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Effect of different level of phosphorus and sulphur on growth and yield attributes of yellow mustard (*Brassica compestris* L.)

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Abstract
A field experiment was conducted at crop research farm (CRF), SHUATS, Allahabad, during the rabi season of 2020 with 9 treatments replicated thrice in randomized block design, to determine the response of different level of Phosphorous and Sulphur on soil health and yield attributes of yellow mustard (*Brassica compestris* L.).This treatment consisted of three treatments, three different level of Phosphorous 0 kg ha^{-1}, 25 kg ha^{-1}, 50 kg ha^{-1} and three different level of Sulphur 0 kg ha^{-1}, 20 kg ha^{-1}, 40 kg ha^{-1}. The results reveal that treatment T_9 (S 40 kg ha^{-1} +$P_2O_5$50 kg ha^{-1}) was found to be the best for obtaining higher seed yield (16.73 q h^{-1}), harvest index (28.77%), test weight (4.67 g) and other growth and yield attributes like higher net returns (Rs 49991.00 ha^{-1}) and B:C ratio (1.96) was also observed.

Keywords: Mustard, phosphorous, sulphur, yield attributes, etc.

Introduction
Rapeseed-mustard are the major oilseed crops, traditionally grown everywhere in the country due to their high adaptability in conventional farming systems.Mustard belongs to the family cruciferae popularly known as rai and is an important Rabi oilseed crop of India. It is one of the edible oilseed crops of India next to groundnut and soybean. In India mustard is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. Rajasthan ranks first in area and production of mustard and rapeseed with 2.50 million ha area and 3.71 tonnes production**.** It occupies about 24.70 per cent of area and 48.28 per cent of production of the total oilseed production in India. Its area, production and productivity in the country is 5.4 million ha, 6.41 million tonnes and 1159 kg ha^{-1}, respectively. The average yield of rapeseed-mustard in India 1022 kg ha^{-1} is far behind the averages of other countries, like Canada-1288 kg ha^{-1}, China-1405 kg ha^{-1}, Germany-3096 kg ha^{-1}, UK-3231 kg ha^{-1} and France-3528 kg ha^{-1} Kumar (1999) [11]. Nitrogen is the most important nutrient, which determines the growth of the Toria crop and increases the amount of protein, methionine dry matter and the yield. Phosphorus and Potash are known to be efficiently utilized in the presence of Nitrogen. It promotes flowering, setting of siliqua and in increase the size of siliqua and yield. Excess supply of nitrogen leads to delayed ripening by encouraging more vegetative growth. The leaves acquire dark green colour and become thick and leathery. Root system is feebly developed and results in low shoot: root ratio. It delays reproductive growth and may affect adversely fruit and grain quality. The plants become more liable to attack of pests and diseases Black (1973) [4], Devlin and Witham (1986) [6], Salisbury and Ross (1992) [20], Scheible *et al.* (1997) [22], Zhang *et al.* (1999) [29], Marschner (2002) [14]. Phosphorus occurs in plants at 0.1 - 0.4% on dry weight basis. It is absorbed by plants from the soil as monovalent (H_2PO_4) and divalent (H_2PO_4) ions. Phosphorus is an essential structural constituent of met biologically active compounds, like nucleic acids, phospholipids, phytin, nicotinamide adenine dinucleotide, nicotinamide adenine dinucleotide phosphate, adenosine triphosphate, pyridoxal phosphate, nucleoproteins, purine and pyramiding nucleotides and flavin nucleotide Devlin and Witham (1986) [6], Hell and Hillebrand (2001) [8], Salisbury and Ross (1992) [20], Marschner (2002) [14]. It plays an important role in photosynthesis, respiration, regulation of a number of enzymes and disease resistance Tamhane *et al.* (1970) [27], Raghotham (1999) [19]. The deficiency of phosphorus leads to increased root: shoot ratio, changes in root morphology and architecture, increased root hair proliferation, root hair elongation, accumulation of anthocyanin pigments, proteoid root formation and increased association with mycorrhizal fungi, shedding of premature leaves and delay in flowering and fruiting Ragothama (1999) [19].

