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Plant Growth and Yield-related Attributes in Sesame (*Sesamum indicum* L.) as a Function of Phosphorus and Sulphur Interaction

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Abstract

*The wide gap still exists between potential productivity and actual productivity of sesame. Apart from other agronomical management practices, imbalanced plant nutrition is the major constraint to the higher productivity of the crop. Optimum nutrition is required for achieving good quality and maximum yield. A research experiment was conducted during the Kharif season of 20019 at the Research Farm, School of Agriculture, ITM University, Gwalior (M.P.). The G-5 variety of sesame was sown in the 30cm rows @5kg ha^{-1} in a randomized block design having a factorial concept with total of twelve treatment combinations consisting of four levels of phosphorus (**P_1**: 15 kg/ ha,**P_2**: 30 kg/ ha,**P_3**: 45 kg/ ha and **P_4**: 60 kg/ha) and three levels of Sulphur (**S_1**: 15 kg/ ha, **S_2**: 30 kg/ ha and **S_3**: 45 kg/ ha) replicated thrice was employed in this study. The application of phosphorus @60 kg /ha increased the grain yield significantly over its lower levels. This might be due to the increase in yield contributing parameters like, number of capsules per plant, the number of seeds per capsule and test weight under this treatment. The highly significant and positive correlation existing between grain yield and yield attributes and nutrients uptakes which support for increased grain yield due to the application of phosphorus.*

Keywords: *Sesame, Phosphorus, Sulphur, Yield, Yield attributes.*

Introduction

The sesame is grown in a wide range of environments, and being a short-duration crop fits well into a number of sequence and intercropping systems. It is grown in India both as Kharif and rabi crops. In North India Region, sesamum is grown as minor crops on relatively poor soils with no manures. This neglect is reflected in low average yields, contributing poor productivity to the national pool of oilseeds. The region, however, has tremendous potential for increasing sesamum production and productivity due to favourable climatic conditions.

Despite being such an important sesame-growing state, the average productivity is very low in comparison to global as well as national levels. Low and scanty rainfall, cultivation of crop on marginal and sub-marginal lands of poor fertility under very poor agronomic practices and inadequate or even no use of fertilizers are the major factors responsible for the low productivity of the crop. Sesame is generally grown on residual fertility in the state but to get good yield, it is essential that the crop is adequately fertilized. The average N, P, K and S removal to produce a ton of sesame is 51.7, 22.9, 64.0 and 11.7 kg, respectively and other micronutrients like Ca, Mg, Zn, Fe, Mn, and Cu are also important[1].

Phosphorus involves in energy transfer metabolic processes and the basic reaction of photosynthesis, the transformation of sugar and starch and nutrient movement in plants. It is known to stimulate an extensive root system thereby enabling the plant to extract moisture and mineral nutrients optimally. Phosphorus fertilization also improves the quality of seeds and serves the dual purpose of increasing the yield of the main crop as wellas the succeeding crop and providing resistance against diseases. Phosphorus is deficient in most of the soils of Madhya Pradesh, particularly in lightly textured ones where most of the sesame is grown.

Sulphur deficiency is widespread in India and is considered as a limiting factor, particularly for oilseeds and paddy. Oilseed crops require more sulphur than cereals as their oil storage organs are mostly proteins, rich in sulphur. The deficiency of sulphur is known to hamper nitrogen metabolism in plants as well as the synthesis of S-contain amino acids and thus exerts adverse effects on both seed and oil yield. Sulphur is another essential plant nutrient, a deficiency of which has been observed in soils of the Gwalior region. Research work done in different parts of the country indicates that the application of sulphur to all crops and oil seeds in particular, is highly profitable and seems to be essential for boosting crop production. Sulphur plays an important role in many physiological processes of plants like the synthesis of sulphur-containing amino acids (Cystine, Cysteine and Methionine), vitamins (biotin and thiamine), co-enzyme-A and metabolism of carbohydrates, protein and fats. It also helps in the synthesis of glucosides in sesame oil and increases the oil quality of oilseed crops. Sulphur also has an essential role in the development of root growth and increases drought and cold tolerance in oilseeds due to di-sulphide linkage. It helps in the control of diseases and pests and hastens the decomposition of crop residues[4,9].

Application of S and P improves soil fertility status but S alone cannot influence P availability. Individual application of different levels of P and S showed a significant effect on yield attributes[4]. 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 sesame is rather limited in the sub-tropical zone of M.P.[6]. It was very much essential to develop a strong workable and compatible package of phosphorus and Sulphur management for sesame based on scientific facts and local conditions. However, the combined effect of phosphorus and Sulphur on sesame has not been studied adequately.

