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Response of Nitrogen and Phosphorus Levels on Growth and Qualitative Characteristics of Sesame (*Sesamum indicum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The nutrient applied is not readily available to the plants due to soil salinity; a sufficient quantity is leached or fixed in the soil. Balanced application of fertilizer like nitrogen and phosphorus play vital role in enhancing the yield of sesame. Nitrogen is a structural component of chlorophyll and protein therefore adequate supply of nitrogen is beneficial for both carbohydrates and protein metabolism as it promotes cell division and cell enlargement, resulting in more leaf area and thus ensuring good seed and dry matter yield. The present investigation was conducted during *kharif* season of 2022 at Chamelti Agriculture Farm, MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan, Himachal Pradesh. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction with EC in safe range, medium in organic

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carbon, available nitrogen, potassium and high in available phosphorus. The field experiment way laid out in factorial randomized block design comprising sixteen treatments with three replication. The experiment consisted of four levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and four level of phosphorus (0, 10, 20 and 30 kg ha^{-1}). RT-127 variety of test crop was used for sowing. This study concluded that application of 60 kg N ha^{-1} along with 30 kg P_2O_5 ha^{-1} was recorded significantly higher plant height, numbers of branches $plant^{-1}$, dry matter accumulation and oil content. Economically, application of 60 kg N ha^{-1} along with 30 kg P_2O_5 ha^{-1} resulted in higher gross returns, net returns and B:C ratio.

Keywords: Sesame; nitrogen; phosphorus; capsules.

1. INTRODUCTION

Oilseeds play a vital role in agricultural and industrial economics in world. Oilseeds are the main source of fats and protein particularly for vegetarians. Sesame is one of the most ancient crop grown for its oil rich seeds. It is a crop of tropical and subtropical areas. Bulk of the sesame in the world is grown in the semi-arid region with little rainfall which is an indication that sesame is drought tolerant crop. China is the world’s higher producer of sesame followed by India and Myanmar. Sudan, Uganda and Nigeria ranked 4th, 5th and 6th in that order [1]. Sesame (*Sesamum indicum* L.), an indigenous oil-producing plant, has been cultivated for the longest period of time in India. It sometimes referred to as til. It belongs to the double-cotyledon plant family Pedaliaceae. Sesame fruit is a capsule, normally pubescent, rectangular in section. In India sesame cultivated on an area 16.22 lakh ha with the production 6.5 lakh tonnes and an average yield 405 kg ha^{-1}. In Himachal Pradesh sesame cultivated on an area 0.004 lakh ha with production of 0.002 lakh tonnes and an average yield of 500 kg ha^{-1}[2]. Sesame oil is referred to as the "Queen of oilseeds" because of its superior nutritional, therapeutic, cosmetic, pharmaceutical, properties. Sesame seeds have high oil quality, protein and antioxidant content. Because it contains the antioxidant compounds “sesamol and sesamolin,” sesame oil is particularly resistant to deterioration.

Nitrogen and phosphorus are vital nutrients essential for the growth and vitality of plants. In agricultural ecosystems, nitrogen is particularly crucial for plant nutrition and metabolic functions, as highlighted by Minz *et al.* [3] in their 2021 study. Increasing the nitrogen levels in sesame plants, as noted by Sayyad-Amin and Ehsanzadeh in [4], leads to higher seed production, mainly due to early biomass production. Nitrogen is a fundamental component of chlorophyll, the pigment responsible for photosynthesis, which is essential for converting sunlight into energy.

Phosphorus, often considered the second most important nutrient after nitrogen, plays a critical role in various plant processes. It is involved in phosphorylation, a chemical reaction that is essential for transferring energy within cells. Additionally, phosphorus is crucial for genetic material transfer, nutrient transport, and the formation of the structural basis for phospholipid cell membranes. Given its central role, phosphorus is often referred to as the "master key element" because it influences a wide range of functions that impact plant growth and metabolism.

