International Journal of Multidisciplinary Informative Research and Review
2020; 1(2): 88-103
Published online October 31, 2020 (https://agribusinessedu.com/ijmirr-journal/)
DOI: 10.5281/zenodo.4309788
ISSN: 2709-6289 (Online)

Application of Various Doses of Nitrogen on the Performance of Okra in Rooftop Garden

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To cite this article:
Md. Hafezur Rahman, Md. Mahbubul Alam, Md. Sazzad Hossain. Application of Various Doses of Nitrogen on the Performance of Okra in Rooftop Garden. *International Journal of Multidisciplinary Informative Research and Review*. Vol. 1, No. 2, 2020, pp. 88 -103.

Abstract: *The present study was carried out at the rooftop garden of Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to September 2019 to investigate the performance of okra with different doses of N in rooftop garden. Four levels of nitrogen (N) viz. N0 = Control (0 kg N ha-1), N1 = 120 kg N ha-1, N2 = 150 kg N ha-1 and N3 = 180 kg N ha-1. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. Data on different growth, yield contributing parameters and yield were recorded and analyzed statistically. The recorded data on different growth yield and yield contributing parameters were significantly influenced by different nitrogen doses. Regarding growth parameters, the highest plant height (123.20 cm), leaf length (30.17 cm) and stem base diameter (3.25) were recorded from the treatment N3 (180 kg N ha-1) whereas control treatment showed lowest results. Again, the highest leaf breadth (37.49 cm), number of leaves plant-1 (62.07), number of branches plant-1 (9.87), number of nodes plant-1 (24.20), number of internodes plant-1 (23.87), fruit petiole length (5.76 cm), fruit length (13.20 cm) and fruit diameter (2.11 cm), number of fruits plant-1 (24.10), single fruit weight (16.59 g), yield plot-1 (3.80 kg) and yield ha-1 (13.89 t) were found from the treatment N2 (150 kg N ha-1). The lowest single fruit weight (15.14 g), number of fruits plant-1 (16.30), yield plot-1 (2.53 kg) and yield ha-1 (9.21 t) were recorded from the control treatment N0 (0 kg N ha-1). From the above result, it can be said that the treatment N2 (150 kg N ha-1) considered as best compared to other studied treatments.*

Keywords: *Germination, Fertilizer, Rooftop garden, Okra, Experiment.*

1. Introduction

Okra, *Abelmoschus esculentus* (L.) Moench is an important vegetable crop consumed worldwide. It is a member of the malvaeceae family. It is widely cultivated in the tropics and subtropics for its immature edible green fruits and consumed as a vegetable, raw, cooked or fried (George, 1999). It is a common ingredient of soups and sauces. The fruits can be conserved by drying or pickling. The leaves are sometimes used as a substitute for spinach. The tender fruits, leaves and succulent shoots are consumed, either in fresh or dried form (Arapitsas, 2008).

In Bangladesh the total production of okra is about 272 thousand tons which was produced from 7683 hectares of land in the year 2018 with average yield about 3.38 t/ha which is very low (BBS, 2019) compared to that of other neighboring country like India (6.12 t/ha) and other developing countries (7.12 t/ha) of the world (Yamaguahi, 1998). So, the yield and total production of okra should be increased.

Rooftop garden plays an important role in the mental well-being of the gardeners as well as in amelioration of the physical environment. The production of fresh fruits and vegetables of the rooftop garden can increase nutritional status of household members of the urban citizens and it will make a positive contribution to the environment. Urban agriculture can supply city-dwellers with a supply of sparkling produce, accelerated food plan and essential family budgetary savings. Vegetated surfaces furnish essential sound insulations homes and are frequently employed for their noise discount doable in city settings. Rooftop gardens guide the social life, as a area to be satisfied outside surroundings with household and friends. It additionally develops a experience of self identification and independence, the place one can in particular acquire self and emotion legislation viewing special flower detached seasons (Rashid *et al.,* 2010) and affords restorative ride from stressful daily things to do in city excessive upward shove residential building.

Nitrogen is important for vegetative growth of plants. Nitrogen had significant effects on plant height, number of leaves and branches/plant, number of fruits/plant, fresh fruit weight and total fresh fruit yield of okra (Uwah *et al.,* 2010). It is difficult element to manage in fertilization system such that adequate but not excessive amount of nitrogen is available during the entire growing season (Akanbi *et al.,* 2010). An adequate supply of nitrogen is essential for vegetative growth and desirable yield (Sajjan *et al.,* 2002). Excessive application of nitrogen can prolong the growing period and delay crop maturity. Excessive nitrogen application causes physiological disorder in crop plant (Obreza and Vavrina, 1993).

2. Literature Review

Okra is specially valued for its tender and delicious edible pods and is an important summer vegetable crop in Bangladesh. Management of fertilizer especially nitrogen is the important factor that greatly affects the growth, development and yield of okra. So it is important to assess the effect of nitrogen for the best growth and yield of okra. However, limited research reports on the performance of okra in response to nitrogen have been done in various part of the world including Bangladesh and the work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works conducted at home and abroad in this aspect reviewed under the following headings:

Hodgon *et al*. (2011) reported that urban agriculture is much more than private gardens and community gardens, and many communities are beginning to see the promise of other forms of urban agriculture.

Moustier (2007) provides an extensive summary of the importance of urban agriculture in 14 African and Asian cities. Among the results they found that 90 % of all vegetables consumed in Dar es Salaam (Jacob et al., 2000) and 60 % of vegetables consumed in Dakar originate from urban agriculture.

Orsini *et al.* (2014) carried out a study of addressing the quantification of the potential of rooftop vegetable production in the city of Bologna (Italy) as related to its citizen’s needs. The potential benefits to urban biodiversity and ecosystem service provision were estimated. RTGs could provide more than 12,000 t year^{-1} vegetables to Bologna, satisfying 77 % of the inhabitants’ requirements.

Fioretti *et al.* (2010) has discovered that thermal reduction ratio (TRR) is positively related to the coverage ratio (CR) of plants and the total leaf thickness (TLT) of plants on the rooftop. The area of shadow increases with CR and reduce the transmission of solar radiation. Higher TLT will provide greater thermal resistance and increase the thermal reduction effect.

Rashid and Ahmed (2010) carried a study on thermal performance of rooftop garden in a six storied building established in 2003. She found that the temperature of this building is 3°C lower than other surrounding buildings and this Green application can reduce the indoor air temperature 6.8°C from outdoor during the hottest summer Period.