Material and Methods

A research experiment was conducted during the Kharif season of 20019 at the Research Farm, School of Agriculture, ITM University, Gwalior (M.P.). The G-5 variety of sesame was sown in the 30cm rows @5kg ha^{-1} in a randomized block design having a factorial concept with total of twelve treatment combinations consisting of four levels of phosphorus (**P_1:** 15 kg/ ha,**P_2:** 30 kg/ ha,**P_3:** 45 kg/ ha and **P_4**: 60 kg/ha) and three levels of Sulphur (**S_1**: 15 kg/ ha, **S_2**: 30 kg/ ha and **S_3**: 45 kg/ ha) replicated thrice was employed in this study.

After field preparation, the seedbeds of 4.0 m x 3.0 m size were prepared as per the plan of the layout. Seeds were sown on the furrow on August, 5th 2019after being treated with Bavistin to control the seed-borne disease.

The experimental plots were fertilized as per treatments. Urea, Single Super Phosphate (SSP) and muriate of potash (MoP) were used as a source of nitrogen, phosphorous and potassium, respectively. Half the amount of the nitrogen at the rate of 60 kg/ha, the whole amount of phosphorus, and MoP @40kg K_2O / ha were applied as basal during land preparation and the remaining amount of nitrogen was top-dressed at the 30 DAS stage.

In addition to rainfall received during the crop season, one irrigation was given through a sprinkler system during dry spells to ensure optimum growth, development and yield of the crop.

Prophylactic plant protection measures were undertaken to protect the crop from insects and diseases. Before sowing, the seeds were treated with Bavistin @ 2 g kg^{-1} to protect them from seed-borne diseases. In order to prevent the attack of Til hawk moth and termites, Phorate 10 G at 10 kg/ha was drilled at the time of sowing. A spray of imidacloprid 17.8 SL @ 0.25 per cent was done on September, 10th 2019 to protect the crop from the damage of sucking insects.

Harvesting was done when the maturity symptoms were observed. The border rows were harvested first as bulk and kept separately. The crop was harvested on the basis of net plot size (3.60 m x 2.90 m). It was harvested manually with the help of the local name of *hansiya* (Sickle). The crop was harvested manually on November 11th 2019. Before harvesting, five plants already tagged were pulled out from every plot to record post-harvest observations. Each bundle was labelled by numbered tag. Harvested plants were sun-drieda for few days at the threshing floor after proper tagging.

In order to evaluate the effect of treatments on growth, yield components, yields, nutrient content and other aspects the of sesame crop, observations were recorded for each parameter as per methodology.

Results and Discussion

Growth parameters of sesame

The result shows (Table 1) that plant height at 30 DAS was influenced significantly due to different levels of phosphorus and sulphur as well as their interaction. At 30 DAS, it ranged from 28.70 to 31.36 cm. The highest plant height (30.64 cm) was found under the application of Sulphur @ 45 kg/ha followed by Sulphur applied @ 30 kg/ha (30.35 cm). There was a significant increase in plant height, recorded with the higher dose of sulphur at this growth stage while lowest plant height (29.98 cm) was recorded with sulphur application @ 15 kg/ha. The treatment combination consisting of the application of phosphorus @ 60 kg/ha with combined application of Sulphur @ 45 kg/ ha produced a significantly highest plant height (31.73 cm) followed by the application of phosphorus @ 60 kg/ha with combined application of sulphur @ 30 kg/ ha (31.46 cm) as compared to all the remaining treatment combinations.

Table 1 Plant height (cm) of sesame at different stages after application of different levels of phosphorus and sulphur

	At 30 DAS					**At 60 DAS**					**At harvest**				
	P_1	**P_2**	**P_3**	**P_4**	**Mean**	**P_1**	**P_2**	**P_3**	**P_4**	**Mean**	**P_1**	**P_2**	**P_3**	**P_4**	**Mean**
S_1	28.11	29.98	30.92	30.90	29.98	89.34	102.23	112.49	112.36	104.11	93.24	108.98	117.93	117.37	109.38
S_2	28.82	30.21	30.92	31.46	30.35	91.29	103.57	112.49	115.32	105.67	96.06	109.37	117.93	120.18	110.88
S_3	29.18	30.25	31.39	31.73	30.64	98.87	108.76	113.73	116.37	109.43	107.52	113.52	119.03	122.50	115.64
Mean	28.70	30.15	31.08	31.36		93.17	104.85	112.90	114.68		98.94	110.62	118.30	120.02	
	P level		**S level**		**PxS**	**P level**		**S level**		**PxS**	**P level**		**S level**		**PxS**
SEm±	0.06		0.06		0.11	0.66		0.57		1.15	0.66		0.58		1.15
C.D.	0.19		0.16		0.32	1.95		1.69		3.37	1.95		1.69		3.37

