



Performance of Blackgram as Influenced by Water Soluble Fertilizers and PGPR under Rainfed Situation

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Authors' contributions

This work was carried out in collaboration among all authors. Author CBRT did the execution of field experiment and laboratory analysis and data recording. Author PBR did the preparation of manuscript.

Author MSM did the preparation of Manuscript. Author NSM did the conceptualization of research work and designing of experiments DR did the manuscript editing and data curation. All authors read and approved the final manuscript.

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ABSTRACT

Lower production potential of blackgram grown under rainfed situation due to lack of proper nutrition during critical crop growth stages. So, investigation was carried out with an objective to study the effect of water-soluble fertilizers and PGPR on performance of blackgram during *Kharif*-2019, a field

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study was carried out at University of Agricultural and Horticultural Sciences, Shivamogga which comes under Southern Transition Zone of Karnataka. Experimental design was laid out in randomized complete block design with thirteen treatments and replicated thrice. Treatments include combination of 19:19:19, monopotassium phosphate @ different dosage foliar spray with and without PGPR treatment along with package of practices. Water soluble fertilizers viz., 19:19:19 (N: P: K) and mono potassium phosphate (0:52:34) were used in treatment combinations along with PGPR. The Results revealed that, foliar application of 19:19:19 and mono potassium phosphate @ 1 per cent each at 30 and 45 days after sowing + PGPR along with a package of practice recorded significantly higher plant height, number of branches per plant, leaf and stem dry weight, crude protein (26.54 %), seed yield (1167 kg ha⁻¹) and haulm yield (2019 kg ha⁻¹) over package of practice treatment and also positive correlation was found between growth and yield parameters with seed yield and haulm yield.

Keywords: *Blackgram; foliar nutrition; PGPR; pulses; water soluble fertilizers; yielding; protein sources.*

1. INTRODUCTION

Agriculture is crucial for addressing the growing global food demand, and optimizing crop yield is essential for ensuring food security. Blackgram (*Vigna mungo* L. Hepper), commonly known as urad dal, is a vital leguminous pulse crop that is widely cultivated in various regions. It plays a significant role in providing protein, accounting for 24% of its content, and offers a calorific value of 347 Kcal per 100 grams. This grain legume is particularly important for food and nutritional security [1]. In India, blackgram represents approximately 13% of the total pulse cultivation area and 10% of the total pulse production. It is grown over an area of about 4.6 million hectares, yielding a production of 3.56 million tonnes with a productivity rate of 654 kg per hectare. In Karnataka, blackgram is cultivated on approximately 138,000 hectares, producing around 47,000 tonnes [2].

Blackgram is an important source of protein, especially for poor people and contribute to nutritional security. However, it is predominantly cultivated by small and marginal farmers under degraded soils and resource-constrained conditions. Many farmers are hesitant to apply a basal dose of fertilizer or less than the recommendation to pulse crops, leading to poor yields [3]. However, soil application of nutrients as a basal dose often fails to meet the demands of growing crops, especially for short-duration crops like blackgram. Given its indeterminate flowering and fruiting habit, there is continuous competition for available assimilates between vegetative and reproductive sinks throughout the growth period. In this context, foliar application of water-soluble fertilizers presents a promising option to enhance the yield of blackgram while

reducing cultivation costs [4]. Supplying legume plants with supplementary nitrogen or a balanced dose of nutrients, especially during the pre-flowering stage, has been found to positively impact seed yield. [4]. However, there are no regional guidelines for foliar nutrition of water-soluble fertilizers during the crop growth period. Apart from this, flower and fruit drop are the significant factors contributing to low yield due to poor flower-to-pod ratio and inadequate pod setting. To boost crop productivity, modern agriculture has increasingly adopted water-soluble fertilizers, which plants can easily absorb and allow precise nutrient delivery. These fertilizers are particularly beneficial in correcting nutrient deficiencies and supporting robust plant growth during critical stages such as flowering and pod filling. The sustainable cultivation of blackgram depends on various factors, including soil fertility and effective nutrient management practices [5]. Plant Growth-Promoting Rhizobacteria (PGPR) comprise a group of beneficial microbes that support soil biological activity and enhance nutrient availability in the rhizosphere. Additionally, PGPR aids in stress tolerance through the release of plant hormones. Understanding the impact of water-soluble fertilizers and PGPR on the correlation between various growth and yield parameters of blackgram is crucial for optimizing nutrient management practices and ensuring the crop's productivity and profitability. Systematic correlation studies between dependent and independent parameters will reveal the extent to which vegetative and yield parameters contribute to the final seed yield at different growth stages. This paper aims to elucidate the complex relationship between the growth and yield parameters of blackgram when subjected to water-soluble fertilizers and PGPR-based

