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Effect on growth and yield characteristics of summer sesame (*Sesamum indicum* L.) as influenced by different levels of nitrogen, phosphorus and biofertilizers

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Abstract
The field experiment was laid out on the plot F-23 College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during the summer season of 2016 to study Effect on growth and yield characteristics of summer sesame (*Sesamum indicum* L.) as influenced by different levels of nitrogen, phosphorus and biofertilizers in south Gujarat condition. The different levels of nitrogen *viz*., N_1: 25 kg/ha, N_2: 50 kg/ha and N_3: 75 kg/ha, different levels of phosphorus P_1: 12.5 kg/ha, P_2: 25 kg/ha and P_3: 37.5 kg/ha and biofertilizers *viz*., B_0: No inoculation and B_1: Inoculation with azotobacter and phosphate solubilizing bacteria to summer sesame in eighteen treatment combinations replicated three in factorial randomized block design. Significantly higher plant height, Number of branches per plant, dry matter production per plant, Number of capsules per plant, Seed yield and haulm yield was recorded in treatment N_3: 75 kg/ha and P_3: 37.5 kg/ha which was at par with N_2: 50 kg/ha and P_2: 25 kg/ha. However, Highest growth and yield attributes was recorded in B_1: Inoculation with azotobacter and PSB.

Keywords: Sesame, nitrogen, phosphorus, biofertilizers, phosphate solubilizing bacteria, seed yield and haulm yield

Introduction
Oilseed crops play a vital role in the Indian agriculture, industry and export trade. In India, oilseed crops occupy an area of about 26.53 million hectares with the production of 31.01 million tonnes and average productivity of 1169 kg/ha (Anonymous, 2014) [1].

Sesame (*Sesamum indicum* L.) is variously known as sesamum, til, simsim, benised, gingelly, gergelim *etc*. It is known as “The queen of the oilseed crops” by virtue of the excellent quality of the oil, flavor, taste and softness. Its oil content generally varies from 46 to 52 percent. It is eaten as raw or either roasted or parched and mixed in many kitchen items. Sesame seed is rich source of linoleic acid, vitamin E, A, B1, B2 and niacin and minerals including calcium and phosphorus. Sesame is cultivated over an area of more than 74.06 lakh ha in world with an annual production of 39.59 lakh tonnes and yield of 535 kg/ha (Anon., 2014) [1]. The area, production and productivity of this crop in Gujarat is 4.02 lakh hectares, 2.41 lakh tonnes and 598 kg/ha, respectively. (Anon., 2014) [1]. In Gujarat, Mahesana, Banaskantha, Sabarkantha, Kheda, Amreli, and Surendranagar are the major districts in which sesame is cultivated. This crop is generally cultivated as sole or mixed crop during kharif, semi-rabi and now a day in summer season in all the districts of the state. The area, production and productivity of sesame are higher in summer season than those of post *kharif* and *kharif* season, but the productivity of sesame in general is much lower than its potential yield. Lower productivity is due to use of sub-optimal rate of fertilizer, poor management and cultivation of sesame in marginal and sub-marginal lands, where deficiency of macronutrient such as nitrogen, phosphorus, potassium and micronutrient is predominant.

Balanced fertilization with N and P is proved beneficial in all the oilseed crops to minimize the unfavorable exploitation of soil fertility and plant nutrient, thus maintain the soil health and plant nutrient at optimum level. Nitrogen, phosphorus and biofertilizers like Azotobacter and phosphate solubilizing bacteria play a vital role in the nutrition of plants. In fact, these fertilizer nutrients are lacking mostly in the soils. Fertility analysis of Indian soils has indicated that the soils are deficient in microorganisms and nutrients. Therefore, application of biofertilizers and inorganic fertilizers becomes essential to raise the crop yield.

