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Effect of phosphorus and sulphur on the growth and yield of black gram (*Vigna mungo* L.)

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Abstract
A field experiment was conducted at the Research Farm, School of Agriculture, ITM University, Gwalior, (M.P.) during the *kharif* season of 2019-20. A set of 12 treatment combinations including four phosphorus levels *viz*., 0 kg/ha (P_0), 20 kg/ha (P_1), 40 kg/ha (P_2) and 60 kg/ha (P_3) with three Sulphur levels *viz*., 10 kg/ha (S_1), 20 kg/ha (S_2) and 30 kg/ha (S_3) were evaluated. Treatments were replicated thrice as per Randomized Block Design with Factorial concept. Crop sown with application of phosphorus @ 60 kg/ha combined application with Sulphur @ 30 kg/ha attained significantly higher plant growth and yield at all the growth stages of plant. The significantly higher plant height, number of branches as well as leaves per plant, number of root nodules per plant, grain and stover yield per hectare of black gram at maximum crop growth stage was recorded under the application of phosphorus @ 60 kg/ha combined application with Sulphur @ 30 kg/ha with the respective values of 23.69, 42.72cm, 11.78,9.92,20.76,15.12 q/ha and37.72 q/ha, respectively proved significantly superior to rest of the treatments. Result showed that black gram variety when sown the application of phosphorus @ 60 kg/ha combined application with Sulphur @ 30 kg/harecorded the maximum and significantly higher values of these parameters.

Keywords: Black gram, sulphur, growth stage, plant population, root nodules, stover yield

Introduction
Black gram (*Vigna mungo* L.) is one of the important kharif pulse crop. It is commonly grown in summer and rainy seasons in northern India. It is a protein rich (25 per cent) staple food containing almost three times that of cereals. It supplies protein requirement of vegetarian population. Black gram accounts for 10 per cent of total pulse production in India. It belongs to Leguminosae and sub family papilionaceae, and is being grown as one of the principle crops since ages in Madhya Pradesh as well as in the country. India is the largest producer as well as consumer of black gram. It produces about 15 to 19 lakh tones black gram annually from about 35 lakh ha of area, with an average productivity of 500 kg/ha (Ministry of Agriculture, GOI 2014-15). It controls soil erosion and competes with weeds effectively due to its deep root system and foliage cover. It fixes atmospheric nitrogen into the soil and improved the soil fertility. It is rich in carbohydrate, protein, fat and phosphoric acid.

Proper fertilization is essential to improve the productivity of black gram. It can meet its nitrogen requirements by symbiotic fixation of atmospheric nitrogen. The nutrients which need attention are phosphorus and sulphur (Nandal, *et al*., 1987) [13]. Black gram being a leguminous crop, requires adequate amount of phosphorus and sulphur as well as apart from other nutrients these are directly involved in growth and development of plant.

Phosphorus is essential constituent of every living cell. It is concerned with structural compounds, nucleic acids for reproductive purpose, and the conservation and transfer of energy in the metabolic reactions taking place. Phosphorus ranks next to nitrogen in importance, and its availability to growing crops is of prime importance. It is an essential constituent of many vital compounds like lecithin and most enzymes. It promotes the development of roots, seed formation, and gives strength to straw, hastens maturity of crops, and increases ratio of grain to straw. Leguminous crops grown under phosphorus deficient conditions may suffer from nitrogen deficiency as well, since the nodule bacteria function normally only when plants are supplied with adequate phosphorus. The phosphorus nutrition is therefore considered critical particularly for legumes.

Sulphur is another essential nutrient which is usually required by leguminous crops in amounts comparable to phosphorus. Sulphur is a part of amino acids cysteine and methionine, hence essential for protein production. Another sulphur containing amino acid cystine is derived by oxidation of cysteine. Sulphur is involved in formation of chlorophyll, activation of enzymes, and is a part of co-enzyme. Sulphur deficiency symptoms, in many ways resemble those of nitrogen, pale yellow or light green leaves.

