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Aditya Bunkar
Department of Agronomy, Institute of Agricultural Science, AKS University, Satna, Madhya Pradesh, India

DP Chaturvedi
Department of Agronomy, Institute of Agricultural Science, AKS University, Satna, Madhya Pradesh, India

Corresponding Author:
Aditya Bunkar
Department of Agronomy, Institute of Agricultural Science, AKS University, Satna, Madhya Pradesh, India

Effect of phosphorus levels and varieties on growth, yield and quality of linseed (*Linum usitatissimum* L.)

Aditya Bunkar and DP Chaturvedi

Abstract
A field experiment was conducted during *rabi* season, 2020-21 to study the effect of linseed under varying levels of phosphorous application and varieties at the student instructional field, department of Agronomy, faculty of Agriculture, AKS University, Satna (M.P.). The experiment consisted of randomize block design having Factorial arrangement with three replications. In this experiment, 12 treatment combinations including four levels of phosphorus as P_0- 0 kg/ha, P_1- 30 kg/ha, P_2- 40 kg/ha and P_3- 50 kg/ha, while three linseed varieties were tested are V_1- JLS-66, V_2- JLS-67 and V_3- JLS-09. During the experiment, it was found that highest plant height (35.99 cm), number of branches per plant (7.93), number of capsules per plant (37.27), number of seeds per capsule (8.73), test weight (9.81 g), seed yield (17.47 q/ha), stover yield (28.92 q/ha) and oil content (40.08 %) at maximum crop growth stage was recorded in plots treated with application of phosphorus @ 50 kg/ha in combination with linseed variety of JLS- 66. It was concluded from the results that linseed variety of JLS- 66 observed maximum plant growth, yield & yield attributing characters as well as quality of linseed.

Keywords: Linseed, varieties, phosphorus, capsules, stover yield, oil

Introduction
Oilseeds play a vital role in human life. Among these, linseed enjoys an important place, being used for domestic, industrial and medicinal purposes. Linseed is an important rabi oilseed crop and is cultivated primarily for oil edible as well industrial purposes. Linseed (*Linum usitatissimum* L.) also known as flax is a member of genus Linum in the family Linaceae.

The use of chemical fertilizers has been doubled during the last two decades. Intensive cropping with high yielding varieties is causing a marked depletion of inherent macro and micro nutrient reserves of soil including nitrogen, phosphorus and sulphur. Beside nitrogen, phosphorus is the second most important plant nutrient and is key element in the process of conservation of solar energy into chemical energy. The optimum supply of phosphorus to the plant stimulates root development and growth, thereby helps to establish seedling quickly and also hastens maturity as well as improves the quality of crop. Several other gross quantitative and qualitative effects on plant growth are attributed to phosphorus fertilization. The phosphorus management in linseed improves yield quantity and quality of produces and reduces the incidence of diseases, pests and cost of cultivation. Majority of cultivated area of the linseed needs fertilization for good yield as phosphorus and sulphur content in soil is low. Phosphorus (P) is usually associated to increased root density proliferation, which aids in extensive exploration, supply of nutrients and water to growing plant parts, thus increase growth and yield (Jahan *et al*., 2019) [8]. Phosphorus is a component of key molecules such as nucleic acids, phospholipids and ATP.

In fact, the extra pressure on the limited land resources and use of high yielding varieties to feed rapidly increasing production have led to the present scenario of shortage of important plant mineral nutrient in major soils on the globe. The deficiency of soil P & S in the agriculture soils has been reported frequently over the past several years (Ahmad *et al*., 2005b) [2]. However, among different region of Asia has the highest phosphorus fertilizer requirement. Since, there is a vast variability in the climatic and edaphic conditions in the linseed growing areas of India, the selection of suitable varieties is another important factor decline the crop response to applied nutrients and thereby the economic yield. In recent years some new varieties of linseed have been released and they need to be tested under irrigated system of Satna. Considering the importance of phosphorus and varieties, this experiment was conducted to investigate the impact of phosphorus and linseed varieties on growth, yield and quality of linseed.

