Plant Archives Vol. 25, Supplement 1, 2025 pp. 816-822 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.108

EFFECT OF PHOSPHORUS AND PHOSPHATE SOLUBILIZING MICROORGANISM ON GROWTH AND YIELD OF BLACKGRAM (*VIGNA MUNGO L.*) UNDER THE ALFISOLS OF TELANGANA INDIA

C. J. Reddy[1], A. K Singh[1], Yabi Gadi[2]* and Y. A. Reddy[1]
[1]School of Agricultural sciences, Nagaland University, Medziphema – 797106, Nagaland, India
[2]School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan- 302017, India
*Corresponding author email: evangelineyabs@gmail.com
(Date of Receiving : 14-08-2024; Date of Acceptance : 11-10-2024)

ABSTRACT

A field experiment was conducted at the farmer's field in Nakrekal Village of Nalgonda district of Telangana state during the period of December 2020 to March 2021 to make a study on "Effect of Phosphorus and Phosphate Solubilizing Microorganism on Growth and Yield of Blackgram [*Vigna mungo* L.] under the Alfisols of Telangana". In this field experiment with 12 treatments and three replications, the experiment was designed using Randomized Block Design (RBD). The study found that varied doses of fertiliser had a significant impact on plant growth, yield attributes, and quality parameters such as protein content, nutrient availability in soil after harvest of blackgram. The crop growth attributes such as plant height, number of leaves plant^{-1} and number of branches plant^{-1} were significantly influenced by its application.

The highest seed yield of 1161.33 kg ha^{-1} and stover yield of 2495.24 kg ha^{-1} was recorded with the treatment of 50 Kg P_2O_5 ha^{-1} + PSM and was significantly superior over all the other treatments. The highest nutrient content was also recorded with the treatment of 50 Kg P_2O_5 ha^{-1} + PSM. The available nutrient in soil was also found to be significantly improved with the application of treatment 50 Kg P_2O_5 ha^{-1} + PSM.

Keywords: Blackgram, Fertilizers, PSM, Yield, Quality

Introduction

India is the major pulse growing country, ranking first with about 90 percent of world area and 85 percent world's production of grain legumes (Singh and Singh, 2012). Pulses are important component of Indian agricultural economy only next to food grains and oil seeds in terms of acreage, production and economic value (Choudhary, 2009 and Ali *et al.*, 2012).

Pulse is the main supply of dietary protein for vegetarians, contributing around 14% of the typical Indian dietary protein. The Blackgram carries around 24% protein, 60% carbohydrates, 10.9% moisture, 1.4% fat, 0.9% fibre, 3.2% minerals and a tiny extent of nutrition B-complex, calcium-154 mg, phosphorus 385 mg, ironic 9.1 mg.

In tropical and subtropical nations, blackgram has been generally disseminated. It is cultivated in *Kharif,* Rabi and summer season in India, Pakistan, Sri Lanka, Burma and several eastern Asian nations. In India black gram is very popularly grown in Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal, Punjab, Haryana, Tamilnadu and Karnataka. In India, it is grown on an area of about 21.67 lakh acres with the total production of 14 lakh tonnes with an average productivity of 452 kg ha^{-1}. In Uttar Pradesh, it is grown on an area of 3.91 lakh ha^{-1} with the production and productivity of 1.72 lakh tonnes and 440 kg ha^{-1}, respectively (Directorate of Economics and Statistics (DES), *3rdAdvance Estimates 2020-21).

Phosphorus increases symbiotic nitrogen fixation because bacterial cells become mobile in the presence of phosphorus, which is required for bacterial cell migration to root hair for nodulation (Charel, 2006). Microorganisms that secrete various organic acids (formic, acetic, butyric, propionic, citric, glucomic, succinic, oxalic, malic, maleic, and lactic acids) play a significant role in the solubilization of soil P and making it available to plants (Gaur, 1991).