Medeiros *et al*. (2018) conducted an experiment to evaluate the different doses of nitrogen on growth and yield of okra (BARI Dherosh-1). Experiment consisted four levels of nitrogen viz. N_0 : 0, N_1 : 110, N_2 : 120 and N_3 : 130 kg N/ha using Randomized Complete Block Design with three replications. Maximum plant height (86.2 cm), number of leaves (43.8/plant), leaf length (28.8 cm), petiole length (23.1 cm), stem diameter (2.3 cm), internode length (14.3 cm), number of branches (4.0/plant), fruit length (16.8 cm), fruit diameter (1.9 cm), number of flower buds (29.4/plant), weight of individual fruit (11.6 g), fresh weight of leaves (298.4 g/plant), dry matter content of leaves (12.0%) and yield (7.1 kg/plot and 16.4 t/ha) was found from N_2 whereas minimum fro m N_0 .

Uddin *et al*. (2014) carried out a study entitled “Impact of nitrogen and spacing on the growth and yield of okra”. 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.

Sunita *et al.* (2006) carried out field experiments to determine the effects of intercrop and NPK fertilizer application on the performance of okra (cv. Arka Anamika). Treatments comprised: two intercrops (cowpea and French bean) and five fertilizer rates (0, 25, 50, 75 and 100% recommended dose of NPK). The results revealed that treatment with 100% recommended dose of fertilizers recorded higher okra equivalent yield (153.16 q/ha) and net returns (Rs. 30,709.91/ha) than the rest of the fertilizer rates. The best performance of okra in terms of yield, number of fruits per plant, fruit weight and plant height were observed with 100% recommended dose of fertilizer.

Manga and Mohammed (2006) performed two field experiments during the rainy seasons of 2002 and 2004 to study the effects of plant population and nitrogen levels on the growth and yield of okra (cv. LD88-1). The treatments consisted of four plant populations and four nitrogen levels (0, 50, 90 and 120 kg/ha). Nitrogen application increased plant height, number of branches per plant, and number of fruits per plant, but did not significantly affect fruit weight. The high nitrogen content of the experimental fields may be the major reason why the yield response to nitrogen was not significant.

Ambare *et al*. (2005) carried out an experiment during the *kharif* season to study the five levels of nitrogen viz., 0, 25, 50, 75 and 100 kg ha^{-1} and four varieties of okra on growth and fruit yield of okra. The results indicated that the higher levels of nitrogen significantly influenced all the characters under study except the diameter of the fruit.

Yadav *et al.* (2004) performed an experiment during *kharif* 2001 to study the effects of different levels of organic manures and N fertilizer (urea) on the growth and yield of okra cv. Varsha Upahar. The treats consisted of 100% recommended dose of N, 75% N as urea + 25% N as Farm Yard Manure (FYM), Poultry Manure (PM) or Vermicompost (VC), 50% N as urea + 50% N as FYM, PM or VC, 25% N as urea + 75% N as FYM, PM or VC and 100% N as VC. The treatment involving 50% N as urea + 50% N as FYM, PM or VC recorded the highest yield (90.61 q/ha).

3. Objectives

The current study was undertaken to determine the optimum levels of nitrogen on the growth and yield of okra with the following objectives

a) To determine the morphological characteristics of okra by applying various doses of nitrogen; and
b) To find out the optimum dose of nitrogen for growth and maximum yield of okra in rooftop garden.

4. Materials and Methods

The experiment was carried out during the period from June to September 2019.

Location of the experimental site

The experiment was conducted at the roof of third floor of Biotechnology department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The duration of the experiment was June to September 2019. The site is 90.2°N and 23.5°E Latitude and at an altitude of 8.25 m from the sea level.

Climatic condition of the experimental site

Experimental location is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment were collected from the Bangladesh Meteorological Department, Agargoan, Dhaka (Appendix I).

Soil characteristics of the experimental site

The soil of the experimental site was collected from outside of Dhaka city which was sandy clay. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and were presented in Appendix II.

Planting materials

The test crop used in the experiment was BARI Dherosh-2.

Collection of seeds

The seeds of okra variety were collected from Bangladesh Agricultural Research Institute (BARI).

Treatment of the experiment

The experiment consisted of single factor. Four levels of nitrogen (N) was considered as treatments which is as follows:

1. N_0 = Control (0 kg N ha^{-1})
2. N_1 = 120 kg N ha^{-1}
3. N_2 = 150 kg N ha^{-1}
4. N_3 = 180 kg N ha^{-1}

Land preparation

The land was preparation was started at 3rd June 2019. The corner of the land was spaded and visible large clods were broken into small pieces. Weeds and stubbles were removed from the field. The layout of the experiment was done in accordance with the design adopted. Finally, individual plots were prepared by using spade before organic manure application. To facilitate water supply in the prepared bed on the rooftop, GI pipe was established with the help of a structure constructed by bricks, sand and cement and pipe was connected with tap water.

Application of manure and fertilizers

Urea, triple super phosphate (TSP), muriate of potash (MP) and borax were used as source of nitrogen, phosphorus, potassium and boron, respectively. Well decomposed cowdung was also applied to the field before final ploughing. Total amount of TSP and 50% of urea were applied as basal doses during final land preparation. The remaining 50% urea was applied as top dressing at flowering and fruiting start stage. The doses and application method of fertilizers were given below:

Manure and fertilizers		Doses/ha
Cowdung		10 t ha^{-1}
Nitrogen (as urea)		As per treatment
TSP		120 kg ha^{-1}
MoP		150 kg ha^{-1}

Design and layout of the experiment

The experiment was laid out in Completely Randomized Design (CRD) having single factors with three replications. Each replication (block) is an area of 11.9 m × 1 m. Each block was consists of 4 plots where 4 treatments were allotted. There were 12 unit plots in the experiment. The size of each plot was (2.75 m × 1 m), which accommodated 10 plants at a spacing of (50 cm × 55 cm). The distance between two blocks and two plots were kept 0.5 m and 0.5 m respectively. The design and layout of the experiment was shown in Appendix III.

Seeds sowing

The okra seeds were sown in the experiment field at 9th June in 2019. Seeds were treated with Bavistin @ 2ml/L of water before sowing the seeds to control the seed borne diseases. The seeds were sown in rows having a depth of 2-3 cm with maintaining distance from 50 cm and 55 cm from plant to plant and row to row, respectively.

Intercultural operation

After raising seedlings, various intercultural operations such as gap filling, weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the okra seedlings.

