EFFECT OF NITROGEN AND SPACING ON GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus viridus* L.)

MD. NIZAM UDDIN MAJUMDER

DEPARTMENT OF HORTICULTURE AND POSTHARVEST TECHNOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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EFFECT OF NITROGEN AND SPACING ON GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus viridus* L.)

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APPROVED BY:

Prof. A. K. M. Mahtabuddin
Dept. of Horticulture and Post harvest technology
SAU, Dhaka
Supervisor

Prof. Md. Ruhul Amin
Dept. of Horticulture and Post harvest technology
SAU, Dhaka
Co-Supervisor

Prof. Md. Ruhul Amin
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled **"Effect of Nitrogen and Spacing on Growth and Yield of Stem Amaranth (*Amaranthus viridus* L.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in HORTICULTURE, embodies the result of a piece of bonafide research work carried out by Md. Nizam Uddin Majumder, (Registration number 02183) under my supervision and guidance. No part of the thesis has been submitted anywhere else 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: 31.12.07
Dhaka, Bangladesh

Professor A. K. M. Mahtabuddin
Dept.of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

DEDICATED

TO

MY BELOVED LATE MOTHER

LIST OF ABBREVIATED TERMS

FULL NAME	ABBREVIATION
Agro – Ecological Zone	AEZ
And others	et al.
Bangladesh Bureau of Statistics	BBS
Centimeter	Cm
Degree Celsius	^0C
Days after Seeding	DAS
Etcetera	etc.
Food and Agriculture Organization	FAO
Gram	g.
Hectare	ha
Hour	hr
Kilogram	kg
Meter	m
Millimeter	mm
Month	Mo
Murate of Potash	MP
Grave	%
Number	no.
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
Triple Super Phosphate	TSP
United Nations Development Program	UNDP

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The Author

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By

MD. NIZAM UDDIN MAJUMDER

ABSTRACT

A field experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March 2007 to June 2007. The experiment consisted of two factors. (A): Four levels of nitrogen i.e. 0 kg N/ha (N_0), 80 kg N/ha (N_2), 110 kg N/ha (N_3), 140 kg N/ha (N_4); (B): Three spacing i.e. 30 cm × 20 cm (S_1), 30 cm × 30 cm (S_2), 30 cm × 40 cm (S_3). The trial was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. At 60 DAS the longest (92.35 cm) stem length was recorded from N_3 and the control condition gave the shortest (83.35 cm). The maximum (22.53 mm) stem diameter was recorded from N_3, while the control condition gave the minimum (19.06 mm). At 60 DAS the maximum (51.26 g) fresh weight of leaves per plant was recorded from N_3 and control condition gave the minimum (40.02 g). At 60 DAS the maximum (6.27%) dry matter content of leaves per plant was recorded from N_3, while the control gave the minimum (4.83%) which was closely (5.75%) followed by N_1. The maximum (128.46 g) fresh weight of stem per plant was recorded from N_3, while the control condition gave the minimum (114.93 g). At 60 DAS the maximum (15.65%) dry matter content of stem per plant was recorded from N_3, while the control condition gave the minimum (13.74%). The highest (20.29 kg) yield per plot was recorded from N_3 and the control gave the lowest (11.02 kg). At 60 DAS the highest (56.35 tonnes) yield per hectare was recorded from N_3 and the control condition gave the lowest (30.61 tonnes). At 60 DAS the longest (90.68 cm) stem length was recorded from S_3 and the shortest (86.71 cm) was from recorded from S_1 and the maximum (21.55 mm) stem diameter was recorded from S_3 and the minimum (18.31 mm) was from recorded from S_1. At 60 DAS the maximum (49.60 g) fresh weight of leaves per plant was recorded from S_3 and the minimum (44.35 g) was from recorded from S_1. The maximum (6.00%) dry matter content of leaves per plant was recorded from S_3 and the minimum (5.42%) was from recorded from S_1. At 60 DAS the maximum (126.10 g) fresh weight of stem per plant was recorded from S_3 and the minimum (120.04 g) was from recorded from S_1. At 60 DAS the maximum (15.34%) dry matter content of stem per plant was recorded from S_3 and the minimum (11.09%) was from recorded from S_1. At 60 DAS the highest (19.48 kg) yield per plot was recorded from S_2 and the lowest (13.20 kg) was from recorded from S_1. At 60 DAS the highest 54.10 tonnes) yield per hectare was recorded from S_2 and the lowest (36.67 tonnes) was from recorded from S_1. The highest (Tk. 731,200) gross return was obtained from the treatment combination of N_2S_2 and the lowest (Tk. 321,950) gross return was obtained from N_0S_1.

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Introduction

INTRODUCTION

Stem amaranth (*Amaranthus viridus* L.) commonly known as Data belongs to the family Amaranthaceae and is commonly used as leafy vegetable. It is mainly grown during summer and rainy season. The plant has fleshy stem and leaves with trailing habit (Bose and Som, 1986). This vegetable is important and popular in Bangladesh for its quick and vigorous growth and also for higher yield potential. It is widely cultivated in Bangladesh, India, in tropical and subtropical parts of Asia, Africa and Central America (Hardwood, 1980).

Amaranth is considered to be the cheapest vegetable in the market. It may be described as a 'poor man's vegetable in Bangladesh (Shanmugavelu, 1989). It is also, considered as a potential upcoming subsidiary food crop for future generation (Teutonico and Knorr, 1985). Its wider environmental adaptability, higher nutritive value, good taste, less risk of crop failure and various biotic and abiotic factors indicate that there is enough scope for its large scale cultivation. Amaranth is fairly rich in vitamin A and ascorbic acid. It has an appreciable amount of iron, calcium, phosphorous, riboflavin, thiamine, niacin and iron (Thompson and Kelly, 1988). Again it contains about 43 calorie per 100 g edible portion which is higher than that of any other common vegetables except potato and taro (Chowdhury, 1967). The juice of leaves is prescribed in cases of constipation, particularly for children and pregnant women (Burkill, 1985).

Total vegetable production in our country is about 1.48 metric tons per year of which 67% is produced in Rabi season and 33% in Kharif season (BBS, 2006). So, it is clear that the vegetable production in Kharif season is very low. Maximum production of different vegetables is concentrated during the months of November and April. Thus, there is a serious scarcity of vegetables during the months of May to September. As the nation runs short of vegetables, its production should be increased to meet the shortfall and feed the ever increasing population of the country.

At present amaranth is being cultivated in an area of 4250 hectare with a total production of 19,6500 metric tonnes. This average yield is only about 35-40 tonnes per hectare (BBS, 2006). Amaranth thrives well in a fertile, clay loam soil because it requires considerable amount of nutrients for rapid growth in a short time.

Amaranth responds greatly to major essential elements like N, P and K for its growth and yield (Mital *et al.*, 1975; Singh *et al.*, 1976; Thompson and Kelly, 1988). Nitrogen plays a vital role as a constituent of protein, nucleic acid and chlorophyll.

Plant density for stem amaranth cultivation is an important criterion for attaining maximum yield. Densely planted crop obstruct proper growth and development. On the other hand, wider spacing ensures the basic requirements but decrease the total number of plants as well as total yield. Yield may be increased upto 25% by using optimum spacing (Bansal, *et al.*, 1995). The adjustment of nitrogen and spacing is also helpful for the optimum growth and development of this crop. Excessive nitrogen and closer spacing produces thin stem amaranth.

Objectives:

1. To determine the optimum dose of nitrogen for growth and ensuring the higher yield of stem amaranth.
2. To find out the optimum plant spacing for stem amaranth.
3. To find out the best combination of nitrogen and plant spacing of stem amaranth to get maximum benefit.

Review of literature

REVIEW OF LITERATURE

Amaranth is one of the important summer vegetable in Bangladesh and in many countries of the world. The crop has drawn less attention of the researchers because normally it grows without care or management practices. For that a very few studies on growth, yield and development aspects of amaranth have been carried out in our country as well as in many other countries of the world. The research work so far done in Bangladesh is not adequate. Nevertheless, some of the important work and research findings related to the use of nitrogen and spacing so far done at home and abroad on this crop have been reviewed and presented in this chapter under the following headings-

2.1 Effect of nitrogen

A field experiment was conducted by Rathore *et al.* (2004) in Rajasthan, India during the winter seasons of 1997-1998 and 1998-1999 to identify the optimum doses of nitrogen for green amaranth cultivar. The crop was supplied with 0, 30, 60 and 90 kg N/ha in the growing period. Of those 90 kg/ha N fertilizer gave significantly higher yield, better growth and higher values for yield components compare to other doses. Application of N enhanced the growth and yield attributes significantly, whereas harvest index remained unaffected for using nitrogen fertilizer.

To evaluate the growth response of amaranth at different nitrogen fertilizer rates during 2001-2002 growing season three field experiments were conducted at the Taiwan Agricultural Research Institute experimental farm by Yung *et al.* (2003). 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 suggested that chlorophyll meter is a suitable tool for the assessment of chlorophyll and nitrogen status in amaranth plants.

Yung *et al.* (2003) carried out a field experiment in Wufeng, Taiwan, to measure canopy reflectance spectra and plant characters of amaranth grown during 2001-2002. Simple linear correlation analysis between plant characters and canopy spectral reflectance existed along the measured spectral bands. The results suggested that plant growth and nitrogen status of vegetable amaranth may be estimated by regression models from canopy spectral characteristics.

Ayodele *et al.* (2002) conducted a field experiment to evaluate the effect of N fertilizer @ 0, 50, 100 and 200 kg/ha on growth and yield of stem amaranth. Plant height, number of leaves produced, fresh and dry weights of plant parts increased with increased nitrogenous fertilizer application within a certain range. Application of fertilizer at 200 kg N/ha increased leaf production upto 75%, and the yield increased upto 114%. The unfertilized plants had yellowish green coloration as compared to the brighter green color observed in fertilized plants.

During rainy season of 1996 and 1997, at Ranichauri, Tehri Garhwal, Uttaranchal, India, a field experiment was conducted by Arya and Singh (2001) to determine the optimum level of N and an appropriate time of its application to amaranth. The treatments consisted of 4 levels of N (0, 40, 80 and 120 kg/ha) and 3 times of application. The optimum and maximum yield estimated through quadratic response was found for 120 kg N/ha. Plant height and plant diameter, dry matter content and yield per plant were also increased up to 120 kg N/ha.

Seeds of amaranth (*Amaranthus* spp.) cultivated under 8 N levels (0, 50, 100, 150, 200, 250, 300, 350 and 400 kg/ha) were evaluated for protein content, protein yield per hectare and some starch characteristics by Hevia *et al.* (2000). The protein content fluctuated between 16.5% (at 0 kg N/ha) and 18.4% (at 200 kg N/ha). The protein yield per hectare varied between 457.2 (at 0 kg N/ha) and 973.4 kg/ha (at 300 kg N/ha), 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.

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 in Kalyani, India. From their experiment they reported that yield components and seed yield increased with increasing N upto 120 kg N/ha.

The effect of nitrogen fertilizer on amaranth yield, yield components, growth and development was investigated by Myers (1998) with five levels of nitrogen fertilizer and three cultivars. Yield was responsive to nitrogen application, but high rates fertilizer can negatively affect the grain yield. In a field experiment during summer 1990/1991 and 1991/92 at Kinnaur, Himachal Pradesh, India was done by Saini and Shekhar (1998) to find out the effect of nitrogen fertilizer on growth and yield of amaranth with 0, 30, 60, 90 and 120 kg N/ha and reported that yield and most yield components increased significantly upto 90 kg N/ha and then decreased.

Small plot trials on dernopodzolic soil in the mountain region with 0, 60 or 120 kg/ha N fertilizer were done by Ozhiganova *et al.* (1996). They reported that the effect of seed inoculation on N fixing activity in the rhizosphere varied greatly with plant growth stage and N rate but there were marked increases at flowering without N fertilizer and at fruiting with N inoculation increased plant height, aboveground plant parts and root fresh weight/plant at all growth stages. Fresh yield increased from 29.9-31.2 t/ha without inoculation but the yields were found to be 36.1, 46.8 and 43.0 t/ha with 0, 60 and 120 kg N, respectively, when seeds were inoculated. Inoculation reduced plant nitrate content and increased crude protein content.

Acar (1996) carried out a field experiment to 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/day. There were no significant effect of N on seed yield and yield components. The increasing trend of yield was recorded with increasing nitrogen fertilizer. There were highly significant positive correlations between seed yield and both cultivars and 1000 seed weight.

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 were 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.

Subhan (1989) carried out a field experiment at Lembang from August to September, 1988 to find out the effect of doses and application time of nitrogen fertilizer on growth and yield of stem amaranth with N @ 0, 30, 70 and 110 kg/ha applied as a single application at sowing time, or as a split application at sowing and 10 days after sowing. Leaf number and stem diameter and petiole length were not affected by N application. Plant height, leaf area and fresh weight, dry matter content increased with increasing N application but root length was reduced by high N application. The highest yields were obtained with a split application of 110 kg N/ha.

2.2 Effect of plant spacing

Moore *et al.* (2004) carried out an experiment to determine the effects of spacing on the harvesting and yield of stem amaranth with 6, 9, 12 and 18 plants/5 m or row. In the competition experiments it was observed that the yield increased upto a certain level, then decrease. In highest spacing per plant yield was increased upto a certain level but the total yield per hectare decreased.

To determine the effect of crop densities (10, 20 and 40 plants m^{-1}) of stem amaranth a field experiment was conducted by Abbasdokht *et al.* (2003) in Iran. Yield and yield contributing characters were statistically significant in different density. In case of 40 plants m^{-1} the minimum yield was obtained. Again 10 plants m^{-1} gave the highest single plant weight and lowest yield when the yield in hectare was considered.

Field trials were conducted in South Florida, United States, between 1996 and 1999 by Santos *et al.* (2003) to determine the extent of yield reduction due to population densities of stem amaranth. They recorded yield reductions which reached 24% with densities higher than 8 plants/6 m row planting. Missinga and Currie (2002) conducted an experiment to assess the impact of plant densities of amaranth on yield and yield contributing characters and reported that spacing didn't affect the individual plant yield but yield per hectare was greatly affected by plant spacing.

Das and Ghosh (1999) conducted an experiment from March to August 1999 in Salna, Gazipur, Bangladesh to evaluate the seed yield potential of 3 amaranthus cultivars (Drutaraj, Bashpata and Sureshsari) grown under 5 different spacing levels (30 × 10, 30 × 15, 30 × 20, 30 × 25 and 30 × 30 cm). Sureshsari recorded a significantly higher seed yield (20.04 g/plant and 3.47 t/ha) than Drutaraj (17.20 g/plant and 2.88 t/ha). Spacing had a pronounced effect on the seed yield and yield contributing characters. Plants grown at the widest spacing of 30 × 30 cm produced the longest stem (95.25 cm), maximum seed yield per plant (24.24 g) and germination percentage of 80.60. However, plants grown at a spacing of 30 × 20 cm recorded the highest seed yield/ha (3.64 t/ha).

Peiretti and Gesumaria (1998) conducted an experiment using inter row spacing on growth and yield of amaranth with four different row spacing and the approximate densities were

100,000, 740,000, 550,000 and 470,000 plants/ha. The vegetative characters and yield per plant at harvest decreased with closer row spacing, particularly at 0.30 m spacing. Yield, however, was only slightly affected or tended to increase with increase in density. Spacing at 0.30 and 0.45 m were considered the most appropriate due to the rate of inter row coverage, which offers advantages for weed control by competition. Yield increase is also facilitated by these spacing.

