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Ingle AA
Assistant Professor, Department of Agronomy, Dhaneshwari Agriculture College Georai Tanda, Paithan Road, Aurangabad, Maharashtra, India

Mahude SV
M.Sc. Scholar, Department of Agricultural Meteorology, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Jadhav SS
Ph.D. Scholar, Department of Agronomy, Post Graduate Institute, MPKV, Rahuri, Maharashtra, India

Corresponding Author:
Ingle AA
Assistant Professor, Department of Agronomy, Dhaneshwari Agriculture College Georai Tanda, Paithan Road, Aurangabad, Maharashtra, India

Effect of phosphorus and Sulphur on growth, yield and quality of Indian mustard (*Brassica juncea* L.)

Ingle AA, Mahude SV and Jadhav SS

Abstract
The experiment was conducted during Rabi season of 2020-21at experimental farm of agronomy, College of Agriculture, Latur, to assess the effect of phosphorus and Sulphur on growth and yield of Indian mustard (*Brassica juncea* L.). The experiment was laid out in Factorial Randomized Block Design (FRBD) with nine treatment combinations, consisting of two factors i.e. different phosphorus levels and Sulphur levels, which includes three levelseach of different phosphorus levels and Sulphur levels application. The study of experiment revealed that an application of 50 Pha^{-1}(P_1) recorded significantly higher growth, yield attributes and seed yield (1897 kg ha^{-1}), over the application of 37.5 kg P ha^{-1}(P_2) and 25kgPha^{-1}(P_1). The application of 45 kg S ha^{-1} (S_3) recorded significantly higher growth, yield attributes and seed yield (1864 kg ha^{-1}) over the application of 30 kg S ha^{-1} (S_2) and 15 kg S ha^{-1}(S_1).

Keywords: Indian mustard, phosphorus, sulphur, siliqua, fertilizers

Introduction
Indian mustard (*Brassica juncea* L.) is also known by a variety of regional names, including Chinese mustard, Rai or Loha, Raya, brown mustard, leaf mustard, and the term "khardal" in the local dialect. (Rafiei *et al.*, 2011). It originated in China, India, and the Middle East and is a member of the Cruciferae family. After palm and soyabean, mustard is the most significant oilseed crop in the world. It is a cool-season crop that grows in temperatures between 6 and 26 degrees Celsius and follows the C3 pathway. Mustard's composition varies it contains 37–49% oil, 14–15% carbohydrates, 25–30% protein, 10–12% fibre, 1–1.5% minerals and vitamins, and 2-3% glucosinolate. Approximately 40–60% of mustard oil is made up of erucic acid, 4.5–13% of linolenic acid, and 25–30% of oleic and linoleic acid, which have higher nutritional value. Based on the information provided, Indian mustard mostly needs RDF, phosphorus, and Sulphur to improve growth, yield, and quality.

Materials and Methods
An experiment entitled as "Effect of phosphorus and Sulphur on growth and yield of Indian mustard (*Brassica juncea* L.**)** was conducted at Experimental Farm, Agronomy Section, College of Agriculture, Latur, during *Rabi* 2020-21. The soil of experimental plot was clayey in texture, slightly alkaline in reaction, low in available nitrogen, medium in available phosphorous, very high in available potassium and low in available Sulphur. The experiment was laid out in Factorial Randomized Block Design (FRBD) with nine treatment combinations, consisting of two factors i.e. different phosphorus levels and Sulphur levels, which includes three levels each of different phosphorus levels and Sulphur levels application. The different P levels were 25 kg P ha^{-1} (P_1), 37.5 kg P ha^{-1} (P_2) and 50 kg P ha^{-1} (P_3) where as, Sulphur levels were 15 kg S ha^{-1} (S_1), 30 kg S ha^{-1} (S_2) and 45 kg S ha^{-1} (S_3).

Results and Discussion
Growth attributes
Data regarding plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1} leaf area plant^{-1} and dry matter plant^{-1} (g) are presented in Table 1. Considerable differences in growth attributes *viz*., plant height(cm), number of branches plant^{-1}, number of leaves plant^{-1}, leaf area plant^{-1} and dry matter plant^{-1} (g) were observed due to different phosphorus levels and Sulphur levels.