This study focused on investigating how different levels of nitrogen and phosphorus affect the growth and quality attributes of sesame plants. This research is particularly important because there is a lack of information regarding these factors in the Mid Hills region of Himachal Pradesh. The primary objective is to identify the optimal nitrogen and phosphorus levels for sesame cultivation in this specific area.

2. MATERIALS AND METHODS

The present research work titled “Response of Nitrogen and Phosphorus Levels on Growth and Qualitative characteristics of Sesame (*Sesamum indicum* L.)” was conducted at Chamelti Agriculture Farm, M S Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan during *kharif* season of 2022. Geographically, Chamelti Agriculture Farm is situated 30 km away from Solan city at an elevation of 1,270 meters above mean sea level lying between latitude 30º 85’67.30 N and longitude 77º 13’20.38 E. The average annual rainfall of this is 791.20 mm. It falls under the mid-hill zone of Himachal Pradesh. The soil of the experimental site was sandy loam in texture, slightly alkaline in reaction with EC in safe range, medium in organic carbon, available nitrogen, potassium and high in available phosphorus. The field experiment way laid out in factorial randomized block design comprising sixteen treatments with three replication. The experiment consisted of four levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}) denoted by symbol N_1, N_2, N_3 and N_4 and four level of phosphorus (0, 10, 20 and 30 kg ha^{-1}) denoted by symbol P_1, P_2, P_3, P_4 during June to September 2022. Sesame variety RT-127 was used as a test crop. To record plant height, height of the five tagged plants in net plot was recorded from the base to the tip of the main shoot at 30, 60 DAS and at harvest stage. Five plants from each plot selected randomly for measurement of height were used to record the total number of branches at harvest To record dry matter accumulation, ten plants randomly selected from each plot and were pulled out at 30, 60, and at harvest stage. The plants were washed out and were allowed to sun dried first and finally oven dried at 65^0 C for 24 hours up to dry and constant weight and recorded accordingly. The oil content was estimated by the Soxhlet apparatus method following the procedure of [5]. Each operation's cost was calculated independently. On a hectare basis, the actual manual and mechanical power used for various operations was recorded, and the cost of each item was estimated by multiplying it by the up-to-date rates, along with the cost of all inputs. The overall cost was calculated by summing all associated expenses for each treatment on a per-hectare basis.

Data recorded on various parameters of the experiment was subjected to analysis by using Fisher's method of analysis of variance (ANOVA) and interpreted as outlined by Gomez and Gomez [6]. The levels of significance used in 'F' and 't' test was p= 0.05. Critical difference values were calculated where F test was found significant.

3. RESULTS AND DISCUSSION

3.1 Effect of Nitrogen and Phosphorus Levels on Plant Height (cm)

Data obtained on the effects of nitrogen and phosphorus on plant height of sesame are presented in Table 1. There was significant increases in plant height with incremental doses of Nitrogen and Phosphorus. Among Nitrogen levels significantly higher plant height (42.90) was observed under 60 kg N ha^{-1} (N_4) which was statistically at par with (N_3) 40 kg N ha^{-1} (40.74) and lowest plant height was observed under control (25.78) at 30 DAS. This trend was consistent and evident across the different stages of plant growth and development. The balanced fertilization of crop may be ascribed to the effect of nitrogen on root development, energy transformation and metabolic processes of the plant, which in term resulted in greater translocation of photosynthates towards the sink development. This result was in conformity with Dongarkar *et al.,* [7]. The supply of nitrogen compared to controlled plot is particularly important for its numerous roles in energy transfer and enhance the uptake of other important cations which results more plant height and development [8].

However among Phosphorus levels significantly higher plant height (40.77) record under 30 kg P_2O_5 ha^{-1} (P_4) which was statistically at par with (P_3) 20 kg P_2O_5 ha^{-1} (38.70). In contrast, the control treatment consistently displayed the lowest plant height (32.18) at 30 DAS. This trend was consistent and evident across the different stages of plant growth and development.

