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Evaluating the impact of bio-fertilizers and weed management on weed dynamics and productivity in chickpea (*Cicer arietinum* L.)

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Abstract
A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Evaluating the impact of bio-fertilizers and weed management on weed dynamics and productivity in chickpea (*Cicer arietinum* L.).The soil was normal in pH of 7.67, electrical conductivity (EC) of 0.25 dSm-1, organic carbon content of 0.40%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 215.98, 19.58, and 149.558 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24.The experiment consisted of 20 treatment combinations, was laid out in Split plot Design (SPD) with three replications.

Keywords: Bio fertilizer, herbicide, chickpea, yield

Introduction

Because of its high protein content and availability of other essential minerals like calcium, iron, and vitamins like niacin, carotene, thiamine, and riboflavin, pulses are a staple of the Indian diet. Since most Indians are vegetarians, pulses provide the majority of the protein needed for human growth and development. They are referred to as wealthy man's veggies and poor man's meat. With a minimal need of 70 g per capita per day, the supply of pulses has decreased correspondingly from 71 g in 1995 to 56 g in 2018. To fulfill the demand, there must be an increase in internal pulse production.

Pulses are a significant component of cattle feed and fodder, including concentrates, hay, and green fodder, in addition to the human diet. They may be produced as a primary crop, an intercrop, or a green manure crop because of their short duration habit. Because pulses fix atmospheric nitrogen via symbiotic nitrogen fixation with the aid of the bacteria Called Rhizobia, they are known to increase soil fertility. As a result, each pulse plant functions as a little fertilizer factory.

Chickpea (*Cicer arietinum* L.), sometimes referred to as Bengal gram and locally as Chana, is a significant and distinctive food legume due to its use in a wide range of culinary items, including snacks and desserts. Vegetables and condiments are created from it all over the globe. Additionally, it is eaten as besan, or processed whole seeds that have been boiled, roasted, parched, fried, steamed, sprouted, etc. Gram is an excellent source of minerals, vitamins, protein (18–22%), carbohydrates (52–70%), fat (4–10%), and other nutrients. It works very well as animal feed. Its stover is worth foraging.

One of the main obstacles to the production of chickpeas is weed infestation. Depending on the cultivars, soil type, soil moisture content, and other environmental factors, uncontrolled weeds may affect chickpea output by 50–90% (Verma *et al*., 2015) [13]. Since weeds compete with crop plants for nutrients, water, light, and space during the early stages of development, controlling weeds is crucial to increasing chickpea yield.

Due to their prolific seed production, weeds are quickly dispersed and difficult to eliminate once established. The majority of them have life cycles that are similar to crop they infiltrate, guaranteeing that their seeds would be mixed with the crops'. Hand weeding is a good way to manage weeds in chickpeas, but because to manpower shortages and rising labor costs, it has become more difficult to accomplish effectively and cannot be done on time. In addition, it takes a lot of time and money. Weeds are more harmful to agriculture than insects, pests, and disease combined, yet since they produce hidden losses in agricultural productivity, farmers have not paid much attention to the problem.

With the advent of herbicides, a variety of weeds in pulses may now be efficiently controlled at a reasonable cost. Numerous researchers from across the nation have reported that the use of pendimethalin as pre-emergence at 1.0 kg ha^{-1} (Tewari *et al*., 2003) [17], imazethapyr as post-emergence at 0.1 kg ha^{-1} (Singh *et al*., 2003) [18], cloinafop-propargyl (Topic 15 WP) as post-emergence at 0.03 kg ha^{-1} and oxyfluorfen (600 g ha^{-1}) as weed control treatment (Yousefi *et al*., 2007) [19] provided effective control of annual broad leafed and grassy weeds in chickpea fields.

Even though chickpeas are a significant rabi pulse crop, there is a dearth of knowledge on efficient weed management, particularly in the eastern region of Uttar Pradesh where several issues cause further delays in chickpea seeding. Currently, a number of very potent and efficient herbicide compounds have been discovered. These molecules might be helpful in controlling the broad range of weeds in chickpeas going forward, especially if they are used in combination.

