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Impacts of integrated nutrient management on growth, development and yield of black gram (*Vigna mungo* L.)

Aman Kumar, Ravikesh Kumar Pal, Naveen Kumar Maurya, Krishna Kumar Singh, Rajat Yadav, Kushal Sachan and Budhesh Pratap Singh

Aman Kumar
Department of Agronomy, Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur, Uttar Pradesh, India

Ravikesh Kumar Pal
Department of Agronomy, Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur, Uttar Pradesh, India

Naveen Kumar Maurya
Department of Agronomy, Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur, Uttar Pradesh, India

Krishna Kumar Singh
Department of Soil Science and Agricultural Chemistry, CSA University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Rajat Yadav
Department of Agronomy, CSA University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Kushal Sachan
Department of Soil Science and Agricultural Chemistry, CSA University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Budhesh Pratap Singh
Department of Vegetable Science CSA University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Corresponding Author:
Aman Kumar
Department of Agronomy, Faculty of Agricultural Sciences & Allied Industries, Rama University, Kanpur, Uttar Pradesh, India

Abstract
At the Agronomy Research Farm of the Faculty of Agriculture Sciences & Allied Industries, Rama University, Kanpur, Uttar Pradesh, an experiment was carried out to investigate the experiments were consisting of 9 treatments with three replications in RBD design, which are: T1 (Control), T_2 (100% RDF), T_3 (100% RDN through compost), T_4 (50% RDF + 50% RDN through compost), T_5 (50% RDF + 25% RDN through compost), T_6 (25% RDF + 50% RDN through compost), T_7 (50% RDF + 25% RDN through compost + Rhizobium), T_8 (25% RDF + 50% RDN through compost + Rhizobium), and T_9 (50% RDF + 50% RDN through compost + Rhizobium). The outcomes demonstrated that applying 50% RDF + 50% RDN via compost + Rhizobium increased plant height at 30 DAS, 45 DAS, and at maturity, the number of branches per plant at 30 DAS and 60 DAS, days to flower initiation, days to flowering, days to crop maturity, and leaf area index (LAI). The study also revealed that the quantity of pods per plant, length of pod (cm), number of seeds per pod, test weight, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), and harvest index were all affected by the application of 50% RDF + 50% RDN through compost + Rhizobium. When compared to the other integrated nutrient management techniques, the 50% RDF + 50% RDN via compost + Rhizobium method was shown to be more lucrative in terms of highest gross revenue (Rs. 55,660.97/ha), net income (Rs. 25,587.97/ha), and B:C ratio (1.85).

Keywords: Integrated nutrient management, Lai, Urd and growth & development

Introduction
A prominent short-duration pulse crop farmed all throughout the nation is black gram, often known as "Urd bean" (*Vigna mungo* L.). Black gram, which belongs to the Fabaceae family, is an Indian native. Due to their high quantities of protein (25-26%), minerals, vitamins, and carbohydrates, seeds are nutrient-dense foods. The urad bean, which can be grown in a range of agroclimatic settings, is a prominent pulse crop in India. Urd bean is a crop that has the potential for intensification and diversification due to its short lifespan and photothermally sensitivity.

India produces 24.5 lakh tons of black gram on 4.6 million hectares at a rate of 533 kg/ha (Agricoop.nic.in, 2020-21). Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Telangana, and Andhra Pradesh are the states that cultivate the most kharif crops. There are limits to our capacity to provide the domestic demand for pulse crops, notably black gram. Good agronomy and fertilizers can boost crop productivity. The cost of fertilizer is increasing, making it increasingly challenging for small farmers to use enough. Maintaining soil health is acknowledged today. Use caution while combining organic and non-organic foods. Vermicompost outperforms other organic manures and has a higher concentration of plant nutrients.

Utilizing organic manure as a component of integrated fertilizer management may enhance soil health. In contrast to synthetic fertilizers, organic manures include micronutrients. To find the right combination, organic manures and chemical fertilizers must be tested. Utilizing an integrated system strategy can boost productivity while using less fertilizer. Ecological soundness encourages sustainable agriculture. Utilizing an integrated plant feeding system, soil fertility is increased and maintained. Increases in soil fertility, economic production, and yield have been seen with the application of organic and inorganic sources (Singh *et al*., 2013; Saket *et al*., 2014) [13, 8].

Organic manures have an effect on the physical, chemical, and biological characteristics of the soil, including the quantity, diversity, and activity of microorganisms, in addition to providing nutrients and organic matter.

