EFFECT OF NITROGEN ON GROWTH PARAMETERS AND YIELD OF RED AMARANTH (*Amaranthus spp.*)

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF NITROGEN ON GROWTH PARAMETERS AND YIELD OF RED AMARANTH (Amaranthus spp.)"*** submitted to Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Botany**, embodies the result of a piece of bona fide research work carried out by **MUSHABBIR HOSSAIN**, Registration No. **09-03651** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: December, 2015
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TO MY

BELOVED PARENTS

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The Author

EFFECT OF NITROGEN ON GROWTH PARAMETERS AND YIELD OF RED AMARANTH (*Amaranthus spp.*)

BY

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ABSTRACT

A field experiment was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November to December (*Rabi* season), 2015 to find out the effect of different levels of nitrogen on growth parameters and yield of red amaranth. The experiment comprised of three red amaranth varieties *viz.* BARI Lalshak-1, Altapety, and Local variety which were grown with four levels of nitrogen *viz.* 0, 60, 90 and 120 kg ha^{-1}. The experiment was chalked out in the Randomized Complete Block Design (RCBD) with three replications. Along with variety and nitrogen, the interaction showed significant variation in case of most of the parameters studied. The highest plant height (37.81 cm), maximum number of leaves $plant^{-1}$ (14.50), stem diameter (9.93 mm), leaf area (538.0 cm^2),fresh weight $plant^{-1}$ (27.07 g), dry weight $plant^{-1}$ (1.11 g) and yield (12.71 t ha^{-1}) were recorded from the variety BARI Lalshak-1 at harvest (36 days after sowing) whereas the minimum from Local variety. Considering different level nitrogen the highest plant height (36.67 cm), number of leaves $plant^{-1}$ (13.78), stem diameter (9.74 mm), dry weight $plant^{-1}$ (1.03 g) and yield (12.73 t ha^{-1}) were obtained from 90 kg N ha^{-1}, while the minimum from 0 kg N ha^{-1}. The maximum leaf area (503.2 cm^2) and weight $plant^{-1}$ (23.48 g) were from 120 kg N ha^{-1} and the minimum from control dose. BARI Lalshak-1 with 90 kg N ha^{-1} provided the highest plant height (44.73 cm), number of leaves $plant^{-1}$ (15.67), stem diameter (10.83 mm), leaf area (622.20 cm^2), weight $plant^{-1}$ (30.90 g), dry weight $plant^{-1}$ (1.32 g) and yield (14.80 t ha^{-1}) while the lowest from Local variety with control dose except plant height.

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LIST OF ABBREVIATIONS

%	=	Percent
0^oC	=	Degree Celsius
AEZ	=	Agro-Ecological Zone
ANOVA	=	Analysis of Variance
BARC	=	Bangladesh Agricultural Research Council
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
Cont'd	=	Continued
CV%	=	Percentage of Coefficient of Variance
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et. al.	=	And others
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
ha^{-1}	=	Per hectare
J.	=	Journal
Kg	=	Kilogram
LSD	=	Least Significant Difference
mm	=	millimeter
N	=	Nitrogen
NPK	=	Nitrogen, Phosphorus and Potassium
pH	=	Hydrogen ion concentration
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
SRDI	=	Soil Resources and Development Institute
T	=	Ton
UNDP	=	United Nations Development Program
viz.	=	Namely

CHAPTER I

INTRODUCTION

Red amaranth is one of the most important and widely grown vegetables. Among the vegetables of tropics, amaranths are very easy to grow. Amaranth is probably the most popular vegetables due to its short duration, quick growing habit and riches in vitamins and minerals. Amaranth may be a promising source of protein to those who are gluten sensitive because its protein does not contain gluten like wheat, corn, millet, wild rice and oats. The leaves and stem of amaranth are rich in protein, fat, calcium, phosphorous, β-carotene, riboflavin, niacin, sodium, iron and ascorbic acid. Calcium, iron and phosphorus are the most important elements among the minerals present in amaranth (FAO, 2003). Again it contains food energy of about 43 caloric per 100 g edible portion which is higher than that of any other common vegetables except potato and taro. The harvested amaranth is 50-80% edible (Oke, 1980). Amaranth leaves are rich and inexpensive source of dietary fibre, protein, vitamins and a wide range of minerals (Shukla *et al.* 2006).

The leafy amaranth is said to be the native of India (Shanmugavelu, 1989; Nath, 1976). It is a popular vegetable in Bangladesh because of its cheapest price, quick growing character and higher yield potential. Among the leafy types, red amaranth (*Amaranthus tricolor* L.) is the most commonly cultivated species in Bangladesh (Shanmugavelu, 1989; Nath, 1976). It plays an important role both in nutrition and food security of Bangladesh. (Tutonic and Knorr, 1995).

Red amaranth is cultivated all over the country in any season due to its adaptability to a wide range of soil and climate (Alam *et al.,* 2007).The total production of amaranth was 69889 metric tons in 2014-15 an area of 26422 acres in Bangladesh (BBS, 2015). However, during winter its growth and development is slower than summer and rainy season (Bose *et al*., 1993). Reasonable yield can be achieved easily from red amaranths even in poor soils.

Growth, yield and quality of red amaranth depend on nutrient availability in soil, which is related to the judicious application of manures and fertilizers. For proper crop production, application of fertilizer at optimum dose is one of the most important factors.

Nitrogen increases the vegetative growth of plants and produces good quality foliage and promotes carbohydrate synthesis. Like other vegetables, application of nitrogen is very essential for red amaranth cultivation. It is necessary for its growth and development, particularly for growth of leaf and healthy shoot development. Nitrogen is required for quick vegetative growth and increased yield. Nitrogen is essential for producing protoplasm and other different compound such as chlorophyll, phosphide, alkali, enzyme, hormone, vitamins, nucleoprotein, RNA, DNA, etc. It is important for metabolic activities. Nitrogen enhances the shoot growth and larger size succulent and attractive leaf which are most desirable for leafy vegetables. Cation exchange capacity of root and other plant nutrient eg. Ca, K, P, etc absorption are increased through the application of nitrogen (Ikbal *et al;* 1992).

In Bangladesh urea is mostly used as the source of nitrogen and split application of this fertilizer is commonly practiced for leafy vegetables production (Hossain, 1990). Red amaranth, as a leafy vegetable responds greatly to major essential elements like N, P and K in respect of its growth and yield (Thompson and Kelly, 1988). It plays a vital role as a constituent of protein, nucleic acid and chlorophyll. Nitrogen progressively increases the marketable yield (Obreza and Vavrina, 1993) but an adequate supply of nitrogen is essential for vegetative growth, and desirable yield (Yoshizawa *et al*., 1981). Excessive application of nitrogen on the other hand, is not only uneconomical but also induces physiological disorder.

The importance of selecting right variety in red amaranth is related to higher yield. Available evidences expose that in red amaranth production, both variety and nitrogen fertilizer play an important role. The yield of red amaranth may be increased through appropriate interrelationship of variety and nitrogen fertilizer

application. In Bangladesh like other management practices, information about nitrogen to be used in red amaranth cultivation is poor. The farmers of Bangladesh cultivate this crop according to their own choice due to the absence or unavailability of standard production technique. As a result, they do not get satisfactory yield and return from investment. The experimental evidences on the effect of variety and nitrogen application on the growth parameters and yield components of red amaranth are limited under Bangladesh conditions. The study was, therefore, carried out to achieve the following objectives:

I. To assess the effect of different levels of nitrogen on growth parameters and yield of red amaranth.

II. To evaluate the performance of three red amaranths' varieties.

CHAPTER II

REVIEW OF LITERATURE

Red amaranth is one of the important vegetables in Bangladesh as well as in many other countries of the world. The crop has received less concentration of the researchers because normally it grows with less care or management practices. For that a very few studies on growth parameters and yield of amaranth have been carried out in our country. The research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important research findings related to nitrogen and variety so far available at home and abroad on this crop have been reviewed in this chapter under the following headings

2.1 Effect of nitrogen on growth parameters

A garden experiment was carried out by Anten and Werger (1996) with amaranth grown from seed, in dense stands in which a size hierarchy of nearly equally aged individuals had developed in order to investigate how nitrogen allocation patterns in plants are affected by their vertical position in the vegetation. Canopy structure, vertical patterns of leaf nitrogen distribution and leaf photosynthetic characteristics were determined in both dominant and subordinate plants. The amount of N which is reallocated from the oldest to the younger, more illuminated leaves higher up in the vegetation may depend on the sink strength of the younger leaves for nitrogen.

Adelasoye and Jegede *et al*. (2003) the plant height was increased as the plant aged. Likewise, the number of leaves was increased with increasing sampling occasions. These growth parameters were increased as the N rate increased from 0 kg N ha^{-1} up to 60 kg N ha^{-1} was reached for all the varieties. There were no significant different between the values obtained from 45 kg and 60 kg N ha^{-1} in all the sampling occasions. The effects of N fertilizer application on the plant height were significantly different at various levels of N. This showed that N

promoted the vegetative growth of amaranth. Nitrogen is an essential component of chlorophyll protoplasm, protein and nucleic acid and its absence at appropriate levels could cause yellowing of leaves and stunting of plant growth. The increase in height and number of leaves as N rates increased, reconfirmed the role of nitrogen in promoting vigorous vegetative growth in leafy vegetables in amaranths. From the above review, it is clear that growth and yield of Red amaranth largely depend upon variety and nitrogen fertilizers. These two factors both in single and combination influence the growth, quality and yield of the crop.