Phosphate uptake by plants and yields were enhanced when P was combined with phosphate solubilizing microorganisms, demonstrating that the phosphate solubilizing microorganisms were able to solubilize phosphates and mobilize phosphorus in crop plants. As a result, the goal of this study was to see how phosphorus levels and phosphate-solubilizing bacteria affected black gram yield and quality. Phosphorus solubilizing bacteria play a significant role in phosphorus nutrition by improving phosphorus availability to plants by solubilizing and mineralizing phosphorus from inorganic and organic soil "P" pools. Lowering of soil pH by microbial generation of organic acids and mineralization of organic Phosphorus by acid phosphatises are the two main mechanisms for mineral phosphate solubilization in soil. Phosphorus uptake is increased by using phosphorus solubilizing bacteria as inoculants. These bacteria also improve the likelihood of phosphatic rocks being used in crop production.

The present study was conducted to evaluate the beneficial effect of phosphorus and in combination with PSB inoculums to determine the nitrogen, phosphorus, potassium and sulphur concentration in roots, shoots and grains and their uptake by black gram plant. In most of the pulses, number of branches, number of pods, seed weight and seeds per pod are the major yield components. In spite of the concerted efforts to combine these major yield components, so far no significant increase in yield of gain could be made except a marginal improvement in the component in pulses, which is major reason for yield stagnation.

The present investigation entitled "Effect of Phosphorus and Phosphate Solubilizing Microorganism on Growth and Yield of Blackgram [*Vigna mungo* L.] under the Alfisols of Telangana'' has been conducted at farmer's field in Nakrekal village of Nalgonda district of Telangana state with objectives to study the effect of phosphorus and PSM on growth, yield and quality of blackgram.

Material and Methods

The present investigation entitled "Effect of Phosphorus and Phosphate Solubilizing Microorganism on Growth and Yield of Black gram (*Vigna mungo L.*) under the Alfisols of Telangana" was conducted in the farmer's field in Nakrekal village of Nalgonda district of Telangana state during 2021. The climate of the experimental farm represents a semi-arid climatic zone with high relative humidity, and an average rainfall ranges from 720-1078 mm per annum. The mean temperature ranges from 29ºC to 38ºC during summer and rarely goes below 18ºC in the winter season. The representative soil samples were collected from the experimental site, processed and physico-chemical properties of the soils were analyzed with prescribed standard procedure. The soil of the experimental field was sandy loam in texture, alkaline in nature having medium organic carbon (%), with low nitrogen, medium in phosphorus, potassium and low in sulphur. The treatments adopted in the study are represented as follows: T_1- control, T_2- Phosphate solubilizing microorganism (PSM), T_3- 10 kg P_2O_5 ha^{-1}, T_4- 20 kg P_2O_5 ha^{-1}, T_5- 30 kg P_2O_5 ha^{-1}, T_6- 40 kg P_2O_5 ha^{-1}, T_7- 50 kg P_2O_5 ha^{-1}, T_8- 10 kg P_2O_5 ha^{-1} + PSM, T_9- 20 kg P_2O_5 ha^{-1}+ PSM, T_{10}- 30 kg P_2O_5 ha^{-1} + PSM, T_{11}- 40 kg P_2O_5 ha^{-1}+ PSM and T_{12}- 50 Kg P_2O_5 ha^{-1} + PSM. These treatments were replicated thrice in a randomized block design. The recommended dose of nitrogen, phosphorus, potassium and sulphur fertilizers (25:50:25) were applied through urea, di-ammonium phosphate, muriate of potash and single super phosphate, respectively. The recommended dose of fertilizers along with recommended dose of phosphate solubilizing microorganism=10ml Kg^{-1} seed). The Black gram variety used for the experiment was PU-31 and was sown on 1st January. After crop maturity, the yield attributing characters and yield data were recorded. Oil content was estimated using soxhlet extraction unit as per method described by AOAC 1960. Seed protein content (%) was estimated by multiplying percent N content in seed with the factor 6.25. After harvest, the soil samples were taken randomly from each plot for analyzing available N (modified kjeldhal method as described by Black, 1965. Available P (vanado-molybdate yellow colour) method as outlined by Jackson, 1973. Available K as mentioned by Chapman and Pratt, 1962 and Available S (turbidimetric method) as detailed by Chensin and Yien, 1950. Plant samples were collected and air dried and then oven-dried at 60-70°d for 12 h. The dried samples were ground and preserved for assessing the nutrient contents and uptake of nutrients. The nutrient uptake was calculated using the following formula:

$$\text{Nutrient uptake} = \frac{\text{Nutrient content (\%) x Total dry matter yield (kg/ha)}}{100}$$

Finally, the experimental data recorded during the course of investigation were statistically analyzed as per standard method prescribed by Cochran and Cox, 1962.