Yields are increased, soil's physical and chemical properties are enhanced, and crop nutrition packages that are scientifically sound, financially viable, practically feasible, and environmentally safe are delivered with integrated nutrient management. Vermicompost and FYM improve the physio-chemistry of the soil and the availability of plant nutrients. Organic farming might not be able to provide the immediate nutritional needs of the crops because of mineralization. Both inorganic (Fertilizers) and organic (FYM and vermicompost) nutrients can be used to provide nutrients for growth. Chemical fertilizers cannot maintain the soil's production when farming is done the way it is now done. Biofertilizers and organic manures seldom ever provide enough nutrients for crops. Combining organic manure and inorganic fertilizers produced the greatest results. It has been proven that mixing chemical and organic fertilizers can boost crop productivity. Utilizing FYM or vermicompost in place of less inorganic fertilizer boosted agricultural productivity, plant growth, and soil fertility. Combining chemical fertilizers with biofertilizers, four organic manures, and chemical fertilizers can help to sustain crop productivity. Chemical fertilizers reduce soil fertility, which leads to unsustainable yields. When intensive farming is practiced for a lengthy period of time, crop quality and soil fertility are reduced.

Materials and Methods

Experiment site

The field experiment was carried out in the kharif season of 2022–2023 at the Rama University's Agricultural Research Farm in Kanpur Nagar, Uttar Pradesh, which is located in the Indo-Gangetic Plain's alluvial tract in the central part of the state between $25^0 26'$ and $26^0 58'$ North latitude and $79^0 31'$ to $31^0 34'$ East longitude, and at an altitude of 125.9 meters. On this property, there are sufficient irrigation facilities. The farm is located on the university's main campus.

Soil of Experimental Field

The experimental field has a sandy loam texture, a pH of 7.18 that is neutral in reaction, 0.32 dSm^{-1} of EC, 0.39 percent of accessible organic carbon, 208.40 kg ha^{-1} of available N, 11.72 kg ha^{-1} of available P, and 198.50 kg ha^{-1} of available K. Additionally, the soil includes Zn (0.48 mg kg^{-1}) and S (8.60 mg kg^{-1}) that are readily accessible.

Study Design

The experiment was laid out in a randomized block design (RBD) assigning treatment combinations *viz*.: T_1 (Control), T_2 (100% RDF), T_3 (100% RDN through compost), T_4 (50% RDF + 50% RDN through compost), T_5 (50% RDF + 25% RDN through compost), T_6 (25% RDF + 50% RDN through compost), T_7 (50% RDF + 25% RDN through compost + Rhizobium), T_8 (25% RDF + 50% RDN through compost + Rhizobium), and T_9 (50% RDF + 50% RDN through compost + Rhizobium) with three replications. Within them, each therapy was distributed at random. Rows were spaced 30 cm apart, and seeds were spaced 10 cm apart.

Leaf area Index (LAI)

According to Gardner *et al*. (1985) [15], the LAI measures how much of the crop's ground area is taken up by its leaf surface (on one side only). 45 DAS is when it was captured.

$$LAI = \frac{(LA_2 + LA_1)}{2} \times \frac{1}{P}$$

Where, the LA = leaf area/plant
P = ground area /plant

Harvest Index

With the use of a formula proposed by Singh and Stockopf (1971), the harvest index was derived.

$$\text{Harvest Index} = \frac{\text{Economic Yield (kg/ha)}}{\text{Biological Yield(kg/ha)}} \times 100$$

Net Profit (ha^{-1})

Using the formula shown below, the net profit from each treatment was determined independently.

Net profit (ha^{-1}) = Gross return - Cost of cultivation

Benefit: Cost ratio (B: C)

B: C ratio was calculated using the following formula:

$$\text{B: C} = \frac{Gross\ monitary\ retern (Rs./ha)}{Total\ cost\ of\ cultivation\ (Rs./ha)}$$

Statistical Analysis

The analysis of variance method in SPSS was used to determine the statistical significance of treatment effects. The 5% probability threshold was used to evaluate the importance of treatment effects. Additionally, the 'F' test and critical difference (CD), as reported by Gomez and Gomez (1984) [16], were used to determine the importance of the difference between treatments.

Result and Discussion

Growth and Phenological characters

Of the INM treatments, T_9 (50% RDF + 50% RDN through compost + Rhizobium) yielded noticeably greater plant height and branches/plant at the 30, 45, and maturity stages. The most branches per plant at the maturity stage were 3.63 at 30 DAS and 7.44 at 60 DAS. Next were the T_3, T_8, and T_7 treatments, which included Rhizobium as well as both inorganic and organic sources of nitrogen. The fourth-best INM therapy was the T_4 regimen, which utilised compost to blend 50% RDF and 50% RDN. These black gram growth indicators (T_5 and T_6) significantly decreased as a result of the lowered nitrogen levels from both organic and inorganic sources (T_5 and T_6).