Effect of phosphorus levels

A plant's ability to grow taller could be attributed to the important function that phosphorus plays in processes like photosynthesis, cell elongation, shoot development, sugar and starch transformation, and nutrient transfer throughout the plant. Comparable outcomes were documented by Shelke *et al.*, (1988) [16], Gurjar *et al.*, (2017) [5].

Application of 50 kg P ha^{-1} at 45, 60, 75, and 90 DAS recorded considerably more branches per plant than application of 25 kg P ha^{-1}, and it was determined to be on par with application of 37.5 kg P ha$^{-1.}$ Comparable outcomes were stated by Pradhan *et al.*, (1994) [13] and Gurjar *et al.*, (2017) [5].

The phosphorus linked to the formation of new tissues, increased cell division, net assimilation rate, and metabolic activities in plants may be the cause of the increase in leaves per plant. Similar result was reported by Arthamwar *et al.*, (1995, 1996 a, b) [1], Pradhan *et al.*, (1994) [13] and Kumar *et al.*, (2001) [8].

At every stage of crop growth, the mean leaf area plants^{-1} was impacted by varying phosphorus levels. While the application of 37.5 kg P ha^{-1} was determined to be on par with the application of 25 kg P ha^{-1}, the application of 50 kg P ha^{-1} recorded a significantly higher mean leaf plants^{-1} area at 30 DAS compared to the application of 25 kg P ha^{-1}. Application of 50 kg P ha^{-1} at 45, 60, 75, and 90 DAS showed larger mean leaf area plants^{-1} than application of 25 kg P ha^{-1} and it was found to be on par with 37.5 kg P ha^{-1} A related finding has been reported by Arthamwar *et al.*, (1995) [1], Pradhan *et al.*, (1994) [13] and Kumar *et al.*, (2001) [8].

Maximum dry matter plants^{-1} was substantially higher with an application of 50 kg P ha^{-1} than with 25 and 35 kg P ha^{-1}. On the other hand, 37.5 kg P ha^{-1} was determined to be equivalent to 25 kg P ha^{-1}. An application of 50 kg P ha^{-1} recorded the maximum dry matter plants^{-1}, surpassing an application of 25 kg P ha^{-1} and shown to be comparable to an application of 37.5 kg P ha^{-1}. An increase in branches, stronger stalks, and other growth characteristics could be the cause of the dry matter rise. An identical result has been revealed by Arthamwar *et al.*, (1995) [1] and Potdar *et al.*, (2019) [12].

Effect of Sulphur levels

The influence of growing plants' metabolism on the application of Sulphur may be the cause of the mustard plant's increases in height. It has to do with cell division; strong root development and the production of chlorophyll lead to increased photosynthesis, which may have caused a rise in plant height. Similar results were reported by Kumar *et al.*, (2001) [8], Singh and Singh (2002) [19] and Negi *et al.*, (2017) [10].

The effect of Sulphur metabolism on growing plants may be the cause of the mustard's increased branching after applying Sulphur. It has to do with cell division; rapid root development and the production of chlorophyll lead to increased photosynthesis, which may have contributed to the branching pattern. Similar outcomes have been identified by Kumar *et al.*, (2001) [8], Singh and Singh (2002) [19] and Negi *et al.* (2017) [10].

Although notably more functional leaves generated with 45 kg P ha^{-1} application, it was found to be on par with 15 and 30 kg P ha^{-1} application. The use of 30 kg P ha^{-1} was equivalent to that of 15 kg P ha^{-1}. When 45 kg P ha^{-1} was applied at 75 and 90 DAS, it produced a considerably higher number of leaves than when 15 and 30 kg P ha^{-1} were applied; however, 30 kg P ha^{-1} was determined to be on par with 15 kg P ha^{-1}. A same conclusion was put forward by Khanpara *et al.*, (1993) [7] and Rajput *et al.*, (2018) [15].