Jahan *et al.* [9] observed that the steady increase in phosphorus levels, or 40 kg P ha^{-1}, greatly boosted the growth-attributing characteristics of sesame, such as leaf area. It may be because phosphorus promotes root extension and root biomass, which led to a larger intake of nutrients used for photosynthesis and energy for metabolic processes required for the development of traits that contribute to crop growth.

Whereas the interaction between the Nitrogen and Phosphorus levels was found non-significant.

3.2 Effect of Nitrogen and Phosphorus Levels on Number of Branches $Plant^{-1}$

Data on the number of branches $plant^{-1}$ at harvest are shown in Table 2.

Among Nitrogen levels significantly higher branches (5.20) was recorded under 60 kg N ha^{-1} (N_4) which was statistically at par with (N_3) 40 kg N ha^{-1}(4.95) and lowest number of branches (3.24) was observed under control at harvest. It might be due to presence of nitrogen which aided in the manufacture of dietary components, causing an increase in cell division and cell growth. Furthermore, it appeared that adding nitrogen increased the fraction of protoplasm in the cell wall, which increased cell size and, as a result, improved growth metrics like numbers of branches plant^{-1}. However, among Phosphorus levels significantly higher branches (4.85) was found under 30 kg P_2O_5 ha^{-1} (P_4) which was statistically at par with (P_3) 20 kg P_2O_5 ha^{-1}(4.66). In contrast, the control treatment consistently displayed the lowest number of branches (3.99). The improvement in growth in term of 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.

Whereas the interaction between Nitrogen and Phosphorus levels was found non-significant.

3.3 Effect of Nitrogen and Phosphorus Levels on Dry Matter Accumulation (g plant^{-1})

The results demonstrate a substantial discrepancy between nitrogen and phosphorus levels and the information in Table 3.

Among the nitrogen levels significantly higher dry matter accumulation (5.97 g plant^{-1}) was recorded under application of (N_4) 60 kg N ha^{-1} which was statistically at par with (N_3) 40 kg N ha^{-1} (5.73 g plant^{-1}). However, lowest dry matter accumulation (3.30 g plant^{-1}) was observed under (N_1) control at 30 DAS and same trend was found at 60 DAS and at harvest. It can be attributed to the better availability of nutrients in root zone for development of the crop. The increase in these components seems to have been brought about by increase in amount of growth substances and naturally occurring phytohormones with increased nitrogen supply. Results of the present investigation are in conformity with those of Okpara *et al.* [10] and Ogundare *et al.* [11] in sesame.

Among the phosphorus levels significantly higher dry matter accumulation (5.92 g plant^{-1}) was found under application of (P_4) 30 kg P_2O_5 ha^{-1} which was statistically at par with (P_3) 20 kg P_2O_5 ha^{-1}(5.75 g plant^{-1}). In contrast, the (P_1) control treatment consistently displayed the lowest dry matter accumulation (3.45 g plant^{-1}) at 30 DAS and same trend was found at 60 DAS and at harvest. Rapid solubilization and mobilization of phosphorus from its inorganic sources might have fulfilled the phosphorus needs for cell elongation and cell division at critical stages of plant growth. Improved growth of sesame grown in Ethiopia with increased NP fertilizer dose was also observed by Zebene and Geleta [12].

Interaction between and nitrogen and phosphorus levels was found non-significant.

