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Impact of phosphorus and Sulphur organo mineral fertilizers on growth and yield attributes of green gram (*Vigna radiate* (L.) Wilczek) on alluvial soil

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Abstract
The aims of our study were to enhance plant growth promotion and yield of Green gram crop by various combinations of phosphorus organo-Mineral Fertilizers (P-OMF), Sulphur Organo-Mineral Fertilizers (S-OMF) and recommended doses of fertilizers (RDF) under two year field experiments. The treatment combination (T_7) (75%RDF +P-OMF@ 5.0 q ha^{-1} +S-OMF@5.0 q ha^{-1}) increased 31.68 cm, 9.75 (q ha^{-1}), 22.43 (q ha^{-1}) and 32.58 (g) Plant height, grain yield, stover yield and test weight in 2013-14 year and also 36.68 cm, 10.02 (q ha^{-1}), 22.14 (q ha^{-1}) and 33.23 (g) in 2014-15 year, respectively. Similarly these treatment combinations showed maximum pod length, Number of pods plant^{-1}, Number of seed pod^{-1}, total nodules plant^{-1}, and dry weight of nodules plant^{-1} (mg). The results showed that the combined application of combination (T_7) (75%RDF +P-OMF@ 5.0 q ha^{-1} +S-OMF@5.0 q ha^{-1}) can be used as efficient fertilizer consortium for Green gram production.

Keywords: Impact of phosphorus, Sulphur, Organo mineral fertilizers, growth and yield of green gram, alluvial soil

Introduction

India is the largest producer of pulses in worldwide 24 per cent share in the global production. The important pulse crops are chickpea, pigeon pea, mung bean, urdbean, lentil and field pea. The major pulse-producing states are Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka and Andhra Pradesh, which together account for about 80 per cent of the total production. The country has been harvesting pulse production of around 14–18 MT, coming from a near-stagnated area of 22–26 m ha, since 1990–91. During this period, an additional population of 350 million has been added, which led to a sharp decline in the availability of pulses. Short fall in pulses has been attributed to a number of factors, the major ones being the increasing population, holding size, rising income, geographical shift, abrupt climatic changes, complex disease–pest syndrome, socio-economic conditions and poor marketing opportunities in relatively low-input management. India grows nearly 22.99 million ha pulses with the annual production of 14.18 million tones with an average productivity of 610 kg/ha (Anonymous, 2014) [2]. The per capita availability of pulses is dwindling fast from 74.9 g in 1959 to 35.5 g in 2014 as against the minimum requirement of 70 g per day/capita prescribed by ICMR which causes malnutrition among the growing population. Therefore, it is necessary to evolve strategy for enhancing the production of pulses to meet the protein requirement of increasing population of the country.

Green gram [*Vigna radiate* (L.) Wilczek] is an important pulse crop of India. It is also commonly known as mungbean, which is an ancient and well known leguminous crop of Asia. The importance of green gram in Indian economy is hardly overemphasized due to its valuable and easily digestible protein, fat, calcium, phosphorus, iron and vitamin B. It is used as a green manuring and cover crop for enriching soil fertility due to its high atmospheric nitrogen fixation capacity through *Rhizobium* root nodulation and addition of huge biomass. Mung bean is sometimes grown for fodder as hay, straw or silage by Mogotsi (2006) [8]. It is particularly valued as early forage as it outcompetes other summer growing legumes like cowpea or velvet bean in their early stages by Lambrides *et al*., (2006) [6]. The average productivity of green gram crop has remained static (343 kg ha^{-1}) due to several reasons *viz.*, lack of suitable seed production techniques, cultural practices, inefficient harvest and post-harvest operations, and proper nutrient management practices, etc. The key role of nutrient in the phenomenal growth in food production in developing countries like is well established in India however, the cost of fertilizers, particularly P and S fertilizers is very high because of non-availability of raw materials suitable for production of conventional phosphatic and sulphur fertilizers. India has large deposits of rock phosphate (RP), most of which are low-grade and unsuitable for manufacturing of commercial P-fertilizers because of their low P content and low reactivity, Narayanasamy and Biswas (1998) [9]. Rock phosphates for direct application are effective in acid soils. However, a minimum processing is required before application in non-acid soils. Some alternative methods for improving low-grade RP are by partial acidulation, Biswas and Narayanasamy (1998) [9]; thermal alteration by Reddy *et al*., (2000) [15]; blending with water-soluble fertilizers dry compaction of RP with water-soluble P fertilizers and preparation of RP-enriched compost (Biswas and Narayanasamy, 2006) [4].

