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Effect of Water-Soluble Fertilizers and Plant Growth Promoting Rhizomicrobial Consortia on Nutrient Content, Uptake and Soil Chemical Properties in Blackgram

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Abstract: The field experiment was conducted with an objective to study the effect of water-soluble fertilizers and PGPR on yield and nutrient uptake of blackgram under rainfed condition during *Kharif*-2019 at University of Agricultural and Horticultural Sciences, Shivamogga. Initial soil nutrient status showed that available nitrogen (242.22 kg ha^{-1}), high phosphorus (75.08 kg P_2O_5 ha^{-1}) and medium potassium (135.63 kg K_2O ha^{-1}) was low. There were thirteen treatments consisting of different combinations of 19:19:19 and monopotassium phosphate (0:52:34) with or without liquid plant growth promoting rhizomicrobial consortia application. Treatments significantly influenced by foliar fertilization and plant growth promoting rhizomicrobial consortia application. The foliar application of 19:19:19 (N: P: K) and monopotassium phosphate (0:52:34) @ 1 per cent each at 30 and 45 days after sowing + PGPR along with a package of practice treatment recorded significantly higher nitrogen, phosphorous, potassium content (3.52, 0.42 and 2.10 %, respectively in seed) and uptake (69.49, 9.26 and 64.08 kg ha^{-1}, respectively) and also observed higher soil available N, P and K at 60 DAS and at harvest stage, respectively in the same treatment over package of practice.

Keywords: Blackgram, Soil fertility, Nutrient uptake, PGPR, Water soluble fertilizers

Blackgram (*Vigna mungo* L.) is a well-known leguminous crop in Asia and is adapted to a wide range of agro-climatic conditions because of its morphological parameters perfectly suited for intercropping and sole cropping systems. It is extensively grown as a grain legume for food and nutritional security (Anonymous 2019). In India, black gram contributes about 13 percent of the total pulse area and 10 percent of their total production and it was cultivated over an area of about 4.6 M ha with a production of 3.56 Mt. with a productivity of 654 kg ha^{-1} and in Karnataka, is cultivated over an area of 1.38 lakh ha with a production of 0.47 lakh tonnes (Anonymous 2018). Black gram is a highly priced pulse having a wide gap between the potential yield and actual yield. Low productivity of blackgram is due to marginal and poor soil fertility and imbalanced nutrition under rainfed condition (Thriveni et al 2023). Black gram is indeterminate flowering and fruiting habit and there was a continuous competition for available assimilates between vegetative and reproductive sinks during critical stages. The availability of nitrogen, phosphorus and potassium are often limiting for proper plant growth and productivity. Soil application of nutrients was often not sufficient to meet the nutrient demand of the crops because majority of the soil applied nutrients are lost or fixed. Foliar application of nutrients was considered an important method of fertilization in rainfed situations since the foliar application of nutrients easily penetrates the leaf cuticle or stomata and enters the cells facilitating easy and rapid utilization and translocation of nutrients from source to sink increases the nutrient content in plant parts (Ramesh et al 2020). Foliar application of fertilizers offers several advantages over traditional soil fertilization methods, effectively circumventing many of the drawbacks associated with soil-based approaches and allowing for rapid absorption and utilization (Kaushal et al 2014). The nutritional management is imperative to ensure better crop production on low fertile soils. PGPR is group of bacteria that colonize the rhizosphere that enhances plant growth and metabolism through different mechanisms. It includes enhanced fixation, mineralization and solubilization of nutrients for easy uptake and assimilation, production of plant growth regulators, siderophore production, as biocontrol agent against plant pathogens (Vejan et al 2016). PGPR application improves soil fertility by encouraging multiplication of beneficial rhizosphere bacteria (Babu et al 2023). The present research aims to determine the effect of water-soluble fertilizers and PGPR on the NPK content and uptake by blackgram and soil nutrient status.

