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Effect of different manures on growth and yield of black gram (*Vigna mungo* L.) under rainfed condition in Bastar Plateau

Ashta Kumar, Parvindra Kumar Salam, Narendra Kumar, Tejpal Chandrakar and Devendra Pratap Singh

Abstract
A study on the "Effect of different manures on growth and yield of black gram (*Vigna mungo* L.) under rainfed conditions in Bastar Plateau" was conducted during the *Kharif* season of 2022 at the New Upland Research cum Instructional Farm, Lamker, under S.G. College of Agriculture and Research Station, Jagdalpur, Bastar (C.G.). The experiment utilized a randomized block design with three replications and ten treatments (T_1-T_{10}). These treatments involved combinations like organic manures with seed inoculation, inorganic fertilizers, and a control. Results showed that in treatment T_8 (Poultry manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), plant height, number of branches plant^{-1}, and leaf area index were significantly highest at all growth stages (30, 60 DAS, and harvest). In T_8, dry matter accumulation, crop growth rate, and relative growth rate were notably highest at 30 and 60 DAS, while in T_7 (Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), they were significantly highest at harvest. Notably, treatment T_7 stood out by promoting the highest growth parameters and achieving a notable increase in nitrogen, phosphorus, and potassium uptake in both grain and stover. Additionally, T_7 demonstrated significant yield improvements, including 37.27 pods plant^{-1}, a grain yield of 10.38 quintals ha^{-1}, and a stover yield of 18.86 quintals ha^{-1}. The treatment also yielded strong economic results with elevated gross returns (₹ 70,404 ha^{-1}), net returns (₹ 62,543 ha^{-1}) and benefit-cost ratio (2.65), underlining its economic viability and profitability.

Keywords: Black gram, farm yard manure, vermicompost, goat manure, poultry manure, *Rhizobium*, PSB and NPK fertilizer

Introduction

Black gram (*Vigna mungo* L.) is a significant pulse crop grown across India, belonging to the "Fabaceae" family. It is known by various names in different Indian languages *Urd* or *Urad* in Hindi, *Adad* in Gujarati, *Masakalai* in Bengali, *Minapa Pappu* in Telugu, *Ulundu* in Tamil, *Uddu bale* in Kannada and *Uzhummu* in Malayalam (Tiwari *et al.*, 2022) [43]. The United Nations designated 2016 as the "International Year of Pulses" (Anonymous, 2016) [3] to increase pulse production and consumption, particularly in India. The country is a major producer and consumer of black gram, which is a protein-rich food, often consumed as split or whole pulse. It's a staple in Indian diets, used in dishes like dal-chawal and dal-roti. Black gram is also rich in nutrients like protein (25 g 100^{-1} g), potassium (983 mg 100^{-1}g), calcium (138 mg 100^{-1} g), iron (7.57 mg 100^{-1} g), niacin (1.447 mg 100^{-1} g), thiamine (0.273 mg 100^{-1} g), riboflavin (0.254 mg 100^{-1} g), and folate (Anonymous, 2019 b; Brink, 2006) [6]. It complements essential amino acids found in cereals and contributes to diets in India and Nepal (Anonymous, 2006) [3]. Moreover, it serves as a dry season intercrop in rice or wheat fields, benefiting soil nutrient levels. Overall, black gram is a tropical leguminous plant with diverse uses and nutritional benefits (Parashar, 2006) [31].

Black gram serves as nutritious fodder for milch animals and fits well in multiple cropping and intercropping systems. After pod picking, the plant can be used as green fodder or green manure. It enriches soil by fixing atmospheric nitrogen (Patre *et al.*, 2022 b) [32]. In 2020-21, India produced 23.4 lakh tonnes of black gram from 46.7 lakh hectares, with a productivity of 501kg ha^{-1} (Anonymous, 2021) [7]. In Chhattisgarh, cultivation covered 74290 ha, yielding 24310 metric tonnes, with a productivity of 327 kg ha^{-1} (Anonymous, 2019 a) [5]. Excessive use of inorganic fertilizers poses health and environmental risks. While pulses fix nitrogen, applying nitrogenous fertilizers during flowering increases yield. Phosphorus and potash fertilizers significantly impact growth and yield (Chen, 2006; Rahman, 2015; Bukhsh *et al.*, 2011; Srinivasarao *et al.*, 2003) [12, 34, 44, 41]. Organic manures like farmyard manure, vermicompost, and goat manure enhance soil properties. Poultry manure increases soil nutrients and organic matter. Biofertilizers, especially *Rhizobium*, boost growth and yield attributes. Phosphorus Solubilizing Bacteria (PSB) improve phosphorus uptake and yield by solubilizing soil-bound phosphate (Vasanthi and Subramanian, 2004; Anasuyamma *et al.*, 2022; Ojeniyi and Adegboyega, 2003; Kirchmann, 1985; Nalawde and Bhalerao, 2015; Gaur 1991) [45, 2, 30, 20, 29, 15].