Results and Discussion

Effect on growth attributes

Plant height (cm) of black gram at 30 DAS, 45 DAS, 60 DAS and at harvest as influenced by different levels of phosphorus are presented in the Table 1. The height of the plant at different stages of observation increased significantly with increased in the levels of phosphorus and PSM. It was observed that the plant height at 30 DAS (43.15 cm), 45 DAS (49.49 cm) 60 DAS (53.87 cm) and at harvest (54.04 cm) was highest with the application of 50 kg P_2O_5 ha^{-1} + PSM. The significant increase might be due to application of phosphorus which plays a vital role in improving the growth and development of plants in terms of plant dry matter, plant height, number of branches per plant with improvement in plant system and rhizosphere nutritional environment ultimately leading to significant increase in photosynthetic activity and plant metabolism. The numbers of leaves per plant at different stages of crop growth were significantly influenced by application of different levels of phosphorus and PSM. The maximum number of leaves per plant at 30 DAS (4.53), 45 DAS (7.53) and 60 DAS (10.07) was recorded with application of 50 kg P_2O_5 ha^{-1} + PSM over rest of the treatments. Similarly, it was observed that increased in levels of phosphorus with combined application of PSM significantly influence the number of branches in plants at harvest. Application of 50 kg P_2O_5 ha^{-1} showed higher number of branches at 30 DAS (4.54), 45 DAS (6.33) 60 DAS (7.20) and at harvest (5.33).

Effect on yield attributes and yield

Application of 50 kg P_2O_5 ha^{-1} + PSM treatment (T_{12}) recorded the maximum number of pods per plant (29.73) while, the lowest number of pods per plant was recorded in control (18.53). The effect of different levels of phosphorus and PSM on number of seeds pod^{-1} was found to be significant. Maximum number of seeds 7.47 was recorded with the application of 50 kg P_2O_5 ha^{-1} + PSM. Early flowering in plants is induced due to application of bio fertilizers as it activates the process of the bio regulators which had a positive effect on early flowering. Inoculation of seeds with PSM had a significant effect on days to start flowering as presented in Table 2 and it was observed that application of 50 kg P_2O_5 ha^{-1}+ PSM takes lesser number of days to 50% flowering as compared to the rest of the treatment. Seed inoculation with PSM had a significant effect on the grain yield. Among the different treatment of seed inoculation, 50 kg P_2O_5 ha^{-1} + PSM treatment of seeds recorded the highest grain yield (1161.33 kg ha^{-1}) and stover yield (2495.25 kg ha^{-1}) over rest of the treatment as mentioned in Table 2. The increase in the seed and stover yield may be due to solubilization of phosphorus by PSB or due to applied phosphorus, thereby increasing the availability of phosphorus to the plants resulting in profuse growth of the plant which ultimately increases the seed and stover yield. These findings were supported by work carried out by Singh (2004), Mir *et al*. (2013). The data recorded in the Table 2 further revealed the effect of different levels of phosphorus and PSM on seed protein content has showed significant result. The highest protein content (24.79%) was recorded with the application of 50 kg P_2O_5 ha^{-1} + PSM. The maximum nitrogen acquisition efficiency (184.44) was recorded with the application of (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM. Increase in protein content in seed of blackgram might be due to enhanced uptake and translocation of nitrates which provide nitrogen for amino acid synthesis. Significant role of these treatments in root enlargement, better microbial activities resulted in more availability and uptake of nitrogen and thereby increased protein content in seed Rathore *et al*. (2015). The observations recorded were found similar with Singh *et al*. (2013), Meena *et al*. (2015).