Gap filling

The seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after germination and such seedling were replaced by new seedlings. Replacement was done with healthy seedling in the afternoon having a boll of earth which was also planted on the same date by the side of the unit plot. The seedlings were given watering for 7 days starting from germination for their proper establishment.

Weeding

The weeding was done by nirani with roots at 15, 30 and 45 days after sowing to keep the plots free from weeds.

Irrigation

Light watering was given by a watering cane at every morning and afternoon and it was continued for a week for rapid and well establishment of the germinated seedlings.

Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedlings in the field. Cut worms were controlled both mechanically and spraying Bavistin 50WP, Furadan 5G, Ripcord 10EC as and when neccary. Some discolored and yellowish diseased leaves were also collected from the plant and removed from the field.

Harvesting

Fruits were harvested at 5 days interval based on eating quality at soft and green condition. Harvesting was started from 9 August, 2019 and was continued up to September 2019.

Data collection

The following parameters were collected during the present study

Growth parameters

1. Plant height (cm)
2. Leaf length (cm)
3. Leaf breadth (cm)
4. Number of leaves $plant^{-1}$
5. Number of branches $plant^{-1}$

6. Number of nodes plant^{-1}
7. Number of internodes plant^{-1}
8. Stem base diameter

Yield contributing parameters

1. Fruit petiol length (cm)
2. Fruit length (cm)
3. Fruit diameter (cm)

Yield parameters

1. Number of fruits plant^{-1}
2. Single fruit weight (g)
3. Yield plot^{-1} (kg)
4. Yield ha^{-1} (t)

Soil and light quality parameters

1. Soil moisture (%)
2. Soil temperature (°C)
3. Light intensity (klux)

Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C software to find out the significance of the difference for nitrogen fertilizer on growth and yield of okra. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the means of treatment combinations was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

5. Results and Discussion

The experiment was considered to investigation of different level of Nitrogen on the performance of okra in rooftop garden. The analysis variances for different characters have been present in (Appendix 1 to 5). Data of the different parameters analyzed statically and the results have been presented in the (Table1 to14 and figures1 to 21 and appendix 6 to7). The results of the present study have been presented and discussed in this chapter under the following headings:

Growth parameters

Plant height (cm)

At 20 DAT, plant height of okra among the treatments was non-significant but at 40 and 60 DAT, it was significantly varied due to different nitrogen doses (Table 1). However, at 20 DAT, the highest plant height (22.95 cm) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest plant height (21.23 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Similarly, at 40 DAT, the highest plant height (71.75 cm) was found from the treatment N_3 (180 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_2 (150 kg N ha^{-1}) whereas the lowest plant height (65.55 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Again, at 60 DAT, the highest plant height (123.20 cm) was found from the treatment N_3 (180 kg N ha^{-1}) which was statistically identical with N_2 (150 kg N ha^{-1}) whereas the lowest plant height (115.10 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

As a result in brief, the highest plant height (22.95, 71.75 and 123.20 cm at 20, 40 and 60 DAT, respectively) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest plant height (21.23, 66.5 and 115.10 cm at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). It was revealed that with the increase of nitrogen plant height increased upto a certain level. Nitrogen ensured favorable condition for the growth of okra plant with optimum vegetative growth and the ultimate results was tallest plant. Singh et al. (2007) found maximum plant height with 100 kg N/ha. Similar result was also observed by Manga and Mohammed (2006).

Table 1. Plant height of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Plant height (cm)		
	20 DAT	40 DAT	60 DAT
N_0	21.23	66.55 b	115.1 b
N_1	21.87	70.83 a	116.2 b
N_2	22.13	71.29 a	121.4 a
N_3	22.95	71.75 a	123.2 a
$LSD_{0.05}$	4.716^{NS}	3.381	2.991
CV(%)	5.71	8.94	7.34

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Leaf length (cm)

At 20 DAT, leaf length of okra among the treatments was non-significant but at 40 and 60 DAT, it was significantly varied due to different nitrogen doses (Table 2). However, at 20 DAT, the highest leaf length (13.10 cm) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest leaf length (12.29 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest leaf length (32.68 cm) was found from the treatment N_3 (180 kg N ha^{-1}) which was significantly different from other treatments. The lowest leaf length (26.51 cm) at 40 DAT was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 60 DAT, the highest leaf length (30.17 cm) was found from the treatment N_3 (180 kg N ha^{-1}) which was statistically identical with N_2 (150 kg N ha^{-1}) whereas the lowest leaf length (25.31 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

As a result in brief, the highest leaf length (13.10, 32.68 and30.17 cm at 20, 40 and 60 DAT, respectively) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest leaf length (12.2926.51 and 25.31 cm) at 20, 40 and 60 DAT, respectively was recorded from the control treatment N_0 (0 kg N ha^{-1}). Medeiros *et al*. (2018) Manga and Mohammed (2006) also found similar result which supported the present study. Singh *et al.* (2007) also recorded the longest leaf with 100 kg N/ha.

Table 2. Leaf length of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	**Leaf length (cm)**		
	20 DAT	**40 DAT**	**60 DAT**
N_0	12.29	26.51 c	25.31 c
N_1	12.75	29.07 b	28.04 b
N_2	13.07	30.26 b	29.57 a
N_3	13.10	32.68 a	30.17 a
$LSD_{0.05}$	0.873^{NS}	2.235	0.8405
CV(%)	8.16	12.28	7.23

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Leaf breadth (cm)

Leaf breadth of okra varied significantly due to different nitrogen doses at different growth stages of crop duration (Table 3). At 20 DAT, the highest leaf breadth (15.54 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest leaf breadth (14.14 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Again, at 40 DAT, the highest leaf breadth (38.53 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments. The lowest leaf breadth (33.81 cm) 40 DAT was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically similar with N_3 (180 kg N ha^{-1}). At 60 DAT, the highest leaf breadth (37.49 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest leaf breadth (32.07 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

As a result in brief, the highest leaf breadth (15.54, 38.53 and 37.49 cm at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest leaf breadth (14.14, 33.81 and 32.07 cm at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

Table 3. Leaf breadth of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	**Leaf breadth (cm)**		
	20 DAT	**40 DAT**	**60 DAT**
N_0	14.14 b	33.81 c	32.07 b
N_1	15.21 a	36.08 b	36.02 a
N_2	15.54 a	38.53 a	37.49 a
N_3	15.53 a	34.37 bc	36.97 a
$LSD_{0.05}$	0.8115	1.907	1.911
CV(%)	8.28	11.17	5.68