Awotundun *et al.* (1995) recommended that amaranth could either be sown on flat or on the raised beds and can thrive on any type of soil, preferably the sandy loam with high organic matter content, adequate nutrients reserves and on an average on 2.28% carbon and 0.21% nitrogen.

Farooqui *et al.* (2009) reported that application of nitrogen (50, 100, 150 and 200 kg ha^{-1}) on production of garlic. It was found that application of nitrogen increased the number of leaves, bulb diameter and fresh weight of garlic and higher yield was found with the application of nitrogen at 200 kg ha^{-1}.

Olaniyi *et al*. (2008) vegetable cropping system requires a greater degree of management and utilizes a large N input than most agronomic cropping systems which suggests that increase in N rate increases cell size and cell number as a result of cell division and expansion leading to increased stem growth, number of leaves and other vegetative parts of the plant. The positive effect of applied N rates on both fresh and dry shoot yields was increased, where NPK was effective in increasing final stem amaranth.

Omolayo (1996) carried out a field experiment on slightly acidic sandy loam soil at the teaching and research farm, University of Ado-Ekiti, Nigeria. They studied the effects of different doses of nitrogen on the growth parameters and the yield of leaf amaranth (*Amaranthus cruentus* L). The treatments consisted of 100, 150 and

200 kg N ha^{-1} in four replications. Plant height, leaf length, number of leaves and leaf area increased with the application of poultry manure from the different sources. They found that application of 150 kg of nitrogen per hectare produced the highest number of leaves, plant height and marketable yield.

Rana *et al. (*2008*)* who recommended 40 kg P_2O_5 and 40 kg K_2O ha^{-1} respectively for enhanced growth and yield of amaranth. This supply 17.6 kg P and 33.2 kg K which is close to the rate that produced the best result in this work. Also reported that optimum levels of N needed to maximize yield in leafy amaranth was in the range of 50 – 200 kg N ha^{-1}. The regression of edible yield to NPK level which was strongly linear indicates that the yield of the crop was still increasing up to the maximum N-fertilizer rate of application. The application of N-containing fertilizer such as NPK is known to promote photosynthetic activities and vegetative growth. Thus, the satisfactory growth and yield of vegetable crop like amaranth depended on the amount of N-supplying fertilizer.

Rice *et al.* (1987) suggested that the application of N at 400 kg ha^{-1} increased leaf number and dry matter production of red amaranth. Nitrogen is the most effective element for leafy vegetables.

Somachi (2003) carried out experiments on nutrient requirements of vegetable amaranth at Thammaasa University, Thailand. Nitrogen was used at 0, 125, 187, 250 and 312 kg ha^{-1} and with application timings at 1) pre-plant and 7 days after sowing, 2) pre-plant and 14 days after sowing, and 3) at 7 and 14 days after sowing. Significant differences were found in height, stem diameter, number of leaves and plant fresh weight. It was also found that the vegetable amaranth with N at 312 kg ha^{-1} applied different at pre-plant and at 7 days after sowing produced the highest yield.

Subhan (1989) reported than N at 0, 30, 70 and 110 kg ha^{-1} was applied to a tricolor as a single application at sowing, or as a split application at sowing and 10

days after sowing Leaf number and stem diameter was not affected by N application. Plant height, leaf area increased with increasing N application while root length was reduced by high N application. The highest yields were obtained with a split application of 110 kg N ha^{-1}.

Three field experiments were conducted at the Taiwan Agricultural Research Institute experimental farm by Yung *et al.* (2003) to evaluate the growth response of amaranth at different nitrogen fertilizer rates during the 2001-2002 growing season. Data on the total leaf chlorophyll, aboveground nitrogen and chlorophyll meter readings from leaves were collected at harvest. Regression analysis indicated positive linear correlation between total leaf chlorophyll and chlorophyll meter readings and between aboveground nitrogen and total leaf chlorophyll. It suggests that chlorophyll meter is a suitable tool for the assessment of chlorophyll and nitrogen status in amaranth plants.

Tongos (2015) reported application of 120 kg N ha^{-1} provided the highest growth and development of vegetable amaranth and should be adopt.

2.2 Effect of nitrogen on yield

Acar (1996) carried out a field experiment on study the effects of nitrogen fertilizer rates on yield and yield components of two amaranth cultivars in 1995 in Samsun, Turkey, with 0, 3, 6, 9 or 12 kg N ha^{-1} per day. From the results reported that there were no significant effects of on seed yield and yield components. There were highly significant positive correlations between seed yield and both cultivars and 1000 seed weight.

Ayodele *et al.* (2002) conducted a field experiment to evaluate the effect of N fertilizer @ 0, 50, 100 and 200 kg ha^{-1} on growth and yield of amaranth. Results showed that plant height, number of leaves produced, fresh and dry weights of plant parts increased with increased nitrogenous fertilizer rate. Application of fertilizer at 200 kg N ha^{-1} increased leaf production up to 75%, on the other hand

yield increases up to 114% in the application of 200 kg N ha^{-1}.The unfertilized plants also had yellowish green coloration compared to the brighter green color observed in fertilized plants.

Belichki (1984) recommended that nitrogen is the most important nutrient for growth and yield of spinach. Maximum growth and yield and frequent harvesting of spinach depend on application of nitrogen. It was suggested that the yield increased by the application of 120 kg ha^{-1} nitrogen.

An experiment carried out by Cole (1979) in South Africa to observe the effects of different doses of nitrogen on yield of amaranths. It was found that the application of 240 kg ha^{-1} of nitrogen increased leaf number, plant height and weight of leafy amaranths.

Das and Ghosh (1999) conducted a field experiment on amaranth during winter, summer and rainy seasons of 1996-1997 with 4 levels of nitrogenous fertilizer @ 0, 40, 80 and 120 kg N ha^{-1} in Kalyani, India. From their experiment they reported that yield components and seed yield increased with increasing N upto 120 kg N ha^{-1}.

Dhesi *et al.* (1989) studied the effect of N (0, 250, 300 kg ha^{-1}) on the growth and yield of spinach in Karnatak, India. They observed that the increasing the level of nitrogen significantly increased leaf number, stem diameter, fresh weight and dry weight of spinach.

Elberhri (1993) stated the effect of nitrogen fertilizer rate on amaranth development and yield. The lines used in this study were D136-1, K266, and 'Plainsman'. Rate of 0, 45, 90,130 and 180kg N ha^{-1} were required to reach maximum yield across cultivars, but varieties differed in responsiveness. For the soils tested, it was clear that amaranth does not need as much N fertilizer as maize, or even sorghum.

Green amaranth cultivar was supplied with 0, 30, 60 and 90 kg N ha^{-1} in a field experiment conducted by Rathore *et al.* (2004) in Rajasthan, India during the winter seasons of 1997-1998 and 1998-1999 to identify the optimum doses. In 90 kg ha^{-1} N fertilizer gave significantly higher yield, better growth and higher values for yield components. Application of N enhanced the growth and yield attributes significantly, whereas harvest index remained unaffected.

Hevia *et al.* (2000) reported protein content fluctuated 6.5% (at 0 kg N ha^{-1}) to 18.4% (200 kg N ha^{-1}). The protein yield per hectare fluctuated between 457.2 (at 0 kg N ha^{-1}) and 973.4 kg ha^{-1} (at 300 kg N ha^{-1}), and was characterized by a quadratic regression as a response to fertilizer application. The starch characteristics were not significantly affected by any of the N levels.

In a field experiment during summer 1990-1991 and 1991-92 at Kinnaur, Himachal Pradesh, India by Saini and Shekhar (1998) to find out the effect of nitrogen fertilizer on growth and yield of amaranth were given 0, 30, 60, 90 and 120 kg N ha^{-1} and reported that yield and most yield components increased significantly up to 90 kg N ha^{-1}, then decreased.

In a field trial, Nahar K. (2006) reported that nitrogen significantly increased the yield of red amaranth.

Materechera and Medupe (2006) investigated the effects of nitrogen fertilization and cutting frequency on growth and yield of leaf amaranth (*Amaranthus hybridus*). They harvested the edible leaves of plants weekly, every 2 weeks, every 3 weeks and once only at the end of the growing period. They applied 40 kg N ha^{-1}. The addition of nitrogen either as chemical fertilizer or manure significantly improved the growth and yields of amaranth. Shorter cutting intervals enhance regrowth, but very frequent (weekly) cutting reduced the total dry matter of edible leaves. They suggested that amaranth has the potential for production as a green leafy vegetable and that nutrient input from both organic and inorganic

fertilizers are essential for high productivity. They concluded that there is a need to cut the leaves of amaranth frequently. Since bi-weekly cutting increased the number of leaves, fresh weight and leaf dry matter produced per plant, a cutting interval of 2 weeks was recommended.

Miah (2013) reported that application of nitrogen significantly increased the yield of amaranth. Considering combined effect of variety and nitrogen the higher yield was found from data Bhutan and 175 kg N ha^{-1}.

Miah *et al.* (2010) conducted an experiment on nutrient accumulation and their uptake by red amaranth as influenced by different levels of nitrogen and suggested that nitrogen 150 kg ha^{-1} can be applied to boost up the production of red amaranth.

