EFFECT OF NITROGEN AND PLANT GROWTH REGULATOR ON THE GROWTH AND YIELD OF RED AMARANTH (*Amaranthus tricolor* L.)

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CERTIFICATE

This is to certify that the thesis entitled, "Effect of Nitrogen and Plant Growth Regulator on The Growth and Yield of Red Amaranth (*Amaranthus tricolor* L.)" **submitted to Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in HORTICULTURE, embodies the result of a piece of bonafide research work carried out by KAMRUN NAHAR, Registration No. 25203/00329 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 has been availed during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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The Author

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ABSTRACT

An experiment was conducted in Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka to find out the effect of nitrogen and plant growth regulator on the growth and yield of red amaranth (*Amaranthus tricolor* L) during the period from November to December 2006. Four levels of nitrogen viz. N_0: 0 kg/ha, N_1: 69 kg/ha, N_2: 92 kg/ha, N_3: 115 kg/ha and different concentration of Indole-3-Acetic Acid (IAA) viz. I_0: 0 *ppm* IAA, I_1: 150 *ppm* IAA, I_2: 200 *ppm* IAA, I_3: 250 *ppm* IAA were used for this experiment. Plant height, stem diameter, leaf area, growth rate of stem diameter, growth rate of height, growth rate of weight and yield were increased as the levels of nitrogen were increased. Incase of different concentrations of Indole-3-Acetic Acid, plant height, stem diameter, leaf area, growth rate of stem diameter, growth rate of height, growth rate of weight and yield were increased up to I_2 level then the parameter mentioned above was decreased. The maximum plant height (46.33 cm), stem diameter (12.33 mm), growth rate of height (1.286 cm/day), growth rate of stem diameter (0.342 mm/day), growth rate of weight (0.716 g/day), leaf area (56.11cm^2) and yield (19.50 t/ha) were measured from N_3I_2 treatment at harvest. The maximum benefit cost ratio (BCR = 2.5) was recorded from N_3I_2 treatment and the minimum (1.86) was found from N_0I_0 treatment.

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LIST OF ABBREVIATIONS

AEZ	:	Agro-ecological zone
BCR	:	Benefit cost ratio
DAS	:	Days after sowing
DAG	:	Days after germination
GR	:	Gross return
TCP	:	Total cost of production
IAA	:	Indole - 3 - acetic acid
df	:	Degrees of freedom
FAO	:	Food and Agricultural Organization
LSD	:	Least significant difference
ppm	:	Parts per million
RCBD	:	Randomized completely block design
SAU	:	Sher-e-Bangla Agricultural University
viz	:	Namely
M.P.	:	Muriate of potash
T.S.P	:	Triple super phosphate

CHAPTER – I

INTRODUCTION

CHAPTER I
INTRODUCTION

Red amaranth (*Amaranthus tricolor* L.) belongs to the Amaranthaceae family and is commonly used as vegetable in Bangladesh. It is a quick growing vegetable and grown all year round. The role of amaranth as an under exploited plant with promising economic value has recently been recognized by the National Academy of Sciences (NAS, 1984). Amaranth is one of those rare plants whose leaves are eaten as a vegetable while the seeds are used as cereals (Oke, 1983; Saunders and Becker, 1983; Kauffman and Haas, 1983). The main vegetable type of amaranth, *Amaranthus tricolor,* seems to have originated in South or Southeast Asia (Grubben and van Sloten, 1981) and then spread through the tropics and the temperate zone (Martin and Telek, 1979). Amaranth leaves contain 17.4-38.3 % dry matter as crude protein, averaging 5% lysine and thus having potential as a protein supplement (Oliveira and Carvalho, 1975).

Nitrogen is essential for producing protoplasm and other different compound such as chlorophyll, phosphide, alkali, enzyme, hormone, vitamins, nucleoprotein, RNA, DNA, etc. It is important for metabolic activities. Nitrogen enhances the shoot growth and larger size succulent and attractive leaf which are most desirable for leafy vegetables. Cation exchange capacity of root and other plant nutrient eg. Ca, K, P, etc absorption are increased through the application of nitrogen (Ikbal *et al*; 1992). Indole-3-Acetic Acid (IAA) helps stem growth, leaf growth, root initiation etc. (Mondal, 2000.)

From the published reports it is known that the indole-3-acetic acid (IAA) has an important role on the growth and yield of tomato, brinjal etc, but there is no published report in respect of the effects of Indole-3-Acetic Acid on the growth and yield of red amaranth. On the other hand, few research work had been conducted to find out the effects of nitrogen on the growth and yield of red amaranth in different parts of the world including Bangladesh. The present study on the effect of different levels of nitrogen and Indole-3-Acetic Acid on the growth and yield of red amaranth has been undertaken with the following objectives:

1. To identify the best level of nitrogen for red amaranth production.
2. To identify the best concentration of Indole-3-Acetic Acid (IAA) for red amaranth production.
3. To study the interaction effects of different levels of nitrogen and Indole-3-Acetic Acid (IAA) for production of red amaranth.

CHAPTER – II

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Red amaranth (*Amaranthus tricolor* L.) is a commonly used vegetable in Bangladesh. The amount of published reports shows that the red amaranth always received little attention of the researchers. There is no research work done combinedly on nitrogen and Indole -3- Acetic Acid (IAA) to evaluate their effects on the growth and yield of red amaranth. Some research works had been conducted on red amaranth in respect of nitrogen in different parts of the world inclouding Bangladesh. The available literatures which are most relevant to the present study have been reviewed here under different headings.

2.1. Yield performance

Amaranth collection showed variation in the growth parameters and productivity assessed by Jha *et al.* (1991). Plants of the same land race exhibited variation in their height, inflorescence length, color and yield. Amaranth attained a height of 0.50 to 2.50 m and their inflorescence length ranged from 12 to 41 cm. The maturity period of different collection varied form 120 to 150 days and the average yield of amaranth grain under natural condition ranged from 380 to 1480 kg/ha. The crop production ability (CPA) appeared to be 4 to 5 times higher than the average yield.

Hamid *et al.* (1989) reported that significant variation was present among 12 (Twelve) amaranth lines (4 exotic and 8 local) for plant height, number of leaves, stem girth and yield. Height and stem girth were positively correlated with yield. In general, the exotic lines were tall and produced higher yields than the local lines but were inferior in taste and cooking quality. The exotic germplasm AM 0008 was the highest yielding, producing 234.40 t/ha. Three local germplasms and three exotic germplasms were found to be promising in respect of yield potential. Among the local germplasms highest yield produced was 122.40 t/ha and lowest yield was 42.80 t/ha.

Olufolaji and Tayo (1989) reported that two determinate early flowering and two indeterminate (late flowering) varieties were grown in two field trials at the National Horticulture Research Institute in Nigeria under two harvesting methods. Pruning was superior to uprooting with respect to total number of leaves and branches developed than actual fresh weight yield, and the dry weight of the various plant parts. The later-flowering, indeterminate varieties performed better (by 57%) than the other varieties. Consequently, the pruned indeterminate varieties developed the highest green vegetative yield and the uprooted determinate varieties developed the least. It is suggested that planting the indeterminate, late flowering varieties at the start of the rains and continuously cutting back is a more profitable method of harvesting than uprooting at the optimum commercial stage.

He also reported the effects of seeding rate on the performance of direct drilled amaranth. Two field trials were conducted to determine the optimum sowing rate of *A. cruentus* required for a vegetative yield of about 20 t/ha. The plants were rainfed in the first trial and irrigated in the second. Sowing rates of 2, 4, 6 and 8 kg/ha were tested in the first trial with additional rates of 10 and 12 kg/ha being tested in the second trial. Seedling establishment, plant height, leaf area index, total plant yield and edible shoot yield were measured. The highest total and edible shoot yields (18.57 and 2.47 t/ha. respectively) were obtained in the irrigated trial at a sowing rate of 6 kg/ha.

