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DEGREE AND FREQUENCY OF NITROGEN AMENDMENTS INFLUENCING THE OFF-SEASON OKRA PRODUCTION IN THE SEMI-ARID NORTH-WESTERN BANGLADESH

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ABSTRACT

Vegetables scarcity due to soil nutrient declination as one of the major concerns has been the persistent scenario in the late and post-monsoon period in Bangladesh. Hence, an experiment was executed at the research field of University of Rajshahi, Bangladesh to investigate the crop yield potentiality of okra upon application of varied nitrogen doses in different frequencies in off-season (July-November, 2019). Upon application five levels of nitrogen amendments viz., 70 kg N/ha and 110 kg N/ha applied in 3 splits and 4 splits and control or farmers' practices [70 kg N/ha once at final land preparation (FLP)] to three okra varieties (Local, BARI Dherosh-2 and Hybrid); the Local cultivar exhibited superiority in most of the vegetative characters except the number of branches and leaves per plant being maximum in Hybrid and root: shoot ratio higher in BARI Dherosh-2. The hybrid variety didn't show much growth after 60 DAS but it performed superior in early flowering (39.27 days) and harvesting (43.67 days) along with the highest yield (374.03 g/plant and 12.47 t/ha) and BARI Dherosh-2 had its excellence in exhibiting extended duration harvesting (57.00 days) and pod dry matter content (30.96 %) in off-season. Again, plants treated with 110 kg N/ha applied in 4 splits exhibited maximum growth at least from 60 DAS to the end of harvest and produced the highest yield (440.24 g/plant and 14.68 t/ha) that yield was almost double to that of control (228.06 g/plant and 7.60 t/ha). Consequently, BARI Dherosh-2 combined with 110 kg N/ha applied in 4 splits gave the utmost yield (469.50 g/plant and 15.65 t/ha) along with maximum pod dry matter (32.03 %) compared to control yield (195.97 g/plant and 6.53 t/ha). Besides, N-amendment extended the harvesting period of okra by at least 8 days (from 43.78 days to 51.22 days) compared to control and BARI Dherosh-2 was harvested for significantly longer duration (61.67 days after the first picking) when 110 kg N/ha applied in 4 splits compared to only 37.67 days of picking period in local cultivar under farmers' practice. Therefore, it is evident that extended but judicial and intermittent N-amendments helped in increased okra production with long duration harvest in the lean season.

Keywords **:** Lean-season, N-amendment, okra (*Abelmoschus esculentus*), semi-arid condition, yield and quality.

Introduction

Bangladesh, being cropping intensive country, attains title as the 3rd most vegetables producing country in the world (Hossain, 2019; Zaman, 2019). But with respect to vegetables consumption requirement of 200 g/person/day (FAO/WHO, 2003), the country's gross production proves insufficient leading to a daily vegetables intake of fairly 166.1 g/person including potato against the desirable 100 g of leafy and 200 g of non-leafy vegetables (Hortex Foundation, 2013). In this regard, the high levels of low birth weight (33%), underweight (41%), stunting (43%) and wasting (17%) among children less than five years; anemia among infants, young children, adolescent girls and pregnant women; and poor diet diversification are of particular concerns (BDHS, 2009). Reports argued that Insufficient fruit and vegetable consumption accounts for 14%, 11%, and 9% of worldwide deaths from gastrointestinal cancer, heart disease, and stroke, respectively (Afshin *et al*., 2019). Again, vegetable production is not uniform round the year in Bangladesh. Vegetables are plenty in winter/*Rabi* season (November-March) producing around 60-70% of total annual production (Weinberger and Genova, 2005), but are lower in summer 7-8 months especially being scarce during the late and post monsoon. Again, the surplus vegetable production in the *Rabi* season reduces the market price and farmers face economic loss (Sharmin *et al*., 2018). On the other hand, during the *Kharif* season deficit vegetable supply causes the price to increase. Few of cucurbitaceous vegetables and some of aroids are common at the last few months of *Kharif* (August to October) period. Moreover, vegetable shortage at that time also leads to the nutrient insecurity to the consumers. Therefore, out of season vegetable production might be a probable solution.

Okra (also called Lady's finger; *Abelmoschus esculentus* (L.) *Moench*), being one of the most important summer vegetables in Bangladesh and having semi-shrub nature of growth with good root systems, can be grown in the late monsoon period for its high nutritive and medicinal values beneficial to the consumers. The green immature pods or fruits of okra contain proteins, fats, carbohydrates, β-carotene, vitamins (B_1, B_2 and B_6), niacin and vitamin C as well as calcium and iron which were reported beneficial in moderating blood pressure, fibrinogen concentration and plasma viscosity in hypertension (Adebawoo *et al*., 2007). But the subsequent vegetative and reproductive growth of this vegetable crop slows down substantially when soil nutrient status becomes poor. Among different soil nutrients, 'nitrogen (N)' is the most essential as is the important constituent of plant parts such as chlorophyll, amino acid, proteins and pigments etc. It is the most essential for growth and development, branching, leaf development and enlargement root expansion, high photosynthetic activity and formation of protoplasm (Khan *et al*., 2013). In addition to the growth and fruit yield of crops, nitrogen not only increases the crop quality but also improves soil characteristics by amending soil micro flora and fauna. In okra, the deficiency of nitrogen caused a decrease in the leaves size, the stem diameter and the height of plant, besides the intense falling of floral buds, and avoiding fruiting (Costa *et al*., 1981; Abd El-Kader *et al*., 2010). Thus, the balanced supply of nitrogen causes positive effect on the growth of the aboveground part, the root and on the quality of the vegetables like okra (Filgueira, 2008). Application of nitrogen has been reported to significantly improve okra growth, dry matter partitioning and fruit yield (Akanbi *et al*., 2002; Akanbi *et al*., 2010; Zubairu *et al*., 2016) under favorable growing condition. But due to heavy rain in 1st half of summer in the north-western and soil culturing, prevalent soil N depletes down through different ways and subsequent rainless conditions results in low nutrient content in soil. So, soil N-amendments might play a vital role in producing quality okra in the late and post monsoon (*Kharif-2*). Again, the north-western part of Bangladesh is characterized by many ecological challenges (Khan *et al*., 2019); soil water shortage being one the most limiting factors obstructing the availability of essential soil nutrients including N mostly. Therefore, the present research experiment was undertaken to evaluate the above and below ground vegetative growth, yield and yield contributing attributes of okra in off-season upon application of varied doses of N with frequency of application and thereby indentify the efficient methods for profitable okra cultivation under semi-arid condition.