Table 1. Plant height (cm) of sesame as influenced by Nitrogen and Phosphorus levels at periodic intervals

Treatments	Plant height (cm)		
	30 DAS	**60 DAS**	**At harvest**
Nitrogen Levels (kg ha^{-1})			
N_1 : 0 kg N	25.78	51.70	72.98
N_2 : 20 kg N	38.43	74.75	114.58
N_3 : 40 kg N	40.74	80.73	122.77
N_4 : 60 kg N	42.90	85.68	130.00
SEm±	0.98	2.20	2.63
LSD (p=0.05)	2.82	6.34	7.61
Phosphorus Levels(kg ha^{-1})			
P_1 : 0 kg P_2O_5	32.18	62.14	90.96
P_2 : 10 kg P_2O_5	36.21	71.81	108.82
P_3 : 20 kg P_2O_5	38.70	77.14	117.16
P_4 : 30 kg P_2O_5	40.77	81.78	123.38
SEm±	0.98	2.20	2.63
LSD (p=0.05)	2.82	6.34	7.61
Interaction (N*P)	NS	NS	NS

Table 2. Numbers of branches plant^{-1} of sesame as influenced by Nitrogen and Phosphorus Levels

Treatments	Number of branches plant^{-1}
Nitrogen Levels (kg ha^{-1})	
N_1 : 0 kg N	3.24
N_2 : 20 kg N	4.69
N_3 : 40 kg N	4.95
N_4 : 60 kg N	5.20
SEm±	0.09
LSD (*p*=0.05)	0.27
Phosphorus levels (kg ha^{-1})	
P_1 : 0 kg P_2O_5	3.99
P_2 : 10 kg P_2O_5	4.57
P_3 : 20 kg P_2O_5	4.66
P_4 : 30 kg P_2O_5	4.85
SEm±	0.09
LSD (*p*=0.05)	0.27
Interaction (N*P)	NS

Table 3. Dry matter accumulation (g plant^{-1}) of sesame as influenced by nitrogen and phosphorus levels

Treatments	Dry matter accumulation (g plant^{-1})		
	30DAS	**60DAS**	**At harvest**
Nitrogen levels (kg ha^{-1})			
N_1 : 0 kg N	3.30	6.67	11.12
N_2 : 20 kg N	5.60	11.58	19.69
N_3 : 40 kg N	5.73	12.38	23.53
N_4 : 60 kg N	5.97	13.87	26.67
SEm±	0.24	0.53	1.29
LSD (*p*=0.05)	0.70	1.54	3.72
Phosphorus levels (kg ha^{-1})			
P_1 : 0 kg P_2O_5	3.45	6.29	10.95
P_2 : 10 kg P_2O_5	5.49	12.39	21.87
P_3 : 20 kg P_2O_5	5.75	12.47	23.21
P_4 : 30 kg P_2O_5	5.92	13.36	24.97
SEm±	0.24	0.53	1.29
LSD (*p*=0.05)	0.70	1.54	3.72
Interaction(N*P)	NS	NS	NS

3.4 Effect of Nitrogen and Phosphorus Levels on Qualitative Characteristics of Sesame

The effects of nitrogen and phosphorous levels on quality parameters (Table 4) are being presented in this section under the relevant headings.

Among the nitrogen levels the significantly higher oil content (50%) was recorded with application of (N_4) 60 kg N ha^{-1} which was statistically at par with (N_3) 40 kg N ha^{-1} (48.51%). However, lowest oil content (45.25%) was found under (N_1) control. This might be due to increased N content in seed resulted increased availability of nitrogen to plants. These results are in close conformity with the findings of Mondal *et al*. [13]; Patra [14]; Tripathy and Bastia [15] in sesame. Among the phosphorus levels significantly higher oil content (49.93%) was recorded with application of (P_4) 30 kg P_2O_5 ha^{-1} which was statistically at par with (P_3) 20 kg P_2O_5 ha^{-1} (48.35%). However, lowest oil content (45.58%) was found under (P_1) control.

The interaction between nitrogen and phosphorus levels could not affect oil content significantly. Data recorded on oil yield of sesame as influenced by nutrients levels are presented in Table 4. Oil yield of sesame was significantly affected by nitrogen and phosphorus levels. The favorable impact of phosphorus on seed yield of sesame might be due to the stimulating effect of phosphorus on different yield attributing character *viz.*, number of capsules plant^{-1} and number of seeds capsule^{-1}. These results are conformity with Choudhari and Patel [16].