MATERIAL AND METHODS

Field experiment was conducted during the *kharif* season of 2019 at University of Agricultural and Horticultural Sciences, Shivamogga which comes under Southern Transition Zone (Zone-7) of Karnataka. The geographical reference point of the experimental site was 13° 58' to 14° 1' North latitude and 75° 34' to 75° 42' East longitude and at an altitude of 650 m above the mean sea level. The soil was sandy loam in texture, slightly acidic pH (6.19) and normal in electrical conductivity (0.70 dS m^{-1}), low organic carbon (0.46%) , low in available nitrogen (242.22 kg ha^{-1}), high in phosphorus (75.08 kg P_2O_5 ha^{-1}) and medium in potassium status (135.63 kg K_2O ha^{-1}). During the cropping period, the total actual rainfall received was 1088.8 mm. The field experiment was laid out in a randomized complete block design with thirteen treatments and three replications. Treatments consisting of different combinations of water-soluble fertilizers *viz.,* 19:19:19 (N: P: K) and mono potassium phosphate (0:52:34) sprayed at 30 and 45 days after sowing with or without liquid PGPR (*Rhizobium leguminosarum*, *Pseudomonas* sp. and *Bacillus* sp) application along with the package of practice *viz.*, (Table 2). Package of practice of blackgram includes 6.5 t ha^{-1} FYM, 13:25:25 kg NPK ha^{-1} + 4 kg $ZnSo_4$ as basal dose. The variety Rashmi (LBG-625) was used in study and it matures in 85 to 90 days with an average yield ranging from 8 to 9 q ha^{-1}. The plots size was 3.6 and 3.0 m prepared by making bunds of 50 cm width and 30 cm height and treatments were allocated randomly in the plots within the blocks. The recommended dose of fertilizers and farm yard manure @ 7.5 t ha^{-1} was applied at the time of sowing common to all the treatments. Liquid plant growth promoting rhizomicrobial consortia (*Rhizobium leguminosarum*, *Pseudomonas sp*. and *Bacillus sp.*) mixed with farm yard manure at 750 ml ha^{-1} incorporated into soil as per treatments at the time of sowing. The one per cent solution of water-soluble fertilizers 19:19:19 and mono potassium phosphate was used for foliar spraying at 30 and 45 days after sowing as per the treatments.

Table 1. Methods followed in soil analysis

Parameter	Method used
pH	Potentiometric (Jackson 1973
EC	Conductometric (Jackson 1973)
Organic carbon	Wet oxidation (Walkley and Black 1934)
Nitrogen	Alkaline permanganate oxidation (Subbhiah and Asija 1956)
Phosphorous	Spectrometric (0.5 M $NaHCO_3$, pH 8.5, blue colour) (Olsen et al 1954)
Potassium	Flame photometric (Neutral N NH_4OAc) (Jackson 1973)

Plant analysis: Seed and plant samples are collected after the harvest of the crop according to treatment. The 500 g of plants and seeds were sampled and each sample was dried under shade and then in a hot air oven at 65°C. Dried samples were grounded 2mm sieve and used for further analysis. These grounded seed and plant samples were used for the estimation of N, P and K content by standard methods and nutrient uptake by the plant is calculated

$$\text{N uptake (kg ha}^{-1}\text{)} = \frac{\text{N content (\%)} \times \text{Dry matter production (kg ha}^{-1}\text{)}}{100}$$

$$\text{P uptake (kg ha}^{-1}\text{)} = \frac{\text{P content (\%)} \times \text{Dry matter production (kg ha}^{-1}\text{)}}{100}$$

$$\text{K uptake (kg ha}^{-1}\text{)} = \frac{\text{K content (\%)} \times \text{Dry matter production (kg ha}^{-1}\text{)}}{100}$$

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Soil analysis: Soil samples were collected from each plot (30 cm depth) at 30, 60 DAS, after harvesting and analyzed for pH, EC, OC and available soil NPK as per the set procedures (Table 1).

Statistical analysis: All the data recorded were processed in Microsoft Excel 2011 and analyzed with ANOVA at 5% level of significance ($P \leq 0.05$) (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

NPK content in blackgram: The significantly higher nitrogen content (3.52 and 1.54 %), phosphorus content (0.42 and 0.22 %), potassium content (2.10 and 1.98 %) in seed and haulm was in treatment receiving T_1+19:19:19 @ 1 per cent + mono potassium phosphate @ 1 per cent at 30 and 45 DAS + PGPR than all other treatments. This was statistically on par with T_1+19:19:19 @ 1 percent + MPP @ 1 percent at 30 DAS + PGPR (Table 2). Foliar application of water-soluble fertilizers s 19:19:19 and mono potassium phosphate facilitates quick penetration through stomata and absorption of nutrients. Increased supply of NPK reflected in greater synthesis of photosynthates and translocation of photosynthates from source to sink, thus improves the nutrient content in seed and nutrient uptake in green gram (Bhavya 2019). PGPR increases the NPK availability in rhizosphere and makes easy absorption by plant roots through fixation, mobilization and solubilization (Vejan et al 2016). The increased nutrient concentration in seed and haulm due to the foliar application of water-soluble fertilizers was also concluded in green gram by Takankhar et al (2018).