Olufolaji and Dinakin (1988) observed that the highest vegetable yield was produced from black seeded cultivars and the highest seed yield was produced from the white seeded cultivars.

Mohideen *et al.* (1985) conducted an experiment for an evaluation program on amaranth under all Indian coordinated vegetable improvement project at the Tamil Nadu Agriculture University. A promising clipping type (A.83) was released as Co.3 amaranth over local type after testing for five seasons. The yield performance of this strain recorded a mean yield of 30,716 kg/ ha as compared to 19,431 kg/ha of the local type.

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

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

Amaranthus spp. both cultivated and uncultivated are widely distributed in Asia, Africa, Europe and America. Amaranth grown as a vegetable can produce up to 40 t fresh matter/ha in 3-5 weeks. Grain amaranth types mature in 4-5 months and yield 0.90 to 1.50 t/ha. Seed protein and lysine content is higher than in cereals (Saunders and Becker, 1983).

Yield of grain and other characteristics of eight grain amaranth were assessed by Mohideen *et al.* (1983). The types A. 144, A. 145, local I and local 2 were comparatively longer in duration with a tall growth habit and with a few or no branches. The Types A. 53, A. 90 and A. 147 were comparatively shorter in duration with dwarf stature and high branching characters. Despite certain unfavorable traits, types A. 144, A. 145 and local 1 could be chosen by virtue of their high yields in areas less prone too heavy winds and also avoiding synchronization of rainfall with seed maturity.

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

According to Prasad *et al.* (1980) correlation coefficients at phenotypic level showed that the yield has increased with an increase in leaf length and the leaf width. The leaf length has also increased with an increase in leaf width. As the leaf number increases, the yield, leaf length and leaf width decreases. Thus it is interpreted that leaf size has a positive association with yield. Hence more emphasis should be given during selection to the size of leaf than to the number of leaves which is negatively correlated with yield.

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

The culture of *Amaranthus* spp. is outlined. The cultivar such as Co.l is grown only for greens which have been reported to yield up to 16000 kg greens/ha and dual purpose types produce 12000 kg greens and 1000 kg grains/ha (Mathai, 1978).

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

Correlation co-efficient was calculated between amaranth yield and seven leaf and stem characters, and between different character combinations. All relationships were significant except that between petiole length and leaf weight (Mohideen and Subramanian, 1974).

Intensive selection work envisaged at vegetable section, Agriculture College and Research Institute, Coimbatore has resulted in the release of a new strain Co.l amaranth suited to Tamil Nadu. The average yield of this new strain is 18.70t/ha greens which is 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 Thandukeerai (Kamala Nathan *et al.,* 1973).

A study was done by Mohideen and Rajagopal (1974) on harvesting method, and suggested on the response on two species of amaranth to clipping. The species *A. tristis* L. (Arakeerai) and *A. blitum* L. (Sirukeerai) where clipped at certain intervals. Arakeerai yielded 11736 kg/ha as compared to Sirukeerai which yielded 8680 kg/ha (35.20 % increase).

They conducted a field trial was with two varieties of amaranth, viz. A. 62 and Co.l (with short and medium duration respectively) to study the effect of transplanting over direct sowing. The result of the study showed that A.62 recorded significantly higher yield in direct sown plot (1750 kg/ha) as compared to transplanted plot (1240 kg/ha, percent increase being 41.50). Co. 1 recorded significantly higher yield (717 kg/ha) in the transplanted crop as against 447 kg/ha in direct sown crop (with 59.70 % increase).

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

2.2. Qualitative performance

Edible portion of leaves and tender stems of amaranth per 100 g fresh weight had moisture 85.70%, protein 4.00%, carbohydrate 6.30 g, mineral matter 2.70 g, fat 0,50 g, fibre 1 g, calcium 397 mg, iron 25.50 mg, phosphorus 83 mg, magnesium 247 mg, vitamin A 92001.U. and vitamin C 99 mg (Aykroyd, 1963).

According to FAO (1972) amaranth contains 5.20 g protein, 0.80 g fat. 341 mg calcium, 76 mg phosphorus, 4.10 mg iron, 0.37 mg riboflavin, 7715 /Ag β- carotene, 1.80 mg niacin, 51 mg sodium, 120 mg ascorbic acid and about 43 calories food energy in 100 g edible portion.

Subbiah *et al.* (1983) studied the influence of stages of harvest on crude protein, carotene, ascorbic acid and chlorophyll contents of amaranth. The leaves were sampled at 27, 36 and 41 days after sowing (DAS). Crude protein (19.30%) and ascorbic acid (162.60 mg/100 g) were highest at 27 DAS, and carotene (11.50 mg/100 g) and chlorophyll (1.17 mg/g) at 36 and 41 DAS respectively.

According to Makus (1984) eight accessions of *Amaranthus tricolor* L. produced between 10.00 to 18.40 t/ha of plant biomass. Average leaf blade elemental levels were 3.84% potash, 3.47% calcium, 0.77% magnesium, 0.44% phosphorus, 0.46% sulphur, 593 *ppm* iron, 562 *ppm* aluminum, 458 *ppm* sodium, 282 *ppm* manganese, 79 *ppm* zinc and 65 *ppm* copper. Four accessions were judged by a taste panel to compare with spinach for organoleptic quality.

Biochemical analysis of Co. 3 amaranth showed that it contained 35.90 mg of ascorbic acid, 11.04 mg of carotene in 100 g of fresh matter. On dry weight basis it contained 12.50%, 17.40% crude fiber, 0.47% phosphors, 3.20% potassium, 0.84% iron, 2.48% calcium and 1.35% magnesium (Mohideen *et al.,* 1985)

Sealy *et al*., (1988) reported that *Amaranthus dubius* L. cv. ibondwe, *A. hybridus* cultivars Quilete and vlete and *A. tricolor* cultivars Red and Tampala were grown in central Texas and harvested 5 weeks after sowing. Leaves were assayed for β-carotene and oxalate content and cooked leaves were evaluated by a taste panel. Leaf yields were highest in vieta (24 t/ha), but Ibondwe proved superior for pythium resistance and β-carotene content (15.40 mg/g fresh weight). It also scored higher than vlete by the taste panel (6.00 vs 4.50) but not as high as red (6.40) and Tampala (6.60) or spinach (6.90). Oxalate content was lowest in quelite (10.20 Ag/g) and moderate in Ibondwe (16.50 /ig). Ibondwe was recommended for summer production for fresh greens in the deep south of the U.S.A.

According to George *et al.,* (1989) on the source and variability for various nutritive aspect in amaranth *(Amaranthus* spp.) thirty germplasm lines belonging to three species viz. *A. tricolor* L., *A. dubius* L. and *A. emeritus* L. were included in the trial. These, 20 were green, 6 green-red and 4 red pigmented. 'Acc 14' *A. cruentus* L. had the highest dry matter (17.17%), followed by 'Acc *65' A. tricolor L.* (16.92%). Red cultivars 'Ace 59' had the highest crude protein (29.13 *%).* Out of 30 entries, 16 had 15.12 - 16.99 % crude protein. These 16 included all red types except 'Acc 59', 2 green-red and *A. dubius L.* entries. The β-carotene was 14.38-36.13 mg/100 g dry matter. The red and green red types showed the highest range of β-carotene. Among the green entries, Co. 2 had the highest oxalate (4.94%). The lowest oxalate was recorded in 'Co. l', (3.04%). All the red and green-red types with high protein and B-carotene also had high oxalate.