Effects of six varieties and two row spacing (12.5 cm and 50.0 cm) on the yield, stand density, height have been studied by Jamriska (1998). Plainsman variety had the best yield (2.69 t/ha), on the other hand, the lowest yield (2.27 t/ha) was noted in K-369 variety. The stands with narrower row spacing produced higher yields than the stands with wider row spacing. Jaishree *et al.* (1996) conducted an experiment to study the effect of plant populations, nitrogen and phosphate on yield and quality of amaranth during kharif season of 1991 at densities of 111,000, 146,000 or 222,000 plants/ha and recorded the highest yield with 146,000 plants/ha.

Bansal *et al.* (1995) reported from an experiment than that the closer inter row (40 cm) and intra row spacing (10 cm) significantly reduced the dry matter accumulation, number of functional leaves and hence yield/plant. An experiment was conducted by Quasem and Hossain (1995) to evaluate 16 germplasms of local stem amaranth in summer. Spacing of 30×15 cm was maintained. Plant height at last harvest was found maximum in SAT 0034 (88.3 cm) and minimum in SAT 0062 (13.4 cm). The highest yield was recorded in SAT 0054 (54 t/ha) and the lowest in SAT 0024 (15.5 t/ha) only.

An experiment was conducted by Hradecka and Buresova (1994) to study the effect of sowing rates on the production parameters of "K-343" amaranth. No significant differences in the leaf area index were recorded between stands sown at rates of 16 and 65 plants/m^2. There were considerable differences in the number and size of leaves. Increased branching in the thin stands also influenced the proportion of leaves and stems in different organs during the growing season.

Row spacing and population effect on yield of grain amaranth was studied by Henderson *et al.* (1993) and stem amaranth was grown in population of 74000, 173000 and 272000 plants/ha. Stands were over sown and thinned by hand to achieve the desired population. The highest yields were obtained with the lowest population. Row spacing had no effect on yield at the lowest plant population, but yields were higher at the widest spacing with 2 times higher population. Grain yield of plants was higher as a result of lower plant population in the wider rows.

Consequently two field experiments were conducted by Norman and Shongwe (1993) on a sandy clay loam soil during the summer growing seasons of 1990-91 and 1991-1992. Seeds were sown in for the 1st experiment with 4 spacing like 60 × 45, 60 × 60, 90 × 45 and 90 × 60, cm and in the second experiment with 5 spacing like 45 × 45, 60 × 45, 60 × 60, 90 × 45, 90 × 60 cm and recorded no significant improvement in shoot, leaf or stem quality with any of the spacing treatment.

Materials and Methods

MATERIALS AND METHODS

The experiment was conducted in the field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from March to June 2007 to find out the effect of nitrogen and plant spacing on the growth and yield of stem amaranth. The materials and methods used for conducting the experiment were presented in this chapter under the following headings-

3.1 Experimental site

The present experiment was carried out in the field of Central Farm and Horticulture Laboratory of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, 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 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28. It had dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI Khamarbari, Dhaka and details of the recorded soil characteristics were presented in Appendix I.

3.3 Weather condition of the experimental site

The climate of experimental site was under the subtropical climate, characterized by three distinct seasons, the monsoon or the rainy season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data related to the temperature, relative humidity and rainfall during the period of the experiment was collected from the Bangladesh Meteorological Department, Dhaka and presented in Appendix II.

3.4 Planting materials

In this research work, the seeds of stem amaranth were used. It is a green stem and leafy type, quick growing and short duration summer vegetable. The seeds of amaranth variety Shurishary were collected from Sher-e-Bangla Agricultural University Farm.

3.5 Treatment of the experiment

The experiment consisted of two factors. Details were presented below:

Factor A: Four levels of nitrogen

i. $N_0 = 0$ kg N/ha
ii. $N_1 = 80$ kg N/ha
iii. $N_2 = 110$kg N/ha
iv. $N_3 = 140$ kg N/ha

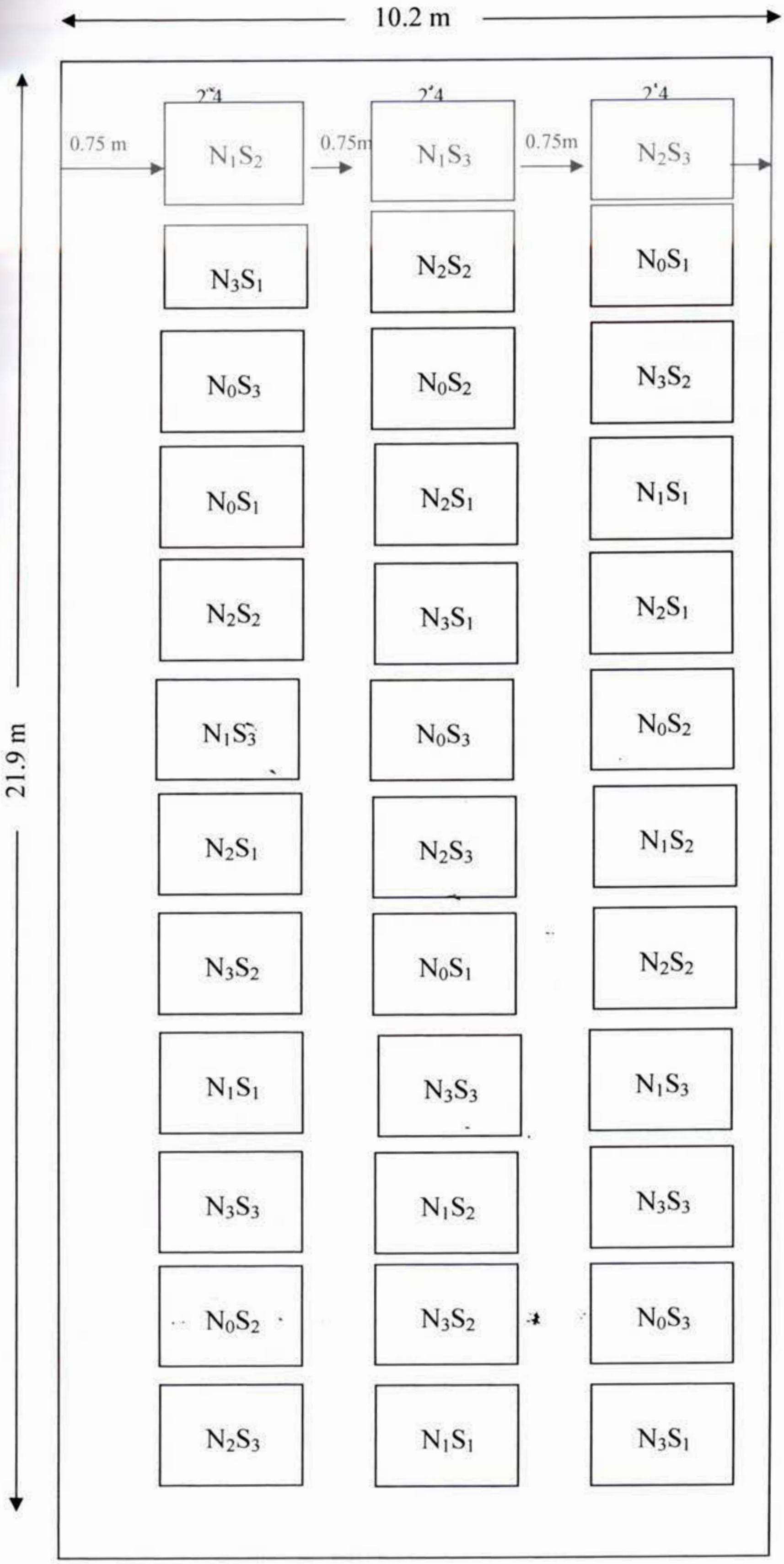
Factor A: Three levels of plant spacing

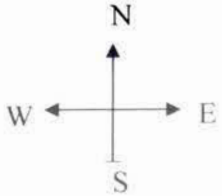
i. $S_1 = 30$ cm × 10 cm
ii. $S_2 = 30$ cm × 20 cm
iii. $S_3 = 30$ cm × 30 cm

There were 12 treatment combinations such as N_0S_1, N_0S_2, N_0S_3, N_1S_1, N_1S_2, N_1S_3, N_2S_1, N_2S_2, N_2S_3, N_3S_1, N_3S_2 and N_3S_3.

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area 21.9 m × 10.2 m was divided into three equal blocks. The layout of the experiment was prepared for distributing the treatment combinations in individual plot of each block. Each block was divided into 12 plots where 12 treatment combinations were allotted at random. There were 36 unit plots altogether in the experiment. The size of the each plot was 2.4 m × 1.2 m. The distance maintained between two blocks and two plots were 75 cm and 50 cm respectively.





Plot size = 2.4 m × 1.2 m
Plot spacing = 50 cm
Between replication = 0.75 m

Factors A:

N_0 = Control
N_1 = 80 kg N/ha
N_2 = 110 kg N/ha
N_3 = 140 kg N/ha

Factors B:

S_1 = 30 cm × 10 cm
S_2 = 30 cm × 20 cm
S_3 = 30 cm × 30 cm

Figure 1. Layout of the experimental plot

3.7 Land preparation

The plot selected for conducting the experiment was opened in the second week of March 2007 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth condition. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil was obtained for sowing stem amaranth seeds. Recommended doses of well-decomposed cow dung manure and chemical fertilizers as indicated below were mixed with the soil of each unit plot.

3.8 Application of manure and fertilizers

Nitrogen and potassium fertilizer in the form of urea and MP were applied respectively. The entire amounts of MP were applied during final preparation of land. Urea was applied in three equal installments at 15, 30 and 45 days after seed sowing of stem amaranth. Well-rotten cow dung 10 t/ha also was applied during final land preparation. The following manures and fertilizers were used as recommended by Rashid (1993) (Table 1).

Table 1. Dose and method of application of fertilizers in stem amaranth field

Fertilizers	Dose/ha	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cow dung	10 tons	100	--	--	--
Nitrogen	As treatment	--	33.33	33.33	33.33
P_2O_5 (as TSP)	100 kg	100	--	--	--
K_2O (as MP)	150 kg	100	--	--	--

3.9 Intercultural operation

After emergence of seedlings, various intercultural operations such as irrigation, thinning, weeding and top dressing etc. were accomplished for better growth and development of the stem amaranth seedlings.

3.9.1 Irrigation and Drainage

Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening up to 1st thinning.

3.9.2 Thinning

First thinning was done 30 days after sowing (DAS), 2nd thinning was done 10 days after the first and 3rd and 4th were done at 10 days interval for proper growth and development of stem amaranth.

3.9.3 Weeding

Weeding was done to keep the plots clean and easy aeration of soil which ultimately ensured better growth and development.

3.9.4 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 3 equal installments at 15, 30 and 45 DAS.

3.10 Plant protection

For controlling leaf caterpillars Nogos @ 1 ml/L water was applied 2 times at an interval of 10 days starting soon after the appearance of infestation.

3.11 Harvesting

To evaluate rate and yield, three harvestings were done at different growth stages. First harvesting was done at 30 days after sowing. Second, third and forth harvesting were done 40, 50 and 60 days after sowing, respectively. Different yield contributing data were recorded from the mean of 10 harvested plants which was selected at random from each unit plot.

3.12 Data collection

Ten plants were randomly selected from each unit plot for the collection of per plant data while the whole plot crop was harvested to record per plot yield data.

3.12.1 Stem length (cm)

The length of stem was recorded in centimeter (cm) at 30, 40, 50 and 60 days after sowing (DAS) in the experimental plots. The height was measured from ground level up to the tip of the growing point.

3.12.2 Stem diameter (mm)

Data were recorded as the average of 10 plants selected at random from the inner rows of each plot starting from 30 DAS to 60 DAS at 10 days interval and the mean value for each stem diameter was recorded.

3.12.3 Number of leaves per plant

Data were recorded as the average of 10 plants selected at random from the inner rows of each plot starting from 30 DAS to 60 DAS at 10 days interval.

3.12.4 Length of leaf (cm)

The measurement was taken from base to tip of the leaf. Data were recorded as the average of 10 leaves selected at random from the inner row plants of each plot starting from 30 DAS to 60 DAS at 10 days interval.Thus the mean was recorded and expressed in centimeter (cm).

3.12.5 Petiole length (cm)

Data were recorded as the average of 10 petiole selected at random from the plant of inner rows of each plot starting from 30 to 60 DAS at 10 days interval.

3.12.6 Petiole diameter (mm)

Diameter of petiole was measured by using a scale. The measurement was taken from circumference of the petiole. Data were recorded as the average of 10 petiole selected at random from the plant of inner rows of each plot starting from 30 to 60 DAS at 10 days interval. Thus the mean was recorded and expressed in millimeter (mm).

3.12.7 Fresh weight of leaves per plant (g)

Leaves of 10 randomly selected plants were detached by a sharp knife and average fresh weight of leaves was recorded in gram. Data were recorded from randomly selected plant of inner rows of each plot starting from 30 to 60 DAS at 10 days interval.

3.12.8 Dry matter content of leaves per plant (%)

After harvesting, randomly selected 100 g of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of leaves were computed by simple calculation from the weight recorded by the following formula :

$$\% \text{ Dry matter of leaves} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100 \quad (\text{g})$$

3.12.9 Fresh weight of stem per plant (g)

After harvesting the fresh stems of sampled plants, fresh weight of stem was taken immediately. Data were recorded from selected random plant of inner rows of each plot starting from 30 to 60 DAS at 10 days interval.

3.12.10 Dry matter content of stems per plant (%)

After harvesting, randomly selected 100 g of stem sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken. The dry matter contents of stems were computed by simple calculation from the weight recorded by the following formula

$$\% \text{ Dry matter of stems} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100 \ (\text{g})$$

3.12.11 Green Yield (kg per plot)

Yield of stem amaranth per plot was recorded as the whole plant in every harvest within a plot (2.4 m × 1.5 m) and was expressed in kilogram. Yield included weight of stem with leaves and total was taken at different time of harvest.

3.12.12 Green Yield (ton per hectare)

3.13 Statistical analysis

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

3.14 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of nitrogen and plant spacing. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 13%. The market price of stem amaranth was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

Results

Discussion

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of nitrogen and plant spacing on growth and yield of stem amaranth. Data on different yield contributing characters and yield at different days after sowing (DAS) were recorded. The analysis of variance (ANOVA) of the data on different yield contributing characters and yield of stem amaranth are given.

4.1 Stem length

Stem length of stem amaranth varied significantly due to the application of different levels of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Figure 2 & 3). At 30 DAS the tallest (32.56) cm maximum stem length was recorded from N_3 (140 kg/ha) which was statistically identical (32.11 cm) to N_2 (110 kg N/ha), while the shortest (25.88 cm)stem length was recorded from N_0 (0 kg N/ha) (Fig 2).The tallest stem length (58.73 cm) was observed from N_3 which was statistically similar (57.42 cm) to N_2 and the shortest (49.81 cm) was recorded from the control condition at 40 DAS. At 50 DAS the maximum stem length (77.97 cm) was recorded from N_3 which was statistically identical (77.53 cm) to N_2 and the shortest (69.13 cm) was found from the control condition. At 60 DAS the tallest stem length (92.48 cm) was recorded from N_3 which was statistically similar (91.64 cm) to N_2, while the control condition gave the shortest (83.48 cm) stem length. The results indicated that nitrogen ensured the favorable condition for the growth of stem amaranth. Vijayakumar *et al*. (1982) also recorded stem length which ranged from 16.05 to 57.25 cm at 30 DAS, 34.95-70.25 cm at 45 DAS and 65 to 122.15 cm at 60 DAS from their experiments.