Effect on nutrient content and total nutrient uptake

The nutrient content in seed was shown in Table 3 which indicated that there was a significant variation between each treatment. The maximum nitrogen content in seed was recorded in treatment (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (3.97%), however the nitrogen content of the stover has showed non-significant variation. The maximum N content in stover was found in treatment (T12) 50 kg P_2O_5 ha^{-1} + PSM (1.92%). The phosphorous content of the seed showed a significant variation between each treatment. The maximum phosphorous content in seed was identified in treatment (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (0.53%), the phosphorous content of the stover showed significant variation. The maximum phosphorous content in stover was found to be (0.32%). Potassium content of the seed showed a non-significant variation between each treatment. The requirement of P was sufficed with the application of P solubilisers which would have solubilised the insoluble form of P during its decomposition. Similar findings were reported by Kabir *et al*. (2011). The long-term use of commercial fertilizers has increased the plant-available soil P of many agricultural soils to excessive levels. Therefore, the rate of P uptake is related to the P concentration in soil solution (Bagyaraj *et al*., 2015)

The maximum potassium content in seed was identified in treatment (T_{12}) P_2O_5 ha^{-1} + PSM (1.95%). The maximum potassium content in stover was found to be (1.70%) in T_{12}. Similarly, sulphur content of the seed showed significant variation among each treatment. The maximum sulphur content in seed was recorded with combined application of 50 kg P_2O_5 ha^{-1} + PSM (0.28%), followed by (T_7), similarly maximum sulphur content in stover was recorded to be (0.15%) in (T_{12}).

The data recorded to the different sources of fertilizers on nutrient uptake by seed and stover is presented in the Table 4. The maximum Nitrogen uptake was identified in treatment (T_{12}) with 50 kg P_2O_5 ha^{-1} + PSM (88.02). Phosphorus uptake by seed and stover was also increased significantly with the application of various treatments. The maximum Phosphorus uptake was identified in treatment (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (11.17) and followed by (T_7) 50 kg P_2O_5 ha^{-1} i.e. (10.89). Similarly, from the data it is observed that potassium uptake by seed and stover increased significantly. The results also indicated that K uptake by grain and straw was significantly affected by the treatments. The maximum potassium uptake was identified in treatment (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (64.94). From the data it is observed that Sulphur uptake by seed and stover increased significantly. The maximum Sulphur uptake was identified in treatment (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (3.72).

The data recorded in the Table 4 revealed the effect of different sources of fertilizers for nitrogen acquisition efficiency. The Maximum i.e. (184.44) was recorded with the application of (T_{12}) 50kg P_2O_5 ha^{-1}+PSM. These findings were similar with the findings of (Majumdar *et al.* 2007).

Effect on available nutrient status in soil

Inoculation of seeds with biofertilizers increased the availability of nutrient in the soil. From the Table 5 it was observed that the highest available nitrogen was recorded with the combined application of 50 kg P_2O_5 ha^{-1} + PSM (261.76 kg ha^{-1}) and phosphorus which received treatment (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM recorded 18.17 kg ha^{-1}. The available potassium was found to be highest in the treatment which received (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (229.08 kg ha^{-1}). Further it was also observed that the highest available sulphur was recorded in the treatment which received (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM (10.88 kg ha^{-1}). Similar results were also recorded by Arbad Niraj and Prakash (2014), Nissa *et al.* (2017) and Kant *et al.* (2017).

However highest soil pH was recorded as (7.90) with control treatment. The percentage of organic carbon was non-significantly increased in soil after harvest and is presented in Table 5. The highest organic carbon was recorded as (0.69%) with (T_{12}) 50 kg P_2O_5 ha^{-1} + PSM, while the lowest soil pH was recorded in control T_1 (0.49). These findings are similar to the results of Arbad and Ismail (2012).

Conclusion

On the basis of the findings from the present investigation, it may be concluded that among the twelve different treatments the application of 50 Kg P_2O_5 ha^{-1} + PSM exhibited better performance in Blackgram crop which influence the growth attributes, flower initiation, yield and quality of the blackgram and also, improving the nutrient content and nutrient uptake in seed and stover and nutrient availability in soil after harvest. So, it can be concluded that the 50 kg P_2O_5 ha^{-1} + PSM application is most effective to increase the yield and quality of blackgram and residual soil nutrient status under the Alfisols condition of Telangana. The application of 50 kg P_2O_5 ha^{-1} + PSM which minimize the cost of fertilizers, and better alternative fertilizers which can be easily handled by the farmers.