Sulphur is known to help in chlorophyll formation, stimulating growth, seed formation and N fixation by enhancing nodule formation. Wide spread S deficiency have been observed on larger areas due to use of high analysis Sulphur free fertilizers like urea and diammonium phosphate (DAP) in high yielding varieties and intensive cropping, and is more conspicuous in light textured soils low in organic matter (Sinha *et al*., 1995) [17].

In fact, Sulphur is the second most important plant nutrient after phosphorus for pulses. A significant response of black gram to application of phosphorus & Sulphur has been reported earlier. Both phosphorus and sulphur can improve the quality and quantity of the crop. Sulphur interacts with phosphorus as phosphate ion is more strongly bound than sulphate (Hedge and Murthy, 2005) [8]. Phosphorus fertilizer application results in increased anion adsorption by phosphate, which releases sulphate ions into the soil solution (Tiwari and Gupta, 2006) [19]. Thus, it may be subjected to leaching if it is not taken up by plant roots.

The interaction of these nutrient elements may affect the critical levels of available phosphorus and Sulphur below which response to their application could be observed. Information on effect of combined application of phosphorus and Sulphur on yield, quality and content of each nutrient in black gram is rather limited in the sub-tropical zone of M.P. Keeping these points in view, the present investigations were under taken.

Materials and Methods

The experiment was carried out at the Research Farm, School of Agriculture, ITM University, Gwalior, (M.P.) during the year 2018-19. The experiment was conducted in randomize complete block design having Factorial concept with three replications. Different rates of phosphorus and Sulphur allocated to the plots as per treatments. The black gram variety was tested for this experiment along with these treatments. The treatments were four levels of phosphorus as P_0- 0 kg/ha, P_1- 20 kg/ha, P_2- 40 kg/ha and P_3- 60 kg/ha, while three levels of Sulphur were tested are S_1- 10 kg/ha, S_2- 20 kg/ha and S_3- 30 kg/ha.The gross and net plot size was 6.0 m x 2.5 m and 5.0 m x 2.0 m, respectively. The fertilizers grades were applied as per treatments. The recommended dose of nitrogen and Sulphur was applied @ 20 P_2O_5 kg/ha and 20 kg K_2O /ha, respectively while, phosphorus (P_2O_5) and Sulphur was applied as per the treatments. All the other agronomic practices were applied uniformly to all the treatments.

Results and Discussion

The result shows that plant height, number of branches per plant, number of leaves per plant, number of root nodules per plant, grain and Stover yield was influenced significantly due to different concentrations of phosphorus and Sulphur.

Data regarding these characters are reported in (Table- 1). Statistical analysis of the data revealed that maximum plant height, number of branches per plant, number of leaves per plant, number of root nodules per plant (40.21 cm, 10.69, 8.70, and 19.19, respectively) were recorded in plots treated with the application of phosphorus @ 60 kg/ha (N_3) while, lowest values were observed in plot that received no phosphorus. Similarly, application of Sulphur @ 30 kg/ha gave maximum plant height, number of branches per plant, number of leaves per plant, number of root nodules per plant value of 39.30 cm, 9.99, 8.02, and 18.20, respectively.

Statistical analysis of data revealed that interaction effect of phosphorus and Sulphur significantly affected plant growth and yield were found significant. Similarly, in interaction the maximum plant height, number of branches per plant, number of leaves per plant, number of root nodules per plant was recorded from plot receiving phosphorus @ 60 kg/ha combined application with Sulphur @ 30 kg/ha, value of 42.72 cm, 11.78, 9.92, and 20.76, respectively while minimum was recorded from plot receiving 0 kg/ha phosphorus with application of Sulphur of 10 kg/ha.

It was observed that plant growth increased gradually with the optimum phosphorus dose. This might be due to higher availability of N & P and their uptake that progressively enhanced the vegetative growth of the plant. This result is similar with the findings of Sharma and Singh (1997) [15] found significant increase in plant height of black gram due to the application of 40 kg P/ ha. According to Mir *et al*. (2013) [12] this could be due to synergistic effect of P and S supplied through different treatments under consideration.