2.3. Organoleptic test

Searching of literature on organoleptic test of amaranth, only a few have been found *A. tricolor* L. was a high yielding and delicious strain. The yield of edible green matter and the leaves were succulent and tasty as was evident from the scoring of organoleptic tests done by Kamala Nathan *et al.,* 1973. They evaluated the appearance, succulence, cooking quality, fiber content and flavor.

According to Hamid *et al.,* (1989) organoleptic test of amaranth have been done by a panel of judges on taste and cooking quality of some local and exotic germplasms. The performance of taste and cooking quality of local germplasm were better than exotic germplasm.

Abbott *et al.,* (1982) studied the sensory evaluation of 20 steamed vegetables: amaranth *(Amaranthus* spp.) on appearance, flavor, texture, and overall eating quality. They rated on hedonic scales by consumers sensory panels. Several entries *of A. tricolor* had nonsignificantly lower scores than spinach *(Spinacia oleracea* L.). Of the *A. tricolor* entries "Chin" was the best overall and "Tampala" (most readily available entry in the U.S.) was intermediate. *A. dubius* was intermediate and *A. cruentus* entries were least acceptable.

Villareal *et al.,* (1979) studied the steamed roots of promising breeding lines and cultivars of sweet potato for evaluating flavor, dryness, stickiness, color and general acceptability and to determine the selection criteria that influence general acceptability. The acceptability ranking of roots varied according to the nationality of the panel members. Based on the result of step wise multiple regression analysis, it appeared that flavor and color would be good eating quality for predicting general acceptability of steamed sweet potato roots. Alcohol insoluble solids and total soluble solids after steaming contributed 85 % to the variation of dryness in sweet potato roots.

It was observed that the red-skinned, white-fleshed, fusiform or elliptical shaped and medium sized cultivars of sweet potato was placed in the list of acceptability score (Hossain and Siddque, 1982).

Khan (1993) reported that the white skinned color, long length and diameter of the pod for shape and size, tasty, flavourness and fibrousness of yardlong bean were considered for judging the highest acceptability score.

2.4 Amaranth and fertilizers

Two year field experiment with N rates of 0, 80 and 120 kg N/ha for amaranth arid quinoa and 0, 30 and 60 kg N/ha for buckwheat and two cultivars of each species arid ranged between 1986 and 27 kg/ha. Nitrogen utilization efficiency (NUE) ranged from 13.9 to 15.4 kg grain yield per kg above ground plant N and decreased with increasing N rate. Higher grain yields and nitrogen utilization efficiency seemed to be mainly inhibited by the low harvest index (0.2223). of the investigated amaranth cultivars. Quinoa yielded between 1790 and 3495 kg grain/h and responded strongly to N fertilization. Nitrogen utilization efficiency averaged 22.2 kg/kg and did not decrease with increasing N rates. The grain yield of buckwheat did not respond to N fertilization arid averaged 1425 kg/ha. N uptake increased only slightly with N fertilization.

Nitrogen utilization efficiency ranged from 16.1 to 20. kg/kg. Main problems occurring with the application of N to buckwheat were grain shattering and lodging (Kaul *et al.* 2005)

Rathore *et al.* (2004) reported that they worked on grain amaranth cultivars GA - 1, Suvarna and Annapurna which were supplied with 0, 30, 60 and 90 kg N/ha in a field experiment conducted in Rajshasthan, India during the winter seasons of 1997-98 and 1998-99 to identify cultivars suitable for cultivation in the region. GA-1 gave significantly higher seed yield, better growth and higher values for yield components over Suvarna and Annapurna. Seed yield increased with increasing rates of N up to 60 kg/ha. Application of N enhanced the growth and yield attributes significantly, whereas harvest index remained unaffected. The optimum and maximum rates of N estimated through quadratic response were 83 and 87 kg N/ha respectively. GA-1 gave the highest gross income (Rs. 24675/ha).

Diaz-ortega *et al.* (2004) studied the amaranth (*Amaranthus hypochondriacs*), which is considered an alternative source of vegetable protein is grown particularly under rainfed conditions. Therefore, it is important to look for better management practices that lead to a more efficient use of resources, such' as water and essential nutrients, to obtain higher yields. The aim of this work was to determine the influence of nitrogen and plant density on the phenology, nitrogen and water use efficiency, biomass production, and seed yield of amaranth planted on-11 June 1999, with 0, 10, and 20 g N/m^2 and 12.5, 25.0. and 33.3 plants/m^2. with the application of N and with a higher plant density (PD), N and water use efficiency were greater, and in consequence, biomass production and yield increased as well these increments were higher with higher N level and higher PD. With 20g N/m^2 and 33.3 plants/m^2 the biomass production of 2827 g/m^2 and seed yield of 346 g/m^2 were obtained. Phenology was not affected by the treatments. The requirement, of soil heat units to physiological maturity was 1629 UC and 385 mm of water used in evapotranspiration.

Franklin (2003) reported that theories and mathematical models were derived to analyse arid plant and forest response to soil nitrogen (N) availability and atmospheric CO_2 concentration. Soil carbon accumulation in response to long-term fertilization was studied measured soil C and 14C of the organic layer in a pine forest in Northern Sweden. Fertilization increased forest growth and drastically reduced long-term decomposition through effects on the decomposers. In 100 years, twice as much carbon would be accumulated in the forest soil where N addition is high as there no N addition occurs. Root: shoot allocation of small plants was modeled using maximization of relative growth rate, with and without explicit inclusion of N based maintenance respiration. The results agreed qualitatively with experimental data from birch and tomato plants and the agreement was considerably improved by the inclusion of maintenance respiration. Senescence and resumption as mechanisms of maximizing photosynthetic production were used to .predict LAI and resumption efficiency in relation to canopy N. This theory explained the observed LAI for four investigated plant species: red amaranth ' (*Amaranthus cruentus*), soybean (*Glycine max*), rice (*Oryza saliva*), and sorghum (*Sorghum bicolor*). Analytical expressions for forest photosynthesis; NPP, growth, LAI, root: leaf. allocation and leaf N concentration were derived using a principle of maximal growth and optimization of canopy N. Whole forest responses to N availability and atmospheric €62 were predicted from basic physiological parameters. The results agreed well with results of elevated CO_2 FACE experiments for sweet gum and loblolly pine trees. Finally, the findings of reduced decomposition and increased growth in response to fertilization and elevated CO_2 were evaluated in the context of the global carbon balance. A simple model of the responses of' global carbon fluxes and pool 'turnover rates combined with a future scenario of CO_2 emissions was subjected to a strong fertilizations effect on the boreal forest components. The results indicate that massive fertilization could temporarily halt the rising of the atmospheric CO_2.

Parthiban *et al.* (2001) reported that the effect of integrated use of nitrogen (at 0, 50, 100, 150 and 200 kg/ ha), farmyard manure (FYM) at 20 ton/ha and biofertilizers (*Azospirillum* and *Azotobacter*, each at 2 kg/ha), on the growth and yield of globe amaranth (*G. globosa*) was investigated in field' experiments conducted at Horticultural College and Research Institute, Periyakularti, Tamil Nadu, India during 1995-96. Twenty treatment combinations were imposed for each type of globe amaranth (pink and white). A maximum number of flowers of 292.56 in pink, 282.05 in white during kharif and 334.71 in pink and 308.35 in white type during summer were recorded in FYM + *Azospirillum* at 200 kg N/ha. The highest flower yield of 17736 kg/ha in pink, 17132 kg/ha in white during kharif and 20287 kg/ha in pink and 18958 kg/ha in white during summer were also recorded in FYM + *Azospirillum* at 200 kg N/ha. However, the 200 and 150 kg levels of N/ha were statistically at per with each other for flower yield.

