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Effect of different levels of Phosphorus and Sulphur on physico-chemical properties of soil, growth and yield of Mustard (*Brassica juncea* L.) Cv. Varuna

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Abstract
The experiment was carried out at Soil Science and Agricultural chemistry research farm SHUATS, Allahabad during *rabi* season (October-March) 2017-18. The experiment was laid out in 3^2 factorial randomized block design with three replications, consisting of nine treatments. Treatment T_8 (@ 40 Phosphorus kg ha^{-1} + 30 kg Sulphur ha^{-1}) was found to be best in pH, EC, O.C (%), available Nitrogen (kg ha^{-1}), Phosphorus (kg ha^{-1}), Potassium (kg ha^{-1}), and Sulphur (ppm) of which the results are 7.44, 0.24, 0.48, 245.22, 23.14, 201.10, 14.88 respectively. Soil chemical properties such as pH, EC, O.C (%), available nitrogen, available phosphorus and sulphur were found to be significant. Soil physical properties such as bulk density (Mg m^{-3}), particle density (Mg m^{-3}) and pore space (%) were found to be non-significant.

Keywords: brown mustard, phosphorus, sulphur, physico-chemical properties

Introduction
Mustard is an important *rabi* season oilseed crop in north India. Mustard is the major source of edible oil of the country. India is one of the largest rapeseed- mustard growing countries in the world, occupying the first rank in area and second in production next to China. The oil content in mustard is varies from 37-49 percent. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout northern India in cooking and frying purpose. It is also used in the preparation of hair oil and medicines. It is used in soap making, in mixtures with mineral oils for lubrication. The oil cakes are used as a cattle feed and manure. Green stems and leaves are a good source of green fodder for cattle. The leaves of young plant are used as green vegetable as they supply enough Sulphur and minerals in the diet. In the tanning industry, mustard oils are used for softening leather (Singh, 2001) [14].

Mustard is rich in minerals like calcium, manganese, copper, iron, selenium, zinc, vitamin A, B, C and proteins. 100 g mustard seed contains 508 kcal energy, 28.09 g carbohydrates, 26.08 g protein, 25-35 percent total fat and 12.2 g dietary fibre (Anonymous, 2016) [2]. Phosphorus plays a great role in enhancing and sustaining crop productivity worldwide. Soil Phosphorus is a finite, non-renewable and limited resource. Continuous supply of Phosphorus through manure and fertilizer is indispensable for crop production sustenance. While good agronomic management requires use of fertilizer Phosphorus to optimize crop growth, excessive application of Phosphorus may degrade water quality. It is also responsible for synthesis of certain vitamins (B12, biotin and thiamine), metabolism of carbohydrates, proteins and oil formation of flavoured compounds in crucifers. Brassica has the highest sulphur requirement owing to the presence of sulphur rich glucosinolates (Bharose *et al*., 2011) [4].

The leaves of Phosphorus deficient fruit trees are frequently finged with brownish colour. The Phosphorus contents in the Phosphorus deficient plants are usually low with about 0.1 percent Phosphorus or less in the dry matter and in cereals and herbage about 0.3 to 0.4% during the vegetative growth stage. Under conditions of Phosphorus deficiency, Phosphorus is withdrawn form order tissue and translocated to meristematic tissue, where metabolism is more rapid. Sulphur is the 13th most abundant element in the earth's crust, averaging between 0.06-0.10 percent and an essential secondary plant nutrient, is required by plant and animals in approximately the same amount as phosphorus. However, recently Sulphur is gaining importance for crop production in the balanced fertilization programme. Sulphur, like phosphorus, potassium and calcium is of terrestrial origin, resulting from the decomposition of rocks. Because of its volatile nature, a large amount of Sulphur has become dispersed in the atmosphere. Such atmospheric fraction contributes significantly to the plant growth and nutrition (Das, 2004) [4].