Materials and Methods

Experimental site and Design

The experiment was conducted at the research field of Crop Science and Technology, Rajshahi University, Rajahahi-6205 during the period from July to November 2019. The site was 24.370^{o}N and 88.637^{o}E latitude and 20.0 m above from the sea level under the Agro-ecological Zone-11 characterized by general soil types predominantly includes calcareous dark grey and calcareous brown floodplain soils elevating about 40 m from sea level. Organic matter content was low in ridges and moderate in the basins. The soil texture was silty clay loam and top soil of the experimental plot was silty clay in texture with low organic matter content having soil pH range of 6.7 to 7.1 (Brammer, 1996). Three popular okra varieties viz., Local cultivar (OP), BARI[1] Dherosh-2 (OP) and commercial Hybrid (F_1) were used where different ways of soil 'N' additions namely 70 kg N/ha applied in 3 splits, 70 kg N/ha in 4 splits, 110 kg N/ha in 3 splits and 110 kg N/ha applied in 4 splits along with control or farmers' practices where 70 kg N/ha was applied at a time during final land preparation were done at factorial Randomized Complete Block Design (RCBD) with three replications. In split application, the amount of N-fertilizer was divided equally according to the doses and the first dose was applied during final land preparation, the following splits were done at 20 days interval stating from 20 days after planting i.e., 20, 40 and 60 days after sowing of okra.

Crop Culturing

The land for the experiment was prepared by ploughing and cross ploughing for six times with a power tiller and subsequent laddering to obtain good tilth and to level the land. All the required manures and fertilizers except urea and muriate of potash (MoP) were applied during final land preparation as per Fertilizer Recommendation Guide-2018 (Ahmed *et al.*, 2018). MoP was applied thrice; at final land preparation, 20 days after sowing and 40 days after sowing and urea was applied as N-source as per treatments. According to the design and aim of the research 36 unit plots of 2 m × 4.5 m in size was prepared in 3 blocks (12 plots per block) maintaining 1.0 m spacing in between blocks and 60 cm spacing in between the plots within the block. Pretreated seeds were primed with water for 8 hrs before direct sowing to the field on 27th of July 2019. To maintain 30 plants in 3 rows having 10 plants per row (spacing; 60 cm × 45 cm), 2 seeds were dibbled in each point and single plant was allowed to grow by removing the other at 5-6 days after germination. Intercultural operations like weeding, irrigation, insect-pests and disease management, lower leaves and shoot pruning etc. were performed accordingly.

Measurement of Vegetative and Reproductive Growth

Vegetative growth parameters like plant height, base diameter (2 cm above soil), number of primary branches/ plant, number of green leaves/plant, canopy dimension and canopy cover, root length, root and shoot fresh weight and root:shoot ratio (fresh weight basis) were estimated at 20, 40, 60 and 80 days after sowing (DAS) and recorded. For measuring root length, root and shoot fresh weight and root : shoot ratio, each time randomly 3 plants were uprooted carefully and data were taken. In all the other cases, 5 plants were randomly selected for data collection. Plants reproductive behaviors namely number of days to first flowering, flowering duration, number of days to first harvest, harvest duration, number of flowers/plant, number of pods/plant, percent pod set, single pod weight, yield/plant and percent pod dry matter content were recorded. Harvesting of green pod was completed finally on 15th of November 2019. In every case, data were collected from 5 randomly selected plants and their averages were considered and single pod weight and dry matter content was calculated by weighing 10 pods and drying the pods throughout the season from the selected plants.

[1] Okra variety released by Bangladesh Agricultural Research Institute (BARI)

Statistical Analysis

Data were assessed with descriptive analysis and two-way ANOVA was performed using MSTAT-C statistical Package software. The treatment means were separated by Fisher's Least Significant Difference (LSD) test, using a p-value of ≤ 0.05 to be statistically significant (Gomez and Gomez, 1984).

Results

Shoot Growth

Increase in shoot growth with the advancement of age is a natural phenomenon but in the off-season varied levels of N-amendments significantly influenced the plant height, stem diameter, number of branches per plant, number of leaves per plant, canopy area and finally shoot fresh weight of the three okra varieties measured at 20, 40, 60 and 80 days after sowing (DAS) (Table-1 to Table-6; Figure-1 and Figure-2). Shoot growth of the treated okra varieties increased steadily up to 80 days after sowing (DAS) but growth rate slowed down after 60 days in both BARI Dherosh-2 and Hybrid variety. The Hybrid variety exhibited the minimum robustness of growth but had the statistically maximum number of branches as well as leaves per plant (3.47 and 30.47, respectively at 80 DAS) while the Local cultivar expressed its potentiality to be the most vigorous plant having maximum plant height, stem diameter, canopy area and shoot fresh weight of 44.47 cm, 4.39 cm, 2038.80 cm^2 and 265.82 g, respectively at 80 DAS. BARI Dherosh-2 had the intermediary shoot growth performances.

Nitrogen doses also had significant impact on shoot growth of okra under study (Figure-2, Table-2 and Table-5). The treatment 110 kg N/ha applied in 4 splits (T_4) performed the best reflecting superiority in terms of stem diameter (4.86 cm), number of branches (3.11/plant), number of leaves (32.89/plant), canopy area (2068.40 cm^2) and shoot fresh weight (273.14 g) at 80 DAS having statistical parity with 110 kg N/ha applied in 3 splits (T_3) treatment whereas plant height was noted maximum in 110 kg N/ha applied in 3 splits (T_3) treatment being statistically identical with that of T_4 treatment. Though plants under control treatment (70 kg N/ha applied at a time during final land preparation; T_0) grew faster as like as the best treatment up to 40 DAS in most of the cases of shoot growth but the rate drastically reduced and ultimately the shortest plant having minimum vigor was registered in control where plant height, stem diameter, number of branches, number of leaves, canopy area and shoot fresh weight were noticed 34.37 cm, 3.37 cm, 2.11/plant, 25.11/plant, 1345.00 cm^2 and 221.83 g, respectively at 80 DAS.

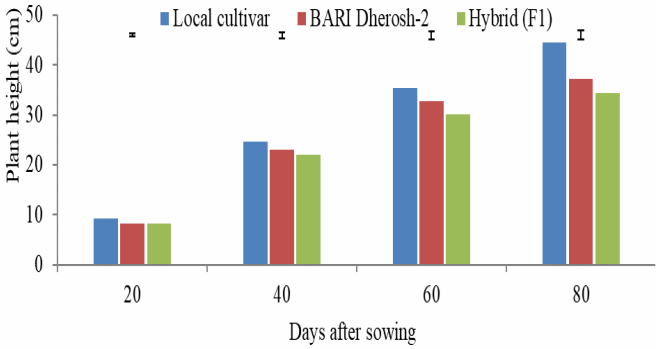

Fig. 1 : Main effect of varieties on plant height of okra at different days after sowing. Vertical bar represents the LSD at $p < 0.05$ level of significance.