Materials and Methods

The experiment was carried out at the student instructional field, department of Agronomy, faculty of Agriculture, AKS University, Satna (M.P.) during *rabi* season of year 2020- 21. The experiment was conducted in randomize complete block design having Factorial concept with three replications. Different rates of phosphorus and linseed varieties allocated to the plots as per treatments. In this experiment, 12 treatment combinations including four levels of phosphorus as P_0- 0 kg/ha, P_1- 30 kg/ha, P_2- 40 kg/ha and P_3- 50 kg/ha, while three linseed varieties were tested are V_1- JLS-66, V_2- JLS-67 and V_3- JLS-09. The gross and net plot size was 5.0 m x 3.5 m and 4.0 m x 3.0 m, respectively. The fertilizers grades were applied as per treatments. The recommended dose of nitrogen and muriate of potash was applied @ 60 kg N/ha and 40 kg K_2O/ha, respectively. Nutrients, phosphorus (P_2O_5) was applied as per the treatments. Half dose of nitrogen and full dose of phosphorus and potassium was applied as basal dose and remaining half dose of nitrogen was applied in two equal splits during first and second irrigation. 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 capsules per plant, number of seeds per capsule, test weight, seed yield, stover yield and oil content was influenced significantly due to different concentrations of phosphorus and linseed varieties.

Data regarding these characters are reported in (Table- 1). Statistical analysis of the data revealed that maximum plant height and number of branches per plant at maximum crop growth stage (34.45 cm and 7.38, respectively) were recorded in plots treated with the application of phosphorus @ 50 kg/ha while, lowest values were observed in plot that received no phosphorus. Similarly, linseed variety of JLS- 66 gave maximum plant height and number of branches per plant with the respective value of 32.00 cm and 6.63, respectively.

Statistical analysis of data revealed that interaction effect between phosphorus and variety significantly affected for plant growth and yield. The maximum plant height and number of branches per plant were recorded from plot receiving phosphorus @ 50 kg/ha in combination with linseed variety of JLS-66, with the respective value of 35.99 cm and 7.93, respectively while minimum was recorded from plot receiving 0 kg/ha phosphorus with linseed variety of JLS-09.

It was observed that plant growth increased gradually with the optimum phosphorus dose. This might be due to higher availability of nitrogen and phosphorus and their uptake that progressively enhanced the vegetative growth of the plant. 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. Phosphorus is also an important nutrient in linseed crop. It is considered to be an effective extractor of soil phosphorus. The increased levels of P accomplished the requirement of P nutrition and caused rapid root development that resulted in improved plant growth which consequently showed significant translocation and storage of photosynthates from source to sink. This result is similar with the findings of Sahu *et al*. (2011) [14] and Amit *et al*. (2017) [3]. The increase in growth parameters is attributed to the stronger role of P in cell division, cell expansion and enlargement which ultimately affect the vegetative growth of crop and effective utilization of nutrients through the extensive root system developed by crop plants under integrated P application.

The significant variations in plant height may be due to the fact that phosphorus application improved the root system through accelerating various. metabolic processes such as cell division, cell development and cell enlargement in roots. The increase in plant height and number of branches per plant was also reported by Amit *et al*. (2017) [3] and Vyas *et al*. (2020) [17].

Increasing the number of branches might be due to the fact that phosphorus application improved the root system through accelerating various. Metabolic processes such as cell division, cell development and cell enlargement in roots. The increase in plant height and number of branches per plant was also reported by Yadav *et al*. (2020) [19], Priyadarshini *et al*. (2021) [11], Sahoo *et al*. (2021) [13] and Sameer *et al*. (2021) [15]. The significant variations in plant height and branches among the varieties may be due to their genetic variability for this trait. The similar results have also been reported by Abhinaw *et al*. (2017) [1]. The present findings have been supported by many workers like Yadav *et al*. (2018) [18] and Biswas *et al*. (2019) [5]. Further, the differential behaviour among the varieties could be explained by the variation in their genetic makeup and their differential behavior under different climatic conditions.

