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Impact of nitrogen and spacing on the growth and yield of okra [Abelmoschus esculentus (L.) Moench]

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Abstract. The present investigations entitled "Impact of nitrogen and spacing on the growth and yield of okra" was carried out during spring summer season 2015. The applications of nitrogen at 100 kg/ha recorded higher yield attributes of the number of nods per plant, leaves per plant, internodes length, plant height, pod length, number of pods per plant, fruit yield per plant and total green pod yield per hectare. Nitrogen application upto125 kg/ha significantly decrease the days to 50% flowering. The pod weight, pod length, number of nodes per plant, number of pods per plant, fruit yield per plant and total green pod yield per hectare increased higher with the optimum plant to plant spacing of 15 cm. The data revealed the interaction between nitrogen level and plant density was present in case of plant growth and yield contributing characters of okra. Although the highest level interaction of 100 kg N/ha with plant to plat spacing 15 cm produced the high number of nods per plant, pod weight, pod length, number of pods per plant, pod yield per plant and total green pod yield per hectare and the days to 50% flowering decreased was recorded with 125 kg N/ha and plant to plant spacing 20 cm. The highest gross return (Rs.94080) and net return (Rs.84621.3) were obtained from N125S20.

1 Introduction

Okra, Ablemoschus esculentus (L) Moench commonly known as lady's finger. Bamy, Bamia (Arabic) (Aldigawi, 1996), Bhindi (India), Ilash (Nigeria) Shigidi, A.I, 1994), belongs to the family Malvaceae.

Okra originated in Asia and Africa (Thomson and Kelly, 1979). It is widely distributed and cultivated in the tropics, sub-tropics and warmer portions of the temperate region of the world on a varying scale (Kochhar, 1986). India is one of the leading producers of okra with a production of 5.784 million tonnes year-1 from an area of 498 million ha. Although the productivity of Okra (NHB, 2014) in India is higher (11.6 tonnes ha-1) than world average productivity (7.35 tonnes ha-1) but lower than that of Egypt (15.70 tonnes ha-1). This is because of low yield due to frequent attacks of pests and diseases, especially the fruit and shoot borer and yellow vein mosaic virus (YVMV) according to Journal of Agricultural Technology (2012). Okra is an important summer vegetable crop grown an area of 3204 thousand hectors, yielding 33351 million tonnes in Punjab (NHB 2014).

There are four known domesticated species of Abelmoschus. Among these, A. esculentus (Common Okra) is most widely cultivated in South and East Asia. The Principle elements present in pods of okra are k, Na, Mg and Ca. Presence of Fe, Zn, Mn and Ni also has been reported (Moyin-Jesu,2007). Fresh pods are low in calories (20 per 100g), including about 30% of the recommended levels of vitamin C (16 to 29 mg), 10 to 20 % of foliate (46 to 88 mg) and about 5% of Vitamin A (14 to 20 RAE)(NAP, 2006). Both pod skin and seeds are excellent source of Zinc (80ug/g)(Glew,1997; Cook et al., 2000). Pods and seeds are rich in Phenolic compounds with important biological properties (Arapirtsas, 2008). Fresh Okra pods are the most important vegetable source of viscous fiber, an important dietary component to lower cholesterol (Kendall and Senkins, 2004). Seed protein is rich in tryptophan (94mg/g N) and also contains adequate amounts of sulfur-containing amino acid (189 mg 1g N) a rare combination that makes okra seeds exceptionally useful in reducing human malnutrition (NAP, 2006). Okra seed flour has been used to supplement corn flour for a very long time in countries like Egypt to make better quality dough (Take el-Kitanb, 1947).

The source of N for crop production may affect the performance of the crop. There is therefore the need to synchronize crop N supply with crop demand (Pang and Letey, 2000). Depletion and or shortage of N indicate that either the crop will not able to maintain its leaf area expansion rate or cannot maintain its leaf and plant N concentration. Either of this will have effects on Crop growth and production of economic products.

