EFFECT OF NITROGEN AND POTASSIUM ON GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus oleraceus*)

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EFFECT OF NITROGEN AND POTASSIUM ON GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus oleraceus*)

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Nitrogen and Potassium on the Growth and Yield of Stem Amaranth (*Amaranthus oleraceus*)"** 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 bona fide research work carried out by **KHADIZA BEGUM**, Registration No. **00663/27460** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

The field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to June 2006 to study the effect of different levels of nitrogen and potassium on growth and yield of stem amaranth. The experiment considered two factors. viz., Four levels of nitrogen (0 kg N/ha (Control), 90 kg N/ha, 100 kg N/ha, 110 kg N/ha) and four levels of potassium (0 kg K_2O/ha (Control), 120 kg K_2O/ha, 130 kg K_2O/ha, 140 kg K_2O/ha). A statistically significant variation was recorded in respect of all characters in relation with different levels of nitrogen at 30, 45, 60 and 75 DAS. At 75 DAS N_3 gave the maximum plant height (107.90 cm), diameter of stem (26.81 mm), number of leaves per plant (45.90), length of leaf (26.18 cm), petiole length (10.14 cm) and petiole diameter (3.70 mm), yield (60.79 t/ha), while the control treatment gave the lowest value. Potassium fertilizer showed a statistically significant variation in terms of characters at 30, 45, 60 and 75 DAS. At 75 DAS treatment K_3 gave the maximum plant height (106.53 cm), stem diameter (25.38 mm), number of leaves per plant (44.95), length of leaf (25.51 cm), petiole length (9.80 cm) and petiole diameter (3.63 mm), yield (67.67 t/ha), while the control treatment gave the lowest value. The combined effect showed significant differences. The maximum growth and yield was performed with the combination N_3K_3 and the minimum was obtained in control condition i.e. N_0K_0. The highest (3.02) benefit cost ratio was obtained from treatment combination N_3K_3 and the lowest (0.76) was found from control treatment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter I

INTRODUCTION

Stem amaranth (*Amaranthus oleraceus*) belongs to the genus *Amaranthus* and the family Amaranthaceae and commonly known as leafy and stem vegetable. This type of vegetable is mainly grown during summer and rainy season and is important in Bangladesh for its quick and vigorus growth and higher yield potential. It is widely grown as a green vegetable in tropical and subtropical parts of Asia, Africa and Central America (Hardwood, 1980).

Stem amaranth is considered as a potential up coming subsidiary food crop for future (Teutonico and Knorr, 1985). It is also considered to be the cheapest vegetable in the market and it could be rigidly described as a 'poor man's vegetable in Bangladesh Shanmugavelu (1989). Consequently, stem amaranth may be harvested over a considerable period of time. Its wider environmental adaptability, higher nutritive value, good taste, less risk to crop failure and various biotic and abiotic factors indicate that there is enough scope for its promotional cultivation. Stem amaranth is fairly rich in vitamin A, ascorbic acid and contains appreciable amounts of iron, calcium, phosphorous, riboflavin, thiamine, niacin and iron (Thompson and Kelly, 1988). It also contains about 43 calorie per 100 g of edible portion which is higher than that of any other common vegetables except potato and taro (Chowdhury, 1967).

Total vegetable production in our country is about 1.29 metric tons per year of which 69% is produced in Rabi season and 31% in Kharif season (BBS, 2005). So, it is clear that the vegetable production in Kharif season is very low. However, the maximum production of different vegetable is concentrated during the month of November and April. Thus there is a serious scarcity of vegetables during the month of May to September. As the nation runs with an acute shortage of vegetables, its production should be increased to meet up the shortage of vegetables and feed the ever increasing population of the country. It has the potentiality of year round production. The soil type and weather are suitable, stem amaranth can play an important role to minimize the scarcity of vegetable during lean period (Hossain, 1996; Talukder, 1999).

The average yield of stem amaranth is only 4.98 t/ha in Bangladesh, which is much lower as compared to other amaranth growing countries. To attaining considerable production and quality yield for any crop it is necessary to proper management including ensuring the availability of essential nutrient.

Stem amaranth responds greatly to major essential elements like N, P and K in respect of its growth and yield (Mital, 1975; Singh *et al.*, 1976; Thompson and Kelly, 1988). Its production can be increased by adopting improved cultural practices. Fertilizer plays a vital role for proper growth and development of stem amaranth. Fertilizer application in appropriate time, appropriate dose and proper method is the prerequisite of amaranth cultivation (Islam, 2003).

Generally, a large amount of nitrogen is required for the growth of the leaf and stem of amaranth (Opena *et al.*, 1988). It plays a vital role as a constituent of protein, nucleic acid and chlorophyll. It is also the most different element to manage in a fertilization system such that an adequate, but not excessive amount of nitrogen is available during the entire growing season (Anon., 1972). Nitrogen progressively increases the marketable yield (Obreza and Vavrina, 1993) but an adequate supply of nitrogen is essential for vegetative growth, and desirable yield (Yoshizawa *et al.*, 1981). Excessive application of nitrogen on the other hand is not only uneconomical but also induces physiological disorder.

Potassium is also one of the important essential macro elements for growth and development of plant. The potassium requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). It is also essential for cell organization, hydration and cell permeability. It is an essential element of chloroplast too. It helps photosynthesis by maintaining iron supply and increases the body substrates. Potassium improves root system of amaranth, so that the roots can absorb the minerals and irons from soil solution efficiently, resulting with higher yield. Potassium fertilizer also increases the stem diameter of amaranth which protects it from lodging.

The optimum proportion of nitrogen and potassium fertilizer enhances the growth and development of a crop as well as ensuring the availability of other essential nutrients for the plant. Again secondary mechanism of interference was the absorption of potassium from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al.*, 2004). Considering the above circumstances, the present investigation has been undertaken with the following objectives:

1. to find out the optimum dose of nitrogen and potassium for growth and maximum yield of stem amaranth,
2. to study the combined effect of nitrogen and potassium for obtaining desirable yield and
3. to calculate the profitability in stem amaranth production.

Chapter II

REVIEW OF LITERATURE

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

2.1 Effect of nitrogen on growth and yield

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

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

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 amaranth. Plant height, number of leaves produced, fresh and dry weights of plant parts increased with increased nitrogenous fertilizer rate. Application of fertilizer at 200 kg N/ha increased leaf production upto 75%, on the other hand yield increased upto 114% with the application of 200 kg N/ha. The unfertilized plants also had yellowish green coloration compared to the brighter green color observed in fertilized plants.

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 fluctuated 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 of fertilizer can negatively affect grain yield.

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

In small plot trials on dernopodzolic soil in the mountain region with 0, 60 or 120 kg/ha N fertilizer by Ozhiganova *et al.* (1996) and 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 and aboveground and root fresh weight/plant at all growth stages. Fresh matter yield increased from 29.9-31.2 t/ha without inoculation to 36.1, 46.8 and 43.0 t 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. From the results it was noted that there were no significant effect of N on seed yield and yield components. 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 had developed in order to investigate how nitrogen allocation patterns in plants are affected by their vertical position in the vegetation. Canopy structure, vertical patterns of leaf nitrogen distribution and leaf photosynthetic characteristics were determined in both dominant and subordinate plants. The amount of N which is reallocated from the oldest to the younger, more illuminated leaves higher up in the vegetation may depend on the sink strength of the younger leaves for nitrogen.

Subhan (1989) conducted a field experiment at Lembang from August to September 1988 to find out the effect of doses N @ 0, 30, 70 and 110 kg/ha and application time of nitrogen fertilizer on growth and yield of amaranth applied as a single application at sowing, or as a split application at sowing and 10 days after sowing. Leaf number and stem diameter were not affected by N application. Plant height, leaf area and fresh weight 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 potassium on growth and yield

A field experiment was conducted by Brahma *et al.* (2002) for two years at Assam Agricultural University in India during Rabi season to study the effect of nitrogen, phosphorous and potassium on the growth and yield. Treatments comprised of five levels of potassium (0, 20, 40, 60 and 80 kg/ha, respectively). They found that growth and yield was highly improved with the increasing level of potassium.

Romero (1999) carried out an experiment in the village of Sella Cercado in Bolivia with four amaranth genotypes. Different variables of amaranth, plant height, plant diameter, grain yield responded well to the potassium at 60 kg/ha. Highest plant diameter was 2.2 cm and plant height was 102.5 cm.

An experiment was conducted by Bhai and Singh (1998) at Palampur, India to investigate the effect of potassium rate (50, 70 or 90 kg/ha). They reported that potassium application significantly increased the plant height, number of nodes per plant and yield.

An experiment was conducted by Zhong *et al.* (1997) in Hanghou, China using a cropping system with amaranth, onion, cabbage, taro and cauliflower to investigate the effect of different potassium fertilizers (sulfate of potash and/or muriate of potash) on the yield and quality of vegetable crops. Market yield of all those vegetables increased significantly with potassium fertilization. Sulphate of potash was more effective in terms of yield and quality compared to muriate of potash.

Cerne and Briski (1994) reported from an experiment that the combination of 400 kg K_2O/ha, manure and irrigation gave the highest total yield of tomato in the 1^{st} and 2^{nd} years (1.03 and 2.25 kg/plant, respectively). Elbehri *et al.* (1993) conducted a field trial in Minnesota, USA to study the response of *Amaranthus* spp. to fertilizers. There was no response to potassium application.

Zaman and Islam (1992) reported that at 15-20 cm × 10 cm spacing along with sufficient irrigation 15-16 t/ha stem yield of amaranth would be obtained from the fertilizer dose at the rate of 150 kg MP/ha in three equal application. George *et al.* (1989) conducted an experiment on the source and variability for various nutritive aspects in amaranths (*Amaranthus* spp.) at five levels of potassium (0, 15, 30, 45, 60 kg/ha). Thirty germplasm lines belonging to three species viz. *Amaranthus tricolor* L., *Amaranthus dubius* L., and *Amaranthus cruentus* L. were included in the trial. 'Accession 14' *Amaranthus cruentus* L. had the highest dry matter (17.17%, followed by 'Accession 65' *Amaranthus tricolor* L. (16.92%) at 60 kg/ha potassium.

Subhan (1989) applied potassium to *Amaranthus tricolor* as a single application at sowing or as a split application at sowing and 10 days after sowing in a field at Lembang, Indonesia. The highest yield was obtained with split application. An experiment was carried out by Olufolaji and Tayo (1989) on amaranth. They reported the effect of seedling rate on the performance of direct drilled amaranth. Two field trials were conducted by using 80 kg MP/ha to determine the optimum sowing rate of *Amaranrhus cruentus* required for a vegetative yield of about 20 t/ha. Seedling establishment, plant height, leaf area index, total plant yield and edible shoot yield were measured. The highest total and edible shoot yield (18.57 and 2.47 t/ha, respectively) were obtained at a sowing rate of 6 kg/ha.

Bressani *et al.* (1987) conducted some experiment on *Amaranthus* spp. to study the response of chemical fertilizers in America, Peru and Guatemala. *Amaranthus* spp. were grown with potassium fertilizer at 0, 30, 60 and 90 kg/ha, respectively. Highest plant height ranged from 43 to 60 cm in different region. Makus (1984) carried out an experiment on *Amaranthus tricolor* L., with five levels of nitrogen with potassium and produced between 10.00 to 18.40 t/ha of plant biomass. All treatments at split application of nitrogen and potassium gave the highest yield response.

A study was conducted by Campbel and Abbott (1982) to evaluate the performance of twenty selected cultivars and strains of *Amaranthus cruentus* L. (*A. caudatus* L.), *A. caudatus* L.), *A. dubis*L., and *A. tricolor* L. from various countries for horticultural potential during 2 (two) successive summer at different level of nitrogen and potassium. The levels of potassium was 0, 20, 40, 60, and 80 kg/ha. Average fresh yields of leaves and stems for 5 trials varied from 4.00 to 16.50 t/ha as the potassium levels were increased. Yield was negatively correlated with leaf stem ratio. The highest leaf : stem ratio was found with 80 kg potassium/ha fertilized field.

Prasad *et al.* (1980) estimated the correlation co-efficient at phenotypic level and found that the yield had increased with an increase in leaf length and the leaf width due to potassium applied @ 40-60 kg/ha. The leaf length had also increased with an increase in leaf width.

2.3 Combined effect of nitrogen and potassium on growth and yield

Effect of NPK mineral fertilizer on the growth response of amaranths resulting from inorganic nutrient sources was investigated by Agele *et al.* (2004) in sandy clay loam soil condition. The application of N 150 kg/ha from NPK fertilizer resulted with maximum yield as well as economic return. A higher proportion of N appeared to be resistant to microbial degradation and was thus unavailable for plant uptake.

Mazumder (2004) reported that the optimum yield of amaranth was obtained from BARI Data-1 at Bangladesh Agricultural Research Institute, Gazipur. The highest yields ranged from 30-40 t/ha as crops were sown between February to March and the fertilizer doses were 200 kg urea, 100 kg triple super phosphate and 200 kg muriate of potash per hectare respectively.

Islam (2003) reported that fertilizer doses at the rate of 200, 100 and 200 kg/ha of urea, triple super phosphate and muriate of potash respectively and maintaining other agricultural practices properly the average yield of amaranth could be raised upto 45 to 50 t/ha.

Thapa and Maity (2002) carried out a field experiment in the sandy loam of West Bengal, India during the summer seasons of 1998 and 1999 to study the effect of different levels of N @ 50, 100 and 150 kg/ha and K_2O @ 40 and 60 kg/ha on the growth and yield of Amaranthus sp. cv. local. The response in terms of growth components such as plant height, number of leaves, and number of branches, leaf area index, yield and dry matter production was highest at the highest nutrient levels. The highest yields of 100.75, 101.5

and 112.47 q/ha was obtained from treatments with N at 150 and 60 kg K_2O /ha, respectively.

An experiment was carried out by Linkui *et al*. (2002) in Shanghi, China to investigate the effect of different bio fertilizers on the yield and quality of 3-coloured amaranth. Fertilizers were applied at the rate of 1.9 kg/plot. Amaranth receiving bio-fertilizers showed a yield increase of 15-38% compared to those receiving exclusive vegetable fertilizers.

The effect of compost and nitrogen fertilizers on the growth, yield and nutrient uptake of amaranth was studied by Akanbi (2000) in Nigeria. Twelve treatments derived from a factorial combination of four levels of compost (0, 1.5, 3.0 and 4.5 t/ha) and three levels of fertilizer (0, 30 and 60 kg N/ha) were carried out on a sandy loam soil. The application of compost and N-fertilizer enhanced plant growth with respect to the control treatments. Plant height, plant diameter, number of leaves, leaf area per plant, dry matter and shoot fresh yield were all significantly affected by different levels of compost in combination with or without N-fertilizers.

Talukdar (1999) conducted an experiment at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. Different growth attributing characters was recorded and found that fertilizer dose with 200-100-200 kg/ha of urea, triple super phosphate and muriate of potash, respectively gave the highest stem yield 355.75 g/plant and green yield 94.41 t/ha.

A field experiment in 1985-1987 at Brahmvar, Karnataka was carried out by Lingaiah *et al*. (1997) to study the response of fertilizers on yield of fertilizer in coastal area with 6 local amaranth cultivars treated with 50:25:25 kg NPK/ha. They found that yield increased with increasing rate of fertilizer comparative to the control condition.

The performance of four varieties, *Amaranths hypochondriacs* 1008, *Amaranthus hypochondriacs* K 372, *Amaranthus cruentus* 17-GUA, Amaranthus cruentus 29-UAS were investigated by Jamriska (1996) by using 85 kg N, 40-60 kg P and 60-65 kg K/ha in respect of seed yield, stand density and height, inflorescence length and its height and 1000 seed weight. Among varieties Amaranthus cruentus 17-GUA was the best with the greatest yield of 3.29 t/ha.

A comparative study on yield and quality of some amaranth genotypes was done by Hossain (1996) in the Bangabandhu Sheikh Mujibur Rahman Agricultural University. Fertilizer dose was cowdung, urea, triple super phosphate and muriate of potash as 20 t, 200, 100 and 200 kg/ha, respectively. Different growth and yield contributing characters were evaluated. He found highest yield 81.24 t/ha with maximum doses of fertilizer combination.