nutrient management treatments, ultimately aiming to optimize crop productivity. Potential use of 19:19:19 and MPP is predominantly used in vegetables and commercial crops but very limited literature is available related to use of water-soluble fertilizers and PGPR in rainfed blackgram. Hence, this study was undertaken on priority to see the influence of combined use of water-soluble fertilizers sprays and plant growth promoting rhizomicrobial consortia on performance of black gram in rainfed conditions and to popularize the same in blackgram under rainfed condition.

2. MATERIALS AND METHODS

A field study was conducted during 2019 *Kharif* season at College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga, come under Southern Transition Zone of Karnataka (Zone-7). The geographically experimental site was located between 13° 58' to 14° 1' North latitude and 75° 34' to 75° 42' East longitude and at 650 m above the mean sea level. The experiment site soil texture was sandy loam with slightly acidic pH (6.19) and the soil texture was sandy loam, slightly acidic pH (6.19) and optimum level of in electrical conductivity (0.70 dS m⁻¹), lower organic carbon 4.56 g kg⁻¹. Initial soil was low in nitrogen availability (242.22 kg ha⁻¹), high in phosphorus availability (75.08 kg P₂O₅ ha⁻¹) and medium potassium availability (135.63 kg K₂O ha⁻¹). The total rainfall received during cropping period was 1088.8 mm. Field experiment was laid out in Randomized Complete Block Design (RCBD) with thirteen treatments and replicated three times. Treatments are allocated randomly b using random number table to reduce the biasness.

Treatments materials used in study was water soluble fertilizers (19:19:19 and Mono potassium phosphate (0:52:34)) and liquid plant growth promoting rhizomicrobial consortia application. Treatments combinations are as follows,

The field was prepared by ploughing with tractor drawn plough and subsequent harrowing and levelling of land for proper seed bed. Pythagoras theorem principle was used to prepare field layout by fixing baseline parallel to bund. Size of gross plot and net plot was 3.6x3 m² and 2.4x2.2 m², respectively. Blackgram variety LBG-625 (Rashmi) was sown at 30m x 10m spacing. Short duration variety having 85 to 90 days with average yield ranging from 8 to 9 q ha⁻¹. Package of practices of blackgram 6.5 t ha⁻¹ FYM, 13:25:25 kg NPK ha⁻¹+ 4 kg ZnSO₄ was applied as a basal dose for all the treatments. Liquid PGPR (*Rhizobium leguminosarum*, *Pseudomonas* sp. and *Bacillus* sp.) applied by mixed with FYM at the rate of 750 ml ha⁻¹ incorporated in to soil before sowing. One percent spray solution was prepared and sprayed at 30 and 45 DAS according to allocated treatments. The biometric observation was recorded manually from the 5 tagged plants from each plot during 30, 45 DAS and at harvesting stage and expressed as mean value of five plants. Yield attribute and yield was recorded at harvest time from each plot separately. Data was analysed in MS excel for ANOVA as per Randomized Block Design [6]. The significance between the treatments was tested using an F test with a 5% level of significance (P ≤ 0.05). Simple correlation between growth and yield parameters of black gram was estimated to know the correlation between these parameters and seed yield.

Table 1. Table of treatment DETAILS

Treatment No.	Treatment details
T ₁	: Package of practice (POP)
T ₂	: T ₁ +19:19:19 @1% at 30 DAS
T ₃	: T ₂ + PGPR
T ₄	: T ₁ +19:19:19 @1% at 30 and 45 DAS
T ₅	: T ₄ + PGPR
T ₆	: T ₁ +MPP @1% at 30 DAS
T ₇	: T ₆ + PGPR
T ₈	: T ₁ +MPP @1% at 30 and 45 DAS
T ₉	: T ₈ + PGPR
T ₁₀	: T ₁ +19:19:19@1% + MPP @1% at 30 DAS
T ₁₁	: T ₁₀ + PGPR
T ₁₂	: T ₁ +19:19:19 @1% + MPP @1% at 30 and 45 DAS
T ₁₃	: T ₁₂ + PGPR