The requirement of nitrogen which varies according to environmental conditions has to be determined by actual field trial for any particular soil and climate. Okra crop response to nitrogen is required dose of nitrogen for the highest fruit yield appeared in various books and journals ranges from 120 to 200 kg/ha (Amjad et al.2001;

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Rahman et al, 1992; Paliwal et al, 1999; Verma and Batra 1999; Rashid, 1999).

Generally, increase in planting density results in increased yield per unit area till a certain limit (Weiner, 1990). Suitable plant spacing can lead to optimum seed yield whereas too high or too low plant spacing could result in relatively low yield and quality (Absar and Siddique, 1982). The plant spacing for okra production suggested by different authors ranges from 20 to 40 cm between plants and 30 to 60 cm between rows (Hossain et al, 1999; Rastagie et al, 1987; Thakur and Arora, 1986; Khan and Jaisal, 1988). Keeping this in view, the present work was, thus, under taken with the following objectives.

- To study the effect of Nitrogen fertilizer on yield and yield attributing characters of Okra
- To study effect of plant density on plant growth and green fruit yield
- To study benefit cost ratio analysis of okra as influenced by nitrogen and spacing

2 Materials and Method

The experiment was conducted at the research farm of Guru Kashi University Talwandi Sabo (Bathinda) during spring summer season 2015.

Table 1. Chemical analyses of the experimental field at sowing time.

Soil properties	Soil Depth	Rating	Method used for estimation
pH	8.02	High	1:2, soil: water suspension with Beckman glass electrode pH meter (Jackson 1973)
EC (d sm^{-1})	0.589	High	1:2, Soil: water suspension with sol bridge conductivity meter (Jackson 1973)
Available N (kg ha^{-1})	225	Medium	Alkaline potassium permanganate method (Subbiah and Asija 1956)
Available P (Kg ha^{-1})	13	Medium	0.5 N Sodium bicarbonate extracyalde P (Olsen *et al* 1954)
Available K (Kg ha^{-1})	138	Medium	NH4OAC method
Textural Class	Sandy Loam		International pipette method (piper 1966)

The chemical analyses of the soil along with the method used for their determination before sowing are presented in the Table. Two factors experiment was laid out in Split Plot Design (SPD) with three replications. The treatments of the experiment were three nitrogen doses viz. 75, 100 and 125 kg/ha and three plant to plant spacing viz. 10 cm, 15 cm and 20 cm. The unit plot size was 3.6m × 3m. Seeds of okra were sown on 10 March 2015. Intercultural operations were done as and when necessary. Data of plant growth and yield contributing characters were recorded from ten randomly selected plants, but yield was recorded on plot basis. Experimental data were subjected to statistical analysis appropriate to the design using procedure developed by Finney and tests of significance were applied.

3 Results and discussion

3.1 Plant Height :(cm)

The data in revealed that the effect of nitrogen, the treatment N100 produced significantly maximum plant height (92.1 cm) as compared to treatment N75 (84.1 cm) and it was found at par with nitrogen level N125 (92.4cm). In case of different plant spacing on height of plant was found to be non significant. The S10 spacing results in maximum average height of plant (91.3 cm). However, the minimum height (87.5 cm) was recorded under the S20 spacing. The interaction effects due to spacing and nitrogen levels on plant height was found to be significant, the maximum height of plant (94.3 cm) was recorded with the combination of N100 and S10. The minimum height of plant (82.3 cm) was recorded with the treatment combination N75 with spacing S20.The interaction of N100 with S15,S20 and N125 with S10,S15,S20 being at par with N100S10 resulted into significantly better plant height than lower treatment. The favorable effect of spacing and nitrogen in promoting the growth of plant in terms of height of plant might be due to the fact that, closer plant spacing have higher plant density which creates competition among the population for light and resulted into increased in plant height. Amongst the nutrients, nitrogen has the property to enhance the vegetative growth and capacity of plants to utilize the greater amount of nitrogen with increasing dose. This might be due to the higher utilization of nitrogen but in the closer spacing there is no scope for horizontal spread so it might have resulted in the increase in plant height. . [7].