An experiment was conducted by Quasem and Hossain (1995) to evaluate 16 germplasm of local stem amaranths in summer at the rate of fertilizer doses of 2010 kg urea, 100 kg triple super phosphate band 200 kg muriate of potash per ha respectively . Plant height at last harvest was found maximum in SAT 0034 as 88.3 cm and the highest yield was recorded in SAT 0054 as 54 t/ha .

A study was conducted by Apaza (1994) in representative areas of the central valley of Tarija in Bolivia. Two species of amaranth were evaluated for their response to eight levels of fertilizer: control treatment, chemical (40-40-20) and (80-80-40) NPK , organic (7.5t/ ga,15t/ha dried ovine manure), mixed (20-20-10+3.75 t/ha and 60-60-30+11.25 t/ha). Highest response was found both chemical and mixed fertilizer 80% and 295 higher than control treatment and organic respectively.

Chakhatrakan *et al.* (1994) conducted a field experiment to study the effect of nitrogen and phosphatic fertilizer application on growth and yield of amaranth with 8 kg of N, P and K kg/10 acres or 16 kg N+8 kg each of P and K or 16 kg P=8 kg each of N and K. Shoot dry matter yield was highest in both species where P rate was doubled. Yields were highest when P and N rates were doubled, respectively.

Rashid (1993) reported that at the fertilizer dose of 200, 100 and 200 kg/ha with urea, triple super phosphate and muriate of potash respectively amaranth gave the highest yield. The average yield at this fertilizer dose ranged from 35-40 t/ha.

Panda *et al.* (1991) carried out a field experiment during 1989-1990 on amaranth growing on acid lateritic soils with N applied at 0, 20, 40 or 60 kg/ha and P_2O_5 and K_2O applied at 0 or 20 kg/ha. P_2O_5 and K_2O were applied as a basal dose at sowing time with N applied either as a full basal dose or 50% basal and 50% as a foliar spray. Highest fresh yield (12.7 t/ha) and protein content (4.9 g/100 g) were obtained with 60 kg N+20 kg P_2O_5+20 kg K_2O/ha with N applied as a full basal dose. The same treatment but when N was applied as 50% basal + 50% foliar spray resulted in the next highest yield and protein content.

Hamid *et al.* (1989) in an experiment used 200 kg urea, 100 kg triple super phospgate and 200 kg muriate of potash per ha and reported that significant variation were present among 12 amaranth lines (4 exotic and 8 local) for plant diameter which was positively correlated with yield. The exotic germplasm AM0008 was the highest yielding, producing 234.40 t/ha. Among the local germplasm highest yield produced was 122.40 t/ha and lowest yield was 42.80 t/ha. Plant height of some exotic and local lines varied from 70.20 to 131.60 cm. The number of leaves and plant diameter per plant in local cultivars ranged from 72 to 162 and 5.30 to 9.30 mm respectively.

Moniruzzaman (1987) reported that optimum yield of amaranth could be found at the rate of 10-12 ton cowdung, 12 kg urea, 8-10 kg triple super phosphate and 5-7 kg muriate of potash per bigha respectively.

Mohideen *et al*. (1985) conducted an experiment for an evaluation program in amaranth under the all Indian coordinated vegetable improvement project at the Tamil Nadu Agriculture University. A promising clipping type (A.83) was released as Co. 3 amaranth over local type after testing for five seasons. Fertilizer doses were 85 kg N, 60 kg P and 60 kg K per hectare respectively. The leaf stem ratio was 2.00 and the yield performance of this stain was recorded a mean yield of 3.716 kg/ha. Highest plant height was recorded as 172.5 cm. The mean weight of 8 types of amaranth was 276.00 g at DAS.

In Himachal Pradesh, at the rate of 60, 50 30 kg NPK per hectare, respective4ly, were recommended for getting the best yield of vegetables (Anon, 1978). Grubben (1977) in an experiment on amaranth recommended fertilizer dose of amaranth as a mixture of 10-10-20 N-P-K applied at 400 kg /ha for plants to be uprooted and at 600 kg/ha for plant to be harvested respectively.

Vijayakumar *et al*. (1982) conducted an experiment with N at 0, 80, 100 or 120 kg/ha and P_2O_5 and K_2O applied at 0, 90, 100 and 120 kg/ha and recorded plant height and which were 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 highest doses of fertilizer.

Rajagopal (1977) reported from a total of 65 types of amaranth were assembled from all over Tamil Nadu and other parts of India and evaluated for yield of greens and others attributes from 1972 onwards. The Co. 1 was used as standard for this evaluation. Further work on the improvement program of this crop in Tamil Nadu Agricultural University by Department of Horticulture, resulted in then identification of A. 25 as a promising selection with high yield potential coupled with good edible plant qualities. Plant height of this strain was 56.30 cm at 40 DAS and 172.20 cm at 70 DAS. The length and breadth of leaves were ranged from 9.80 to 10.20 cm and 5.10 to 7.60, respectively.

Intensive selection work envisaged at vegetable section, Agriculture College and Research Institute, Coimbatore has resulted with release of a new strain Co. 1 amaranth suited to Tamil Nadu. Fertilizers were used as 85 kg N, 60 kg P and 60 kg K/ha. The average yield of this new strain is 18.70 t/ha green with 31 to 51 percent increase over local types. The leaves and stems are succulent, tasty and nutritious. It can be grown throughout the year for use as 'Mulaikeerai' and 'Thaṇdukeeṛai' (Kamaḷaṇathan *et al.*, 1973).

Chapter III
MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at the Farm of Agril. University, Shere-Bangla, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated in $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude (Anon, 1989).

3.2 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was shallow red brown terrace soil. The selected experimental 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 presented in Appendix I.

3.3 Weather condition of the experimental site

The climate of experimental site was subtropical, 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). Meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and presented in Appendix II.

3.4 Planting materials

Seeds of stem amaranth were used as planting materials. The seeds were collected from Dhaka seed store, Siddique Bazar, Dhaka.

3.5 Treatment of the experiment

The experiment had two factors:

Factor A: Nitrogen (4 levels)

i. N_0: 0 kg N/ha (Control)
ii. N_1: 90 kg N/ha
iii. N_2: 100 kg N/ha
iv. N_3: 110 kg N/ha

Factor B: Potassium (4 levels)

i. K_0: 0 kg K_2O/ha (Control)
ii. K_1: 120 kg K_2O/ha
iii. K_2: 130 kg K_2O/ha
iv. K_3: 140 kg K_2O /ha

There were on the whole 16 treatment combinations such as N_0K_0, N_0K_1, N_0K_2, N_0K_3, N_1K_0, N_1K_1, N_1K_2, N_1K_3, N_2K_0, N_2K_1, N_2K_2, N_2K_3, N_3K_0, N_3K_1, N_3K_2 and N_3K_3.

3.6 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 33.5 m × 10 m was divided into three equal blocks. Each block was divided into 16 plots where 16 treatment combinations were allotted at random. There were 48 unit plots altogether in the experiment. The size of the each unit plot was 2.0 m × 1.5 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m respectively. The seeds were sown maintaining the distance row to row 20 cm and plant to plant 25 cm. The layout of the experiment is shown in Figure 1.

3.7 Land preparation

The plot selected for conducting the experiment was opened in the First 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. The experimental plot was partitioned into unit plots in accordance with the design mentioned in Figure 1. Welldecomposed cowdung manure, poultry litter and chemical fertilizers as indicated below were mixed with the soil of each unit plot.

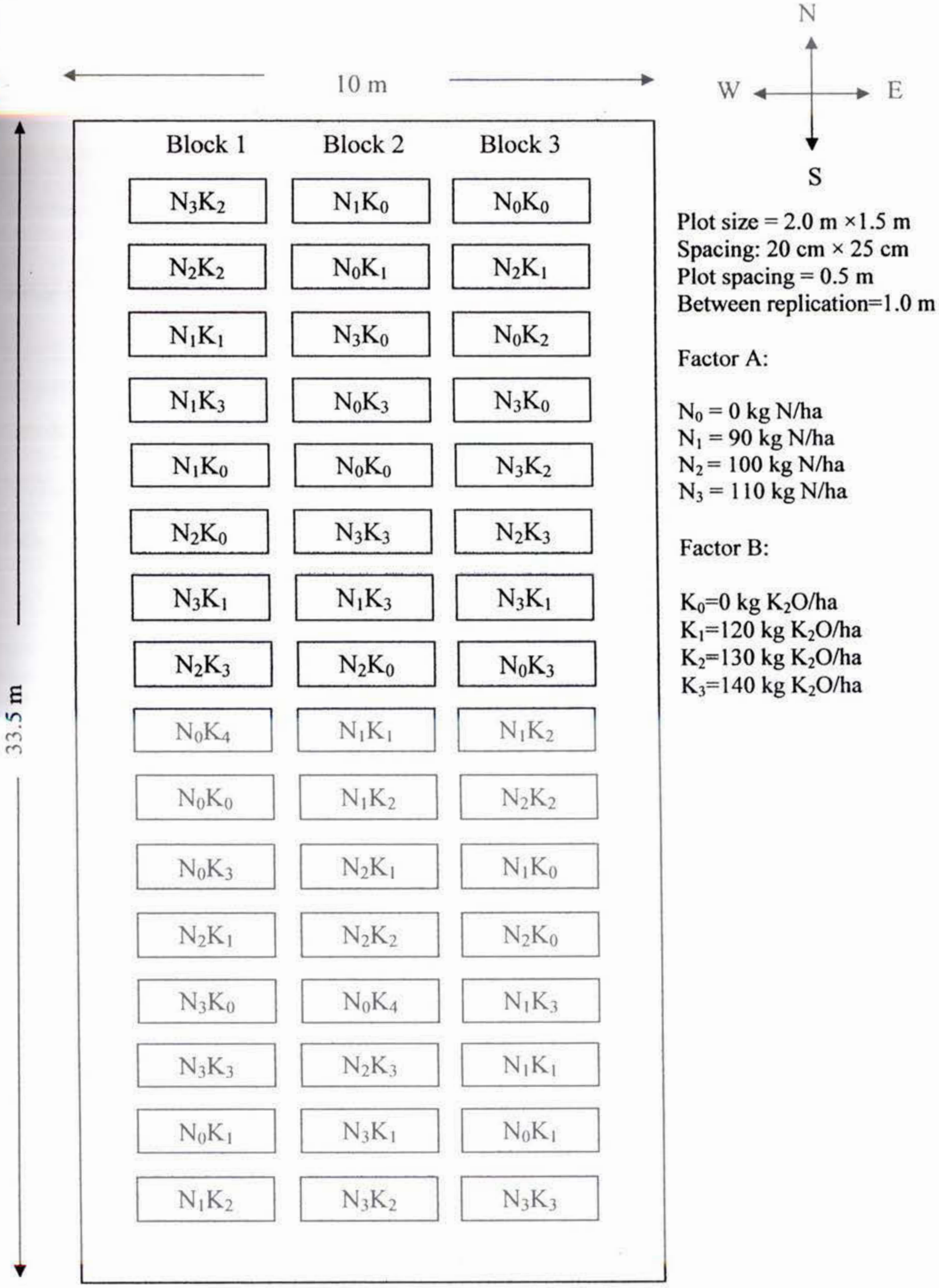

Figure 1. Field layout of two factors experiment in the Randomized Complete Block Design (RCBD)

3.8 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O were urea, TSP and MoP, respectively. The entire amount of TSP and MoP were applied during the final land preparation. Urea was applied in three equal installments at 15, 30 and 45 days after sowing seeds. Well-rotten total amount of was applied during final land preparation. The following amount of manures and fertilizers were used (Table 1).

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

Fertilizers and manure	Dose/ha	Application (%)			
		Basal	15 DAT	30 DAT	45 DAT
Cowdung	20 tons	100	--	--	--
Nitrogen	As treatment	--	33.33	33.33	33.33
P_2O_5 (as TSP)	220 kg	100	--	--	--
K_2O (as MoP)	As treatment	100	--	--	--

3.9 Seed sowing

Seeds were sown in the field in the third week of March with maintaining the distance between plant to plant and row to row.

3.10 Intercultural operation

When the seedlings started to emerge the bed was always kept under careful observation. After emergence of seedlings, various intercultural operations, thinning, weeding, top dressing was accomplished for better growth and development of stem amaranth seedlings.

3.10.1 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 upto first thinning. Further irrigation was done as and when needed. Stagnant water was effectively drained out at the time of heavy rain.

3.10.2 Thinning

First thinning was done at 15 days after sowing (DAS), 2nd thinning was done at 10 days after the first and 3rd was done at 10 days after the second for proper growth and development of stem amaranth seedlings.

3.10.3 Weeding

Weeding was done to keep the plots free from weeds, easy aeration of soil, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully after complete emergence of amaranth seedlings whenever it was necessary. Breaking the crust of the soil was done when needed.

3.10.4 Top Dressing

After basal dose, the remaining doses of urea were top-dressed in three equal installments. The fertilizers were applied on both sides of plant rows and mixed well with the soil by hand. Earthing up was done with the help of nirani immediately after top-dressing of nitrogen fertilizer.

3.11 Plant Protection

For controlling leaf caterpillars Nogos @ 1 ml/l water was applied two times at an interval of 10 days starting soon after the appearance of infestation. There was no remarkable attack of disease.

3.12 Harvesting

To evaluate yield, four times harvesting were done at different growth stages. First harvesting was done at 30 days after sowing. Second, third and fourth harvesting were done 45, 60 and 75 days after sowing, respectively. Different yield contributing data were recorded from the mean of 10 harvested sample plants which were selected at random from each unit plot.

3.13 Data collection

Data were recorded on the following parameters from the sample plants during the course of experiment. Ten plants were randomly selected from each unit plot for the collection of data while the whole plot crop was harvested to record per plot data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid the border effect.

3.13.1 Plant height

The height of plant was recorded in centimeter (cm) at 30, 45, 60 and 75 days after sowing (DAS) in the experimental plots. The height was measured from the ground level up to the tip of the growing point.

3.13.2 Stem diameter

Stem diameter of amaranth plant was measured in millimeter (mm) with a thread and then in a meter scale as the outer surface of the stem. Data were recorded as the average of 10 random selected plants from the inner rows of each plot starting from 30 to 75 DAS at 15 days interval and mean value for each stem diameter was recorded.

3.13.3 Number of leaves per plant

The total number of leaves per plant was counted. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot starting from 30 to 75 DAS at 15 days interval.

3.13.4 Length of leaf

The length of leaves was measured by using a meter scale. The measurement was taken from base to the tip of the leaf. Average length of leaves was taken from 10 random selected plants from inner rows of each plot. Data was recorded from 30 to 75 DAS at 15 days interval. Mean was expressed in centimeter (cm).

3.13.5 Petiole length

Petiole length was measured from junction to the stem to the starting point of leaf base. 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 75 DAS at 15 days interval. Thus mean was recorded and expressed in centimeter (cm).

3.13.6 Petiole diameter

The diameter of the petiole was measured in millimeter (mm) with a thread and then in a meter scale as the outer surface of the petiole and mean value was recorded. Data were recorded as the average of 10 petiole from random selected the plant of inner rows of each plot starting from 30 to 75 DAS at 15 days interval.

3.13.7 Fresh weight of stem per plant

Fresh weight of stem was taken after cutting immediately the fresh stems of sample plants. Average weight was calculated in gram. Data were recorded starting from 30 to 75 DAS at 15 days interval.

3.13.8 Fresh weight of leaves per plant

Leaves of ten randomly selected plants were detached by a sharp knife and fresh weight of leaves was recorded in gram. Data were recorded as the average of 10 random selected plant of inner rows of each plot starting from 30 to 75 DAS at 15 days interval.

3.13.9 Dry matter of stems

After harvesting 100 g of stem sample previously sliced into very thin pieces were put into envelop and placed in oven and dried at 60^0C for 72 hours. The sample was then transferred into desiccators and allowed to cool down to the room temperature and then 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

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

3.13.10 Dry matter of leaves

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 to the 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

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

3.13.11 Green yield

Yield per hectare of stem amaranth was calculated by converting the weight of plot yield to hectare and was expressed in ton.