Barrales (2000) reported that because of its high nutritional value and its ability to adapt over a wide range of environments, amaranth is an alternative for Mexican agricultural production. This work was done in

Huazulco, Morelos, Mexico, in 1998, under rainfed conditions to evaluate the effect of nitrogen and phosphorus fertilization in grain production of amaranth var. Revancha. Levels of nitrogen tested were 0, 40, 80, and 120 kg/ha, and those of phosphorus were 0, 40, and 80 kg/ha. The combination of factors resulted in 12 treatments, analyzed in a randomized complete block design with three replications. It was found that the quantity of water was the environmental factor that most influenced the low output. During the growing season rainfall was 664.8 nm, of which 11.29% fell during the stage of emergence, and it was observed that seeds were washed out. During grain filling stage, 57.6% of the rain fell, which was excessive and caused the inflorescences to rot. From an economic perspective, the treatment that resulted in the best grain yield was 120-00, although it is recommended that phosphorus be applied, so that the treatment that promoted the highest agronomical yields was 120 - 80.

Akanbi *et al.* (2000) reported the effect of compost (maize stove's) and nitrogen (N) fertilizer on the growth, shoot yield and nutrient uptake of amaranth (*Amaranths cruentus* L. var. $NHAC_3$) was studied over a period of two years. Twelve treatments derived from a factorial combination of four levels of compost (0, 1.5, 3.0 and 4.5t/ha) and 3 levels of fertilizer (0, 30 and 60 Kg N/ha) were carried out on a sandy loam soil. The experiment was arranged in a randomized complete block design with three replications. The application of compost and N fertilizer enhanced plant growth with respect to the controls. Plant height, stem girth, number of leaves and 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 fertilizer. The highest plant height (46.0 cm) and leaf area/plant (1548 cm^2) were obtained with combined application of 30 Kg

N and 3.0 t/ha compost respectively. The cumulative fresh shoot yield increased with increase in compost rate up to 3.0 t/ha and there after decreased. Amaranth growth and shoot yield results indicated that this crop reacts strongly and positively to application of compost but less strongly and inconsistently to the .treatment levels N fertilizer. Nevertheless, as a result of compost application, the results indicated a decrease in the optimal levels of N fertilizer application. The treatments also have positive significant effect on N, P and K uptake. The highest N and P .uptake were, produced with combined application of 30 Kg N and 4.5 t/ha compost. However, there were no significant difference between N uptake obtained at this rate and that of 30 kg N and 3.0 t/ha compost treatment. Therefore, 30 Kg N/ha combined with 3.0 t/ha compost appeared to be the best for optimum growth, shoot yield and nutrient uptake of 4 amaranth.

The effect of different N fertilizer rates (0, 50, 100, 150, 200, 250, 300, 350 and 400 kg/ha) on the protein content and starch characters of amaranth *(Amaranthus spp.)* seeds was investigated during 1996 and 1997 in Chilean, Chile. Protein content varied between 16.5% in the control treatment (no N applied), and 18.4% in the 200 kg N/ha treatment. A linear regression was obtained as a response to N application. Protein yield per hectare varied between 457.2 *kg/ha* in the control and 973.4 kg/ha in the 300 kg N/ha treatment. A quadratic regression was obtained as a response to N application. The evaluated starch characters were not significantly affected by N fertilizer rate (Wilckens *et al.* 2000).

A field experiment was conducted on *Amaranthus tricolor* (cv. Lal sak) during the winter, summer and rainy seasons of 1996 - 97, testing 4 levels of N (0, 40, 80 and 120 kg N/ha) in Kalyani, India. Sowing during winter/rabi was best in terms of seed yield, followed by sowing during pre kharif/summer and kharif/rains. Yield components and seed yield increased with' increasing N, up to 120 kg/ha. The highest seed yield of 0.45 t/ha was obtained in rabi/November sown crops with 120 kg N/ha (Das and Ghosh 1999).

Delchev (1999) reported that *Amaranthus cruelties* was grown as a catch crop in irrigated conditions on odorized soil in 1986-88 at Pazardzhik, Bulgaria at row spacing of 12.5 or 25.0 cm and given 0, 70, 140, 210 or 280 kg N/ha. Optimum production conditions of 210 kg N and narrow row spacing gave 50.97 t fresh weight, 8.4 t dry weight and 96.6 kg crude protein/ha.

Moudry *et al.* (1999) conducted in small-plot multifactorial trials at Ceske Budejovice, Czech Republic in 1997-99; eight genotypes of *Amaranthus* (including *A. hybridus, A. hypochdndriacus* and *A. cruentus)* were compared on acid pseudogley soil. Each genotype was sown at weekly intervals at 24 or 36 plants/ha and given 0 or 50 kg N fertilizer/ha. Some treatments had to be eliminated because of Fusarium infection. Average seed yields of all genotypes were generally increased by N application but not in each particular growing season. Seed yields were higher at the higher plant density except in 1998. Sowing in May was considered best. Average seed yields ranged from 1.31 to 2.46 t/ha with N application without significant differences between the genotypes. Myers (1998) studied the effect of N fertilizer on amaranth (*Amaranthus spp.*) grain yield, yield components, and growth and development in three Missouri environments with five levels of N fertilizer (NH_4NO_3) broadcast presowing at 0, 45, 90, 135 or 180 kg N/ha) and three cultivars

(Plainsman, D 136, and K 266). Averaged across cultivars and environments, N fertilizer at the top rate of 180 kg N/ha produced a yield increase of 42% relative to plots receiving no N fertilizer. Yields were consistently improved by additions of 45 and 90 kg N/ha, but additional N fertilizer above 90 kg N/ha rate increased yield in only one out of three environments. At one site where yield components were evaluated, yield differences were due to increase in seed number per plant, since seed weight and plant population at maturity were unaffected by N fertilizer rate. Plots with high rates of N fertilizer had later maturity, as indicated by time of flowering and seed moisture. Average moisture of seeds harvested from plots receiving 180 kg N/ha was 320 g/kg, while seeds from plots with no N fertilizer had 240 g/kg moisture. Comparing the same high-N treatment to the control with no N showed height increases of 14, 24, and 44%' in the three environments. Although amaranth yield is responsive to N application, high rates of N fertilizer can negatively affect grain harvest in terms of excessive plant height, increased lodging, and delayed crop maturity.

Jhon (1992) reported that seedlings of *Gomphrena globosa*, grown for cut flowers, were planted on 6 June in silty loam soil with a pH of 6.8, 26.79 kg available P_2O_5/ha, 316.80 kg available K_2O/ha and 1.08% organic C. The effects of 3 spacing (20 X 30, 20 X 45 and 20 X 60 cm), 3 rates of N (0, 100 and 200 kg/ha) and pinching vs. non-pinching were compared. A base dressing of 25 t manure, 100 kg P_2O_5 and 100 kg K_2O/ha and half the N dose were applied before planting. The remaining N was top-dressed. Plant width, number of branches/plant and number and weight of flowers/plant increased significantly with wider spacing and increasing N rate. However, the total flower yield/unit area was greatest with a spacing of 20 X 30 cm. The number and weight of flowers were significantly greater in pinched than in non pinched plants. Plant height was not significantly influenced by any of the treatments.