Materials and Methods

The research entitled **"**Effect of different manures on growth and yield of black gram (*Vigna mungo* L.) under rainfed condition in Bastar Plateau" was conducted at New Upland Research cum Instructional Farm Lamker, which falls under S.G. College of Agriculture and Research Station, Jagdalpur, Bastar (C.G.). The study was carried out during the *Kharif* season of 2022. The state of Chhattisgarh is located between 17º30' and 24º45' N latitude and 17º30' and 84º15' E longitude whereas Bastar lies at 19º10' N latitude and 81º95' E longitude with and altitude of 559 meters above mean sea level. Lamker comes under the Bastar district which lies between 19º22'38'' N latitude and 81º87'99'' E longitude. The experimental fields soil type was Entisols, characterized by an acidic pH of 5.62, medium organic carbon content, low availability of nitrogen, medium availability of phosphorus and medium availability of potassium. The research area experiences a sub-humid climate typical of the Bastar Plateau. During the *Kharif* season of 2022, the black gram crop received a total rainfall of 613.30 mm, slightly exceeding the regional average. Throughout the experimental period, the highest recorded temperature ranged from 28.30 °C to 32.40 °C, while the lowest temperature ranged from 10.60 °C to 22.30 °C. The variety chosen for the study was Indira urd-1, planted on August 22, 2022, with a spacing of 30 cm × 10 cm and harvest was conducted on November 21, 2022.

The experiment employed a randomized block design (RBD) with three replications. The study encompassed various treatments, denoted as T_1 to T_{10}. These treatments included T_1 (Farm yard manure @ 4 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_2 (Farm yard manure @ 6 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_3 (Vermicompost @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_4 (Vermicompost @ 2 t ha^{-1} + Seed inoculation with Rhizobium + PSB), T_5 (Goat manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_6 (Goat manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_7 (Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_8 (Poultry manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB), T_9 (100% Inorganic *i.e.*, 20:40:20 kg NPK ha^{-1}) and T_{10} (Absolute Control). The study aimed to assess the impact of these treatments on the growth and yield of black gram under rainfed conditions in Bastar Plateau.

Results and Discussion

Plant height (cm)

Treatment T_8 consistently yielded significantly taller plants at all growth stages 30, 60 and at harvest. This performance was comparable to treatment T_9 and T_6 at 30 and 60 DAS. Conversely, treatment T_{10} consistently exhibited the lowest plant height across all growth stages (Table: 1). plant height, align closely with the findings of Dhivya, R.S. and Ray, L. I.P. (2020) [13], Verma *et al.* (2022) [46], Mahamud *et al.* (2022) [26], Rohan *et al.* (2022) [36], Ganvit *et al.* (2022) [14] and Akter. (2021) [1], This consistency in outcomes across studies suggests that the beneficial impacts of poultry manure on crop growth are well-supported by multiple research findings.

Number of branches plant^{-1}

Treatment T_8 consistently resulted in the highest number of branches plant^{-1} at 30, 60 and at harvest stages, standing out significantly among all treatments. This performance was comparable to treatment T_9 and T_7 at 30 DAS, T_7, T_9 and T_4 at 60 DAS and at harvest, treatment T_7, T_9 and T_4 exhibited similar results (Table: 1). Conversely, the lowest number of branches was observed in the control treatment, T_{10}. These results are also similar findings by Dhivya, R.S. and Ray, L. I.P. (2020) [13], Akter *et al.* (2021) [1], ganvit *et al.* (2022) [14], Rohan *et al.* (2022) [36], Tripathi *et al.* (2017) [44] and Sarker *et al.* (2020) [38].