3.14 Statistical analysis

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

3.15 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of nitrogen and potassium. All input costs were considered in computing the cost of production. The market price of stem amaranth was considered for estimating the return. The benefit cost ratio (BCR) was calculated as follows:

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

Chapter IV

RESULTS AND DISCUSSION

Data on different yield contributing characters and yield at different days after sowing (DAS) were recorded to find out the optimum levels of nitrogen and potassium on stem amaranth. The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix III-VIII. The results have been presented and discussed, and possible interpretations have been given under the following headings

4.1 Plant height

Plant height varied significantly due to the individual application of different level of nitrogen and potassium at 30, 45, 60 and 75 DAS (Figure 2 and 3). At 30 DAS nitrogen at a level of 110 kg/ha (N_3) gave the longest plant (36.03 cm) which was closely (34.24 cm) followed by N_2 at a level of 100 kg N/ha, while the control (0 kg N/ha) gave the shortest plant (28.00 cm). The longest plant (68.46 cm) was observed from N_3 which was closely (66.92 cm) followed by N_2 and the shortest (59.73 cm) was found from control at 45 DAS. At 60 DAS the longest plant (90.88 cm) was recorded from N_3 which was statistically similar to (89.64 cm) N_2 and the shortest (81.37 cm) was from control. Nitrogen at a level of 110 kg/ha (N_3) gave the longest plant (107.90 cm) at 75 DAS which was statistically similar (106.43 cm) with N_2, while control gave the shortest (98.27 cm). These results indicated that nitrogen increase the growth of stem amaranth to ensured the longest plant than control. Probably highest amount of nitrogen ensured the favorable condition for vegetative growth as a result highest amount of nitrogen produced longest plant than the others. The results of this study were comparable to the findings of Vijayakumar *et al.* (1982) who recorded plant height which were 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.

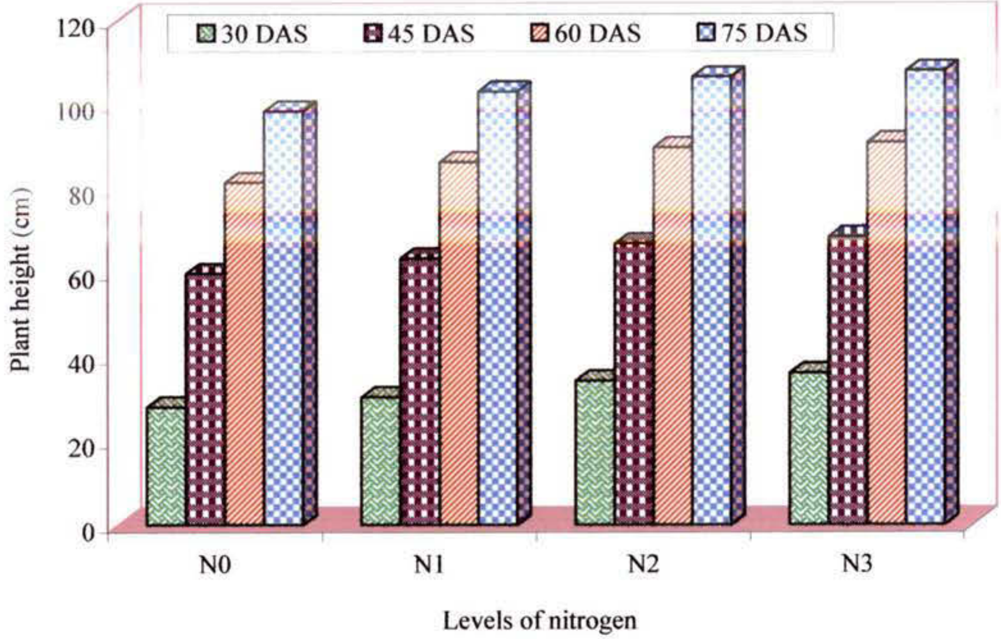

Figure 2. Effect of nitrogen on the plant height of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}

N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

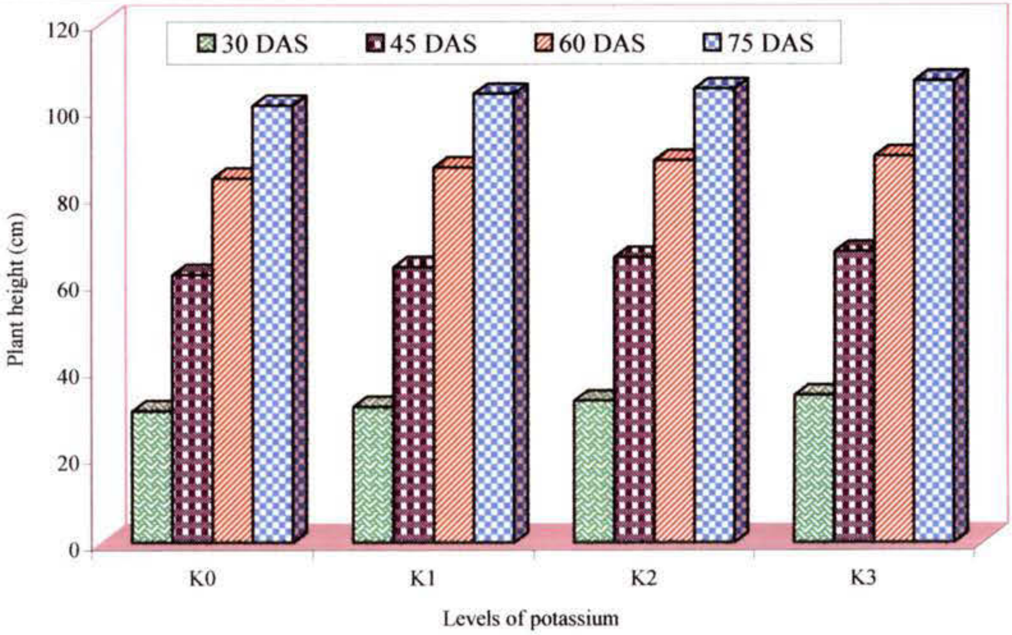

Figure 3. Effect of potassium on plant height of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}

K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

Different levels of potassium showed significant differences on the plant height at 30, 45, 60 and 75 DAS (Figure 3). The longest plant (34.05 cm) was recorded from 140 kg K_2O/ha (K_3) which was statistically similar (32.77 cm) with K_2 at 130 kg K_2O/ha and the shortest (30.40 cm) was obtained from control i.e. 0 kg K_2O/ha at 30 DAS. At 45 DAS the longest plant (67.16 cm) was found from K_3 which was statistically similar (65.92 cm) with K_2, while the shortest (61.81 cm) was found from control. The longest plant (89.20 cm) was recorded from K_3 which was similar (88.23 cm) with K_2 and the shortest (84.07 cm) was recorded from control at 60 DAS. At 75 DAS the longest plant (106.53 cm) was recorded from K_3 which was statistically similar (104.71 cm) with K_2 and the shortest (100.83 cm) was found from control. Highest amount of nitrogen ensured the favorable conditions for vegetative growth as a result longest plant were produced. Bhai and Singh (1998) reported that potassium application significantly increased the plant height

The variation was found due to the combined effect of nitrogen and potassium in terms of plant height at different days after sowing (Appendix III). The longest plant (38.22 cm) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the shortest plant (26.38 cm) (Table 2). At 45 DAS significant variation in terms of plant height was also observed among the treatment combinations and the longest plant (72.90 cm) was observed from the treatment combination of N_3K_3 whereas the shortest (55.12 cm) was recorded from control treatment. At 60 DAS the longest plant (93.55 cm) was recorded from the treatment combination of N_3K_3 and the shortest (75.52 cm) was recorded from the control. The longest plant (112.05 cm) was recorded from the treatment combination N_3K_3 and the shortest (91.87 cm) was found from N_0K_0 at 75 DAS. From the results it was revealed that both nitrogen and potassium favored the plant height. The results compared to Talukder (1999) recorded plant height from 32.50 to 81.84 cm and similar trend of result reported by Hossain (1996).

Table 2. Combined effect of nitrogen and potassium on plant height and diameter of stem amaranth

Treatment	Plant height (cm) at				Stem diameter (mm) at			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0K_0	26.38 i	55.12 f	75.52 d	91.87 e	10.75 g	14.05 h	18.10 f	20.38 g
N_0K_1	27.49 i	59.82 ef	83.51 c	100.49 cd	11.33 fg	15.25 gh	20.35 de	22.85 ef
N_0K_2	28.77 ghi	62.26 de	82.94 c	100.04 d	11.59 efg	15.25 gh	19.92 e	22.25 f
N_0K_3	29.38 fghi	61.70 de	83.53 c	100.70 cd	11.59 efg	15.69 fg	20.16 de	22.68 ef
N_1K_0	28.26 hi	61.60 de	84.63 c	101.40 cd	12.53 def	16.67 efg	21.66 cde	23.90 def
N_1K_1	29.74 efghi	62.69 de	85.64 bc	102.38 cd	11.82 efg	15.87 fg	20.89 de	23.18 ef
N_1K_2	31.21 defgh	64.10 cde	86.88 abc	103.68 bcd	12.88 de	17.03 def	22.06 bcd	24.30 cde
N_1K_3	32.23 cdefg	65.06 bcde	87.71 abc	104.52 bcd	12.53 def	16.81 efg	21.81 cde	24.06 def
N_2K_0	32.77 cdef	65.53 bcde	88.20 abc	104.98 bcd	14.31 bc	18.44 bcd	23.49 abc	25.70 abcd
N_2K_1	33.25 bcde	66.00 bcd	88.59 abc	105.38 bcd	14.69 abc	18.94 abc	23.84 ab	26.09 abc
N_2K_2	34.56 bcd	67.21 bcd	89.73 abc	106.51 abc	14.62 bc	18.90 abc	23.82 ab	26.01 abc
N_2K_3	36.38 ab	68.96 abc	92.02 ab	108.85 ab	15.70 ab	20.04 ab	24.96 a	27.19 ab
N_3K_0	34.22 abc	64.98 bcde	87.93 abc	105.08 bcd	13.88 cd	18.16 cde	23.21 abc	25.55 bcd
N_3K_1	35.12 abc	65.84 bcd	88.70 abc	105.86 bcd	14.85 abc	19.17 abc	24.03 ab	26.57 ab
N_3K_2	36.56 ab	70.11 ab	93.35 a	108.62 ab	15.76 ab	20.08 ab	24.75 a	27.54 ab
N_3K_3	38.22 a	72.90 a	93.55 a	112.05 a	16.14 a	20.48 a	25.10 a	27.59 a
Significance level	**	**	**	**	**	**	**	**
CV (%)	5.98	8.62	6.02	8.07	5.88	5.04	6.73	6.25

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

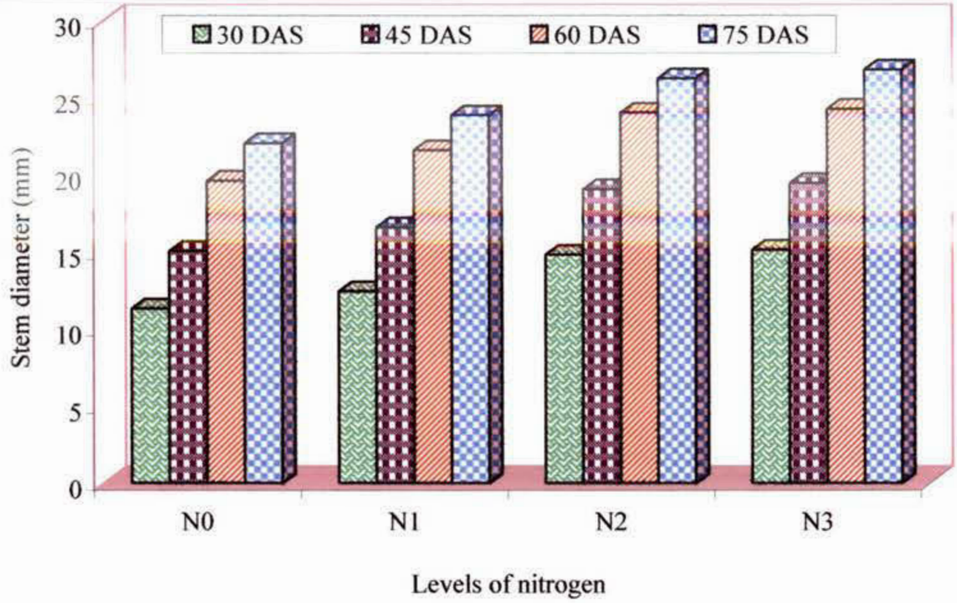

Figure 4. Effect of nitrogen on stem diameter of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}

N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

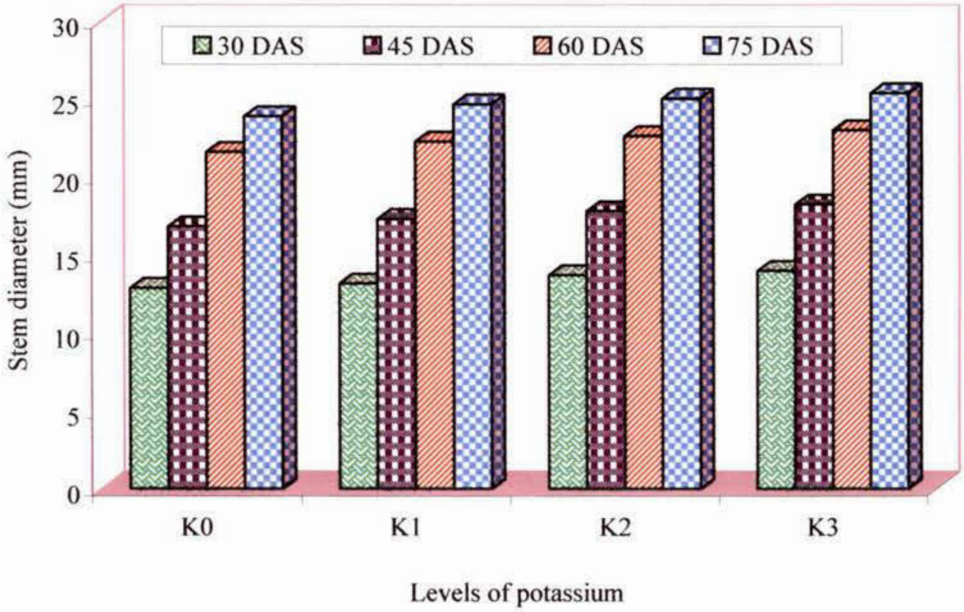

Figure 5. Effect of potassium on stem diameter of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}

K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

4.2 Stem diameter

Stem diameter showed statistically significant differences done to the application of different level of nitrogen at 30, 45, 60 and 75 DAS (Figure 4 and 5). The maximum stem diameter (15.15 mm) was found from N_3 which was closely (14.83 mm) followed by N_2 treatment, while the control (0 kg N/ha) gave the minimum (11.32 mm) at 30 DAS. At 45 DAS the maximum stem diameter (19.47 mm) was observed from N_3 treatment which was statistically similar (19.08 mm) with N_2 treatment and the minimum (15.06 mm) was recorded from control. The maximum stem diameter (24.27 mm) was recorded from N_3 treatment which was closely followed (24.03 mm) by N_2 treatment and the minimum (19.63 mm) was recorded from the control at 60 DAS. Nitrogen at a level of 110 kg/ha as treatment gave the maximum stem diameter (26.81 mm) at 75 DAS which was statistically similar (26.81 mm) with N_2 treatment, while the control gave the minimum (22.04 mm). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum stem diameter was observed. Saini and Shekhar (1998) stem diameter increased significantly upto 90 kg N/ha, and then decreased.