Table 1: Plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1} leaf area index plant^{-1} and dry matter plant^{-1} (g) of mustard as influenced by different treatments

Treatments	Plant height	Number of branches plant^{-1}	Number of leaves plant^{-1} at 60 DAS	Leaf area plant^{-1} at 60 DAS	Dry matter plant^{-1}
A) Phosphorus levels					
P_1: 25 kg P ha^{-1}	140.96	13.67	25.33	45.29	76.40
P_2: 37.5 kg P ha^{-1}	153.42	14.96	28.89	56.71	85.39
P_3: 50 kg P ha^{-1}	154.20	16.01	30.69	57.71	87.30
SE±	3.71	0.42	0.87	2.11	2.62
CDat5%	11.12	1.28	2.61	6.32	7.86
B) Sulphur levels					
S_1:1l5 kg S ha^{-1}	144.41	14.56	27.92	48.71	79.46
S_2: 30 kg S ha^{-1}	145.53	15.17	28.22	52.98	81.08
S_3:345 kg S ha^{-1}	156.63	15.96	29.77	58.01	88.56
SE±	3.71	0.42	0.87	2.11	2.62
CD at 5%	11.12	1.28	2.61	6.32	7.86
Interaction (P×S)					
SE±	6.43	0.74	1.51	3.65	4.54
CD at 5%	NS	NS	NS	NS	NS
General Mean	149.19	15.15	28.49	53.24	83.08

A plant's average leaf area per plant was greatly impacted by varying Sulphur levels during the entire crop growth cycle. Application of 45 kg S ha^{-1} recorded considerably increased mean leaf area compared to application of 15 kg S ha^{-1}, and it was determined to be on par with 30 kg S ha^{-1}. Applying 45 kg S ha^{-1} at 45 DAS resulted in a much higher mean leaf area than applying 15 kg S ha^{-1}, and it was estimated to be on par with 30 kg S ha^{-1}; however, applying 30 kg S ha^{-1} stayed on par with 15 kg S ha^{-1}. Compared results have been outlined by Khanpara *et al.*, (1993) [7] and Rajput *et al.*, (2018) [15].

An application of 45 kg S recorded significantly highest dry matter plant^{-1} over 15 kg S ha^{-1} and It was found on par with an application of 30 kg S ha^{-1}, while an application of 30 kg S ha^{-1} remained found at par with15 kg S ha^{-1}. Results are in line with Kumar *et al.* (2017) [9].

Interaction effect

Table 1's data showed that the interaction between varying phosphorus and Sulphur levels on plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1}, leaf area plant^{-1} and dry matter plant^{-1} (g) was non-significant.

Yield and yield attributes

Data regarding number of siliqua^{-1}, number of seeds siliqua-^{1}, seed yield plant^{-1} (g) and straw yield plant^{-1} (g) and seed yield ha^{-1} (kg) are presented in Table 2. Considerable differences in the yield and yield attributes *viz*., number of siliqua plant^{-1}, number of seeds siliqua plant^{-1}, seed yield plant^{-1} (g), straw yield plant^{-1} (g) seed yield kg ha^{-1} were observed due to different phosphorus levels and Sulphur levels.

Effect of phosphorus levels

In comparison to 25 kg P ha^{-1}, an application of 50 kg P ha^{-1} was found to be on par with 37.5 kg P ha^{-1} in terms of the number of siliqua plant^{-1}. Same results were revealed by Pradhan *et al*., (1994) [13], Kumar *et al*., (2001) [8], Singh (2002) [19], Potdar *et al*., (2019) [12].

An application of 50 kg P ha^{-1} was observed significantly maximum in number of seeds siliqua^{-1} (16.92) over 25 kg P ha (14.20) and was found at par with 37.5 kg P ha^{-1} (16.87). An application of 25 kg P ha^{-1} recorded minimum number of seeds siliqua^{-1}.

An application of 50 kg P ha^{-1} was observed significantly highest seed yield plant^{-1} (29.12 g) over 25 kg P ha^{-1} (24.97 g) and was found on par with 37.5 kg P ha^{-1} (28.86 g). The results are in line with Paul *et al*., (2016) [11], Singh and Thenua (2016) [20], Gurjar *et al*., (2017) [5].

An application of 50 kg P ha^{-1} (58.58 g) observed significantly higher in straw yield plant^{-1} over 25 kg P ha^{-1} (51.58 g) and it was found on par with 37.5 kg P ha^{-1} (57.40 g). Application of 25 kg P ha^{-1} recorded lowest straw yield plant^{-1}. The similar results reported by Paul *et al.,* (2016) [11], Singh and Thenua (2016) [20], Gurjar *et al.,* (2017) [5].

