 kg/ha. In terms of stover yield, T9 again led with 3283 kg/ha, while T6 recorded 3267 kg/ha. The lowest seed yield was seen in the weedy check (T10) at just 633 kg/ha, which also had the lowest stover yield of 1250 kg/ha. The harvest index was highest for T6 at 38.1%, indicating effective conversion of biomass into grain.

The results highlight the critical impact of weed management on chickpea productivity. The weed-free treatment (T9) demonstrated optimal conditions for growth, resulting in significantly higher yields across all metrics. This treatment effectively eliminated competition for resources, allowing the plants to maximize their growth potential and thus achieving the highest seed and stover yields. In contrast, the weedy check (T10) illustrates the negative consequences of uncontrolled weed growth, leading to drastically reduced yields. This stark difference emphasizes the necessity of timely weed control measures to prevent competition that can severely limit crop performance. The performance of Pendimethalin + Imazethapyr (T6) suggests that this combination is particularly effective for managing weeds while promoting high yields and stover production. Its ability to maintain a high harvest index indicates that it not only suppresses weed growth but also supports chickpea development efficiently. This aligns with findings from other studies that advocate for integrated weed management strategies to enhance crop yields and sustainability (Kumari et al., 2021; Singh et al., 2020).

Conclusion

The study concluded the significant impact of effective weed management on chickpea productivity. Among the treatments, Pendimethalin + Imazethapyr @ 750 g/ha as pre-emergence emerged as the most effective herbicidal approach, achieving weed control efficiency comparable to the weed-free treatment while minimizing weed density and dry matter accumulation. The weed-free treatment recorded the highest seed yield (2033 kg/ha), closely followed by Pendimethalin + Imazethapyr (2010 kg/ha), indicating its potential for resource-efficient weed management. Whereas, the weedy check exhibited the highest weed density and dry matter, resulting in the lowest yield (633 kg/ha), emphasizing the detrimental effects of uncontrolled weed growth. The findings highlight the critical role of integrated herbicide strategies in reducing weed competition and improving harvest index and crop yields. Incorporating pre-emergence and post-emergence herbicides in weed management programs can significantly enhance chickpea production while ensuring sustainable and efficient agronomic practices.

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Table 3. Densityofdifferentdominatedweedsasinfluencedbyvariousweedmanagementtreatments

Treatments	*Chenopodium murale* L.		*Chenopodium album* L.		*Rumex dentatus*	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
T_1:Imazethapyr50 g/ha20DAS	1.34 (1.30)	1.43 (1.55)	1.28 (1.15)	1.33 (1.27)	1.24 (1.05)	1.27 (1.12)
T_2:Propylthiouracil+Imazethapyr50g/ha20 DAS	3.96 (15.25)	4.38 (18.67)	2.81 (7.45)	2.89 (7.88)	2.35 (5.05)	2.54 (5.97)
T_3:SodiumAcetate+Clodinagan200g/ha20 DAS	4.08 (16.17)	4.53 (20.08)	3.03 (8.67)	3.08 (9.00)	1.91 (3.14)	2.59 (6.20)
T_4:Fomesafen+Fluazinam200g/ha20DAS	3.45 (11.42)	3.89 (14.62)	2.43 (5.42)	2.56 (6.05)	1.63 (2.16)	2.61 (6.30)
T_5:Bentazole750g/ha30DAS	3.66 (12.87)	3.94 (15.03)	3.09 (9.03)	3.13(9.30)	2.11(3.95)	2.12 (4.00)
T_6:Pendimethalin+Imazethapyr750g/haPE	1.31 (1.23)	1.31 (1.23)	1.26 (1.10)	1.29(1.17)	0.71 (0.00)	1.24 (1.05)
T_7:Pendimethalin750 g/haPE	1.64 (2.20)	1.96 (3.33)	1.31 (1.22)	1.34 (1.30)	1.23 (1.02)	1.28 (1.15)
T_8:Sulfentrazone75g/haPE	3.31 (10.48)	3.59 (12.40)	1.72 (2.47)	1.88 (3.05)	1.41 (1.50)	1.72 (2.47)
T_9:Weedfree	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10}:Weedycheck	10.73 (114.67)	10.84 (116.92)	4.67 (21.33)	5.79 (33.08)	2.65 (6.55)	2.93 (8.08)
S Em±	0.06	0.08	0.05	0.04	0.03	0.03
D.(P=0.05)	0.20	0..25	0.15	0.14	0.10	0.11

Table 4. Total density of weeds at various stages as influenced by weed management treatments