Different level of potassium showed significant variation on the stem diameter at 30, 45, 60 and 75 DAS (Figure 5). The maximum stem diameter (13.99 mm) was recorded from 140 kg K_2O/ha which was statistically similar (13.71 mm) with K_2 and the minimum (12.87 mm) was obtained from control at 30 DAS. At 45 DAS the maximum stem diameter (18.25 mm) was found from K_3 which was statistically similar (17.82 mm) with K_2 treatment, while the minimum (16.83 mm) was found from the control. The maximum stem diameter (23.01 mm) was recorded from treatment K_3 which was statistically similar (22.64 mm) with K_2 and the minimum (21.61 mm) was from the control at 60 DAS. At 75 DAS the maximum stem diameter (25.38 mm) was recorded from K_3 treatment which was statistically similar (25.03 mm) with K_2 and the minimum (23.89 mm) was recorded from control condition. Romero (1999) reported that highest plant diameter was 2.2 cm produced from at 60 kg/ha.

The stem diameter was found significantly influenced by the interaction of nitrogen and potassium (Appendix III) at different days after sowing. The maximum stem diameter (16.14 mm) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum (10.75 mm) stem diameter (Table 2). At 45 DAS the maximum stem diameter (20.48 mm) was observed from the treatment combination of N_3K_3 whereas the minimum (14.05 mm) was recorded from control treatment. At 60 DAS the maximum stem diameter (25.10 mm) was recorded from the treatment combination of N_3K_3 and the minimum (18.10 mm) was recorded from the control. The maximum stem diameter (27.59 mm) was recorded from the treatment combination of N_3K_3 and the minimum (20.38 mm) was from treatment N_0K_0 at 75 DAS. Talukder (1999) recorded the stem diameter of three cultivar of amaranth which ranged from 1.22 to 1.50 cm at 30 DAS, 1.98 to 2.38 cm at 37 DAS and 2.35 to 2.98 cm at 44 DAS. Those were more or less similar with the present study at 25, 35 and 44 DAS observations. Hossain (1996) also found the similar trend of result in 11 amaranth cultivars.

4.3 Number of leaves per plant

Number of leaves per plant varied statistically due to the individual application of different level of nitrogen and potassium at 30, 45, 60 and 75 DAS. Nitrogen at a level of 110 kg/ha of treatment N_3 gave the maximum number of leaves (18.66) at 30 DAS which was statistically similar (17.69) with N_2 treatment at a level of 100 kg N/ha, while the control treatment (0 kg N/ha) gave the minimum (11.85) at 30 DAS (Figure 6). The maximum number of leaves (25.64) was observed from treatment N_3 which was statistically similar (24.96) with N_2 treatment and the minimum (18.74) was from the control treatment at 45 DAS. At 60 DAS the maximum number of leaves (39.08) was recorded from the treatment of N_3 which was statistically similar (38.36) with N_2 treatment and the minimum (31.97) was from the control treatment. Nitrogen at a level of 110 kg/ha gave maximum

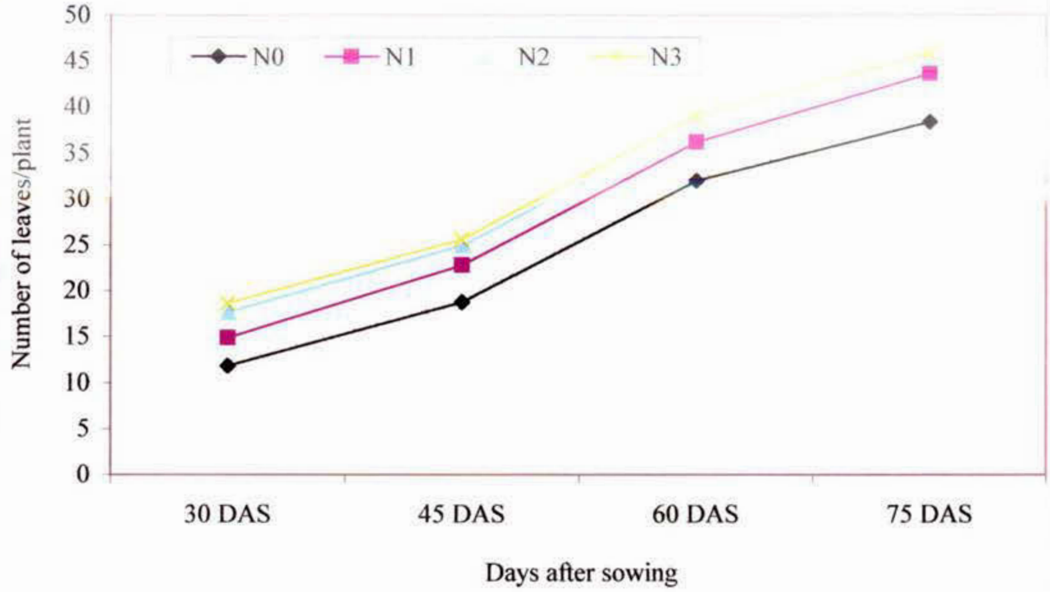

Figure 6. Effect of nitrogen on number of leaves/plant of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

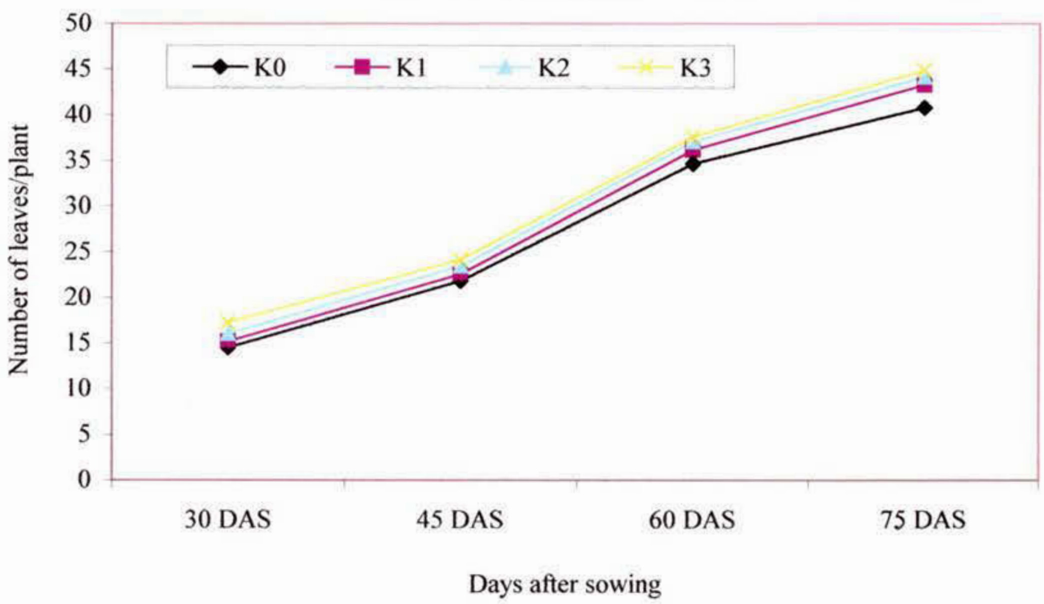

Figure 7. Effect of potassium on number of leaves/plant of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

number of leaves (45.90) at 75 DAS which was statistically similar (45.37) with N_2 treatment, while the control treatment gave the minimum (38.36). The results of this study agreed with the study of Acar (1996), who reported that number of leaves per plant increased with the increasing levels of nitrogen.

Different level of potassium showed significant differences on the number of leaves per plant at 30, 45, 60 and 75 DAS (Figure 7). The maximum number of leaves (17.29) was recorded from 140 kg K_2O/ha as treatment K_3 which was closely (16.10) followed by K_2 at 130 kg K_2O/ha and the minimum (14.50) was from control i.e. 0 kg K_2O/ha at 30 DAS. At 45 DAS the maximum (24.18) number of leaves was found from K_3 followed (23.52) by K_2 treatment, while the minimum (21.82) was from the control. The maximum number of leaves (37.58) was recorded from the treatment of K_3 which was statistically similar (37.15) to K_2 and the minimum (34.69) from control treatment at 60 DAS. At 75 DAS the maximum number of leaves (44.95) was recorded from K_3 treatment which was statistically similar (44.20) to K_2 and the minimum (40.79) was from control condition.

The combined effect of nitrogen and potassium in terms of number of leaves per plant at different days after sowing was also significant (Appendix IV). The maximum number of leaves was (20.28) recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum (10.53) number of leaves (Table 3). At 45 DAS the maximum number of leaves (27.76) was observed from the treatment combination of N_3K_3 whereas the minimum (17.59) was recorded from control. At 60 DAS the maximum number of leaves (40.10) was recorded from the treatment combination of N_3K_3 and the minimum (30.88) was recorded from the control treatment. The maximum number of leaves (47.45) was recorded from the treatment combination of N_3K_3 and the minimum (35.70) was obtained from the treatment N_0K_0 at 75 DAS. Hamid *et al.* (1989) found in an experiment that the maximum number of leaves per plant at 49 DAS ranged from 72.3 to 162.

Table 3. Combined effect of nitrogen and potassium on number and length of leaf of stem amaranth

Treatment	Number of leaves per plant				Length of leaf (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0K_0	10.53 i	17.59 f	30.88 e	35.70 g	7.59 i	11.94 i	16.29 h	20.78 e
N_0K_1	11.50 hi	18.39 ef	31.43 e	38.17 fg	8.16 hi	12.58 hi	16.74 gh	22.32 de
N_0K_2	11.96 ghi	19.12 def	32.13 e	38.76 efg	8.81 fghi	13.20 fghi	17.35 fgh	22.93 cd
N_0K_3	13.40 fgh	19.87 def	33.44 de	40.79 def	9.57 efghi	13.98 efgh	18.04 efgh	23.97 bcd
N_1K_0	13.55 fgh	21.52 cde	33.87 cde	41.38 cdef	9.80 efgh	14.21 efgh	18.31 defgh	23.93 bcd
N_1K_1	14.39 efg	22.31 bcd	36.10 bcd	43.54 abcd	8.55 ghi	13.09 ghi	17.17 fgh	22.66 cde
N_1K_2	15.47 def	23.33 bc	37.08 abc	44.48 abcd	10.30 defg	14.65 defg	18.76 defg	24.43 bcd
N_1K_3	16.22 cdef	24.03 bc	37.76 ab	45.14 abc	9.93 efgh	14.33 efgh	18.44 defg	24.06 bcd
N_2K_0	16.61 bcde	24.40 abc	36.35 abcd	42.65 bcde	10.53 defg	14.93 cdefg	19.04 cdef	24.66 bc
N_2K_1	16.97 bcde	24.73 abc	38.44 ab	45.80 ab	11.11 bcde	15.45 abcde	19.56 bcde	25.22 ab
N_2K_2	17.91 abcd	25.62 ab	39.29 ab	46.62 ab	11.10 bcde	15.44 abcde	19.53 bcde	25.21 ab
N_2K_3	19.27 ab	25.08 abc	39.36 ab	46.40 ab	12.76 abc	17.03 ab	21.05 abc	26.92 a
N_3K_0	17.32 bcd	23.77 bc	37.64 ab	43.45 abcd	10.84 cdef	15.19 bcdef	18.87 def	24.76 bc
N_3K_1	18.00 abcd	25.01 abc	38.85 ab	45.74 ab	12.19 abcd	16.48 abcd	20.19 abcd	26.02 ab
N_3K_2	19.06 abc	26.01 ab	39.74 ab	46.96 ab	13.07 ab	16.81 abc	21.45 ab	26.84 a
N_3K_3	20.28 a	27.76 a	40.10a	47.45 a	13.68 a	17.38 a	22.00 a	27.10 a
Significance level	**	**	**	**	**	**	**	**
CV (%)	9.70	8.26	5.32	6.28	10.53	7.33	5.78	7.53

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

4.4 Length of leaf

Length of leaf varied statistically due to the application of different level of nitrogen at 30, 45, 60 and 75 DAS (Appendix IV). Nitrogen at N_3 110 kg/ha gave the maximum length of leaf (12.45 cm) at 30 DAS which was closely followed (11.38 cm) by N_2 treatment at a level of 100 kg N/ha, while the control treatment (0 kg N/ha) gave the minimum (8.53 cm) at 30 DAS. The maximum length of leaf (16.46 cm) was observed from the treatment of N_3 which was statistically similar (15.71 cm) with N_2 treatment and the minimum (12.93 cm) was found from the control at 45 DAS. At 60 DAS the maximum length of leaf (20.63 cm) was recorded from N_3 and the minimum (17.10 cm) was obtained from the control treatment. Nitrogen at N_3 level as 110 kg/ha gave maximum length of leaf (26.18 cm) at 75 DAS which was closely followed (25.50 cm) by N_2, while control treatment showed the minimum (22.50 cm) length of leaf (Figure 8). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum leaf length was observed. Saini and Shekhar (1998) reported that leaf length increased significantly upto 90 kg N/ha, and then decreased.

Different level of potassium showed significant differences on the length of leaf at 30, 45, 60 and 75 DAS (Figure 9). The maximum length of leaf (11.49 cm) was recorded from 140 kg K_2O/ha for treatment K_3 which was closely followed (10.82 cm) by K_2 at 130 kg K_2O/ha and the minimum (9.69 cm) was recorded from control i.e. 0 kg K_2O/ha at 30 DAS. At 45 DAS the maximum length of leaf (15.68 cm) was found from K_3 which was statistically similar (15.03 cm) with K_2 treatment, while the minimum (14.07 cm) was obtained from the control. The maximum length of leaf (19.88 cm) was recorded from the treatment of K_3 which was statistically similar (19.27 cm) with K_2 and the minimum (18.13 cm) was found from the control at 60 DAS. At 75 DAS the maximum length of leaf (25.51 cm) was recorded from K_3 treatment which was closely followed (24.85 cm) by K_2 and the minimum (23.53 cm) was found from control condition (Figure 9).

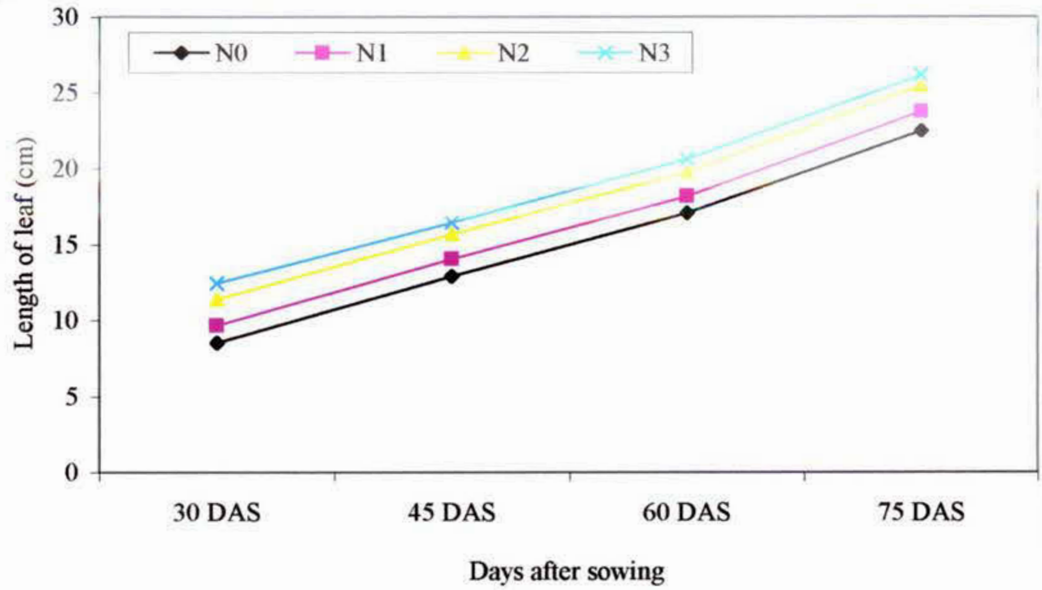

Figure 8. Effect of nitrogen on length of leaf of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}