Materials and Methods

A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Evaluating the impact of bio-fertilizers and weed management on weed dynamics and productivity in chickpea (*Cicer arietinum* L.).The soil was normal in pH of 7.67, electrical conductivity (EC) of 0.25 dSm-1, organic carbon content of 0.40%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 215.98, 19.58, and 149.558 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24.The experiment consisted of 20 treatment combinations,(4 biofertilizer, T1RDF (20 kg N, 50 kg P and 20 kg ha^{-1}, T2RDF + Rhizobium culture, T3RDF + PSB (Phosphorus Solubilizing Bacteria),T4 RDF + Rhizobium culture + PSB & 5 Weed management, W1Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE), W2 Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i ha^{-1}, W3 Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb clodinafop 0.060 kg a.i. ha^{-1}(POE), W4 Two hand weeding (25 and 50 DAS), W5 Weedy check) was laid out in Split plot Design (SPD) with three replications.

Results and Discussion

Plant height (cm)

The results makes it clear that bio-fertilizers had a major impact on plant height during all development phases. RDF + Rhizobium culture + PSB treatment resulted in a maximum plan height of 11.24 cm at 30 DAS, which was statistically comparable to RDF + Rhizobium culture and RDF + PSB (Phosphorus Solubilizing Bacteria) application, but much higher. Nevertheless, the least when RDF (20 kg N, 50 kg P, and 20 kg ha^{-1}) is used. At harvest stage and at DAS 60, 90, and 120, similar trends were seen.

Plant height significantly varied at periodic intervals according to weed control techniques as well. Applying Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb clodinafop 0.060 kg a.i. ha^{-1} (POE) resulted in a significantly higher plant height (10.88 cm) at 30 DAS. This was comparable to applying Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethpyr 0.060 kg a.i. ha^{-1} (POE) and Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE), but significantly higher than two hand weeding and weedy check Varshney *et al*. (2014) [11]. Maximum plant height was measured at 60, 90, and 120 days after seeding, with two hand weedings (at 25 and 50 DAS) compared to the other treatments. Among the herbicidal treatments, Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb clodinafop 0.060 kg a.i. ha^{-1} (POE) was shown to considerably increase plant height (22.90 cm) Veeraputhiram *et al*. (2018) [12]. Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb clodinafop 0.060 kg a.i. ha^{-1} (POE) was comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethpyr 0.060 kg a.i. ha^{-1} (POE), and was considerably higher than the remainder of the herbicidal treatment at all stages except at harvest.

It was discovered that there was no significant interaction between the various therapies.

Number of main branches (plant^{-1})

At 30 and 60 DAS, the application of RDF + Rhizobium culture + PSB resulted in a considerably greater number of main branches (3.06 plant^{-1}), compared to the other treatments; however, at 90 and 120 DAS, as well as at harvest, it was on par with RDF + Rhizobium culture.

Regarding weed management techniques, the application of Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} as post emergence resulted in the maximum number of main branches (2.65 plant^{-1}) at 30 DAS. This was statistically comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} as post emergence, but significantly higher than the remaining weed management techniques. With two hand weeding treatments (25 and 50 DAS), a greater number of main branches (5.10 plant^{-1}) was observed at 60 DAS. This was comparable to the application of Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb clodinafop 0.060 kg a.i. ha^{-1} (POE), but significantly higher than the remainder of the weed management. The same trend was also observed at 90, 120 DAS, and harvest. Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} (POE) was found to be herbicidal, with the highest number of main branches (4.85 plant^{-1}) among the samples. This was statistically comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} as post emergence. A same pattern was also seen at harvest stage, 90, and 120 DAS. Weed control and biofertilizer were shown to have no significant relationship.