Mowrin M. (2013) reported that application of nitrogen significantly increased the yield of amaranth. The maximum yield was obtained from application of 80 kg N ha^{-1}.

Olofintoye *et al.* (2015) reported that application of nitrogen higher than 100 kg ha^{-1} was effective for good yield of red amaranth.

2.3 Effect of variety on growth parameters

Aktaruzzaman (2013) carried out an experiment on morphological characterization of thirty –one germplasm of red amaranth and found significant variation among the red amaranth germplasm.

Aynehband (2008) reported that, plant height in three of fodder amaranth varieties (70 days after sowing), Trigin (223 cm) recorded significantly higher plant height compared to Amont (216 cm) and Plainsman (161 cm).

Gimplinger *et al.* (2008) reported that there is significant difference in plant height in stem amaranth genotypes due to different plant density. Raising plant population pressure drastically reduced the growth and yield attributing characters. The stem amaranth genotypes plant height was significantly differing due to

different seed rates i.e., 2 kg ha^{-1} gave more (122 cm) followed by 1 kg ha^{-1} (119 cm) and least plant height was recorded in 4 kg ha^{-1} (114 cm). It is because as the seed rate increases the self-thinning of plants takes place varying plant height (Bruce Gelinas and Philippe, 2008).

In a field experiment Olaniyi and Adelasoye (2008) evaluated two varieties of stem amaranth NH84/593-1and NH84/594 obtained from National Horticultural Research Institute (NIHORT) Ibadan were grown for two consecutive growing seasons from August to December on beds. Data were recorded on growth and yield of stem amaranth varieties. Plant height was measured with a meter ruler from the base to the tip of the main shoots. Number of leaves was recorded by counting of leaves. The higher growth parameters were recorded for NH84/593-1 while NH84/594 gave the least values with and without N application. The varietyNH84/593-1 is more productive between two stem amaranth varieties considered in his study.

Miah (2013) reported stem amaranth varieties had significant effect on plant height, number of leaves per plant, stem diameter, leaf area and yield per hectare.

Srinivasaiah *et al.* (2000) assessed three *Amaranthus tricolor* cultivars, Arka Surguna, AG-114 and Local, sown at 30 day intervals from 15 July 1997 to 15 February 1998, evaluated in Bangalore, Karnataka, India. Data were recorded for days to 50% flowering, days to seed maturity, number of panicles per plant, length of panicle, weight of panicle and seed yield. The earliest flowering was obtained in the August sown crop, while the earliest maturity was observed in the July sown crop. The November-sown crop gave the highest values for number, length and weight of panicles and recorded the highest seed yield with fairly good seed quality. The July and February sown crops recorded low seed yield but had better seed quality than crops sown on other dates. Among the cultivars, AG-114 recorded the highest values for all yield attributes irrespective of the date of sowing.

Yield of grain and other characteristics of eight red amaranth varieties were assessed by Mohideen *et al*. (1983). The types A.144, A.145 and local 1 were comparatively longer in duration with a tall growth habit and with a few or no branches. The types A.53, A.90 and A. 147 were comparatively shorter in duration with dwarf stature and high branching characters. Despite certain unfavorable traits, types A. 144, A. 145 and local 1 could be chosen by virtue of their high yields in areas less prone too heavy winds and also avoiding synchronization of rainfall with seed maturity.

2.4 Effect of variety on yield

A field trial was carried out by Mohideen and Rajagopal (1979) with two varieties of Red amaranth, *viz.* A.62 and Co.1 (with short and medium duration respectively) to study the effect of transplanting over direct sowing. The result of the study, A. 62 found significantly higher yield in direct sown plot 1750kg ha^{-1}) as compared to transplanted plot (1240 kg ha^{-1}, percent increase being 41.50). Co. l recorded significantly higher yields in the transplanted (717 kg ha^{-1} as against 447 kg ha^{-1} in direct sown crop (with 59.70 % increase).

A study was done by Mohideen and Rajagopal (1974) on harvesting method and suggested on the response on two species of amaranth to clipping. The species *A. tristis* L. (Arakeerai) and *A. blitum* L. (Sirukeerai) where clipped at certain intervals. Arakeerai yielded 11736 kg ha^{-1} as compared to Sirukeerai which yielded 8680 kg ha^{-1} (35.20 % increases). They conducted a field trial was with two varieties of amaranth, *viz.* A. 62 and Co. l (with short and medium duration respectively) to study the effect of transplanting over direct sowing. The result of the study showed that A.62 recorded significantly higher yield in direct sown plot (1750 kg ha^{-1}) as compared to transplanted plot (1240 kg ha^{-1}, percent increase being 41.50). Co. 1 recorded significantly higher yield (717 kg ha^{-1} in the transplanted crop as against 447 kg ha^{-1} in direct sown crop (with 59.70 %

increase). The optimum stage of harvest in amaranth could be fixed at the 25th day after sowing, as at this stage the performance of the types was found to be superior with increases in leaf weight, stem weight, leaf length, leaf breadth, stem diameter and plant height (Mohideen, 1978).

According to Vijayakumar (1980) the optimum stage of harvest is between 25 to 30 days after sowing to get the highest yield as well as nutritious and palatable greens. He recorded yield on the 30^{th} day of harvest which ranged from 9.20 t ha^{-1} to 47 t ha^{-1}.

Bhuyan *et al.* (1983) experimented the possibilities of growing some exotic varieties of amaranth during summer season in Bangladesh. The variety R- 149 gave the highest yield of 20.60 kg ha^{-1} followed by R-104 with 14.90 kg ha^{-1}, which is extremely poor compared to the potential yield of 2-3 t ha^{-1} (Grubben and Van Sloten, 1981).

Campbell and Abbott (1982) to evaluate the performance of twenty selected cultivars and strains of *Amaranthus cruentus* L. *(A. caudatus* L.), *A. dubius* L. and *A. tricolor* L. from various countries for horticultural potential during 2 (two) successive summer. Average fresh yields of leaves and stems were in 5 trials ranged from 4.00 to 16.50 t ha^{-1}. Yields were highest for *A. dubius* L., intermediate for *A. cruentus* L. and lowest for *A. tricolor* L. Yield was negatively correlated with leaf stem ratio. The highest leaf: stem ratio was found for *A. tricolor* L. selections.

Hamid *et al.* (1989) stated that significant variations were present among 12 amaranth lines for plant height, number of leaves, stem girth and yield. Height and stem girth were positively correlated with yield. In general, the 6 exotic lines were taller and produced higher yields than the local lines but were inferior in taste and cooking quality. The exotic germplasm AM 0008 was the highest yielding, producing 23.44 t ha^{-1}. Three local germplasm and three exotic germplasm were

found to be promising in respect of yield potential. Among the local germplasm, highest yield produced 12.24 t ha^{-1} and lowest yield was 4.28 t ha^{-1}.

In a field trial Mowrin M. (2013) carried out an experiment with three red amaranth cultivars and found significant yield variation among the cultivars. The highest yield (15.78 t ha^{-1}) was found from the cultivar altapety and lowest yield (12.62 t ha^{-1}) from local cultivar.

In an experiment Joshi (1985) found that the new amaranth cv. Annapurna produces an average grain yield of 2.23 t ha^{-1} at four locations. Its highest yield was 4.10 t ha^{-1} at Solan. It gave a 3- year average yield of 2.47 t ha^{-1} at Simla. Its popping quality is excellent and the grain pops 4 to 5 times its size.

Mohideen *et al*. (1985) carried out an experiment for an evaluation program in amaranth under the all Indian coordinated vegetable improvement project at the Tamil Nadu Agriculture University. A promising clipping type (A.83) was released as Co.3 amaranth over local type after testing for five seasons. The yield performance of Co.3 was recorded 30.71 t ha^{-1} of greens as compared to 19.43 t ha^{-1} of the local type.

Olufolaji and Dinakin (1988) stated the percentage of lodging, shoot length and number, leaf size and number, and yield of vegetable and seed for 15 cultivars belonging to various *Amaranthus* species or species hybrids grown in field beds during 1986. The highest vegetable yield was given by the black-seeded cultivars and highest seed yield by the white ones.

Olufolaji and Tayo (1989) studied on the effects of seeding rate on the performance of amaranth. Two field trials were conducted to determine the optimum sowing rate of *A. cruentus* required for a vegetative yield of about 20 t ha^{-1}. The plants were rain fed in the first trial and irrigated in the second. Sowing rates of 2, 4, 6 and 8 kg ha^{-1} was tested in the first trial with additional rates of 10 and 12 kg ha^{-1} being tested in the second trial. Seedling establishment, plant

height, leaf area index, total plant yield and edible shoot yield were measured. The highest total and edible shoot yields (18.57 and 2.47 t ha^{-1}, respectively) were obtained in the irrigated trial at a sowing rate of 6 kg ha^{-1}.

Rajagopal *et al.* (1977) reported that a total of 65 types of amaranth were assembled from all over Tamil Nadu and other parts of India and evaluated for yield of greens and other attributes from 1972 onwards. The Co. l was used as standard for these evaluations. Further work on the improvement program of this crop in Tamil Nadu Agricultural University by Department of Horticulture, resulted in the identification of A. 25 as a promising selection with high yield potential coupled with good edible plant qualities .This selection has been released for cultivation as Co.2 amaranth by the Tamil Nadu Agricultural University. It is mainly suited for early harvest as tender green (Mulaikeerai) and can be cultivated all through the year.