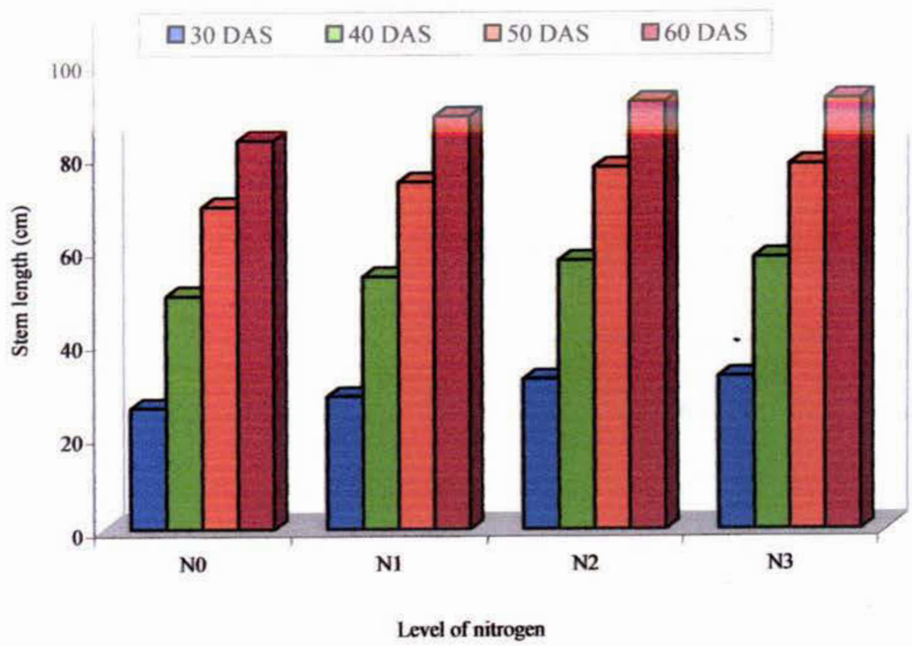


Figure 2. Effect of nitrogen on stem length of amaranth

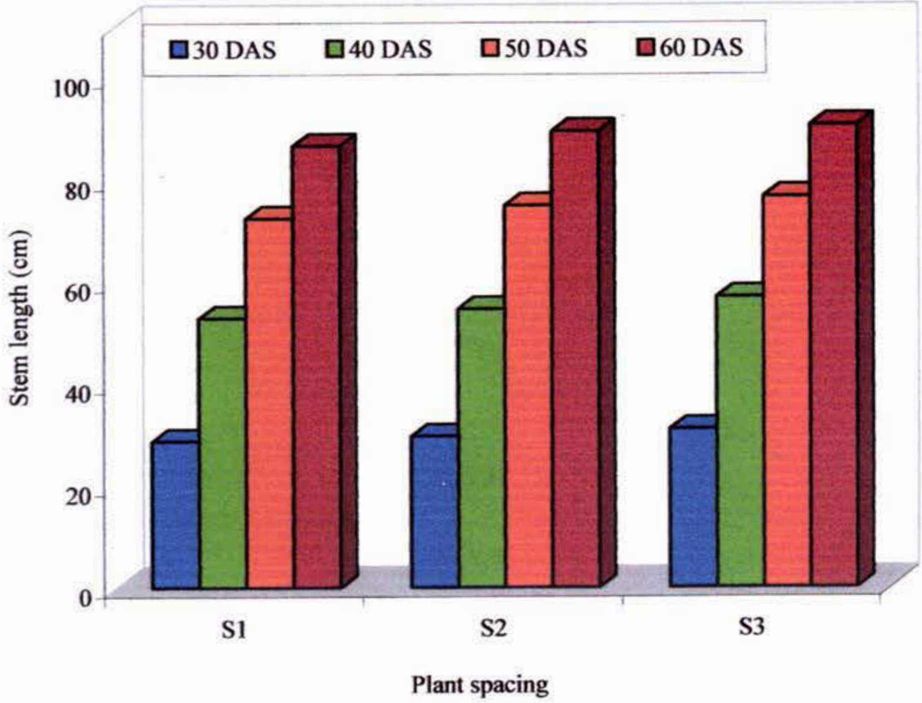


Figure 3. Effect of plant spacing on stem length of amaranth

Different plant spacing showed significant differences on stem length at 30, 40, 50 and 60 DAS (Figure 3). The tallest stem length (31.24 cm) was recorded from S_3 (30 cm × 40 cm) which was statistically identical (29.43 cm) to S_2 (30 cm × 20 cm) and the shortest (28.67 cm) was recorded from S_1 (30 cm × 10 cm) at 30 DAS. At 40 DAS the tallest stem length (57.19 cm) was found from S_3 which was statistically similar (54.52 cm) to S_2, while the shortest (53.01 cm) was from S_1. The tallest stem length (76.69 cm) was recorded from S_3 which was statistically identical (75.40 cm) to S_2 and the shortest (72.78 cm) was recorded from S_1 at 50 DAS. At 60 DAS the tallest stem length (90.77 cm) was found from S_3 which was statistically identical (90.02 cm) to S_2 and the shortest (86.66 cm) was from found from S_1. Wider spacing ensures maximum soil nutrients and light for the plants as a result maximum growth of stem amaranth. Similar findings also reported by Abbasdokht *et al.* (2003) from their experiment.

The variation was observed due to combined effect of nitrogen and plant spacing in terms of stem length at different days after sowing (Appendix III). At 30 DAS the tallest stem length (33.87 cm) was recorded from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the shortest stem length (24.79 cm) (Table 2). At 40 DAS the tallest stem length (61.60 cm) was observed from N_3S_3 whereas the shortest (46.03 cm) was found from N_0S_1. At 50 DAS the tallest stem length (81.86 cm) was recorded from N_3S_3 and the shortest (63.85 cm) was obtained from N_0S_1.The tallest stem length (94.45 cm) was recorded from N_3S_3 and the minimum (77.38 cm) from N_0S_1 at 60 DAS. From the results it was reveals that both nitrogen and plant spacing favored growth of stem amaranth and the ultimate results is the longest stem length with maximum nitrogen and plant spacing. The results are compared to Talukder (1999) recorded stem length from 32.50 to 81.84 cm.

Table 2. Combined effect of nitrogen and plant spacing on stem length and diameter of stem amaranth

Nitrogen and Plant spacing	Stem length (cm) at				Stem diameter (mm) at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0S_1	24.73 e	46.03 d	63.85 c	77.38 f	9.39 e	12.66 e	15.51 d	17.59 e
N_0S_2	25.70 e	50.64 cd	72.05 b	86.41 e	9.81 de	13.61 cde	17.53 bc	19.93 cd
N_0S_3	27.21 de	53.26 bc	71.81 b	85.99 e	10.16 cde	13.43 de	17.01 cd	19.21 de
N_1S_1	27.14 de	52.97 bc	73.47 b	87.36 de	11.01 bcd	14.70 bcd	18.72 abc	20.93 bcd
N_1S_2	28.42 cde	54.02 bc	74.69 b	88.01 cde	10.33 cde	14.01 cde	17.88 bc	20.16 cd
N_1S_3	29.72 bcd	55.41 abc	75.19 ab	89.73 bcde	11.37 abc	15.16 bc	19.05 abc	21.33 abcd
N_2S_1	31.27 abc	56.92 ab	76.77 ab	90.99 abcd	11.55 abc	16.26 bc	19.49 ab	21.51 abc
N_2S_2	31.97 abc	57.36 ab	77.36 ab	91.54 abc	11.93 ab	15.72 ab	19.62 ab	22.00 abc
N_2S_3	33.16 ab	58.52 ab	78.49 ab	92.86 ab	11.99 ab	15.51 ab	19.51 ab	21.92 abc
N_3S_1	31.62 abc	56.23 abc	76.73 ab	91.48 abcd	10.79 bcd	14.92 bcd	19.40 ab	21.72 abc
N_3S_2	32.57 ab	57.05 ab	76.26 ab	91.98 abc	11.71 ab	15.96 ab	20.42 a	22.62 ab
N_3S_3	33.87 a	61.60 a	81.86 a	94.59 a	12.82 a	17.02 a	21.01 a	23.42 a
$LSD_{(0.05)}$	3.547	5.379	6.160	3.464	1.206	1.431	1.902	1.923
CV(%)	7.03	9.78	6.86	6.30	6.39	5.67	6.97	5.39

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

4.2 Stem diameter

Stem diameter varied significantly due to the application of different levels of nitrogen at 30, 40, 50 and 60 DAS in stem amaranth (Figure 4). At 30 DAS the maximum stem diameter (11.90 mm) was recorded both from N_2 and N_3 at nitrogen 110 and 140 kg/ha, respectively and the minimum (9.99 mm) stem diameter was found from N_0 as 0 kg N/ha. Similarly the maximum (16.11 mm) stem diameter was recorded from N_3 which was closely followed (15.52 mm) by N_2 and the minimum (13.42 mm) was found from the control at 40 DAS. At 50 DAS the maximum stem diameter (20.33 mm) was recorded from N_3 which was statistically identical (19.41 mm) with N_2 and the minimum (16.61 mm) was found from the control condition. At 60 DAS the maximum (22.67 mm) stem diameter was recorded from N_3 which was statistically identical (21.89 mm) with N_2, while the control condition gave the minimum (19.31 mm). The results indicated that optimum nitrogen ensured the favorable condition for the growth of stem amaranth.

Significant differences in respect of stem diameter at 30, 40, 50 and 60 DAS were recorded for different plant spacing. The maximum (11.65 mm) stem diameter was observed in S_3 (30 cm × 40 cm) which was statistically identical (11.11 mm) with S_2 (30 cm × 30 cm) and the minimum (10.76 mm) was recorded from S_1 (30 cm × 20 cm) at 30 DAS. At 40 DAS the maximum (15.47 mm) stem diameter was found from S_3 which was statistically identical (14.82 mm) with S_2 and the minimum (14.60 mm) was found from S_1. The maximum (19.14 mm) stem diameter was obtained from S_3 which was statistically similar (19.01 mm) with S_2 and the minimum (18.43 mm) was recorded from S_1 at 50 DAS. At 60 DAS the maximum (21.63 mm) stem diameter was recorded from S_3 which was statistically similar (19.03 mm) with S_2 and the minimum (18.67 mm) was noted from S_1.

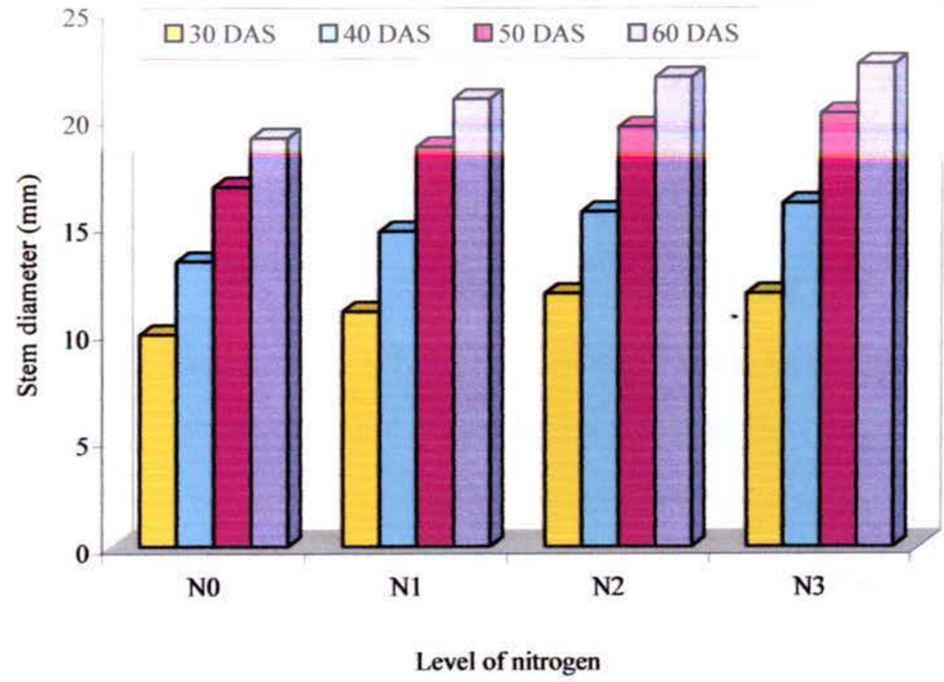


Figure 4. Effect of nitrogen on stem diameter of amaranth

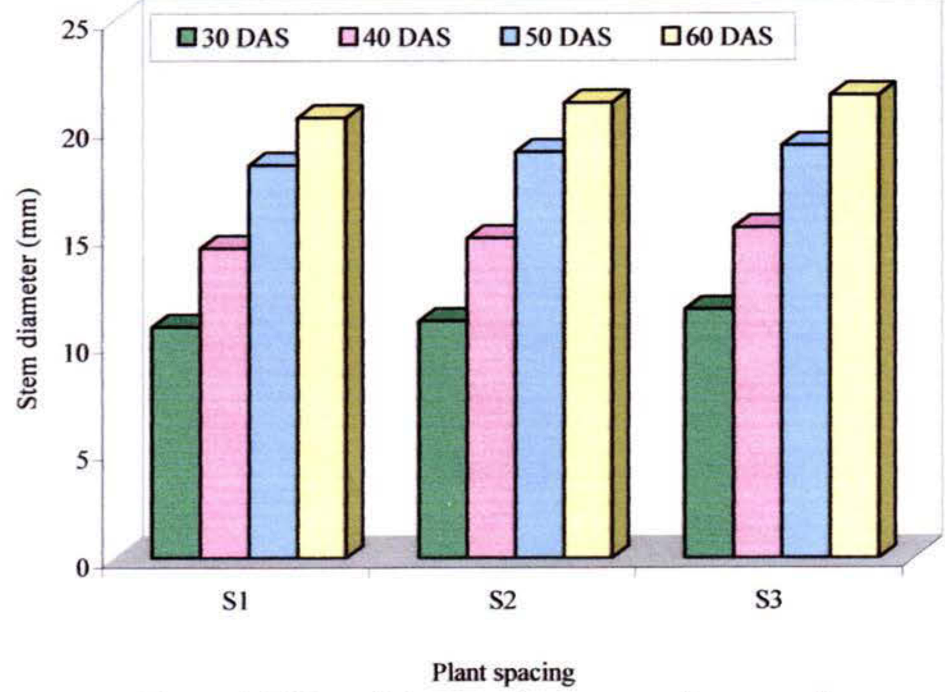


Figure 5. Effect of plant spacing on stem diameter of amaranth

The variation was also recorded due to the combined effect of nitrogen and plant spacing in terms of stem diameter at different days after sowing (Appendix III). At 30 DAS the maximum stem diameter (12.82 mm) was recorded from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing). On the other hand, N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the minimum stem diameter (9.39 mm) (Table 2). At 40 DAS the maximum (17.02 mm) stem diameter was found from N_3S_3 whereas the minimum (12.66 mm) was recorded in N_0S_1. At 50 DAS the maximum (21.01 mm) stem diameter was found from N_3S_3 and the minimum (15.51 mm) was recorded from N_0S_1. The maximum (23.42 mm) stem diameter was recorded from N_3S_3 and the minimum (17.59 mm) from N_0S_1 at 60 DAS. Both nitrogen and plant spacing favored growth of stem amaranth and the ultimate result was the maximum development of stem diameter.