Data regarding maximum number of capsules per plant, number of seeds per capsule, test weight, seed yield, stover yield and oil content are reported in (Table-1). Statistical analysis of the data revealed that maximum number of capsules per plant, number of seeds per capsule, test weight, seed yield, stover yield and oil content (34.87, 8.02, 9.40 g, 16.54 q/ha, 27.33 q/ha and 39.66 %, respectively) were recorded in plots treated with the application of phosphorus @ 50 kg/ha while, lowest values were observed in plot that received no phosphorus. However, linseed variety of JLS - 66 gave highest value of 32.15, 7.35, 8.73 g, 14.77 q/ha, 26.16 q/ha and 38.99 %, respectively, respectively for above characters.

Statistical analysis of data revealed that interaction effect between phosphorus and varieties significantly affected number of capsules per plant, number of seeds per capsule, test weight, seed yield, stover yield and oil content were found significant. Similarly, the maximum values of these parameters were recorded from plot receiving phosphorus @ 50 kg/ha in combination with linseed variety of JLS- 66, with the respective values of 37.27, 8.73, 9.81 g, 17.47 q/ha, 28.92 q/ha and 40.08 %, respectively while minimum values were recorded from plot receiving 0 kg/ha phosphorus with linseed varieties of JLS-09.

Application of phosphorus was found significantly superior for yield and yield attributes as well as oil content. The plant treated with optimum phosphorus doses, resulting increased the root through better root development and more nutrient availability, resulting in vigorous plant growth and dry matter accumulation leading to flowering, fruiting and capsule formation. The maximum number of capsules per plant with optimum phosphorus rates was attributable to better root growth which in turn led to increase in seed yield. These findings are in agreement with the findings of Singh *et al*. (2018) [16] and Parmar *et al*. (2020) [9]. The significant variations in among the various treatments may be due to the fact that phosphorus application improved the root system through accelerating various metabolic processes such as cell division, cell development and cell enlargement in roots. The increase in and number of branches per plant was also reported by Patil *et al*. (2018) [10] and Gautam *et al*. (2020) [7].

The better growth of plant in terms of height, branch and leaf number might have helped in improving yield parameters and yield of linseed 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 nitrogen, phosphorus and potassium on growth and partitioning of photosynthates to sink development has led to increased number of capsules per plant, number of seeds/capsule and test weight. With increase in photosynthetic products, coupled with efficient translocation, plant produced more capsules/plant with a greater number of seeds per capsule. Significant increase in seed and straw yields appeared to be on account of beneficial effects of phosphorus and potassium on growth and yield attributes. Similar findings have also been reported by Priyadarshini *et al*. (2021) [11]. It is well documented that phosphorus increases root formation and in turn yield. Increased yield attributes of this treatment might be due to increased growth parameters. This was in line with the results reported by Gautam *et al*. (2020) [7].

The effect of phosphorus may be due to utilization of more quantities of nutrients through their well- developed root system and nodules which might have resulted in better growth and yield at medium. These results confirm the earlier findings of Anjali *et al*. (2020) [4] and Chauhan *et al*. (2020) [6].

The better growth of plant in terms of height, branches and leaf number might have helped in improving yield parameters and yield of linseed 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.

The enhanced seed and stover yield due to phosphorus application may be attributed to the activation of metabolic processes, where its role in building phospholipids and nucleic acid is known. The stimulation effects of P on growth and yield attributes and enhanced nitrogen activity in plant which in turn reflected positively on economic yield of the crop. The improved fertility status of the plots, which received higher amount of phosphorus in linseed, might have improved the plant growth and yield attributes. Higher uptake of nutrients particularly phosphorus and potassium enhanced the photosynthetic efficiency as well as translocation of photosynthates from source to sink which resulted an increase in yield. The results are in close conformity with the findings of Biswas *et al*. (2019) [5].

This increase in seed yield of JLS-66 might be due to higher production efficiency which was reflected through improvement in different yield contributing characters. Differential yield potential due to different linseed varieties was reported by Biswas *et al*. (2019) [5].

Increase in seed yield and its parameters may be due to increase in the number of leaves which worked as an efficient photosynthesis structure and produced high amount of carbohydrates in the plant system. More number of branches which borne more number of flowers, which resulted higher capsule/plant and seed yield and their attributes. Similar findings also reported by Richa *et al*. (2019) [12].