N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

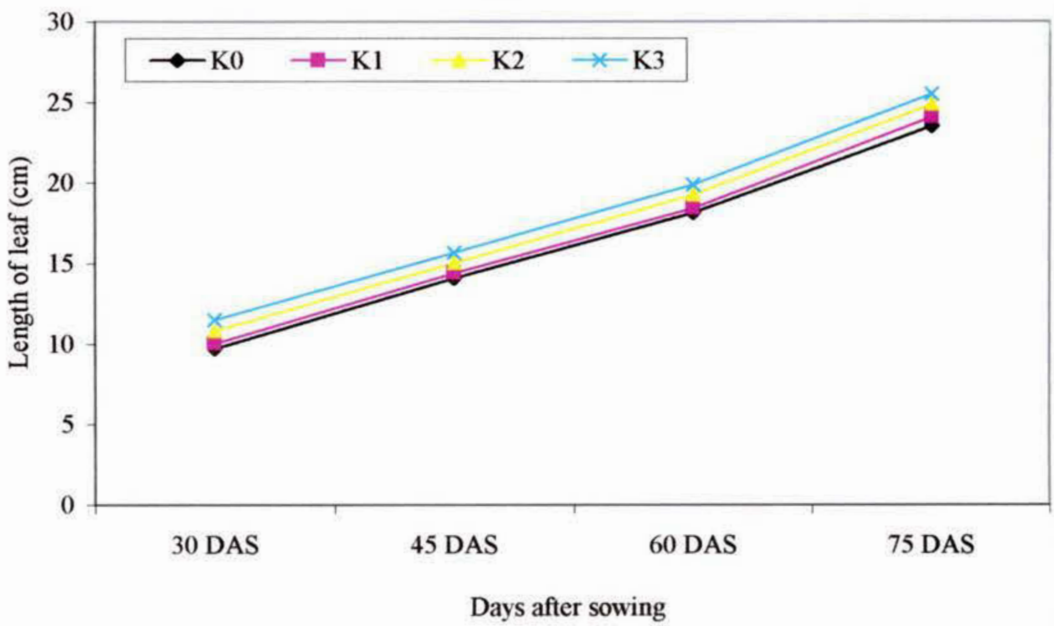

Figure 9. Effect of potassium on length of leaf of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}

K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

The combined effect of nitrogen and potassium in terms of length of leaf at different DAS was also significant (Appendix IV). The maximum length of leaf (13.68 cm) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum (7.59 cm) length of leaf (Table 3). At 45 DAS the maximum length of leaf (17.38 cm) was observed from the treatment combination of N_3K_3 whereas the minimum (11.94) was recorded from control treatment. At 60 DAS the maximum length of leaf (22.00 cm) was recorded from the treatment combination of N_3K_3 and the minimum (16.29 cm) was recorded from the control. The maximum length of leaf (27.10 cm) was recorded from N_3K_3 and the minimum (20.78 cm) was obtained from the treatment N_0K_0 at 75 DAS. Hossain (1996) recorded the length of leaves of 11 genotypes of amaranth. The length of leaves ranged from 7.83 to 12.73 cm at 35 DAS and 9.98 to 13.80 cm at 45 DAS which was much lower than the present study.

4.5 Petiole length

Petiole length varied statistically due to the application of different levels of nitrogen at 30, 45, 60 and 75 DAS (Appendix V). At 30 DAS N_3 gave the longest petiole (6.19 cm) which was statistically similar (6.13 cm) with N_2 treatment at a level of 100 kg N/ha, while the control treatment (0 kg N/ha) gave the shortest (4.95 cm) at 30 DAS. The longest petiole (8.65 cm) was observed from treatment N_3 which was statistically similar (8.43 cm) with N_2 treatment and the shortest (7.06 cm) was found from the control treatment at 45 DAS. At 60 DAS the longest petiole (9.86 cm) was recorded from the treatment N_3 which was statistically similar (9.66 cm) with N_2 treatment and the shortest (8.19 cm) was obtained from the control treatment. Nitrogen at N_3 level as 110 kg/ha gave the longest petiole (10.14 cm) at 75 DAS which was statistically similar (9.90 cm) with N_2 treatment, while the control gave the shortest (8.48 cm) petiole (Figure 10). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum petiole length was observed. Das and Ghosh (1999) reported that petiole length increasing N upto 120 kg N/ha.

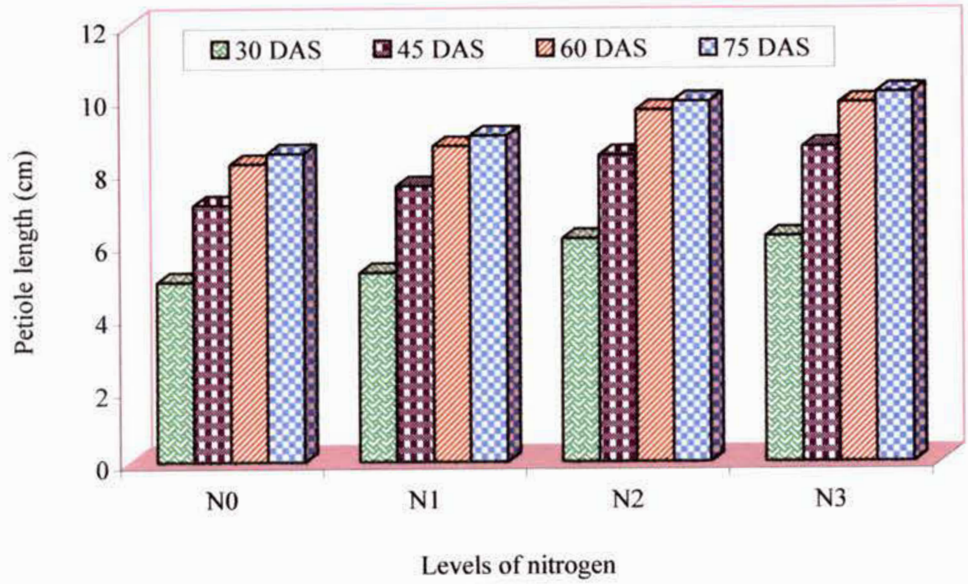

Figure 10. Effect of nitrogen on petiole length of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

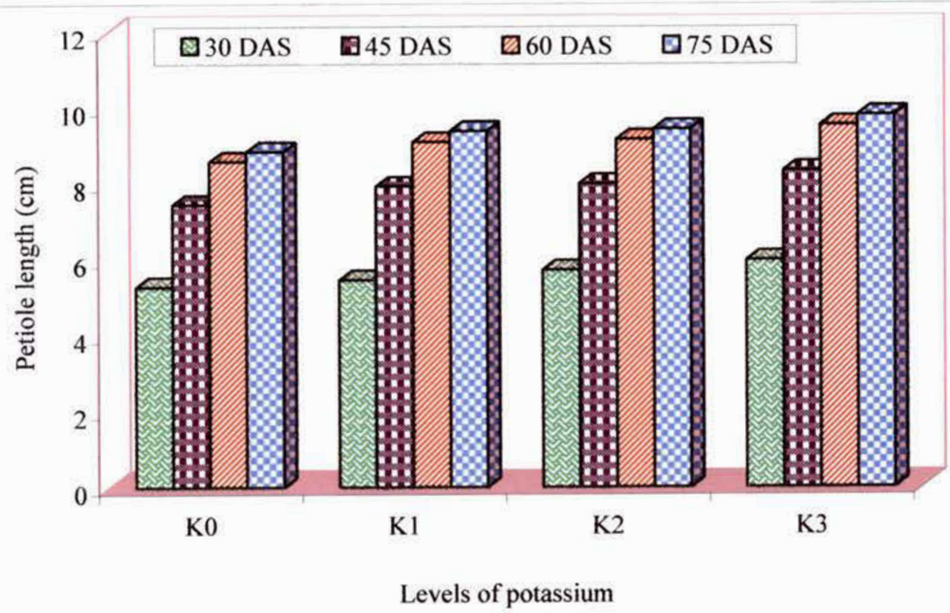

Figure 11. Effect of potassium on petiole length of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

Different levels of potassium showed significant differences on the petiole length at 30, 45, 60 and 75 DAS (Figure 11). The longest petiole (5.98 cm) was recorded from K_3 which was statistically similar (5.73 cm) with K_2 and the shortest (5.29 cm) was from control at 30 DAS. At 45 DAS the longest petiole (8.34 cm) was found from K_3 which was followed (8.00 cm) by K_2 treatment, while the shortest (7.45 cm) was from the control. The longest petiole (9.54 cm) was recorded from K_3 treatment which was closely followed (9.17 cm) by K_2 and the shortest (8.59 cm) from the control at 60 DAS. At 75 DAS the longest petiole (9.80 cm) length was recorded from K_3 treatment which was statistically similar (9.44 cm) with K_2 and the shortest (8.85 cm) was from control condition. Potassium fertilizer increased petiole length with maximum vegetative growth. Bressani *et al.* (1987) reported longest petiole length from highest doses of potassium.

The combined effect of nitrogen and potassium in terms of petiole length at different days after sowing were also significant (Appendix V). The longest petiole (6.58 cm) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the shortest petiole (4.57 cm) (Table 4). At 45 DAS significant variation in terms of petiole length was also observed among the treatments and the longest petiole (8.96 cm) was observed from the treatment combination of N_3K_3 whereas the shortest (6.66 cm) was recorded from control. At 60 DAS the longest petiole (10.21 cm) was recorded from the treatment combination of N_3K_3 and the shortest (7.85 cm) was recorded from the control treatment. The longest petiole (10.47 cm) was recorded from the treatment combination of N_3K_3 and the shortest (8.09 cm) from N_0K_0 at 75 DAS. Mazumder (2004) reported that fertilizer doses were 200 kg urea, 100 kg triple super phosphate and 200 kg muriate of potash produced maximum petiole length compare control.

Table 4. Combined effect of nitrogen and potassium on petiole length and diameter of stem amaranth

Treatment	Petiole length (cm) at				Petiole diameter (mm) at			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0K_0	4.57 ef	6.66 f	7.85 f	8.09 g	2.39 c	2.57 f	3.08 c	3.23 e
N_0K_1	4.41 f	6.90 ef	8.01 f	8.32 fg	2.39 c	2.71 ef	3.21 bc	3.41 bcde
N_0K_2	5.41 bcde	7.17 def	8.26 ef	8.57 efg	2.43 c	3.10 bcd	3.25 bc	3.52 abcde
N_0K_3	5.40 bcde	7.50 cde	8.64 def	8.94 def	2.42 c	3.20 bc	3.38 abc	3.58 abcde
N_1K_0	5.00 cdef	7.11 def	8.06 f	8.34 fg	2.47 bc	3.03 cde	3.24 bc	3.31 cde
N_1K_1	4.87 def	7.34 cdef	8.44 def	8.77 defg	2.45 bc	3.02 cde	3.30 bc	3.42 bcde
N_1K_2	5.41 bcde	7.87 bcd	9.04 bcde	9.28 bcde	2.41 c	3.17 bc	3.33 bc	3.50 abcde
N_1K_3	5.54 bcd	8.00 bc	9.18 bcd	9.44 bcd	2.46 bc	3.20 bc	3.39 abc	3.53 abcde
N_2K_0	5.72 abcd	7.72 bcde	8.94 cde	9.20 cde	2.51 bc	2.80 def	3.14 c	3.29 de
N_2K_1	6.12 ab	8.53 ab	9.77 ab	10.00 ab	2.34 c	3.29 bc	3.51 ab	3.67 abc
N_2K_2	6.11 ab	8.50 ab	9.72 abc	9.98 abc	2.68 abc	3.20 bc	3.39 abc	3.56 abcde
N_2K_3	6.42 a	8.89 a	10.17 a	10.37 a	2.55 bc	3.25 bc	3.43 abc	3.58 abcde
N_3K_0	5.86 abc	8.33 ab	9.52 abc	9.78 abc	2.45 bc	3.17 bc	3.30 bc	3.59 abcde
N_3K_1	6.48 a	8.46 ab	9.64 abc	9.92 abc	2.79 ab	3.30 bc	3.42 abc	3.66 abcd
N_3K_2	5.99 ab	8.94 a	10.11 a	10.44 a	2.69 abc	3.42 ab	3.53 ab	3.71 ab
N_3K_3	6.58 a	8.96 a	10.21 a	10.47 a	2.90 a	3.72 a	3.72 a	3.83 a
Significance level	**	**	**	**	**	**	**	**
CV (%)	8.09	5.52	7.77	7.46	7.19	8.17	5.37	5.38

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

N_0 : 0 kg N ha^{-1} K_0 : 0 kg K_2O ha^{-1}
N_1 : 90 kg N ha^{-1} K_1 : 120 kg K_2O ha^{-1}
N_2 : 100 kg N ha^{-1} K_2 : 130 kg K_2O ha^{-1}
N_3 : 110 kg N ha^{-1} K_3 : 140 kg K_2O ha^{-1}

4.6 Petiole diameter

Petiole diameter varied significantly due to the application of different levels of nitrogen at 30, 45, 60 and 75 DAS (Appendix V). Treatment N_3 gave the maximum petiole diameter (2.71 mm) at 30 DAS which was closely followed (2.52 mm) by N_2 treatment, while the control treatment (0 kg N/ha) showed the minimum (2.41 mm) at 30 DAS. The maximum petiole diameter (3.40 mm) was observed from treatment N_3 which was closely followed (3.14 mm) by N_2 treatment and the minimum (2.89 mm) was from the control treatment at 45 DAS. At 60 DAS the maximum petiole diameter (3.49 mm) was recorded from the treatment N_3 which was statistically similar (3.37 mm) with N_2 and the minimum (3.23 mm) was from the control. Treatment N_3 gave the maximum petiole diameter (3.70 mm) at 75 DAS which was statistically similar (3.53 mm) with N_2 treatment, while the minimum (3.43 mm) was found from control treatment (Figure 12). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum petiole diameter was observed. Das and Ghosh (1999) reported that petiole diameter increasing N upto 120 kg N/ha.

Different levels of potassium showed significant differences on the petiole diameter at 30, 45, 60 and 75 DAS (Figure 13). The maximum petiole diameter (2.58 mm) was recorded from 140 kg K_2O/ha (K_3) which was statistically similar (2.55 mm) with K_2 and the minimum (2.45 mm) was obtained from control at 30 DAS. At 45 DAS the maximum petiole diameter (3.34 mm) was found from K_3 followed (3.22 mm) by K_2 treatment, while the minimum (2.89 mm) was from the control. The maximum petiole diameter (3.48 mm) was recorded from the treatment of K_3 which was statistically similar (3.37 mm) by K_2 and the minimum (3.19 mm) was found from the control at 60 DAS. At 75 DAS the maximum petiole diameter (3.63 mm) was recorded from K_3 treatment which was closely followed (3.57 mm) by K_2 and the minimum (3.36 mm) was from control condition. Bressani *et al.* (1987) reported longest petiole diameter from highest doses of potassium.