It also causes a decrease in photosynthesis Hewitt (1963) [9]. Excess supply of phosphorus results in increased root growth compared with shoot growth Tamhane *et al.* (1970) [27].

Sulphur deficiency in crops is gradually becoming widespread in different soils in several states of India due to continuous use of sulphur free fertilizers, high yielding crop varieties, intensive multiple cropping systems and high sulphur requiring crops. Sulphur performs many physiological functions like synthesis of cystein, methionine, chlorophyll and oil content of oilseed crops. It is also responsible for synthesis of certain vitamins (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 Karthikeyan and Shukla (2008). Sulphur is also important for oil content. Fertilizer, organic manures and irrigation water etc. are also important source of Sulphur which contribute considerable amount of Sulphur to the soil Das (2004). Soils, which are deficient in sulphur, cannot on their own provide adequate sulphur to meet crop demand resulting in sulphur deficient crops and sub-optimal yields Chattopaddhyay *et al.* (2012).

Materials and Method

An experiment is conducted to study the “Response of different level of Phosphorus and Sulphur on Soil properties and Yield of Yellow Mustard”. The Experiment is conducted on yellow mustard crop during Rabi season 2020-2021 on crop research farm of department of Soil Science & Agriculture Chemistry, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, 211007 (U.P) India. It is located at 25^0 57’ N latitude, 81^0 57’ E longitude and 98 m above the mean sea level. The annual rainfall is 1100 mm. The soil of the experimental field is sandy loam in texture with pH 7.6, medium available nitrogen, available phosphorus, available potassium and medium organic carbon. The physico-chemical properties of experimental field were determined in composite soil sample taken before sowing.

Table 1: Soil Physico-chemical properties of experimental field

S. No.	Soil Properties	Value (Results)
1.	Sand (%)	55
2.	Silt (%)	25
3.	Clay (%)	20
4.	Soil Texture	Sandy Loam
5.	Water holding capacity	48.31%
6.	Soil colour	Dry condition – Light yellowish brown Wet condition – Olive brown
7.	Particle density	2.50 Mg m^{-3}
8.	Bulk density	1.39 Mg m^{-3}
9.	Pore space	43.32%
10.	Soil pH (1:2)	7.6
11.	Electrical conductivity	0.14 dSm^{-1}
12.	Organic carbon	0.43%
13.	Available nitrogen	205.32 kg
14.	Available phosphorus	14.77 kg
15.	Available potassium	113.05 kg
16.	Available sulphur	8.9 ppm

The experiment was laid out in plot of (2 x 1 m^2) consisting of 9 treatments with 3 replication. Phosphorus and sulphur were supplied through single sulphate phosphate (12% P_2O_5) and elemental sulphur (90% S), respectively. The phosphorus is applied in amount of 0, 25 and 50 kg ha^{-1} and sulphur is applied in 0, 20 and 40 kg ha^{-1}, respectively. Recommended dose of NPK *i.e.*, 80 kg N ha^{-1} and 40 kg K_2O ha^{-1} was applied uniformly through urea and MOP, respectively. Sulphur was applied through elemental sulphur as per treatment. Quantity of fertilizer for each plot was calculated on the basis of gross plot size. The mustard variety 'T-42' was sown in 19^{th} of November at a distance of 30 cm x 15 cm by using 5 kg ha^{-1} seed rate. Recommended half dose of nitrogen and full dose of phosphorus in each amount of (25 kg ha^{-1} and 50 kg ha^{-1}) and potassium was applied as basal dressing at the time of sowing and remaining half dose of nitrogen was top dressed in two equal split doses each after first and second irrigation in the form of urea, SSP and MOP. As per treatments, total amount of sulphur (20 kg ha^{-1} and 40 kg ha^{-1}) was given at the time of sowing through basal application. The mustard variety T-42 was sown in recommended manner. Thinning and weeding carried out in two phases. Two irrigations are given to mustard crop. First irrigation is applied after 30 days of sowing and second irrigation is given at the flowering stage, after 60- 65 days of sowing. To check the damage by mustard aphids Indosulfan 35 E.C. spraying has been done at the rate of 1.25 lit. ha^{-1}.