Table 1 : Effect of different amount of phosphorus fertilizers and PSM on growth attributes of blackgram

Treatments	Plant height (cm)				Number of leaves $plant^{-1}$				Number of Branches			
	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest	30 DAS	45 DAS	60 DAS	At harvest
T_1	23.83	31.89	35.54	36.03	2.63	5.07	8.27	3.13	2.66	3.58	4.53	3.93
T_2	26.93	33.31	37.01	38.06	2.73	5.20	8.47	3.33	2.73	3.64	4.94	4.13
T_3	28.94	34.73	39.40	40.53	3.07	5.47	8.67	3.53	3.10	3.91	5.20	4.27
T_4	32.91	37.79	42.85	43.54	3.33	5.87	8.93	3.80	3.33	4.59	5.68	4.53
T_5	36.06	40.43	46.06	47.25	3.67	6.40	9.53	4.00	3.67	5.29	5.95	4.67
T_6	38.56	45.18	49.17	50.26	3.93	6.73	9.73	4.47	3.93	5.67	6.38	4.93
T_7	41.57	48.07	52.16	53.01	4.27	7.13	9.93	4.73	4.27	6.10	6.90	5.27
T_8	30.01	36.26	41.12	42.16	3.20	5.67	8.73	3.60	3.20	4.22	5.35	4.47
T_9	34.51	38.75	44.81	45.43	3.53	6.27	9.33	3.93	3.53	4.98	5.81	4.67
T_{10}	37.48	42.99	47.93	48.57	3.73	6.53	9.67	4.13	3.73	5.43	6.18	4.80
T_{11}	39.91	46.59	50.29	51.05	4.13	6.93	9.87	4.60	4.13	5.70	6.78	5.07
T_{12}	43.15	49.49	53.87	54.04	4.53	7.53	10.07	5.13	4.54	6.33	7.20	5.33
SEm±	0.64	0.35	0.37	0.69	0.22	0.2	0.28	0.15	0.23	0.12	0.20	0.16
CD (p=0.05)	1.89	1.04	1.09	2.02	0.64	0.59	0.82	0.43	0.67	0.36	0.60	0.46

Table 2 : Effect of different amount of phosphorus fertilizers and PSM on yield attributes of blackgram

Treatments	Days to start flowering	Days to 50 % flowering	Number of pods plant^{-1}	Number of seeds pod^{-1}	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Protein content (%)
T_1	36.33	41.67	18.53	4.27	639.82	1799.55	18.69
T_2	35.67	41.33	20.87	4.87	691.82	1847.21	19.69
T_3	35.67	41.00	21.53	5.07	704.00	1887.10	20.29
T_4	35.33	40.67	22.93	5.67	789.46	1979.78	21.15
T_5	34.67	40.33	24.67	6.00	841.52	2007.66	21.83
T_6	34.33	40.00	26.80	6.40	936.12	2142.44	22.58
T_7	34.00	39.67	28.87	6.93	1076.67	2364.80	24.10
T_8	35.33	40.67	21.87	5.40	752.39	1919.01	20.75
T_9	34.67	40.33	23.87	5.93	826.80	1997.01	21.38
T_{10}	34.33	40.00	25.20	6.20	886.07	2088.89	22.10
T_{11}	34.00	39.67	27.93	6.73	980.09	2263.62	23.13
T_{12}	32.67	39.33	29.73	7.47	1161.33	2495.24	24.79
SEm±	0.32	0.42	0.21	0.19	8.03	20.81	0.42
CD (p=0.05)	0.93	NS	0.62	0.55	23.56	61.04	1.24

Table 3 : Effect of different amount of phosphorus fertilizers and PSM on nutrient content of seed and stover of blackgram