Treatments	Total density of weeds (No./m^2)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1:Imazethapyr50 g/ha20DAS	1.46 (1.67)	2.04 (3.67)	1.95 (3.33)	2.12 (4.00)
T_2:Propylthiouracil+Imazethapyr50g/ha20 DAS	3.48 (11.67)	5.33 (28.00)	5.46 (29.33)	5.82 (33.33)
T_3:SodiumAcetate+Clodinagan200g/ha20 DAS	3.44 (11.33)	5.40 (28.67)	5.67 (31.67)	6.03 (35.88)
T_4:Fomesafen+Fluazinam200g/ha20DAS	3.72 (13.33)	4.41 (19.00)	4.91 (23.67)	5.30 (27.58)
T_5:Bentazole750g/ha30DAS	1.34 (1.33)	3.88 (14.67)	4.13 (16.67)	4.33 (18.33)
T_6:Pendimethalin+Imazethapyr750g/haPE	1.17 (1.00)	1.68 (2.33)	2.04 (3.67)	2.11(4.00)
T_7:Pendimethalin750 g/haPE	1.56 (2.00)	2.24 (4.53)	2.53 (6.00)	2.53 (6.00)
T_8:Sulfentrazone75g/haPE	3.13 (9.33)	5.14 (26.00)	5.34 (28.00)	5.48 (29.53)
T_9:Weedfree	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10}:Weedycheck	4.29 (18.00)	12.07 (145.33)	12.52 (156.33)	12.60 (158.33)
S Em±	0.13	0.15	0.13	0.14
D.(P=0.05)	0.40	0.46	0.40	0.44

Table 5. Totaldrymatterofweedsatvariousgrowthstagesas influencedbyweedmanagementtreatments

Treatments	Total dry matter of weeds (g/m^2)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1:Imazethapyr50 g/ha20DAS	1.57 (1.97)	1.88 (3.05)	2.01 (3.58)	2.41 (5.32)
T_2:Propylthiouracil+Imazethapyr50g/ha20 DAS	2.96 (8.25)	3.65 (12.83)	3.87 (14.50)	3.88 (14.56)
T_3:SodiumAcetate+Clodinagan200g/ha20 DAS	3.14 (9.33)	3.74 (13.50)	3.96 (15.17)	3.99 (15.40)
T_4:Fomesafen+Fluazinam200g/ha20DAS	3.32 (10.57)	3.63 (12.67)	3.66 (12.92)	3.83 (14.17)
T_5:Bentazole750g/ha30DAS	1.58 (2.00)	3.16 (9.50)	3.53 (12.00)	3.65 (12.83)
T_6:Pendimethalin+Imazethapyr750g/haPE	1.26 (1.25)	1.68 (2.33)	1.79 (2.72)	2.04 (3.71)
T_7:Pendimethalin750 g/haPE	1.57 (1.97)	1.97 (3.42)	2.06 (3.75)	2.71 (6.89)
T_8:Sulfentrazone75g/haPE	2.98 (8.38)	3.74 (13.50)	3.60 (12.50)	3.70 (13.17)
T_9:Weedfree	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10}:Weedycheck	3.78 (13.80)	5.81 (33.25)	6.43 (40.83)	6.80 (45.87)
S Em±	0.10	0.09	0.09	0.09
D.(P=0.05)	0.31	0.29	0.27	0.30

Table 6. Weedcontrolefficiencyandweedindexasinfluencedbyweedmanagementtreatments

Treatments	WCE (%)				Weed index (%)
	30 DAS	60 DAS	90 DAS	At harvest	
T_1:Imazethapyr50 g/ha20DAS	85.75	90.83	91.22	88.39	17.21
T_2:Propylthiouracil+Imazethapyr50g/ha20 DAS	40.22	61.40	64.49	68.26	45.08
T_3:SodiumAcetate+Clodinagan200g/ha20 DAS	32.37	59.40	62.86	66.42	48.36
T_4:Fomesafen+Fluazinam200g/ha20DAS	23.43	61.90	68.37	69.11	54.10
T_5:Bentazole750g/ha30DAS	85.51	71.43	70.61	72.02	31.15
T_6:Pendimethalin+Imazethapyr750g/haPE	90.94	92.98	93.35	91.92	1.15
T_7:Pendimethalin750 g/haPE	85.75	89.72	90.82	84.98	21.31
T_8:Sulfentrazone75g/haPE	39.25	59.40.	69.39	71.29	32.79
T_9:Weedfree	100.00	100.00	100.00	100.00	68.85
T_{10}:Weedycheck	-	-	-	-	-

Table 7. Seedyield,StoveryieldandHarvestindexofchickpeaasinfluencedbyvariousweedmanagementtreatments

Treatments	Seed yield/plant (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Biomass yield (kg/ha)	Harvest Index (%)

T_1:Imazethapyr50 g/ha20DAS	5.30	1683	2883	4566	36.85
T_2:Propylthiouracil+Imazethapyr50g/ha20 DAS	3.58	1117	2483	3600	31.02
T_3:SodiumAcetate+Clodinagan200g/ha20 DAS	3.59	1050	2417	3467	30.28
T_4:Fomesafen+Fluazinam200g/ha20DAS	2.98	933	2217	3150	29.61
T_5:Bentazole750g/ha30DAS	4.23	1400	2683	4083	34.28
T_6:Pendimethalin+Imazethapyr750g/haPE	6.20	2010	3267	5277	38.08
T_7:Pendimethalin750 g/haPE	4.99	1600	2950	4550	35.16
T_8:Sulfentrazone75g/haPE	4.25	1367	2517	3884	35.19
T_9:Weedfree	6.24	2033	3283	5316	38.24
T_{10}:Weedycheck	2.47	633	1250	1883	33.62
S Em±	0.33	98.36	156.92	245.02	0.85
D.(P=0.05)	1.00	292.25	466.26	728.00	2.55