Table 2. Effect of various levels of Nitrogen fertilizer and spacing on the plant height (cm) of okra.

Treatment	Spacing (cm)			Mean
N Kg/ha	S_{10}	S_{15}	S_{20}	
N_{75}	86.0	84.0	82.3	84.1
N_{100}	94.3	92.3	89.6	92.1
N_{125}	93.6	93.0	90.6	92.4
Mean	91.3	89.7	87.5	

3.2 Days to 50% flowering:

Mean days to flowering decreased gradually with the increasing levels of applied nitrogen from 75 Kg/ha to 125 Kg/ha. It decreased from 52.7 days to 48.1 days with the increasing level of nitrogen. Similar results were computed in case of spacing that was from spacing S10 to

S20. The data indicated that the interaction effect of nitrogen and spacing was also significant .The lowest days to 50% flowering (45.3days) were recorded with N125 and S20. The treatment consisting of N125 and S15 was at par with N125 and S20. The interaction effects of N100 with S20 and N75 with S20 were at par with each other. [7, 33].

Table 3. Effect of various levels of Nitrogen fertilizer and spacing on the Days to 50% flowering of okra.

Treatment	**Spacing (cm)**			
N Kg/ha	S_{10}	S_{15}	S_{20}	**Mean**
N_{75}	55.1	53.9	49.3	52.7
N_{100}	53.0	52.1	49.3	51.5
N_{125}	50.0	48.9	45.3	48.1
Mean	52.7	51.6	48.0	

3.3 Single pod weight :(g)

The Nitrogen doses brought about significant increase in fresh weight of fruits when compared with their respective lower levels. The maximum and minimum average fruit weight was noted under N_{100} (9.4 g) and N_{75} (6.7g), respectively and at par (9.8g) with application of N_{125}. The plant geometry also caused significant effect on the fresh weight of okra fruits. Higher the plant density, lower the fresh weight of okra pods were recorded. As the plant density was lowered the average weight of pods were significantly increased.

Table 4. Effect of various levels of Nitrogen fertilizer and spacing on the Single pod weight (g) of okra.

Treatment	**Spacing(cm)**			
N Kg/ha	S_{10}	S_{15}	S_{20}	**Mean**
N_{75}	6.2	7.0	7.1	6.7
N_{100}	8.2	10.2	9.8	9.4
N_{125}	9.7	9.5	10.1	9.8
Mean	8.0	8.9	9.0	

Low plant density, spacing S_{15} revealed the significant increase (8.9 g) in fresh weight of okra fruits. The minimum fresh weight (8.0 g) was noted under low spacing S10. The data indicated that the interaction effect of nitrogen and spacing was significantly higher from the lower treatment. The highest pod weight of 10.2g was obtained with N_{100} and S_{15}. The interaction effects of N_{125} with S_{10}, S_{15}, S_{20} and N_{100} with S_{20} were at par with $N_{100}S_{15}$ for single pod weight. [38, 24].

3.4 Leaves per plant:

The treatment N_{100} recorded maximum leaves per plant (22.2) and it was at par with treatment N_{125} having 23.4 leaves per plant. However, minimum leaves per plant (19.3) were recorded in the treatment N_{75}. An increase in nitrogen supply induced more leaves per plant. The average leaves per plant (22.8) were found to be maximum in the spacing S_{20}. However, average minimum leaves per plant (20.6) were recorded in the spacing S_{10}. Wider spacing provided more space for growth, which increased the number of branches per plant, and ultimately increases the number of leaves per plant. The interaction effects due to spacing and nitrogen levels on leaves per plant were found to be significant. Combination of N_{125} nitrogen with spacing S_{20} proved to be the overall best treatment which increased leaves per plant (24.6) from other combination of treatments. The interaction of N_{125} with S_{15}, S_{10} being at par with $N_{125}S_{20}$ treatment. The interaction of N_{100} with S_{20}, S_{10} being at par with each other. . [12, 25].