The fast increase in plant height in the early stage of plant growth may be attributed to the higher number of leaves producing higher food material for growth of the plant. In fact, more and large sized leaves were responsible for preparing more food photosynthates which increased cell division and resulted in rapid growth of the plants. The later stage of plant growth, plant height became slow which may be due to the fact that plants started entering from vegetative to the reproductive phase of growth and development and the dry matter accumulation were concentrated in reproductive parts of plant.

Application of phosphorus improved the nutrient availability status, resulting into grater removal which might have increased the photosynthesis and then translocated the synthase to different parts for promoting meristematic development in potential apical buds and intercalary meristems and hence increased growth parameters of the crop. The increase in plant growth might be due to the better nutrition and their utilization under well fertilized plots as compared to lower levels which could not meet out the nutrition requirement of the crop. The results were also found in conformity with those reported by Chaubey *et al*. (2000) [6], Jat *et al*. (2012) [9] and Akter *et al*. (2013) [1] that application of S significantly increased the plant growth. Increasing in plant height might be due to favourable function of Sulphur being a major structural constituent of cell helps in stimulating the cell division and cell enlargement, which increased plant height.

Moreover, Sulphur being essential constituent of various amino acids and proteins as well as structural constituent of cell influenced different physiological processes such as cell division and elongation. Phosphorus has important role in conversion of solar energy into chemical energy and it has also beneficial effect on root proliferation that increases the absorption of plant nutrients and moisture from soil. These findings are substantiated with those reported by Srinivas and Mohammad (2002) [18], Singh *et al*. (2009) [16] and Chaudhari *et al*. (2016) [7].

The increased growth parameter may be attributed to increased cell division due to sufficient supply of Sulphur and phosphorus. Vegetative growth mainly consists of new leaves, stem and nodules. Photosynthetic products transported to these sites are used predominantly in the synthesis of protein. Similar reasons were also proposed by Chandra and Pareek (2007) [5].

More number of branches and leaves per plant under the influence of increased phosphorus levels seems to be due to its increased absorption and utilization of radiant energy which ultimately resulted in high dry matter production by crop plant. Further higher number of branches and leaves per plant with nitrogen, phosphorus and potassium with Sulphur may be ascribed to the penetration of roots to deeper depths, resulting in more absorption of water and nutrients in the plots where treatments. Sulphur and its association with phosphorus increased chlorophyll and increased phosphatase activity (that increased phosphorus supply to plants).

The increase in number of nodules per plant might be due to better root biomass with increasing levels of these nutrients. Phosphorus, being the constituent of nucleic acid and different forms of proteins, might have stimulated cell division resulting in increased growth of plants. Yadav (2011) [20] in the same crop found that interaction of P and S significantly influenced number of nodules per plant.

Data regarding highest grain and Stover yield are reported in (Table- 1). Statistical analysis of the data revealed that maximum grain and Stover yield (14.12 q/ha and 35.42 q/ha, respectively) were recorded in plots treated with the application of phosphorus @ 60 kg/ha (N_3) while, lowest values were observed in plot that received no phosphorus. However, application of Sulphur @ 30 kg/ha gave highest grain and Stover yield value of 12.55 q/ha and 31.85 q/ha, respectively.

Statistical analysis of data revealed that interaction effect of phosphorus and Sulphur significantly affected grain and Stover yield were found significant. Similarly, in interaction the maximum values of these parameters were recorded from plot receiving phosphorus @ 60 kg/ha combined application with application of Sulphur @ 30 kg/ha, value of 15.12 q/ha and 37.72 q/ha, respectively while minimum values were recorded from plot receiving 0 kg/ha phosphorus with application of Sulphur of 10 kg/ha.