3. RESULTS AND DISCUSSION

3.1 Plant Height

Plant height is a crucial growth parameter that indicates the vegetative growth response of the crop to the applied nutrients. Considerably maximum plant height (45.58, 59.30 and 67.16 cm was obtained at 45 DAS, 60 DAS and at harvest stage, respectively). The plant height was increases with advancing crop stage up to harvest, However, rapid increase in plant hight was noticed during 60 DAS to harvest than sowing to 60 DAS. Foliar application of water-soluble fertilizers directly on foliage facilitates rapid absorption, translocation of nutrients leading to increased activity of meristematic cells, rate of cell division and cell elongation attribute to enhanced plant height. PGPR application mobilizes the unavailable nutrients makes easy uptake and improved metabolic processes and better vegetative growth of plant. PGPR show positive interactions with soil microorganisms in the rhizosphere and beyond in bulk soil, which ultimately increases plant growth rate. Greater plant height was noted with application of FYM and PGPR [7].

3.2 Number of Branches per Plant

Branching serves as a significant growth parameter in pulse crops such as black gram, like tillering in cereals. The number of branches per plant determines the quantity of flowers and pods produced in black gram. Statistically greater number of branches 8.72 at 45 DAS, 9.96 at 60 DAS and 10.63 at harvest stage was found in T₁₃ treatment. The rise in branches per plant could be attributed to the acceleration of various metabolic processes such as photosynthesis and symbiotic biological N₂ fixation. This increase may also be influenced by higher nutrient availability during the initial stages of the crop, potentially facilitated by PGPR application, leading to enhanced sprouting of auxiliary buds. This might also due to greater absorption, mobilization and translocation of major nutrients by foliar nutrition of water soluble fertilizers.

3.3 Leaf and Stem Dry Weight per Plant

Significantly higher leaf dry weight (4.12, 7.19, 1.94 g plant⁻¹) and stem dry weight (1.52, 2.75 and 4.36 g plant⁻¹) at 45, 60 days after sowing and at harvest stage was noticed in the treatment receiving 19:19:19 @ 1 per cent + mono potassium phosphate @ 1 % at 30 and 45 DAS +

PGPR along with package of practices when compared to rest of the treatments except (T₁₁) with POP+19:19:19 @ 1 per cent + Mono potassium phosphate @ 1 per cent at 30 DAS+ PGPR (3.69, 6.86 and 1.71; 1.36, 2.37 and 3.93 g plant⁻¹ leaf and stem dry weight, respectively) at 45, 60 DAS and at harvest, respectively. Leaf dry weight was highest at peak vegetative stage when crop has better foliage cover as crop advances to harvest stage the leaves become dry and withers from the plant, only skeleton stem will remain at harvesting time.

3.4 Crude Protein

Significantly superior crude protein content was found in foliar application of 19:19:19 and MPP each @ 1 % at 30 and 45 DAS + PGPR with package of practices (26.54 %) and which showed on par to the T₁₁ (24.54 %) and T₁₂ (24.35 %) as compared to remaining treatments. This is may be due to soil application of PGPR increases the nutrient mobilization and nutrient availability and foliar application of 19:19:19 and MPP at flowering and pod setting stage results in effective absorption of nitrogen and its assimilation as amino acids and biosynthesis of proteins in sink. Increased nitrogen content in seeds results in higher protein content [8].

3.5 Grain and Haulm Yield

In the present study, seed yield and haulm yield was varied significantly among the applied treatments of water-soluble fertilizers and PGPR (Table 2). Application of 19:19:19 and MPP each @ 1 % at 30 and 45 DAS + PGPR + package of practice was recorded substantially higher seed and haulm yield (1067 and 2019 kg ha⁻¹, respectively) as compared to other treatments except T₁₁: T₁+19:19:19 @ 1%+ MPP @ 1% at 30 DAS+ PGPR (1085 and 1861 kg ha⁻¹) was showed on par results with respect of seed and haulm yield, respectively. The percent increment of seed and haulm yield in T₁₃ was about 45.43 and 25.43 %, respectively as compared to T₁. Increase in yield, might be due to foliar spraying of water-soluble fertilizers (19:19:19 and MPP) during 30 and 45 DAS, this facilitates rapid absorption and translocation of nutrients. The application of PGPR enhances the activity of effective root nodules, leading to increased mobilization and absorption of nutrients from the root zone [9]. This, in turn, results in a greater assimilatory leaf area, facilitating efficient translocation of photosynthates from source to sink. These improvements are reflected in the