In India, the most significant and popular sources S fertilizers are elemental sulphur, ammonium sulphate, single superphosphate (SSP), potassium sulphate, potassium magnesium sulphate, gypsum and pyrite. These materials have the advantages of supplying sulphur primarily as a component of multi-nutrient fertilizers in a sulphate form that is immediately available for plant uptake. Elemental sulphur-containing fertilizers are the most concentrated sulphur carriers. The manufacturer of single super phosphate using rock-phosphate and sulphuric acid but potassium sulphate was totally imported. Besides using the other costly nutrient supplying material such as inorganic fertilizers (DAP, SSP and SOP) these low cost materials can effectively be used as a source for phosphorus and sulphur, if modified or altered by some suitable chemical or biological means. One of the possible means of utilizing both low grade rock phosphate and pyrite is by mobilizing their insoluble P and S through composting by technology where inert P and S sources are expected to be converted intosoluble forms because of the acidic environment prevailing during composting. Also this would provide an efficient method for the utilization of these indigenous resources, in a practical and economic way. Preparation of rock phosphate and pyrite enriched compost or P/S-organo mineral fertilizers (OMF)could be an option to improve soil quality by increasing microbial activities as well as physical and chemical properties of the soil, thereby provides better soil environment for growth and development. However, very limited information is available on preparation of organo mineral fertilizers using crop residues mixed(rice straw) with rock phosphate and pyrite along with microbial inoculation to enhance biodegradation process of organic matter as well as to improve the quality of product, an area that requires thorough investigation. Hence, it is important to develop a suitable technique for preparation of good quality of compost in the shortest possible time and evaluate its effectiveness as source of nutrients for crop production under intensive cropping system and the capacity to improve soil health.

The alternative means to utilize these large quantities of nutrient-rich biomass and to recycle them back to the field is to convert them into a value added product known as compost. Composting is recognized as an economical and sustainable option for waste management as it is easy to undertake and can be conducted in the local site of the produce by Singh and Amberger, (1998) [17] and Biswas *et al.,* (2009) [3]. However, traditional composts prepared from farm wastes have low nutrient content, particularly P and S and these nutrients need to be enriched. Therefore, compost may be prepared from rice straw enriched with rock phosphate and pyrite using cellulose, degrading phosphate solubilizers and sulphur dissolving microorganisms such as *Trichoderma,* PSB and *Thiobacillispp.* The rock phosphate (RP) and pyrite enriched compost in plant nutrition is now attracting the attention of agriculturists and soil scientists throughout the world. The cost of chemical fertilizer has increased in recent times throughout the world in general, and India in particular. Therefore, it is the need of the day to find an alternate source of phosphate and sulphate fertilizers.

The organo-mineral fertilizers (OMF) are a betteralternative to inorganic fertilizers as it improve not only soil but also increase its organic matter content.The applications of OMF improve the physical, chemical and microbiological properties of the soil. The important role of OMF is to improve the yield and quality of different crops and enrich nutrient status of soil. Organo-mineral fertilizers (OMF) offer several advantagesover organic amendments or mineral fertilizers. Theyimprove plant-mineral interaction by reducing mineral absorption of nutrients. A good alternative of management of alluvial soils in an eco-friendly way is to use varioustypes of organo-mineral fertilizers. The organo-mineral fertilizers in the soil provide structure and forms stable aggregates. This provides the conducive environment for the survival of living organisms. Currently many efforts are being made in order to restore fertility and productivity of soil using this technique. Organo-mineral fertilizers may be described as mineral products whose formation is induced by-products of biological activity, dead and decaying organisms, non-biological organic compounds. Organo-mineral fertilizers form bio-minerals that are formed by incorporation into natural mineral such as rock- phosphate, pyrite, gypsum, waste mica and rice straw or crop residueetc. The organo-mineral fertilizers are organic amendments of mineral fertilizers. OMFs are enriched with the complex structures containing macro and micronutrients with natural organic substances like fulvic and humic substances. They are produced by tertiary humic acid (peat, lignite, silt) and other rock phosphates and pyrites by the treating with solutions like ammonium solution, phosphoric acid and potassium salt. Organo-mineral fertilizers have various compositionsnamelyPhosphate enriched organo mineral fertilizer (P-OMF), Sulphur enriched organo mineral fertilizer (S-OMF), Potassium enriched organo mineral fertilizer (K-OMF), humoammophos, peatammonia fertilizer (PAF), Peat mineral ammonia fertilizer (PMAF) and humate of potassium and ammonium etc.Organo-mineral fertilizers (OMF) offer several advantages over organic amendments or mineral fertilizers. They improve plant-mineral interaction by reducing mineral sorption of phosphorus and sulphur decreasing the transformation of P_2O_5 into plant unavailable forms. It is envisaged that the development of OMF will go some way to secure the agricultural route for disposal by offering farmers a value added product. It may also enable farmers to reduce the reliance on mineral fertilizers which are going up in price. The potential environmental risk associated with the use of OMF and the effects on pulse and cereal crops need to be quantified. Effective communication of technical-scientific information to end users is crucial to establishing public confidence in the use of organic-based fertilizers such as organo-mineral fertilizers of P and S. Strategies for the production and application of organo-mineral fertilizers need to be developed to optimize their agronomic performance and to minimize potential environmental risks arising from their use. It is understood that the development of OMF products constitutes a sustainable approach towards the efficient use of organic resources in agriculture. Considering above aspect in mind, it is essential to develop a cost effective eco-friendly sustainable system where the supply of nutrients to plants canbe ensured. In this respect development of enriched Organo-mineral fertilizer using crop residues mixed with natural mineral inoculated with microbial culture through composting holds a great promise in India.