The marked increase in yield attributes under JLS-66 might be due to its genetic potential when grown under semi-arid conditions and improved growth at successive stages as reflected by higher production of dry matter production at different stages and at harvest. The yield attributes indicating the suitability of variety for growing in a prevailing climatic and soil moisture conditions. Seed yield is the net resultant effect of various agronomic input influencing growth and yield attributing characters during the life cycle of crop.

The probable reason for enhanced seed yield may be due to cumulative effects of varietal characters and sufficient quantity of nutrient on vegetative growth which ultimately lead to more photosynthetic activities while, application of nutrient levels enhances carbohydrate and nitrogen metabolism of pectic substances, as well as improve the water metabolism and water relation in the plants. The variation in yield attributes of JLS-66 variety may be due to genetic characteristics among different genotypes under present investigation. These findings are in agreement with the findings of Yogesh *et al*. (2017) [20] and Biswas *et al*. (2019) [5].

The application of adequate amount of phosphorus influenced the vigour of plants which has ultimately produce higher concentration of oil content. Similar results found by Singh *et al*. (2018) [16] and Priyadarshini *et al*. (2021) [11].

The overall performance of yield, yield attributes and quality were better because the most important weather parameter i.e. even distribution and more quantity rainfall during the experimental year which helped in better crop growth that ultimately reflected in the yield of crop.

Table 1: Effect of Phosphorus Levels and varieties their interaction on growth, yield and quality of Linseed

Tr.	Plant height (cm)	Number of branches/Plant	Number of capsules per plant	Number of seeds/capsule	Test weight (g)	Seed yield (q/ha)	Stover yield (q/ha)	Oil content (%)
	Effect of Phosphorus							
P_0	26.63	5.49	27.44	6.11	7.31	11.84	24.32	37.54
P_1	30.72	6.22	29.67	6.67	8.38	13.07	24.79	38.64
P_2	31.96	6.49	31.80	7.20	8.72	14.47	25.99	38.98
P_3	34.45	7.38	34.87	8.02	9.40	16.54	27.33	39.66
S. Em±	0.73	0.20	0.82	0.22	0.21	0.38	0.45	0.18
C.D. (P=0.05)	2.14	0.60	2.40	0.63	0.63	1.12	1.33	0.54
V_1	32.00	6.63	32.15	7.35	8.73	14.77	26.16	38.99
V_2	30.95	6.37	30.83	7.00	8.44	13.74	25.43	38.70
V_3	29.88	6.18	29.85	6.65	8.18	13.44	25.23	38.42
S. Em±	0.84	0.24	0.95	0.25	0.25	0.44	0.52	0.21
C.D. (P=0.05)	2.47	0.69	2.77	0.73	0.73	1.29	1.53	0.63
P_0V_1	28.52	5.60	28.00	6.33	7.78	12.36	24.35	38.04
P_0V_2	27.00	5.47	27.40	6.27	7.36	11.64	24.32	37.63
P_0V_3	24.37	5.40	26.93	5.73	6.78	11.53	24.28	36.94
P_1V_1	30.88	6.33	30.47	6.87	8.42	13.47	24.98	38.69
P_1V_2	30.87	6.20	30.20	6.80	8.42	12.94	24.81	38.68
P_1V_3	30.40	6.13	28.33	6.33	8.29	12.81	24.57	38.55
P_2V_1	32.61	6.67	32.87	7.47	8.89	15.78	26.37	39.16
P_2V_2	32.11	6.53	31.53	7.13	8.76	14.03	25.93	39.02
P_2V_3	31.17	6.27	31.00	7.00	8.50	13.61	25.68	38.76
P_3V_1	35.99	7.93	37.27	8.73	9.81	17.47	28.92	40.08
P_3V_2	33.80	7.27	34.20	7.80	9.22	16.33	26.68	39.48
P_3V_3	33.57	6.93	33.13	7.53	9.16	15.81	26.40	39.42
S. Em±	0.42	0.12	0.47	0.12	0.12	0.22	0.26	0.11
C.D. (P=0.05)	0.87	0.25	0.98	0.26	0.26	0.46	0.54	0.22

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