Materials and Methods

The experiment was conducted in the research farm of Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences Allahabad which is situated about six km away from Allahabad city on the right bank of Yamuna river. The experimental site is located in the sub-tropical region with 250 24’8” N *latitude* 81051’3” E longitudes and 98 meter the mean sea level *altitudes*. The experiment was laid out in a 32 RBD factorial design with three levels of phosphorus and sulphur with nine treatments, each consisting of three replicates. The total number of plots was 27. Mustard (*Brassica juncea* L.) Cv. Varuna” was sown in *rabi* season, of plots size2x2 m with row spacing 30 cm and plant to plant distance 10 cm. The Soil of experimental area falls in order of *Inceptisols* and is alluvial in nature. Both the mechanical and chemical analysis of soil was done before starting of the experiment to ascertain the initial fertility status (Table 01 and 02). The soil samples were randomly collected from 0-15cm depths prior to tillage operations. The treatment consisted of nine combination of inorganic source of fertilizers T_0 (@ 0 P kg ha^{-1} + 0 S kg ha^{-1}), T_1 (@ 0 P kg ha^{-1} + 15 S kg ha^{-1}), T_2 (@ 0 P kg ha^{-1} + 30 S kg ha^{-1}), T_3 (@ 20 P kg ha^{-1} + 0 S kg ha^{-1}), T_4 (@ 20 P kg ha^{-1} + 15 S kg ha^{-1}), T_5 (@ 20 P kg ha^{-1} + 30 S kg ha^{-1}), T_6 (@ 40 P kg ha^{-1} + 0 S kg ha^{-1}), T_7 (@ 40 P kg ha^{-1} + 15 S kg ha^{-1}), T_8 (@ 40 P kg ha^{-1} + 30 S kg ha^{-1}) the source of phosphorus and sulphur was Di-Ammonium phosphate and zinc sulphate respectively.

Physical and chemical analysis of soil samples (Pre-Sowing) (Table 01 and 02) Response on bulk density, particle density and pore space of soil after crop harvest

The result depicted in table 3 shows that the maximum bulk density of soil (Mg m^{-3}), was found for T_0 (@ 0 P kg ha^{-1} + 0 S kg ha^{-1}) which was 1.48 and minimum was found for T_7 (@ 40 P kg ha^{-1} + 15 S kg ha^{-1}) which was 1.38 (Mg m^{-3}). The interaction effect of phosphorus and sulphur on bulk density (Mg m^{-3}) of soil was found non-significant.

The results show that the maximum particle density of soil (Mg m^{-3}), was found for T_7 (@ 40 P kg ha^{-1} + 15 S kg ha^{-1}) which was 2.64 and minimum was found for T_0 (@ 0 P kg ha^{-1} + 0 S kg ha^{-1}) which was 2.59 (Mg m^{-3}). The interaction effect of phosphorus and sulphur on particle density (Mg m^{-3}) of soil was found non-significant.

The results show that the maximum pore space (%) of soil, was found for T_8 (@ 40 P kg ha^{-1} + 30 S kg ha^{-1}) which was 49.45 and minimum was found for T_0 (@ 0 P kg ha^{-1} + 0 S kg ha^{-1}) which was 44.53. The interaction effect of phosphorus and sulphur on pore space (%) of soil was found non-significant.

Chemical properties

Response on pH and EC at 25˚C (dS m^{-1}) of soil after crop harvest

The result depicted in table 3 shows that the pH and EC of soil in which the maximum pH and EC at 25˚C (dS m^{-1}) was found for T_0 (@ 0 P kg ha^{-1} + 0 S kg ha^{-1}) which were 7.79 and 0.28 and minimum was found for T_6 (@ 40 P kg ha^{-1} + 0 S kg ha^{-1}) which were 7.43 and 0.21. The interaction effect of phosphorus and sulphur on pH and EC was found significant.

Response of organic carbon (%), available nitrogen, phosphorus, potassium and sulphur (kg ha^{-1}) of soil after crop harvest

The result depicted in table 3 shows that the Maximum Organic carbon (%), available nitrogen, phosphorus, potassium and sulphur (kg ha^{-1}) in soil were found for T_8 (@ 40 P kg ha^{-1} + 30 S kg ha^{-1}) which were 0.48, 245.22, 23.14, 201.10, 14.88 kg ha^{-1} respectively and minimum was found for T_0 (@ 0 P kg ha^{-1} + 0 S kg ha^{-1}) which were 0.26, 222.85, 13.00, 170.80, 06.21 kg ha^{-1} respectively. The interaction effect of phosphorus and sulphur on available nitrogen and potassium was found significant and the interaction effect of phosphorus and sulphur on organic carbon (%), available phosphorus and sulphur was also found significant. Combined application of phosphorus and sulphur were bringing significant increase in available nitrogen and available potassium. The results are similar with the finding of Gauttam *et al.*, 2013 [19].