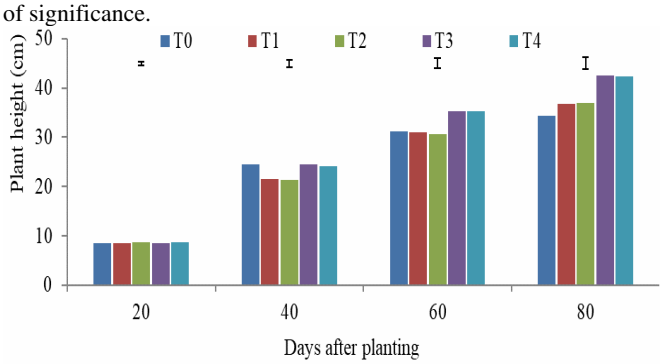

Fig. 2 : Main effect of N-amendments on plant height of okra at different days after sowing. Vertical bar represents the LSD at $p < 0.05$ level of significance. Here, T_0= control; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Furthermore, variety and N-amendment in combination administered significant variations in the plant shoot growth characters up to 80 DAS except at 20 DAS (Table-3 and Table-6). Plant height, stem diameter, canopy coverage and shoot fresh weight at 80 DAS were recorded the highest (49.67 cm, 4.90 cm, 2557.10 cm^2 and 295.85 g, respectively) in Local cultivar when treated with 110 kg N/ha in 4 splits (V_1T_4). While, number of branches (4.33/plant) and number of leaves (35.00/plant) were counted maximum in plants of Hybrid variety under 110 kg N/ha applied in 4 splits (V_1T_4) treatment having been identical with V_1T_3 treatment. Whether, the shortest plant (30.67 cm) having minimum stem diameter (3.27 cm), the lowest canopy coverage (1226.60 cm^2) and minimum shoot fresh weight (206.45 g) was observed in Hybrid variety treated with farmers' practice or control treatment (V_3T_0). Local cultivar receiving almost all the N-amendments and only 70 kg N/ha applied at time resulted in the minimum number of branches (1.67/plant) as well as leaves (24.00/plant), respectively at 80 DAS. Irrespective of variety and N-amendment combinations, number of branches didn't increase after 60 DAS except at V_1T_2 and V_1T_4 treatments.

Table 1 : Main effect of variety on stem diameter and number of leaves per plant of okra at different days after sowing

Variety	Stem Diameter (cm) at different DAS				Number of branches per plant at different DAS			
	20	40	60	80	20	40	60	80
Local cultivar	1.88a	2.63	3.69	4.39	1.0	1.47b	1.67c	1.87c
BARI Dherosh-2	1.68b	2.50	3.61	4.33	1.0	1.87a	2.40b	2.47b
Hybrid variety	1.67b	2.49	3.72	4.18	1.0	1.87a	3.47a	3.47a
LSD (0.05)	0.13	0.24	0.32	0.34	-	0.31	0.38	0.36
CV	10.00	12.56	11.53	10.66	-	24.22	20.13	18.39
Level of significance	**	NS	NS	NS	-	*	**	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively

Table 2 : Main effect of N-amendment on stem diameter and number of leaves per plant of okra at different days after sowing

N-amendment	Stem Diameter (cm) at different DAS				Number of branches per plant at different DAS			
	20	40	60	80	20	40	60	80
T_0	1.76	2.54	2.94c	3.37c	1.0	1.56	2.11c	2.11c
T_1	1.72	2.50	3.70ab	4.24b	1.0	1.78	2.33bc	2.33bc
T_2	1.77	2.43	3.54b	4.38b	1.0	1.56	2.44abc	2.67ab
T_3	1.71	2.62	4.09a	4.67ab	1.0	1.89	2.78ab	2.78ab
T_4	1.77	2.60	4.08a	4.86a	1.0	1.89	2.89a	3.11a
LSD (0.05)	0.17	0.31	0.41	0.44	-	0.41	0.49	0.46
CV	10.00	12.56	11.53	10.66	-	24.22	20.13	18.39
Level of significance	NS	NS	**	**	-	NS	*	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively. Here, T_0= control or farmers' practice where 70 kg N/ha was applied at a time during FLP; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits.

Table 3 : Combined effect of variety and N-amendment on plant height, stem diameter and number of leaves per plant of okra at different days after sowing .

Variety × N-amendment	Plant height (cm) at different DAS				Base diameter (cm) at different DAS				No. of branches/plant at different DAS			
	20	40	60	80	20	40	60	80	20	40	60	80
V_1T_0	9.50	26.27a	33.63bc	37.83def	1.93	2.60	3.10cd	3.50cd	1	1.33	1.67f	1.67f
V_1T_1	9.40	22.87bc	33.13bc	42.40bc	1.93	2.63	3.80abc	4.37ab	1	1.67	1.67f	1.67f
V_1T_2	9.07	22.63bc	33.97bc	43.23b	1.83	2.53	3.47bcd	4.53ab	1	1.00	1.67f	2.00ef
V_1T_3	8.87	26.23a	38.07a	49.23a	1.80	2.70	4.07ab	4.67ab	1	1.67	1.67f	1.67f
V_1T_4	9.43	25.10ab	37.67a	49.67a	1.90	2.70	4.00ab	4.90a	1	1.67	1.67f	2.33def
V_2T_0	8.30	24.40ab	32.03bcd	34.60fgh	1.70	2.43	2.87d	3.33cd	1	1.67	2.00ef	2.00ef
V_2T_1	8.03	21.10c	31.03cde	34.77fgh	1.60	2.47	3.60abc	4.30ab	1	1.67	2.33def	2.33def
V_2T_2	8.37	20.93c	30.53cde	34.80fg	1.73	2.43	3.53a-d	4.50ab	1	2.00	2.33def	2.67cde
V_2T_3	8.30	24.17ab	34.97ab	40.17b-e	1.67	2.60	4.00ab	4.70ab	1	2.00	2.67cde	2.67cde
V_2T_4	8.33	24.17ab	35.30ab	41.23bcd	1.70	2.57	4.03ab	4.83ab	1	2.00	2.67cde	2.67cde
V_3T_0	8.07	22.70bc	28.17e	30.67h	1.63	2.60	2.87d	3.27d	1	1.67	2.67cde	2.67cde
V_3T_1	8.07	20.67c	28.63de	33.23gh	1.63	2.40	3.70abc	4.07bc	1	2.00	3.00cd	3.00cd
V_3T_2	8.53	20.37c	27.60e	32.93gh	1.73	2.33	3.63abc	4.10bc	1	1.67	3.33bc	3.33bc
V_3T_3	8.23	23.03bc	33.03bc	38.33c-f	1.67	2.57	4.20a	4.63ab	1	2.00	4.00ab	4.00ab
V_3T_4	8.47	23.03bc	33.03bc	36.33efg	1.70	2.53	4.20a	4.83ab	1	2.00	4.33a	4.33a
LSD (0.05)	1.30	2.72	3.66	4.12	0.29	0.53	0.71	0.77	-	0.70	0.84	0.80
CV (%)	9.07	7.02	6.68	6.37	10.00	12.56	11.53	10.66	-	24.22	20.13	18.39
Level of significance	NS	**	**	**	NS	NS	**	**	-	NS	**	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively. Here, V_1= Local cultivar, V_2= BARI Dherosh-2 and V_3= Hybrid (F1) variety; T_0= control where 70 kg N/ha was applied at a time during FLP; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Table 4 : Main effect of variety on number of leaves per plant, canopy coverage and shoot fresh weight of okra at different days after sowing