An application of 50 kg P ha^{-1} was found significantly highest in seed yield ha^{-1} over 25 kg P ha and it was found on par with 37.5 kg P ha^{-1}. Better development and yield-attributing traits may be the cause of the increase in seed yield kg ha^{-1}. The similar results reported by Paul *et al.,* (2016) [11], Singh and Thenua (2016) [20] and Gurjar *et al.,* (2017) [5].

Table 2: Number of siliqua plant^{-1}, number of seeds siliqua^{-1}, seed yield plant^{-1} (g), straw yield plant^{-1} (g), seed yield ha^{-1} (kg) of mustard as influenced by different treatments

Treatments	Number of siliqua plant^{-1}	Number of seeds siliqua^{-1}	Seed yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Seed yield ha^{-1} (kg)
A) Phosphorus levels					
$P_{1:}$ 25 kg P ha^{-1}	1069.80	14.20	24.97	51.58	1499
$P_{2:}$ 37.5 kg P ha^{-1}	1182.13	16.87	28.56	57.40	1849
$P_{3:}$ 50 kg P ha^{-1}	1182.72	16.92	29.12	58.58	1897
SE±	32.79	0.58	0.99	1.91	63
CD at 5%	98.31	0.78	2.97	5.73	188
B) Sulphur levels					
S:1l5 kg S ha^{-1}	1093.31	14.41	24.11	48.56	1510
$S_{2:}$ 30 kg S ha^{-1}	1147.61	16.29	27.13	54.40	1722
$S_{3:}$ 45 kg S ha^{-1}	1193.73	16.50	29.70	60.11	1864
SE±	32.79	0.13	0.99	1.91	63
CD at 5%	98.31	0.40	2.97	5.73	188
C) Interaction (P×S)					
SE±	56.80	1.03	1.71	3.31	109
CD at 5%	NS	NS	NS	NS	NS
General Mean	1144.89	15.86	25.56	55.11	1724

Effect of sulphur levels

When 45 kg S ha^{-1} was applied, compared to 15 kg S ha^{-1}, the number of siliqua plants generated was much larger and was determined to be on par with 30 kg P ha^{-1}. The number of siliqua plant^{-1}may have increased as a result of their translocation into different plant parts and enhanced production of biomass, both of which increased yield attributes. The production of more biomass overall and its transportation across the plant's numerous sections may be the cause of the increase in siliqua plant^{-1}numbers.

Same results were reported by Chand *et al*., (1997 a, b) [4], Kumar *et al*., (2001) [8], Singh and Singh (2002) [19] and Singh *et al*. (2000) [17].

When 45 kg S ha^{-1} was applied, the number of seeds siliqua^{-1} (16.50) was much higher than when 15 kg S ha^{-1} (14.41), and it was found to be on par with 30 kg S ha^{-1} (16.29). The maximum number of seeds siliqua^{-1} may result from the interaction between yield and growth characteristics. The analogous results revealed by Singh and Kumar (2014).

The maximum seed yield per plant (29.70 g) was achieved with an application of 45 kg S ha^{-1}, which was shown to be equivalent to 30 kg S ha^{-1} (27.13 g) when compared to 15 kg S ha^{-1} (24.11 g). Plant^{-1}'s maximum seed output may be caused by sulfur's role in the synthesis of fatty acids. The greatest seed yield Plant^{-1} is the outcome of enhanced siliqua Plant^{-1}'s due to the synthesis of various amino acids. The similar outcomes reported by Chand *et al*., (1997) [4], Kachroo and Kumar (1999) [6] and Bohra and Srivastava (2002) [3].

In comparison to the application of 15 kg S ha^{-1} (48.65 g), which was determined to be on par with 30 kg S ha^{-1} (54.40 g), the application of 45 kg S ha^{-1} (60.11 g) showed a significantly higher straw yield Plant^{-1}. A rise in plant height, branch count, dry matter content, and siliqua Plant^{-1} may all contribute to an increase in straw yield. The comparable results were reported by Chand *et al*., (1997) [4], Kachroo and Kumar (1999) [6] and Bohra and Srivastava (2002) [3].

A 45 kg S ha^{-1} application was found to be on par with 30 kg S ha^{-1} in terms of seed yield kg ha^{-1}, which was shown to be superior above 15 kg S ha^{-1}. The heightened yield-attributing characteristics of fatty acids resulting from the involvement of Sulphur in their synthesis could account for the ha^{-1} rise in seed yield. Results was in line with Chand *et al*., (1997), Kachroo and Kumar (1999) [6] and Bohra and Srivastava (2002) [3].