Dry matter accumulation (g plant^{-1})

Treatment T_8 exhibited significantly higher dry matter accumulation at both 30 and 60 DAS after sowing. This result was in line with treatment T_4 and T_2 at 30 DAS and with treatments T_4, T_2, T_7, T_6 and T_1 at 60 DAS. At harvest, treatment T_7 displayed the highest dry matter accumulation, which was at par with T_8, T_2, T_6 and T_4. Conversely, treatment T_{10} consistently showed the lowest dry matter accumulation across all growth stages (Table: 1). Dhivya, R.S. and Ray, L. I.P. (2020) [13], Mahamud *et al.* (2022) [26], Rohan *et al.* (2022) [36] Kumar *et al.* (2020 a) [23], Anasuyamma *et al.* (2022) [2], Raviteja *et al.* (2022) [35], Akter *et al.* (2021) [1], Meena *et al.* (2022) [27] Chaudhary *et al.* (2020) [11] and Sharma and Pathania (2019) [39] also found similar result which supported the present study. The greatest recorded dry matter plant^{-1} (in grams) was produced, according to Kadam *et al.* (2014) [19], by applying vermicompost at a rate of 2.5 tonnes ha^{-1} and inoculating PSB seeds.

Leaf area index

Treatment T_8 demonstrated the highest leaf area index at both 30 and 60 days after sowing (DAS). However, its values were comparable to those of treatment T_9 and T_7 at 30 DAS and to treatments T_7, T_6, T_2, T_5, T_4, T_9 and T_1 at 60 DAS. Conversely, treatment T_{10} exhibited the lowest leaf area index at both 30 and 60 DAS (Table: 2). These findings align with similar results obtained by Dhivya, R.S. and Ray, L. I.P. (2020) [13], Akter *et al.* (2021) [1], Kumar *et al.* (2020 b) [25] and Suthakar *et al.* (2022) [42]. Gobi and Gunasekaran (2012) [17] reported that Vermicompost had significant positive effects on leaf growth, shoot length, root length, number of leaves and leaf area index.

Crop growth rate (g day^{-1} plant^{-1})

The recorded data indicates that treatment T_8 had the highest crop growth rate (CGR) at both 30 and 60 days after sowing (DAS). It was comparable to treatments T_4 and T_2 at 30 DAS and treatments T_7, T_4 and T_2 at 60 DAS, where similar results were observed. Meanwhile, treatments T_6, T_1, T_3 and T_5 exhibited similar CGR values. At harvest, treatment T_7 demonstrated the highest CGR, which was at par with treatments T_2, T_8, T_6, T_9 and T_4. In contrast, treatment T_{10} exhibited the lowest CGR across all growth stages (Table: 2).

Priyadharshini *et al.* (2021) [33], Kumar *et al.* (2021) [24], Geetha and Velayutham (2009) [16].

Relative growth rate (g g^{-1} day^{-1})

The data indicates that treatment T_8 exhibited the highest relative growth rate (RGR) at 60 days after sowing (DAS) and this was consistent with results similar to treatments T_7, T_6, T_4, T_2, T_1, T_3 and T_5. At harvest, treatment T_7 demonstrated significantly higher RGR, which was at par with treatments T_8, T_6, T_2, T_4 and T_9. However, treatment T_{10} showed the lowest RGR both at 60 DAS and at harvest (Table: 2). Priyadharshini *et al.* (2021) [33], Kumar *et al.* (2021) [24], Geetha and Velayutham (2009) [16].

Pod length (cm), Number of pods plant^{-1}, Number of seeds pod^{-1} and Test weight (g)

Treatment T_7 exhibited significantly higher number of pods plant^{-1}, which was similar to treatments T_4, T_8 and T_6. Conversely, treatment T_{10} had the lowest number of pods plant^{-1}. While pod length, number of seeds pod^{-1} and test weight did not show significant differences, numerically treatment T_7 displayed the highest values for pod length, number of seeds pod^{-1} and test weight. On the other hand, treatment T_{10} had the lowest values for these parameters (Table: 3). Similar result was obtained the findings are consistent with those of previous studies conducted by Sangeetha *et al.* (2013) [37] Kumar *et al.* (2021) [24], Akter (2021) [1], Ganvit *et al.* (2022) [14] and Rohan *et al.* (2022) [36]. These studies have also reported similar results, highlighting the positive impact of specific treatments on various growth and yield parameters in crops. Kadam *et al.* (2014) [19] also observed similar results. showed that the highest number of pods plant^{-1} was observed when vermicompost was applied at a rate of 2.5 tonnes ha^{-1} along with seed inoculation using PSB.