Sulphur (S_1-S_3) and phosphorus (P_1-P_4) levels; CD at P= 0.05; DAS- days after sowing; PxS- phosphorus and sulphur interaction

The lowest plant height (28.11 cm) was noticed under the application of phosphorus @ 15 kg/ha with a combined application of sulphur @ 15 kg/ ha treatment combination. Similar observations were reported at 60 DAS and at harvest. The data revealed that the maximum height of sesame at all the growth stages was obtained by application of 60 kg P_2O_5/ ha which was followed by application of 45 kg P_2O_5/ ha. Sharma (1994) recorded significantly maximum plant height and head diameter by application of 40 kg P_2O_5/ ha. The increase in height with 60 kg P_2O_5/ ha may be attributed to rapid mobilization of P from inorganic fertilizers which might have met the P requirement in cell elongation and cell division at critical stages of plant growth.

The number of branches is one of the important growth parameters contributing to green yield in any crops as well as the grain yield of any crop. The number of branches is an index of growth and development indicating the infrastructure build-up of plants. The data pertaining to the number of branches (Table 2) at 30, 60 DAS and at harvest as influenced by different levels of phosphorus and sulphur treatments revealed that branch emergence continued to increase with the advancement in age of the crop growth and a rapid increase in the number of branches was noticed during earlier period of crop growth up to 60 DAS. The subsequent emergence of branches was slower up to maturity. An examination of data shows highly significant effect of different levels of phosphorus and sulphur as well as their interaction on number of branches at every growth stage. The maximum number of branches per plant (2.81) was observed in the application of phosphorus @ 60 kg/ha and found significantly superior over other treatments and closely followed by 2.59 with the application of phosphorus @ 45 kg/ha. Maximum number of branches per plant (2.58) was found under the application of sulphur @ 45 kg/ha followed by sulphur applied @ 30 kg/ha (2.44). There was a significant increase in number of branches per plant, recorded with higher dose of sulphur at this growth stage while, minimum number of branches per plant (2.35) was recorded with sulphur application @ 15 kg/ha. The treatment combination consisting of application of phosphorus @ 60 kg/ha with combined application of Sulphur @ 45 kg/ ha produced significantly maximum number of branches per plant (3.05) followed by application of phosphorus @ 60 kg/ha with combined application of sulphur @ 30 kg/ ha (2.81) as compared to all the remaining treatment combinations. Similar trends were reported at 60 DAS and at harvest.

The improvement in growth in term of plant height and number of branches per plant, owing to phosphorus application could be attributed to its important role in rapid cell-division and elongation in the meristematic regions and apical growth, thereby improving the growth parameters.

The sesame crop responded favourably to phosphorus fertilization in terms of the plant height and number of branches per plant at all the stages of observation. The significant improvement in these growth parameters of the crop was observed up to 60 kg/ha.

Table 2 Number of branches per plant of sesame at different stages after application of different levels of phosphorus and sulphur

	At 30 DAS					At 60 DAS					At harvest				
	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean	P_1	P_2	P_3	P_4	Mean
S_1	2.00	2.33	2.48	2.58	2.35	1.96	2.37	2.58	2.62	2.38	2.28	2.90	3.12	3.18	2.87
S_2	2.02	2.34	2.61	2.81	2.44	2.16	2.38	2.65	2.78	2.49	2.53	2.91	3.19	3.24	2.97
S_3	2.24	2.36	2.67	3.05	2.58	2.29	2.40	2.71	3.01	2.60	2.88	3.09	3.22	3.38	3.14
Mean	2.09	2.34	2.59	2.81		2.14	2.38	2.65	2.80		2.56	2.97	3.18	3.27	
	P level		S level		PxS	P level		S level		PxS	P level		S level		PxS
SEm±	0.03		0.03		0.06	0.03		0.03		0.05	0.04		0.04		0.07
C.D.	0.10		0.09		0.18	0.09		0.08		0.15	0.12		0.10		0.21

Sulphur (S_1-S_3) and phosphorus (P_1-P_4) levels; CD at P= 0.05; DAS- days after sowing; PxS- phosphorus and sulphur interaction

It can be ascribed to the better nutritional environment in the root zone for growth and development of the crop as well as in the plant system. Since, phosphorus has long been considered as an essential constituent of nucleic acids (RNA and DNA), nucleoproteins, amino acids, proteins, phospholipids and several co-enzymes. Being a vital component of ADP and ATP, it plays an important role in conservation and transfer of energy in metabolic reactions of all living cells including biological energy transformations.