Vijayakumar *et al.* (1982) experimented the growth of nineteen types of Amaranthus found that the optimum stage of harvest in most of the types could be fixed around 25-30 days after sowing to get high yield of palatable greens. Type A.144 consistently performed well followed by A.104 and A. 56. Campbell and Abbott (1982) described that mean fresh yields (leaves and stems) for five trials sown in different dates ranged from 4.0 to 16.5 t ha^{-1}. Yields were highest for *A. dubius*. Entries with a high leaf: stem ratio probably had the greatest market potentials and highest ratios were found in *A. tricolor.*

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods used in performing this experiment. It offers a brief description of soil, weather, crop, treatment, experimental design, intercultural operations, data recording, data processing and statistical analysis.

The experiment was conducted at the Research farm, Sher-e-Bangla Agricultural University, Dhaka during the period from November to December 2015 to find out the effect of nitrogen on growth parameters and yield of red amaranth (*Lal Shak*).

3.1 Experimental site

The present experiment was carried out in the Research Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the experimental site is $23^0 74^/$N latitude and $90^0 35^/$E longitude and at an elevation of 8.2 m from sea level (Anon., 1989).

3.2. Climate of the experimental site

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). There was no rainfall during the month of December, January and February. The average maximum temperature of experimental site during the period of study was 28°C and the average minimum temperature was 13.33°C. Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix I.

3.3 Characteristics of the soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and Tejgaon soil series. It has shallow red brown terrace soil. The experimental site was a non- calcarious medium high land and dark grey in color (FAO, 1988). Soil texture was silty loam with a pH of 6.7. Soil samples from 0-15 cm depths were collected from experimental field. The analysis was done by Soil Resource and Development Institute (SRDI), Dhaka. The details of the plot soil have been presented in Appendix II.

3.4 Plant materials

Three red amaranth varieties namely BARI Lalshak-1, Altapety and Local variety were used for this experiment. The seeds of the red amaranth varieties were procured from Bangladesh Agricultural Research Institute, Gazipur; Bangladesh Agricultural Development Corporation seed sale centre, Motijhill and Sher-e-bangla Nagar local nursery. Altapety is a variety of BADC. BARI Lalshak-1 is a BARI developed variety. A local variety was collected from local shop of Sher-e-bangla Nagar, Dhaka.

3.5 Experimental Treatments

It was a factorial experiment and included two factors. One was variety and other was nitrogen level.

Varieties (Factor A)	**Nitrogen levels (Factor B)**
i. Local variety	i. 0 kg ha^{-1}
ii. Atapety	ii. 60 kg ha^{-1}
iii. BARI Lalshak-1	iii.90 kg ha^{-1}
	iv. 120 kg ha^{-1}

The treatment combinations of the experiment were thirty six (36).

3.6 Experimental design

The experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. The treatment combinations were randomly assigned to each unit plot so as to allot one treatment combination once in each replication. There were three blocks and each block containing 12 plots. Thus the total number of plots was 36. The size of unit plot was 1.5 m^2 (1.5 m × 1 m). The distance between the plot to plot and the block to block were maintained 0.5 m and 1.0 m, respectively.

3.7 Land preparation

The experimental land was prepared with the help of power tiller by three successive ploughing and cross-ploughing followed by laddering. Weeds and crop residues of previous crop were removed from the field. The experimental plot was divided into the unit plots in accordance with the experimental design.

3.8 Manure and fertilizer application

The well-decomposed cow-dung was applied @ 3.5 t ha^{-1}. The fertilizers, TSP and MP were applied @ 27 and 35 kg ha^{-1}, respectively (BARC, 2005). Urea is used as nitrogen source and was applied according to treatments. All the doses of cow-dung, TSP, MP and half of urea were applied during final land preparation and remaining urea applied at 20 days after sowing (DAS) followed by irrigation.

3.9 Seed sowing

Seeds were sown in well-prepared land on 14 November, 2015. The seeds were sown at about 1.3 cm depth by broadcasting method and covered uniformly with light soil for proper germination at 1.5-2.0 kg ha^{-1}.

3.10 Intercultural operation

After the establishment of crops, various intercultural operations were accomplished for better growth and development of the red amaranth crops.

3.10.1 Thinning

Thinning was done at 10 days after sowing (DAS) and 20 DAS. Thinning was done in the entire unit plots with special care to maintain constant plant population per plot.

3.10.2 Weed control

Weddings were done to keep the plots free from weeds, which ultimately ensured better growth and development. It keeps the soil aerated by breaking the soil crust. It also conserves the soil moisture. The newly emerged weeds were uprooted carefully by mechanical means.

3.10.3 Irrigation and drainage

Irrigation was done as and when the field seemed dry to each plot to ensure sufficient moisture for normal crop growth. Proper drainage facilities were developed to avoid stagnation of water.

3.11 Harvesting

Red amaranth were harvested at 36 days after sowing on 20 December, 2015.Harvesting was done plot wise by uprooting the plants by hand carefully and calculated yield $plot^{-1}$ in kg and then it was converted in ton $hectare^{-1}$.

12. Data collection

The data were recorded from randomly selected 10 plants from each unit plot for the collection of per plant data and the whole plant of each unit plot was harvested to record per plot data. The data were recorded for the following parameters.

3.12.1 Plant height

Plant height was measured from the soil level to the terminal leaf using a meter scale in centimeter (cm). From each unit plot 10 sample plants were measured and

mean value was recorded. Plant height was recorded periodically to observe the growth parameters of plants at 15, 22, 29, and at 36 days after sowing (DAS).

3.12.2 Leaves plant^{-1}

To estimate number of leaves per plant, leaves were counted at 15, 22, 29 and 36 days after sowing (DAS) from 10 selected plants. Leaves plant $^{-1}$ was counted periodically to observe growth parameters of plants. All the leaves of selected plants were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting.

3.12.3 Stem diameter

Stem diameter (mm) at the base of the 10 sample plants were measured by Slide Calipers periodically at 22, 29, and 36 days after sowing (DAS) to observe growth features of plants and the average of stem diameter of plant was recorded.

3.12.4 Leaf area plant^{-1}

Ten plants from each plot were randomly selected, then the length and breadth of the leaves were measured with a centimeter scale and the data were averaged and recorded as leaf area (cm^2). The formula is as below-

Leaf area (cm^2) = Length (cm) X Breadth (cm) X Correction Factor (CF).

3.12.5 Fresh weight plant^{-1}

10 sample plants per plot were taken at harvest and then individual fresh weight (g) per plant was calculated and recorded.

3.12.6 Dry weight plant^{-1}

After the final harvest 10 sample plants per plot were selected. The selected plants were sun dried and put into paper bag separately. Then the selected plants were oven dried for 72 hours at 70^0 C. Dry weight (g) plant^{-1} was taken with the help of an electronic balance.

3.12.7 Yield hectare^{-1}

After 36 days of sowing red amaranths were harvested calculated yield plot^{-1} in kg was converted into ton ha^{-1}.

3.13 Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT-C package programme. The mean for all the treatments were calculated and analyzed and analyses of variance of all the characters were performed by F-variance test. The significance of differences between the pairs of treatment means was estimated by Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to find out the effect of nitrogen on growth parameters and yield of red amaranth. This chapter reports the results of the experiment. The data are presented in the form of tables and figures. The mean results of the experiment on the effect of nitrogen and variety along with different interactions, summaries of analysis of variance (ANOVA) on various characters and different matrix are presented in appendices III to VI. The results are discussed and interpreted under the following subheads.

4.1 Plant height

4.1.1 Effect of variety

Plant height was significantly varied among the studied varieties (*viz.* BARI Lalshak-1, Altapety and Local variety) of red amaranth at different days after sowing (DAS) (Figure 1 and Appendix III). Results showed that the BARI Lalshak-1 was evident for the highest plant height at all growth stages and it was also noticed that plant height differs variety to variety. The tallest plant at 15, 22, 29 DAS and at harvest (36 DAS) were 5.61, 14.21, 24.31, and 37.81 cm respectively, was obtained with BARI Lalshak-1. The competition in accordance with plant height among the varieties the smallest plant was demonstrated with Local variety. The lowest plant height at 15, 22, 29 DAS and at harvest (36 DAS) were 4.76, 11.39, 18.91 and 27.14 cm respectively, which showed significant variation with BARI Lalshak-1. Yield of red amaranth is positively correlated with plant height. The result shows that the local variety produces the shortest plant height. This finding was in agreement with Hamid *et al.*, 1989 and Mowrin, 2013).