Table 2: Experimental details of Yellow Mustard

S. No.	Particulars	Value
1.	Variety	T-42
2.	Germination %	80%
3.	Physical purity	75%
4.	Genetic purity	80%
5.	Seed rate	80%
6.	Test weight	4.2 g.
7.	Planting distance (cm)	30 x 15
8.	Depth of seed sowing	3-4 cm
9.	Season of seed sowing	Winter
10.	Crop length (in day)	90-100
11.	No. of treatment	9
12.	No. of replication	3
13.	Total no. of plots	27
14.	Design	RBD

The crop was harvested after 100 days of sowing, when it becomes mature as judged by visual observations. The production of net plot is weighted individually and recorded after threshing. Threshing is done by wooden sticks and seed weight. Plant samples were taken randomly from each treatment at maturity stage. These plant samples were oven dried, and weight of plants were taken for the analysis of growth parameters and yield attributes characteristics. Plant height, number of branches, number of siliqua plant^{-1}, number of seed siliqua^{-1}, seed yield and harvest index (%) recorded before and after harvesting. For oil content estimation seed samples were kept in the oven at 70°C for the removal of moisture. After removal of the moisture the seed was grounded in a pestle-mortar for extraction of oil. The conventional soxthlel method was used for estimation of oil.

Results and Discussion

The result of the experiment revealed that the treatment T_9 (S 40 kg ha^{-1} + P_2O_5 50 kg ha^{-1}) gives the best plant height (cm), no of branches, no of siliqua plant^{-1}, seed yield (q ha^{-1}) and oil content (%).

Plant height (cm) of mustard

As illustrated in table 3 the combined effect of Phosphorus and Sulphur @ 50 kg P ha^{-1} and 40 kg S ha^{-1} gave the maximum increase in plant height about 96.63 cm at 60 DAS and 97.67 cm at harvest. Therefore, it can be concluded that the interaction between phosphorus and sulphur found synergetic on plant height at 60 DAS and at harvest. It was observed that effect of Phosphorus was higher in magnitude than the effect of Sulphur on plant height during entire plant growth period. The application of Phosphorus and Sulphur @50 kg ha^{-1} and @40 kg ha^{-1} were found beneficial for early well developed and matured growth of mustard plants. The plant height of mustard from 30 DAS upto maturity significantly increased with the application of 50 kg ha^{-1} Phosphorus it is attributed due to the increased of Phosphorus availability to mustard plant and the mustard plant (root) was observed efficient quantity of phosphorus upto the maturity of the crop. It is attributed due to the increased in plant height of mustard. The results are in conformity with those already reported by Bhan and Singh (1976) [3], Patel *et al.* (1980) [15], Singh *et al.* (1991) [24], Prasad *et al.* (1991), Punia *et al.* (1993) [18], Khafi *et al.* (1997) [10], and Yadav *et al.* (2010) [28]. Significantly lowest plant height was noted by zero sulphur as compared with higher doses of sulphur. The increase in plant height under sulphur treatment might be due to effect of sulphur in metabolism of growing plants. It is directly related with cell division, enlargement and elongation. These findings endorse the results of Fasricha and Randhawa (1973), Pathak and Tripathi (1979) [16] and Singh *et al.* (1994) [25].

Table 3: Effect of different level of Phosphorus and Sulphur on plant height (cm) at 60 DAS

	Level of Phosphorous (P)			
Level of Sulphur (S)	**0 kg ha^{-1}**	**25 kg ha^{-1}**	**50 kg ha^{-1}**	**Mean (S)**
0 kg ha^{-1}	4.24	4.30	4.30	4.30
20 kg ha^{-1}	4.53	4.50	4.50	4.54
40 kg ha^{-1}	4.53	5.23	5.23	5.21
Mean (P)	4.43	4.68	4.68	
	F-test	S. Em. (±)	S. Em. (±)	
Due to Sulphur (S)	S	0.111	0.235	
Due to Phosphorus (P)	S	0.111	0.235	
Inter (S x P)	S	0.192	0.406	