The increased availability of phosphorus owing to its application in soluble form to the soil which was otherwise poor in its P content might have led to significant improvement in the concentration and uptake of this nutrient which in turn helped in early root development and ramification, thereby leading to increased growth in terms of plant height, branches per plant and dry matter accumulation. The greater uptake of phosphorus as well as of N and S due to synergistic effect which might have increased the photosynthetic and carbohydrates synthesis and then translocation to different parts for promoting meristematic development in potential apical buds and intercalary meristems which ultimately increased the root and shoot development. Application of 45 kg S/ha produced significant improvement in plant height and number of branches of sesame.

Sulphur is the fourth major nutrient in crop production, involved in the synthesis of chlorophyll and methionine recorded increase in plant height with the increase in S level. The maximum plant height recorded with 60 kg S/ha. The rate of increase in growth characters is more with higher rate of S application perhaps due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body, which ultimately increased the vegetative growth[2, 7, 8].

Significant increase in plant height and number of branches per plant was observed due to the application of sulphur up to 45 kg/ha. It is because of the fact that application of sulphur has been reported to improve not only the availability of sulphur itself but of other nutrients too, which are considered important for the growth and development of plant. Sulphur has also been reported to help in lowering the soil pH, which is the main reason for greater availability and mobility of nutrients especially of P, Fe, Mn and Zn, Sulphur in the form of sulphate is involved in various metabolic and enzymatic activities of plants. It is also a constituent of glutathione, a compound supposed to play part in plant respiration and synthesis of oils[3].

Further, sulphur also plays a vital role in chlorophyll formation as it is constituent of succinyl Co-A which is involved in chlorophyll synthesis. The profound influence of sulphur fertilization on plant height and branches could be attributed to increased metabolic processes in plants which seems to have promoted meristematic activities causing higher apical growth and expansion of photosynthetic surface. Furthermore, the improved nutritional environment at the cellular level and leaf chlorophyll content appear to have increased the photosynthetic rate. Thus, it is obvious that the improved growth and development of the crop plants in the present investigation might be the result of enhanced metabolic activities and photosynthetic rate resulting in improvement in plant height, branches per plant and ultimately the accumulation of dry matter at the successive growth stages[5].

The higher content of sulphur in plants is known to have role in better development and thickening of xylem and collenchyma tissues. Such favourable effects might have resulted in stronger stem thereby increasing the number of primary branches per plant.

Interaction application of phosphorus and Sulphur play significantly role on growth and photosynthetic structure of test plants. The growth development and other growth behavior of tagged plants was highly improved due to present treatments may be attributed to its role in development of tissue, Xylem and collenchyma's fibers.

Phosphorus and Sulphur fertilization enhanced the plant growth of sesame. There is progressive increase in plant growth under suitable combination of P and S for sesame crop with the application of 60 kg P_2O_5/ ha along with 45 kg S/ ha which might be attributed to the role of phosphorus and Sulphur in the formation of growth hormones and rapid cell division, differentiation and maturation caused by these nutrients which might have brought increased plant growth in sunflower.

Yield attributing characters

The result shows (Table 3) that number of capsules per plant was influenced significantly due to different levels of phosphorus and sulphur as well as their interactions. Maximum number of capsules per plant (42.36) was observed in the application of phosphorus @ 60 kg/ha found significantly superior over other treatments and closely followed by 41.60 with the application of phosphorus @ 45 kg/ha. The maximum number of capsules per plant (39.86) was found under the application of sulphur @ 45 kg/ha followed by sulphur applied @ 30 kg/ha (38.50). There was a significant increase in number of capsules per plant, recorded with higher dose of sulphur at this growth stage while, minimum number of capsules per plant (37.35) was recorded with Sulphur application @ 15 kg/ha. The treatment combination consisting of application of phosphorus @ 60 kg/ha with combined application of sulphur @ 45 kg/ ha (P_4S_3) produced significantly maximum number of capsules per plant (43.51) followed by application of phosphorus @ 60 kg/ha with combined application of sulphur @ 30 kg/ ha (42.30) as compared to all the remaining treatment combinations. The minimum number of capsules per plant (30.32) was noticed with the application of phosphorus @ 15 kg/ ha in combination with application of sulphur @ 15 kg/ha treatment combination[10].