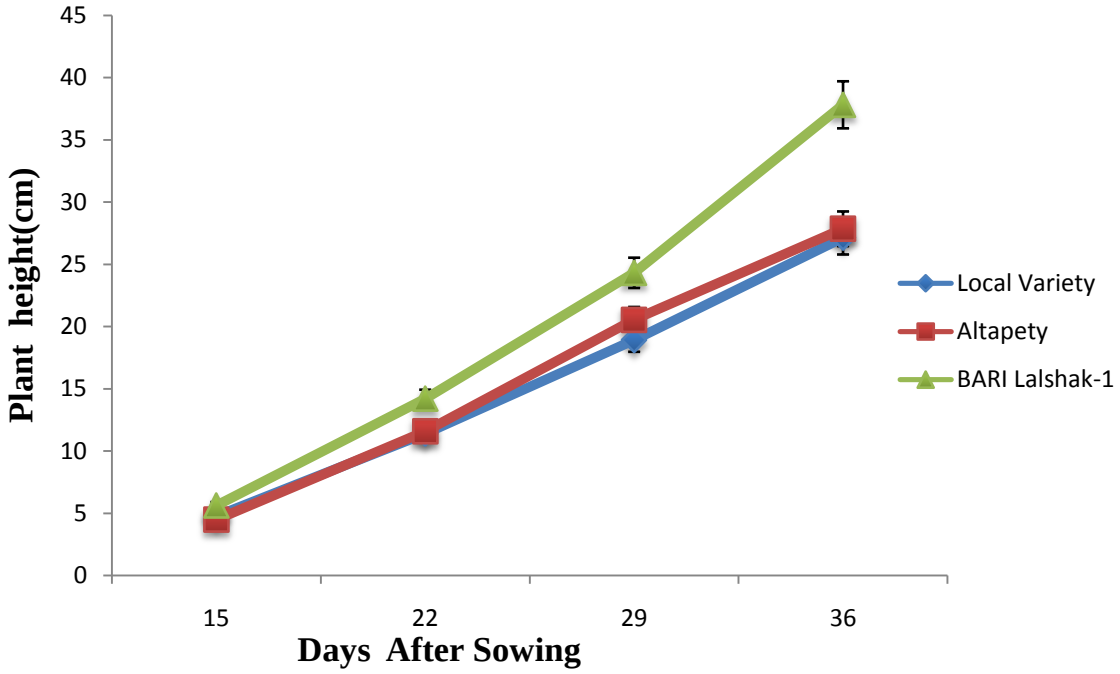

Figure 1. **Effect of variety on plant height at different days after sowing in red amaranth.** (*Vertical bars represent LSD at 0.05 level of probability)*

4.1.2 Effect of nitrogen

The plant height varied significantly due to the individual application of different doses of nitrogen at 15, 22, 29 and at harvest (36 DAS), (Figure 2). The tallest plant height at all the observations was observed from the plot that received 90 kg N ha^{-1}.The maximum plant height was measured 5.54, 15.03, 24.50 and 36.67 cm from the application of 90 kg N ha^{-1} at 15, 22, 29 and 36 DAS respectively. The shortest plant height was calculated 4.28, 9.98, 17.10 and 24.98 cm from control dose at 15, 22, 29 and 36 DAS respectively. Nitrogen is an element which enhances vegetative growth of plant and thus higher plant height is the result of nitrogen. The result showed that 90 kg N ha^{-1} gave the higher plant height in comparison with 120 kg N ha^{-1}.The result also showed nitrogen increases the growth of plant which ensures higher plant height and excessive nitrogen is not economical.

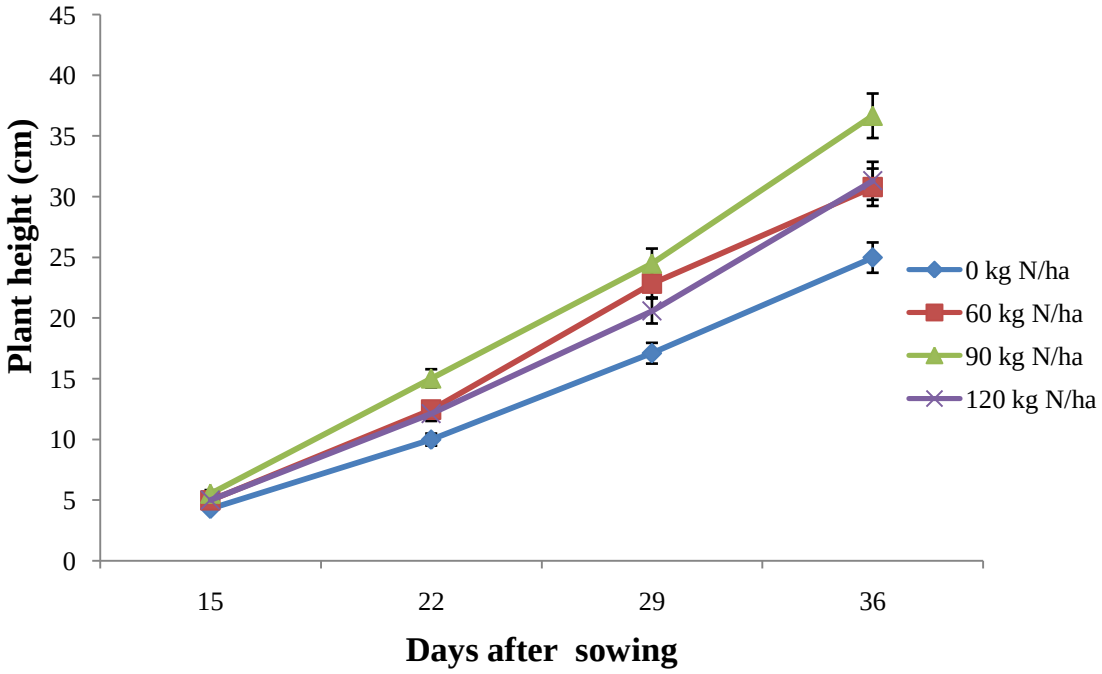

Figure 2. Effect of different doses of nitrogen on plant height at different days after sowing in red amaranth. (*Vertical bars represent LSD at 0.05 level of probability)*

4.1.3 Interaction effect of variety and nitrogen

The significant variation was recorded due to interaction effect of variety (BARI Lalshak-1, Altapety and Local variety) and different levels of nitrogen (0, 60, 90 and 120 kg ha^{-1}) in terms of plant height at different days after sowing (DAS) (Table 1 and Appendix III). The tallest plant at 15 DAS (6.83 cm), 22 DAS (18.93 cm), and 36 DAS (44.73 cm) was recorded from BARI Lalshak-1 with 90 kg N ha^{-1} and at 29 DAS the tallest plant was from BARI Lalshak-1 with 60 kg N ha^{-1}. On the other hand, the shortest plant height at 15 DAS (4.03 cm), 22 DAS (9.23 cm), and 36 DAS (21.40 cm) was recorded from Altapety with control dose, and 29 DAS (16.60 cm) from Local variety with control dose. The result showed that interrelationship between BARI Lalshak-1 along with 90 kg N ha^{-1} provided the highest plant height. The use of good variety and addition of nitrogen either as chemical fertilizer or manure significantly improved the growth and yields of amaranth (Materechera and Medupe, 2006).

Table 01. Interaction effect of variety and nitrogen on plant height at different days after sowing in red amaranth

(Variety X Nitrogen*)	Plant height (cm)			
	15 DAS	22DAS	29DAS	36DAS
BARI Lalshak-1 X				
0	4.67 cdef	10.57 gh	17.43 f	30.60 e
60	5.33bc	14.33 b	29.90 a	41.27 b
90	6.83 a	18.93 a	28.10 b	44.73 a
120	5.60 b	13.00 cd	21.80 d	34.63 c
Altapety X				
0	4.03 f	9.23 i	17.27 f	21.40 h
60	4.73 cde	11.47 efg	19.23 e	25.93 g
90	4.53 def	13.57 bc	23.93 c	33.23 cd
120	4.57 def	12.07 def	21.73 d	30.83 e
Local variety X				
0	4.13ef	10.13 hi	16.60 f	22.93 h
60	4.83 cd	11.53 efg	19.37 e	25.13 g
90	5.27 bc	12.60 cde	21.47 d	32.03 de
120	4.87 cd	11.30 fg	18.20 ef	28.47 f
LSD $_{0.05}$	0.61	1.05	1.68	1.63
CV%	7.23	5.00	4.65	3.11

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. *= kg ha^{-1}

4.2 Number of leaves plant^{-1}

4.2.1 Effect of variety

Number of leaves plant^{-1} is an important parameter for measuring yield performance of red amaranth. The number of leaves plant^{-1} varied significantly of red amaranth

varieties at different days after sowing (DAS) (Figure 3). Number of leaves plant^{-1} is important growth parameters of plant. The maximum number of leaves plant $^{-1}$ was found from BARI Lalshak-1at all growth stages. The maximum number of leaves plant^{-1} at 15, 22, 29 and at harvest (36 DAS) was recorded 5.42, 8.25, 11.00 and 14.50 respectively from BARI Lalshak-1 which varied significantly with Altapety and Local variety (RM). The minimum number of leaves plant^{-1} at 15, 22, 29 and at harvest (36 DAS) was observed 3.92, 6.67, 9.17 and 11.75 from Local variety.