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Number of leaves plant^{-1}

At 20 DAT, number of leaves plant^{-1} of okra among the treatments was non-significant but at 40 and 60 DAT, it was significantly varied due to different nitrogen doses (Table 4). However, at 20 DAT, the highest number of leaves plant^{-1} (10.40) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest number of leaves plant^{-1} (9.40) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest number of leaves plant^{-1} (56.80) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments whereas the lowest number of leaves plant^{-1} (47.60) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}). At 60 DAT, the highest number of leaves plant^{-1} (62.07) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments whereas the lowest number of leaves plant^{-1} (54.60) was recorded from the control treatment N_0 (0 kg N ha^{-1})

As a result in brief, the highest number of leaves plant^{-1} (10.40, 56.80 and 62.07 at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest number of leaves plant^{-1} (9.40, 47.60 and54.60 at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Soni *et al*. (2006) reported that number of leaves per plant increased with increasing rates of N up to 125 kg/ha. Medeiros *et al*. (2018) also observed similar result and found highest number of leaves plant^{-1} from 120 kg N ha^{-1}.

Table 4. Number of leaves plant^{-1} of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Number of leaves plant^{-1}		
	20 DAT	**40 DAT**	**60 DAT**
N_0	9.40	47.60 c	54.60 c
N_1	9.53	47.87 c	58.27 b
N_2	10.40	56.80 a	62.07 a
N_3	9.53	51.87 b	59.80 b
$LSD_{0.05}$	1.265^{NS}	3.147	2.058
CV(%)	6.52	11.17	9.34

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Number of branches plant^{-1}

Significant variation was recorded at different growth stages of okra due to different nitrogen doses (Table 5). At 40 DAT, the highest number of branches plant^{-1} (7.60) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) whereas the lowest number of branches plant^{-1} (5.80) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_3 (180 kg N ha^{-1}). At 60 DAT, the highest number of branches plant^{-1} (9.87) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest number of branches plant^{-1} (8.60) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}).

As a result in brief, the highest number of branches plant^{-1} (7.60 and 9.87 at 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest number of branches plant^{-1} (5.80 and 8.60 at 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Soni *et al.* (2006) reported that number of branches increased with increasing rates of N up to 125 kg/ha. Medeiros *et al*. (2018) also found similar result with the present study and found highest number of branches plant^{-1} from 120 kg N ha^{-1}.

Table 5. Number of branches plant^{-1} of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Number of branches plant^{-1}	
	40 DAT	**60 DAT**
N_0	5.80 b	8.60 b
N_1	7.07 a	8.73 b
N_2	7.60 a	9.87 a
N_3	6.20 b	8.67 b
$LSD_{0.05}$	0.6686	0.9199
CV(%)	8.91	10.16

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Number of nodes plant^{-1}

Number of nodes plant^{-1} of okra varied significantly due to different nitrogen doses at different growth stages of crop duration (Table 6). At 20 DAT, the highest number of nodes plant^{-1} (5.13) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest number of nodes plant^{-1} (4.27) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest number of nodes plant^{-1} (11.27) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_3 (180 kg N ha^{-1}) whereas the lowest number of nodes plant^{-1} (9.47) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 60 DAT, the highest number of nodes plant^{-1} (24.20) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_3 (180 kg N ha^{-1}) whereas the lowest number of nodes plant^{-1} (23.47) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

As a result in brief, the highest number of nodes plant^{-1} (5.13, 11.27 and24.20 at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest number of nodes plant^{-1} (4.27, 9.47 and 23.47 at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

Table 6. Number of nodes plant^{-1} of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Number of nodes plant^{-1}		
	20 DAT	**40 DAT**	**60 DAT**
N_0	4.27 b	9.47 b	23.47 b
N_1	4.87 ab	9.53 b	23.53 b
N_2	5.13 a	11.27 a	24.20 a
N_3	5.07 a	10.47 ab	23.67 ab
$LSD_{0.05}$	0.641	1.266	0.6596
CV(%)	6.65	11.67	5.67

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Number of internodes plant^{-1}

Number of internodes plant^{-1} was influenced significantly due to different nitrogen doses at different growth stages of crop duration (Table 7). At 20 DAT, the highest number of internodes plant^{-1} (4.13) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest number of internodes plant^{-1} (3.27) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest number of internodes plant^{-1} (10.27) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_1 (120 kg N ha^{-1}) whereas the lowest number of internodes plant^{-1} (8.47) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_3 (180 kg N ha^{-1}). At 60 DAT, the highest number of internodes plant^{-1} (23.87) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) whereas the lowest number of internodes plant^{-1} (22.33) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_3 (180 kg N ha^{-1}).

Table 7. Number of internodes plant^{-1} of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Number of internodes plant^{-1}		
	20 DAT	**40 DAT**	**60 DAT**
N_0	3.27 b	8.47 b	22.33 b
N_1	4.07 a	9.47 ab	23.80 a
N_2	4.13 a	10.27 a	23.87 a
N_3	3.87 ab	8.53 b	22.53 b
$LSD_{0.05}$	0.641	1.284	0.7967
CV(%)	8.39	12.95	6.20

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

As a result in brief, the highest number of internodes plant^{-1} (4.13, 10.27 and 23.87 at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest number of internodes plant^{-1} (3.27, 8.47 and 22.33 at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). The result obtained from the present study was similar with the present findings Medeiros *et al*. (2018) which supported the present study.

Stem base diameter

At 20 and 40 DAT, stem base diameter of okra among the treatments was non-significant but at 60 DAT, it was significantly varied due to different nitrogen doses (Table 8). However, at 20 DAT, the highest stem base diameter (0.78) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest stem base diameter (0.68) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest stem base diameter (0.91) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest stem base diameter (0.86) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 60 DAT, the highest stem base diameter (3.25) was found from the treatment N_3 (180 kg N ha^{-1}) which was statistically similar with N_2 (150 kg N ha^{-1}) whereas the lowest stem base diameter (2.88) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically similar with N_1 (120 kg N ha^{-1}).

As a result in brief, the highest stem base diameter (0.78, 0.91 and 3.25 at 20, 40 and 60 DAT, respectively) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest stem base diameter (0.68, 0.86 and 2.88 at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Medeiros *et al*. (2018) and Candido *et al.* (2011) also found similar result which supported the present study. Singh *et al*. (2007) recorded maximum stem diameter with the application of 100 kg N/ha.