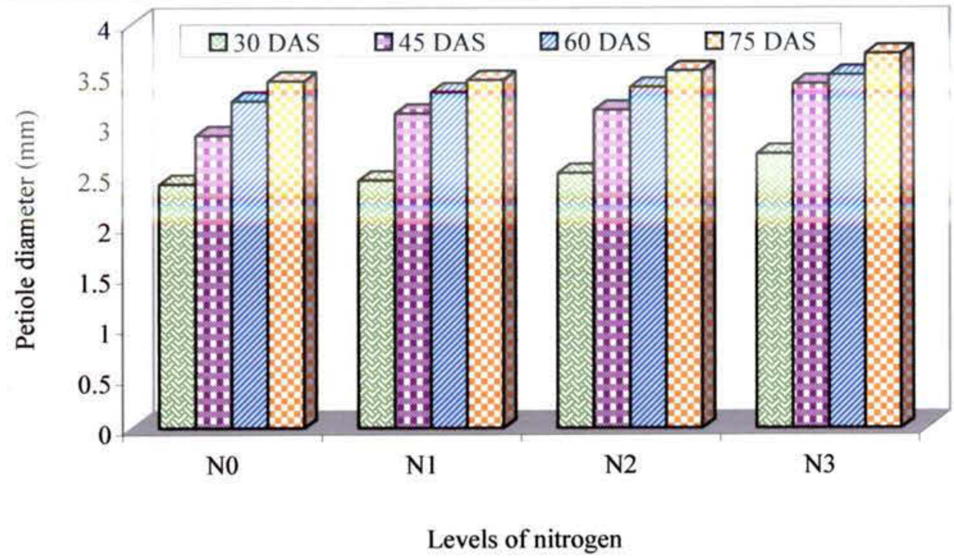

Figure 12. Effect of nitrogen on petiole diameter of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

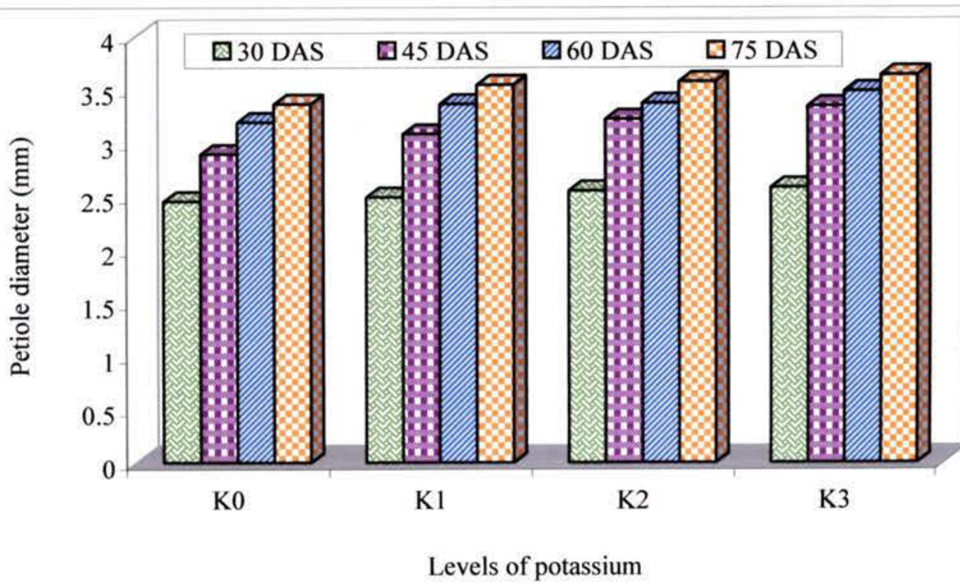

Figure 13. Effect of potassium on petiole diameter of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

The combined effect of nitrogen and potassium in terms of petiole diameter at different days after sowing was also significant (Appendix V). The maximum petiole diameter (2.90 mm) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) performed the minimum petiole diameter (2.39 mm) (Table 4). At 45 DAS significant variation in terms of petiole diameter was also observed among the treatments and the maximum petiole diameter (3.72 mm) was observed from the treatment combination of N_3K_3 whereas the minimum (2.57 mm) was recorded from control treatment. At 60 DAS the maximum petiole diameter (3.72 mm) was recorded from the treatment combination of N_3K_3 and the minimum (3.08 mm) was recorded from the control. The maximum petiole diameter (3.83 mm) was recorded from the treatment combination of N_3K_3 and the minimum (3.23 mm) was found from the treatment combination of N_0K_0 at 75 DAS (Table 4).

4.7 Fresh weight of stem per plant

Fresh weight of stem per plant differed statistically due to the application of different level of nitrogen at 30, 45, 60 and 75 DAS (Appendix VI). Nitrogen at N_3 level as 110 kg/ha gave the maximum fresh weight of stem per plant (42.24 g) which was statistically similar (41.40 g) with N_2 treatment at a level of 100 kg N/ha, while the control treatment (0 kg N/ha) gave the minimum (33.50 g) at 30 DAS. The maximum fresh weight of stem per plant (75.68 g) was observed from treatment N_3 which was statistically similar (74.58 g) with N_2 treatment and the minimum (64.23 g) was from the control at 45 DAS. At 60 DAS the maximum fresh weight of stem per plant (107.44 g) was recorded from N_3 which was statistically similar (106.05 g) with N_2 treatment and the minimum (93.69 g) was found from the control. At 75 DAS treatment N_3 showed the maximum fresh weight of stem per plant (138.92 g) which was statistically similar (137.29 g) with N_2 treatment, while the control treatment gave the minimum (124.01 g). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum fresh weight of stem per plant was observed. Anten and Werger (1996) reported that 150 kg N produced maximum fresh weight per plant.

Table 5. Main effect of nitrogen and potassium on fresh weight of stem and leaves of stem amaranth

Treatment	Fresh weight stem/plant (g)				Fresh weight leaves/plant (g)			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen								
N_0	33.50 c	64.23 c	93.69 c	124.01 c	10.37 c	19.81 c	32.65 c	44.88 c
N_1	36.74 b	69.85 b	101.18 b	131.89 b	14.86 b	26.75 b	38.63 b	52.40 b
N_2	41.40 a	74.58 a	106.05 a	137.29 a	19.16 a	30.31 a	41.67 a	54.95 a
N_3	42.24 a	75.68 a	107.44 a	138.92 a	20.69 a	31.40 a	42.70 a	55.54 a
Significance level	**	**	**	**	**	**	**	**
Potassium								
K_0	36.48 c	67.55 c	98.01 b	128.38 b	14.26 c	25.13 b	36.49b	48.43 b
K_1	37.57 bc	69.91 bc	101.61 ab	132.58 a	15.31 c	26.43 ab	38.63 ab	51.88 a
K_2	39.27 ab	73.00 ab	104.01 a	134.44 a	16.92 b	27.93 a	39.97 a	53.43 a
K_3	40.56 a	73.89 a	104.73 a	136.72 a	18.60 a	28.78 a	40.56 a	54.04 a
Significance level	**	**	**	**	**	**	**	**

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

Different level of potassium showed significant differences in respect of fresh weight of stem per plant at 30, 45, 60 and 75 DAS (Table 5). The maximum fresh weight of stem per plant (40.56 g) was recorded from 140 kg K_2O/ha for treatment K_3 which was statistically similar (39.27 g) with K_2 at 130 kg K_2O/ha and the minimum (36.48 g) was found from control i.e. 0 kg K_2O/ha at 30 DAS. At 45 DAS the maximum fresh weight of stem per plant (73.89 g) was found from K_3 which was statistically similar (73.00 g) with K_2 treatment, while the minimum (67.55 g) was from the control. The maximum fresh weight of stem per plant (104.73 g) was recorded from the treatment of K_3 which was similar (104.01 g) with K_2 and the minimum (98.01 g) was recorded from the control at 60 DAS. At 75 DAS the maximum fresh weight of stem per plant (136.72 g) was recorded from K_3 treatment which was statistically similar (134.44 g) with K_2 and K_1 (132.58 g). The minimum fresh weight of stem per plant was (128.38 g) recorded from control treatment. Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum fresh weight of stem per plant was observed. Das and Ghosh (1999) reported that fresh weight of stem increasing N upto 120 kg N/ha.

The fresh weight of stem per plant was not significantly influenced by the interaction effect of nitrogen and potassium. The maximum fresh weight of stem per plant (44.94 g) was recorded at 30 DAS from N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 gave the minimum fresh weight of stem per plant (31.82 g) (Table 6). At 45 DAS the maximum fresh weight of stem per plant (81.59 g) was observed from N_3K_3 whereas the minimum (58.88 g) was recorded in control. At 60 DAS the maximum fresh weight of stem per plant (111.26 g) was recorded from N_3K_3 and the minimum (85.98 g) was recorded from the control. The maximum fresh weight of stem per plant (145.29 g) was recorded from the treatment combination of N_3K_3 and the minimum (114.56 g) was from the treatment N_0K_0 at 75 DAS. The results on stem weight per plant at different harvesting period obtained in this study are comparable to the findings of Talukder (1999) who recorded the stem weight of 25.93 to 41.55 g at 30 DAS, 119.07 to 180.02 g at 37 DAS and 193.68 g to 291.68 g at 44 DAS, respectively in three amaranth cultivars.

Table 6. Combined effect of nitrogen and potassium on fresh weight of stem and leaves of stem amaranth

Treatment	Fresh weight stem/plant (g)				Fresh weight leaves/plant (g)			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0K_0	31.82 h	58.88 g	85.98 f	114.56 f	8.13 i	18.17 f	31.12 e	41.73 f
N_0K_1	33.16 gh	65.12 efg	97.29 cde	127.95 de	9.60 hi	19.49 f	31.89 e	44.36 ef
N_0K_2	34.70 efgh	68.37 def	96.53 de	127.29 e	10.98 ghi	20.68 ef	32.87 e	46.21 def
N_0K_3	34.30 fgh	64.56 fg	94.98 e	126.24 e	12.76 fgh	20.92 ef	34.73 de	47.22 cdef
N_1K_0	34.51 fgh	67.53 def	98.94 cde	129.35 de	12.73 fgh	24.66 de	35.34 cde	49.09 bcde
N_1K_1	35.78 defgh	68.97 cdef	100.34 cde	130.96 cde	14.04 efg	25.93 cd	38.48 bcd	52.26 abcd
N_1K_2	37.72 cdefg	70.80 bcdef	102.10 bcde	132.96 bcde	15.83 def	27.62 bcd	39.86 abcd	53.63 abc
N_1K_3	38.96 bcdef	72.11 bcdef	103.31 abcde	134.31 bcde	16.84 cde	28.80 bcd	40.83 ab	54.62 ab
N_2K_0	39.61 abcdef	72.72 bcdef	103.97 abcd	135.07 bcde	17.52 cd	29.39 bcd	38.83 abcd	50.96 abcde
N_2K_1	40.19 abcd	73.35 bcde	104.56 abcd	135.66 bcde	18.01 cd	29.94 abc	41.78 ab	55.58 ab
N_2K_2	41.76 abc	74.96 abcd	106.17 abc	137.40 abcd	19.46 bc	31.40 ab	42.99 ab	56.79 a
N_2K_3	44.03 ab	77.30 abc	109.49 ab	141.03 ab	21.67 ab	30.50 abc	43.08 ab	56.48 a
N_3K_0	39.99 abcde	71.06 bcdef	103.14 abcde	134.56 bcde	18.66 bcd	28.30 bcd	40.65 abc	51.95 abcd
N_3K_1	41.15 abcd	72.19 bcdef	104.25 abcd	135.74 bcde	19.58 bc	30.37 abc	42.36 ab	55.31 ab
N_3K_2	42.90 abc	77.88 ab	111.13 a	140.11 abc	21.40 ab	32.02 ab	43.62 ab	57.09 a
N_3K_3	44.94 a	81.59 a	111.26 a	145.29 a	23.13 a	34.89 a	44.15 a	57.83 a
Significance level	**	**	**	**	**	**	**	**
CV (%)	7.38	6.22	8.51	3.75	11.08	9.99	7.41	7.10

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

4.8 Fresh weight of leaves per plant

Fresh weight of leaves per plant varied significantly due to the application of different level of nitrogen at 30, 45, 60 and 75 DAS (Appendix VI). Nitrogen at N_3 level as 110 kg/ha performed the maximum fresh weight of leaves per plant (20.69 g) at 30 DAS which was statistically similar (19.16 g) with N_2 treatment at a level of 100 kg N/ha, whiles the minimum (10.37 g) was found from control treatment. The maximum fresh weight of leaves per plant (31.40 g) was observed from treatment N_3 which was statistically similar (30.31 g) with N_2 treatment and the minimum (19.81 g) was obtained from the control treatment at 45 DAS. At 60 DAS the maximum fresh weight of leaves per plant was (42.70 g) recorded from the treatment N_3 which was statistically similar (41.67 g) with N_2 and the minimum (32.65 g) was found from the control treatment. Nitrogen at a level of 110 kg/ha of treatment N_3 gave the maximum fresh weight of leaves per plant (55.54 g) at 75 DAS which was statistically similar (54.95 g) with N_2, while the minimum (44.88 g) was obtained from control (Table 5). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum fresh weight of leaves observed. Das and Ghosh (1999) reported that fresh weight of leaves increasing N upto 120 kg N/ha.

Different levels of potassium showed significant differences on the fresh weight of leaves per plant at 30, 45, 60 and 75 DAS (Table 5). The maximum fresh weight of leaves per plant (18.60 g) was recorded from 140 kg K_2O/ha for treatment K_3 which was closely (16.92 g) followed by K_2 and the minimum (14.26 g) was from control at 30 DAS. At 45 DAS the maximum fresh weight of leaves per plant (28.78 g) was found from K_3 which was statistically similar (27.93 g) to K_2 treatment, while the minimum (25.13 g) was from the control. The maximum fresh weight of leaves per plant (40.56 g) was recorded from the treatment of K_3 which was statistically followed (39.97 g) by K_2 and K_1. The minimum (36.49 g) was found from the control at 60 DAS. At 75 DAS the maximum fresh weight of leaves per plant (54.04 g) was recorded from K_3 treatment which was similar (53.43 g) with K_2 and K_1 while the minimum (48.43 g) was from control condition. Romero (1999) reported that fresh weight of leaves responded well to the potassium at 60 kg/ha.

The fresh weight of leaves per plant was significantly influenced by the interaction of nitrogen and potassium (Appendix VI). The maximum fresh weight of leaves per plant (23.13 g) was recorded at 30 DAS from the treatment combination of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), which was similar (21.40 g) with N_3K_3 while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum fresh weight of leaves per plant (8.13 g) (Table 6). At 45 DAS the maximum fresh weight of leaves per plant (34.89 g) was observed from the treatment combination of N_3K_3 which were similar with N_3K_2, N_3K_1, N_3K_0, N_2K_3, N_2K_2 whereas the minimum (18.17 g) was recorded in control. At 60 DAS the maximum fresh weight of leaves per plant (44.15 g) was recorded from the treatment combination of N_3K_3 which were similar with N_3K_2, N_3K_1, N_2K_0, N_2K_1, N_2K_2, N_2K_3, N_1K_2 and N_2K_3. The minimum (31.12 g) was recorded from control treatment. The maximum fresh weight of leaves per plant (57.83 g) was recorded from the treatment combination of N_3K_3 and the minimum (41.73 g) was found from the treatment combination of N_0K_0 at 75 DAS. The results on leaves weight per plant are not similar to the findings of Talukder (1999) who recorded the leaves weight of 49.53 g to 78.90 g at 37 DAS and 61.54 g to 92.02 g at 44 DAS in three amaranth cultivars.

4.9 Dry matter of stem

Dry matter of stem in percentage significantly varied due to the application of different level of nitrogen and potassium at 30, 45, 60 and 75 DAS (Appendix VII). Treatment N_3 gave the maximum dry matter of stem (5.33 %) at 30 DAS which was statistically similar (5.16 %) with N_2 treatment, while the control treatment (0 kg N/ha) gave the minimum (4.18%) at 30 DAS. The maximum dry matter of stem (9.30%) was observed from treatment N_3 which was statistically similar (9.02%) with N_2 treatment and the minimum (7.60%) was obtained from the control treatment at 45 DAS. At 60 DAS the maximum dry matter of stem (12.87%) was recorded from the treatment N_3 which was statistically similar (12.60%) with N_2 treatment and the minimum (11.08%) was from the control treatment. Treatment N_3 gave the maximum dry matter of stem (16.88%) at 75 DAS which was statistically similar (16.73%) with N_2 treatment, while the minimum (15.05%) was found from control treatment (Table 7). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum dry matter content of stem.

Different levels of potassium showed significant differences in respect of dry matter of stem at 30, 45, 60 and 75 DAS (Table 7). The maximum dry matter of stem (5.04%) was recorded from treatment K_3 which was followed (4.89%) by K_2 at 130 kg K_2O/ha and the minimum (4.55%) was from control at 30 DAS. At 45 DAS the maximum dry matter of stem (8.97%) was found from K_3 which was similar (8.75%) with K_2 treatment, while the minimum (8.16%) was from control. The maximum dry matter of stem (12.48%) was recorded from K_3 which was statistically similar (12.39%) with K_2 and the minimum (11.63%) from the control at 60 DAS. At 75 DAS the maximum dry matter of stem (16.88%) was recorded from K_3 treatment followed (16.26%) by K_2 and the minimum (15.53%) was from control condition. Romero (1999) observed earlier dry matter responded well to the potassium at 60 kg/ha.

