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Effect of biofertilizer on growth, yield attributes and yield of summer black gram [*Vigna mungo* (L.) Hepper]

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Abstract
The yield of black gram is very poor as compared to many other legume crops. Indian soils are medium to poor status within both available nitrogen and phosphorus. Therefore, the present investigation is carried out to study the effect of different treatments on growth, yield attributes, the yield for summer black gram. Field experiment is conducted during the summer season of the years 2020 and 2021 on black gram in Rajkot (Gujarat). Six treatments comprised of alone and combined application of chemical fertilizers (50% and 100% RDF) and biofertilizers (Seed treatment with Rhizobium and application PSM on the soil) following randomized block design (RBD) with four replications. The results of the experiment revealed that treatment T6 increased significantly the growth parameters vis., plant height and number of branches/plant, however, plant height was remained statistically on par with treatment T2 in the pooled results. Treatment T6 increased significantly the yield attributes *viz*., number of pods /plant, number of grains/pod, and 100-grain weight. Treatment T6 recorded significantly higher grain yield 989 kg ha^{-1} and straw yield 1972 kg ha^{-1}. However, grain yield was remained statistically on par with treatment T2 in the pooled results.

Keywords: Biofertilizers, PSM, Rhizobium, RDF, Summer Black gram

Introduction
India is the world's largest producer and consumer of black gram. It contributes more than 70% to global production (Singh, 2021) [15]. It is a summer pulse crop with a short duration with a maturity period of just 90 days (Hussain *et al.*, 2011) [3]. More than 90% of black gram production comes from nine states. During 2017-2018, Gujarat occupies an area of about 1.33 lakh hectares producing 0.96 lakh tonnes of black gram so it contributes 2.64% and 2.92% to the total India's black gram area and production, respectively. The area under urd bean in India has increased from 2.83 million ha in 1980-81 to 5.03 million ha in 2017-18 whereas production of the plant during the same period has increased from 0.96 million tons to 3.28 million tons. Whereas yield during the same period has increased from 339 kg ha^{-1} to 352 kg ha^{-1} (Keifer and Effenberger, 2018) [7]. The yield of black gram is very poor as compared to many other legume crops (Siddikee *et al.*, 2019) [13]. One of the main causes of black gram's low productivity is poor soil fertility. Indian soils are medium to poor status within both available nitrogen and phosphorus (Shekhawat *et al.*, 2018) [12]. Plants use nitrogen primarily as a component of chlorophyll, glucosinolates, alkaloids and growth hormones (Kumar, 2018). Nitrogen is considered one of the master nutrients that enhance the metabolic processes that rely on protein, which leads to an increase in the crop's vegetative, yield, and reproductive growth (Sumalatha *et al.*, 2018) [16]. Phosphorus is the most important alimentary element for pulse production and the application of phosphorous significantly affects on nutritional quality and yield of pulses (Patel *et al.*, 2019) [11]. Despite applications of NPK, black gram shows signs of stagnation or low productivity (Jangir *et al.*, 2016) [4]. Several experiments have been conducted to investigate the impact of bio-fertilizers alone or with other chemical fertilizers. Recently bio-fertilizer has begun on a large scale as a promising component to integrating it in nutrient supply systems in agriculture (Palaniraja, 2018) [10].
From commonly used biofertilizers are Rhizobium and P-solubilizers, Rhizobium is useful for leguminous crops like groundnut, soybean because it benefits 10 – 35% yield increase, and 50– 200 kg N ha^{-1} and P-solubilizers, it is useful for Soil application for all crops it benefits 5–30% yield increase (Kumar, 2018) [8]. Inoculating pulse plant grains with a suitable Rhizobium helps to increase soil fertility (Shekhawat *et al.*, 2018) [12] and helps in boosting legumes production (Jangir *et al.*, 2016) [4]. Also, compared to applying nitrogen fertilizer, it is a less expensive and usually more effective agronomic practice for ensuring enough nitrogen nourishment of legumes (Heisnam *et al.*, 2017) [2].

Phosphorus is required by Rhizobium for its survival and growth in the soil. In addition, only 15 to 20% of phosphorous applied to the first crop is utilized (Kant *et al.*, 2017) [6]. In addition, microorganisms play a big role in solubilizing inorganic phosphorous in the soil that is not available to the plant and makes it available for plant uptake after solubilization. Effective microorganisms like fungi and bacteria lead to solubilization where brings the dissolution of bound forms of phosphates through lowering the pH by microbial secreting of organic acids such as acetic, glycolic, fumaric, formic, propionic, and succinic acids (Patel *et al.*, 2019) [11]. And by Organic Phosphorus Mineralization by acid phosphatases (Singh *et al.*, 2018) [14]. The present investigation is carried out to study the effect of different treatments on growth, yield attributes, and yield of summer black gram.