Number of lateral branches (plant^{-1})

Application of RDF + Rhizobium culture + PSB resulted in a considerably larger number of lateral branches (2.86 plant^{-1}) at 30 DAS, which was significantly higher than RDF (20 kg N, 50 kg P, and 20 kg ha^{-1}) but on par with RDF + Rhizobium culture and RDF + PSB (Phosphorus Solubilizing Bacteria) Upadhaya *et al*. (2022) [9]. RDF + Rhizobium culture + PSB, however, was considerably greater than RDF + PSB and RDF (20 kg N, 50 kg P, and 20 kg ha^{-1}) at 60 and 90 DAS, on par with RDF + Rhizobium culture. RDF + Rhizobium culture + PSB was observed to have considerably larger lateral branches plant^{-1} at 120 DAS and harvest stage compared to the other treatments Vaishya *et al*. (2015) [10].

When using Pendimethalin at a rate of 1.0 kg a.i. ha^{-1} (PE), the highest number of lateral branches (2.32 $plant^{-1}$) was seen at 30 DAS in the case of weed control techniques. fb Imazethapyr 0.060 kg a.i. ha^{-1} as post-emergence and Pendimethalin @ 1.0 kg a.i. ha^{-1} as pre-emergence were statistically comparable to fb Clodinafop 0.060 kg a.i. ha^{-1} as post-emergence, but much higher than the other weed management strategies Verma (2015) [13]. The maximum number of lateral branches (6.97 $plant^{-1}$) was observed with two hand weeding treatments (25 and 50 DAS) at 60, 90, and 120 DAS. This was significantly higher than the other treatments and on par with the application of Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb clodinafop 0.060 kg a.i. ha^{-1} (POE) Vikram *et al*. (2018) [14].

The maximum number of lateral branches (6.75) was recorded by Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1}, which was comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} post-emergence at 60, 90, and 120 DAS and at harvest stage Walkley *et al*. (2022) [15]. Weed control and biofertilizer were shown to have no significant relationship.

Number of nodules $plant^{-1}$

The application of 100% RDF + Rhizobium culture + PSB was the biofertilizer that produced the highest number of nodules $plant^{-1}$ (18.50), which was noticeably greater than the other treatments at 30 DAS. While RDF + Rhizobium culture + PSB recorded the highest number of nodules at 90 DAS, the trend at 60 DAS was similar to that of RDF + Rhizobium culture.

Additionally, weed control techniques had a major impact on the number of nodules $plant^{-1}$. A significantly higher number of nodules (15.95 $plant^{-1}$) were recorded upon application of Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} as post emergence. This was statistically comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} as post emergence and Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) at 30 DAS stage Wani *et al*. (2017) [16]. The highest number of nodules (24.00 $plant^{-1}$) was observed at 60 DAS after two hand weeding sessions (25 and 50 DAS). This was comparable to the post-emergence amounts of Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} and Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1}, but significantly higher than the remaining weed management techniques in both years. Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} (POE) was applied as a herbicidal treatment, and it resulted in a higher number of nodules (23.47 $plant^{-1}$); this number was statistically comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} as post-emergence during both years. At 90 DAS, a similar tendency was also seen.

Weed control and biofertilizers were shown to have no significant relationship.

Dry matter accumulation (g m^{-2})

The highest dry matter accumulation (14.04 g m-2) seen at 30 DAS was substantially greater than that of the other treatments; the same trend was observed at 120 DAS and throughout harvest. The application of 100% RDF + Rhizobium culture + PSB. When RDF + Rhizobium culture + PSB was applied, the highest dry matter accumulation of chickpea was seen at 60 DAS, and this was comparable to RDF + Rhizobium culture. At 90 DAS, a similar pattern was seen.

At different phases of development, the dry matter accumulation (g m-2) of chickpea was also considerably impacted by weed control strategies. Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} (POE) was applied at 30 DAS, and the maximum dry matter accumulation (13.00 g m-2) was recorded. This was statistically comparable to Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} (POE) and Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE). The application of Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Clodinafop 0.060 kg a.i. ha^{-1} (POE) and Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) fb Imazethapyr 0.060 kg a.i. ha^{-1} (POE) resulted in the maximum dry matter accumulation (59.08 g m-2) at 60 DAS, while being significantly higher than the other treatments. A same pattern was also seen at harvest stage, 90, and 120 DAS.