The combined effect of nitrogen and potassium in terms of dry matter of stem at different days after sowing was also significant. The maximum dry matter of stem (5.62%) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum dry matter of stem (4.02%) (Table 8). At 45 DAS significant variation in terms of dry matter of stem was also observed among the treatments and the maximum dry matter of stem (10.06%) was observed from the treatment combination of N_3K_3 whereas the minimum (7.06%) was recorded in control. At 60 DAS the maximum dry matter of stem (13.41%) was recorded from the treatment combination of N_3K_3 and the minimum (10.08%) was recorded from the control. The maximum dry matter of stem (17.97%) was recorded from the treatment combination of N_3K_3 and the minimum (13.87%) was found from the treatment N_0K_0 at 75 DAS. Hossain (1996) recorded the dry matter content of 11 amaranth genotypes which was ranged from 7.26 to 10.07% at 55 DAS. This was lower than the present study.

Table 7. Main effect of nitrogen and potassium on dry matter of stem and leaves of stem amaranth

Treatment	Dry matter of stem (%)				Dry matter of leaves (%)			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Nitrogen								
N_0	4.18 c	7.60 c	11.08 c	15.05 c	2.12 c	2.93 c	4.94 c	5.79 c
N_1	4.55 b	8.35 b	12.00 b	16.04 b	2.75 b	3.77 b	5.67 b	6.68 b
N_2	5.16 a	9.02 a	12.60 a	16.73 a	3.34 a	4.23 a	6.04 a	7.04 a
N_3	5.33 a	9.30 a	12.87 a	16.88 a	3.57 a	4.44 a	6.15 a	7.17 a
Significance level	**	**	**	**	**	**	**	**
Potassium								
K_0	4.55 c	8.16 c	11.63 b	15.53 c	2.66 c	3.61 c	5.42 b	6.26 b
K_1	4.73 bc	8.38 bc	12.04 ab	16.03 bc	2.83 bc	3.74 bc	5.66 ab	6.66 a
K_2	4.89 ab	8.75 ab	12.39 a	16.26 ab	3.02 ab	3.94 ab	5.82 a	6.84 a
K_3	5.04 a	8.97 a	12.48 a	16.88 a	3.27 a	4.09 a	5.89 a	6.92 a
Significance level	**	**	**	**	**	**	**	**

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

Table 8. Combined effect of nitrogen and potassium on dry matter of stem and leaves of stem amaranth

Treatment	Dry matter of stem (%)				Dry matter of leaves (%)			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
N_0K_0	4.02 f	7.06 g	10.08 e	13.87 d	1.88 g	2.72 g	4.75 d	5.44 f
N_0K_1	4.15 ef	7.69 fg	11.56 cd	15.21 c	2.07 fg	2.86 g	4.80 d	5.75 ef
N_0K_2	4.34 ef	7.86 efg	11.43 cd	15.42 c	2.13 fg	2.96 fg	5.04 d	5.82 def
N_0K_3	4.22 ef	7.78 fg	11.24 d	15.69 c	2.42 efg	3.20 efg	5.18 cd	6.17 cdef
N_1K_0	4.19 ef	8.16 def	11.82 bcd	15.64 c	2.46 efg	3.50 def	5.27 bcd	6.32 bcde
N_1K_1	4.49 def	8.15 def	11.83 bcd	15.88 c	2.63 def	3.65 cde	5.72 abc	6.58 abcd
N_1K_2	4.61 cde	8.52 cdef	12.11 bcd	16.29 bc	2.84 cde	3.91 bcd	5.79 abc	6.88 abc
N_1K_3	4.90 bcd	8.55 cdef	12.26 abcd	16.35 bc	3.06 bcde	4.02 bcd	5.88 ab	6.96 abc
N_2K_0	4.97 bcd	8.70 bcdef	12.33 abcd	16.28 bc	3.05 bcde	4.18 bc	5.74 abc	6.53 abcde
N_2K_1	5.04 bc	8.83 bcde	12.37 abcd	16.55 abc	3.19 bcd	4.18 bc	6.01 a	7.09 ab
N_2K_2	5.20 ab	9.04 bcd	12.63 abc	16.60 abc	3.43 abc	4.35 ab	6.16 a	7.33 a
N_2K_3	5.44 ab	9.51 abc	13.06 ab	17.50 ab	3.69 ab	4.22 bc	6.24 a	7.22 a
N_3K_0	5.04 bc	8.71 bcdef	12.30 abcd	16.35 bc	3.25 abcd	4.06 bcd	5.92 ab	6.75 abc
N_3K_1	5.25 ab	8.86 bcde	12.39 abcd	16.46 abc	3.43 abc	4.25 bc	6.10 a	7.24 a
N_3K_2	5.42 ab	9.58 ab	13.37 a	16.75 abc	3.68 ab	4.54 ab	6.26 a	7.33 a
N_3K_3	5.62 a	10.06 a	13.41 a	17.97 a	3.92 a	4.92 a	6.31 a	7.34 a
Significance level	**	**	**	**	**	**	**	**
CV (%)	6.10	6.22	5.32	4.97	12.70	8.62	6.30	6.55

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

4.10 Dry matter of leaves

Dry matter of leaves varied statistically due to the individual application of different levels of nitrogen and potassium at 30, 45, 60 and 75 DAS (Appendix VII). Nitrogen at a level of 110 kg/ha (N_3) gave the maximum dry matter of leaves (3.57%) at 30 DAS which was statistically similar (3.34%) with N_2 treatment at a level of 100 kg N/ha, while the control treatment (0 kg N/ha) gave the minimum (2.12%) at 30 DAS. The maximum dry matter of leaves (4.44%) was observed from treatment N_3 which was statistically similar (4.23%) with N_2 treatment and the minimum (2.93%) was from the control treatment at 45 DAS. At 60 DAS the maximum dry matter of leaves (6.15%) was recorded from the treatment N_3 which was statistically similar (6.04%) with N_2 treatment and the minimum (4.94%) was from the control treatment. Nitrogen at N_3 level as 110 kg/ha gave the maximum dry matter of leaves (7.17%) at 75 DAS which was statistically similar (7.04%) with N_2 treatment, while the control treatment gave the minimum (5.79%). Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum dry matter of leaves was observed. Subhan (1989) reported similar findings.

Different level of potassium showed significant differences on the dry matter of leaves at 30, 45, 60 and 75 DAS (Table 7). The maximum dry matter of leaves (3.27%) was recorded from 140 kg K_2O/ha (K_3) which was similar (3.02%) by K_2 at 130 kg K_2O/ha and the minimum (2.66%) was from control i.e. 0 kg K_2O/ha at 30 DAS. At 45 DAS the maximum dry matter of leaves (4.09%) was found from K_3 followed (3.94%) by K_2 treatment, while the minimum (3.61%) was from the control. The maximum dry matter of leaves (5.89%) was recorded from the treatment of K_3 which was similar (5.82%) by K_2 and the minimum (5.42%) was from the control at 60 DAS. At 75 DAS the maximum dry matter of leaves (6.92%) was recorded from K_3 treatment similar (6.84%) with K_2 and K_1 the minimum (6.26%) was from control treatment. Bhai and Singh (1998) reported that dry matter of leaves increased with increasing of potassium.

The combined effect of nitrogen and potassium was also significant in terms of dry matter of leaves at different days after sowing. The maximum dry matter of leaves (3.92%) was recorded at 30 DAS from the combined effect of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum dry matter of leaves (1.88%). At 45 DAS significant variation in terms of dry matter of leaves was also observed among the treatments and the maximum dry matter of leaves (4.92%) was observed from the treatment combination of N_3K_3 whereas the minimum (2.72%) was recorded from control treatment. At 60 DAS the maximum dry matter of leaves (6.31%) was recorded from the treatment combination of N_3K_3 and the minimum (4.75%) was recorded from the control. The maximum dry matter of leaves (7.34%) was recorded in from the treatment combination of N_3K_3 and the minimum (5.44%) was from the treatment N_0K_0 at 75 DAS (Table 8).

4.11 Yield per hectare

Yield per hectare varied statistically due to the application of different level of nitrogen and potassium at 30, 45, 60 and 75 DAS (Appendix VIII). Treatment N_3 gave the maximum yield (16.96 t/ha) at 30 DAS which was statistically similar (16.04 t/ha) with N_2 treatment at a level of 100 kg N/ha, while the control treatment (0 kg N/ha) showed the minimum yield (11.94 t/ha) at 30 DAS. The maximum yield (26.91 t/ha) was observed from treatment N_3 which was statistically similar (25.25 t/ha) with N_2 treatment and the lowest yield (18.21 t/ha) was from the control treatment at 45 DAS. At 60 DAS the maximum yield (40.39 t/ha) was recorded from N_3 which was statistically similar (38.68 t/ha) with N_2 treatment and the minimum yield (22.90 t/ha) was from the control treatment. Treatment N_3 gave the maximum yield (60.79 t/ha) which was statistically similar (59.54 t/ha) with N_2, while the control treatment gave the minimum (31.58 t/ha) at 75 DAS. Highest amount of nitrogen ensured favorable condition for vegetative growth as a result maximum yield was observed. Saini and Shekhar (1998) reported that yield increased significantly upto 90 kg N/ha, and then decreased.

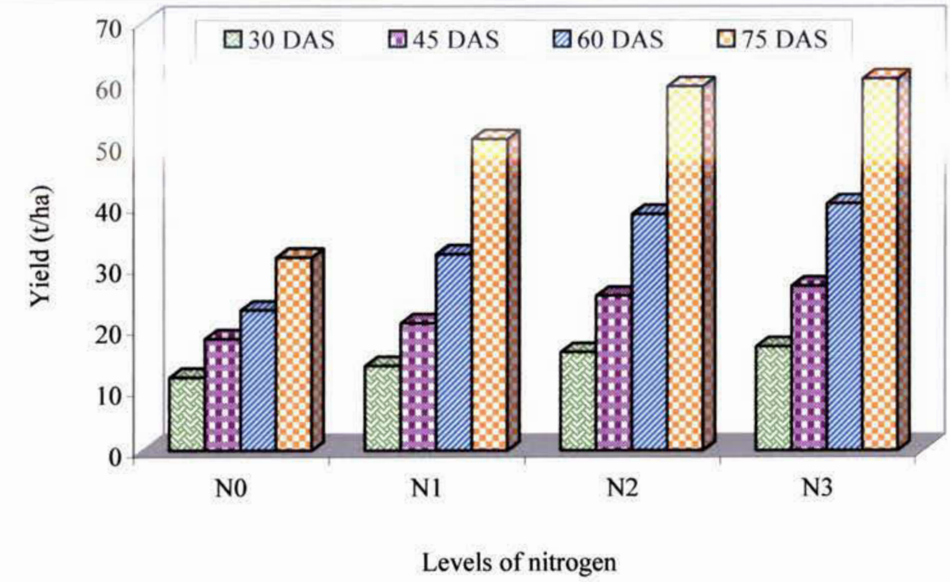

Figure 14. Effect of nitrogen on yield per ha of stem amaranth

N_0 : 0 kg N ha^{-1} N_1 : 90 kg N ha^{-1}

N_2 : 100 kg N ha^{-1} N_3 : 110 kg N ha^{-1}

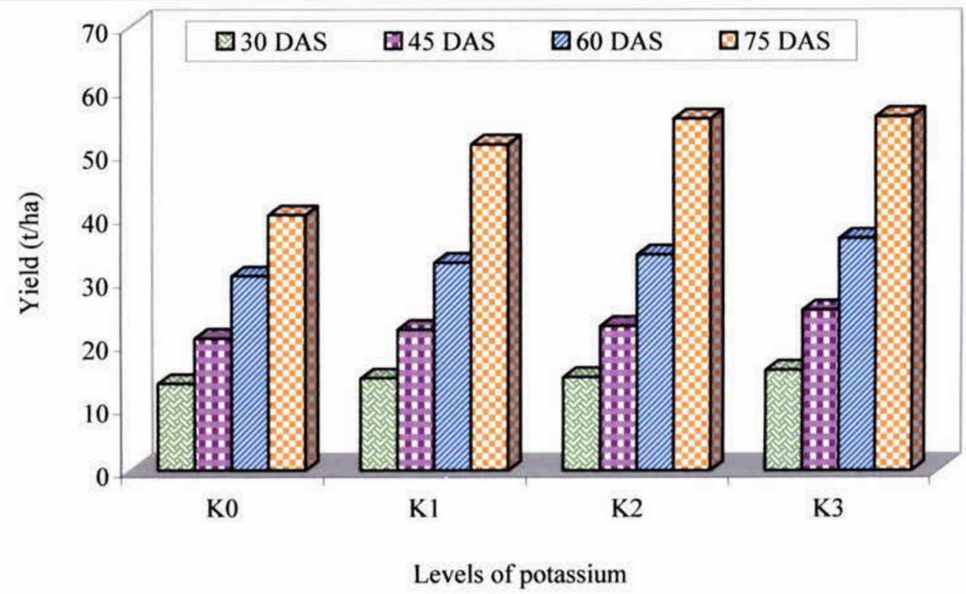

Figure 15. Effect of potassium on yield per ha of stem amaranth

K_0 : 0 kg K_2O ha^{-1} K_1 : 120 kg K_2O ha^{-1}

K_2 : 130 kg K_2O ha^{-1} K_3 : 140 kg K_2O ha^{-1}

Different level of potassium showed significant differences in respect of yield per hectare in ton at 30, 45, 60 and 75 DAS (Figure 15). The maximum yield (15.82 t/ha) was recorded from K_3 which was closely followed (14.71 t/ha) by K_2 and the minimum (13.69 t/ha) was from control at 30 DAS. At 45 DAS the maximum yield (25.31 t/ha) was found from K_3 which was closely followed (22.37 t/ha) by K_2 treatment, while the minimum (20.85 t/ha) was from the control. The highest yield (36.59 t/ha) was recorded from K_3 similar (34.03 t/ha) with K_2 and the minimum (30.68 t/ha) from the control at 60 DAS. At 75 DAS the maximum yield (55.75 t/ha) was recorded from K_3 treatment which was statistically similar (55.42 t/ha) with K_2 and the minimum yield (40.29 t/ha) was obtained from control condition. Bhai and Singh (1998) reported that potassium application significantly increased yield.

The combined effect of nitrogen and potassium in terms of yield per hectare at different days after sowing was also significant. At 30 DAS the maximum yield (17.91 t/ha) was recorded from the treatment combination of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha), while the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha) gave the minimum yield (10.85 t/ha) (Table 9). At 45 DAS the maximum yield (28.80 t/ha) was observed from the treatment combination of N_3K_3 whereas the minimum (16.21 t/ha) was recorded from control. At 60 DAS the maximum yield (42.82 t/ha) was recorded from the treatment combination of N_3K_3 and the minimum yield (16.59 t/ha) was recorded from the control. The maximum yield (67.67 t/ha) was recorded in from the treatment combination of N_3K_3 and the minimum (27.19 t/ha) from the treatment N_0K_0 at 75 DAS. The results on leaves weight per plant are not similar to the findings of Talukder (1999) who recorded yield of 68.44 t/ha to 79.58 t/ha at 37 DAS and 78.45 t/ha to 97.12 t/ha at 44 DAS in three amaranth cultivars.

Table 9. Combined effect of nitrogen and potassium on yield (t/ha) of stem amaranth

Treatment	Yield (t/ha)			
	30 DAS	45 DAS	60 DAS	75 DAS
N_0K_0	10.85 e	16.21 e	16.59 i	27.19 e
N_0K_1	11.40 e	16.00 e	20.48 hi	32.16 e
N_0K_2	12.19 de	18.45 de	24.89 gh	33.13 e
N_0K_3	13.34 cde	22.18 bcd	29.65 efg	33.85 e
N_1K_0	13.29 cde	19.70 cde	29.01 fg	35.53 e
N_1K_1	12.81 cde	18.76 de	31.18 defg	51.20 cd
N_1K_2	14.43 bcd	21.94 bcd	33.36 cdef	56.80 bcd
N_1K_3	14.81 bc	22.69 bcd	34.84 bcdef	60.25 abc
N_2K_0	14.72 bc	22.65 bcd	41.10 ab	49.19 d
N_2K_1	16.06 ab	25.30 ab	36.57 abcde	62.88 ab
N_2K_2	15.93 ab	25.06 ab	37.15 abcd	64.09 ab
N_2K_3	17.44 a	28.01 a	39.89 abc	61.99 ab
N_3K_0	15.90 ab	24.85 abc	36.00 abcdef	49.25 d
N_3K_1	16.31 ab	25.64 ab	40.71 ab	59.36 abc
N_3K_2	17.70 a	28.38 a	42.01 ab	66.89 a
N_3K_3	17.91 a	28.80 a	42.82 a	67.67 a
$LSD_{(0.05)}$	2.215	4.698	6.275	8.410
Significance level	**	**	**	**
CV (%)	9.04	12.36	11.23	9.94

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

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

4.12 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. Prices of stem amaranth were considered at 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-

4.12.1 Gross return

In the combination of nitrogen and potassium showed different gross return under the trial (Table 10). The highest gross return (Tk. 786,096) was obtained from the treatment combination of N_3K_3 (110 kg N/ha + 140 kg K_2O/ha) and the second highest gross return (Tk. 774,995) was obtained in N_3K_2 (100 kg N/ha + 140 kg K_2O/ha). The lowest gross return (Tk. 354,243) was obtained from the control treatment i.e. N_0K_0 (0 kg N/ha + 0 kg K_2O/ha).