4.3 Number of leaves per plant

Number of leaves per plant differ significantly due to the application of different levels of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Figure 6 and 7). At 30 DAS the highest (16.71) number of leaves per plant was obtained from N_3 (nitrogen 140 kg/ha) which was statistically identical (15.73) with N_2 (110 kg N/ha), while the lowest (9.73) number of leaves per plant was recorded from N_0. The highest (22.01) number of leaves per plant was observed from N_3 which statistically similar (21.50) to N_2 and the lowest (14.74) was recorded from the control condition 40 DAS. At 50 DAS the highest number of leaves (33.84) per plant was recorded from N_3 which was statistically similar (32.74) to N_2 and the lowest (26.16) was recorded from the control condition. Similarly at 60 DAS the highest number of leaves (40.93) per plant was recorded from N_3 which was statistically identical (40.12) with N_2 and the control produced the lowest (32.53).

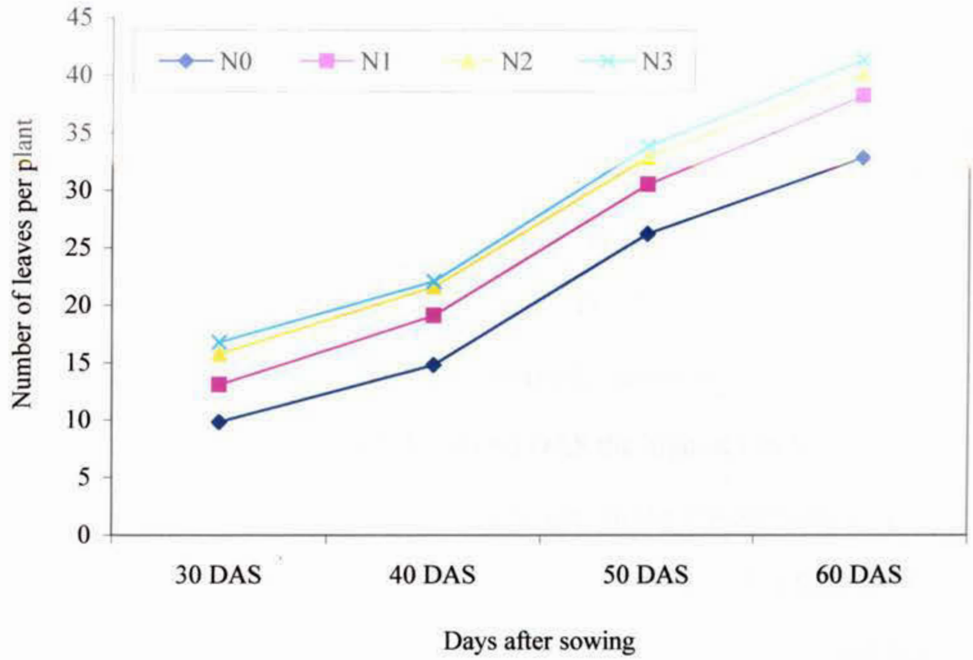


Figure 6. Effect of nitrogen on number of leaves per stem of amaranth

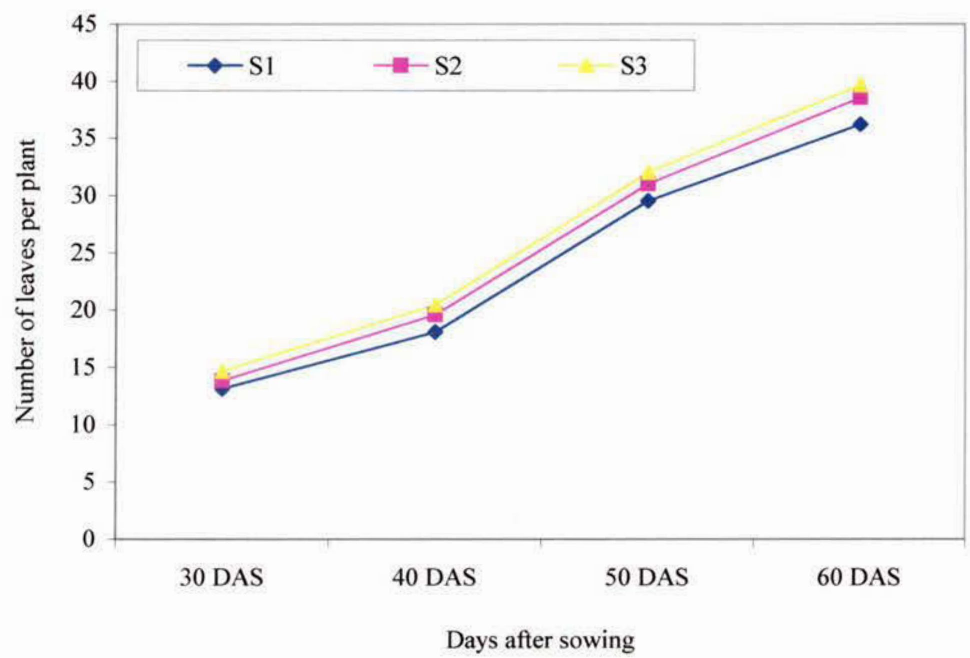


Figure 7. Effect of plant spacing on number of leaves per stem of amaranth

Different plant spacing showed significant variation on number of leaves per plant at 30, 40, 50 and 60 DAS. The highest number of leaves (14.50) per plant was observed from S_3 (30 cm × 30 cm) which was statistically identical (13.84) with S_2 (30 cm × 20 cm) and the lowest (13.14) was obtained from S_1 (30 cm × 10 cm) at 30 DAS. At 40 DAS the highest (20.35) number of leaves per plant was recorded from S_3 which was statistically similar (19.43) S_2, while the lowest (18.03) was noted from S_1. The highest (32.01) number of leaves per plant was recorded from S_3 which was statistically identical (30.98) with S_2 and the lowest (29.54) was found from S_1 at 50 DAS. At 60 DAS the highest (36.10) number of leaves per plant was observed from S_3 which was statistically similar (38.55) with S_2 and the lowest (36.20) was from recorded from S_1. Agele *et al.* (2004) reported that fertilizer both organic and inorganic influence the growth of plant and produced highest number of leaves per plant.

The variation was recorded due to the combined effect of nitrogen and plant spacing on number of leaves per plant at different days after sowing (Appendix IV). At 30 DAS the highest number of leaves (17.60) per plant was recorded from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the lowest number of leaves (9.24) per plant. At 40 DAS the highest (23.46) number of leaves per plant was observed from N_3S_3, while the lowest (13.44) was recorded in N_0S_1. At 50 DAS the highest (35.17) number of leaves per plant was recorded from N_3S_3 and the lowest (25.48) was recorded from N_0S_1. The highest (42.76) number of leaves per plant was recorded from N_3S_3 and the lowest (31.07) was noted from N_0S_1 at 60 DAS (Table 3). From the results it was observed that both nitrogen and plant spacing favored growth of stem amaranth and finally highest number of leaves per plant was produced. Bansal *el al.* (1995) reported that wider spacing produced highest number of leaves than the closer spacing in stem amaranth cultivation even with adequate nutrients supply.

Table 3. Combined effect of nitrogen and plant spacing on number of leaves per plant and length of leaf of stem amaranth

Nitrogen and Plant spacing	Number of leaves per plant at				Length of leaf per plant at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0S_1	9.24 f	13.44 e	25.48 d	31.07 f	5.87 f	8.36 f	11.94 g	16.46 e
N_0S_2	10.03 ef	15.18 de	26.03 d	32.77 ef	6.41 ef	9.89 ef	12.46 fg	17.78 de
N_0S_3	10.23 ef	15.77 de	26.81 d	34.81 def	7.04 cdef	10.66 de	13.06 defg	18.49 cd
N_1S_1	12.31 de	17.81 cd	28.49 cd	37.10 cde	8.37 bcde	10.46 de	14.23 cdef	19.57 bcd
N_1S_2	12.98 cd	19.23 bc	30.81 bc	39.19 abcd	7.15 def	10.37 de	13.10 efg	18.55 cd
N_1S_3	14.19 bcd	20.24 abc	31.76 ab	40.42 abc	8.61 abcd	11.99 bcd	14.51 bcde	20.18 bc
N_2S_1	15.35 abc	20.65 abc	31.16 bc	38.82 bcd	9.13 abc	11.23 cde	14.72 bcde	20.39 bc
N_2S_2	15.71 abc	21.65 ab	33.47 ab	41.05 ab	9.65 ab	12.77 abc	15.49 bc	20.04 ab
N_2S_3	16.63 ab	22.54 ab	34.94 ab	42.32 ab	9.46 ab	12.69 abc	15.30 bc	20.78 ab
N_3S_1	16.10 ab	20.48 abc	33.05 ab	40.17 abc	8.30 bcde	11.45 cde	15.01 bcd	19.99 bc
N_3S_2	16.76 ab	22.36 ab	34.01 ab	42.06 ab	9.80 ab	13.76 ab	16.13 ab	21.76 ab
N_3S_3	17.60 a	23.46 a	35.17 a	42.76 a	10.61 a	14.21 a	17.63 a	22.43 a
$LSD_{(0.05)}$	2.399	2.940	2.914	3.905	1.776	1.719	1.723	1.810
CV(%)	10.20	8.95	5.57	6.05	12.54	8.81	7.02	7.41

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

4.4 Length of leaf

Length of leaf of stem amaranth varied significantly due to the application of nitrogen in different level at 30, 40, 50 and 60 DAS (Figure 8 and 9). At 30 DAS the longest leaf (9.42 cm) was recorded from N_3 (140 kg/ha) which was statistically identical (9.27 cm) to N_2 (110 kg N/ha), while the shortest (6.57 cm) length of leaf was observed from N_0 as 0 kg N/ha. The longest leaf (12.99 cm) was observed from N_3 which was closely (12.51 cm) followed by N_2 and the shortest (9.50 cm) was recorded from the control condition at 40 DAS. At 50 DAS the longest leaf (16.13 cm) was recorded from N_3 which was statistically similar (14.99 cm) with N_2 and the shortest (14.42 cm) was found from the control condition. At 60 DAS the longest leaf (21.37 cm) was recorded from N_3 which was statistically identical (20.56 cm) with N_2, while the control condition gave the shortest (17.77 cm).

Different plant spacing showed significant differences on length of leaf at 30, 40, 50 and 60 DAS. The longest leaf (9.06 cm) was recorded from S_3 (30 cm × 30 cm) which was statistically identical (8.14 cm) to S_2 (30 cm × 20 cm) and the shortest (30 cm × 20 cm) was found from at 30 DAS. At 40 DAS the longest leaf (12.48 cm) was recorded from S_3 which was statistically identical (11.67 cm) to S_2, while the shortest (10.32 cm) was found from S_1. The longest leaf (15.09 cm) was recorded from S_3 which was statistically identical (14.46 cm) with S_2 and the shortest (13.92 cm) was recorded from S_1 at 50 DAS. At 60 DAS the longest length (20.63 cm) was observed from S_3 which was statistically similar (19.56 cm) with S_2 and the shortest (19.27 cm) was from recorded from S_1.

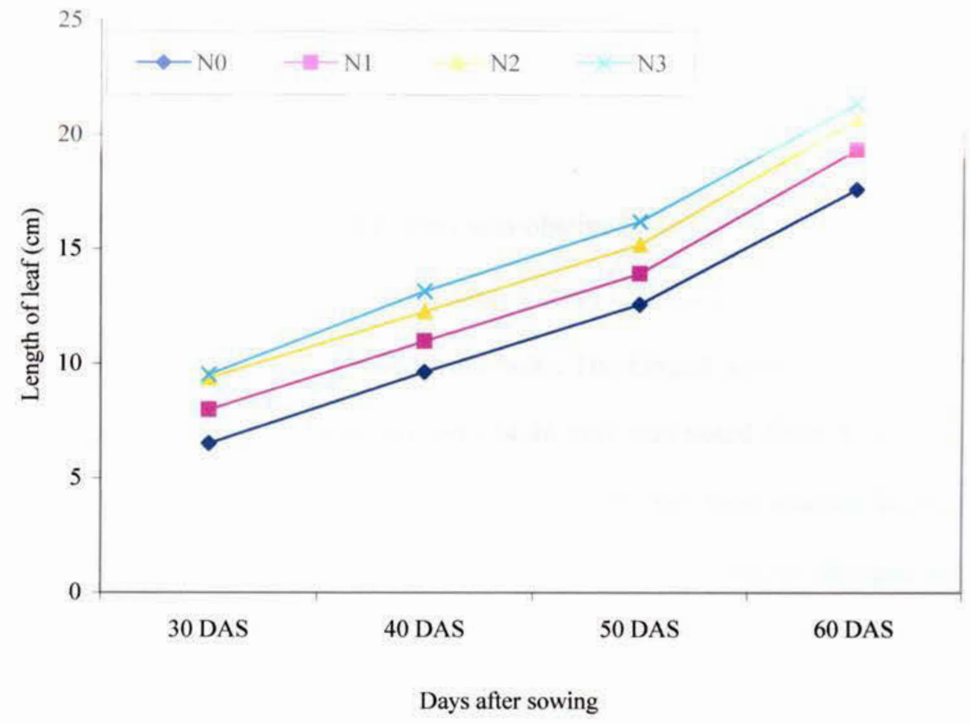


Figure 8. Effect of nitrogen on length of leaf of amaranth

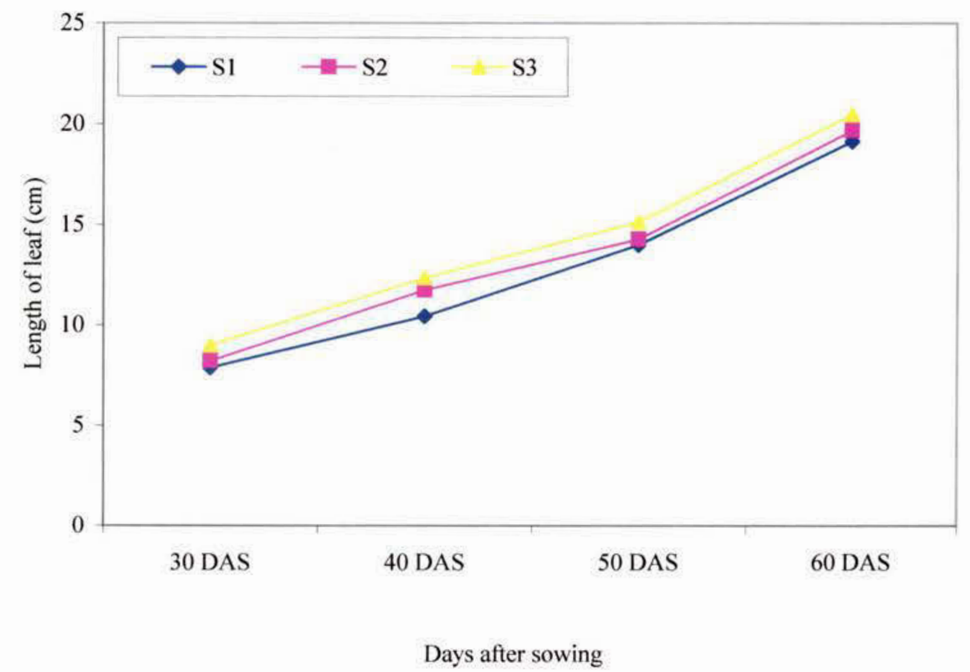


Figure 9. Effect of plant spacing on length of leaf of amaranth

The variation was recorded due to the combined effect of nitrogen and plant spacing in terms of length of leaf at different days after sowing (Appendix IV). At 30 DAS the longest leaf (10.61 cm) was recorded from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the shortest of leaf (5.87 cm) (Table 3). At 40 DAS the longest leaf (14.21 cm) was obtained from N_3S_3 and the shortest (8.36 cm) was recorded in N_0S_1. At 50 DAS the longest leaf (17.63 cm) was recorded from N_3S_3 and the shortest (11.94 cm) was recorded from N_0S_1. The longest leaf (22.43 cm) was found from N_3S_3. On the other hand, the shortest (14.46 cm) was noted from N_0S_1 at 60 DAS (Table 3). From the results it was found that both nitrogen and plant spacing favored growth of stem amaranth and produced longest length of leaf with maximum nitrogen and plant spacing.