At all development stages examined, the interaction impact between biofertilizer and weed control techniques was unable to achieve a level of significance.

Table 1: Plant height (cm) of chickpea at different growth stages as influenced by bio-fertilizers and weed management.

Treatment	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Bio-fertilizers					
RDF (20 kg N, 50 kg P and 20 kg K ha^{-1})	10.42	19.38	38.48	45.19	43.07
RDF + *Rhizobium* culture	10.60	20.93	40.09	45.87	44.25
RDF + PSB (Phosphorus Solubilizing Bacteria)	10.52	20.82	39.21	45.66	43.33
RDF + *Rhizobium* culture + PSB	11.24	21.78	41.04	47.86	45.78
SEm±	0.26	0.41	0.72	0.79	0.68
CD at 5%	0.81	1.26	2.24	2.41	2.12
Weed management					
Pendimethalin @ 1.0 kg a.i. ha^{-1}(PE)	10.62	19.12	37.33	43.16	40.04
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*Imazethapyr 0.060 kg a.i. ha^{-1} (POE)	10.76	20.03	39.71	45.16	41.74
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*clodinafop 0.060 kg a.i. ha^{-1} (POE)	10.88	22.90	43.35	49.75	47.64
Two hand weeding (25 and 50 DAS)	9.78	24.25	45.46	53.75	51.33
Weedy check	9.32	17.33	32.67	38.91	37.01
SEm±	0.18	0.31	0.50	0.68	0.66
CD at 5%	0.56	0.98	1.47	1.97	1.90

Table 2: Number of main branches (plant^{-1}) of chickpea as influenced by bio-fertilizers and weed management at various growth stages.

Treatment	Number of main branches per plant				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**At harvest**
Bio-fertilizers					
RDF (20 kg N, 50 kg P and 20 kg K ha^{-1})	1.60	3.32	5.32	5.27	5.27
RDF + *Rhizobium* culture	2.66	4.66	6.90	6.85	6.85
RDF + PSB (Phosphorus Solubilizing Bacteria)	2.22	3.98	6.00	5.94	5.94
RDF + *Rhizobium* culture + PSB	3.06	5.60	7.60	7.51	7.51
SEm±	0.10	0.13	0.27	0.25	0.26
CD at 5%	0.33	0.41	0.83	0.78	0.79
Weed management					
Pendimethalin @ 1.0 kg a.i. ha^{-1}(PE)	2.30	4.45	6.47	6.41	6.41
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*Imazethapyr 0.060 kg a.i. ha^{-1} (POE)	2.45	4.62	6.75	6.67	6.67
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*clodinafop 0.060 kg a.i. ha^{-1} (POE)	2.65	4.82	7.10	6.93	6.93
Two hand weeding (25 and 50 DAS)	1.88	5.10	7.35	7.16	7.16
Weedy check	1.70	2.95	4.85	4.80	4.80
SEm±	0.07	0.08	0.18	0.13	0.12
CD at 5%	0.21	0.26	0.59	0.41	0.41

Table 3: Number of lateral branches (plant^{-1}) of chickpea as influenced by bio-fertilizers and weed management at various growth stages.

Treatment	Number of lateral branches per plant				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**At harvest**
Bio-fertilizers					
RDF (20 kg N, 50 kg P and 20 kg K ha^{-1})	1.14	4.70	6.70	7.08	6.53
RDF + *Rhizobium culture*	2.44	6.96	8.00	8.16	7.96
RDF + *PSB (Phosphorus Solubilizing Bacteria)*	1.86	5.76	7.28	7.70	6.96
RDF + *Rhizobium culture + PSB*	2.86	7.58	8.60	9.24	8.78
SEm±	0.35	0.21	0.23	0.25	0.22
CD at 5%	1.12	0.63	0.71	0.78	0.68
Weed management					
Pendimethalin @ 1.0 kg a.i. ha^{-1} PE	2.05	6.35	7.60	8.04	7.55
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*Imazethapyr 0.060 kg a.i. ha^{-1} (POE)	2.20	6.57	7.85	8.19	7.77
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*clodinafop 0.060 kg a.i. ha^{-1} (POE)	2.32	6.75	8.05	8.45	7.95
Two hand weeding (25 and 50 DAS)	1.75	6.97	8.32	8.75	8.17
Weedy check	1.30	4.60	6.45	6.15	5.80
SEm±	0.25	0.12	0.13	0.12	0.11
CD at 5%	0.78	0.37	0.42	0.39	0.32

Table 4: Number of nodule (plant^{-1}) of chickpea as influenced by bio-fertilizers and weed management at various growth stages.