Table 2. Effect of water-soluble fertilizers and liquid PGPR on growth parameters and crude protein content in blackgram

Treatment No.	Plant height (cm)			No. of branches plant ⁻¹			Leaf dry weight (g plant ⁻¹)			Stem dry weight (g plant ⁻¹)			CP %
	45 DAS	60 DAS	At harvest	45 DAS	60 DAS	At harvest	45 DAS	60 DAS	At harvest	45 DAS	60 DAS	At harvest	
T ₁	27.27	35.32	37.15	4.71	6.47	6.87	2.53	3.15	1.24	0.53	1.56	1.96	20.15
T ₂	32.83	38.59	42.02	5.35	7.68	7.89	2.63	4.31	1.28	0.66	1.64	3.16	22.45
T ₃	35.07	42.02	46.67	5.80	8.42	8.64	2.72	4.35	1.31	0.70	1.68	3.21	22.67
T ₄	32.80	40.99	45.71	6.20	8.36	8.81	2.78	4.50	1.42	0.72	1.73	3.24	22.54
T ₅	35.07	50.66	56.37	7.73	8.63	8.79	3.11	5.41	1.61	0.90	2.13	3.57	22.76
T ₆	32.53	39.95	45.54	5.30	7.85	7.87	2.62	4.38	1.34	0.65	1.66	3.15	22.74
T ₇	33.70	42.22	47.38	5.94	8.47	8.58	2.70	4.42	1.39	0.71	1.71	3.26	23.74
T ₈	32.53	41.11	45.35	6.23	8.44	8.74	2.76	4.56	1.43	0.73	1.76	3.30	23.64
T ₉	37.93	50.85	56.55	8.23	8.60	8.73	3.12	5.84	1.62	1.26	2.29	3.66	23.98
T ₁₀	36.20	44.16	51.30	6.20	8.41	8.75	3.02	5.65	1.58	1.21	2.01	3.51	23.92
T ₁₁	41.12	57.36	64.49	8.30	9.63	9.76	3.69	6.86	1.71	1.36	2.37	3.93	24.54
T ₁₂	38.40	51.22	57.27	7.83	8.60	8.76	3.21	5.85	1.61	1.23	2.23	3.65	24.35
T ₁₃	45.58	59.30	67.16	8.72	9.96	10.63	4.12	7.18	1.94	1.52	2.75	4.36	26.54
S. Em.±	2.4	2.66	3.2	0.50	0.4	0.6	0.24	0.45	0.10	0.06	0.15	0.23	0.8
CD @ 5%	6.9	7.77	9.3	1.47	1.3	1.8	0.71	1.33	0.30	0.19	0.43	0.68	2.3

T₁: package of practice (POP)(6.5 t ha⁻¹ FYM, 13:25:25 kg NPK ha⁻¹ + 4 kg ZnSo₄ as basal dose); T₂: T₁+19:19:19 @1 per cent at 30 DAS; T₃: T₂ + PGPR; T₄: T₁ +19:19:19 @1 per cent at 30 and 45 DAS; T₅: T₄+ PGPR; T₆: T₁+MPP @1 per cent at 30 DAS; T₇: T₆ + PGPR; T₈: T₁+MPP @1 per cent at 30 and 45 DAS; T₉: T₈ + PGPR; T₁₀: T₁+19:19:19@1 per cent + MPP @1 per cent at 30 DAS; T₁₁: T₁₀ + PGPR; T₁₂: T₁+19:19:19 @1 per cent + MPP @1 per cent at 30 and 45 DAS and T₁₃: T₁₂ + PGPR

Table 3. Effect of water soluble fertilizers and liquid PGPR on seed yield, haulm yield and harvest index of blackgram

Treatment No.	Grain yield	Haulm yield	Harvest index
T ₁	802	1603	0.33
T ₂	869	1640	0.35
T ₃	876	1653	0.35
T ₄	883	1708	0.34
T ₅	965	1767	0.35
T ₆	868	1624	0.35
T ₇	877	1657	0.35
T ₈	886	1715	0.34
T ₉	967	1753	0.36
T ₁₀	955	1733	0.36
T ₁₁	1085	1861	0.37
T ₁₂	994	1706	0.36
T ₁₃	1167	2019	0.37
S. Em.±	44.69	72.20	0.02
CD @ 5%	130.46	210.81	NS