4.5 Petiole length

Petiole length of stem amaranth varied significantly due to the application of different levels of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Table 4). At 30 DAS the longest petiole (4.85 cm) was recorded from N_3 which was statistically similar (4.79 cm and 4.69 cm) with N_2 and N_1 as 110 kg and 80 N/ha, while the shortest petiole (4.32 cm) was obtained from N_0 as 0 kg N/ha. The longest petiole (6.79 cm) was observed from N_2 and N_3 and the shortest (6.18 cm) was recorded from the control condition at 40 DAS. At 50 DAS the longest petiole (7.83 cm) was recorded from N_3 which was statistically identical (7.70 cm and 7.59 cm) to N_2 and N_1, respectively. On the other hand shortest (7.10 cm) was found from the control. At 60 DAS the longest petiole (7.91 cm) was recorded from N_3 which was statistically identical (7.88 cm and 7.74 cm) with N_2 and N_1, while the control condition gave the shortest (7.26 cm).

Table 4. Effect of nitrogen and plant spacing on petiole length and diameter of stem amaranth

Nitrogen and Plant spacing	Petiole length (cm) at				Petiole diameter (mm) at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Nitrogen								
N_0	4.32 b	6.18 b	7.10 b	7.26 b	2.25 c	2.62 b	3.04 b	3.24 b
N_1	4.69 a	6.71 a	7.59 a	7.74 a	2.40 b	2.98 a	3.18 a	3.33 ab
N_2	4.79 a	6.79 a	7.70 a	7.88 a	2.47 ab	3.01 a	3.24 a	3.43 a
N_3	4.85 a	6.79 a	7.83 a	7.91 a	2.52 a	2.97 a	3.26 a	3.47 a
$LSD_{(0.05)}$	0.363	0.397	0.382	0.382	0.087	0.203	0.124	0.155
Plant spacing								
S_1	4.43 b	6.30 b	7.22 b	7.33 b	2.34 b	2.73 b	3.06 b	3.22 b
S_2	4.69 ab	6.74 a	7.70 a	7.85 a	2.42 a	2.90 ab	3.23 a	3.42 a
S_3	4.86 a	6.81 a	7.75 a	7.91 a	2.48 a	3.06	3.24 a	3.45 a
$LSD_{(0.05)}$	0.315	0.344	0.331	0.331	0.076	0.176	0.107	0.134
CV(%)								

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

Different plant spacing showed significant differences on petiole length at 30, 40, 50 and 60 DAS. The longest petiole (4.86 cm) was observed from S_3 (30 cm × 40 cm) which was statistically identical (4.69 cm) with S_2 (30 cm × 30 cm) and the shortest (4.43 cm) was recorded from S_1 (30 cm × 20 cm) at 30 DAS. At 40 DAS the longest petiole (6.81 cm) was found from S_3 which was statistically identical (6.74 cm) with S_2, while the shortest (6.30 cm) was from S_1. The longest petiole (7.75 cm) was recorded from S_3 which was statistically identical (7.70 cm) with S_2 and the shortest (7.22 cm) was observed from S_1 at 50 DAS. At 60 DAS the longest petiole (7.91 cm) was recorded from S_3 which was statistically identical (7.85 cm) with S_2 and the shortest (7.33 cm) was from recorded from S_1 (Table 4). The maximum space creates an opportunity for receiving light and plant essentials nutrients for maximum vegetative growth for stem amaranth with longest petiole. Yung *et al.* (2003) also reported longest petiole length with using wider spacing from their experiments.

The variation was recorded due to combined effect of nitrogen and plant spacing for petiole length at different days after sowing (Appendix V). At 30 DAS the longest petiole (5.23 cm) was recorded from N_3S_2 (140 kg N/ha + 30 cm × 20 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the shortest petiole (3.86 cm). At 40 DAS the longest petiole (7.16 cm) was recorded from N_3S_2 whereas the shortest (5.96 cm) was recorded in N_0S_1. At 50 DAS the longest petiole (8.22 cm) was recorded from N_3S_2 and the shortest (6.92 cm) was recorded from N_0S_1. The longest petiole (8.30 cm) was recorded from N_3S_2 and the shortest (7.14 cm) from N_0S_1 at 60 DAS (Table 5). From the results it was reveals that both nitrogen and plant spacing favored growth of stem amaranth and the ultimate results is the longest petiole length with maximum nitrogen and plant spacing.

Table 5. Combined effect of nitrogen and plant spacing on petiole length and diameter of stem amaranth

Nitrogen and Plant spacing	Petiole length (cm) at				Petiole diameter (mm) at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0S_1	3.86 d	5.96 c	6.92 c	7.14 c	2.15 d	2.39 d	2.91 d	3.00 c
N_0S_2	4.14 cd	6.13 c	7.03 c	7.23 c	2.30 c	2.51 cd	3.07 cd	3.29 abc
N_0S_3	4.85 ab	6.42 abc	7.29 bc	7.51 bc	2.34 c	2.95 ab	3.10 cd	3.39 ab
N_1S_1	4.73 abcd	6.43 abc	7.21 c	7.32 c	2.46 bc	2.90 ab	3.15 bcd	3.17 bc
N_1S_2	4.47 bcd	6.62 abc	7.55 abc	7.72 abc	2.41 bc	2.93 ab	3.19 abc	3.34 ab
N_1S_3	4.98 ab	7.12 a	8.07 a	8.23 ab	2.37 c	3.08 ab	3.22 abc	3.42 ab
N_2S_1	4.69 abcd	6.28 bc	7.19 c	7.40 c	2.43 bc	2.75 bcd	3.08 cd	3.12 bc
N_2S_2	4.94 ab	7.06 ab	7.99 ab	8.16 ab	2.30 c	3.20 a	3.40 a	3.59 a
N_2S_3	4.90 ab	7.03 ab	7.95 ab	8.13 ab	2.64 a	3.11 ab	3.28 abc	3.48 ab
N_3S_1	4.70 abcd	6.54 abc	7.62 abc	7.76 abc	2.33 c	2.80 abc	3.19 bcd	3.42 ab
N_3S_2	5.23 a	7.16 a	8.22 a	8.30 a	2.67 a	2.97 ab	3.26 abc	3.47 ab
N_3S_3	4.73 abc	6.66 abc	7.70 abc	7.78 abc	2.57 ab	3.09 ab	3.37 ab	3.52 ab
$LSD_{(0.05)}$	0.629	0.688	0.662	0.662	0.152	0.351	0.214	0.268
CV(%)	7.97	6.15	5.17	8.07	9.74	7.13	9.95	7.66

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

N_0: 0 kg N/ha S_1: 30 cm × 10 cm
N_1: 80 kg N/ha S_2: 30 cm × 20 cm
N_2: 110 kg N/ha S_3: 30 cm × 30 cm
N_3: 140 kg N/ha

4.6 Petiole diameter

Petiole diameter of stem amaranth varied significantly due to the application of different levels of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Table 4). At 30 DAS the maximum (2.52 mm) petiole diameter was recorded from N_3 (140 kg/ha) which was statistically identical (2.47 mm) to N_2 (110 kg N/ha), while the minimum (2.25 mm) petiole diameter was observed from N_0 which was closely (2.40 mm) followed by N_1 (80 kg N/ha). The maximum (3.01 mm) petiole diameter was observed from N_2 which was closely (2.98 mm and 2.97 mm) followed by N_1 and N_3 and the minimum (2.62 mm) was recorded from the control at 40 DAS. At 50 DAS the maximum (3.26 mm) petiole diameter was recorded from N_3 which was statistically similar (3.24 mm and 3.18 mm) to N_2 and N_1 and the minimum (3.04 mm) was found from the control condition. At 60 DAS the maximum (3.47 mm) petiole diameter was recorded from N_3 which was statistically identical (3.43 mm) to N_2, while the control condition gave the minimum (3.24 mm) which was closely (3.33 mm) followed by N_1 (Table 4).

Different plant spacing showed significant differences on petiole diameter at 30, 40, 50 and 60 DAS. The maximum (2.48 mm) petiole diameter was recorded from S_3 (30 cm × 40 cm) which was statistically identical (2.42 mm) to S_2 (30 cm × 30 cm) and the minimum (2.34 mm) was found from S_1 (30 cm × 20 cm) at 30 DAS. At 40 DAS the maximum (3.06 mm) petiole diameter was found from S_3 which was statistically identical (2.90 mm) with S_2, while the minimum (2.73 mm) was from S_1. The maximum (3.24 mm) petiole diameter was obtained from S_3 which was statistically identical (3.23 mm) with S_2 and the minimum (3.06 mm) was observed from S_1 at 50 DAS. At 60 DAS the maximum (3.45 mm) petiole diameter was recorded from S_3 which was statistically identical (3.42 mm) with S_2 and the minimum (3.22 mm) was from obtained from S_1 treatment (Table 4).

The variation was recorded due to the combined effect of nitrogen and plant spacing in terms of petiole diameter at different days after sowing (Appendix V). At 30 DAS the maximum petiole diameter (2.67 mm) was observed from N_3S_2 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 20 cm plant spacing) gave the minimum (2.15 mm) petiole diameter. At 40 DAS the maximum (3.20 mm) petiole diameter was observed from N_2S_2 whereas the minimum (2.39 mm) was recorded in N_0S_1. At 50 DAS the maximum (3.40 mm) petiole diameter was recorded from N_2S_2 and the minimum (2.91 mm) was recorded from N_0S_1. The maximum petiole diameter (3.59 mm) was recorded from N_2S_2 and the minimum (3.00 mm) from N_0S_1 at 60 DAS (Table 5).

4.7 Fresh weight of leaves per plant

Fresh weight of leaves per plant of stem amaranth differed significantly due to the application of different levels of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Table 6). At 30 DAS the maximum (19.59 g) fresh weight of leaves per plant was recorded from N_3 (140 kg/ha) which was statistically similar (18.04 g) to N_2, while the minimum (9.28 g) fresh weight of leaves per plant was recorded from N_0. The maximum (28.95 g) fresh weight of leaves per plant was observed from N_3 which was statistically similar (28.40 g) to N_2 and the minimum (17.60 g) was recorded from the control condition. At 50 DAS the maximum (39.44 g) fresh weight of leaves per plant was recorded from N_3 which was statistically identical (38.25 g) with N_2 and the minimum (29.01 g) was found from the control condition. At 60 DAS the maximum fresh weight of leaves (51.26 g) per plant was recorded from N_3 which was statistically identical (50.36 g and 47.58 g) to N_2 and N_1, while control condition gave the minimum (40.02 g).

Table 6. Main effect of nitrogen and plant spacing on fresh weight leaves and dry matter content of leaves of stem amaranth

Nitrogen and Plant spacing	Fresh weight (g) of leaves per plant at				Dry matter content (%) of leaves per plant at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Nitrogen								
N_0	9.28 c	17.60 c	29.01 c	40.02 b	1.85 c	2.54 c	4.15 c	4.83 c
N_1	13.91 b	24.23 b	34.94 b	47.58 a	2.47 b	3.39 b	4.87 b	5.75 b
N_2	18.04 a	28.40 a	38.25 a	50.36 a	3.05 a	3.95 a	5.25 a	6.14 ab
N_3	19.59 a	28.95 a	39.44 a	51.26 a	3.32 a	4.06 a	5.39 a	6.27 a
$LSD_{(0.05)}$	1.750	2.573	2.754	3.530	0.324	0.292	0.298	0.445
Plant spacing								
S_1	13.82 b	23.02 b	33.43 a	45.01 b	2.51 b	3.25 b	4.60 b	4.56 b
S_2	14.92 b	24.70 ab	35.74 ab	48.82 a	2.75 ab	3.39 b	5.10 ab	6.01 a
S_3	16.51 a	26.19 a	37.30 a	50.43 a	2.91 a	3.81 a	5.23 a	6.22 a
$LSD_{(0.05)}$	1.515	2.229	2.385	3.057	0.281	0.253	0.258	0.385
CV(%)								

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

Different plant spacing showed significant differences on fresh weight of leaves per plant at 30, 40, 50 and 60 DAS. The maximum (16.51 g) fresh weight of leaves per plant was found from S_3 (30 cm × 30 cm) and the minimum (13.82 g) was recorded from S_1 (30 cm× 10 cm) at 30 DAS. At 40 DAS the maximum fresh weight of leaves (26.19 g) per plant was found from S_3 which was statistically identical (24.76 g) with S_2, while the minimum (23.02 g) was from S_1. The maximum fresh weight of leaves (37.30 g) per plant was obtained from S_3 and the minimum (33.43 g) was recorded from S_1 at 50 DAS. At 60 DAS the maximum fresh weight (50.43 g) of leaves per plant was recorded from S_3 which was statistically identical (47.96 g) with S_2 and the minimum (45.01 g) was found from S_1. From the results it was observed that plant spacing provided enough opportunity for the plant to receive maximum light and as a result maximum photosynthesis could occur. For that maximum growth was attained and maximum foliage coverage with highest number and weight of leaves per plant of stem amaranth was found. Yoshizawa *et al.* (1981) reported similar results.

The variation was recorded due to the combined effect of nitrogen and plant spacing in terms of fresh weight of leaves per plant at different days after sowing (Appendix VI). At 30 DAS the maximum fresh weight of leaves (22.63 g) per plant was observed from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the minimum fresh weight of leaves (8.02 g) per plant (Table 7). At 40 DAS the maximum fresh weight of leaves (32.33 g) per plant was observed from N_3S_3 whereas the minimum (17.10 g) was recorded in N_0S_1. At 50 DAS the maximum (42.19 g) fresh weight of leaves per plant was recorded from N_3S_3 and the minimum (28.06 g) was found from N_0S_1. The maximum fresh weight of leaves (55.02 g) per plant was observed from N_3S_3 and the minimum (37.96 g) from N_0S_1 at 60 DAS.