Subhan (1989) reported than N at 0, 30, 70 and 110 kg/ha was applied to a tricolor as a single application at sowing, or as a split application at sowing and 10 days after sowing Leaf number and stem diameter were not affected by N application. Plant height, leaf area increased with increasing N application while root length was reduced by high N application. The highest yields were obtained with a split application of 110 Kg N/ha.

CHAPTER – III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

An experiment was conducted to find out the effects of different levels of nitrogen and growth regulator (IAA) on the growth and yield of red amaranth at the Horticultural Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from November to December 2006. The materials and methods of the research programme is furnished in different sub heading as noted below:

3.1. Climate

The climate of the experimental site is under subtropical region. The experimental period was from November to December 2006 characterized by plenty of sunshine and scarce rainfall. The average maximum and minimum temperatures was 29.30^0c and 15.97^0c respectively during the experimental period. The maximum and minimum temperatures, humidity, rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate division) (Appendix I).

3.2. Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988). The analytical data of the soil sample collected from the experimental area were determined in soil testing laboratory, SRDI, Khamarabari, Dhaka and presented in Appendix II. The experimental site was medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plot as according to

FAO (1988) is shown below:

AEZ No. - 28

Soil Series- Tejgaon

General Soil: - Non calcareous dark grey.

3.3. Plant Materials

The seed of red amaranth under the study was collected from Kustia Seed Store, Mirpur, Dhaka. The collected seed was BARI variety Lalshak-1 (Altapeti).

3.4. Plant growth regulator

Indole-3-Acetic Acid used as plant growth regulator for the experiment.

3.5. Treatments of the experiment

Two factors of the experiment were: (A) four different levels of nitrogen and (B) four different concentrations of plant growth regulator (IAA) including control treatment:

Factor A: Levels of nitrogen -

No: 0 kg nitrogen/ha ≈ 0 kg/ha urea.

N_1: 69 kg nitrogen/ha ≈ 150 kg/ha urea.

N_2: 92 kg nitrogen/ha ≈ 200 kg/ha urea.

N_3: 115 kg nitrogen/ha ≈ 250 kg/ha urea.

The total amount of nitrogen applied in the experimental plots was through urea fertilizers.

Factor B. Concentrations of Indole-3-Acetic Acid (IAA) -

I_0: 0 *ppm* IAA

I_1:150 *ppm* IAA

I_2: 200 *ppm* IAA

I_3: 250 *ppm* IAA

Source of IAA: Prepared solution of active ingredient of Indole -3 Acetic Acid

The growth regulator (IAA) is a hetero auxin, commonly used as a growth hormone. The chemical name of IAA is Indole -3- Acetic Acid. Its chemical formula is $C_{10}H_9NO_2$. Mol. Wt. 175.18; C 68.56%, H 5.18%, N 8.00%, O 18.27%, indole 66.86%, acetic acid 34.28%. It is crystal powder, insoluble in water or chloroform; freely soluble in alcohol, acetone and ether.

There were altogether 16 treatment combinations such as N_0I_0, N_0I_1, N_0I_2, N_0I_3, N_1I_0, N_1I_1, N_1I_2, N_1I_3, N_2I_0, N_2I_1, N_2I_2, N_2I_3, N_3I_0, N_3I_1, N_3I_2, N_3I_3.

3.6. Experimental design and layout

Forty-eight treatments (4x4x3) were accommodated followed by randomized complete block design with three replications. Four doses of nitrogen and Iindole-3-Acetic Acid (IAA) (including control) were assigned in the plots. The experimental area was divided into 3 (three) replications and the doses of nitrogen and Indole-3-Acetic Acid (IAA) were randomly assigned. The area of the experimental land was 20.5m x 9.5m. The size of each plot was 2m x 1m and the distance between two blocks and two plots was kept 0.5 m. A layout of the experiment has been shown in Fig. 1.

3.7. Land preparation

The selected land was opened on 15th November 2006 with the help of a power tiller and then it was kept open to sun for 7 (seven) days prior to further ploughing. Afterwards it was prepared by ploughing and cross ploughing followed by laddering.

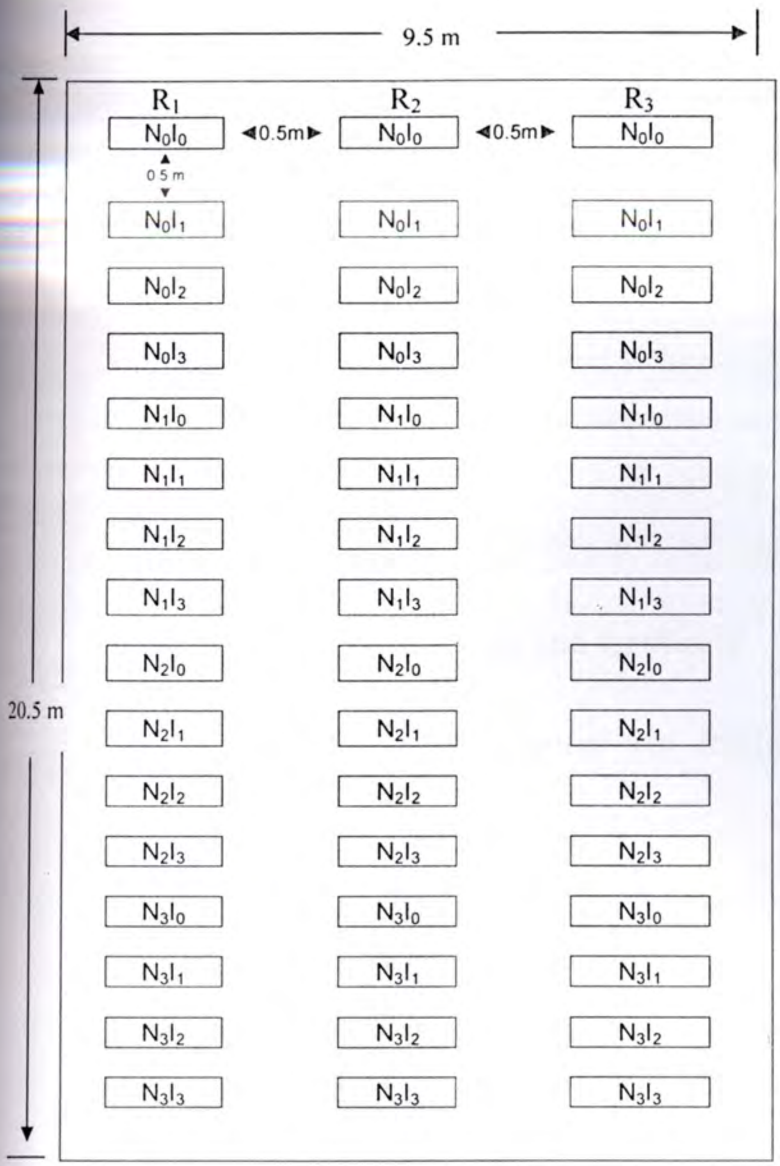
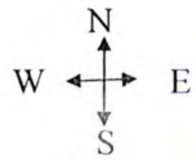


Fig. 1. Field layout of the two factors experiment in the Randomized Complete Block Design (RCBD).



Plot size: 2 m × 1 m

Space between two plots or blocks: 0.5m

Land size: $20.5 \times 9.5 m^2$

Height of the each plot: 15 cm

Different levels of nitrogen:

N_0: 0 kg/ha nitrogen

N_1: 69 kg/ha nitrogen

N_2: 92 kg/ha nitrogen

N_3: 115kg/ha nitrogen

Different levels of IAA:

I_0: 0 *ppm* IAA

I_1: 150 *ppm* IAA

I_2: 200 *ppm* IAA

I_3: 250 *ppm* IAA

Seed rate: 2.5 kg/ha

Seed/plot: 0.5 g

Required seed: 24 g

The weed and stubbles were removed from the plots after each laddering. Simultaneously the clods were broken and the soil was made in to good tilth. Finally, the plots were raised up to 15 cm from the ground level.