Materials and Methods

Experiment was conducted in fruit zone area of Marwadi University, Gauridad, Rajkot (Gujarat) during summer season of the years 2020 and 2021. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction. The soil was low in available nitrogen, medium in available phosphorus and available potassium. The soil was free from any kind of salinity or sodicity hazards. The black gram [*Vigna mungo* (L.) *Hepper*] variety Gujarat.1 was selected for this study, this variety is recommended by Junagadh Agricultural University, Junagadh. This variety is suitable for Kharif as well as the summer season. Randomized Block Design (RBD) was used with six treatments and four replications and each consisted of a T1= Absolute control, T2= Recommended dose of fertilizer (RDF) 20-40-0 Kg NPK/ha, T3= Rhizobium inoculation + 50% RDF, T4= Phosphate Solubilizing Microorganism (PSM) + 50% RDF, T5= Rhizobium inoculation + PSM + 50% RDF, T6= Rhizobium inoculation + PSM + 100% RDF. The crop was fertilized with farm yard manure at the rate @5 t ha-*1* in all plots. Chemical fertilizer was applied as per treatments. PSM was applied at basal application along with irrigation water @1 L/ha. The seeds were treated with Rhizobium inoculation before sowing @10 ml/Kg seed as per treatments.

The crop response to treatment application under the present investigation was evaluated on the basis of biometric studies where plant population, plant height (cm) and number of brunches /plant were recorded at the harvest of the crop. Plant population was done by counting the number of plants in 1-meter row length in each net plot area and converted into No. of plants/ha. The plant height (cm) and number of brunches/plant were measured of the randomly selected five tagged plants in each net plot of all replication at harvest. An average value for each plot was computed and recorded. The average number of pods / plant and number of grains / pod was recorded at harvest on the basis of five randomly selected plants from each net plot. Black gram grain samples were drawn from produce after weighing of each net plot yield. From these, 100 grains were counted and weighed. After harvesting and winnowing, grain yield from each net plot was weighted separately and recorded and it was converted into kg ha^{-1}. Straw yield was calculated by subtracting each net plot's grain yield from the respective total dry matter converted to kg ha^{-1}.

Results and Discussion

Growth parameters

The data on plant population, plant height and number of branches/plant recorded at harvest of the crop as influenced by various treatments are presented in Table-1. The analysis of variance is given in Appendix I. The final plant population of black gram was not significantly affected due to various treatments. Different treatments exerted their significant influences on plant height and number of branches / plant during 2020, 2021 and in pooled results.

Significantly higher plant height (43.5 cm) (44.3 cm) (43.9 cm) in the years 2020, 2021 and in the pooled results, respectively was recorded with treatment T6 which remained statistically on par with treatment T2. The lowest plant height was recorded under T1 in the both years and in the pooled results. In the year 2020, 2021 and in pooled results the treatment T6 produced significantly the highest number of branches/plant (5.28) (4.95) and (5.11), respectively. Treatment T6 was statistically on par with treatment T2 in the year 2020. Treatment T1 found significantly inferior by recording the lowest number of branches/plant 3.8 and 4.08 in 2021 and in pooled results, respectively. Such results were also observed by Jaybhay *et al.* (2017) [5] on the effect of Rhizobium + PSB + 100% RDF with respect to plant dry matter content, CGR and RGR of soybean, Bunker *et al.* (2018) [1] on the effect of Rhizobium + PSB + 20:40 kg NP ha^{-1} with respect to plant height of garden pea, Suresh *et al.* (2021) [17] on effect of Rhizobium leguminosarum + PSF + RDF with respect to plant height and number of branches/plant of groundnut.

Yield attributes

Data pertaining to number of pods/plant, number of grains/pod and 100-grain weight as influenced by various treatments recorded at harvest is presented in Table-2 and their analysis of variance is furnished in Appendix-I. Data indicated that the effect of different treatments on number of pods/plant and 100-grain weight were found significant in both the years as well as in pooled results. Whereas in case of number grains/pod was found significant in the year 2020 and in pooled results only.