Number of branches mustard

As illustrated in table 4 clearly show that the phosphorus and sulphur were found significant, but P × S interactions were non-significant on the number of branches of mustard plants at 30 DAS and significant at 60 DAS and at harvest. The combined effect of phosphorus and sulphur @ 50 kg P ha^{-1} and 40 kg S ha^{-1} produced the maximum no branches 60 DAS and at harvest was 5.87 and 6.47 respectively with (S_{40} P_{50}) treatment combination. It was observed that effect of Phosphorus was higher in magnitude than the effect of Sulphur on plant height during entire plant growth period. The application of Phosphorus and Sulphur @ 50 kg ha^{-1} and @ 40 kg ha^{-1} were found beneficial for early well developed and matured growth of mustard plants. The plant height of mustard from 30 DAS upto maturity significantly increased with the application of 50 kg ha^{-1} phosphorus it is attributed due to the increased of phosphorus availability to mustard plant and the mustard plant (root) was observed efficient quantity of phosphorus upto the maturity of the crop. It is attributed due to the increased the plant height of mustard. The results are in conformity with those already reported by Bhan and Singh (1976) [3], Patel *et al.* (1980) [15], Singh *et al.* (1991) [24], Prasad *et al.* (1991), Punia *et al.* (1993) [18], Khafi *et al.* (1997) [10], and Yadav *et al.* (2010) [28]. Significantly lowest plant height was noted by zero sulphur as compared with higher doses of sulphur. The increase in plant height under sulphur treatment might be due to effect of sulphur in metabolism of growing plants. It is directly related with cell division, enlargement and elongation. These findings endorse the results of Fasricha and Randhawa (1973), Pathak and Tripathi (1979) [16] and Singh *et al.* (1994) [25].

Table 4: Effect of different level of Phosphorus and Sulphur on no of siliqua plant^{-1}

	Level of Phosphorous (P)			
Level of Sulphur (S)	**0 kg ha^{-1}**	**25 kg ha^{-1}**	**50 kg ha^{-1}**	**Mean (S)**
0 kg ha^{-1}	4.24	4.30	4.30	4.30
20 kg ha^{-1}	4.53	4.50	4.50	4.54
40 kg ha^{-1}	4.53	5.23	5.23	5.21
Mean (P)	4.43	4.68	4.68	
	F-test	S. Em. (±)	S. Em. (±)	
Due to Sulphur (S)	S	0.111	0.235	
Due to Phosphorus (P)	S	0.111	0.235	
Inter (S x P)	S	0.192	0.406	

Number of siliqua plant^{-1} mustard

As illustrated in Table 5 clearly show that the phosphorus and sulphur were found significant and P × S interactions were significant on the no of siliqua plant^{-1} of mustard plants. The combined effect of phosphorus and sulphur @ 50 kg P ha^{-1} and 40 kg S ha^{-1} produced the maximum no of siliqua plant^{-1} 289.97 with (S_{40} P_{50}) treatment combination. It was observed that effect of Phosphorus was higher in magnitude than the effect of Sulphur on plant height during entire plant growth period. The application of Phosphorus and Sulphur @ 50 kg ha^{-1} and @ 40 kg ha^{-1} was found beneficial for early well developed and matured growth of mustard plants. It is attributed due to increase the number of primary and secondary branches per plant because, increased the availability of P_2O_5 to mustard plant. The number of primary and secondary branches per plant increased the number of siliqua per plant increases. The number of seeds per siliqua increases due to the more availability of P_2O_5 nutrient to mustard plant. The results are in conformity with those already reported by Singh *et al.* (1991) [24], Prasad *et al.* (1991), Punia *et al.* (1993) [18], Arthamwar *et al.* (1996) [1], Khafi *et al.* (1997) [10] and Yadav *et al.* (2010) [28]. The siliqua per plant of mustard significantly increased up to 50 kg ha^{-1} was reported by Kumar *et al.* (2002) [13].