Table 5. Effect of various levels of nitrogen fertilizer and spacing on the leaves per plant (No) of okra.

Treatment	**Spacing(cm)**			
N Kg/ha	S_{10}	S_{15}	S_{20}	**Mean**
N_{75}	17.0	20.3	20.6	19.3
N_{100}	22.3	21.0	23.3	22.2
N_{125}	22.6	23.0	24.6	23.4
Mean	20.6	21.4	22.8	

3.5 Number of green fruits per plant::

Average numbers of fruits per plant were significantly influenced by nitrogen application. Significantly higher numbers of fruits per plant (31.2) were obtained with application of 100 kg N per hectare and highest number of fruits per plant (36.7) with application of 125 kg N per hectare. The plant under application of 75 kg N per hectare showed significantly minimum (22.3) number of fruits per plant. The plant population affected the production of fruits per plant significantly. Wider spacing expressed significantly greater number of fruits per plant The maximum and minimum number of fruits as influenced by plant density were recorded under S_{20}(31.5) and S_{10}(28.8) spacing, respectively. The significantly increased number of fruits per plant (30.1) was noticed under spacing S_{15}. The data indicated that nitrogen and spacing interaction was significant. The highest number of pods per plant (40.2) was obtained with combination of N_{125} and S_{20} which was significantly the best than all other nitrogen and spacing combinations. The interaction effects of N_{125} with S_{10}, S_{15} and N_{100} with S_{10}, S_{15}, S_{20} was at par with each other and superior than the lower treatment. . [7, 34].

Table 6. Effect of various levels of nitrogen fertilizer and spacing on number of green pods per plant (No) of okra.

Treatment	**Spacing (cm)**			
N Kg/ha	S_{10}	S_{15}	S_{20}	**Mean**
N_{75}	21.6	22.0	23.3	22.3
N_{100}	30.6	32.3	30.6	31.2
N_{125}	34.3	36.0	40.3	36.7
Mean	28.8	30.1	31.4	

3.6 Number of nodes per plant:

Number of nodes on main stem were significantly increased, as nitrogen applications increased from 75 kg/ha to 100 kg/ha and at par with higher dose of nitrogen i.e. 125 kg/ha. The maximum and minimum numbers of nodes were 36.3 and 29.5 respectively. Significantly increased number of nodes per plant was (35.8) when the nitrogen level was N_{100}.The minimum and maximum numbers of nodes per plant were recorded under spacing of S_{10} (32.8) and S_{20} (34.6), respectively. Significantly increased number of nodes per plant was (34.2) when the spacing was S_{15}. The higher number of nodes per plant (37.1) was recorded with combination of N_{125} and S_{20}. The interaction of N_{125} with S_{10}, S_{15} and N_{100} with S_{15}, S_{20} were at par with $N_{125}S_{20}$. [11, 12].

Table 7. Effect of various levels of nitrogen fertilizer and spacing on number of nodes per plant (No) of okra.

Treatment	Spacing (cm)			
N Kg/ha	S_{10}	S_{15}	S_{20}	Mean
N_{75}	28.6	30.0	30.0	29.5
N_{100}	34.6	36.0	37.0	35.8
N_{125}	35.3	36.6	37.1	36.3
Mean	32.8	34.2	34.6	

3.7 Green fruit yield per plant:

Green fruit yield per plant was increased with the increased dose of nitrogen from 75 kg/ha to 125 kg/ha. Significantly higher fruit yield per plant was recorded under N_{100} which was 302g .The minimum fruit yield per plant was 164g at application of 75 Kg N/ha. Wider spacing expressed significantly greater green fruit yield per plant. The maximum and minimum green fruit yield per plant as influenced by plant density were recorded under S_{20} (283g) and S_{10} (251g) spacing, respectively. Significant increase in green fruit yield per plant (272g) was noted at the spacing of S_{10}. The higher number of fruit yield per plant (355g) was recorded with combination of $N_{125}S_{20}$. The interaction of N_{125} with S_{10}, and S_{15} were at par with combination of N_{125} and S_{20}. The interaction of N_{100} with S_{10}, S_{15}, S_{20} were at par with each other. [30].