Table 7. Combined effect of nitrogen and plant spacing on fresh weight of leaves and dry matter content of leaves of stem amaranth

Nitrogen and Plant spacing	Fresh weight (g) of leaves per plant at				Dry matter content (%) of leaves per plant at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0S_1	8.02 g	17.10 f	28.06 d	37.96 f	1.72 f	2.45 e	4.12 c	4.73 d
N_0S_2	9.39 fg	17.65 f	28.43 d	40.11 ef	1.85 ef	2.67 e	4.21 c	5.04 cd
N_0S_3	10.85 efg	18.84 ef	28.72 d	42.37 def	1.90 ef	2.71 e	4.36 c	5.17 cd
N_1S_1	12.46 def	22.82 de	33.00 cd	45.57 cde	2.33 de	3.27 d	4.67 bc	5.61 bc
N_1S_2	13.90 de	24.09 cd	36.01 bc	48.26 abcd	2.51 cde	3.41 cd	5.09 ab	5.83 abc
N_1S_3	15.78 cd	25.78 bcd	37.10 abc	50.01 abc	2.51 bcd	3.77 bcd	5.13 ab	6.10 ab
N_2S_1	18.01 bc	27.55 abcd	36.16 abc	47.03 bcde	2.79 bcd	3.84 bc	5.11 ab	5.74 abc
N_2S_2	18.10 bc	28.10 abc	39.03 ab	52.00 abc	3.07 abc	3.92 bc	5.41 a	6.37 ab
N_2S_3	20.78 ab	29.56 ab	40.75 ab	53.10 ab	3.33 ab	4.12 ab	5.56 a	6.66 a
N_3S_1	19.43 abc	26.46 abcd	37.62 ab	48.12 abcd	3.10 ab	3.86 bc	5.26 a	6.03 ab
N_3S_2	20.88 ab	29.20 ab	39.43 ab	52.11 abc	3.28 ab	4.03 ab	5.47 a	6.55 a
N_3S_3	22.63 a	32.33 a	42.19 a	55.02 a	3.71 a	4.57 a	5.67 a	6.82 a
$LSD_{(0.05)}$	3.031	4.457	4.770	6.114	0.562	0.505	0.516	0.770
CV(%)	11.77	10.62	7.96	7.63	12.41	8.58	6.20	7.91

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

4.8 Dry matter content of leaves per plant

Dry matter content of leaves per plant of stem amaranth varied significantly due to the application of different levels of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Table 6). At 30 DAS the maximum (3.32%) dry matter content of leaves per plant was recorded from N_3 (140 kg/ha) which was statistically similar (3.05%) to N_2 (110 kg N/ha), while the minimum (1.85%) dry matter content of leaves per plant was recorded from N_0 (0 kg N/ha). The maximum (4.06%) dry matter content of leaves per plant was recorded from N_3 which was closely followed (3.95%) by N_2 and the minimum (2.54%) was recorded from the control at 40 DAS. At 50 DAS the maximum (5.39%) dry matter content of leaves per plant was recorded from N_3 which was statistically identical (5.25%) to N_2 and the minimum (4.15%) was found from the control condition. At 60 DAS the maximum (6.27%) dry matter content of leaves per plant was recorded from N_3 which was statistically identical (6.14%) to N_2, while the control gave the minimum (4.83%).

Different plant spacing showed significant variation in respect of dry matter content of leaves per plant at 30, 40, 50 and 60 DAS. The maximum dry matter content (2.91 %) of leaves per plant was recorded from S_3 (30 cm × 30 cm) which was statistically similar (2.66%) to S_2 (30 cm × 20 cm) and the minimum (2.51 %) was obtained from S_1 at 30 DAS. At 40 DAS the maximum (3.81 %) dry matter content of leaves per plant was found from S_3, while the minimum (3.25 %) was from S_1. The maximum (5.23 %) dry matter content of leaves per plant was recorded from S_3 and the minimum (4.60 %) was recorded from S_1 at 50 DAS. At 60 DAS the maximum (6.22 %) dry matter content of leaves per plant was recorded from S_3 which was statistically identical (5.82%) to S_2 and the minimum (4.56 %) was found from S_1 (Table 6).

The variation was recorded due to combined effect of nitrogen and plant spacing in terms of dry matter content of leaves per plant at different days after sowing (Appendix VI). At 30

DAS the maximum (3.71%) dry matter content of leaves per plant was recorded from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the minimum (1.72 %) dry matter content of leaves per plant (Table 7). At 40 DAS the maximum (4.57 %) dry matter content of leaves per plant was recorded from N_3S_3 whereas the minimum (2.45 %) was recorded in N_0S_1. At 50 DAS the maximum (5.67 %) dry matter content of leaves per plant was recorded from N_3S_3 and the minimum (4.12 %) was observed from N_0S_1. The maximum dry matter content (6.82 %) of leaves per plant was recorded from N_3S_3 and the minimum (4.73 %) from N_0S_1 at 60 DAS.

4.9 Fresh weight of stem per plant

Fresh weight of stem per plant of stem amaranth varied significantly due to the application of different level of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Table 8). At 30 DAS the maximum (38.53 g) fresh weight of stem per plant was observed from N_3 (140 kg/ha) which was statistically identical (37.71 g) to N_2 as 110 kg N/ha, while the minimum (30.42 g) fresh weight of stem per plant was recorded from N_0. The maximum (69.73 g) fresh weight of stem per plant was observed from N_3 which was closely followed (69.70 g) by N_1 and N_2 whereas the minimum (60.14 g) was observed from the control at 40 DAS. At 50 DAS the maximum (102.00 g) fresh weight of stem per plant was recorded from N_3 which was statistically similar (100.68 g) to N_2 and the minimum (89.05 g) was found from the control treatment. At 60 DAS the maximum (128.46 g) fresh weight of stem per plant was recorded from N_3 which was statistically identical (127.70 g) to N_2, while the control condition gave the minimum (114.93 g).

Table 8. Main effect of nitrogen and plant spacing on fresh weight stems and dry matter content of stem of stem amaranth

Nitrogen and Plant spacing	Fresh weight of stem (g) per plant at				Dry matter content (%) of stem per plant at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Nitrogen								
N_0	30.42 c	60.14 b	89.05 c	114.93 b	4.05 b	7.35 c	10.48 d	13.74c
N_1	33.19 b	65.12 a	96.24 b	122.75 a	4.31 b	8.09 b	11.38 c	14.85 b
N_2	37.71 a	69.70 a	100.68 ab	127.70 a	4.95 a	8.67 a	11.91 b	15.38 a
N_3	38.53 a	69.73 a	102.00 a	128.46 a	5.12 a	8.86 a	12.38 a	15.65 a
$LSD_{(0.05)}$	2.482	4.630	4.930	5.463	0.306	0.519	0.469	0.530
Plant spacing								
S_1	33.82 b	64.65 b	95.02 b	126.10 b	4.51 b	8.03 b	11.01 b	13.85 b
S_2	34.98 ab	66.73 ab	98.82 ab	126.77 ab	4.73 ab	8.29 ab	11.87 b	14.94 a
S_3	36.77 a	70.34 a	100.07 a	133.23 a	4.81 a	8.69 a	12.72 a	16.13 a
$LSD_{(0.05)}$	2.149	4.009	4.269	4.731	0.265	0.450	0.406	0.459

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

Different plant spacing showed significant differences on fresh weight of stem per plant at 30, 40, 50 and 60 DAS. The maximum fresh weight of stem (36.77 g) per plant was recorded from S_3 (30 cm × 30 cm) which was statistically identical (34.98 g) to S_2 (30 cm × 20 cm) and the minimum (33.82 g) was recorded from S_1 (30 cm × 10 cm) at 30 DAS. At 40 DAS the maximum (70.34 g) fresh weight of stem per plant was found from S_3 which was statistically similar (66.73 g) with S_2, while the minimum (64.65 g) was from S_1. The maximum fresh weight of stem (100.07 g) per plant was recorded from S_3 which was statistically identical (98.82 g) to S_2 and the minimum (95.02 g) was recorded from S_1 at 50 DAS. At 60 DAS the maximum fresh weight of stem (133.23 g) per plant was recorded from S_3 which was statistically identical (126.77 g) with S_2 and the minimum (126.10 g) was from recorded from S_1.

The variation was recorded due to combined effect of nitrogen and plant spacing in terms of fresh weight of stem per plant at different days after sowing (Appendix VII). At 30 DAS the maximum (41.11 g) fresh weight of stem per plant was obtained from N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the minimum fresh weight of stem (28.95 g) per plant (Table 9). At 40 DAS the maximum (74.13 g) fresh weight of stem per plant was observed from N_3S_3 whereas the minimum (55.37 g) was recorded in N_0S_1. At 50 DAS the maximum (109.09 g) fresh weight of stem per plant was recorded from N_3S_3 and the minimum (83.13 g) was obtained from N_0S_1. The maximum fresh weight of stem (133.13 g) per plant was recorded from N_3S_3 and the minimum (108.78 g) from N_0S_1 at 60 DAS. From the results it was revealed that both nitrogen and plant spacing favored growth of stem amaranth and the ultimately maximum fresh weight of stem per plant was found from maximum nitrogen and plant spacing.

Table 9. Combined effect of nitrogen and plant spacing on fresh weight stems and dry matter content of stem of stem amaranth

Nitrogen and Plant spacing	Fresh weight of stem (g) per plant at				Dry matter content (%) of stem per plant at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0S_1 10	28.95 e	55.37 d	83.13 c	108.18 c	4.09 c	7.03 e	9.47 e	12.89 e
N_0S_2 20	30.15 de	62.70 cd	95.09 b	121.73 b	4.22 c	7.77 de	11.00 cd	14.24 d
N_0S_3 30	30.73 de	65.55 bc	93.99 b	120.27 b	4.34 c	7.91 cde	10.99 d	14.43 cd
N_1S_1 10	30.51 de	63.85 bc	95.88 b	123.34 ab	4.13 c	8.20 bcd	11.36 bcd	14.63 bcd
N_1S_2 20	33.19 cde	65.97 abc	97.21 b	125.01 ab	4.50 bc	8.14 bcd	11.33 bcd	14.81 bcd
N_1S_3 30	35.42 bcd	67.99 abc	97.92 ab	126.98 ab	4.67 bc	8.55 bcd	11.76 bcd	15.46 bc
N_2S_1 10	37.03 abc	69.81 abc	100.13 ab	129.43 ab	4.93 ab	8.62 abc	11.84 bcd	15.33 bc
N_2S_2 20	38.44 abc	70.43 abc	101.10 ab	130.23 ab	4.99 ab	8.88 abc	11.91 bc	15.51 ab
N_2S_3 30	39.83 ab	72.23 ab	103.70 ab	132.90 ab	5.17 a	9.15 ab	12.22 b	15.66 ab
N_3S_1 10	47.43 abc	68.05 abc	99.56ab	129.14 ab	5.01 ab	8.72 abc	11.87 bcd	15.46 bc
N_3S_2 20	38.77 ab	70.23 abc	102.40 ab	130.51 ab	5.23 a	8.80 abc	12.00 bc	15.59 ab
N_3S_3 30	41.11 a	74.13 a	109.09 a	133.13 a	5.42 a	9.51 a	13.76 a	16.84 a
$LSD_{(0.05)}$	4.298	8.129	8.538	9.462	0.530	0.899	0.812	0.918
CV(%)	7.26	7.16	5.25	8.53	6.80	6.44	7.16	8.63

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

N_0: 0 kg N/ha　　S_1: 30 cm × 10 cm

N_1: 80 kg N/ha　　S_2: 30 cm × 20 cm

N_2: 110 kg N/ha　　S_3: 30 cm × 30 cm

N_3: 140 kg N/ha

4.10 Dry matter content of stem per plant

Dry matter content of stem per plant of stem amaranth differed significantly due to the application of different level of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Table 8). At 30 DAS the maximum (5.12%) dry matter content of stem per plant was recorded from N_3 (140 kg/ha) which was statistically similar (4.95%) to N_2 (110 kg N/ha) whereas the minimum (4.05 %) was found from control treatment. The maximum (8.86%) dry matter content of stem per plant was observed from N_3 which was closely (8.67%) followed by N_2 and the minimum (7.35%) was recorded from the control condition at 40 DAS. At 50 DAS the maximum dry matter content of stem (12.38%) per plant was observed from N_3 and the minimum (10.48%) was found from the control condition. At 60 DAS the maximum dry matter content of stem (15.65%) per plant was recorded from N_3 which was statistically similar (15.38%) to N_2, while the control condition gave the minimum (13.74%).

Different plant spacing showed significant variation in case of dry matter content of stem per plant at 30, 40, 50 and 60 DAS. The maximum dry matter content of stem (4.81%) per plant was recorded from S_3 (30 cm × 30 cm) which was statistically followed (4.73%) by S_2 (30 cm × 20 cm) at 30 DAS and the minimum (4.51 %) was obtained from S_1. At 40 DAS the maximum dry matter content of stem (8.69 %) per plant was found from S_3, which was statistical identical (8.29 %) to S_2 while the minimum (8.03 %) was from S_1. The maximum (12.72 %) per plant was recorded from S_3 which was statistically identical (11.87%) with S_2 and the minimum (11.01 %) was noted from S_1 at 50 DAS. At 60 DAS the maximum (16.13%) dry matter content of stem per plant was recorded from S_3 which was statistically identical (14.80 %) to S_2 and the minimum (13.85 %) was from recorded from S_1.

The variation was recorded due to the combined effect of nitrogen and plant spacing in terms of dry matter content of stem per plant at different days after sowing (Appendix VII). At 30 DAS the maximum (5.42 %) dry matter content of stem per plant was recorded from

N_3S_3 (140 kg N/ha + 30 cm × 30 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the minimum (4.09%) dry matter content of stem per plant (Table 9). At 40 DAS the maximum (9.51%) dry matter content of stem per plant was observed from N_3S_3 whereas the minimum (7.93 %) was recorded in N_0S_1. At 50 DAS the maximum (13.76%) dry matter content of stem per plant was recorded from N_3S_3 and the minimum (9.47 %) was found from N_0S_1. The maximum (16.48 %) dry matter content of stem per plant was recorded from N_3S_3 and the minimum (12.89 %) from N_0S_1 at 60 DAS.

4.11 Yield per plot

Yield per plot of stem amaranth varied significantly due to the application of different level of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Figure 10 & 11). At 30 DAS the highest yield (5.34 kg) per plot was recorded from N_3 (140 kg/ha) which was statistically identical (5.18 kg) to N_2 (110 kg N/ha), while the lowest yield (3.42 kg) per plot was obtained from N_0. The highest yield (8.56 kg) per plot was recorded from N_3 which was statistically identical (8.30 kg) to N_2 and the lowest (5.87 kg) was recorded from the control condition. At 50 DAS the highest yield (12.84 kg) per plot was recorded from N_3 which was statistically similar (12.34 kg) to N_2 and the lowest (7.19 kg) was found from the control condition. At 60 DAS the highest yield (20.29 kg) per plot was recorded from N_3 which was statistically similar (19.85 kg) to N_2, while the control gave the lowest yield (11.02 kg). The results indicated that nitrogen provided favorable condition for the growth of stem amaranth which ultimately ensured highest yield.