Variety	No. of leaves/plant at different DAS				Canopy coverage at different DAS (cm^2)				Shoot fresh weight at different DAS (g)			
	20	40	60	80	20	40	60	80	20	40	60	80
Local cultivar	5.13	12.07b	21.93c	27.73b	168.79a	968.78	1462.50	2038.80a	40.51	134.36	212.69	265.82a
BARI Dherosh-2	5.20	13.13a	25.27b	28.80b	127.56b	956.43	1442.00	1583.70b	39.20	131.86	208.14	244.27b
Hybrid variety	5.40	13.73a	28.87a	30.47a	136.45b	942.80	1430.10	1487.5b	40.01	130.60	216.06	234.05b
LSD (0.05)	0.39	0.84	1.80	1.64	20.37	104.22	148.79	156.14	2.66	7.31	11.45	10.71
CV	10.08	8.65	9.48	7.56	18.84	14.58	13.77	12.26	8.93	7.38	7.21	5.77
Level of significance	NS	**	**	**	**	NS	NS	**	NS	NS	NS	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,** represent Not significant and Significant at 1% level of probability, respectively

Table 5 : Main effect of N-amendment on number of leaves per plant, canopy coverage and shoot fresh weight of okra at different days after sowing

N-amendment	Number of leaves/ plant at different DAS				Canopy coverage (cm^2) at different DAS				Shoot fresh weight (g) at different DAS			
	20	40	60	80	20	40	60	80	20	40	60	80
T_0	5.33	13.33a	22.89b	25.11c	146.77	1037.10a	1265.10b	1345.00c	40.13	137.44a	194.91b	221.83c
T_1	5.22	12.22b	23.67b	27.00bc	141.25	833.90b	1272.30b	1508.00bc	39.67	124.09b	200.33b	237.65b
T_2	5.11	11.89b	24.11b	28.56b	143.23	801.90b	1280.90b	1570.10b	39.31	121.92b	201.24b	240.62b
T_3	5.22	13.78a	27.78a	31.44a	140.57	1065.20a	1691.30a	2025.20a	39.71	139.76a	231.87a	267.00a
T_4	5.33	13.67a	28.33a	32.89a	149.52	1041.80a	1714.60a	2068.40a	40.71	138.17a	233.15a	273.14a
LSD (0.05)	0.51	1.08	2.32	2.12	26.29	134.55	192.09	201.57	3.44	9.43	14.78	13.82
CV	10.08	8.65	9.48	7.56	18.84	14.58	13.77	12.26	8.93	7.38	7.21	5.77
Level of significance	NS	**	**	**	NS	**	*	**	NS	**	**	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively. Here, T_0= control or farmers' practice where 70 kg N/ha was applied at a time during FLP; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Table 6 : Combined effect of variety and N-amendment on plant height, stem diameter and number of leaves per plant of okra at different days after sowing

Variety × N-amendment	Number of leaves per plant at different DAS				Canopy coverage (cm^2) at different DAS				Shoot fresh weight (g) at different DAS			
	20	40	60	80	20	40	60	80	20	40	60	80
V_1T_0	5.33	12.33bcd	21.00d	24.00g	178.91a	1062.40ab	1326.70c	1472.40cde	41.67	141.20ab	199.98de	234.40de
V_1T_1	5.33	11.67cd	21.00d	26.00efg	176.10abc	861.20bcd	1299.70c	1821.40bc	41.80	127.37a-f	202.88b-e	258.03bcd
V_1T_2	5.00	10.67d	21.33d	27.67def	160.89a-d	790.10d	1360.00bc	1931.90b	39.13	121.76def	206.44b-e	260.41bc
V_1T_3	4.67	13.00abc	23.00cd	29.00c-f	151.00a-d	1102.80a	1666.50ab	2411.40a	38.07	143.01a	228.19ab	280.41ab
V_1T_4	5.33	12.67abc	23.33cd	32.00abc	177.06ab	1027.30abc	1659.50ab	2557.10a	41.87	138.47abc	225.96abc	295.85a
V_2T_0	5.33	13.67ab	23.00cd	25.67fg	130.89cd	1056.10ab	1308.90c	1336.00e	39.60	137.29a-d	194.08e	224.63ef
V_2T_1	5.00	11.67cd	24.00bcd	27.00efg	117.18d	783.10d	1286.50c	1379.20de	37.73	119.84f	197.96e	230.80e
V_2T_2	5.00	12.33bcd	24.00bcd	28.67c-f	127.33d	810.00cd	1267.10c	1434.60de	38.73	123.29c-f	196.53e	238.40cde
V_2T_3	5.33	14.00ab	27.67b	31.00bcd	130.85cd	1064.90ab	1662.80ab	1836.70b	39.93	139.43abc	225.47a-d	260.70bc
V_2T_4	5.33	14.00ab	27.67b	31.67abc	131.55bcd	1068.00ab	1684.60ab	1931.90b	40.00	139.44abc	226.68ab	266.80b
V_3T_0	5.33	14.00ab	24.67bcd	25.67fg	130.50c	992.70a-d	1159.60c	1226.60e	39.13	133.83a-f	190.68e	206.45f
V_3T_1	5.33	13.33abc	26.00bc	28.00def	130.49c	857.50bcd	1230.60c	1323.30e	39.47	125.05b-f	200.14de	224.10ef
V_3T_2	5.33	12.67abc	27.00bc	29.33cde	141.47a-d	805.60cd	1215.60c	1343.80e	40.07	120.71ef	200.74cde	223.04ef
V_3T_3	5.67	14.33a	32.67a	34.33ab	139.86a-d	1028.10abc	1744.80a	1827.40b	41.13	136.84a-e	241.94a	259.90bc
V_3T_4	5.33	14.33a	34.00a	35.00a	139.96a-d	1030.10abc	1799.80a	1716.20bcd	40.27	136.60a-e	246.81a	256.76bcd
LSD (0.05)	0.88	1.88	4.02	3.67	45.54	233.05	332.70	349.14	5.96	16.33	25.61	23.94
CV (%)	10.08	8.65	9.48	7.56	18.84	14.58	13.77	12.26	8.93	7.38	7.21	5.77
Level of significance	NS	**	**	**	*	*	**	**	NS	**	**	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively. Here, V_1= Local cultivar, V_2= BARI Dherosh-2 and V_3= Hybrid (F1) variety; T_0= control where 70 kg N/ha was applied at a time during FLP; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Root Growth

Okra varieties under different nitrogen amendments had distinct rooting characters thereby exhibiting statistical variations in root lengths and weights except at 20 DAS (Table 7, 8 and 9). Root length of Local cultivar increased rapidly up to 80 DAS producing the longest root having maximum fresh weight throughout the growth period (24.39 cm and 48.11 g, respectively at 80 DAS). Root growth rate of the other two varieties slowed down after 60 DAS and the extent was more in Hybrid variety exhibiting the shortest and lightest root (20.39 cm and 41.21 g, respectively at 80 DAS. Meanwhile, in terms of N-amendments root growth rate was significantly higher in plants treated with 110 kg N/ha applied in 3/4 splits (T_3 and T_4) producing the statistically longest root up to 80 DAS (24.39 cm and 24.53 cm, respectively) and both treatments had numerically same root fresh weight (50.40 g). Control plants possessed the shortest (19.03 cm) as well as lightest (35.96 g) root at 80 DAS. Moreover, in variety-N combinations, root length and fresh weight at earlier days after sowing i.e., 20 and 40 DAS though differed significantly; statistical similarity was noticed at latter DAS. At 80 DAS, the longest (21.93 cm) as well as heaviest (55.95 g) root was noted in Local cultivar under 110 kg N/ha applied in 4 splits (V_1T_4) which had statistical harmony with V_1T_3 combination for root length and V_2T_3 and V_2T_4 for root fresh weight. Significantly minimum root length and root fresh weight at 80 DAS (17.70 cm and 32.94 g, respectively) was measured in Hybrid variety under control treatment (V_3T_0) but the same variety receiving 110 kg N/ha applied in 3/4 splits (V_3T_3 andV_3T_4) exhibited the statistically uniform root length to the best one and the highest root fresh weight at 60 DAS.