3.8. Seed sowing and germination

The seeds of red amaranth (*Amaranthus tricolor* L.) were mixed with sandy soil just to increase the volume then it was sown in well prepared experimental plot. The date of seed sowing was 24 November 2006. Seeds were germinated 3 to 4 days after sowing.

3.9. Application of manures and fertilizers

The following doses of manures and fertilizers were applied to the experimental plot except urea.

Manure and fertilizer	Doses
Cow dung	10 t/ha
Muriate of potash (MP)	200 kg/ha
Triple super phosphate (TSP)	100 kg/ha

The entire quantity of above mentioned cow dung muriate of potash and triple super phosphate were applied during final land preparation. The total amount of urea was applied as top dressing in three equal installments at 15, 20 and 25 days after sowing.

3.10. Preparation of Indole-3-Acetic Acid (IAA)

Firstly, 150, 200 and 250 mg IAA crystal was weighed by an electric balance, then it was dissolved separately in small quantity of absolute alcohol (95%) and then the volume was raised up to 1000 ml with distilled water. The prepared volume of the solution by 150, 200, 250 mg IAA crystal is treated as 150, 200 and 250 *ppm* solution of IAA respectively.

3.11. Application of Indole-3-Acetic Acid (IAA)

Freshly prepared aqueous solution of Indole-3-Acetic Acid (IAA) was sprayed three times on the leaves of the plants. First spraying was done 15 days after sowing, second and third spraying were done at 20 and 25 days after sowing respectively. Control plots were sprayed only with tap water.

3.12. Intercultural operations

3.12.1. Thinning

Thinning operation of the red amaranth plots were done by hand.

3.12.2. Irrigation

Light irrigation was given for better germination of the seeds and the plants were irrigated by watering cane as and when necessary.

3.12.3. Pest and disease control

No major disease was observed and commercial pesticide (Savin) was sprayed to control the mite pests.

3.13. Harvesting

All the plants were harvested from plots for data collection 36 days after sowing.

3.14. Data collection

The data were recorded from randomly selected 10 plants from each unit plot and the whole plant of each unit plot was weighed after harvesting. The data were recorded for the following parameters.

a) Height of the plant (cm)

b) Stem diameter of the plant (mm)

c) Weight of single plant (g)

d) Leaf area (cm^2)

e) Growth rate in diameter (mm/day)

f) Growth rate in height (cm/day)

g) Growth rate in weight (g/day)

h) Yield (kg/plot)

i) Yield (t/ha).

3.14.1. Plant height (cm)

Plant height was measured in centimeter (cm) by using a scale 15, 22, 29 and 36 days after sowing from the point of ground level to the tip of the plant leaf.

3.14.2. Stem diameter of plant (mm)

Randomly 10 plants were selected and measured each stem of the plant against a roller having mm scale, then the sum of stem diameter was divided by 10 to record stem diameter of plant.

3.14.3. Weight of single plant (g)

Randomly 10 plants were selected from the each plot and the sum of the weight of 10 plants was divided by 10 then it was recorded as weight of single plant (g).

3.14.4. Leaf area (cm ^{2})

Ten plants from each plot were randomly selected, then the length and breadth of the leaves were measured against a centimeter scale and the data were recorded as leaf area (cm^2). The formula is as below:
Leaf area (cm^2) = Length of leaf (cm) × Breadth of leaf (cm).

3.14.5. Growth rate of stem diameter (mm/day)

At the date of harvesting, the stem diameter of randomly selected 10 plants from each unit plot was measured against a roller having mm scale and the diameter was divided by total growing period (36 days). The growth rate was calculated by using the following formula.

$$\text{Growth rate of stem diameter} = \frac{\text{Diameter of the stem (mm) at harvest}}{\text{Total growing period (36 days)}}$$

3.14.6. Growth rate of height (cm/day)

At the harvesting date the average weight was counted from randomly selected 10 plants of each plot and the weight was divided by the total growing period (36 days) and finally recorded as growth rate in height (cm/ day). The formula is as follows:

$$\text{Growth rate of height} = \frac{\text{Height of a plant (cm) at harvest}}{\text{Total growing period (36 days)}}$$

3.14.7. Growth rate of weight (g/day)

At the date of harvesting, 10 plants were selected randomly from each unit plot, then the average weight of ten plants was divided by the total growing period and recorded as growth rate in weight (g/day). It was calculated by using the following formula.

$$\text{Growth rate of weight} = \frac{\text{Weight of single plant (g) at harvest}}{\text{Total growing period (36 days)}}$$

3.14.8. Yield (kg/plot)

At the date of harvesting (36 days after sowing) total plants of each plot was weighed and recorded as yield (kg/plot).

3.14.9. Yield (t/ha)

The yield (t) of red amaranth per hectare was calculated by converting the total yield (kg) of red amaranth per plot.

3.15. Benefit cost ratio

The benefit cost ratio was computed by dividing the total return with the total cost of production of red amaranth.

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

3.16. Statistical analysis

The collected data on different parameters were analyzed by a MSTAT-C package computer programme. Mean Separation was also done using LSD values with the help of the same computer package. The percentage data were subjected to appropriate transformation like square root according to Gomez and Gomez. 1984.

CHAPTER – IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from this experiment with discussion are presented below:

4.1. Plant height (cm)

The plant height varied significantly due to the different levels of nitrogen. The maximum plant height was measured 15.17, 24.8, 36.08, 45.42 cm from N_3 treatment followed by 14.27, 23.62, 35.5, 43.92 cm from N_2 treatment and 13.19, 21.83, 33.85, 42.98 cm under N_1 treatment at 25, 22, 29 and 36 days after sowing respectively (Fig. 2).

The effect of Indole-3-Acetic Acid (IAA) on plant height of red amaranth was statistically significant. The maximum plant height was 14.91, 23.47, 35.35 and 44.44 cm under I_2 treatment and the minimum was 12.01, 21.02, 32.56, and 41.75 cm under I_0 treatment at 15, 22, 29, and 36 days after sowing respectively (Fig. 3).

The nitrogen and Indole-3-Acetic Acid (IAA) combination also influenced plant height significantly. The maximum plant height was observed 16.66, 26.34, 36.64 and 46.33 cm under N_3I_2 treatment and the minimum was 9.16, 17.20, 27.59 and 37.00 cm under N_0I_0 treatment at 15, 22, 29 and 36 days after sowing respectively (Table 3).

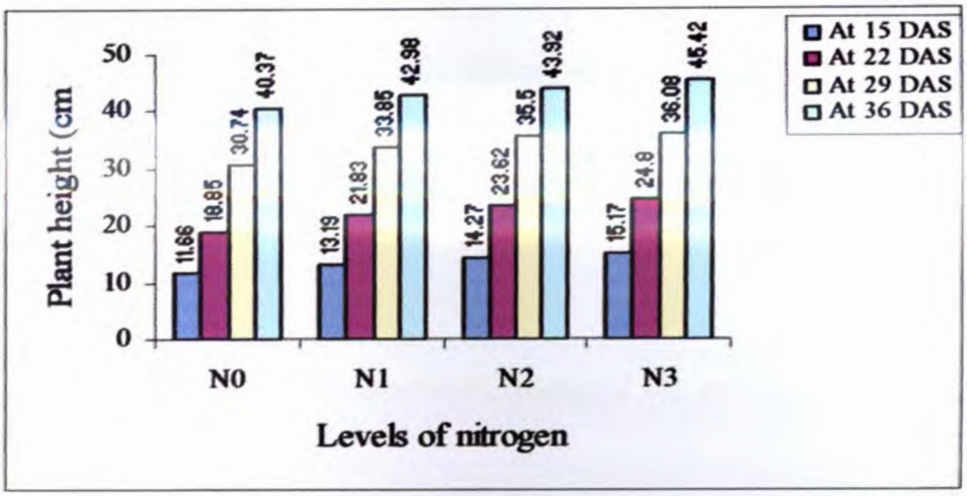


Fig. 2. Main effect of different levels of nitrogen on plant height of red amaranth at different days after sowing.