Table 8. Stem base diameter of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Stem base diameter		
	20 DAT	40 DAT	60 DAT
N_0	0.68	0.86	2.88 c
N_1	0.65	0.87	3.06 bc
N_2	0.70	0.89	3.10 ab
N_3	0.78	0.91	3.25 a
$LSD_{0.05}$	0.179^{NS}	0.141^{NS}	0.189
CV(%)	4.67	7.76	6.47

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Yield contributing parameters

Fruit petiole length (cm)

Significant variation was recorded for fruit petiole length among the treatment due to different nitrogen doses at different growth stages of crop duration (Table 9). At 20 DAT, the highest fruit petiole length (6.13 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest fruit petiole length (5.41 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest fruit petiole length (5.94 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest fruit petiole length (5.07 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 60 DAT, the highest fruit petiole length (5.76 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest fruit petiole length (5.08 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

As a result in brief, the highest fruit petiole length (6.13, 5.94 and 5.76 cm at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest fruit petiole length (5.41, 5.07 and 5.08 cm at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Uwah *et al*. (2010) and Medeiros *et al*. (2018) reported longest petiole with the application of 120 kg N/ha.

Table 9. Fruit petiole length of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Fruit petiole length (cm)		
	20 DAT	40 DAT	60 DAT
N_0	5.41 b	5.07 b	5.08 b
N_1	5.95 a	5.70 a	5.48 ab
N_2	6.13 a	5.94 a	5.76 a
N_3	5.84 ab	5.61 a	5.40 ab
$LSD_{0.05}$	0.456	0.419	0.532
CV(%)	5.47	6.09	9.64

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Fruit length (cm)

Significant variation was recorded for fruit length among the treatment due to different nitrogen doses at different growth stages of crop duration (Table 10). At 20 DAT, the highest fruit length (18.11 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments whereas the lowest fruit length (14.12 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_3 (180 kg N ha^{-1}). At 40 DAT, the highest fruit length (16.00 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) whereas the lowest fruit length (12.99 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_3 (180 kg N ha^{-1}). At 60 DAT, the highest fruit length (13.20 cm) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments whereas the lowest fruit length (10.73 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically identical with N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}).

As a result in brief, the highest fruit length (18.11, 16.00 and 13.20 cm at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest fruit length (14.12, 12.99 and 10.73 cm at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Jalal-ud-Din *et al.* (2002) observed that pod length showed a favorable behavior under 150 kg N/ha, but above this particular dose it declined.

Table 10. Fruit length of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Fruit length (cm)		
	20 DAT	40 DAT	60 DAT
N_0	14.12 c	12.99 b	10.73 b
N_1	16.63 b	15.00 a	11.05 b
N_2	18.11 a	16.00 a	13.20 a
N_3	15.02 c	13.02 b	11.04 b
$LSD_{0.05}$	1.217	1.798	1.162
CV(%)	7.38	8.39	8.68

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Fruit diameter (cm)

Fruit diameter of okra was not significantly influenced due to different nitrogen doses during crop duration (Table 11). However, At 20 DAT, the highest fruit diameter (2.10 cm) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest fruit diameter (1.89 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 40 DAT, the highest fruit diameter (2.09 cm) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest fruit diameter (1.89 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}). At 60 DAT, the highest fruit diameter (2.11 cm) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest fruit diameter (1.73 cm) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

As a result in brief, the highest fruit diameter (2.10, 2.09 and 2.11 cm at 20, 40 and 60 DAT, respectively) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest fruit diameter (1.89, 1.85 and 1.73 cm at 20, 40 and 60 DAT, respectively) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Ambare *et al*. (2005) reported that the higher levels of nitrogen significantly influenced all the characters under study except the diameter of the fruit.

Table 11. Fruit diameter of okra at different days after transplanting (DAT) as influenced by different doses of nitrogen (N)

Treatment	Fruit diameter (cm)		
	20 DAT	40 DAT	60 DAT
N_0	1.89	1.85	1.73
N_1	2.09	2.06	1.97
N_2	2.10	2.09	2.11
N_3	1.93	1.86	1.83
$LSD_{0.05}$	0.26^{NS}	0.47^{NS}	0.49^{NS}
CV(%)	6.52	6.00	8.80

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Yield parameters

Number of fruits $plant^{-1}$

Significant variation was found for number of fruits plant^{-1} among the treatment due to different nitrogen doses (Fig. 1). Results indicated that the highest number of fruits plant^{-1} (24.10) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments followed by N_1 (120 kg N ha^{-1}) and N_3 (180 kg N ha^{-1}) whereas the lowest number of fruits plant^{-1} (16.30) was recorded from the control treatment N_0 (0 kg N ha^{-1}). Jana *et al*. (2010) reported that 150 kg N ha^{-1} produced the highest number of fruits per plant (13.7). Medeiros *et al*. (2018) also found similar result with the present study.