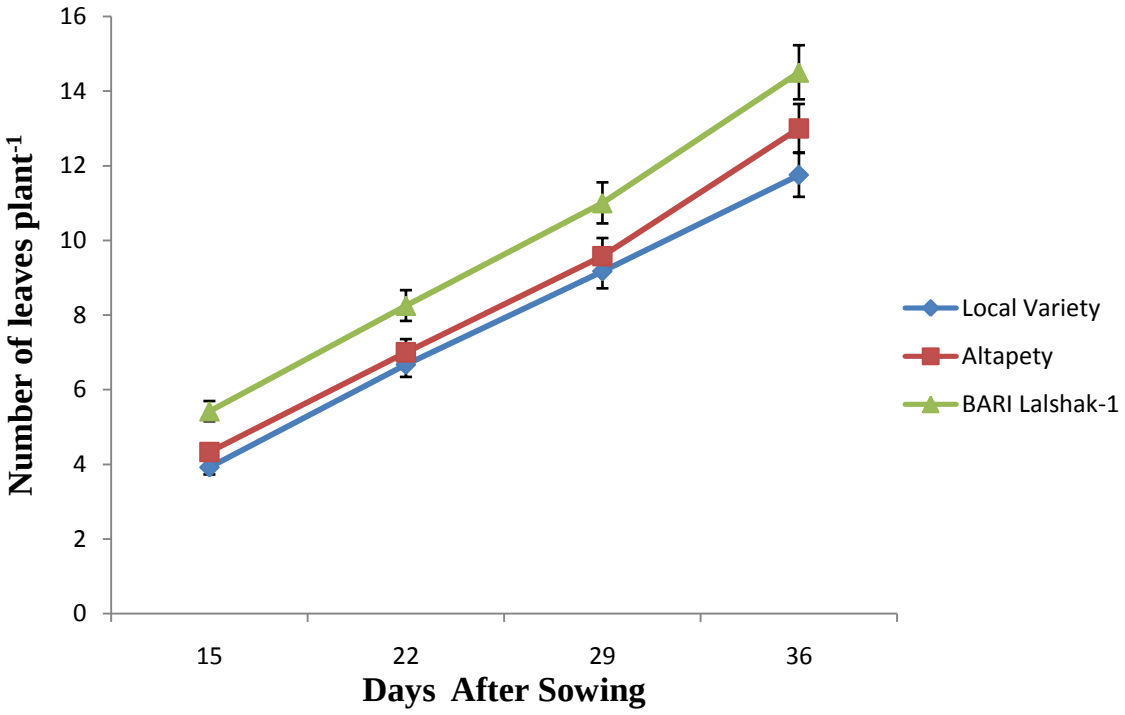

Figure 3. Effect of variety on number of leaves plant^{-1} at different days after sowing in red amaranth. *(Vertical bars represent LSD at 0.05 level of probability)*

4.2.2 Effect of nitrogen

Number of leaves varied significantly with different doses of nitrogen at 15 and 29 days after sowing (DAS). The maximum number of leaves at 15 and 29 DAS was recorded 5 and 11 respectively with the application of 90 kg N ha^{-1} and the minimum number of leaves at 15 and 29 DAS was found 3.89 and 8.89

respectively with control dose. No significant variation was found with different doses of nitrogen at 22 and 36 DAS. The maximum number of leaves at 22 DAS was recorded 8 with the application of 120 kg N ha^{-1} and minimum number of leaves at 22 DAS was found 6.67 with control dose. The maximum number of leaves at 36 DAS was recorded 13.78 with the application of 90 kg N ha^{-1} and minimum number of leaves at 36 DAS was found 12.44 with control dose.

Table 2. Effect of different doses of nitrogen on number of leaves plant^{-1} in red amaranth at different days after sowing

Nitrogen*	No. of leaves per plant			
	15DAS	22DAS	29DAS	36DAS
0	3.89 b	6.67 a	8.89 c	12.44 a
60	4.56 ab	7.11 a	9.556 bc	12.89 a
90	5.00 a	7.44 a	11.00 a	13.78 a
120	4.78 ab	8.00 a	10.22 ab	13.22 a
LSD $_{0.05}$	1.04	1.40	1.03	1.36
CV (%)	13.46	11.28	6.14	6.13

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability *= kg ha^{-1}

4.2.3 Interaction effect of variety and nitrogen

Number of leaves per plant was significantly influenced by the interaction effect of variety and different doses of nitrogen. The interaction effect of variety and different doses of nitrogen at different days after sowing was also significant. At 15, 29 and 36 DAS, the maximum number of leaves plant^{-1} (6, 12 and 15.67) respectively, was found from the treatment combination of variety BARI Lalshak-1 and 90 kg N ha^{-1}. After 15 DAS the minimum number of leaves plant^{-1} (3.67) was found from Local variety and Altapety with control dose. The result indicated that the interaction between BARI Lalshak-1 and 90 kg N ha^{-1} gave the maximum number of leaves.

Table 3. Interaction effect of variety and nitrogen on number of leaves plant^{-1} at different days after sowing in red amaranth

(Variety X Nitrogen*)	No. of leaves plant^{-1}			
	15DAS	22DAS	29DAS	36DAS
BARI Lalshak-1 X				
0	4.33 bc	7.33 bc	9.67 cd	13.00 cd
60	5.33 ab	8.00 b	11.00 ab	14.67 ab
90	6.00 a	8.00 b	12.00 a	15.67 a
120	6.00 a	9.67 a	11.33 a	14.67 ab
Altapety X				
0	3.67 c	6.33 c	8.67 de	11.67 def
60	4.33 bc	6.67 bc	9.00 cde	13.00 cd
90	4.67 bc	7.00 bc	11.00 ab	13.67 bc
120	4.67 bc	8.00 b	9.67 cd	13.67 bc
Local variety X				
0	3.67 c	6.33 c	8.33 e	12.67 cde
60	4.00 c	6.67 bc	8.67 de	11.00 f
90	4.33 bc	7.33 bc	10.00 bc	12.00 def
120	3.67 c	6.33 c	9.67 cd	11.33 ef
LSD $_{0.05}$	1.03	1.37	1.02	1.32
CV (%)	13.46	11.28	6.14	6.13

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. *= kg ha^{-1}

Good foliage indicates higher growth, development and productivity of a plant. The variation in number of leaves might be due to the environmental condition. It can also be due to the genetic makeup, physical characteristics and soil factors (Aynehband, 2008)

4.3 Stem diameter

4.3.1 Effect of variety

Significant variation was found among red amaranth varieties considering stem diameter at different days after sowing (DAS) (Figure 4). The variety BARI Lalshak-1 showed the maximum stem diameter and Local variety showed the minimum stem diameter. The maximum stem diameter at 22, 29 and 36 DAS was found 4.32, 6.11, and 9.93 mm respectively from BARI Lalshak-1 and the minimum stem diameter at 22, 29 and 36 DAS was recorded 3.01, 5.13, and 8.70 mm respectively from Local variety which varied significantly with the variety Altapety at 22, 29 and 36 DAS respectively. These findings are similar with Olufolaji and Dinakin (1988).

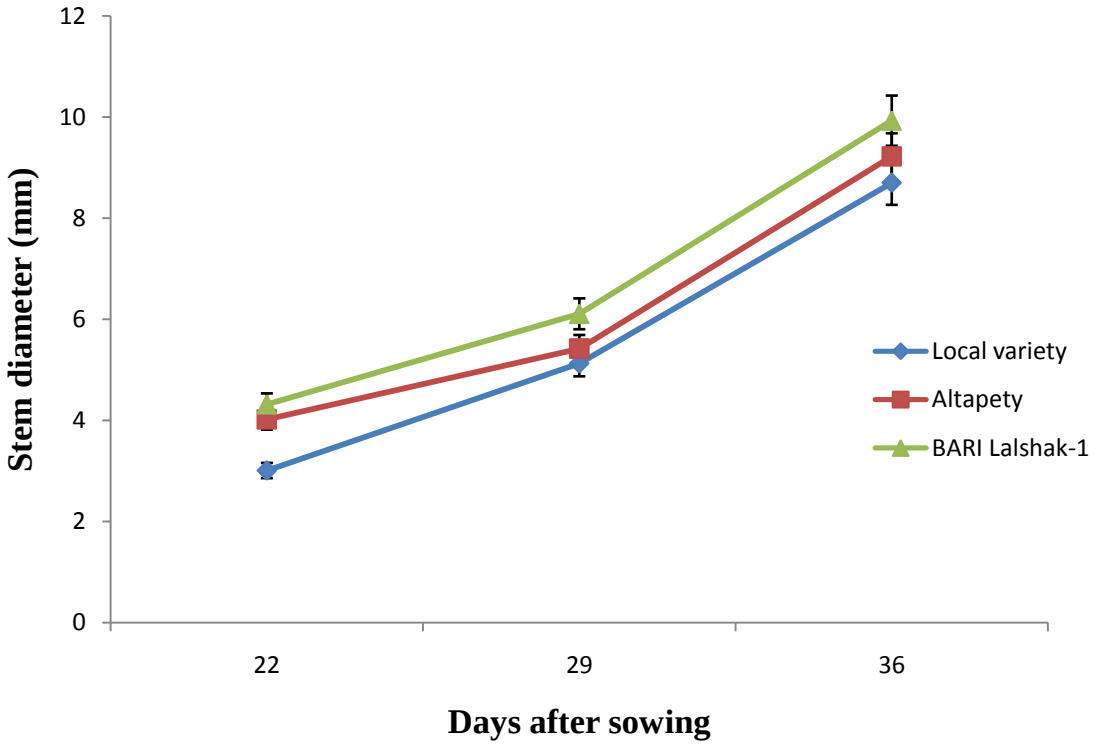

Figure 4. Effect of variety on stem diameter at different days after sowing in red amaranth. *(Vertical bars represent LSD at 0.05 level of probability)*