Treatments	Nutrient content of seed (%)				Nutrient content of stover (%)			
	N	P	K	S	N	P	K	S
T_1	2.99	0.29	1.52	0.158	1.04	0.11	1.26	0.107
T_2	3.15	0.31	1.59	0.173	1.19	0.12	1.28	0.119
T_3	3.25	0.34	1.62	0.180	1.27	0.14	1.31	0.121
T_4	3.38	0.39	1.67	0.205	1.43	0.18	1.39	0.128
T_5	3.49	0.44	1.70	0.226	1.58	0.21	1.48	0.135
T_6	3.61	0.48	1.78	0.248	1.67	0.26	1.58	0.143
T_7	3.86	0.51	1.86	0.269	1.81	0.29	1.67	0.151
T_8	3.32	0.37	1.63	0.192	1.35	0.15	1.35	0.124
T_9	3.42	0.42	1.69	0.212	1.51	0.19	1.44	0.131
T_{10}	3.54	0.46	1.75	0.235	1.61	0.24	1.55	0.137
T_{11}	3.70	0.49	1.83	0.251	1.78	0.28	1.61	0.148
T_{12}	3.97	0.53	1.95	0.287	1.92	0.32	1.70	0.155
SEm±	0.07	0.02	0.04	0.08	0.05	0.01	0.04	0.002
CD (p=0.05)	0.20	0.05	NS	0.24	0.15	0.02	NS	NS

Table 4 : Effect of different amount of phosphorus fertilizers and PSM on total nutrient uptake and protein content

Treatment	Total Nitrogen Uptake	Total Phosphorus uptake	Total Potassium uptake	Total Sulphur uptake
T_1	41.91	4.06	32.46	1.202
T_2	43.84	4.88	34.58	1.418
T_3	46.77	5.04	36.09	1.497
T_4	55.03	6.02	40.67	1.87
T_5	61.18	7.67	43.94	2.171
T_6	69.51	9.09	50.45	2.626
T_7	84.31	10.89	59.47	3.249
T_8	50.88	5.72	38.23	1.682
T_9	58.5	7.24	42.73	2.014
T_{10}	64.89	8.47	47.97	2.369
T_{11}	76.56	9.72	54.27	2.798
T_{12}	88.02	11.17	64.94	3.72
SEm±	1.19	0.19	0.93	0.56
CD (p=0.05)	3.49	0.56	2.73	1.65

Table 5 : Effect of different amount of phosphorus fertilizers and PSM on soil available nutrient status after harvesting of crop

Treatments	Soil pH	Organic carbon (%)	Available nutrient (kg ha^{-1})			
			N	P	K	S
T_1	7.90	0.49	233.82	10.66	209.70	6.06
T_2	7.88	0.53	236.15	11.43	210.06	6.57
T_3	7.87	0.55	238.41	12.78	211.03	6.84
T_4	7.84	0.59	243.07	13.96	215.58	7.56
T_5	7.80	0.64	251.58	15.11	220.09	8.24
T_6	7.77	0.67	257.76	16.15	224.78	8.87
T_7	7.79	0.68	259.30	17.27	227.65	9.83
T_8	7.86	0.57	240.63	13.43	213.17	7.30
T_9	7.82	0.62	247.37	14.21	216.98	7.79
T_{10}	7.79	0.65	254.61	15.72	222.52	8.53
T_{11}	7.77	0.68	258.12	17.37	226.65	9.62
T_{12}	7.78	0.69	261.76	18.17	229.08	10.88
SEm±	0.04	0.01	5.27	0.37	0.37	0.13
CD (p=0.05)	NS	NS	15.45	1.08	1.09	0.37

Conflict of Interest

The author affiliated to School of Agricultural Sciences, Nagaland University, Medziphema, India, declare no conflicts related to the research on Effect of Phosphorus and Phosphate Solubilizing Microorganism on Growth and Yield of Blackgram (*Vigna mungo L.*) under the Alfisols of Telangana.

Acknowledgements

The author expresses sincere gratitude to the School of Agricultural Sciences, Nagaland University, Medziphema, India, Department of Agriculture for providing the necessary resources and assistance for conducting this research and is also grateful for farmer's field in Nakrekal village of Nalgonda district of Telangana state for conducting the trial. We also acknowledge the contributions of our fellow researchers Yabi Gadi and Y. A. Reddy. The author is thankful to Dr. A.K Singh for his support during the entire course of research work. Additionally, we extend our appreciation to all individuals who directly or indirectly contributed to the successful completion of this research.

References

Arbad, B.K., Ismail, S. (2012). Effect of continuous use of chemical fertilizers and manures on soil biological and chemical properties in soybean safflower system. *Journal of Soil and crops*. **22**(1): 109-114

Ali, M., Kumar, N., Ghosh, P. K. (2012). Milestones on agronomic research in pulses in India. *Indian Journal of Agronomy*. **57**: 52-57.