Where: N_0: 0 kg/ha nitrogen, N_1: 69 kg/ha nitrogen

N_2: 92 kg/ha nitrogen, N_3: 115 kg/ha nitrogen

DAS: Days after sowing.

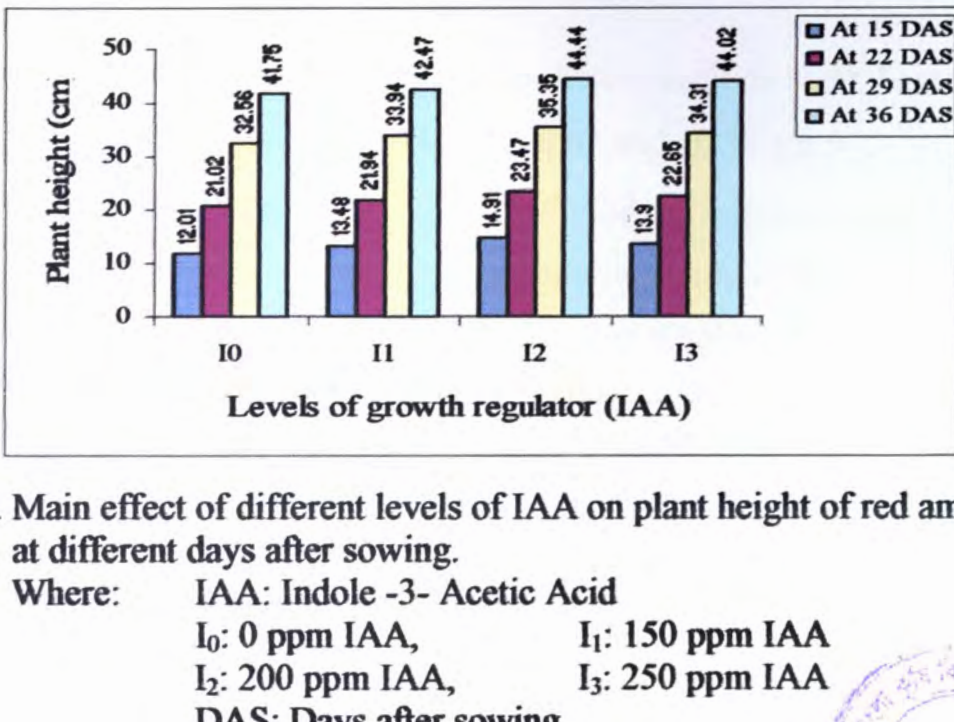


Fig. 3. Main effect of different levels of IAA on plant height of red amaranth at different days after sowing.

Where: IAA: Indole -3- Acetic Acid

I_0: 0 ppm IAA, I_1: 150 ppm IAA

I_2: 200 ppm IAA, I_3: 250 ppm IAA

DAS: Days after sowing.

On every date of data collection, highest levels of nitrogen i.e. N_3 treatment gave highest result but higher concentration of growth regulator (IAA) i.e. I_3 treatment gave fewer result than I_2 treatment (Table 1&2).

4.2. Stem diameter (mm)

The application of different levels of nitrogen on red amaranth appreciably increased the stem diameter.

The maximum stem diameter was recorded 5.37, 6.85, 9.44 and 11.51 cm under N_3 treatment and the minimum was 3.41, 4.67, 6.69, and 8.50 cm under N_0 treatment at 15, 22, 29 and 36 days after sowing respectively (Fig. 4).

It was found that IAA had an overall significant result on stem diameter. The maximum stem diameter was 4.71, 6.21, 8.63 and 10.53 cm with I_2 treatment and the minimum was 4.24, 5.13, 7.58 and 9.52 cm I_0 treatment at 15, 22, 29 and 36 days after sowing respectively. In every date of data collection, I_2 treatment gave wider stem diameter than I_3 (Fig. 5).

In combination of different levels of nitrogen and growth regulator (IAA) significantly influenced the stem diameter of red amaranth. N_3I_2 treatment combination gave maximum stem diameter viz. 5.65, 8.33, 10.03, 12.33 mm and N_0I_0 treatment gave minimum viz. 3.12, 4.33, 6.23, 08.04 mm at 15, 22, 29, 36 days after sowing respectively. The stem diameter was always lowest under N_3I_3 treatment than N_3I_2 treatment which indicated that the stem diameter was adversely affected at highest concentration of IAA (Table 3).

Table 1. Main effect of different levels of nitrogen on the weight of plant, growth rate of stem diameter, growth rate of height, growth rate of weight, leaf area and yield of red amaranth. (*Amaranthus tricolor* L.).

Treatments	Weight of single plant (g)	Growth rate of stem diameter (mm/day)	Growth rate of height (cm/day)	Growth rate of weight (g/day)	Leaf area (cm^2)	Yield	
						kg/plot	t/ha
N_0	17.64 b	0.24 d	1.12 c	0.49 c	33.51 d	2.84 c	14.23 d
N_1	18.88 b	0.27 c	1.19 b	0.52 c	39.41 c	3.09 c	15.47 c
N_2	23.03 a	0.29 b	1.22 ab	0.64 b	44.26 b	3.46 b	17.33 b
N_3	24.83 a	0.32 a	1.26 a	0.69 a	50.97 a	3.71 a	18.58 a
CV%	8.89	6.28	5.63	7.64	5.32	9.17	8.18
LSD 5%	1.582	0.008	0.045	0.037	1.865	0.252	1.119
LSD 1%	2.13	0.011	0.061	0.05	2.512	0.336	1.506

Where: N_0: 0 kg/ha nitrogen, N_1: 69 kg/ha nitrogen
N_2: 92 kg/ha nitrogen, N_3: 115 kg/ha nitrogen

4.3. Weight of single plant (g)

The weight of single plant varied significantly among the treatment means of nitrogen. The maximum weight of single plant was 24.83 g under N_3 treatment and the minimum was 17.67 g under N_0 treatment at harvest (Table 1).

The weight of single plant significantly varied when the concentration of IAA was varied. The recoded weight of single plant was in the range of 19.95 g to 23.72 g under I_0 and I_2 treatment respectively (Table 2).

Nitrogen and IAA combination influenced weight of plant significantly. The maximum weight of single plant was 25.8 g under N_3I_2 treatment and the minimum was 14.66g under N_0I_0 treatment (Table 5).