NPK uptake by blackgram: Significantly higher nitrogen uptake (40.40, 31.10 and 69.49 kg ha^{-1}), phosphorus uptake (4.82, 4.44 and 9.26 kg ha^{-1}), potassium uptake (24.10, 39.98 and 64.08 kg ha^{-1}) in seed, haulm and total uptake, respectively was in treatment receiving T_1+19:19:19 @ 1 per cent + mono potassium phosphate @ 1 per cent at 30 and 45 DAS + PGPR than all other treatments. This was statistically on par with T_1+19:19:19 @ 1 per cent + MPP @ 1 per cent at 30 DAS + PGPR. Higher NPK content and higher biomass production attributed to increased NPK uptake by crop. PGPR regulates hormonal and nutritional balance, inducing resistance against plant pathogens and solubilizing nutrients for easy uptake by plants. These results are similar to the findings of Mamathashree et al (2017) and Sharifi et al (2018). Chetana and Math (2018) and Manasa et al (2015) also observed the same trend.

Soil chemical properties: The soil analyses results indicated that there was no substantial changes in soil chemical properties like pH, EC and organic carbon content after harvest of the crop (Table 4). However, higher pH (6.23), OC (4.61 g kg^{-1}) was with T_1+19:19:19 @ 1 per cent + mono potassium phosphate @ 1 per cent at 30 and 45 DAS +

Table 2. Effect of water soluble fertilizers and PGPR on NPK content (%) in blackgram

Treatments details	Seeds			Haulm			Total		
	N	P	K	N	P	K	N	P	K
T_1: Package of practices	3.22	0.36	1.11	1.21	0.15	1.31	3.74	0.51	2.42
T_2: T_1+ 19:19:19 @1% at 30 DAS	3.24	0.38	1.59	1.23	0.17	1.41	4.53	0.55	3.00
T_3: T_2 + PGPR	3.36	0.38	1.58	1.38	0.17	1.53	4.78	0.55	3.11
T_4: T_1 +19:19:19 @1% at 30 and 45 DAS	3.32	0.38	1.70	1.35	0.17	1.51	4.76	0.56	3.21
T_5: T_4+ PGPR	3.37	0.38	1.79	1.38	0.18	1.53	4.83	0.57	3.32
T_6: T_1+ MPP @1% at 30 DAS	3.35	0.39	1.72	1.26	0.17	1.44	4.63	0.56	3.16
T_7: T_6 + PGPR	3.43	0.38	1.75	1.37	0.17	1.55	4.8	0.56	3.30
T_8: T_1+ MPP @1% at 30 and 45 DAS	3.38	0.40	1.75	1.38	0.18	1.66	4.93	0.58	3.41
T_9: T_8 + PGPR	3.42	0.38	1.80	1.38	0.18	1.67	4.74	0.57	3.47
T_{10}: T_1+ 19:19:19@1%+ MPP @1% at 30 DAS	3.40	0.38	1.69	1.34	0.17	1.72	4.72	0.56	3.41
T_{11}: T_{10} + PGPR	3.48	0.40	1.85	1.44	0.19	1.90	4.84	0.60	3.75
T_{12}: T_1+ 19:19:19 @1% + MPP @1% at 30 and 45 DAS	3.41	0.38	1.77	1.31	0.18	1.72	4.55	0.56	3.49
T_{13}: T_{12} + PGPR	3.52	0.42	2.10	1.54	0.22	1.98	5.05	0.64	4.08
CD (p=0.05)	0.06	0.03	0.28	0.11	0.02	0.25	0.64	0.05	0.47

See table 2 for treatment details; Package of practices: 6.5 t ha^{-1} FYM, 13:25:25 kg NPK ha^{-1} + 4 kg $ZnSo_4$

Table 3. Effect of water-soluble fertilizers and PGPR on NPK uptake by blackgram (kg ha^{-1})

Treatments	Seeds			Haulm			Total		
	N	P	K	N	P	K	N	P	K
T_1	25.82	2.89	8.91	19.39	2.07	21.00	45.21	4.99	29.91
T_2	28.17	3.30	13.83	20.17	2.79	23.13	48.35	6.09	36.95
T_3	29.46	3.33	13.85	22.82	2.81	25.30	52.27	6.14	39.15
T_4	29.34	3.36	15.03	23.06	2.90	25.80	52.41	6.26	40.82
T_5	32.54	3.67	17.28	24.39	3.18	27.04	56.93	6.85	44.32
T_6	29.10	3.39	14.94	20.47	2.76	23.39	49.57	6.15	38.33
T_7	30.11	3.34	15.36	22.70	3.15	25.68	52.81	6.49	41.05
T_8	29.97	3.55	15.52	23.67	3.09	28.48	53.64	6.64	43.99
T_9	33.09	3.68	17.41	24.20	3.42	29.29	57.29	7.10	46.70
T_{10}	32.50	3.63	16.15	23.24	2.95	29.82	55.73	6.58	45.98
T_{11}	38.82	4.46	20.63	26.81	3.87	35.37	65.63	8.33	56.01
T_{12}	33.93	3.78	17.61	25.36	3.07	29.36	59.29	6.85	46.97
T_{13}	40.40	4.82	24.10	31.10	4.44	39.98	71.50	9.26	64.08
CD (p=0.05)	4.67	0.51	4.24	4.86	0.61	6.12	9.60	1.16	8.27