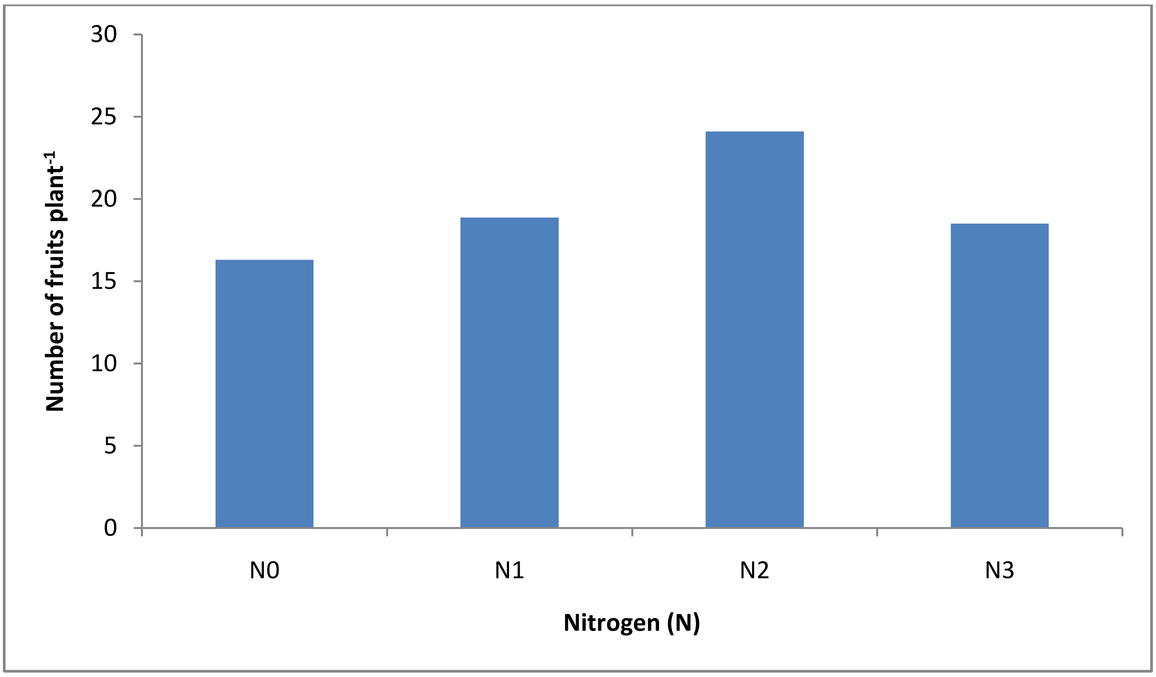

Fig. 1. Number of fruits plant^{-1} of okra as influenced by different doses of nitrogen
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Single fruit weight (g)

Single fruit weight was significantly affected among the treatments due to different nitrogen doses (Fig. 2). Results revealed that the highest single fruit weight (16.59 g) was found from the treatment N_2 (150 kg N ha^{-1}) which was statistically similar with N_1 (120 kg N ha^{-1}) whereas the lowest single fruit weight (15.14 g) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically similar with N_3 (180 kg N ha^{-1}).

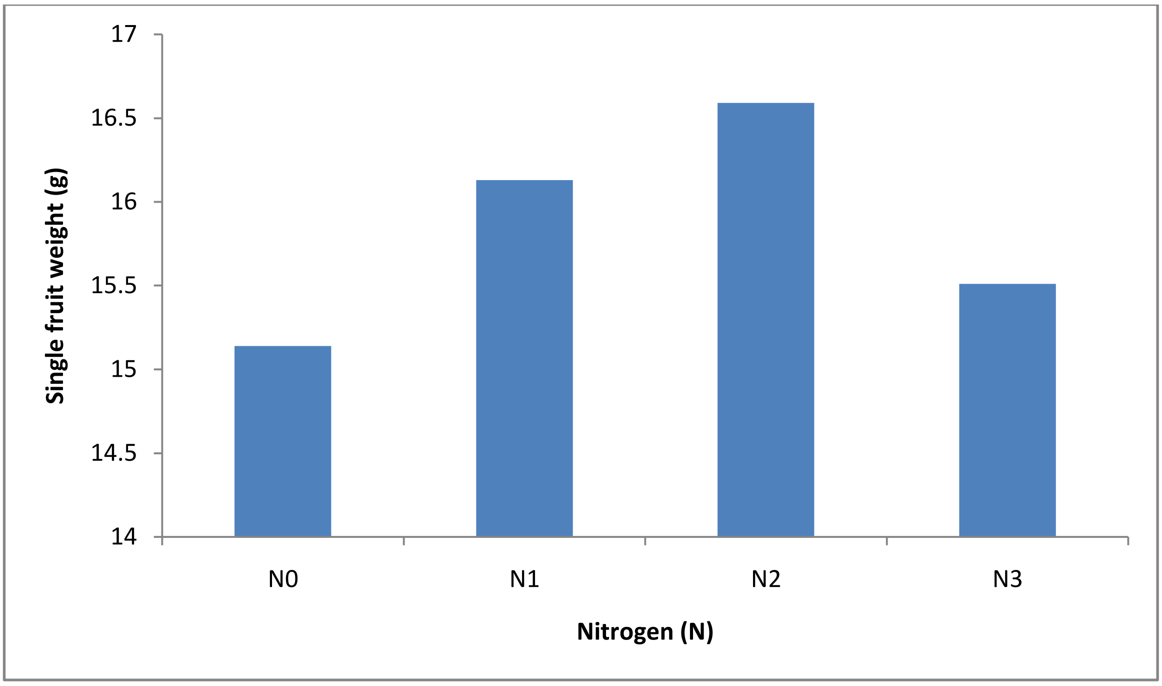

Fig. 2. Single fruit weight of okra as influenced by different doses of nitrogen (N)
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Yield plot^{-1} (kg)

Significant variation was found for yield plot^{-1} among the treatment due to different nitrogen doses (Fig. 3). Results indicated that the highest yield plot^{-1} (3.80 kg) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments followed by N_1 (120 kg N ha^{-1}) whereas the lowest yield plot^{-1} (2.53 kg) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically similar with N_3 (180 kg N ha^{-1}).