Methods and Materials

The present investigation was conducted at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *kharif* and *rabi* season of 2013-14 and 2014-15. The detailed account of materials used and experimental procedures employed during the course of investigation have been described in this chapter.

Treatment details

The treatments considered of recommendation dose of fertilizers, the level of phospho-organo-mineral fertilizer and two level of sulphur organo-mineral fertilizer including control. The phosphorus, Organo-Mineral Fertilizers (P-OMF) and Sulphur Organo-Mineral Fertilizers(S-OMF) were applied once in green gram crop, whereas, recommended doses of fertilizers (RDF) were applied as per treatments and second residual wheat crop was grown as residual crop without application of P-OMFand S-OMF, Table1.

Table 1: Treatment combination and recommendation dose of fertilizers

Treatments	Fertilizer concentration
T_1	Control
T_2	50% RDF*
T_3	75%RDF
T_4	100%RDF
T_5	75%RDF + P-OMF**@ 5.0 q ha^{-1}
T_6	75%RDF +S-OMF***@ 5.0 q ha^{-1}
T_7	75%RDF +P-OMF@ 5.0 q ha^{-1} +S-OMF@5.0 q ha^{-1}

*Recommended dose of fertilizer, ** (P-OMF) Phosphorus Organo-mineral fertilizer and ***(S-OMF) Sulphur Organo-mineral fertilizer

Application of treatments

The treatments considered of recommended dose of fertilizers (50,75 and 100%) individually or in combination of P-OMF and S-OMF, Organo-mineral fertilizers each @ 5.0 q ha^{-1} and10.0 q ha^{-1} were applied in soil at the time of sowing of Green gram only. Whereas recommended dose N, P and K of fertilizers were applied in both direct green gram crop as well as residual wheat crop. Full dose of phosphorous in the form of di-ammonium phosphate @ 60 kg ha^{-1}and potassium in the form of sulphate of potash @ 40 kg ha^{-1} and half dose of nitrogen through urea were applied as basal dose at the time of sowing to with crop grown in sequence. The half dose of nitrogen was applied after first and second irrigation. P and S organo-mineral fertilizers were not applied in residual wheat crop grown in sequence.

Preparation of field Green gram

Proper field preparation is essential for a healthy green gram crop. The land was ploughed by soil turning plough followed by two disking. The field was irrigated to obtain proper tilth. Finally the lay out was done to meet the requirements of the experimental design.

Crops and their variety

Green gram was grown as direct crop followed by seceding wheat as residual test crop in the experiment field. Green gram (*Vignaradiata* L Wilczek) Variety HUM-12, developed at Department of Genetic and plant breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi was used in the study. This variety suits well in drained rainfed condition, fits in the green gram-wheat cropping system of Northern India

Observations for green gram attributes

The appropriate plant number according to requirement per experimental plot as a sample size and a random sampling technique (Gomez and Gomez, 1984) were adopted for recording growth and development of the test crops at various stages of observations. Destructive sampling was done for dry matter accumulation studies. The growth indices of the crop like Plant height, pod length, Number of pods plant^{-1}, Number of seed pod^{-1}, total nodules plant^{-1}, dry weight of nodules plant^{-1} (mg), stover (q ha^{-1}), grain (q ha^{-1}) and test weight (g) during both the years were recorded with standard procedure.