Combined application of phosphorus and Sulphur were found significantly superior for seed yield. This was largely attributed to better growth of plant which resulted in adequate supply of photosynthates for development of sink under optimum level of inorganic fertilizer. Positive response in terms of seed yield to inorganic fertilizers have also been reported by Singh *et al*., (2009) [16], Kumar *et al.* (2012) [10] and Patel (2010) [14]. Malik *et al.* (2003) [11] was found that seed yield was significantly affected by varying levels of Sulphur and phosphorus.

The increase in grain and Stover yield was due to the cumulative effect of increased growth and yield parameters. This could be attributed to better supply of Sulphur, phosphorus and potassium resulting in higher branch and pod and there by higher yield. It is an established fact that phosphorus plays an important role in the formation of new shoots and number of branches/plant. In addition, it regulates the photosynthetic and carbohydrate metabolism which can be considered to be one the major factors limiting growth particularly during the reproductive phase.

The better growth of plant in terms of height and leaf number might have helped in improving yield parameters and yield of black gram through better translocation of food reserves to sink. The levels of phosphorus regulate the starch/sucrose ratio in the source levels and the reproductive organs. Thus, the stimulatory effect of Sulphur, phosphorus and potassium on growth and partitioning of photosynthates to sink development has led to increased yield attributes. The corresponding lower values of these parameters at lower doses further lend support to the above statement. With increase in photosynthetic products, coupled with efficient translocation, plant produced more pods/ plant with a greater number of seeds per pod. Significant increase in grain and straw yields appeared to be on account of beneficial effects of Sulphur, phosphorus and potassium on growth and yield attributes. Similar findings have also been reported by Bansal (2009) [3], Bhat *et al.* (2009) [4].

Table 1: Effect Of Phosphorus And Sulphur On Growth And Yield Of Black Gram

Treatment	Plant height (cm)	Number of branches per plant	Number of leaves per plant	Number of root nodules per plant	Grain yield per hectare (q/ha)	Stover yield per hectare (q/ha)
	Effect of phosphorus levels					
P_0	36.78	7.68	5.37	11.22	9.76	24.87
P_1	37.67	8.85	6.81	14.76	10.88	27.79
P_2	38.27	9.39	7.33	17.03	11.69	29.75
P_3	40.21	10.69	8.70	19.19	14.12	35.42
S.Em±	0.24	0.10	0.10	0.37	0.09	0.24
CD	0.71	0.30	0.30	1.07	0.27	0.71
S_1	37.31	8.41	6.10	13.19	10.75	27.34
S_2	38.09	9.06	7.03	15.25	11.54	29.19
S_3	39.30	9.99	8.02	18.20	12.55	31.85
S.Em±	0.21	0.09	0.09	0.32	0.08	0.21
CD	0.61	0.26	0.26	0.93	0.23	0.61
P_0S_1	36.42	7.06	4.39	9.17	9.19	23.52
P_1S_1	37.37	7.88	5.90	9.43	10.36	26.52
P_2S_1	37.47	8.90	6.55	16.47	10.73	27.27
P_3S_1	37.98	9.80	7.59	17.72	12.72	32.03
P_0S_2	36.79	7.79	5.70	9.31	9.58	24.21
P_1S_2	37.82	8.56	6.29	16.22	10.63	27.08
P_2S_2	37.82	9.41	7.54	16.41	11.43	28.94
P_3S_2	39.92	10.48	8.61	19.09	14.52	36.52
P_0S_3	37.13	8.19	6.02	15.20	10.51	26.89
P_1S_3	37.83	10.12	8.24	18.63	11.66	29.76
P_2S_3	39.51	9.85	7.91	18.21	12.92	33.05
P_3S_3	42.72	11.78	9.92	20.76	15.12	37.72
S.Em±	0.42	0.18	0.18	0.63	0.16	0.42
CD	1.23	0.52	0.51	1.85	0.47	1.23

Conclusion

Based upon this experiment it is concluded that application of higher level of phosphorus at the rate of 60 kg/ ha combined application with Sulphur at the rate of 30 kg/ ha recorded the maximum growth and grain yield of black gram.

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