Treatment	Number of nodule per plant		
	30 DAS	**60 DAS**	**90 DAS**
Bio-fertilizers			
RDF (20 kg N, 50 kg P and 20 kg K ha^{-1})	8.24	12.76	15.04
RDF + Rhizobium culture	16.68	23.80	26.54
RDF + PSB (Phosphorus Solubilizing Bacteria)	14.66	21.60	24.78
RDF + Rhizobium culture + PSB	18.50	27.96	29.60
SEm±	0.53	0.75	1.03
CD at 5%	1.72	2.41	3.12
Weed management			
Pendimethalin @ 1.0 kg a.i. ha^{-1} PE	14.95	20.82	22.05
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*Imazethapyr 0.060 kg a.i. ha^{-1} (POE)	15.72	23.07	25.42
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*clodinafop 0.060 kg a.i. ha^{-1} (POE)	15.95	23.47	26.65
Two hand weeding (25 and 50 DAS)	11.30	24.00	27.05
Weedy check	10.00	14.27	16.77
SEm±	0.34	0.63	0.80
CD at 5%	1.03	1.96	2.45

Table 5: Dry matter accumulation (g m^{-2}) of chickpea as influenced by bio-fertilizers and weed management at various growth stages.

Treatment	Dry matter accumulation (g m^{-2})				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Bio-fertilizers					
RDF (20 kg N, 50 kg P and 20 kg K ha^{-1})	10.16	49.11	175.00	304.88	373.58
RDF + *Rhizobium* culture	13.04	56.64	188.36	369.57	496.75
RDF + PSB (Phosphorus Solubilizing Bacteria)	11.76	52.97	180.56	314.88	465.00
RDF + *Rhizobium* culture + PSB	14.04	59.13	198.02	425.30	575.42
SEm±	0.26	1.33	4.25	12.06	15.26
CD at 5%	0.83	4.12	13.26	36.25	46.65
Weed management					
Pendimethalin @ 1.0 kg a.i. ha^{-1}(PE)	12.55	56.08	190.99	370.69	495.78
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*Imazethapyr 0.060 kg a.i. ha^{-1} (POE)	12.75	56.76	194.20	400.22	510.40
Pendimethalin @ 1.0 kg a.i. ha^{-1} (PE) *fb*clodinafop 0.060 kg a.i. ha^{-1} (POE)	13.00	57.80	196.15	403.89	528.58
Two hand weeding (25 and 50 DAS)	10.60	59.08	200.30	415.98	541.28
Weedy check	9.35	42.58	144.91	223.65	312.40
SEm±	0.18	0.82	3.03	8.16	10.97
CD at 5%	0.53	2.39	9.12	25.26	33.17

Conclusion

In conclusion, the study highlights the significant influence of biofertilizers and weed management techniques on various growth parameters of chickpea plants. Biofertilizers, particularly RDF + Rhizobium culture + PSB, consistently promoted superior plant height, number of main and lateral branches, nodulation, and dry matter accumulation across different growth stages compared to conventional RDF treatments. Similarly, herbicidal strategies, notably Pendimethalin combined with Clodinafop or Imazethapyr, showed comparable or enhanced effects on these parameters, particularly evident in lateral branches and nodulation. However, no significant interaction was observed between biofertilizer and weed control methods, indicating independent effects on chickpea growth. These findings underscore the potential for optimizing chickpea cultivation through tailored biofertilization and weed management practices to enhance productivity and sustainability.

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