4.12 Yield per hectare

Yield per hectare of stem amaranth varied significantly due to the application of different level of nitrogen and plant spacing at 30, 40, 50 and 60 DAS (Figure 12 & 13). At 30 DAS the highest yield (14.82 t/ha) was recorded from N_3 (140 kg/ha) which was statistically identical (14.40 t/ha) to N_2 (110 kg N/ha), while the lowest (9.51 t/ha) yield per hectare was recorded from N_0 (0 kg N/ha). The highest yield (23.77 t/ha) was observed from N_3 which was statistically similar (23.06 tonnes) to N_2 and the lowest (16.31 t/ha) was recorded from control condition at 40 DAS. At 50 DAS the highest yield (35.66 t/ha) was observed from N_3 which was statistically identical (34.28 t/ha) to N_2 and the lowest (19.97 t/ha) was found from the control condition. At 60 DAS the highest yield (56.35 t/ha) was recorded from N_3 which was statistically similar (55.15 t/ha) to N_2, while the control condition gave the lowest yield (30.61 t/ha).

Different plant spacing showed significant differences in yield per hectare at 30, 40, 50 and 60 DAS. The highest yield (13.51 t/ha) was recorded from S_2 (30 cm × 30 cm) which was statistically similar (12.84 t/ha) to S_3 (30 cm × 30 cm) at 30 DAS. At 40 DAS the highest yield (22.33 t/ha) was found from S_3 which was statistically identical (20.36 t/ha) to S_2. The highest yield (32.04 t/ha) was recorded from S_2 which was statistically identical (29.81 t/ha) to S_3 at 50 DAS. At 60 DAS the highest (54.10 t/ha) yield was recorded from S_2 which was closely (49.28 t/ha) followed by S_3 and the lowest (36.67 t/ha) was from recorded from S_1.

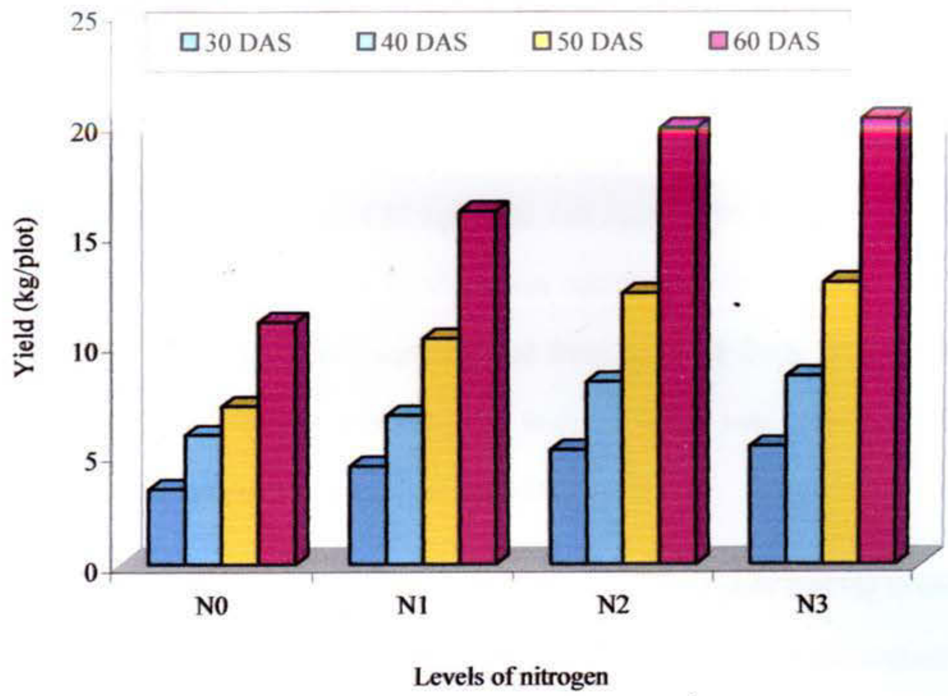


Figure 10. Effect of nitrogen on yield per plot of amaranth

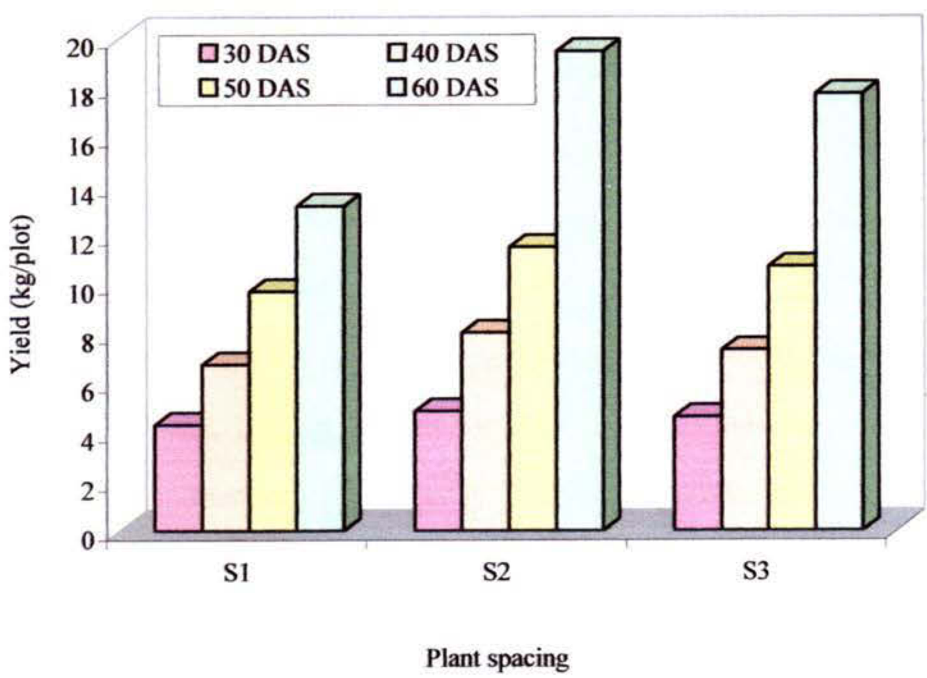


Figure 11. Effect of plant spacing on yield per plot of amaranth

Different plant spacing showed significant differences in yield per plot at 30, 40, 50 and 60 DAS. The highest yield (4.93 kg) per plot was recorded from S_2 (30 cm × 20 cm) which was statistically identical (4.70 kg) to S_3 (30 cm × 30 cm) and the lowest yield (4.35 kg) was recorded from S_1 (30 cm × 10 cm) at 30 DAS. At 40 DAS the highest yield (8.08 kg) per plot was found from S_2 and lowest (4.88 kg) yield was found from S_1. The highest yield (11.64 kg) per plot was recorded from S_2 which was statistically identical (10.73 kg) to S_3 whereas the lowest (10.02 kg) yield was obtained from S_1 at 50 DAS. At 60 DAS the highest yield (19.53 kg) per plot was recorded from S_2 which was closely (17.74 kg) followed by S_2 and the lowest (13.48 kg) was recorded from S_1.

The variation was recorded due to combined effect of nitrogen and plant spacing in terms of yield per plot at different days after sowing (Appendix VIII). At 30 DAS the highest yield (5.99 kg) per plot was recorded from N_3S_2 (140 kg N/ha + 30 cm × 20 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the lowest (3.00 kg) yield per plot (Table 10). At 40 DAS the highest yield (9.67 kg) per plot was observed from N_3S_2 whereas the lowest (5.29 kg) was recorded in N_0S_1. At 50 DAS the highest yield (14.40 kg) per plot was recorded from N_2S_2 and the lowest (5.53 kg) was observed from N_0S_1. The highest yield (23.28 kg) per plot was recorded from N_2S_2 and the lowest (8.93 kg) from N_0S_1 at 60 DAS. Nitrogen ensured vegetative growth with maximum number of leaves, length of leaves, petiole length and diameter of stem and petiole and ultimately with highest yield. On the other hand, spacing ensured optimum light and nutrients which helped attaining highest yield. Teutonico and Knorr (1985) reported similar results earlier from their experiment.

Table 10. Combined effect of nitrogen and plant spacing on yield per plot and hectare of stem amaranth

Nitrogen and Plant spacing	Yield (kg/plot) at				Yield (t/ha) at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_0S_1	3.00 f	5.29 f	5.53 f	8.93 g	8.33 f	14.70 f	15.35 f	24.80 g
N_0S_2	3.44 ef	6.36 def	8.03 e	13.42 f	9.54 ef	17.68 def	22.30 e	37.28 f
N_0S_3	3.84 de	5.96 ef	8.02 e	10.71 g	10.66 de	16.57 ef	22.27 e	29.75 g
N_1S_1	4.17 cd	6.34 def	9.25 de	11.43 fg	11.57 cd	17.61 def	25.71 de	31.75 fg
N_1S_2	4.69 bc	6.93 cde	11.06 bcd	18.96 cd	13.03 bc	19.24 cde	30.72 bcd	52.67 cd
N_1S_3	4.51 bc	7.01 cde	10.56 cd	17.81 de	12.52 bc	19.48 cde	29.33 cd	49.48 de
N_2S_1	4.71 bc	7.50 cd	12.78 ab	15.91 e	13.07 bc	20.82 cd	35.50 ab	44.19 e
N_2S_2	5.78 a	9.19 ab	14.40 a	23.28 a	16.05 a	25.53 ab	39.99 a	64.67 a
N_2S_3	5.07 b	8.22 bc	11.59 bc	20.38 bc	14.09 b	22.83 bc	32.20 bc	56.60 bc
N_3S_1	4.95 b	7.88 c	11.35 bc	16.54 de	13.75 b	21.90 c	31.53 bc	45.96 de
N_3S_2	5.99 a	9.67 a	12.65 ab	22.25 ab	16.63 a	26.86 a	35.15 ab	61.80 ab
N_3S_3	5.07 b	8.12 bc	12.76 ab	22.07 ab	14.09 b	22.56 bc	35.46 ab	61.31 ab
$LSD_{(0.05)}$	0.631	1.193	1.861	2.427	1.752	3.312	5.169	6.742
CV(%)	8.10	9.55	10.30	8.53	8.10	9.55	10.30	8.53

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

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

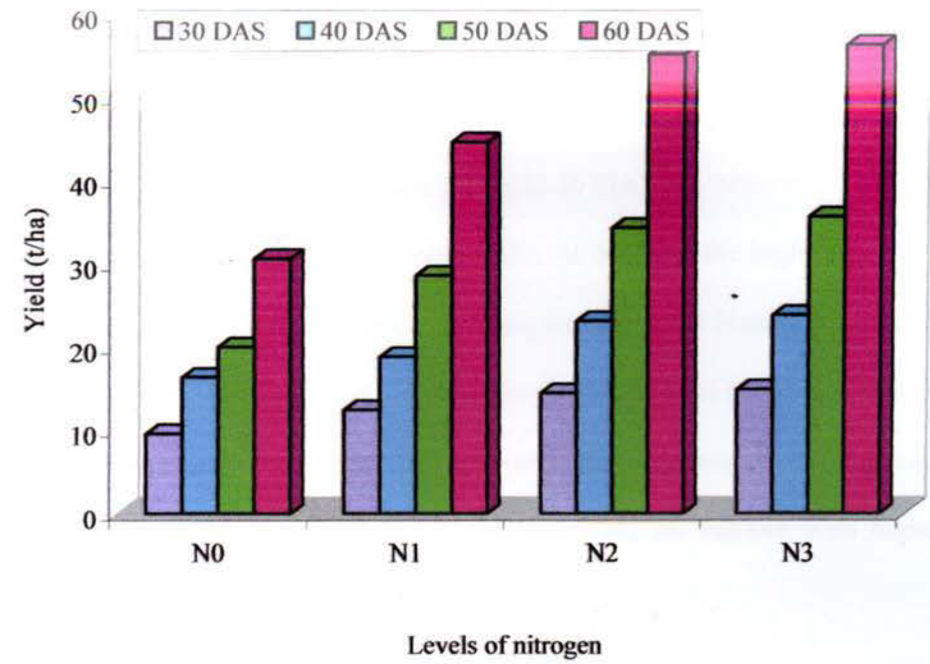


Figure 12. Effect of nitrogen on yield per hectare of amaranth

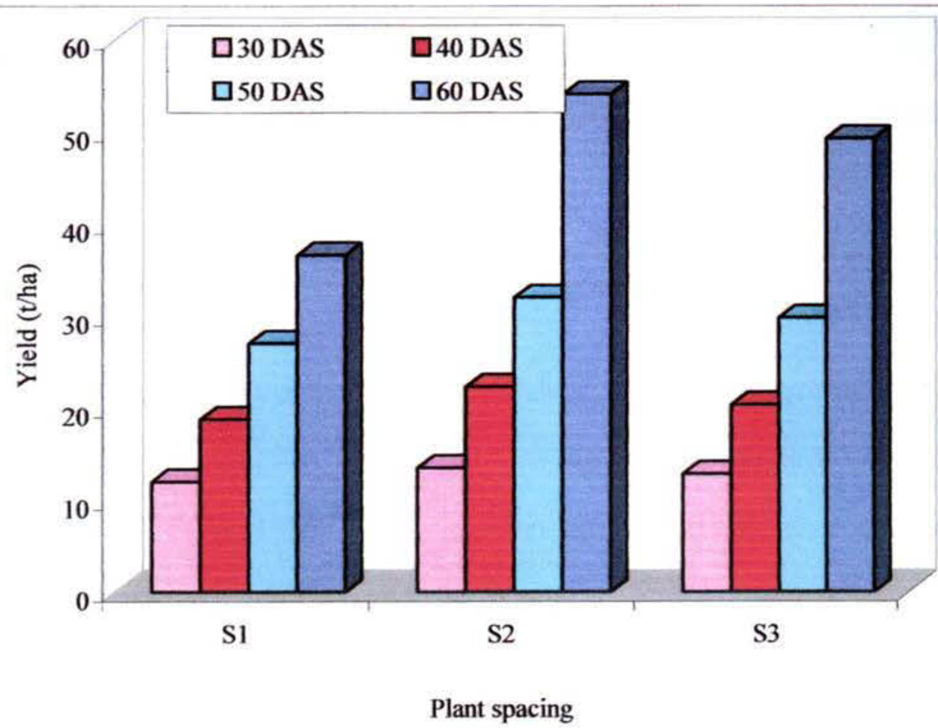


Figure 13. Effect of plant spacing on yield per hectare of amaranth

The variation was recorded due to the combined effect of nitrogen and plant spacing in terms of yield per hectare at different days after sowing (Appendix VIII). At 30 DAS the highest yield (16.63 t/ha) was recorded from N_3S_2 (140 kg N/ha + 30 cm × 20 cm plant spacing), while N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing) gave the lowest yield (8.33 t/ha) (Table 10). At 40 DAS the highest yield (26.86 t/ha) was observed from N_3S_2 whereas the lowest (14.70 t/ha) was obtained from N_0S_1. At 50 DAS the highest yield (39.99 t/ha) was found from N_2S_2 and the lowest (15.35 t/ha) was recorded from N_0S_1. The highest yield (64.67 t/ha) was recorded from N_2S_2 and the lowest (24.80 t/ha) from N_0S_1 at 60 DAS. From the results it was noted that both nitrogen and plant spacing favored growth of stem amaranth and the ultimate result was the highest yield per hectare with highest dose of nitrogen and plant spacing.