The maximum number of grains per capsule (67.87) was observed in the application of phosphorus @ 60 kg/ha found significantly superior over other treatments and closely followed by 66.41 with the application of phosphorus @ 45 kg/ha. Maximum number of grains per capsule (64.34) was found under the application of Sulphur @ 45 kg/ha followed by sulphur applied @ 30 kg/ha (61.70). There was a significant increase in number of grains per capsule, recorded with higher dose of sulphur at this growth stage while, minimum number of grains per capsule (60.77) was recorded with sulphur application @ 15 kg/ha. The interaction effect between phosphorus and sulphur levels was found to be significant for variation in number of grains per capsule where the treatment combination consisting of application of phosphorus @ 60 kg/ha with combined application of sulphur @ 45 kg/ha produced significantly maximum number of grains per capsule (69.49) followed by application of phosphorus @ 60 kg/ha with combined application of sulphur @ 30 kg/ ha (67.89) as compared to all the remaining treatment combinations.

The result shows that test weight was also influenced significantly due to different levels of phosphorus and sulphur. The highest test weight (3.03 g) was observed in the application of phosphorus @ 60 kg/ha found significantly superior over other treatments and closely followed by 2.77 g with the application of phosphorus @ 45 kg/ha. Highest test weight (2.88 g) was found under the application of sulphur @ 45 kg/ha followed by sulphur applied @ 30 kg/ha (2.70 g). There was a significant increase in test weight, recorded with higher dose of sulphur at this growth stage while, lowest test weight (2.58 g) was recorded with sulphur application @ 15 kg/ha. The interaction effect between phosphorus and sulphur levels was also found to be significant for variation in test weight. The treatment combination consisting of application of phosphorus @ 60 kg/ha with combined application of sulphur @ 45 kg/ ha produced significantly highest test weight (3.48 g) followed by application of phosphorus @ 60 kg/ha with combined application of sulphur @ 30 kg/ ha as compared to all the remaining treatment combinations.

The improvement in yield because of P fertilization might have attained mainly to adequate supply of phosphorus, which helped in maintaining better source-sink interrelationship by increasing sink capacity owing to its key role in energy transformation. Further, increased phosphorus supply influences root mass development, which performs indirect function for formation of hormones and cytokinin which promote flower initiation in several plants. The significant increase in grain yield appeared to be on account of beneficial effects of phosphorus on growth and yield attributes, which finally reflect in higher grain yield of sunflower. Such increase in yield due to P fertilization could be attributing to the fact that phosphorus plays a key role in root development, energy transformation and metabolic processes in plants[10].

The influence of phosphorus and Sulphur in enhancing the “Source capacity” is well evident. It may thus be pointed out the increased “Source capacity” might have helped in developing efficient “Sink strength” which in turn has led to proper storage of increased number of available metabolites given a positive influence on yield attributing characters in sesame.

Table 3 Yield characters of sesame after application of different levels of phosphorus and zinc

	Number of capsules per plant					**Number of seeds per capsule**					**Test weight of sesame (g)**				
	P_1	**P_2**	**P_3**	**P_4**	**Mean**	**P_1**	**P_2**	**P_3**	**P_4**	**Mean**	**P_1**	**P_2**	**P_3**	**P_4**	**Mean**
S_1	30.32	36.76	41.08	41.25	37.35	51.01	60.53	65.33	66.21	60.77	2.21	2.62	2.72	2.78	2.58
S_2	32.39	37.56	41.75	42.30	38.50	51.59	61.00	66.33	67.89	61.70	2.53	2.65	2.78	2.84	2.70
S_3	35.79	38.16	41.97	43.51	39.86	55.73	64.59	67.56	69.49	64.34	2.56	2.68	2.82	3.48	2.88
Mean	32.83	37.49	41.60	42.36		52.78	62.04	66.41	67.87		2.43	2.65	2.77	3.03	
	P level		**S level**		**PxS**	**P level**		**S level**		**PxS**	**P level**		**S level**		**PxS**
SEm±	0.38		0.33		0.65	0.23		0.20		0.40	0.06		0.05		0.10
C.D.	1.11		0.96		1.92	0.68		0.59		1.18	0.16		0.14		0.28

Sulphur (S_1-S_3) and phosphorus (P_1-P_4) levels; CD at P= 0.05; DAS- days after sowing; PxS- phosphorus and sulphur interaction

Favourable effect of P and S application on growth and yield attributes further get reflected on the grain yield, biological yield and harvest index. The results of this study have indicated greater translocation of photosynthates form source to reproductive sinks under their combined application resulting in greater seed and biological yield. The similar results were reported in sunflower by Naresh *et al*. (2016).

Conclusion

It can be concluded that the phosphorus and sulphur application significantly increased the growth and yield attributing parameters. Study suggests that, the maximum production of sesame crop can be attained by the application of 60 kg phosphorus /ha in combination with 45 kg sulphur / ha in Gwalior region of Madhya Pradesh.

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