Statistical analysis and interpretation of data

All the data reported in the manuscript were analysed statically applying Randomized Block Design (RBD) by the method of "Analysis of Variance" as described by Gomez and Gomez (1984). The statistical significance of the treatment effect was judged with the help of variance ratio test. Critical Difference (C.D.) at 0.05% level of significance was worked out to determine the difference between treatment means.

Results and discussion

The plant height is one of the important characteristics, which indicates the nutrient absorption capacity as well as health of the plants. The plant height influenced significantly with application of P and S of Organo-mineral fertilizers in green gram at all the growth stages in green gram. The maximum plant height was recorded by T_7 (32.68 cm and 36.68 cm) followed by T_6, T_5 over control T_1 (28.89 cm and 31.63 cm) at 90 days after sowing (DAS) in 2013-14 and 2014-15 respectively (Table 2). Maximum plant height has been obtained by T_7 treatment due to application of (50%RDF+P-OMF@10.0qha^{-1}+S-OMF@10.0qha^{-1}). The effect was effective in both the years of field investigation on green gram with addition of P and S organo-mineral fertilizers. Almost similar result was also noticed with the plant height and dry matter. Considering the single factor rock phosphate enriched compost showed superior stem growth mainly due to the fact that rock phosphate enriched compost has high plant available phosphate (Nishanth and Biswas 2008, Odongo *et al*., 2007) [10, 11] compared to rock phosphate amended substrates and those without phosphorus. Thus, at higher compost doses

Table 2: Effect of direct application of P and S organo-mineral fertilizers on plant height yield and test weight

Treatment	2013-14				2014-15			
	Plant height (cm) at 90 DAS	Grain (q ha^{-1})	Stover (q ha^{-1})	Test weight (1000 grain weight) (g)	Plant height (cm) at 90 DAS	Grain (q ha^{-1})	Stover (q ha^{-1})	Test weight (1000 grain weight)(g)
T_1	28.89	6.41	13.78	28.30	31.63	6.52	14.21	28.87
T_2	26.70	7.42	14.04	30.24	33.40	7.41	14.51	30.84
T_3	26.89	7.51	17.25	31.45	33.49	7.65	18.23	32.08
T_4	27.13	8.06	19.90	32.01	34.39	8.78	21.77	32.65
T_5	29.80	8.25	20.64	30.28	35.80	9.14	19.73	30.89
T_6	30.95	10.38	23.86	32.01	36.20	11.02	24.13	32.65
T_7	31.68	9.75	22.43	32.58	36.68	10.02	22.14	33.23
SEm±	1.01	0.32	0.74	0.96	1.16	0.34	0.76	0.98
CD (P=0.05)	2.90	0.93	2.14	2.78	3.34	0.97	2.20	2.83

Table 3: Effect of direct application of P and S organo-mineral fertilizers on pod parameters

Treatment	2013-14					2014-15				
	Pod length (cm)	Number of pods plant $^{-1}$	Number of seeds pod $^{-1}$	Total nodules plant^{-1}	Dry weight of nodules plant^{-1} (mg)	Pod length (cm)	Number of pods plant $^{-1}$	Number of seeds pod $^{-1}$	Total nodules plant^{-1}	Dry weight of nodules plant^{-1} (mg)
T_1	7.25	10.20	6.45	27.89	15.64	7.39	10.40	6.58	30.20	17.30
T_2	8.10	11.71	7.16	28.50	18.56	8.33	10.92	7.30	30.78	19.39
T_3	8.17	11.98	7.51	28.84	18.80	8.85	12.22	7.66	31.52	19.86
T_4	8.45	12.03	7.59	29.48	19.14	8.93	12.27	7.74	32.02	20.02
T_5	8.50	12.53	7.84	32.17	19.36	8.99	12.78	8.00	33.20	20.56
T_6	8.55	12.86	7.98	34.66	19.94	9.16	12.99	8.17	35.25	20.82
T_7	8.65	13.76	8.17	37.81	20.00	9.40	13.82	8.33	38.81	21.30
SEm±	0.29	0.43	0.25	1.17	0.63	0.30	0.44	0.26	1.21	0.67
CD (P=0.05)	0.83	1.24	0.73	3.38	1.83	0.87	1.28	0.75	3.50	1.93

to substitute peat the use of rock phosphate enriched compost has resulted to supply more phosphorus to seedling shoots than rock phosphate amended substrate mixtures by (Nishanth and Biswas 2008, Odongo *et al*., 2007, Akande *et al*., 2005) [10, 11].