4.3.2 Effect of nitrogen

Significant variation was found in respect of stem diameter due to the application of different doses of nitrogen at different days after sowing (DAS) (Table 4 and Appendix V). The maximum stem diameter at 22 and 29 DAS was recorded 4.03 and 5.93 mm respectively from the application of 120 N kg ha^{-1} and after 36 DAS it was found 9.74 mm from the application of 90 N kg ha^{-1}. The minimum stem diameter at 22, 29 and 36 DAS was measured 3.41, 4.90 and 8.60 mm respectively at control doses of nitrogen. Reddy *et al.* (2002) reported that plant height, area and leaf, stem diameter and yield per hectare of amaranth increased with the increasing rates of N and in combination with P and K

Table 4. Effect of different doses of nitrogen on stem diameter in red amaranth at different days after sowing

Nitrogen*	Stem diameter (mm)		
	22DAS	29DAS	36DAS
0	3.41 d	4.90 d	8.60 d
60	3.62 c	5.41 c	9.10 c
90	3.90 b	5.72 b	9.74 a
120	4.03 a	5.93 a	9.53 b
LSD $_{0.05}$	0.011	0.012	0.015
CV (%)	3.05	1.49	0.87

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability *= kg ha^{-1}

4.3.3 Interaction effect of variety and nitrogen

The interaction effect of variety and nitrogen was found significant in terms of stem diameter at different days after sowing (DAS) (Table 5 and Appendix V). The maximum stem diameter at 22, 29 and 36 DAS was recorded 4.52, 6.73 and 10.83 mm respectively from the treatment combinations of BARI Lalshak-1 with

application of 90 kg N ha^{-1} and the minimum stem diameter 2.61, 4.42 and 8.40 mm was observed at 22, 29 and 36 DAS respectively from the treatment combination of Local variety with control dose.

Table 5. Interaction effect of variety and nitrogen on stem diameter at different days after sowing in red amaranth

(Variety X Nitrogen*)	**Stem diameter** (mm)		
	22DAS	**29DAS**	**36DAS**
BARI Lalshak-1 X			
0	4.01 f	5.41 g	8.80 h
60	4.20 d	6.02 c	9.62 c
90	4.52 a	6.73 a	10.83 a
120	4.33 b	6.30 b	10.24 b
Altapety X			
0	3.71 h	4.92 k	8.71 i
60	3.82 g	5.20 i	9.12 f
90	4.12 e	5.70 e	9.41 e
120	4.24 c	5.82 d	9.54 d
Local variety X			
0	2.61 l	4.42 l	8.40 k
60	2.90 k	5.03 j	8.52 j
90	3.12 j	5.23 h	8.90 g
120	3.43 i	5.60 f	8.80 h
LSD $_{0.05}$	0.012	0.014	0.016
CV (%)	3.05	1.49	0.87

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. *= kg ha^{-1}

4.4 Leaf area

4.4.1 Effect of variety

Leaf area is another important parameter for measuring yield performance of red amaranth. Significant variation was found in terms of leaf area of experimented red amaranth varieties (Table 6). The maximum leaf area was recorded 538 cm^2 from the variety BARI Lalshak-1 and minimum leaf area was found 387.9 m^2 from the Local variety.

4.4.2 Effect of nitrogen

Different doses of nitrogen showed significant variation in case of leaf area (Table 7 and Appendix VI). The highest leaf area was recorded 503.2 cm^2 at 120kg N ha^{-1} and the lowest was 363.4 cm^2 at control dose. The result shows that increasing nitrogen dose increases the leaf area.

4.4.3 Interaction effect of variety and nitrogen

Leaf area was significantly influenced (Table 8 and Appendix VI) by the interaction effect of variety and nitrogen. The maximum leaf area was recorded 622.2 cm^2 in treatment combination of BARI Lalshak-1and 90 kg N ha^{-1} and the minimum leaf area (320.4 cm^2) was recorded from Local variety with control dose. The variation of leaf area among different levels of nitrogen might be due to found that higher levels of nitrogen encourage the vegetative growth i.e. higher leaf area of red amaranth (Materechera and Medupe, 2006).

4.5 Fresh weight $plant^{-1}$

4.5.1 Effect of variety

The variety BARI Lalshak-1produced maximum fresh weight $plant^{-1}$ (27.07 g) and the Local variety produced minimum fresh weight $plant^{-1}$ (13.19 g). The result showed that significant variation was found considering fresh weight $plant^{-1}$ among the studied varieties (Table 7 and Appendix VI).

4.5.2 Effect of nitrogen

Different doses of nitrogen showed significant variation (Table 7) in terms of fresh weight plant^{-1}.The maximum fresh weight plant^{-1} was observed (23.48 g) at the application of 120 kg N ha^{-1} and the minimum fresh weight plant^{-1} (16.22 g) was found at control dose.

4.5.3 Interaction effect of variety and nitrogen

The interaction effect of variety and nitrogen in case of fresh weight plant^{-1} was found significant (Table 8 Appendix VI).The maximum fresh weight plant^{-1} (30.90 g) was found from the treatment combination of variety BARI Lalshak-1 with the application of 90 kg N ha^{-1} and the minimum fresh weight plant^{-1} (10.18 g) was recorded from the Local variety with no nitrogen application. The findings exposed that interaction between BARI Lalshak-1 and 90 kg N ha^{-1} gave the highest fresh weight plant^{-1}. Belichki (1984) stated that maximum growth and yield of leafy vegetable depend on application of proper amount of nitrogen.

Table 6. Effect of variety on leaf area, fresh weight plant^{-1}, dry weight, and yield in red amaranth

Variety	Leaf area plant^{-1} (cm^2)	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)	Yield (t ha^{-1})
BARI Lalshak-1	538.00 a	27.07 a	1.11 a	12.71 a
Altapety	425.10 b	20.94 b	0.94 b	11.46 b
Local variety	387.90 c	13.19 c	0.79 c	10.54 c
LSD $_{0.05}$	5.50	0.96	0.05	0.46
CV (%)	0.66	2.85	2.62	2.35

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

4.6 Dry weight plant^{-1}

4.6.1 Effect of variety

The effect of variety considering dry weight plant^{-1} has been presented in Table 6. The highest dry weight of plant (1.11 g) was recorded from the variety BARI Lalshak-1 and the lowest dry weight of plant (0.79 g) was recorded from the Local variety.

4.6.2 Effect of nitrogen

There was a significant variation in dry weight due to different treatments of nitrogen (Table 7).The Maximum dry weight plant^{-1} (1.03 g) was observed at 90 kg N ha^{-1} which was statistically similar to 120 kg N ha^{-1} and different from others (Table 7). The lowest dry weight (0.83 g) was found at control dose.

Table 7. Effect of different levels nitrogen on leaf area, fresh weight plant^{-1}, dry weight, and yield in red amaranth

Nitrogen*	Leaf area plant^{-1} (cm^2)	Fresh weight plant^{-1} (g)	Dry weight (g plant^{-1})	Yield (t ha^{-1})
0	363.40 d	16.22 c	0.83 c	9.70 c
60	439.50 c	19.28 b	0.92 b	11.70 b
90	495.20 b	22.64 a	1.03 a	12.73 a
120	503.20 a	23.48 a	0.99 a	12.14 b
LSD $_{0.05}$	5.05	0.98	0.04	0.44
CV (%)	0.66	2.85	2.62	2.35

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability *=kg ha^{-1}

4.6.3 Interaction effect of variety and nitrogen

The interaction effects of variety and different levels of nitrogen on dry weight plant^{-1} have been presented in Table 8. The highest dry weight plant^{-1} (1.32g) was recorded from the treatment combination of variety BARI Lalshak-1 with

the application of 90 kg N ha^{-1} and the lowest dry weight of plant (0.68 g) was found from the Local variety with no nitrogen application.

4.7 Yield per hectare

4.7.1 Effect of variety

Experimental results revealed that statistically significant variation was found in respect to yield among studied red amaranth varieties (Table 6 and Appendix VI).The maximum yield was recorded (12.71t ha^{-1})from the variety BARI Lalshak-1 and the minimum yield was found (10.54t ha^{-1}) from the Local variety.

4.7.2 Effect of nitrogen

Statistically significant variation was exposed in terms of yield of red amaranth due to application of different doses of nitrogen (Table 7 and Appendix VI). The maximum yield was recorded (12.73t ha^{-1}) at the application of 90 kg N ha^{-1} and the minimum yield was found (9.7 t ha^{-1}) at control dose.Growth features like plant height, numbers of leaves $plant^{-1}$, stem diameter, leaf area are related to yield of red amaranth and these parameters are positively influenced by nitrogen. The above parameters were the highest at 90 kg N ha^{-1}; hence, yield was the maximum at 90 kg N ha^{-1}.

4.6.3 Interaction effect of variety and nitrogen

There was a significant interaction effect of variety and nitrogen in case of yield of red amaranth (Table 8 and Appendix VI).The maximum yield (14.80t ha^{-1}) was found from the treatment combination of variety BARI Lalshak-1 with the application of 90 kg N ha^{-1} and the minimum yield (9.07 t ha^{-1}) was found from the treatment combination of Local variety with no nitrogen application.

Nitrogen progressively increases the marketable yield (Obreza and Vavrina, 1993) but an adequate supply of nitrogen is essential for vegetative growth and desirable yield (Yoshizawa *et al*.1981).Application of excessive nitrogen is not economical.