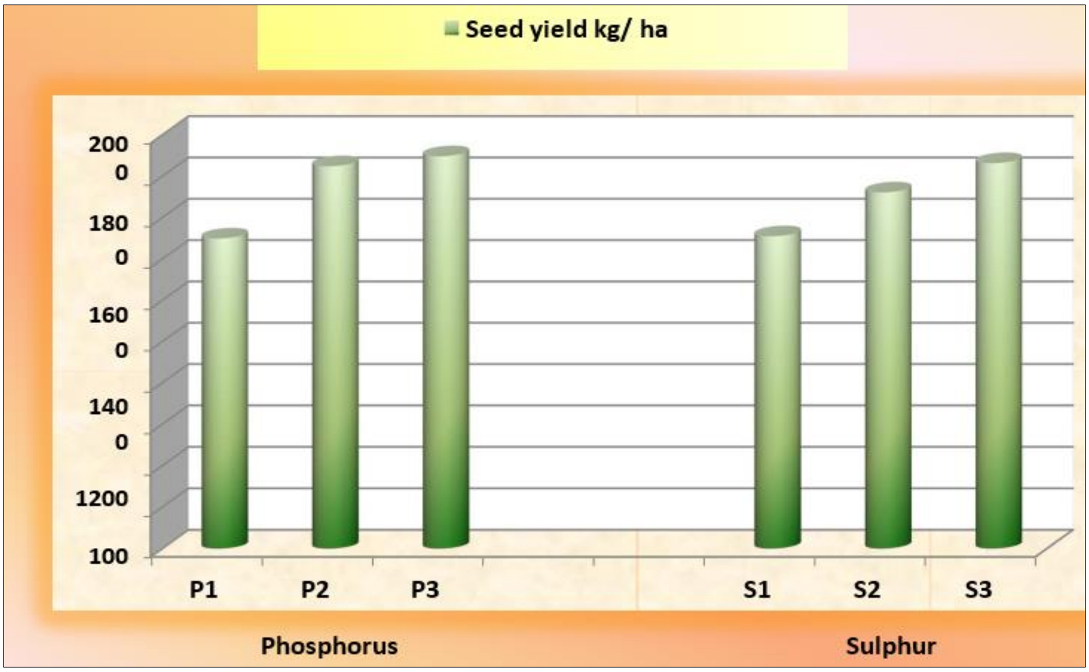

Fig 1: Seed yield (kg ha^{-1}) of mustard as influenced by different treatments

Interaction effect

Data presented in Table 2 showed that the interaction effect of different phosphorus levels and Sulphur levels on number of siliqua plant$^{-1,}$ number of seeds siliqua^{-1}, seed yield plant^{-1} (g), straw yield plant^{-1} (g), seed yield ha^{-1} (kg) was found statistically non-significant.

Higher growth and yield attributes, seed yield (1897 kg ha^{-1}) and straw yield (4723 kg ha^{-1}) was observed with an application of 50 kg P ha^{-1} (P_3) which was followed by an application of 37.5 kg P ha^{-1}(P_2) and it was significantly superior over an application of 25 kg P ha^{-1} (P_1).

Higher growth and yield attributes, seed yield (1864 kg ha^{-1}), straw yield (4843 kg ha^{-1}) was observed with an application of 45 kg S ha^{-1} (S_3) which was followed by an application of 30 kg S ha^{-1}(S_2) and it was significantly superior over an application of 15 kg S ha^{-1} (S_1). In case of seed yield application of 50 kg P ha^{-1} and 45 kg S ha^{-1}performed better.

Conclusion

An application of 37.5 kg P ha^{-1}(P_2) and 25 kg P ha^{-1} (P_1) found beneficial for obtaining higher growth and yield attributes, seed yield (1897 kg ha^{-1}), straw yield (4723 kg ha^{-1}).

An application of 45 kg S ha^{-1} (S_3) and 30 kg S ha^{-1}(S_2) found beneficial for obtaining higher growth and yield attributes, seed yield (1864 kg ha^{-1}), straw yield (4843 kg ha^{-1}).

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