Table 7 : Main effect of variety on root length and root fresh weight of okra

Variety	Root length (cm) at different DAS				Root fresh weight (g) at different DAS			
	20	40	60	80	20	40	60	80
Local cultivar	8.30	15.03a	20.15a	24.39a	6.04	21.81	37.48	48.11a
BARI Dherosh-2	7.93	14.45ab	19.28b	21.59b	5.74	20.90	36.40	42.39b
Hybrid variety	7.97	14.10b	18.74b	20.39c	5.78	20.32	37.06	41.21b
LSD (0.05)	0.34	0.66	0.85	0.96	0.29	1.05	1.61	2.10
CV	5.69	6.08	5.88	5.79	6.71	6.72	5.83	6.39
Level of significance	NS	*	**	**	NS	NS	NS	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively

Root to shoot ratio (Fresh weight basis)

Local cultivar had maximum root to shoot ratio upto 60 DAS and BARI Dherosh-2 then occupied the position for the next period (Figure-3). Whereas, control treatment exhibited the lowest root:shoot ratio at all the DAS compared to all other treatments. At 60 and 80 DAS, 110 kg N/ha applied in 4 splits (T_4) (0.179) and 3 splits (T_3) (0.196), respectively resulted in the highest root:shoot ratio in okra under study (Figure-4). Once again, significant influence was noticed on root to shoot ratio of okra due to the combined effect of variety and N-amendment (Table-9). At 40 DAS, statistically maximum root:shoot ratio (0.168) was recorded in Local cultivar fertilized with 70 kg N/ha in 3 splits (V_1T_2) and minimum ratio (0.150) was noted in BARI Djerosh-2 under control (V_2T_0). At 60 DAS, not statistically but numerically superior root:shoot ratio (0.181) was estimated in V_2T_4 combinations while minimum ratio (0.170) was in V_3T_1 combination. Furthermore, at 80 DAS, significantly the highest root:shoot ratio (0.207) was calculated in V_2T_4 treatment combination being statistically similar to that of V_1T_3 and V_2T_3 while the lowest root:shoot ratio (0.160) was observed in V_3T_0 treatment.

Table 8 : Main effect of N-amendment on root length and root fresh weight of okra

N-amendment	Root length (cm) at different DAS				Root fresh weight (g) at different DAS			
	20	40	60	80	20	40	60	80
T_0	7.47d	14.41b	17.59b	19.03c	5.34	20.83b	32.50c	35.96c
T_1	7.83cd	13.69b	18.51b	21.18b	5.67	19.66b	34.68b	40.45b
T_2	8.06bc	13.66b	18.40b	21.48b	5.84	19.59b	34.90b	42.31b
T_3	8.38ab	15.50a	21.23a	24.39a	6.12	22.58a	41.29a	50.40a
T_4	8.60a	15.39a	21.22a	24.53a	6.30	22.39a	41.53a	50.40a
LSD (0.05)	0.44	0.85	1.1	1.24	0.38	1.36	2.08	2.71
CV	5.69	6.08	5.88	5.79	6.71	6.72	5.83	6.39
Level of significance	**	**	**	**	NS	**	**	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represent Not significant, Significant at 5% and Significant at 1% level of probability, respectively. Here, T_0= control or farmers' practice where 70 kg N/ha was applied at a time during FLP; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

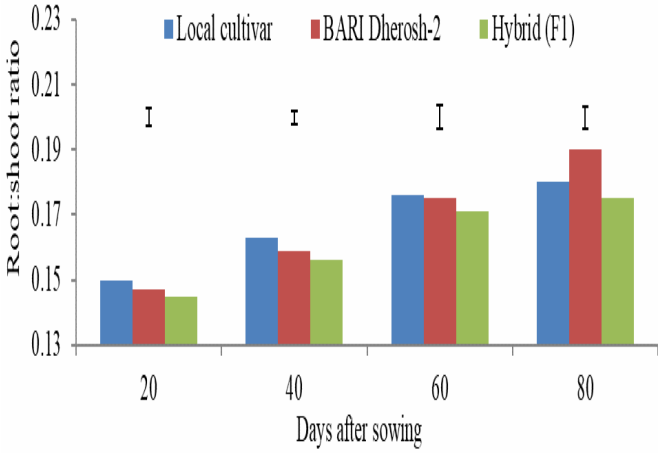

Fig. 3 : Main effect of varieties on root to shoot ratio of okra at different days after sowing. Vertical bar represents the LSD at $p < 0.05$ level of significance.

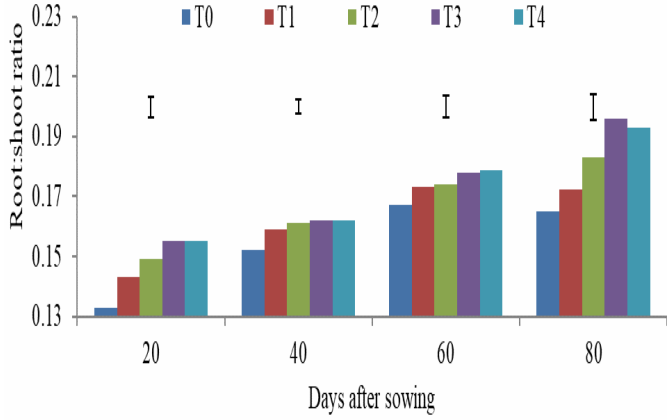

Fig. 4 : Main effect of N-amendments on root to shoot ratio of okra at different days after sowing. Vertical bar represents the LSD at $p < 0.05$ level of significance. Here, T_0= control, T_1= 70 kg N/ha in 3 splits, T_2= 70 kg N/ha in 4 splits, T_3= 110 kg N/ha in 3 splits and T_4= 110 kg N/ha in 4 splits

Table 9 : Combined effect of variety and N-amendment on root length and root fresh weight of okra at different days after sowing