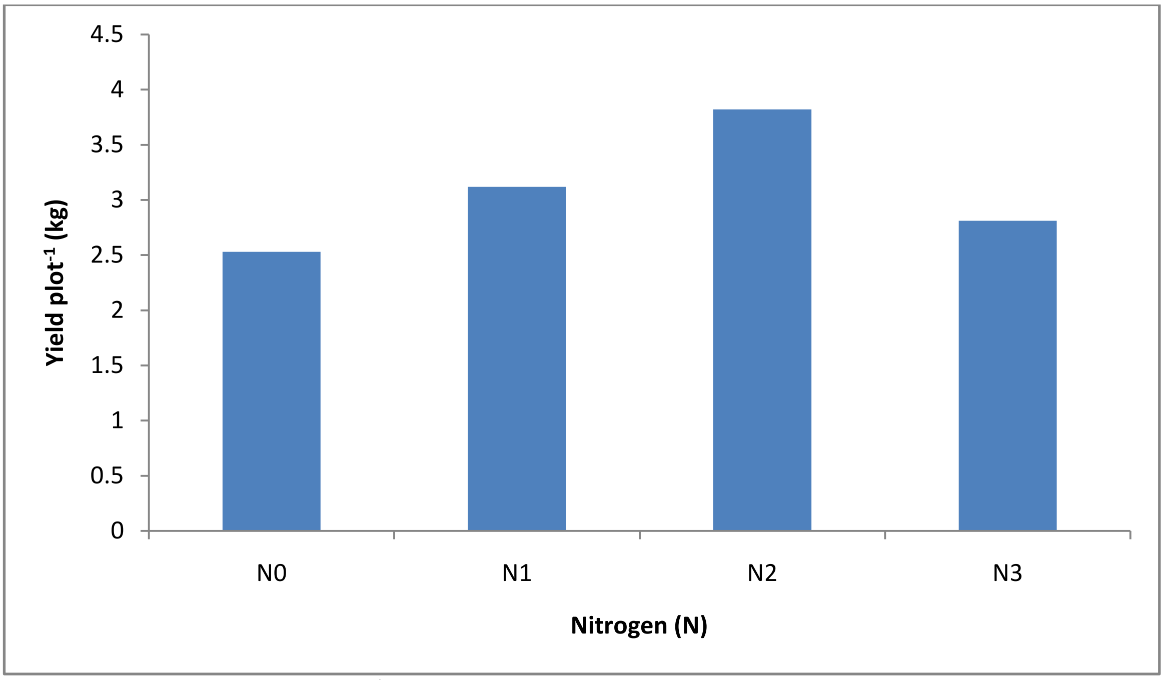

Fig. 3. Yield plot^{-1} of okra as influenced by different doses of nitrogen (N)
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Yield ha^{-1} (t)

Yield ha^{-1} was significantly affected among the treatments due to different nitrogen doses (Fig. 4 and Appendix XVI). Results revealed that the highest yield ha^{-1} (13.89 t) was found from the treatment N_2 (150 kg N ha^{-1}) which was significantly different from other treatments followed by N_1 (120 kg N ha^{-1}) whereas the lowest yield ha^{-1} (9.21 t) was recorded from the control treatment N_0 (0 kg N ha^{-1}) which was statistically similar with N_3 (180 kg N ha^{-1}). Jana *et al.* (2010) reported that 150 kg N ha^{-1} produced the highest fruit yield (12.2 t ha^{-1}). Similar result was also observed by Medeiros *et al*. (2018) who found okra yield (16.4 t/ha) from 120 kg N ha^{-1}.

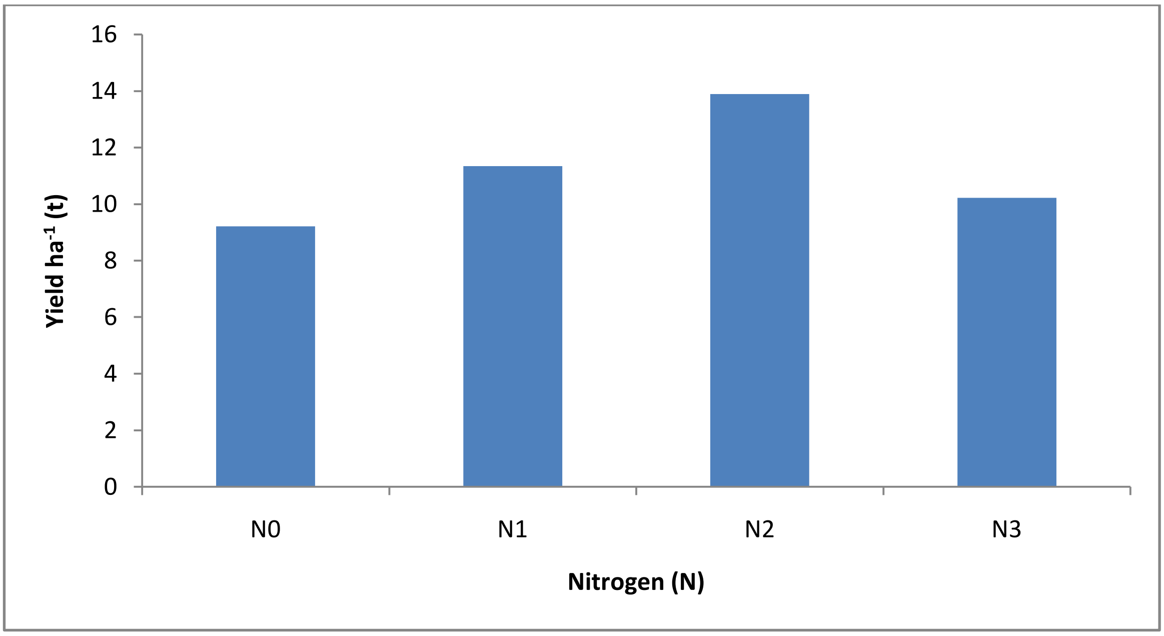

Fig. 4. Yield ha^{-1} of okra as influenced by different doses of nitrogen (N)
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

Quality parameters of soil and light

Soil moisture (%)

Non-significant variation was recorded for soil moisture content influenced by different nitrogen doses (Fig. 5 and Appendix XVII). However, the highest soil moisture (22.13%) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest soil moisture (20.55%) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

Soil temperature (°C)

Non-significant variation was recorded for soil temperature influenced by different nitrogen doses (Fig. 6 and Appendix XVII). However, the highest soil temperature (16.20°C) was found from the treatment N_3 (180 kg N ha^{-1}) whereas the lowest soil temperature (15.82°C) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

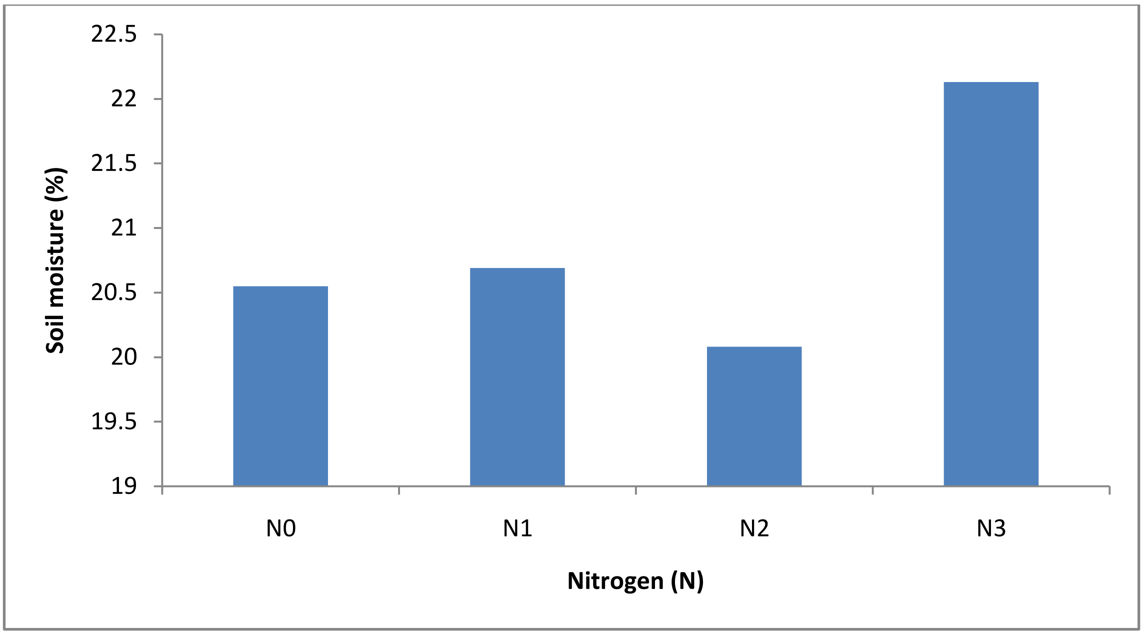

Fig. 5. Soil moisture of the field as influenced by different doses of nitrogen (N)
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