The grain and stover yield for T_6 treatment of green gram influenced significantly with application of P and S of organo-mineral fertilizers. The T_6 treatment caused maximum grain and stover yield (10.38 and 23.86 q ha^{-1}) and (11.02 and 24.13 q ha^{-1}) in year 2013-14 and 2014-15, respectively followed by T_7 treatment over control. Discussion valid reason for enhanced grain and stover yield due to applied P and S organo-mineral fertilizers over out in soil. Kushwaha (2007) [5] also found similar results that the increase in yield attributing characters and yield in higher levels of rock phosphate with phosphate solubilizing bacteria and their interaction with organic manures were attributed to the increased availability of phosphorus which also favored the symbiotic N_2 fixation and higher growth of plants, thereby had positive effect on yield and attributes. The test weight in green gram varied from 28.30 to 32.58 g and 28.87 to 33.23 g in 2013-14 and 2014-15. The enhancement of test weight due to boldness of grain by different organo-mineral fertilizers application. Statistically, 1000-grain weight was similar among the treatments. Maximum and minimum filled grains were obtained from straw compost and TSP, respectively by Osivand *et al.*, (2009) [12].

The pod length influenced significantly with application of P and S of Organo-mineral fertilizers in green gram at all the growth stages. The maximum pod length was recorded by T_7 (8.65 and 9.40 cm) followed by T_6, T_5 over control T_1 (7.25 and 7.39 cm) in year 2013-14 and 2014-15 (Table 3). Maximum pod lenght has been obtained by T_7 treatment due to application of (50%RDF+P-OMF@10.0qha^{-1}+S-OMF@10.0qha^{-1}). The effect was effective in both the years of field investigation on green gram with addition of P and S organo-mineral fertilizers. Osivand *et al* (2009) [12] reported similar findings far an increase in biometric parameters when of different from RP-composts was applied. The highest pod length and productive tillers were obtained from straw compost. The number of pods plant^{-1} varied from 10.30 to 13.76 and 10.40 to 13.83 plants^{-1} in 2013-14 and 2014-15. The maximum and significant results were influenced by treatment T_7, T_6, T_5, T_4 and T_3 as compared to control treatment in both the year. This observation is considered by the earliar findings of Biswas and Narayanasamy, (2006) [4] who reported that mungbean pod yield increased significantly with addition of phosphate enriched compost.

The maximum number of seeds pod^{-1} was recorded by T_7 (8.17 and 8.33) followed by T_6, T_5 as compared to over control T_1 (6.45 and 6.58) in 2013-14 and 2014-15 respectively. Maximum number of seeds pod^{-1} has been obtained by T_7 treatment due to application of (50%RDF+P-OMF@10.0qha^{-1}+S-OMF@10.0qha^{-1}). The effect was effective in both the years of field investigation on green gram with addition of P and S organo-mineral fertilizers. Kushwaha (2007) [5] reported an increase in yield attributing characters with use of rock phosphate along with PSB and also attributed to the increased availability of phosphorus with addition of organic manures which also favored the symbiotic N_2 fixation and higher growth of plants, thereby had positive effect on yield attributes. These results are close conformity with the findings by Sharma *et al*. Prasad (2009) [13], and Saravanan and Panneerselvam (2014) [16]. The total nodules plant^{-1} influenced significantly with application of P and S of organo-mineral fertilizers in green gram in which T_7, T_6 and T_5 treatment caused more yield over control in both the year. Rahman *et al.*, (2006) [14] found that amended compost increased the number of nodules pulse crop. Meena and Sharma (2005)[7] also found that application of DAP in soybean registered significantly higher yield attributes *viz.*

number of pod plant, number of seed per pod,total nodules seed index and seed yield plant as compared to control. The dry weight of nodules plant^{-1} varied from (15.64 to 20.00 mg) and (17.30 to 21.30) in year 2013-14 and 2014-15, respectively. The significant dry weight of nodules plant^{-1} was recorded by all the treatment over control T1. Similar result was also reported by Osivand *et al* (2009) [12]. Sulphur plays an important role in improving the quality of pulses. Examined whether the effect of sulphate addition on N fixation resulted from a stimulation of host plant growth, a specific effect of Sulphur on nodulation, or a specific effect of Sulphur on nodule metabolism.

Conclusions

These studies show that a treatment combination with (75%RDF +P-OMF@ 5.0 q ha^{-1} +S-OMF@5.0 q ha^{-1}) can enhance Plant height, grain yield, stover yield, test weight, pod length, Number of pods plant^{-1}, Number of seed pod^{-1}, total nodules plant^{-1}, and dry weight of nodules plant^{-1} in Green gram. This fertilizer consortium may be used as efficient Green gram production in farmer's fields. It is a cost effective technology.

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