Grain yield (q ha^{-1}), Stover yield (q ha^{-1}) and Harvest index

Treatment T_7 demonstrated significantly higher grain (10.38 q ha^{-1}) and stover (18.86 q ha^{-1}) yields compared to all other treatments. Additionally, it was at par with treatments T_2 for grain yield and T_2, T_4, T_8 and T_6 for stover yield. Conversely, treatment T_{10} yielded the lowest results. Although harvest index did not exhibit significant differences, numerically treatment T_7 displayed the highest value, while treatment T10 (control) had the lowest harvest index (Table: 3). The outcomes are consistent with findings from a range of studies, including those by Dhivya, R.S. and Ray, L. I.P. (2020) [13], Priyadharshini *et al.* (2021) [33], Kumar *et al.* (2021) [24], Akter (2021) [1], Tripathi *et al.* (2017) [44], Solanki *et al.* (2022) [40], Suthakar *et al.* (2022) [42], Haridha *et al.* (2022) [18] and Kudi and Singh (2016) [22]. These collective studies further validate the relationship between specific agricultural practices and their impact on the growth, yield attributes and grain yield of black gram.

Economics

Treatment T_7 exhibited significantly higher gross return (₹ 70,404 ha^{-1}), net return (₹ 62,543 ha^{-1}) and benefit-cost (B:C) ratio (2.65). It was also at par with treatment T_2 in terms of gross return (₹ 66,893 ha^{-1}) and with treatment T_6 for net return (₹ 54,323 ha^{-1}). Conversely, treatment T_{10} yielded the lowest gross return, net return and B:C ratio among the treatments (Table: 4). The application of various manure treatments, particularly Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB, resulted in higher yields and lower investment costs, leading to increased net returns and favorable benefit-cost (B:C) ratios. This observation is consistent with similar findings reported by Dhivya, R.S. and Ray, L. I.P. (2020) [13], Priyadharshini *et al.* (2021) [33], Kumar *et al.* (2021) [24] and Bhadu *et al.* (2018) [8].

Table 1: Effect of manures on growth attributes of black gram (*Vigna mungo* L.)

Treatments		Plant height (cm)			No. of branches (plant^{-1})			Dry matter accumulation (g plant^{-1})		
		30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest	30 DAS	60 DAS	At Harvest
T_1 -	Farm yard manure @ 4 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	22.51	44.30	50.97	2.20	4.67	4.97	0.77	4.90	8.09
T_2 -	Farm yard manure @ 6 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	24.00	46.87	52.57	2.33	5.27	5.33	0.87	5.23	9.76
T_3 -	Vermicompost @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	22.49	39.53	46.90	2.27	4.93	5.07	0.61	4.62	7.74
T_4 -	Vermicompost @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	23.35	45.07	50.43	2.33	5.87	5.90	0.94	5.30	9.35
T_5 -	Goat manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	21.80	42.73	45.40	2.30	5.33	5.37	0.62	4.59	7.75
T_6 -	Goat manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	23.87	52.67	56.80	2.31	5.37	5.40	0.65	4.96	9.42
T_7 -	Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	25.11	44.67	55.67	2.40	6.17	6.20	0.85	5.20	10.13
T_8 -	Poultry manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	28.30	59.47	63.10	2.80	6.27	6.30	0.95	5.32	9.83
T_9 -	100% Inorganic *i.e.*, 20:40:20 kg NPK ha^{-1}	26.09	40.33	53.13	2.73	6.07	6.13	0.83	3.96	8.17
T_{10} -	Absolute Control	20.84	29.93	36.80	2.05	4.20	4.50	0.55	3.37	6.46
SEm±		1.22	2.36	1.85	0.13	0.25	0.24	0.03	0.22	0.34
CD at 5%		3.65	7.08	5.53	0.40	0.75	0.72	0.08	0.65	1.00
CV%		8.87	9.19	6.25	9.71	8.00	7.59	5.78	7.90	6.69

Table 2: Effect of manures on growth attributes of black gram (*Vigna mungo* L.)