Table 8. Effect of various levels of nitrogen fertilizer and spacing on green fruit yield per plant (g) of okra.

Treatment	Spacing (cm)			
N Kg/ha	S_{10}	S_{15}	S_{20}	Mean
N_{75}	146.6	165.0	182.6	164.7
N_{100}	288.6	306.6	313.0	302.7
N_{125}	340.0	344.6	355.0	346.5
Mean	251.7	272.0	283.5	

3.8 Pod length :(cm)

The increase in nitrogen levels up to N_{100} brought about significant improvement in pod length of okra. The maximum and minimum fruit length was recorded under N_{100} (9.4 cm) and N_{75} (6.8 cm), respectively, which was at par with treatment N_{125} (9.9 cm). The closer spacing expressed significantly shorter fruits when compared with wider spacing. Maximum and minimum pod lengths were procured under spacing S_{20} (9.0cm) and spacing S_{10} (8.3 cm), respectively. The maximum pod length of 10.3 cm was produced by the combined effect of N_{125} and S_{20} which was significantly higher than all other combinations. The interaction effect of N_{125} with S_{15}, S_{10} and N_{100} with S_{15}, S_{20} being at par with N_{125} and S_{20} significantly produced longer pod than lower treatment. [4].

Table 9. Effect of various levels of nitrogen fertilizer and spacing on pod length (cm) of okra.

Treatment	Spacing (cm)			
N Kg/ha	S_{10}	S_{15}	S_{20}	Mean
N_{75}	6.5	6.9	7.0	6.8
N_{100}	8.5	10.2	9.6	9.4
N_{125}	10.0	9.5	10.3	9.9
Mean	8.3	8.9	9.0	

3.9 Pod diameter :(cm)

The diameter of pod were recorded by using venire caliper and the means were worked out and expressed in cm. Application of higher levels of nitrogen that was N_{100} (1.50 cm) and N_{125} (1.86 cm) proved more effective in respect of diameter when compared with N_{75} (1.05 cm). The maximum diameter of pod was produced with N_{100} dose. [1, 29].

Table 10. Effect of various levels of nitrogen fertilizer and spacing on pod diameter (cm) of okra .

Treatment	Spacing (cm)			
N Kg/ha	S_{10}	S_{15}	S_{20}	Mean
N_{75}	0.96	1.06	1.13	1.05
N_{100}	1.43	1.46	1.60	1.50
N_{125}	1.76	1.88	1.95	1.86
Mean	1.38	1.47	1.56	

3.10 Internode length :(cm)

The mean internode length increased gradually with the increasing level of applied nitrogen. It increased from 2.16 cm in plot applied with nitrogen dose of N_{75} to 2.82 cm and 3.04 cm with nitrogen application of N_{100} and N_{125} respectively. Significant increase was noticed with increased dose of nitrogen N_{100}. The internode length was significantly influenced by within row spacing of plants. But spacing has opposite effect on internode length. Internode length decreases from 3.0 cm to 2.5 cm and to

2.4 cm when spacing is increased from S_{10} to S_{15} and to S_{20} respectively.

Table 11. Effect of various levels of nitrogen fertilizer and spacing on internode length (cm) of okra.