See table 2 for treatment details

Table 4. Effect of water-soluble fertilizers and PGPR on soil NPK status at different crop stages

Treatments	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	Available nitrogen ($kg\ ha^{-1}$)			Available phosphorous ($kg\ ha^{-1}$)			Available potassium ($kg\ ha^{-1}$)		
				30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	6.15	0.73	4.50	248.58	232.32	212.81	78.32	75.3	73.25	147.87	122.2	110.52
T_2	6.18	0.70	4.57	251.95	233.87	214.30	79.52	76.32	74.26	148.68	126.25	116.2
T_3	6.17	0.69	4.56	253.06	236.00	222.83	80.25	78.68	76.38	150.81	131.87	120.9
T_4	6.23	0.70	4.53	255.64	240.87	221.68	80.25	79.98	77.86	149.25	132.18	122.2
T_5	6.22	0.70	4.54	256.34	242.30	224.65	81.85	79.35	77.95	149.25	132.18	122.2
T_6	6.16	0.71	4.59	255.35	240.89	223.09	82.35	80.65	78.35	150.74	131.92	125.85
T_7	6.21	0.70	4.55	254.07	243.20	228.02	82.35	80.32	78.86	151.53	134.23	126.12
T_8	6.15	0.71	4.57	254.45	241.20	225.43	81.32	79.35	77.42	150.12	132.83	123.36
T_9	6.19	0.70	4.51	256.85	243.25	232.65	84.36	81.25	78.38	150.45	137.6	129.32
T_{10}	6.11	0.70	4.61	256.64	243.52	231.73	83.45	80.32	78.26	149.32	134.58	126.2
T_{11}	6.18	0.71	4.59	255.63	244.80	233.72	84.32	81.32	79.32	152.15	140.23	130.25
T_{12}	6.21	0.72	4.61	256.12	244.54	230.76	83.65	80.66	78.23	151.82	136.52	127.85
T_{13}	6.20	0.71	4.62	256.19	245.60	237.41	85.57	82.25	80.35	152.2	142.58	132.87
CD (p=0.05)	NS	NS	NS	NS	8.2	7.9	NS	3.28	2.34	NS	9.2	10.2

See table 2 for treatment details; Package of practices: 6.5 t ha^{-1} FYM, 13:25:25 kg NPK ha^{-1} + 4 kg $ZnSo_4$

PGPR and higher electrical conductivity (0.73) in treatment receiving only package of practices.

The available nitrogen, phosphorous and potassium in the soil at 30 DAS was non-significant but this was differed significantly at 60 DAS and after harvest of crop by the foliar application of water-soluble fertilizers and PGPR (Table 4). Significantly higher available nitrogen, phosphorous and potassium (245.60, 82.25 and 142.58 kg ha^{-1}, respectively) at 60 DAS and at after harvest of the crop was in treatment receiving T_1+19:19:19 @ 1 per cent + mono potassium phosphate @ 1 per cent at 30 and 45 DAS + PGPR (237.41, 80.35 and 132.87 kg ha^{-1}, respectively) followed by T_1+19:19:19 @ 1 per cent + mono potassium phosphate @1 per cent at 30 DAS+ PGPR at 60 DAS and after harvest of the crop as compared to control. Consequently, lower available nitrogen, phosphorous and potassium were observed in the treatment receiving an only package of practices without any foliar spray. The soil fertilization, N_2-fixation (*Rhizobium* sp.), mineralization, nutrient solubilization process and production of organic acids due to the decomposition of organic matter by microorganisms, which cover on sesquioxide and thus reduce the phosphate fixing capacity (Rajput et al 2016). All these activities make greater availability of nutrients in soil. Lower availability of N, P and K in the soil at later stages of the crop and after harvest of crop. This might be due to the increased nutrient absorption from soil as crop growth advances. Application of liquid PGPR increases nutrient availability in the rhizosphere through fixation, mobilization and solubilization and facilitates easy for uptake.

CONCLUSION

The foliar application of water-soluble fertilizers and liquid PGPR along with the package of practice significantly influences the soil nutrient status, foliar application of 19:19:19 and MPP @1 % at 30 and 45 DAS facilitates rapid absorption and assimilation of applied nutrients, translocation results in improving the crop nutrient content and nutrient uptake of blackgram which is directly reflected on the final yield.

AUTHOR CONTRIBUTIONS

RT Chethan Babu: Conceptualization and Execution of field experiment and laboratory analysis, data analysis, writing, NS Mavarkar: Conceptualization of research work, supervision, BR Praveen: Preparation of manuscript, editing, R Dileep: Laboratory analysis, Data analysis and S Sudarshan: Editing.

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