Variety × N-amendment	Root length (cm) at different DAS				Root fresh weight (g) at different DAS				Root:shoot ratio at different DAS			
	20	40	60	80	20	40	60	80	20	40	60	80
V_1T_0	7.80b-e	15.00abc	18.37def	20.33de	5.60bcd	21.76a-d	34.14b	37.85g	0.135	0.155def	0.171	0.162f
V_1T_1	8.13a-d	14.10bcd	19.10cde	23.27b	5.91abc	20.28b-e	35.56b	43.30def	0.142	0.160a-d	0.176	0.168ef
V_1T_2	8.20abc	14.20bcd	19.47bcd	24.03b	5.96ab	20.44b-e	36.19b	47.16cd	0.152	0.168a	0.175	0.181cde
V_1T_3	8.47ab	16.10a	21.93a	26.90a	6.19ab	23.55a	40.84a	56.29a	0.163	0.165abc	0.179	0.201ab
V_1T_4	8.90a	15.77a	21.90a	27.40a	6.56a	23.02a	40.67a	55.95a	0.157	0.166ab	0.180	0.189bcd
V_2T_0	7.23e	14.23bcd	17.67def	19.07ef	5.16d	20.58b-e	32.87bc	39.14fg	0.131	0.150f	0.169	0.174def
V_2T_1	7.67cde	13.60cd	18.50def	20.53de	5.54bcd	19.54de	34.39b	41.03efg	0.147	0.163abc	0.174	0.178cde
V_2T_2	7.97b-e	13.57cd	18.30def	20.77cde	5.78bcd	19.46de	34.01bc	45.32cde	0.149	0.158c-f	0.174	0.191bc
V_2T_3	8.30abc	15.40ab	20.83abc	23.50b	6.07ab	22.40abc	39.87a	52.02ab	0.152	0.161a-d	0.177	0.200ab
V_2T_4	8.47ab	15.47ab	21.10ab	24.10b	6.18ab	22.50ab	40.88a	55.05a	0.155	0.161a-d	0.181	0.207a
V_3T_0	7.37de	14.00bcd	16.73f	17.70f	5.26cd	20.14cde	30.49c	32.94h	0.135	0.151ef	0.160	0.160f
V_3T_1	7.70b-e	13.37d	17.93def	19.73ef	5.56bcd	19.15e	34.09bc	38.23g	0.141	0.153def	0.170	0.171ef
V_3T_2	8.00b-e	13.20d	17.43ef	19.63ef	5.79bcd	18.87e	34.51b	39.57fg	0.145	0.157c-f	0.173	0.177cde
V_3T_3	8.37abc	15.00abc	20.93abc	22.77bc	6.11ab	21.77a-d	43.15a	48.39bc	0.149	0.159bcd	0.178	0.186cd
V_3T_4	8.43abc	14.93abc	20.67abc	22.10bcd	6.18ab	21.65a-d	43.04a	46.92cd	0.154	0.159b-e	0.174	0.183cde
LSD (0.05)	0.77	1.48	1.91	2.14	0.66	2.36	3.61	4.76	0.012	0.0082	0.0125	0.0131
CV (%)	5.69	6.08	5.88	5.79	6.71	6.72	5.83	6.28	4.86	3.10	4.30	4.43
Level of significance	**	**	**	**	**	**	**	**	**	**	NS	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,*,** represents Not significant, Significant at 5% and Significant at 1% level of probability, respectively. Here, V_1= Local cultivar, V_2= BARI Dherosh-2 and V_3= Hybrid (F1) variety; T_0= control or farmers' practices where 70 kg N/ha was applied at a time during final land preparation; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Time and duration of flowering and harvesting

Number of days required for first flowering, flowering duration, number days required for first harvest, harvesting duration, number of pods/plant and percent pod set varied significantly among the varieties and among the variety-N combinations while all but days required for the first flowering was significant for N-amendments (Table 10, 11 and 12, respectively). Flower initiation occurred in minimum possible time (39.27 days) as well as early harvesting (in 43.67 days) was noticed in the Hybrid variety. While, the Local cultivar took maximum time for initiating the first flower (49.00 days) and first harvesting (54.93 days) as well. Besides, in BARI Dherosh-2 flowering occurred for the longest duration (56.13 days) and thereby harvesting duration was maximum (57.00 days). Flowering and harvesting was accomplished within the shortest period (41.13 and 42.00 days, respectively) in the Local cultivar (Table-10). In terms of N-amendments, no variation was noticed for the first flowering but statistically the most delayed harvesting was noticed in plants where 70 kg N/ha was applied in 3 splits (T_1) and 4 splits (T_2) while minimum time for the same was observed in plants receiving 110 kg N/ha in 3 (T_3) and 4 (T_4) installments. Statistically the lengthiest flowering duration (50.33 days) and harvesting duration (51.22 days) was recorded in 110 kg N/ha applied in 4 splits (T_4) treatment while the control treatment accounted for the shortest period of flowering (43.22 days) as well as harvesting (43.78 days) (Table-11). In off-season, flowering and fruiting behavior of okra was significantly varied due to the combination effect of variety and N-amendment too (Table-8), where Local cultivar treated with 110 kg N/ha applied in 3 splits (V_1T_3) and 110 kg N/ha applied in 4 splits (V_1T_4) required maximum time for flowering (51.67 days) and harvesting (58.00 days), respectively exhibiting statistical similarity with each other along with V_1T_2. Flowering duration and harvesting duration of the combined effect followed similar trend of sole effect of N-amendments showing maximum duration by V_2T_4 in both cases (60.33 and 61.67 days, respectively) which had statistical similarity with V_2T_3. On the other hand, harvest duration for V_1T_0 treatment was recorded for only 37.67 days being statistically dissonant from all other treatment combinations (Table-12).

Flowers and pods setting

Number of flowers and pods per plant and pod set percentage differed significantly due to application of varied nitrogen amendments to different okra varieties in offseason (Table 10, 11 and 12). Number of flowers and number of pods per plant as well as pod set percentage were statistically inferior in Local cultivar to that of the others. Number of flowers (26.67/plant) and number of pods (25.27/plant) was counted maximum in Hybrid variety but superiority in pod set percentage (95.07%) was observed in BARI Dherosh-2. BARI Dherosh-2 and Hybrid variety showed statistical unity with each other with respect to flowers and pod setting characters (Table-10). Again, plants fertilized with 110 kg N/ha in 3 splits (T_3) and 4 splits (T_4) resulted in statistically maximum number of flowers and pods per plant and pod set percent as well (28.33, 26.89 and 94.55 and 28.78, 27.11 and 93.79, respectively). Whereas, control (70 kg N/ha applied once at FLP) exhibited the lowest number of flowers (19.33) and pods (16.44) per plant and pod set percent (84.44) (Table-11). Number of flowers/plant and pods/plant was counted the most in Hybrid cultivar receiving 110 kg N/ha in 3 installments (V_3T_3) which had similar statistics with that of V_2T_3, V_2T_4 and V_3T_4 treatments. Pod set percentage significantly ranged from 73.09 % in V_1T_0 to 97.70% in V_2T_4 having uniformity with all the N-amendment and variety combinations for BARI Dherosh-2 and Hybrid variety and V_1T_3 (Table-12).