4.12.2 Net return

The highest net return (Tk. 590,731) was obtained from the treatment combination N_3K_3 and the second highest net return (Tk. 580,099) was obtained from the treatment combination N_3K_2. The lowest net return (Tk. 152,934) was obtained from the control treatment.

4.12.3 Benefit cost ratio

The combination of nitrogen and potassium for benefit cost ratio was different in all treatment combination (Table 10). The highest benefit (3.02) was found from the treatment combination N_3K_3 and the second highest benefit cost ratio (2.98) was estimated from the treatment combination N_3K_2. The lowest benefit cost ratio (0.76) was obtained from the control treatment i.e. N_0K_0 (Table 10). From economic point of view, it was apparent from the above results that the treatment combination N_3K_3 was more profitable than other treatment combinations.

Table 10. Cost and return of stem amaranth cultivation as influenced by nitrogen and potassium

Treatment Combination	Cost of production (Tk./ha)	Yield (t/ha)				Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
		30 DAS	45 DAS	60 DAS	75 DAS			
N_0K_0	189210	10.85	16.21	16.59	27.19	354243	152934	0.76
N_0K_1	194426	11.40	16.00	20.48	32.16	400248	205822	1.06
N_0K_2	194896	12.19	18.45	24.89	33.13	443352	248456	1.27
N_0K_3	195366	13.34	22.18	29.65	33.85	495156	299790	1.53
N_1K_0	189730	13.29	19.70	29.01	35.53	487705	297975	1.57
N_1K_1	194426	12.81	18.76	31.18	51.20	569820	375394	1.93
N_1K_2	194896	14.43	21.94	33.36	56.80	632729	437833	2.25
N_1K_3	195366	14.81	22.69	34.84	60.25	663033	467667	2.39
N_2K_0	189730	14.72	22.65	41.10	49.19	638372	448642	2.36
N_2K_1	194426	16.06	25.30	36.57	62.88	704138	509712	2.62
N_2K_2	194896	15.93	25.06	37.15	64.09	711239	516343	2.65
N_2K_3	195366	17.44	28.01	39.89	61.99	736740	541374	2.77
N_3K_0	189730	15.90	24.85	36.00	49.25	630074	440344	2.32
N_3K_1	194426	16.31	25.64	40.71	59.36	710185	515759	2.65
N_3K_2	194896	17.70	28.38	42.01	66.89	774995	580099	2.98
N_3K_3	195366	17.91	28.80	42.82	67.67	786096	590731	3.02

Market price of stem amaranth @ Tk. 5000/t

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

Chapter V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from March to June 2006 to study the effect of different levels of nitrogen and potassium on growth and yield of stem amaranth. The experiment considered two factors. Factor A: Levels of nitrogen (4 levels) i.e. 0 kg N/ha (Control), 90 kg N/ha, 100 kg N/ha, 110 kg N/ha; Factor B: Levels of potassium (4 levels) i.e. 0 kg K_2O/ha (Control), 120 kg K_2O/ha, 130 kg K_2O/ha, 140 kg K_2O/ha. There were on the whole 16 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the amaranth. Data were collected in respect of the plant growth characters and green yield of amaranth at different days after sowing. The data recorded from different characters were statistically analyzed to find out the significance of difference of different levels of nitrogen and potassium on yield and yield contributing characters of stem amaranth.

A significant variation was recorded from all the characters in relation different levels of nitrogen at 30, 45, 60 and 75 DAS. Treatment N_3 gave the longest plant (36.03 cm) at 30 DAS while the control treatment gave the shortest (28.00 cm). The longest plant (68.46 cm) was observed from treatment N_3 and the shortest (59.73 cm) was from the control treatment at 45 DAS. At 60 DAS the longest plant (90.88 cm) was recorded from the treatment N_3 and the shortest (81.37 cm) was from the control treatment. Treatment N_3 gave the longest plant (107.90 cm) at 75 DAS, while the control treatment gave the shortest (98.27 cm). Treatment N_3 gave the maximum stem diameter (15.15 mm) at 30 DAS while the control treatment (0 kg N/ha) gave the minimum (11.32 mm) at 30 DAS. The maximum stem diameter (19.47 mm) was found from treatment N_3 and the minimum (15.06 mm) was from the control treatment at 45 DAS. At 60 DAS the maximum stem diameter (24.27 mm) was recorded from the treatment N_3 and the minimum (19.63 mm) was recorded from the control treatment. Treatment N_3 gave the maximum stem diameter (26.81 mm) at 75 DAS, while the control treatment gave the minimum (22.04 mm). Treatment N_3 gave the highest yield (16.96 t/ha) at 30 DAS, while the control treatment gave the lowest (11.94 t/ha) at 30 DAS. The highest yield (26.91 t/ha) was obtained from treatment of N_3 and the lowest (18.21 t/ha) was from the control treatment at 45 DAS. At 60 DAS the highest yield (40.39 t/ha) was recorded from the treatment N_3 and the lowest (22.90 t/ha) was from the control treatment. Treatment N_3 gave the highest yield (60.79 t/ha) at 75 DAS, while the control treatment gave the lowest (31.58 t/ha).

Potassium showed significant variation in terms of all recorded characters at 30, 45, 60 and 75 DAS. The longest plant (34.05 cm) was recorded in from K_3 and the shortest (30.40 cm) was found from control at 30 DAS. At 45 DAS the longest plant (67.16 cm) was found from K_3, while the shortest (61.81 cm) was obtained from the control treatment. The longest plant (89.20 cm) was recorded from the treatment of K_3 and the shortest (84.07 cm) from the control at 60 DAS. At 75 DAS the longest plant (106.53 cm) was recorded from K_3 treatment and the shortest (100.83 cm) was found from control condition. The maximum stem diameter (13.99 mm) was recorded from K_3 and the minimum (12.87 mm) were obtained from control treatment at 30 DAS. At 45 DAS the maximum stem diameter (18.25 mm) was found from K_3, while the minimum (16.83 mm) was from the control. The maximum stem diameter (23.01 mm) was recorded from the treatment of K_3 and the minimum (21.61 mm) from the control at 60 DAS. At 75 DAS the maximum stem diameter (25.38 mm) was recorded from K_3 treatment and the minimum (23.89 mm) was found from control condition. The highest yield (15.82 t/ha) was recorded from treatment K_3 and the lowest (13.69 t/ha) was from control at 30 DAS. At 45 DAS the highest yield (25.31 t/ha) was found from K_3, while the lowest (20.85 t/ha) was found from the control. The highest yield (36.59 t/ha) was recorded from the treatment of K_3 and the lowest (30.68 t/ha) from the control at 60 DAS. At 75 DAS the highest yield (55.75 t/ha) was recorded from K_3 treatment and the lowest (40.29 t/ha) was obtained from control treatment.

Conclusion:

The maximum growth and yield was attained with the combination of N_3K_3 and the minimum was found from control condition i.e. N_0K_0. The highest gross return (Tk. 786,096) was obtained from the treatment combination N_3K_3 and the lowest gross return (Tk. 354,243) was obtained in control treatment. The highest net return (Tk. 590,731) was obtained from the treatment combination N_3K_3 and lowest (Tk. 152,934) was found from the control treatment. The highest benefit cost ratio (3.02) was recorded from the treatment combination N_3K_3 and the lowest (0.76) was obtained in the control.

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances;

2. Both nitrogen and potassium significant influenced on growth and yield of stem amaranth. So, for growing amaranth nitrogen and potassium must be included in the fertilization program for further study.

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APPENDICES

Appendix I. Mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Analytical data
Sand (%)	33.22
Silt (%)	60.45
Clay (%)	6.31
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.15
Organic carbon (%)	1.38
Total nitrogen (%)	0.08
Available P (ppm)	21.2
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 2006

Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
March 06	31.25	21.55	74.65	35
April 06	33.74	23.87	85.52	69
May 06	34.20	24.20	77.35	161
June 06	33.40	26.80	69.54	179

Source : Bangladesh Metrological Department (Climate Division), Agargoan, Dhaka-1212

Appendix III. Analysis of variance of the data on plant height and stem diameter of amaranth as influenced by nitrogen and potassium

Source of variation	Degrees of freedom	Mean square							
		Plant height (cm) at				Stem diameter (mm) at			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.871	10.338	6.457	4.327	0.489	0.452	1.334	1.598
Nitrogen (A)	3	159.208**	182.246**	217.101**	219.500**	41.526**	52.649**	57.854**	58.568**
Potassium (B)	3	30.500**	68.430**	60.372**	68.521**	3.106**	4.566**	4.230*	4.902**
Interaction (A×B)	9	0.321**	6.193**	8.865**	10.346**	0.705**	0.753**	1.032**	1.228**
Error	30	3.703	8.921	12.232	10.155	0.625	0.781	1.123	1.107

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix 1V. Analysis of variance of the data on leaf number and leaf length of amaranth as influenced by nitrogen and potassium

Source of variation	Degrees of freedom	Mean square							
		Number of leaves at				Length of leaves (cm) at			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.360	0.024	0.797	8.593	0.797	1.306	0.967	1.371
Nitrogen (A)	3	112.816**	115.705**	122.837**	142.368**	36.629**	30.559**	30.174**	33.514**
Potassium (B)	3	17.404**	12.837*	19.708**	39.225**	7.884**	6.099**	7.687**	9.103**
Interaction (A×B)	9	0.104*	1.005*	0.713*	0.601*	1.111**	0.885**	1.183*	1.397*
Error	30	2.342	3.620	3.754	5.221	1.223	1.175	1.195	1.232

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix V. Analysis of variance of the data on petiole length and petiole diameter of amaranth as influenced by nitrogen and potassium

Source of variation	Degrees of freedom	Mean square							
		Petiole length (cm) at				Petiole diameter (mm) at			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.150	0.009	0.074	0.044	0.009	0.002	0.006	0.003
Nitrogen (A)	3	4.832**	6.629**	7.584**	7.333**	0.210**	0.524**	0.146**	0.183**
Potassium (B)	3	1.113**	1.585**	1.810**	1.817**	0.041	0.446**	0.170**	0.167**
Interaction (A×B)	9	0.237**	0.142**	0.178**	0.155**	0.043**	0.057**	0.018**	0.014**
Error	30	0.207	0.192	0.188	0.175	0.033	0.037	0.032	0.036

** : Significant at 1% level of probability

Appendix VI. Analysis of variance of the data on fresh weight of stem and leaves of amaranth as influenced by nitrogen and potassium

Source of variation	Degrees of freedom	Mean square							
		Fresh weight of stem (g) at				Fresh weight of leaves (g) at			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	1.886	14.895	9.195	0.529	1.039	0.119	0.441	5.598
Nitrogen (A)	3	202.108**	327.349**	462.644**	542.099**	259.052**	327.891**	244.672**	288.274**
Potassium (B)	3	39.009**	101.736**	110.144**	149.506**	43.323**	31.337**	39.220**	75.743**
Interaction (A×B)	9	1.161*	14.280*	19.444*	26.021*	0.237*	2.977*	1.429*	0.593*
Error	30	8.061	19.556	21.243	24.907	3.253	7.308	8.316	13.616

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VII. Analysis of variance of the data on dry matter of stem and leaves of amaranth as influenced by nitrogen and potassium

Source of variation	Degrees of freedom	Mean square							
		Dry matter of stem (%) at				Dry matter of leaves (%) at			
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.046	0.364	0.390	0.060	0.033	0.043	0.031	0.023
Nitrogen (A)	3	3.423**	6.933**	7.574**	8.385**	5.047**	5.363**	3.537**	4.595**
Potassium (B)	3	0.534**	1.597**	1.797**	3.751**	0.835**	0.534**	0.531*	1.047**
Interaction (A×B)	9	0.031*	0.170*	0.383*	0.360*	0.006*	0.065*	0.019*	0.033*
Error	30	0.086	0.283	0.416	0.647	0.140	0.110	0.129	0.191

** : Significant at 1% level of probability; * : Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data on yield per hectare of amaranth as influenced by nitrogen and potassium

Source of variation	Degrees of freedom	Mean square			
		Yield (t/ha) at			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.135	7.329	0.091	14.846
Nitrogen (A)	3	60.889**	192.535**	754.037**	2181.877**
Potassium (B)	3	9.208**	41.839**	73.443**	626.453**
Interaction (A×B)	9	1.218*	6.266*	27.726*	41.339*
Error	30	1.765	7.936	14.159	25.437

** : Significant at 1% level of probability

Appendix IX. Production cost of stem amaranth per hectare

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Seed cost (Tk)	Irrigation Cost	Thinning cost	Pesticides	Manure and fertilizers				Miscellaneous cost	Sub Total (A)
							Cowdung	Urea	TSP	MP		
N_0K_0	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	0.00	3300.00	0.00	10000.00	83000.00
N_0K_1	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1200.00	3300.00	3000.00	10000.00	87200.00
N_0K_2	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1320.00	3300.00	3300.00	10000.00	87620.00
N_0K_3	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1440.00	3300.00	3600.00	10000.00	88040.00
N_1K_0	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	0.00	3300.00	0.00	10000.00	83000.00
N_1K_1	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1200.00	3300.00	3000.00	10000.00	87200.00
N_1K_2	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1320.00	3300.00	3300.00	10000.00	87620.00
N_1K_3	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1440.00	3300.00	3600.00	10000.00	88040.00
N_2K_0	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	0.00	3300.00	0.00	10000.00	83000.00
N_2K_1	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1200.00	3300.00	3000.00	10000.00	87200.00
N_2K_2	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1320.00	3300.00	3300.00	10000.00	87620.00
N_2K_3	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1440.00	3300.00	3600.00	10000.00	88040.00
N_3K_0	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	0.00	3300.00	0.00	10000.00	83000.00
N_3K_1	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1200.00	3300.00	3000.00	10000.00	87200.00
N_3K_2	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1320.00	3300.00	3300.00	10000.00	87620.00
N_3K_3	25000.00	6000.00	1200.00	3500.00	3000.00	1000.00	30000.00	1440.00	3300.00	3600.00	10000.00	88040.00

N_0 : 0 kg N ha^{-1}
N_1 : 90 kg N ha^{-1}
N_2 : 100 kg N ha^{-1}
N_3 : 110 kg N ha^{-1}

K_0 : 0 kg K_2O ha^{-1}
K_1 : 120 kg K_2O ha^{-1}
K_2 : 130 kg K_2O ha^{-1}
K_3 : 140 kg K_2O ha^{-1}

Labour @ Tk. 80/capita/day, Bullock @ Tk. 100/pair/day, Cowdung : 20 t @ Tk. 1500/t, Urea : @ Tk. 6/kg, TSP : 220 kg @ Tk. 15/kg and MP : @ Tk. 15/kg

Appendix IX. Contd.,

B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13% of value of land Tk. 8,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 12 months (Tk. 13% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
N_0K_0	91000	4150	11030	106210	189210
N_0K_1	91000	4360	11866	107226	194426
N_0K_2	91000	4381	11895	107276	194896
N_0K_3	91000	4402	11924	107326	195366
N_1K_0	91000	4150	11580	106730	189730
N_1K_1	91000	4360	11866	107226	194426
N_1K_2	91000	4381	11895	107276	194896
N_1K_3	91000	4402	11924	107326	195366
N_2K_0	91000	4150	11580	106730	189730
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