Table 8. Interaction effect of variety and nitrogen on leaf area, fresh weight plant^{-1}, dry weight, and yield in red amaranth

(Variety X Nitrogen*)	Leaf area plant^{-1} (cm^2)	Fresh weight plant^{-1} (g)	Dry weight (g plant^{-1})	Yield (t ha^{-1})
BARI Lalshak-1 X				
0	402.50 h	22.35 d	0.92 d	10.03 g
60	519.00 c	26.47 c	1.07 b	12.50 c
90	622.20 a	30.90 a	1.32 a	14.80 a
120	608.30 b	28.58 b	1.11 b	13.50 b
Altapety X				
0	367.40 j	16.12 f	0.87 e	10.00 g
60	418.80 g	18.25 e	0.92 d	12.10 cd
90	449.00 e	22.90 d	0.94 d	12.03 cd
120	465.10 d	26.50 c	1.00 c	11.70 de
Local variety X				
0	320.40 k	10.18 i	0.68 g	9.07 h
60	380.80 i	13.12 h	0.75 f	10.50 f
90	414.30 g	14.13 g	0.84 e	11.37 e
120	436.20 f	15.35 f	0.87 e	11.23 e
LSD $_{0.05}$	5.05	0.97	0.05	0.47
CV (%)	0.66	2.85	2.62	2.35

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. *=kg ha^{-1}

Chapter V

SUMMARY AND CONCLUSION

Red amaranth (*Amaranthus spp.*) is an important leafy vegetable under Amaranthaceae family. In Bangladesh it is a popular vegetable and it grows all the season with less care and management in Bangladesh prospect. Generally Bangladeshi farmers produce less productive varieties of red amaranth in household and commercial scale with less care and management. Nitrogen is a key factor for growth and development of plants. If proper doses of nitrogen is maintained the production could be increased.

In order to select the best varieties and find out the optimum nitrogen dose for higher yield of red amaranth, a research work was conducted at the Research farm of Sher-e-Bangla Agricultural University, Dhaka during November to December, 2015. The two factors experiment comprised of three red amaranth varieties *viz.* BARI Lalshak-1 Altapety, and Local variety and four levels of nitrogen *viz*. 0, 60, 90 and 120 kg ha^{-1}. Nitrogen was applied in the form of urea according to treatment. Irrigation and other intercultural operation were done when needed. The experiment was set up in Randomized Complete Block Design (RCBD). Each treatment was replicated thrice. There were 12 treatment combinations. The size of a unit plot was 1.5 m x 1.0 m. Seeds were sown in 14 November, 2015. Ten sample plants were randomly selected for data collection from each plot at 7 days interval. Observations were made on plant height (cm), number of leaves per plant, stem diameter (cm), leaf area (cm^2), weight $plant^{-1}$ (g), dry weight (g) and yield (t ha^{-1}).

The collected data were statistically analyzed for evaluation of the treatments for screening of best red amaranth variety, the most effective nitrogen doses and the best interaction of these two factors. The statistically analyzed data and the means were adjudged by DMRT at 5% level of significance.

In case of variety, the result showed that significant variation was found in all the parameters studied. The growth parameters were studied and it was found significant considering variety. The maximum plant height (37.81 cm), number of leaves plant^{-1} (14.50), stem diameter (9.93 mm), leaf area (538.0 cm^2), weight plant^{-1} (27.07 g), dry weight plant^{-1} (1.11 g) and yield (12.71 t ha^{-1}) were found from the variety BARI Lalshak-1 at harvest (36 DAS). The minimum plant height (27.14 cm), number of leaves plant^{-1} (11.75), stem diameter (8.70 mm), leaf area (387.9 cm^2), weight plant^{-1} (13.19 g), dry weight plant^{-1} (0.79 g) and yield (10.54 t ha^{-1}) were found from the Local variety at harvest (36 DAS).

In terms of nitrogen, the experiment revealed that significant variation was observed in almost all the parameters studied. Growth features were also found significant in respect to different doses of nitrogen. The maximum plant height (36.67 cm), number of leaves plant^{-1} (13.78), stem diameter (9.74 mm), dry weight plant^{-1} (1.03 g) and yield (12.73 t ha^{-1}) were recorded from the application of 90 kg N ha^{-1} respectively at harvest (36 DAS) and the maximum leaf area (503.2 cm^2) and weight plant^{-1} (23.48 g) were calculated from the application of 120 kg N ha^{-1} at harvest (36 DAS). In case of number of leaves plant^{-1} non-significant variation was found at 22 and 36 DAS. The minimum plant height (24.98 cm), number of leaves per plant (12.44), stem diameter (8.60 mm)), leaf area (363.40 cm^2), weight plant^{-1} (16.22 g), dry weight plant^{-1} (0.83 g) and yield per hectare (9.70 t ha^{-1}) were recorded at harvest (36 DAS)from control dose.

Considering interaction effect of variety and nitrogen it was exposed that significant variation was obtained in almost all parameters studied. Growth parameters were also significantly influenced in the interaction effect of variety and nitrogen. Significant variation was found on yield contributing characters and yield of red amaranth. The maximum plant height (44.73 cm), number of leaves plant^{-1} (15.67), stem diameter (10.83 mm), leaf area (622.20 cm^2), weight plant^{-1} (30.90 g), dry weight plant^{-1} (1.32 g) and yield (14.80 t ha^{-1}) were recorded from

the treatment combination of variety BARI Lalshak-1 with the application of 90 kg N ha^{-1} at harvest (36 DAS). The minimum plant height (21.40 cm) was observed from variety Altapety and control dose. The minimum number of leaves $plant^{-1}$ (11.00) was found from Local variety and 60 kg N ha^{-1}. The minimum stem diameter (8.40 mm), leaf area (320.40 cm^2), weight $plant^{-1}$ (10.18 g), dry weight $plant^{-1}$ (0.68 g) and yield (9.07 t ha^{-1}) were found from the treatment combination of Local variety and control dose at harvest (36 DAS).

Finally, it may be concluded that –

- BARI Lalshak-1 was the best among the studied varieties.
- All the test varieties produced their maximum yield with the application of 90 kg N ha^{-1}

Recommendations:

- The variety BARI Lalshak-1 should be cultivated with 90 kg N ha^{-1} for achieving higher yield.
- However, it needs more trials under farmer's field conditions at different Agro-Ecological Zones of Bangladesh for the conformation of the results.

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APPENDICES

Appendix I. Monthly records of meteorological observation at the period of experiment (November, 2015 to March, 2016)

Name of months	Temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November, 2015	30	15	66	24
December, 2015	28	13	63	5
January, 2016	26	12	54	8

Source: Weather Yard, Bangladesh Metrological Department, Dhaka.

Appendix II. Characteristics of soil of the experimental field

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Research farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
Flood Level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
P^H	6.7
Organic carbon(%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available p(ppm)	20.00
Exchangeable K(me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. Analysis of variance of the data on plant height at different days after sowing in red amaranth

Source of Variances	Degrees of freedom	Mean square			
		Plant height at different days after sowing			
		15DAS	**22DAS**	**29DAS**	**36DAS**
Replication	2	0.08	0.18	0.11	3.45
Variety (A)	2	4.19*	29.72*	92.03*	426.90*
Nitrogen (B)	3	2.43*	38.64*	92.23*	205.42*
Interaction(AXB)	6	0.49*	5.60*	22.46*	23.51*
Error	22	0.13	0.38	0.98	0.92

* = Significant at 5% level probability

Appendix IV. Analysis of variance of the data on number of leaves per plant at different days after sowing in red amaranth

Source of variances	Degrees of freedom	Mean square			
		Number of leaves per plant at different days after sowing			
		15DAS	**22DAS**	**29DAS**	**36DAS**
Replication	2	1.86	0.19	3.25	0.54
Variety (A)	2	7.19*	8.36*	11.08*	22.75*
Nitrogen (B)	3	2.07*	2.84^{NS}	7.36*	2.84^{NS}
Interaction(AXB)	6	0.38*	1.18*	0.31*	2.57*
Error	22	0.38	0.68	0.37	0.64

* = Significant at 5% level of probability

NS= Non Significant

Appendix V. Analysis of variance of the data on stem diameter at different days after sowing in red amaranth

Source of Variances	Degrees of freedom	Mean square		
		Stem diameter (mm) at different days after sowing		
		22DAS	**29DAS**	**36DAS**
Replication	2	0.02	0.01	0.03
Variety (A)	2	0.49*	0.34*	0.43*
Nitrogen (B)	3	0.06*	0.21*	0.21*
Interaction(AXB)	6	0.00*	0.01*	0.03*
Error	22	0.00	0.00	0.00

* = Significant at 5% level of probability

Appendix VI. Analysis of variance of the data on leaf area, fresh weight plant^{-1}, dry weight and yield in red amaranth

Source of Variances	Degrees of freedom	Mean square			
		Leaf area per plant ($cm^{2)}$	Fresh weight (g $plant^{-1}$)	Dry weight (g $plant^{-1}$)	Yield (t ha^{-1})
Replication	2	35.76	0.45	0.001	0.714
Variety (A)	2	73339.61*	580.58*	0.31*	14.194*
Nitrogen (B)	3	37418.79*	99.80*	0.07*	15.591*
Interaction(AXB)	6	3253.75*	9.84*	0.02*	1.437*
Error	22	8.88	0.34	0.001	0.07

* = Significant at 5% level of probability