Materials and Methods

The field experiment was laid out on the plot F-23 College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during the summer season of 2016 to study Effect on growth and yield characteristics of summer sesame (*Sesamum indicum* L.) as influenced by different levels of nitrogen, phosphorus and biofertilizers in south Gujarat condition. The soil of the experimental field was clayey in texture and slightly alkaline in reaction (pH 7.6), organic carbon (0.57%) and available nitrogen (198.24 kg/ha), available phosphorus (30.87 kg/ha) and available potassium (372.81 kg/ha). The different levels of nitrogen *viz*., N_1: 25 kg/ha, N_2: 50 kg/ha and N_3: 75 kg/ha, different levels of phosphorus P_1: 12.5 kg/ha, P_2: 25 kg/ha and P_3: 37.5 kg/ha and biofertilizers *viz*., B_0: No inoculation and B_1: Inoculation with azotobacter and phosphate solubilizing bacteria to summer sesame in eighteen treatment combinations replicated three in factorial randomized block design.

The crop was fertilized as per treatments of the experiment. Amount of nitrogen and phosphorus in the form of urea and DAP was applied as per treatment for all the plots. Inoculation of biofertilizers (Azotobacter + PSB) to sesame seeds according to treatment of plot. Full dose of phosphorus and half dose of nitrogen applied at the time of sowing as per treatment combinations in the experiment. Remaining half dose of nitrogen was applied at 30 DAS as per treatment.

Result and Discussion

Effect of nitrogen on growth and yield parameters

The data presented in (Table 1) showed that effect of different levels of nitrogen significantly higher plant height at harvest (98.84 cm) was recorded in treatment N_3 (75 kg N ha-^{1}). The increase in plant height under treatment N_3 and N_2 were to the tune of 15.18 and 13.04 percent at harvest, respectively as compared to N_1. The increase in plant height with increased nitrogen levels would be attributed to favourable effect of nitrogen in increasing cell wall material resulted in increased size of cell which in turn expressed morphologically as increased plant height. (Enhance vegetative growth under the influence of nitrogen application). These results finding are in agreement with finding of Tiwari *et al*. (2001) [18], Patel (2007) [10] and Vaghani (2010) [17]. The results pertaining to number of branches per plant in Table 1 indicated that treatment N_3 (75 kg ha-^{1}) recorded significantly higher number of branches per plant at harvest (5.32). The increase in number of branches per plant under treatment N_3 and N_2 were to the tune of 18.23 and 14.68 percent at harvest, respectively as compared to treatment N_1. This might be due to favourable influence of nitrogen in produces cell division and cell elongation which promoted vegetative growth and ultimately increased number of branches per plant. These results are in agreement with those reported by Patel (2007) [10] and Vaghani (2010) [17].

An appraisal of data on dry matter production per plant in (Table 1) revealed that the different levels of nitrogen significantly higher dry matter production per plant (g) was recorded at harvest (34.08) in treatment N_3 (75 kg ha-^{1}), but it was remained statistically at par with dry matter production per plant (g) at harvest (32.11) in treatment N_2 (50 kg N ha-^{1}). The increase in dry matter production at harvest was 19.58 percent respectively in N_3 over N_1. The increase in the total dry matter production may be due to better source and sink capacity developed due to better dry matter production and its accumulation in assimilatory surface area and increase in the photosynthetic efficiency and thus increased the production of photosynthates reflected in better growth and ultimately in higher dry matter accumulation. The present result is in accordance with that of Kalaiselvan *et al*. (2001) [8] and Patel *et al*. (2014) [9].

The results pertaining to yield attributes characters (Table 2) showed that fertilizing the crop with nitrogen significantly not influenced the yield attributes like number of seeds per capsule of sesame crop. The application of N_3 (75 kg N ha^{-1}) significantly increased number of capsule per plant (33.41) to the tune of 6.33 and 29.15 percent over N_2 and N_1. Significantly higher harvest index (37.88%) was observed in treatment N_2 (50 kg N ha^{-1}). The increase in harvest index 6.1 and 0.1 percent in N_2 over N_1 and N_3. Nitrogen had increased photosynthetic activity during the reproductive phase and activity channelized the photosynthates accumulated during the source to the sink. The results were also accordance with findings of Dinakaran *et al.* (2001) [8], Chaubey *et al.* (2003) [2] and Patel *et al.* (2014) [9].