Conclusion

It is concluded from the experiment that Treatment combination T_8 (@ 40 P kg ha^{-1} + 30 S ha^{-1}) was found to be best for pH, EC (dS m^{-1}), organic carbon (%), available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}), potassium (kg ha^{-1}) and sulphur (ppm) which were as 7.44, 0.24, 0.48, 245.22, 23.14, 201.10, 14.88 respectively. Soil chemical properties such as available N, P, K and S were found to be significant as well as pH, EC were also found to be significant. But in case of physical properties of soil as bulk density (Mg m^{-3}), particle density (Mg m^{-3}) and percent pore space (%) were found to be non-significant.

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Table 1: Physical analysis of pre-sowing soil sample

Particulars	Result	Method employed
Sand (%)	62	Bouyoucous (1927) [5].
Silt (%)	23	
Clay (%)	15	
Textural class	Sandy loam	
Bulk density (Mg m^{-3})	1.36	Muthuval (1992) [12].
Particle density (Mg m^{-3})	2.42	Muthuval (1992) [12].
Pore space (%)	53	Muthuval (1992) [12].

Table 2: Chemical analysis of pre-sowing soil sample

Particulars	Results	Methods employed
pH (1:2)	7.70	Jackson, 1958 [10].
EC (dS m^{-1})	0.28	Wilcox, 1950 [20].
Organic carbon (%)	0.35	Walkley and Black, 1947 [19]
Available nitrogen (kg ha^{-1})	254.45	Subbaih and Asija, 1956 [16].
Available phosphorus (kg ha^{-1})	23.41	Olsen *et al*., 1954 [12].
Available potassium (kg ha^{-1})	108.78	Toth and Prince, 1949 [17].
Available sulphur (ppm)	18.48	Chesnin and Yien, 1960 [6].

Table 3: Soil properties

Treatment	pH (w/v)	EC (dS m^{-1})	B.D (Mg m^{-3})	P.D (Mg m^{-3})	P.S (%)	O.C (%)	Nitrogen (Kg ha^{-1})	Phosphorous (Kg ha^{-1})	Potassium (Kg ha^{-1})	Sulphur (ppm)
T_0	7.79	0.28	1.48	2.59	44.53	0.26	222.85	13.00	170.80	06.21
T_1	7.63	0.27	1.42	2.60	45.08	0.33	227.64	13.98	174.50	07.42
T_2	7.70	0.24	1.43	2.62	45.27	0.32	242.02	18.45	177.20	10.33
T_3	7.50	0.23	1.44	2.61	45.33	0.29	233.09	16.20	175.40	08.98
T_4	7.71	0.28	1.38	2.63	46.23	0.30	238.77	17.35	180.60	10.35
T_5	7.53	0.26	1.42	2.62	46.95	0.43	243.36	19.96	185.40	11.34
T_6	7.43	0.21	1.40	2.62	46.58	0.27	224.36	16.23	187.10	10.67
T_7	7.67	0.23	1.38	2.64	46.76	0.39	235.34	20.82	194.90	13.37
T_8	7.44	0.24	1.39	2.62	49.45	0.48	245.22	23.14	201.10	14.88
F-test	S	S	NS	NS	NS	S	S	S	S	S
S. Em. (±)	0.056	0.008	0.015	0.008	0.773	0.023	1.711	0.527	0.889	0.364
C.D. (at 5 %)	0.168	0.023	-	-	-	0.069	5.173	1.595	2.718	1.101

Note: The soil pH, EC, B.D, P.D, P.S, O.C, NS, S and ppm long form's as potential of hydrogen ion, Electrical conductivity, Bulk density, Particle density, Pore space, Organic carbon, Non-Significance, Significance, parts per million respectively.

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