The INM treatments that generated late flower initiation in 40.20 to 37.20 days, blooming in 52.92 to 45.03 days, and crop maturity in 79.53 to 71.13 days were T_2 (100% RDF) and T_9 (50% RDF + 50% RDN via compost + Rhizobium). Treatments T_8, T_7, T_4, and T_3 also displayed late blooming and crop maturity with larger supply of nitrogen from both sources.

On the other hand, the lack of nitrogen in treatment T6 and the reduced nitrogen supply in treatments T_5 and T_6 resulted in a shortened vegetative growth period and an earlier transition into the reproductive phase, with flowering occurring between 52.92 and 45.03 days, flowering occurring between 40.80 and 37.20 days, and crop maturity occurring between 79.53 and 71.13 days.

The LAI was greatest in the case of T_9 treatment (4.42), then

T_3 (4.17), T_8 (3.96), and T_7 (3.66). T_4 (3.46) placed sixth overall. However, it was just 3.57 in the control therapy.

Blackgram and other pulse crops' vegetative growth parameters have been positively impacted by integrated nutrient management, according to numerous researchers. (Ghulam *et al*., 2011; Beg, 2012; Singh *et al*., 2013; Raj *et al*., 2014) [3, 1, 13, 7]

Yield attributing characters

The most successful treatment was T_9 with 50% RDF and 50% RDN via compost and Rhizobium. The maximum pods per plant were therefore 33.69, 8.31 cm long pod length, 8.85 seeds per pod, and 47.85 g for 1,000 seeds. The 100% RDN using compost T_3 treatment came in second place. This was followed by the application of T_8 (25% RDF+ 50% RDN through compost + Rhizobium) and T_7 (50% RDF+ 25% RDN through compost + Rhizobium) treatments. The control treatment had significantly less test weight (42.42 g), pods per plant (28.17), pod length (6.75 cm), and seed weight (6.57 seeds/pod). The findings are in agreement with those of a number of studies, including Shete *et al*. (2010) [10], Ghulam *et al*. (2011) [3], Elamin and Madhavi (2015) [2], and Singh *et al*. (2016) [12].

Productivity parameters

With the exception of T_3 (100% RDN via compost), which yielded 715.53 kg/ha of seed, the grain yield was much greater (809.13 kg/ha) when 50% RDF + 50% RDN through compost + Rhizobium were treated compared to the other INM treatments. With yields of 678.09 and 639.60 kg/ha, T_8 (25% RDF + 50% RDN through compost + Rhizobium) and T_7 (50% RDF + 25% RDN through compost + Rhizobium) placed second and third, respectively. The lesser RDF supply compared to T_5 and T_6 treatments significantly reduced the yield. The control treatment, which did not use fertilizer, however, produced the least amount of grain per hectare (402 kg/ha). The stover yield and harvest index were also affected similarly by the INM treatments, with T_9, T_3, T_8, and T_7 reporting their higher values in the same sequence. Numerous studies' findings (Hakeem *et al*., 2007, Singh *et al*., 2008, Shete *et al*., 2010, Ghulam *et al*., 2011, Beg, 2012, Saravana *et al*., 2013, Kumawat *et al*., 2013, Saket *et al*., 2014, Yadav and Meena, 2014) [4, 11, 10, 6, 8, 14] have been included in this article.

Economics

Out of all the INM treatments, T_9 with 50% RDF + 50% RDN through compost + Rhizobium generated the greatest net income of up to Rs. 25587.97/ha with a 1.85 B:C ratio. This revenue was higher than the control when compared. The next treatments, T_3, T_8, and T_7 (Rs. 18766.32, Rs. 17286.5, and Rs. 15013.61/ha, respectively), contained the highest dosages of RDF through inorganic-cum-organic sources of nutrients with Rhizobium. The net profit under 100% RDF from an inorganic source was Rs. 7105.96/ha.