Application of nitrogen brought about significant variation in seed yield of sesame (Table 2). The application of N_3 (75 kg N ha^{-1}) produced significantly higher seed yield (999.10 kg ha^{-1}) of sesame to the tune of 0.13 and 23.19 percent increase over N_2 and N_1, respectively. This might be due to the improvement in growth characters that favorably modified the yield attributes. Amount of nitrogen plays an important role in plant metabolism by virtue of being an essential constituent of diverse types of metabolically active compounds like amino acids, proteins, nucleic acid, enzymes, co-enzymes and alkaloids which are important for higher growth and yield. This increase in growth and yield attributes ultimately helped in realization of higher seed yield. The results obtained in this study are in agreement with those reported by Chaubey *et al.* (2003) [2], EL-Mahdi (2008) [4] and Patel *et al.* (2014) [9].

Similarly, haulm yield was also significantly influenced due to application of different levels of nitrogen. The results in respect of haulm yield in (Table 2) indicated that application of N_3 (75 kg N ha^{-1}) significantly increased the haulm yield (1639.49 kg ha^{-1}) to the tune of 0.35 and 13.22 percent over N_2 and N_1, respectively. This might be profound increase in plant height and number of branches per plant with increasing nitrogen levels in Table 1 resulted in higher haulm yield. Appreciable higher N and P uptake by haulm with higher levels of nitrogen might have favourable modified the plant growth and ultimately resulted into higher haulm yield. The results obtained in this study are in agreement with those reported by Dinakaran *et al.* (2001) [8], Sarala and Jagannatham (2002) [14], Chaubey *et al.* (2003) [2] and Patel *et al.* (2014) [9].

The application of N_2 (50 kg N ha^{-1}) recorded significantly the highest harvest index (37.88%), which was at par with N_3. While lower harvest index (35.71%) was registered with application of N_1 (25 kg N ha^{-1}).

Effect of Phosphorus on growth and yield parameters

Significantly increase plant height at harvest (98.54 cm) was observed with the application of P_3 (37.5 kg P_2O_5 ha^{-1}). The increase in plant height under treatment P_3 and P_2 were to the tune of 10. 76 and 10.00 percent at harvest, respectively as compared to treatment P_1. These results in agreement with these reported by Patra (2001) [11] and Jadhav *et al.* (2015) [7].

Similarly, number of branches per plant at harvest was significantly influenced due to different levels of phosphorus (Table 1). The significantly higher number of branches per plant at harvest (5.22) was observed with the application of P_3 (37.5 kg P_2O_5 ha^{-1}), The increase in number of branches per plant under treatment P_3 and P_2 were to the tune of 9.35 and 8.98 percent and at harvest as compared to treatment P_1. Application of higher dose of phosphorus (37.5 kg P_2O_5 ha^{-1}) created a situation favourable for higher uptake of N, P and K by plant and resulted higher plant growth *viz*., plant height and number of branches per plant. These results are concerent with those reported by Patra (2001) [11], Thanki *et al.* (2004) [16] and Jadhav *et al.* (2015) [7].

The results pertaining to dry matter production in Table 1 revealed that the different levels of phosphorus were found dry matter production per plant (g) at harvest (33.24) was significantly increased up to P_3 (37.5 kg P_2O_5 ha^{-1}). The increase in dry matter production per plant under treatment P_3 and P_2 were to the tune of 10.31 and 10.10 percent at harvest, respectively as compared to treatment P_1. The increase in the total dry matter production may be due to better source and sink capacity developed due to better dry matter production and its accumulation in assimilatory surface area and increase in the photosynthetic efficiency and thus increased the production of photosynthates reflected in better growth and ultimately in higher dry matter accumulation. Similar findings were also reported by Jadhav *et al.* (2015) [7].

The results pertaining to yield attributes (Table 2) showed that fertilizing the sesame crop with phosphorus significantly increased yield attributes of sesame crop. The application of P_3 (37.5 kg P_2O_5 ha^{-1}) remarkably increased number of capsule per plant (32.56) to the tune of 6.50 and 18.09 percent over P_2 and P_1. The application of 25 kg P_2O_5 ha^{-1} remarkably increased harvest index (38.15). The increase in harvest index 4.7 and 3.5 percent in N_2 over N_1 and N_3. This might be attributed to the role played by phosphorus nutrition in metabolism of plant. Phosphorus is a structural element of certain co-enzymes like ATP, ADP and AMP which are involved in energy transfer and thus, improve photosynthesis process.