Table 10 : Main effect of variety on flowering and fruiting behavior of okra in the off-season

Variety	Days to first flowering	Flowering duration	Days to first harvest	Harvest duration	Number of flowers/ plant	Number of pods/ plant	Pod set (%)	Single pod weight (g)	Yield/ plant (g)	Yield /ha (t)	Pod dry matter content (%)
Local cultivar	49.00a	41.13c	54.93a	42.00c	21.93b	18.40b	83.10b	16.67a	309.70b	10.32b	29.63b
BARI Dherosh-2	41.87b	56.13a	46.27b	57.00a	25.87a	24.73a	95.07a	14.66b	366.37a	12.21a	30.96a
Hybrid variety	39.27c	43.27b	43.67c	43.80b	26.67a	25.27a	94.46a	14.70b	374.03a	12.47a	28.72c
LSD (0.05)	2.06	1.01	2.19	0.85	1.23	1.76	3.65	1.07	31.55	1.05	0.62
CV (%)	6.36	2.87	6.07	2.40	6.66	10.32	5.37	9.37	12.05	12.05	2.78
Level of significance	**	**	**	**	**	**	**	**	*	*	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; ** represents Significant at 1% level of probability

Table 11 : Main effect of N-amendment on flowering and fruiting behavior of okra in the off-season

N-amendment	Days to first flowering	Flowering duration	Days to first harvest	Harvest duration	Number of flowers /plant	Number of pods /plant	Pod set (%)	Single pod weight (g)	Yield/ plant (g)	Yield /ha (t)	Pod dry matter content (%)
T_0	42.78	43.22c	47.67	43.78d	19.33c	16.44c	84.44c	14.00b	228.06c	7.60c	29.60bc
T_1	43.11	45.11b	47.67	46.00c	23.22b	21.00b	89.67b	15.23ab	315.97b	10.53b	29.18c
T_2	44.89	46.33b	49.78	47.00c	24.44b	22.56b	91.95ab	14.80b	331.66b	11.06b	29.53bc
T_3	43.44	49.22a	47.67	50.00b	28.33a	26.89a	94.55a	16.28a	434.26a	14.48a	30.43a
T_4	42.67	50.33a	48.67	51.22a	28.78a	27.11a	93.79ab	16.41a	440.24a	14.68a	30.10ab
LSD (0.05)	2.66	1.30	2.83	1.10	1.60	2.27	4.71	1.39	40.73	1.36	0.80
CV	6.36	2.87	6.07	2.40	6.66	10.32	5.37	9.37	12.05	12.05	2.78
level of significance	NS	**	NS	**	**	**	**	**	**	**	*

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; NS,** represent Not significant and Significant at 1% level of probability, respectively. Here, T_0= control or farmers' practices where 70 kg N/ha was applied at a time during final land preparation; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Table 12 : Combined effect of variety and N-amendment on flowering and fruiting behavior of okra under semi-arid upland condition in the off-season

Variety × N-amendment	Days to first flowering	Flowering duration	Days to first harvest	Harvest duration	Number of flowers /plant	Number of pods /plant	Pod Set (%)	Single Pod weight (g)	Yield/ plant (g)	Yield/ha (t)	Pod dry matter content (%)
V_1T_0	47.00bc	37.00f	52.33bc	37.67h	17.33e	12.67f	73.09e	15.43abc	195.97i	6.53i	29.59bcd
V_1T_1	46.67bcd	39.67e	51.67cd	41.00fg	19.67de	16.00ef	81.24de	16.63ab	267.17gh	8.91gh	29.05cde
V_1T_2	51.00ab	41.33de	57.00ab	42.33efg	23.00bc	19.00de	82.53cd	16.00abc	304.80efg	10.16efg	30.00bc
V_1T_3	51.67a	42.33d	55.67abc	43.00e	24.33b	22.00cd	90.55abc	17.53a	385.37cd	12.85cd	29.64bcd
V_1T_4	48.67ab	45.33c	58.00a	46.00d	25.33b	22.33cd	88.10bcd	17.77a	395.20bcd	13.17bcd	29.85bc
V_2T_0	42.33def	52.67b	47.00def	53.00c	19.33de	17.33e	89.56abc	12.73d	219.80hi	7.33hi	30.86ab
V_2T_1	43.00cde	53.33b	47.33de	54.33bc	25.00b	23.33c	93.17ab	14.70bcd	341.87de	11.40de	30.67ab
V_2T_2	42.67cde	54.67b	47.00def	55.00b	25.33b	24.67bc	97.33a	14.33bcd	352.23de	11.74de	30.45b
V_2T_3	40.67ef	59.67a	45.00ef	61.00a	29.00a	28.33ab	97.58a	15.83abc	448.47abc	14.95abc	32.03a
V_2T_4	40.67ef	60.33a	45.00ef	61.67a	30.67a	30.00a	97.70a	15.70abc	469.50a	15.65a	30.80ab
V_3T_0	39.00ef	40.00e	43.67ef	40.67g	21.33cd	19.33de	90.67abc	13.83cd	268.40fgh	8.95fgh	28.34de
V_3T_1	39.67ef	42.33d	44.00ef	42.67ef	25.00b	23.67c	94.60ab	14.37bcd	338.87def	11.30def	27.84e
V_3T_2	41.00ef	43.00d	45.33ef	43.67e	25.00b	24.00c	95.98ab	14.07cd	337.93def	11.26def	28.13e
V_3T_3	38.00f	45.67c	42.33f	46.00d	31.67a	30.33a	95.51ab	15.47abc	468.93a	15.63a	29.61bcd
V_3T_4	38.67ef	45.33c	43.00ef	46.00d	30.33a	29.00a	95.56ab	15.77abc	456.03ab	15.20ab	29.66bcd
LSD (0.05)	4.61	2.25	4.90	1.91	2.76	3.94	8.16	2.40	70.54	2.35	1.38
CV (%)	6.36	2.87	6.07	2.40	6.66	10.32	5.37	9.37	12.05	12.05	2.78
Level of significance	**	**	**	**	**	**	**	*	**	**	**

Means in a column followed by the same letters are not significantly different at $p \leq 0.05$ level of significance; ** represents Significant at 1% level of probability. Here, V_1= Local cultivar, V_2= BARI Dherosh-2 and V_3= Hybrid (F1) variety; T_0= control or farmers' practices where 70 kg N/ha was applied at a time during final land preparation; T_1= 70 kg N/ha applied in 3 splits, T_2= 70 kg N/ha applied in 4 splits, T_3= 110 kg N/ha applied in 3 splits and T_4= 110 kg N/ha applied in 4 splits