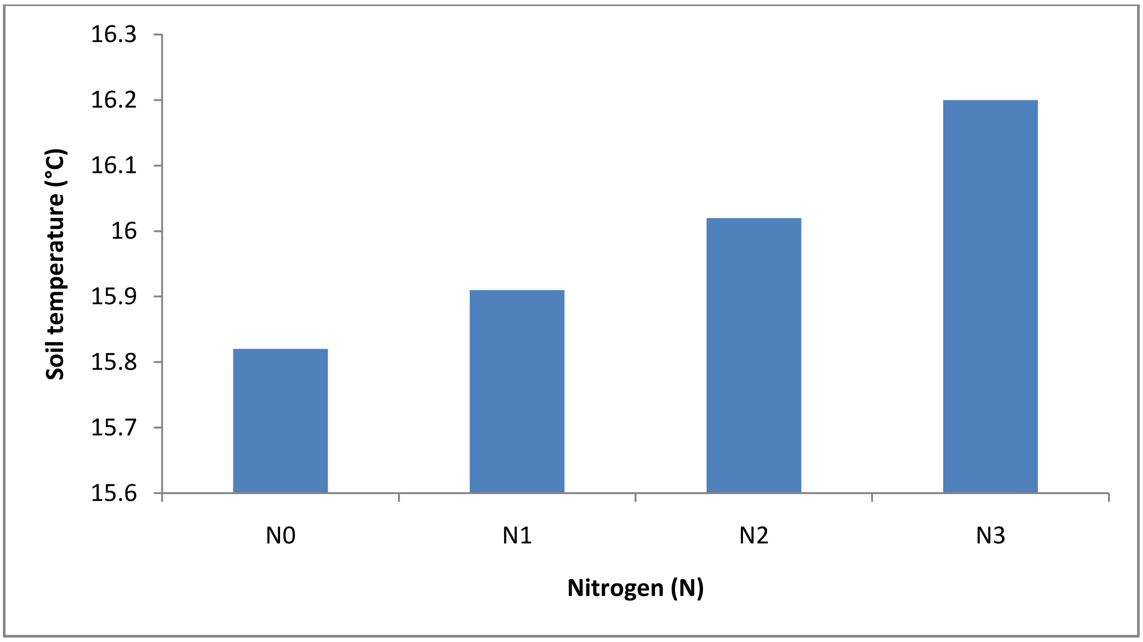

Fig. 6. Light quality of study area as influenced by different doses of nitrogen
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1} **Light intensity (klux)**

Non-significant variation was recorded for light intensity influenced by different nitrogen doses (Fig. 7 and Appendix XVII). However, the highest light intensity (32.54 klux) was found from the treatment N_2 (150 kg N ha^{-1}) whereas the lowest light intensity (30.46 klux) was recorded from the control treatment N_0 (0 kg N ha^{-1}).

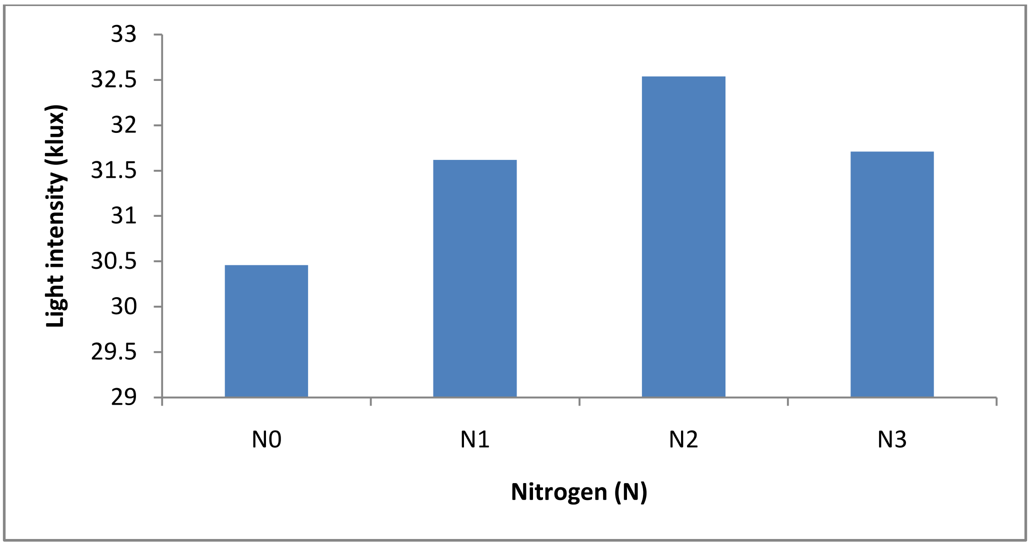

Fig. 7. Light intensity of study area as influenced by different doses of nitrogen
N_0 = Control (0 kg N ha^{-1}), N_1 = 120 kg N ha^{-1}, N_2 = 150 kg N ha^{-1}, N_3 = 180 kg N ha^{-1}

6. Conclusion

Considering the growth parameters, yield contributing parameters and yield, it is apparent that the treatment N2 (150 kg N ha-1) gave performance in most of cases. This treatment also showed highest number of fruits plant-1 (24.10) and yield ha-1 (13.89 t). So, the treatment of N2 (150 kg N ha-1) was better than rest of the treatments and this treatment can be considered as best compared to other treatments.

7. Recommendations

Considering the situation of the present experiment, further studies in the following areas may be suggested:

a) Further study is needed in the rooftop garden for definite results of the present experiment.
b) Other doses of N and/or other plant nutrients can be included to conduct related experiment.
c) Scope to conduct similar experiment for other season in the rooftop.

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