In the year 2020 treatment T6 recorded significantly higher number of pods/plant (21.35) over rest of the treatments except treatment T2 and T5. In second year and in pooled results significantly maximum number of pods/plant 21.75 and 21.55, respectively were observed with treatment T6, which was at par with treatment T2. On the other hand, treatment T5 was found superior over treatments T3, T4 and T1 in pooled results of two years. Significantly, the lowest numbers of pods/plant were observed with treatment T1. *Viz.*, 16.13, 16.38 and 16.25 in 2020, 2021 and pooled results, respectively. Significantly maximum number of grains/pod 5.35 and 5.4 was recorded under treatment T6 in 2020 and in pooled results, respectively. However, it was found statistically on par with treatments T2 and T5. On the other hand, significantly the lowest number of grains/pod was recorded with treatment T1 *viz.*, 4.75, 4.73 in 2020 and in pooled results, respectively. But remained statistically at par with treatments T3 and treatment T4 in year 2020 and in pooled results. Significantly, maximum 100- grains weight (4.43 g) in pooled results was recorded under treatment T6.

However, it was found statistically on par with treatments T2 and T5. Treatments T4 and T3 found at par with each other and inferior to treatments T6, T2 and T5. Significantly the minimum100-grains weight was observed in treatment T1 with 3.84 g in pooled results.

The increase in yield attributes might be due to the availability of macronutrients (N, P) in optimum quantity in combination with the biofertilizers. Such results were also observed by Nandania (2005) [9] on the effect of Rhizobium + PSM + 100% RDF with respect to number of pods/plant, number of grains/pod and 100-grain weight of gram. Bunker *et al.* (2018) [1] in the effect of Rhizobium + PSB + 20:40 NP with respect to number of pods/plant and grains/pod of garden pea and. Suresh *et al.* (2021) [17] on the effect of Rhizobium leguminosarum + PSF + 100% RDF with respect to number of pods/plant, number of grains/pod and 100-grain weight of ground nut.

Grain and Straw yield

The data pertaining to the effect of different treatments on grain yield and straw yield of black gram recorded after harvest are presented in Table-3 and their analysis of variance are furnished in Appendix-I. Results presented in Table-3 revealed that grain yield and straw yield of black gram was significantly influenced due to different treatments tried in this experiment during 2020, 2021 and in pooled results.

Treatment T6 found significantly superior over others treatments except treatment T2 in respect of grain yield and straw yield recorded during the year 2020, 2021 and in pooled results. With grain yield 989 kg ha^{-1} and straw yield 1972 kg ha^{-1} in pooled results. Where treatment T1 found significantly inferior by recorded significantly the lowest yield of grain and straw yield during both years as well as in pooled results. It appears that a combination of biofertilizers and applied macronutrients (phosphor and nitrogen in optimum quantity) may result in increased grain yield and straw yield. There might have been an increase in grain yield due to the increase in pods/plant and grains/pod (Table-2) and an improvement in plant height and number of branches/plant (Table-1) may have led to improved straw yields. These findings are parallel to those of Nandania (2005) [9] on the effect of Rhizobium + PSM + 100% RDF with respect to grain yield and straw yield of gram, Jaybhay *et al.* (2017) [5] on the effect of Rhizobium + PSB + 100% RDF with respect to grain yield of soybean, Kant *et al.* (2017) [6] on the effect of Rhizobium + PSB + 75 kg P2O5 ha^{-1} with respect to grain and straw yield of black gram and Bunker *et al.* (2018) [1] on the effect of Rhizobium + PSB + 20:40 NP with respect to green pod yield of garden pea.

Table 1: Effect of different treatments on Plant population and growth parameters of summer black gram

Treatment	Plant population (lakh/ha)			Plant height (cm)			No. of branches/plant		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T1=Absolute control	2.00	2.00	2.00	28.20	29.45	28.83	4.35	3.80	4.08
T2= RDF 20-40-0 (NPK Kg /ha)	2.22	2.17	2.19	42.00	44.00	43.00	4.80	4.45	4.63
T3= Rhizobium inoculation + 50% RDF	2.22	2.00	2.11	34.20	32.75	33.48	4.75	4.38	4.56
T4= PSM + 50% RDF	2.00	2.06	2.03	33.25	35.25	34.25	4.70	4.33	4.51
T5= Rhizobium inoculation + PSM + 50% RDF	2.06	2.06	2.06	38.50	38.25	38.38	4.75	4.40	4.58
T6= Rhizobium inoculation + PSM + 100% RDF	2.22	2.17	2.19	43.50	44.30	43.90	5.28	4.95	5.11
S.Em±	0.10	0.10	0.06	1.57	1.73	1.01	0.17	0.16	0.10
C.D. at 5%	NS	NS	NS	4.73	5.20	2.92	0.53	0.48	0.30
C.V%	8.20	8.37	8.28	7.42	8.00	7.72	6.35	6.26	6.31