Application of phosphorus brought significant variation in seed and haulm yields of sesame (Table 2). The significant response in seed and haulm yield (967.75 and 1653.53 kg ha^{-1}) of sesame was obtained with application of P_3 (37.5 kg P_2O_5 ha^{-1}) to the tune of 0.27 and 11.19 percent of seed yield and 6.19 and 9.45 percent of haulm yield over P_2 and P_1, respectively. The increase in seed and haulm yield of sesame with higher level of phosphorus evidently resulted higher number of capsules per plant in Table 4.6. Higher seed yield under the treatment P_3 (37.5 kg P_2O_5 ha^{-1}) was also probably a consequence of greater amount of nutrients uptake. Among the phosphorus is a fascinating plant nutrient and involved in a wide range of plant processes from cell division to the development of good root system and ensuring timely and uniform ripening of the crop. It is needed mostly by young, fast growing tissues and performs a number of functions related to growth, development, photosynthesis and utilization of carbohydrates. It is constituent of ADP to ATP, two of the most important substances in life processes. These all processes favourable improved with higher rate of phosphorus and resulted into higher seed and haulm yield of sesamum. These results are in agreement with these reported by Thanki *et al.* (2004) and Thakur *et al.* (2015).

It was apparent from the data presented in (Table 2) that harvest index was significantly influenced due to different levels of phosphorus. Significantly the highest harvest index (38.15%) was recorded in treatment P_2 (25 kg P_2O_5 ha^{-1}). While the lowest harvest index (36.43%) was recorded in treatment P_1 (12.5 kg P_2O_5 ha^{-1}).

Effect of Biofertilizers on growth and yield parameters

Significant the highest plant height at harvest (96.20 cm) was observed under biofertilizers (*Azotobacter* + *PSB*) inoculation to sesame seeds. While the lowest plant height at harvest (91.35 cm) was recorded with no inoculation of seed with biofertilizers.

The results pertaining to number of branches per plant (Table 1) indicated that the biofertilizers (*Azotobacter* + *PSB*) inoculation to sesame seeds was found significant effect on number of branches per plant at harvest (5.14). While the lowest number of branches per plant at harvest (4.89) was recorded with no inoculation of biofertilizers. This might be due to favourable effect of biofertilizers like *Azotobacter* which is most important non-symbiotic N-fixing microorganisms. The beneficial effect of *Azotobacter* is N-fixing capacity and also ability to produce growth promoting substances.

The results pertaining to dry matter production (Table 1) revealed that the biofertilizers (*Azotobacter* + *PSB*) inoculation to sesame seeds significantly the highest dry matter production per plant (g) at harvest (32.41 g) was recorded with biofertilizers inoculation to sesame seeds. While the lowest dry matter production per plant (g) at harvest (30.71 g) was recorded with no inoculation of biofertilizers. The increase in the total dry matter production may be due to better source and sink capacity developed due to better dry matter production and its accumulation in assimilatory surface area and increase in the photosynthetic efficiency and thus increased the production of photosynthates reflected in better growth and ultimately in higher dry matter accumulation. Similar results were obtained by Ghosh (2000) [5], Paul and Savithri (2003) [12] and Sabannavar and Lakshman (2008) [13].

The results pertaining to yield attributes characters (Table 2) showed that the biofertilizers (*Azotobacter* + *PSB*) inoculation to sesame seeds was significantly influenced on yield attributes like number of capsule per plant. Significantly higher number of capsule per plant (31.11) was recorded with biofertilizers inoculation to sesame seeds. The lowest number of capsules per plant (29.35) was recorded with no inoculation of sesame seeds with biofertilizers. The effect on number of seeds per capsule, length of capsule and test weight and harvest index was found non-significant due to different levels of biofertilizers. These results are corroborated with those of Ghosh and Mohiuddin (2000) [5] and Sabannavar and Lakshman (2008) [13].