Treatment	**Spacing (cm)**			
N Kg/ha	**S_{10}**	**S_{15}**	**S_{20}**	**Mean**
N_{75}	2.4	2.0	2.0	2.1
N_{100}	3.2	2.7	2.4	2.8
N_{125}	3.3	2.9	2.8	3.0
Mean	3.0	2.5	2.4	

The maximum internode length of 3.30 cm was produced by the combined effect of N125 and S10 cm which was significantly higher than all other combinations. The interaction effect of N125 with S15 and N100 with S10, being at par with N125 and S10 significantly produced longer internode. The interaction effects of N100 with S15 and N125 with S20 being at par with each other. The increase in internode length at higher level of nutrients in the present study might be due to higher absorption of nutrients, especially nitrogen which enhanced the cell division, cell elongation with concomitant increase in metabolic activity by which meristmatic activity of tissue increased manifold and led to increase in internode length. [28].

3.11 Total green pod yield :(q/ha)

The yield of green pods was noted significantly greater (72.4 q) under N_{100} and at par with N_{125} (76.0 q) against the minimum (53 q) recorded under lower level N_{75}. Regarding the plant density, S_{20} spacing produced the highest yield (68.7 q) against the minimum (64.4 q) recorded under S_{10} spacing. Significantly increase in yield (68.2 q) was noted under S_{15} spacing. The maximum total green pod yield (77.6 q/ha) was produced by the combined effect of N_{125} and S_{15} spacing which was significantly higher than all other combinations. The interaction effect of $N1_{25}$ with S_{10}, S_{20} and N_{100} with S20 being at par with $N_{125}S_{15}$ combination significantly. The significant increase in total yields might also be attributed to the increased branching as pod developed in the axils of every branch once flowering has began. Number of nodes per plant also increased with fertilizer application along with optimum spacing of 15 cm with-in row plant spacing. Since every node has a potential to produce flower which directly influence the yield per plot. [5, 17, 24].

Table 12. Effect of various levels of nitrogen fertilizer and spacing on total green pod yield (q/ha) of okra.

Treatment	**Spacing (cm)**			
N Kg/ha	**S10**	**S15**	**S20**	**Mean**
N75	49.6	54.0	55.3	53.0
N100	69.3	73.0	75.0	72.4
N125	74.3	77.6	76.0	76.0
Mean	64.4	68.2	68.7	

3.12 Benefit cost ratio analysis of okra

Analysis of cost and return revealed that the gross and net returns were higher at higher doses of N and spacing. The highest gross return (Rs.94080) and net return (Rs.84621.3) were obtained from N125S20. The BCR was also higher (9.54) under the same treatment combination. [39].

Table 13. Effect of nitrogen and spacing on benefit

cost ratio analysis of okra yield..

S. N	Treatment	Yield (t/ha)	Cost of cultivation (t/ha)	Gross income (t/ha)	Net returns (t/ha)	Benefit cost ratio
1	$N_{75}S_{10}$	51.9	17715.2	62280	44564.8	3.51
2	$N_{75}S_{15}$	54.0	12065.2	64800	52734.8	5.37
3	$N_{75}S_{20}$	55.3	8915.2	66360	57444.8	7.44
4	$N_{100}S_{10}$	69.3	17986.9	83160	65173.1	4.62
5	$N_{100}S_{15}$	73.0	12336.9	87600	75263.1	7.10
6	$N_{100}S_{20}$	75.0	9186.9	90000	80813.1	9.79
7	$N_{125}S_{10}$	74.3	18258.7	89160	70901.3	4.88
8	$N_{125}S_{15}$	77.6	12608.7	93120	80511.3	7.38
9	$N_{125}S_{20}$	78.4	9458.7	94080	84621.3	9.94
	C.D (p=0.05)	3.92				

a. Price of okra: Rs. 12.00

b. $BCR: \frac{\text{Gross return}}{\text{Cost of production}}$

4 Conclusion

On the basis of both individual and combined effects of nitrogen and spacing, 100 kg N/ha and 15 cm plant to plant spacing may be considered optimum for obtaining high yield with good quality. So, this proposal is useful for improving the productivity profitability of okra growers in Punjab.

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