Treatments		Leaf Area Index		CGR (g day^{-1} $plant^{-1}$)			RGR (g g^{-1} day^{-1})	
		30 DAS	60 DAS	0-30 DAS	30-60 DAS	60-At Harvest	30-60 DAS	60-At Harvest
T_1 -	Farm yard manure @ 4 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.63	2.96	0.026	0.137	0.106	0.047	0.039
T_2 -	Farm yard manure @ 6 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.71	3.10	0.029	0.145	0.151	0.049	0.050
T_3 -	Vermicompost @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.64	2.91	0.020	0.134	0.104	0.046	0.038
T_4 -	Vermicompost @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.67	3.02	0.031	0.145	0.135	0.049	0.047
T_5 -	Goat manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.50	3.06	0.021	0.133	0.105	0.046	0.039
T_6 -	Goat manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.72	3.14	0.022	0.144	0.149	0.049	0.050
T_7 -	Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.76	3.28	0.028	0.145	0.164	0.049	0.053
T_8 -	Poultry manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	0.90	3.45	0.032	0.146	0.150	0.049	0.050
T_9 -	100% Inorganic *i.e.*, 20:40:20 kg NPK ha^{-1}	0.82	2.97	0.028	0.104	0.140	0.038	0.047
T_{10} -	Absolute Control	0.48	2.30	0.018	0.094	0.103	0.034	0.038
SEm±		0.05	0.16	0.001	0.007	0.010	0.002	0.002
CD at 5%		0.15	0.49	0.003	0.022	0.029	0.007	0.007
CV%		12.29	9.36	6.088	9.748	12.665	8.639	8.388

Table 3: Effect of manures on yield attributes, yield and harvest index of black gram (*Vigna mungo* L.)

Treatments		Pod length (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest Index (%)
T_1 -	Farm yard manure @ 4 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.20	22.80	6.23	32.53	7.93	14.69	35.04
T_2 -	Farm yard manure @ 6 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.43	30.07	6.60	33.74	9.86	18.04	35.36
T_3 -	Vermicompost @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.27	26.07	6.27	31.82	6.86	14.20	32.49
T_4 -	Vermicompost @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.53	33.47	6.53	32.78	9.47	17.82	34.91
T_5 -	Goat manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.17	25.67	6.17	32.67	7.46	13.90	34.92
T_6 -	Goat manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.33	30.80	6.53	33.76	9.46	17.24	35.44
T_7 -	Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.77	37.27	7.10	35.31	10.38	18.86	35.50
T_8 -	Poultry manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	4.30	31.80	6.27	34.00	8.69	17.52	33.22
T_9 -	100% Inorganic *i.e.*, 20:40:20 kg NPK ha^{-1}	4.49	27.60	6.66	33.38	7.15	13.51	34.53
T_{10} -	Absolute Control	4.13	13.00	6.07	30.90	4.01	8.88	31.14
SEm±		0.13	2.18	0.21	0.91	0.27	0.69	1.05
CD at 5%		NS	6.52	NS	NS	0.82	2.07	NS
CV%		5.30	13.55	5.60	4.77	5.84	7.72	5.30

Table 4: Effect of manures on economics (gross return, net return and benefit cost ratio) of black gram (*Vigna mungo* L.)

Treatments		Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T_1 -	Farm yard manure @ 4 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	33585	53833	42638	1.27
T_2 -	Farm yard manure @ 6 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	41585	66893	53032	1.28
T_3 -	Vermicompost @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	27585	46711	37516	1.36
T_4 -	Vermicompost @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	37585	64253	51725	1.38
T_5 -	Goat manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	23585	50669	42807	1.82
T_6 -	Goat manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	29585	64185	54323	1.84
T_7 -	Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	23585	70404	62543	2.65
T_8 -	Poultry manure @ 2 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB	29585	59118	49256	1.66
T_9 -	100% Inorganic *i.e.*, 20:40:20 kg NPK ha^{-1}	20456	48516	41697	2.04
T_{10} -	Absolute Control	17425	27389	21581	1.24
SEm±					0.07
CD at 5%					0.22
CV%					7.66

Conclusion
In the one-year experiment, the best results were seen in T_7 (Poultry manure @ 1 t ha^{-1} + Seed inoculation with *Rhizobium* + PSB) showed the best growth outcomes in black gram. It led to high yield traits, including 37.27 pods $plant^{-1}$, grain yield of 10.38 quintals ha^{-1}, stover yield of 18.86 quintals ha^{-1}. T_7 had elevated gross returns (₹ 70,404 ha^{-1}), net returns (₹ 62,543 ha^{-1}), and benefit-cost ratio (2.65), highlighting its economic viability and profitability.

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