Bagyaraj, D. J., Sharma, M. P., Maiti, D. (2015). Phosphorus nutrition of crops through arbuscular mycorrhizal fungi. *Curr. Sci*. **108**: 1288-93

Black, C.A. (Ed). (1965). Methods of soil analysis. Part I and Part II. American Society of Agronomy, inc., Publisher, Madison, Wisconsin, USA.

Bray, R.H., Kurtz, L.T. (1945). Determination of soil organic and available form of phosphorus in soil. *Soil Science*. **59**: 39-45.

Charel, J.D. (2006). Response of green gram [*Vigna radiata* L. wilczek] to phosphorus and sulphur with and without PSB inoculation. M. Sc. Thesis, Anand Agricultural University, Aanand.

Chapman, H.D., Pratt, P.F. (1962). Methods of analysis for soils, plants and water, University of California Agriculture Division.

Chesnin, L., Yien, C.H. (1950). Turbidimetric determination of available sulphur. *Soil Science Society of American Proceedings*. **15**: 149-151.

Choudhary, A.K. (2009). Role of phosphorus in pulses and its management. Indian Farmer's Digest., **42**(9): 32-34.

Cochran, W.G. and Cox, G.M. 1962. Experimental design (2nd Edition). Asian Publishing House, New Delhi.

Gaur, A.C. (1991). Phosphate solubilizing micro-organism and bio-fertilizers. Omega Scientific Publishers, New Delhi, 176.

Hanway, J., Heidal, H.S. (1952). Soil testing laboratory procedures. *Jowa Agriculture*. **57**: 1-31-50.

Jackson, M.L. (1973). Soil chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi, pp: 31.

Kant, S., Kumar, A., Kumar, S., Kumar, V., Gurjar, O.P. (2017). Effect of biofertilizers and P levels on yield, nutrient content, uptake and physic-chemical properties of soil under black gram (*Vigna mungo* L.). *International Journal of Current Microbiology and Applied Science*. **6**: 1243-51.

Kabir, M. H., Talukder, N. M, Uddin, M. J., Mahmud, H. and Biswas, B. K. (2011). Total nutrient uptake by grain plus straw and economic of fertilizer use of rice mutation STL-655 grown under boro season in saline area. *J. Environ. Sci. Nat. Resour*. **4**: 83-87

Mir, A.H., Lal, S.B., Salmani, M., Abid, M., Khan, I. (2013). Growth, yield and nutrient content of black gram (*Vigna* *mungo*) as influenced by levels of phosphorus, sulphur and Phosphate Solubilizing Bacteria. *SAARC Journal of Agriculture*. **11**: 1-6.

Meena, R. S., Dhakal, Y.N., Verma, S.K., Singh, A. (2015). Growth, yield and nutrient content of mungbean (*Vigna radiate* L. Wilczek) in response to INM in eastern Uttar Pradesh, India. *Bangladesh Journal of Botany*. **44**: 479-482

Nissa, S., Bashir, S., Dar, S.A., Baba, J.A., Hakeem, S.A., Wani, R.A., Mughal, M.N., Basu, Y.A. (2017). Effect of Rhizobium and PSB in combination with phosphorus on the enrichment of soil fertility and its effect on yield of green gram (*Vigna radiata* L.). *International Journal of Current Microbiology and Applied Science*. 3648-52.

Rathore, D.K., Gupta, A.K., Choudhary, R.R., Sadhu, A.C. (2015). Effect of integrated phosphorus management on growth, yield attributes and yield of summer green gram (*Vigna radiata* L.). *The Bioscan*. **10**: 05-07.

Singh, Y.P. (2004). Role of sulphur and phosphorus in black gram production. Fertilizer news. **49**: 33-36.

Singh, A.K., Singh, R.S. (2012). Effect of phosphorus and bioinoculants on yield, nutrient uptake and economics of long duration pigeonpea (*Cajanus cajan*). *Indian Journal of Agronomy*. **57**(3): 265-269.

Singh, R., Malik, J.K., Thenua, O.V.S., Kumar, A. (2013). Response of pigeonpea (*Cajanus Cajan*) + mungbean (*Phaseolus Radiatus*) intercropping system to phosphorus and biofertilizers. *Legume Research*.**36**:323-31.