RDF: Recommended dose of fertilizers, PSM: Phosphate Solubilizing microorganisms, C.V: Coefficient of variation, C.D: Critical difference, NS- Non Significant at P > 0.05

Table 2: Effect of different treatments on yield attributes of summer black gram

Treatment	No. of pods per plant			No. of grains per pod			100- grains weight (g)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
T1=Absolute control	16.13	16.38	16.25	4.75	4.70	4.73	3.73	3.95	3.84
T2= RDF 20-40-0 (NPK Kg /ha)	20.75	21.60	21.18	5.10	5.25	5.18	4.33	4.34	4.33
T3= Rhizobium inoculation + 50% RDF	18.55	18.55	18.55	4.90	5.00	4.95	4.14	4.07	4.10
T4= PSM + 50% RDF	18.35	18.63	18.49	4.80	5.00	4.90	4.25	4.16	4.20
T5= Rhizobium inoculation + PSM + 50% RDF	20.25	19.25	19.75	5.05	5.20	5.13	4.20	4.28	4.24
T6= Rhizobium inoculation + PSM + 100% RDF	21.35	21.75	21.55	5.35	5.45	5.40	4.28	4.57	4.43
S.Em±	0.67	0.63	0.40	0.15	0.19	0.10	0.13	0.12	0.08
C.D. at 5%	2.02	1.90	1.15	0.44	NS	0.30	0.38	0.37	0.22
C.V%	6.04	5.63	5.84	5.05	6.36	5.76	5.30	5.07	5.19

RDF: Recommended dose of fertilizers, PSM: Phosphate Solubilizing microorganisms, C.V: Coefficient of variation, C.D: Critical difference, NS- Non Significant at P > 0.05

Table 3: Effect of different treatments on grain yield and straw yield of summer black gram

Treatment	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2020	2021	Pooled	2020	2021	Pooled
T1=Absolute control	675	699	687	1350	1381	1366
T2= RDF 20-40-0 (NPK Kg /ha)	956	966	961	1912	1718	1815
T3= Rhizobium inoculation + 50% RDF	822	834	828	1589	1642	1616
T4= PSM + 50% RDF	828	832	830	1525	1634	1580
T5= Rhizobium inoculation + PSM + 50% RDF	832	838	835	1603	1685	1644

T6= Rhizobium inoculation + PSM + 100% RDF	985	992	989	1951	1994	1972
S.Em±	40	42	25	75	70	44
C.D. at 5%	121	126	73	225	211	128
C.V%	8.17	8.44	8.31	7.80	7.24	7.52

RDF: Recommended dose of fertilizers, PSM: Phosphate Solubilizing microorganisms, C.V: Coefficient of variation, C.D: Critical difference, NS- Non Significant at P > 0.05

Appendix I: Analysis of variance (M.S.S.) of different characters

	Year 2020			Year 2021			pooled				
S V	**R**	**T**	**E**	**R**	**T**	**E**	**R/Y**	**Y**	**T**	**Y × T**	**E**
d. f.	**3**	**5**	**15**	**3**	**5**	**15**	**6**	**1**	**5**	**5**	**30**
Characters											
Plant population	0.02	0.05	0.03	0.09	0.02	0.03	0.06	0.02	0.06	0.02	0.03
Plant height at harvest	3.31	134.34	7.38	2.60	145.05	8.93	2.96	6.31	275.70	3.69	8.16
No. of branches per plant	0.01	0.35	0.09	0.11	0.54	0.08	0.06	1.80	0.87	0.01	0.08
No. of pods per plant	2.52	14.98	1.35	0.88	16.68	1.19	1.70	0.20	30.89	0.77	1.27
No of grains per pod	0.06	0.20	0.06	0.01	0.27	0.11	0.04	0.14	0.45	0.01	0.08
Test weight (g)	0.18	0.19	0.05	0.04	0.19	0.05	0.11	0.06	0.34	0.05	0.05
Grain yield (Kg ha^{-1})	595.43	49341.87	4816.31	2890.11	45219.87	5270.91	1742.77	1323	94457.93	103.80	5043.61
Straw yield (Kg ha^{-1})	912.44	216325.07	16661.91	27560.44	154042.40	14724.31	14236.44	5125.33	346537.93	23829.53	15693.11

Conclusion

For getting maximum yield from summer black gram crop it should be fertilized with recommended dose of fertilizer ((RDF) 20-40-0 Kg NPK/ha) along with seed inoculation with rhizobium and soil application of Phosphate Solubilizing Microorganism.

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