**Refer Table 1 for treatment details*

Table 4. Correlation between seed yield, haulm yield of blackgram and different growth parameters at different growth stages as influenced by water soluble fertilizers and PGPR

	Plant height				Number of branches per plant			
	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
Seed yield	0.94	0.96	0.96	0.97	0.75	0.90	0.88	0.90
Haulm yield	0.91	0.89	0.88	0.88	0.68	0.84	0.86	0.91
	Number of leaves per plant				Leaf area			
	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
Seed yield	0.96	0.96	0.94	0.91	0.83	0.96	0.94	0.95
Haulm yield	0.97	0.91	0.91	0.90	0.81	0.94	0.93	0.91
	LAI				Leaf dry matter			
	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
Seed yield	0.86	0.97	0.94	0.95	0.89	0.99	0.97	0.96
Haulm yield	0.88	0.94	0.92	0.91	0.82	0.96	0.89	0.94
	Stem dry matter				Number of nodules per plant			
	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
Seed yield	0.87	0.93	0.96	0.88	0.69	0.68		
Haulm yield	0.76	0.84	0.91	0.82	0.64	0.65		

Table 5. Correlation studies between yield and yield attribute as influenced by water soluble fertilizers and PGPR

	No. of Pods plant ⁻¹	No. of Seeds Plant ⁻¹	Pod length	TW	Pod dry weight	Seed yield	Haulm Yield
No. of Pods plant ⁻¹	1						
Seeds plant ⁻¹	0.94	1					
Pod length	0.94	0.88	1				
TW	0.90	0.92	0.91	1			
Pod dry weight	0.92	0.95	0.89	0.95	1		
Seed yield	0.93	0.96	0.90	0.95	0.93	1	
Haulm Yield	0.93	0.95	0.86	0.86	0.86	0.95	1

production of better yield-attributing parameters. Greater number of yield attributing parameters enhances the yield of blackgram. The similar results are reported by Jadhav et al. [10]; Das and Jena [4] in black gram and Meena et al. [11] in green gram.

3.6 Correlation between Growth Parameters and Seed, Haulm Yield

From the tabulated data presented in Table 3, significant and positive relationship was noticed between seed yield and haulm yield with plant height (0.947 and 0.918), number of branches (0.753 and 0.681), leaves number (0.960 and 0.976), leaf area (0.836 and 0.811), LAI (0.868 and 0.881), leaf dry matter (0.898 and 0.823), stem dry matter (0.875 and 0.769) and number of nodules (0.694 and 0.647) at 30 DAS. Significant and positive relationship was observed between seed yield with plant height (0.966 and 0.892), number of branches (0.902 and 0.841), leaves number (0.963 and 0.919), leaf area (0.969 and 0.945), LAI (0.971 and 0.945), leaf dry matter (0.991 and 0.965), stem dry matter (0.934 and 0.842) and number of nodules (0.681 and 0.655) at 45 DAS.

Significant and positive relationship was witnessed between seed yield and haulm yield with plant height (0.964 and 0.889), number of branches (0.889 and 0.863), leaves number (0.941 and 0.913), leaf area (0.942 and 0.930), LAI (0.941 and 0.927), leaf dry matter (0.975 and 0.894) and stem dry matter (0.969 and 917) at 60 DAS. Significant and positive relationship was noticed between seed yield and haulm yield with plant height (0.970 and 0.889), number of branches (0.903 and 0.901), leaves number (0.918 and 0.901), leaf area (0.956 and 0.911), LAI (0.956 and 0.917), leaf dry matter (0.968 and 0.942) and stem dry matter (0.889 and 0.827) at harvest stage. Growth parameters have positive relationship with crop productivity [12].

3.7 Correlation between Yield Parameters and Seed Yield

From the correlation studies data in the Table 4 revealed that there is a significantly positive relationship was observed between seed yield with number of pods (0.935), number of seeds (0.962), pod length (0.901), test weight (0.957), pod dry weight (0.934) and haulm yield (0.950). Correlation studies showed that, more than 90 % of seed yield is contributed by the yield parameters such as number of pods, number of

seeds, pod length, pod weight and test weight. Similar results are reported by Bhavya et al. [13].

4. CONCLUSION

Foliar application of 19:19:19 and mono potassium phosphate each @ 1% at 30 and 45 DAS + PGPR with a package of practices will be better option for higher growth, yield and crude protein content in blackgram. Further, Correlation studies concluded that all the growth and yield parameters are positively correlated with seed yield and haulm yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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