Table 1: Growth and phenological characters of blackgram as influenced by different INM treatments

Treatment No.	Treatments	Plant height (cm)			No. of branches/plant		Days to flower initiation	Days to flowering	Days to crop maturity	Leaf area index
		30 DAS	45 DAS	At maturity	At 30 DAS	At 60 DAS				
T_1	Control	16.12	32.25	52.15	2.09	4.56	37.20	45.03	71.13	2.85
T_2	100% RDF (inorganic)	16.74	35.10	58.74	2.22	5.22	40.80	53.40	79.05	3.36
T_3	100% RDN through compost (organic)	17.67	38.47	57.33	3.12	7.29	39.30	49.47	76.96	4.17
T_4	50% RDF + 50% RDN through compost	16.62	34.75	56.02	2.55	4.74	40.20	49.08	77.48	3.57
T_5	50% RDF + 25% RDN through compost	16.62	36.30	57.70	2.34	5.34	38.52	48.06	75.45	3.09
T_6	25% RDF + 50% RDN through compost	15.60	34.38	57.21	2.43	4.77	38.10	49.50	74.88	3.12
T_7	50% RDF + 25% RDN through compost + Rhizobium	16.92	35.16	55.68	2.79	5.73	39.60	47.85	77.52	3.66
T_8	25% RDF + 50% RDN through compost + Rhizobium	16.96	33.72	58.23	2.97	5.91	40.50	48.81	77.25	3.96
T_9	50% RDF + 50% RDN through compost + Rhizobium	17.73	38.67	61.64	3.63	7.44	40.20	52.92	79.53	4.59
S.Em		0.44	0.92	1.49	0.07	0.15	1.03	1.30	0.96	0.10
C.D. (P = 0.05)		NS	2.80	4.53	0.21	0.45	NS	3.92	2.01	0.29

Table 2: Yield attributes and productivity parameters of blackgram as influenced by different INM treatments

Treatment No.	Treatments	No. of pods/plant	Length of pod (cm)	No. of seeds/pod	1000- seed weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
T_1	Control	28.17	6.75	6.57	42.42	418.08	1294.27	24.42
T_2	100% RDF (Inorganic)	29.46	7.38	7.68	42.66	522.09	1547.52	25.23
T_3	100% RDN through compost (Organic)	31.73	8.01	8.31	47.13	715.53	1715.28	29.43
T_4	50% RDF + 50% RDN through compost	27.81	7.41	6.96	45.18	501.27	1606.53	23.79
T_5	50% RDF + 25% RDN through compost	29.22	7.74	7.71	44.22	517.92	1386.30	27.18
T_6	25% RDF + 50% RDN through compost	29.64	7.65	7.29	44.73	574.08	1411.80	28.92
T_7	50% RDF + 25% RDN through compost + Rhizobium	30.36	6.33	7.80	45.24	639.60	1560.84	29.07
T_8	25% RDF + 50% RDN through compost + Rhizobium	30.36	7.71	8.04	43.89	678.09	1547.97	30.45
T_9	50% RDF + 50% RDN through compost + Rhizobium	33.69	8.31	8.85	47.85	809.13	1881.99	30.06
S.Em ±		0.78	0.19	0.20	0.78	15.49	40.89	0.71
C.D. (P= 0.05)		2.36	0.59	0.60	1.17	46.84	123.66	2.15

Table 3: Economics of blackgram as influenced by different INM treatments

Treatment No.	Treatments	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	B: C Ratio
T_1	Control	25617	29146.4	3529.4	1.14
T_2	100% RDF (inorganic)	29209	36314.96	7105.96	1.24
T_3	100% RDN through compost (organic)	30517	49283.32	18766.32	1.62
T_4	50% RDF + 50% RDN through compost	30013	35011.66	4998.66	1.17
T_5	50% RDF + 25% RDN through compost	28713	35846.28	7133.28	1.25
T_6	25% RDF + 50% RDN through compost	29265	39583.44	10318.44	1.35
T_7	50% RDF + 25% RDN through compost + Rhizobium	29073	44086.61	15013.61	1.52
T_8	25% RDF + 50% RDN through compost + Rhizobium	29325	46611.5	17286.5	1.59
T_9	50% RDF + 50% RDN through compost + Rhizobium	30073	55660.97	25587.97	1.85

Conclusion

The second-best treatment, T_3, was found to be comparable to T_9 in terms of seed yield (688 kg ha^{-1}), when compared to other nutrient management strategies. T_9 produced superior yield qualities, including number of pods/plant (33.69), number of seeds/pod (8.85), and seed yield (809.13 kg ha^{-1}) (50% RDF + 50% RDN via compost + Rhizobium). The 50% RDF + 50% RDN through compost + Rhizobium approach was shown to be more profitable when compared to the other integrated nutrient management methods in terms of maximum gross income (Rs. 55660.97/ha), net income (Rs. 25587.97/ha), and B:C ratio (1.85).

As a consequence of this finding, it was concluded that the application of fertiliser, compost, and rhizobium all together was more effective than the application of any of these components alone. It is also essential to point out that the agro-climatic conditions of Kanpur proved to be the most conducive environment for the successful implementation of these therapies.

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