Table 5: Effect of different level of Phosphorus and Sulphur on no of siliqua plant^{-1}

	Level of Phosphorous (P)			
Level of Sulphur (S)	0 kg ha^{-1}	25 kg ha^{-1}	50 kg ha^{-1}	Mean (S)
0 kg ha^{-1}	246.04	257.00	257.20	253.41
20 kg ha^{-1}	266.87	281.30	283.97	277.38
40 kg ha^{-1}	288.50	289.80	289.97	289.42
Mean (P)	267.13	276.03	277.04	
	F-test	S. Em. (±)	C.D. at 5%	
Due to Sulphur (S)	S	1.725	3.656	
Due to Phosphorus (P)	S	1.725	3.656	
Inter (S x P)	S	2.987	6.333	

Seed Yield (q ha^{-1}) of mustard

As illustrated in table 6 shows that phosphorus, sulphur and P×S interaction were significantly influenced the seed yield of mustard. The combined effect of phosphorus @ 50 kg P ha^{-1} and sulphur @ 40 kg S ha^{-1} produced the maximum seed yield of 16.73 with ($S_{40}P_{50}$) treatment combination. The nitrogen uptake by mustard seed, stover and total nitrogen uptake by mustard plant was significantly increased with the application of 40 kg S ha^{-1}. It is attributed due to the increased the biomass yield and seed yield (q ha^{-1}) with the application of 40 kg S ha^{-1}. The same findings also reported by Saran and Giri (1990) [21], Chaudhary *et al.* (1992) [5], Dubey and Khan (1993) [7], and Singh *et al.* (1998) [26]. The phosphorus uptake by the seeds, stover and total phosphorus uptake by mustard plant was observed significantly higher in the application of 40 Kg S ha^{-1}. It is attributed due to the significantly highest yield of biomass and seed yield of mustard. It is attributed due to the application of 40 kg S ha^{-1} was significantly increased the biomass yield (q ha^{-1}), seed yield (q ha^{-1}) ultimately the phosphorus uptake increased with the application of 40 kg S ha^{-1}. The same findings also reported by Sharma and Kamath (1991) [23], Chaudhary *et al.* (1992) [5].

Table 6: Effect of different level of Phosphorus and Sulphur on seed yield at 60 DAS

	Level of Phosphorous (P)			
Level of Sulphur (S)	0 kg ha^{-1}	25 kg ha^{-1}	50 kg ha^{-1}	Mean (S)
0 kg ha^{-1}	14.10	14.57	14.60	14.42
20 kg ha^{-1}	14.77	15.33	15.57	15.22
40 kg ha^{-1}	16.40	16.70	16.73	16.61
Mean (P)	15.09	15.53	15.62	
	F-test	S. Em. (±)	C.D. at 5%	
Due to Sulphur (S)	S	0.059	0.125	
Due to Phosphorus (P)	S	0.059	0.125	
Inter (S x P)	S	0.102	0.217	

Oil content (%) of mustard

As illustrated in table 7 shows that phosphorus, sulphur and P×S interaction significantly influenced the oil content of mustard. The combined effect of phosphorus @ 50 kg P ha^{-1} and sulphur @ 40 kg S ha^{-1} produced the maximum oil content of 39.74% with ($S_{40}P_{50}$) treatment combination. These findings were also supported by Bhagat *et al.* (2005) [2] reported that the application of 40 kg S ha^{-1} produced significantly highest seed yield, protein, oil content, protein and oil yield, concentration, uptake and availability of nitrogen, phosphorus and sulphur of crops.

Table 7: Effect of different level of Phosphorus and Sulphur on Oil content (%)

	Level of Phosphorous (P)			
Level of Sulphur (S)	0 kg ha^{-1}	25 kg ha^{-1}	50 kg ha^{-1}	Mean (S)
0 kg ha^{-1}	22.71	31.99	32.59	29.10
20 kg ha^{-1}	32.95	34.76	37.64	35.12
40 kg ha^{-1}	38.80	39.27	39.74	39.27
Mean (P)	31.49	35.34	36.66	
	F-test	S.Em. (±)	C.D. at 5%	
Due to Sulphur (S)	S	0.218	0.463	
Due to Phosphorus (P)	S	0.218	0.463	
Inter (S x P)	S	0.378	0.801	

Conclusion

It may be concluded the application of 40 kg ha^{-1} Sulphur, 50 kg ha^{-1} Phosphorus supplied through inorganic fertilizers gave the best results it term of growth and yield of mustard and soil physico-chemical properties. It was observed that phosphorus and sulphur is not only beneficial for mustard crop but also their interaction in soil and plant effects the growth and yield of mustard and its yield attributes. It is also observed that for growth and yield phosphorus is more important in compare to sulphur.

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