4.13 Economic analysis

Input costs for land preparation, seed cost, fertilizer, thinning, irrigation and man power required for all the operations from sowing to harvesting of stem amaranth were recorded for unit plot and converted into cost per hectare. Price of stem amaranth was considered as per market rate. The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under the following headings-

4.13.1 Gross return

The combination of nitrogen and plant spacing showed different gross return under the trial. The highest gross return (Tk. 731,200) was obtained from the treatment combination N_2S_2 (110 kg N/ha + 30 cm × 20 cm plant spacing) and the second highest gross return (Tk. 702,200) was obtained in N_3S_2 (140 kg N/ha + 30 cm × 20 cm plant spacing). The lowest gross return (Tk. 321,950) was obtained in the control treatment i.e. N_0S_1 (0 kg N/ha + 30 cm × 10 cm plant spacing).

Table 11. Cost and return of stem amaranth cultivation as influenced by nitrogen and plant spacing

Treatment Combination	Cost of production (Tk./ha)	Yield at harvest (t/ha)				Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
		30 DAS	40 DAS	50 DAS	60 DAS			
N_0S_1	203957	8.33	14.70	15.35	24.80	321950	117993	0.58
N_0S_2	191665	9.54	17.68	22.30	37.28	427950	236285	1.23
N_0S_3	191106	10.66	16.57	22.27	29.75	396250	205144	1.07
N_1S_1	192761	11.57	17.61	25.71	31.75	433200	240439	1.25
N_1S_2	192202	13.03	19.24	30.72	52.67	578300	386098	2.01
N_1S_3	191643	12.52	19.48	29.33	49.48	554050	362407	1.89
N_2S_1	192963	13.07	20.82	35.50	44.19	567900	374937	1.94
N_2S_2	192403	16.05	25.53	39.99	64.67	731200	538797	2.80
N_2S_3	191844	14.09	22.83	32.20	56.60	628600	436756	2.28
N_3S_1	193164	13.75	21.90	31.53	45.96	565700	372536	1.93
N_3S_2	192605	16.63	26.86	35.15	61.80	702200	509595	2.65
N_3S_3	192046	14.09	22.56	35.46	61.31	667100	475054	2.47

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 10 cm
S_2: 30 cm × 20 cm
S_3: 30 cm × 30 cm

4.13.2 Net return

In case of net return different treatment combination showed different levels of net return. The highest net return (Tk. 538,797) was obtained from the treatment combination N_2S_2 and the second highest net return (Tk. 509,595) was obtained from the combination N_3S_2. The lowest (Tk. 117,993) net return was obtained in the control treatment i.e. N_0S_1.

4.13.3 Benefit cost ratio

In the combination of different level of nitrogen and plant spacing highest benefit cost ratio (2.80) was noted from the combination of N_2S_2 and the second highest benefit cost ratio (2.65) was estimated from the combination of N_3S_2. The lowest benefit cost ratio (0.58) was obtained in the control i.e. N_0S_1 (Table 11). From economic point of view, it is apparent from the above results that the combination of N_2S_2 was more profitable than rest of the combination.

Summary & conclusion

SUMMARY AND CONCLUSION

A field experiment was conducted in the field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from March 2007 to June 2007 to study the effect of nitrogen and plant spacing on growth and yield of amaranth. The experiment consisted of two factors i.e. (A): Levels of nitrogen (4 levels) i.e. 0 kg N/ha (N_0), 80 kg N/ha (N_2), 110 kg N/ha (N_3), 140 kg N/ha (N_4) and (B) plant density (3 levels) i.e. 30 cm × 10 cm (S_1), 30 cm × 20 cm (S_2), 30 cm × 30 cm (S_3). There were on the whole 12 treatments combinations. The trial was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. The data obtained for different characters were statistically analyzed to find out the significance of the nitrogen and plant spacing on yield and yield contributing characters of amaranth.

At 60 DAS the longest stem length (92.48cm) was recorded from N_3 and the control condition gave the shortest (83.48cm). The maximum (22.67mm) stem diameter was recorded from N_3, while the control condition gave the minimum (19.31 mm). At 60 DAS the highest (40.93) number of leaves per plant was recorded from N_3 and the control produced the lowest (32.53). The longest leaf (21.37 cm) was recorded from N_3, while the control condition gave the shortest (17.77 cm). The longest petiole (7.91 cm) was recorded from N_3 while the control condition gave the shortest (7.26 cm) at 60 DAS. The maximum petiole diameter (3.47 mm) was recorded from N_3 and the control condition gave the minimum (3.24 mm). At 60 DAS the maximum fresh weight of leaves (51.26 g) per plant was recorded from N_3 and control condition gave the minimum (40.02 g). At 60 DAS the maximum dry matter content (6.27%) of leaves per plant was recorded from N_3, while the control gave the minimum (4.83%). The maximum fresh weight of stem (128.46 g) per plant was recorded from N_3, while the control condition gave the minimum (114.93 g). At 60 DAS the maximum dry matter content of stem (15.65%) per plant was recorded from N_3, while the control condition gave the minimum (13.74%). The highest yield (20.29 kg) per plot was recorded from N_3 and the control gave the lowest (11.02 kg). At 60 DAS the highest yield (56.35 tonnes) per hectare was recorded from N_3 and the control condition gave the lowest (30.61 tonnes).

At 60 DAS the longest (90.77 cm) stem length was recorded from S_3 and the shortest (86.66 cm) was found from S_1 and the maximum stem diameter (21.63 mm) was recorded from S_3 and the minimum (19.03 mm) was recorded from S_1. At 60 DAS the highest (39.44) number of leaves per plant was observed from S_3 and the lowest (36.10) was recorded from S_1. At 60 DAS the longest leaf (20.63 cm) was observed from S_3 and the shortest (19.27 cm) from S_1. The longest petiole (7.91 cm) was recorded from S_3 and the shortest (7.33 cm) was recorded from S_1. At 60 DAS the maximum petiole diameter (3.45 mm) was recorded from S_3 while the minimum (3.22 mm) was found from S_1. At 60 DAS the maximum fresh weight of leaves (50.43 g) per plant was recorded from S_3 and the minimum (45.01 g) was recorded from S_1. The maximum dry matter content of leaves (6.22 %) per plant recorded from S_3 and the minimum (4.56 %) was recorded from S_1. At 60 DAS the maximum fresh weight of stem (133.23 %) per plant was recorded from S_3 and the minimum (126.10g) recorded from S_1. At 60 DAS the maximum dry matter content of stem (16.13 %) per plant recorded from S_3 and the minimum (13.85 %) was found from S_1. At 60 DAS the highest yield (19.53 kg) per plot was recorded from S_2 and the lowest (13.48 kg) recorded from S_1. At 60 DAS the highest yield (54.10 tonnes) per hectare was recorded from S_2 and the lowest (36.67 tonnes) was from S_1. The highest (Tk. 731,200) gross return was obtained from the treatment combination N_2S_2 and the lowest (Tk. 321,950) was noted in the control treatment (N_0S_1).

CONCLUSION:

Among the treatment combinations N_2S_2 (110 kg N with 30 cm × 20 cm spacing) perform the highest yield (64.67 t/ha) & cost benefit ratio (2.80). The treatment combination of N_2S_2 is more economic viable compare to other combinations. It may say that for ensuring the higher yield 110 kg N & 30cm × 20 cm spacing may be used in stem amaranth production.

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

1. This study may be carried out in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Nitrogen had significant influence on the growth and yield of stem amaranth. So, for growing stem amaranth higher doses of nitrogen may be included in fertilization program;
3. An additional combination of plant density may be included to observe the performance.

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Appendix

APPENDIX

Appendix I. Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	33.18
Silt	60.61
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.19
Organic carbon (%)	1.41
Total nitrogen (%)	0.08
Available P (ppm)	21.4
Exchangeable K (%)	0.2

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from March to June 2007

Month	Air temperature (^{0}C)		RH (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
March 07	31.4	19.6	54	11	8.2
April 07	33.6	23.6	69	163	6.4
May 07	34.7	25.9	70	185	7.8
June 07	32.4	25.5	81	628	4.7

Source : Dhaka metrological center

Appendix III. Analysis of variance of the data on stem length and diameter as influenced by nitrogen and plant spacing in stem amaranth

Source of variation	Degrees of freedom	Mean square							
		Stem length (cm) at				Stem diameter (mm) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	5.593	23.712	6.205	10.805	0.422	1.182	1.644	1.618
Nitrogen (A)	3	91.221**	127.068**	154.129**	151.060**	7.512*	13.313**	20.251*	20.699**
Plant spacing (B)	2	16.516*	51.184**	55.072*	49.838**	2.145*	2.652*	2.523 *	3.344
Interaction (A×B)	6	0.130 *	6.166 *	13.485 *	14.532*	0.659 *	0.889 *	1.293 *	1.459 *
Error	22	4.388	10.092	13.232	4.184	0.507	0.714	1.262	1.290

** : Significant at 0.01 level of probability; * : Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of leaves per plant and length of leaf as influenced by nitrogen and plant spacing in stem amaranth

Source of variation	Degrees of freedom	Mean square							
		Number of leaves per plant at				Length of leaf at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	6.398	1.918	12.518	16.358	1.295	2.080	1.452	1.450
Nitrogen (A)	3	87.129**	98.901**	103.747**	126.395**	17.699**	21.095**	22.321**	24.666**
Plant spacing (B)	2	7.182*	17.015**	18.996**	38.058**	3.927*	11.501**	4.305*	5.523**
Interaction (A×B)	6	0.164 *	0.173 *	0.671 *	0.284 *	1.226 *	0.930 *	1.305 *	1.473
Error	22	2.007	3.015	2.961	5.319	1.100	1.030	1.035	1.143

** : Significant at 0.01 level of probability; * : Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on petiole length and diameter as influenced by nitrogen and plant spacing in stem amaranth

Source of variation	Degrees of freedom	Mean square							
		Petiole length (cm) at				Petiole diameter (mm) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.184	0.078	0.080	0.053	0.002	0.022	0.014	0.017
Nitrogen (A)	3	0.508*	0.782*	0.921**	0.813**	0.128**	0.297**	0.088**	0.098*
Plant spacing (B)	2	0.585*	0.924*	1.046**	1.227**	0.063**	0.328**	0.123**	0.197**
Interaction (A×B)	6	0.260 *	0.183 *	0.228 *	0.202 *	0.053**	0.062 *	0.015 *	0.021 *
Error	22	0.138	0.165	0.153	0.153	0.008	0.043	0.016	0.025

** : Significant at 0.01 level of probability; * : Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on fresh weight and dry matter content of leaves per plant as influenced by nitrogen and plant spacing in stem amaranth

Source of variation	Degrees of freedom	Mean square							
		Fresh weight (g) of leaves per plant at				Dry matter content (%) of leaves per plant at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	1.161	0.053	1.548	1.622	0.112	0.009	0.170	0.005
Nitrogen (A)	3	192.160**	246.827**	196.281**	234.234**	3.856**	4.307**	2.790**	3.801**
Plant spacing (B)	2	21.520**	27.962*	36.993*	86.598**	0.465*	0.457*	0.498*	1.062*
Interaction (A×B)	6	0.244 *	1.172 *	1.437 *	0.851 *	0.014 *	0.043 *	0.022 *	0.031 *
Error	22	3.204	6.929	7.935	13.037	0.110	0.089	0.093	0.207

** : Significant at 0.01 level of probability; * : Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on fresh weight and dry matter content of stem per plant as influenced by nitrogen and plant spacing in stem amaranth

Source of variation	Degrees of freedom	Mean square							
		Fresh weight of stem (g) per plant at				Dry matter content (%) of stem per plant at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	4.089	24.878	14.209	0.941	0.028	0.844	0.122	2.064
Nitrogen (A)	3	132.198**	187.638**	307.064**	349.082**	2.316**	4.169**	5.975**	6.410**
Plant spacing (B)	2	23.658*	89.838*	109.598*	115.443*	0.346*	1.074*	2.595**	2.429**
Interaction (A×B)	6	0.178*	10.686*	26.620*	31.765*	0.009*	0.110*	0.857*	0.381*
Error	22	6.443	22.426	25.937	31.225	0.098	0.282	0.230	0.294

** : Significant at 0.01 level of probability; * : Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on yield kg per plot and tonnes per hectare as influenced by nitrogen and plant spacing in stem amaranth

Source of variation	Degrees of freedom	Mean square							
		Yield (kg/plot) at				Yield (t/ha) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.006	0.013	1.193	1.182	0.044	0.099	9.204	9.123
Nitrogen (A)	3	6.866**	14.673**	59.235**	166.357**	52.979**	113.219**	457.059**	1283.62**
Plant spacing (B)	2	0.909**	4.965**	9.832**	125.978**	7.012**	38.311**	75.864**	972.050**
Interaction (A×B)	6	0.560*	0.436*	2.412*	3.893*	4.323**	3.362*	18.611*	30.038*
Error	22	0.139	0.496	1.208	2.054	1.071	3.826	9.320	15.851

** : Significant at 0.01 level of probability; * : Significant at 0.05 level of probability

Appendix IX. Cost of production

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Seed cost (Tk)	Irrigation Cost	Thinning cost	Pesticides	Manure and fertilizers				Sub Total (A)
							Cowdung	Urea	TSP	MP	
N_0S_1	28000.00	8000.00	1800.00	5000.00	2500.00	3500.00	20000.00	0.00	1800.00	2250.00	72850.00
N_0S_2	28000.00	8000.00	1800.00	5000.00	2000.00	3500.00	20000.00	0.00	1800.00	2250.00	72350.00
N_0S_3	28000.00	8000.00	1800.00	5000.00	1500.00	3500.00	20000.00	0.00	1800.00	2250.00	71850.00
N_1S_1	28000.00	8000.00	1800.00	5000.00	2500.00	3500.00	20000.00	480.00	1800.00	2250.00	73330.00
N_1S_2	28000.00	8000.00	1800.00	5000.00	2000.00	3500.00	20000.00	480.00	1800.00	2250.00	72830.00
N_1S_3	28000.00	8000.00	1800.00	5000.00	1500.00	3500.00	20000.00	480.00	1800.00	2250.00	72330.00
N_2S_1	28000.00	8000.00	1800.00	5000.00	2500.00	3500.00	20000.00	660.00	1800.00	2250.00	73510.00
N_2S_2	28000.00	8000.00	1800.00	5000.00	2000.00	3500.00	20000.00	660.00	1800.00	2250.00	73010.00
N_2S_3	28000.00	8000.00	1800.00	5000.00	1500.00	3500.00	20000.00	660.00	1800.00	2250.00	72510.00
N_3S_1	28000.00	8000.00	1800.00	5000.00	2500.00	3500.00	20000.00	840.00	1800.00	2250.00	73690.00
N_3S_2	28000.00	8000.00	1800.00	5000.00	2000.00	3500.00	20000.00	840.00	1800.00	2250.00	73190.00
N_3S_3	28000.00	8000.00	1800.00	5000.00	1500.00	3500.00	20000.00	840.00	1800.00	2250.00	72690.00

N_0: 0 kg N/ha
N_1: 80 kg N/ha
N_2: 110 kg N/ha
N_3: 140 kg N/ha

S_1: 30 cm × 20 cm
S_2: 30 cm × 30 cm
S_1: 30 cm × 40 cm