Single pod weight, Yield and Pod dry matter content

Single pod weight, yield/plant, yield/ha and pod dry matter content of three okra varieties grown under semi-arid condition in the off-season varied with N-amendments and variety-N interactions (Table-10, 11 and 12). Local cultivar produced the heaviest fruit (16.67 g) but gave the lowest pod yield (324.09 g/plant and 10.32 t/ha). While, single pod weight and pod yield per plant was statistically similar in BARI Dherosh-2 and Hybrid variety but numerically higher yield in Hybrid variety (374.03 g/plant and 12.47 t/ha). Pods

of BARI Dherosh-2 contained maximum dry matter (30.96 %) among the three varieties while pod dry matter content was minimum (28.72 %) in Hybrid variety (Table-10). Again, plants treated with 110 kg N/ha applied in 4 splits (T_4) gave the highest yield (440.24 g/plant and 14.68 t/ha) producing the heaviest pod (16.41 g) and was statistically similar with T_3 treatment for all these three parameters. Control treatment had the lowest yield (228.06 g/plant and 7.60 t/ha). Dry matter content in pod was observed the highest (30.43 %) in T_3 treatment having statistical harmony with T_4 treatment and the lowest pod dry matter (29.18 %) was measured in T_1 treatment (Table-11). The combination effect also revealed similar type of observation for single pod weight, yield and pod dry matter content where Local cultivar supplied with 110 kg N/ha in 4 splits (V_1T_4) had the largest fruit in terms of weight (17.77 g) having the closest statistical similarity with V_1T_3. Pod yield was measured statistically maximum (469.50 g/plant and 15.65 t/ha) in BARI Dherosh-2 with 110 kg N/ha applied in 4 splits (V_2T_4) which had similarity with V_2T_3, V_3T_3 and V_3T_4. Statistically minimum yield (195.97 g/plant and 6.53 t/ha) was observed in control treated Local cultivar (V_1T_0). Again, pods of BARI Dherosh-2 fertilized with 110 kg N/ha applied in 3 splits (V_2T_3) had the highest dry matter (32.03 %) which had statistical unity with all other N-BARI Dherosh-2 combinations except V_2T_2. On the other hand, Hybrid variety combined with 70 kg N/ha applied in 3 splits (V_3T_1) exhibited the lowest dry matter content (27.84 %) which was statistically alike with V_3T_2 (Table-12).

Discussion

Besides genetic potentiality of crop species/cultivars on growth and reproduction, nitrogen, amongst the nutrients, has the ability to promote plant growth as the nutrient element is directly associated with enhanced cell division and formation of more tissues resulting in profuse vegetative growth and thereby increased plant height (Firoz, 2009). Superiority in most of the vegetative parameters in the Local cultivar was due to its natural robustness of growth. Also, the Local cultivar had the inherent genetic capability to cope up with the prevailing soil and weather condition of the growing region in the off-season. But the reproductive behaviors of Local cultivar were inferior to the others. In few cases Hybrid variety lost its growth speed up to 80 DAS was might be the reflection of varietal potentiality. Optimum level of vegetative growth and statistically similar to the highest yielder (Hybrid variety) was the representation of the varietal characters. Olamide *et al*. (2012) noticed that local okra got luxuriant growth upon nutrient supply. While Singh *et al*. (2018) noted that among five okra varieties, the local cultivar exhibited superior vegetative growth more than 100 days after planting but resulted in the lowest yield as per its genetic potentiality. Again, robust vegetative growth of Local cultivar due to higher doses of nitrogen was the resultant of more N uptake by lengthy and healthy roots as reported by Ruža *et al*. (2013) in potato.

Increase in the application of nitrogen rate and installments was accounted for the increase in vegetative growth components of plants and resulted in more branching with new leaf formation, higher number of roots with higher root biomass. Increased number of branches as well as a greater number of leaves with higher N doses and application installments came to produce higher canopy area resulting in high shoot biomass. Statistically minimum vegetative growth from control treatment might be due to its poor nutritional status which resulted in retarded growth. Khan *et al*. (2013) and Uddin *et al*. (2014) noticed that nitrogen ensured favorable condition for the growth of okra plant with optimum vegetative growth and the ultimate results was the tallest plant having higher base diameter and maximum number of branches and leaves. Singh *et al*. (2007) recorded maximum plant diameter with the application of 100 kg N/ha whereas Ogunlela *et al*. (2005) reported that nitrogen (N) promotes branching and leaf growth. Moniruzzaman *et al*. (2007) found similar results and reported that plants that grew in the pots treated with N produced higher number of leaves per plant than those of other fertilizers. Besides shoot growth, root morphology also greatly influenced by soil nitrogen amendments (Qi *et al*., 2019; Costa *et al*., 2013).

Though okra is an indeterminate plant, but attainment of proper physical growth and physiological maturity is essential to set flowers and fruits. Here, plants those received higher nitrogen frequently got expected growth earlier than those were unhealthy. Plant growth and development, especially flowering as well as fruiting, is dependent on the interaction of many complex processes which are influenced by both genetic and environment. Smith *et al*. (2022) investigated that common beans under long duration nutrient supplements produce flowers and fruits for longer duration. Nutrient particularly N is the prime element of leaf chlorophyll; healthy leaf is accountable for higher photosynthate accumulation as well as hormonal regulation to prevent formation of abscission layers in flowers resulting in maximum flowering and fruit setting. The findings are in line with Monti *et al*. (2016) who indicated that low N availability causes reduction in leaf N, reduced number of flowers and low fruit set in pea. Lee *et al*. (1990) also found similar results that N rates up to 100 kg/ha could increase the green pod number of okra. On the other hand, Jana *et al*. (2010) reported that 150 kg N/ha produced the highest number of fruits (13.7/plant). Increased size of green pod due to the application of N because of the mobility of photosynthates from the source to sink that also resulted in higher dry matter content in pod. Similar observation of increased fruit weight was also recorded by Sultana *et al*. (2022) in egg-plant and Howlader *et al*. (2019) in tomato. Uddin *et al*. (2014) reported that maximum yield was found from 110 kg N/ha (16.4 t/ha) while minimum yield from 0 kg N/ha (12.3 t/ha). Similarly, Jana *et al*. (2010) and Akanbi *et al*. (2010) reported that application of N led to significant influence on fresh fruit yield of okra. Thereafter, it is evident that nitrogen amendments can significantly influence the okra yield in the lean period of vegetable cultivation.

Conclusion

In the post monsoon period having prevailed soil nutrient shortage especially ‘N’ in the north-western part of Bangladesh, varied nitrogen doses were applied at different frequencies to three okra varieties and the results reflected that, five different ‘N’ amendments significantly influenced the growth and production in such challenging condition. Though Local okra cultivar showed vigorous growth in most of the vegetative parameters, promising reproductive behavior of BARI Dherosh-2 and Hybrid (F_1) variety made them the highest yielder (12.21 t/ha and 12.47 t/ha, respectively). On the other hand, 110 kg N/ha applied in 3 or 4 installments resulted in auspicious vegetative as well as reproductive growth of okra with the yield of 14.48 t/ha and

14.68 t/ha, respectively. Combinely, BARI Dherosh-2 treated with 110 kg N/ha applied in 4 splits produced maximum yield (469.50 g/plant and 15.65 t/ha) and Hybrid variety with same N-amendments also had statistically uniform yield. Local cultivar was the least yielder when 70 kg N/ha was applied at a time during the final land preparation (195.97 g/plant and 6.53 t/ha).

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