The biofertilizers (*Azotobacter* + *PSB*) inoculation to sesame seeds was brought significant variation in seed and haulm yields of sesamum (Table 2). Significantly the highest seed (967.14 kg ha^{-1}) and haulm (1620.52 kg ha^{-1}) yields of sesame were recorded with biofertilizers (*Azotobacter* + *PSB*) inoculation to sesame seeds. While the lowest seed (901.69 kg ha^{-1}) and haulm (1527.01 kg ha^{-1}) yields were recorded with no inoculation of biofertilizers. Similar results were found by Ghosh and Mohiuddin (2000) [5]. Different levels of biofertilizers were did not produced significant effect on harvest index (%) of sesame.

Table 1: Plant height, Number of branches per plant and dry matter production per plant influenced by different levels of nitrogen, phosphorus and biofertilizers

Treatments	Plant height (cm)	Number of branches per plant	Dry matter production per plant (g)
	At harvest	At harvest	At harvest
Nitrogen levels			
N_1: 25 kg N ha^{-1}	87.44	4.56	28.50
N_2: 50 kg N ha^{-1}	95.05	5.16	32.11
N_3: 75 kg N ha^{-1}	98.84	5.32	34.08
S.Em.±	1.99	0.10	0.69
C.D. at 5%	5.93	0.30	2.06
Phosphorus levels			
P_1: 12.5 kg P_2O_5 ha^{-1}	89.58	4.79	30.19
P_2: 25 kg P_2O_5 ha^{-1}	93.21	5.03	31.26
P_3: 37.5 kg P_2O_5 ha^{-1}	98.54	5.22	33.24
S.Em.±	1.99	0.10	0.69
C.D. at 5%	5.93	0.30	2.06
Biofertilizers inoculation			
B_0: No inoculation	91.35	4.89	30.71
B_1: Seed inoculation with *Azotobacter* and *PSB*	96.20	5.14	32.41
S.Em.±	1.63	0.08	0.57
C.D. at 5%	4.84	0.25	1.68
Interaction			
N x P, N x B, P x B, N x P x B	NS	NS	NS
C.V.%	9.02	8.23	9.32

Table 2: Number of capsule per plant, seed yield (kg/ha), haulm yield (kg/ha) and harvest index (%) influenced by different levels of nitrogen, phosphorus and biofertilizers

Treatments	Number of capsule per plant	Seed yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)
	At harvest	At harvest	At harvest	
Nitrogen levels				
N_1: 25 kg N ha^{-1}	25.87	806.38	1448.04	35.71
N_2: 50 kg N ha^{-1}	31.42	997.77	1633.77	37.88
N_3: 75 kg N ha^{-1}	33.41	999.10	1639.49	37.85
S.Em.±	0.72	26.62	37.82	0.12
C.D. at 5%	2.15	79.09	112.38	0.35
Phosphorus levels				
P_1: 12.5 kg P_2O_5 ha^{-1}	27.57	870.35	1510.77	36.43
P_2: 25 kg P_2O_5 ha^{-1}	30.57	965.15	1557.00	38.15
P_3: 37.5 kg P_2O_5 ha^{-1}	32.56	967.75	1653.53	36.86
S.Em.±	0.72	26.62	37.82	0.12
C.D. at 5%	2.15	79.09	112.38	0.35
Biofertilizers inoculation				
B_0: No inoculation	29.35	901.69	1527.01	37.01
B_1: Seed inoculation with Azotobacter and PSB	31.11	967.14	1620.52	37.28
S.Em.±	0.59	21.74	30.88	0.10
C.D. at 5%	1.75	64.58	91.76	NS
Interaction				
N x P, N x B, P x B, N x P x B	NS	NS	NS	NS
C.V.%	10.15	12.09	10.20	1.35

Conclusion

Based on field experimentation, it was concluded that the maximum seed yield and haulm yield of summer sesame can be obtained by fertilizing the crop with N_3 (75 kg N ha^{-1}), P_3 (37.5 kg P_2O_5 ha^{-1}) and inoculation of seeds with biofertilizers (*Azotobacter* + *PSB*) in south Gujarat heavy rainfall Agro-ecological situation III (AES-III).

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