The oil content was estimated by the Soxhlet apparatus method following the procedure of [5]. The oil content of sesame ranged between 30.23 and 40.69% reported by Mondal [17]. The higher level of N and P (60:30) kg ha^{-1} increased the oil content in sesame.

With respect to nitrogen levels, significantly higher oil yield (258.9 kg ha^{-1})was recorded under (N_4) 60 kg N ha^{-1} which was statistically at par with (N_3) 40 kg N ha^{-1}(239.26 kg ha^{-1}) and the lowest oil yield (143.7 kg ha^{-1}) was obtained under (N_1) control treatment.

Among the phosphorus levels significantly higher oil yield (247.0 kg ha^{-1}) was recorded under (P_4) 30 kg P_2O_5 ha^{-1} which was statistically at par with (P_3) 20 kg P_2O_5 ha^{-1}(235.24 kg ha^{-1}) and the lowest oil yield (164.9 kg ha^{-1}) was obtained under (P_1) control treatment during experimentation.

The interaction effect of nitrogen and phosphorus levels non-significantly affected oil yield of sesame.

3.5 Economics

The cost of cultivation varied according to different levels of nitrogen and phosphorus application (Table 5). The net returns and B:C ratio increase with increasing levels of nitrogen and phosphorus. The maximum net returns (₹ 28982) and B:C ratio (1.43) was recorded under 60 kg N ha^{-1}. Application of 30 kg P_2O_5 ha^{-1} also gave the maximum net returns ₹ 27003 ha^{-1} and B:C ratio (1.27) as compared to control treatment.

Table 4. Oil content and oil yield of sesame as influenced by nitrogen and phosphorus levels

Treatments	Qualitative characters	
	Oil Content (%)	**Oil Yield (kg ha^{-1})**
Nitrogen Levels(kg ha^{-1})		
N_1 : 0 kg N	45.25	157.45
N_2 : 20 kg N	47.00	219.85
N_3 : 40 kg N	48.51	239.26
N_4 : 60 kg N	50.00	258.97
SEm±	0.81	7.15
LSD (*p*=0.05)	2.35	20.64
Phosphorus Levels(kg ha^{-1})		
P_1 : 0 kg P_2O_5	41.5	164.9
P_2 : 10 kg P_2O_5	45.3	206.7
P_3 : 20 kg P_2O_5	48.4	232.3
P_4 : 30 kg P_2O_5	49.0	247.0
SEm±	0.8	7.0
LSD (*p*=0.05)	2.4	20.3
Interaction (N*P)	NS	NS

Table 5. Economics (₹ ha^{-1}) of sesame as influenced by nitrogen and phosphorus levels

Treatments	Economics (₹ ha^{-1})			B;C ratio
	Cost of cultivation	**Gross Returns**	**Net Returns**	
Nitrogen Levels (kg ha^{-1})				
N_1 : 0 kg N	19382	33130.	13748	0.71
N_2 : 20 kg N	19642	44518	24876	1.26
N_3 : 40 kg N	19902	46874	26971	1.35
N_4 : 60 kg N	20163	49145	28982	1.43
Phosphorus Levels (kg ha^{-1})				
P_1 : 0 kg P_2O_5	18366	37326	18959	1.03
P_2 : 10 kg P_2O_5	19303	42695	23391	1.21
P_3 : 20 kg P_2O_5	20241	45465	25223	1.24
P_4 : 30 kg P_2O_5	21178	48182	27003	1.27

4. CONCLUSIONS

On the basis of one year study it may be concluded that the application of 60 kg N ha^{-1} along with 30 kg P_2O_5 ha^{-1} was recorded significantly higher growth, yield and qualitative characters of sesame. Economically, application of 60 kg N ha^{-1} along with 30 kg P_2O_5 ha^{-1} resulted in higher gross returns, net returns and B:C ratio.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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