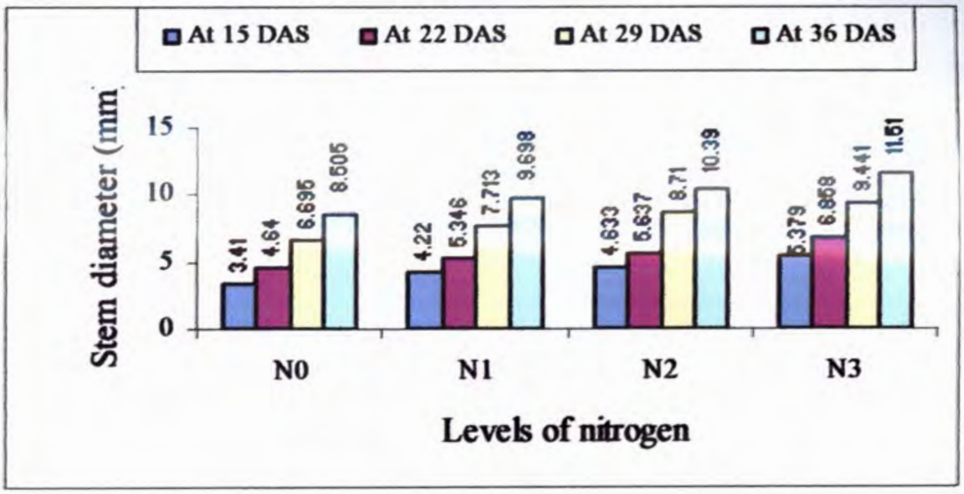


Fig. 4. Effect of different levels of nitrogen on stem diameter of red amaranth at different days after sowing.

Where: N_0: 0 kg/ha nitrogen, N_1: 69 kg/ha nitrogen
N_2: 92 kg/ha nitrogen, N_3: 115 kg/ha nitrogen
DAS: Days after sowing.

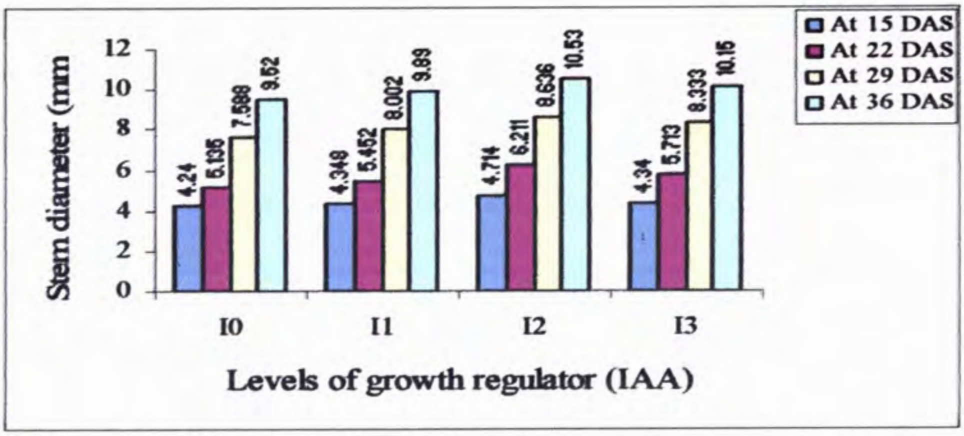


Fig. 5. Effect of different levels of IAA on stem diameter of red amaranth at different days after sowing.

Where: IAA: Indole -3- Acetic Acid
I_0: 0 *ppm* IAA, I_1: 150 *ppm* IAA
I_2: 200 *ppm* IAA, I_3: 250 *ppm* IAA

4.4. Leaf area (cm^2)

The leaf size was recorded at harvest. The size of leaf varied significantly due to the application of different levels of nitrogen. Maximum leaf size was 50.97 cm^2 in N_3 treatment and the minimum was 33.50 cm^2 in N_0 treatment. (Table 1).

IAA concentration also had significant effect on leaf size. Highest concentration of IAA always showed insignificant effect than the moderate concentration. The maximum and minimum effects of this parameter were 43.76 cm^2 and 40.06 cm^2 under I_2 and I_0 treatment respectively (Table 2).

The combined effect of nitrogen and IAA on leaf size was highly significant. N_3I_2 treatment combination gave maximum leaf size (56.11 cm^2) and the minimum size of leaf (31.53 cm^2) was under N_0I_0 treatment (Table 5).

4.5. Growth rate of stem diameter (mm/day)

The growth rate in stem diameter among the different levels of nitrogen varied significantly. N_3 level of nitrogen had maximum growth rate in stem diameter (0.32 mm/day) and the minimum was 0.24 mm/day in N_0 treatment (Table 1).

The effect of IAA on growth rate of stem diameter was significant. I_2 treatment showed maximum growth rate in stem diameter (0.29 mm/day) and minimum was 0.26 mm/day under I_0 treatment (Table 2).

The combination of different levels of nitrogen and IAA influenced the growth rate in stem diameter significantly. The growth rate in stem diameter was in the range from 0.22 mm/day to 0.34 mm/day across the treatment combination. N_2I_2 and N_2I_3 treatment combination showed statistically similar result on growth rate in stem diameter. The maximum (0.34 mm/day) and minimum (0.22 mm/day) growth rate in stem diameter was observed in N_3I_2 treatment and N_0I_0 treatment respectively (Table 4).

Table 2. Main effect of different levels of growth regulator (IAA) on the weight of single plant, growth rate of plants, leaf size and yield of red amaranth. (*Amaranthus tricolor* L.).

Treatments	Growth rate in stem diameter (mm/day)	Growth rate in height (cm/day)	Growth rate in weight (g/day)	Leaf size (cm^2)	Yield	
					(kg/plot)	(t/ha)
I_0	0.26 c	1.16 c	0.55c	40.06 c	3.07 b	15.35 b
I_1	0.27 b	1.18 bc	0.56 bc	41.67 bc	3.27 ab	16.36 ab
I_2	0.29 a	1.23 a	0.64 a	43.76 a	3.43 a	17.19 a
I_3	0.28 b	1.22 ab	0.59 b	42.66 ab	3.34 a	16.70 a
CV%	6.28	5.63	7.64	5.32	9.17	8.18
LSD 5%	0.008	0.456	0.037	1.865	0.250	1.119
LSD 1%	0.011	0.061	0.05	2.512	0.336	1.506

Where I_0: 0 *ppm* IAA, I_1: 150 *ppm* IAA, I_2: 200 *ppm* IAA and I_3: 250 *ppm* IAA

4.6. Growth rate of height (cm/day)

The main effect of different levels of nitrogen on growth rate in height of red amaranth was statistically significant. The maximum growth rate in height was 1.26 cm/day under N_3 treatment and the minimum was 1.12 cm/day under N_0 treatment (Table 1).

The different levels of IAA concentration also showed a significant result on growth rate in height. It ranged from 1.16 cm/day to 1.23 cm/day under I_0 and I_2 treatment respectively (Table 2).

The combined effect of nitrogen and IAA on growth rate in height varied significantly. The maximum growth rate was 1.29 cm/day and minimum was 1.03 cm/day under N_3I_2 and N_0I_0 treatments respectively (Table 4).

4.7. Growth rate of weight (g/day)

In case of growth rate in weight, the single effect of nitrogen varied significantly. The maximum growth rate in weight was 0.69 g/day under N_3 treatment and the minimum was 0.49 g/day under N_0 treatment (Table 1).

The main effect of growth regulator (IAA) on the growth rate in weight was statistically significant. The maximum growth rate in weight was 0.64 g/day and minimum was 0.55 g/day under I_2 and I_0 treatments respectively (Table 2).

The combined effect of different levels of nitrogen and growth regulator (IAA) was significant. The maximum growth rate in weight was 0.72 g/day and minimum was 0.41 g/day under N_3I_2 and N_0I_0 treatments respectively (Table 4).

4.8. Yield (t/ha)

The main effect of different levels of nitrogen on the yield (t/ha) of red amaranth was significant. The highest yield (18.58 t/ha) was obtained under N_3 treatment and the minimum was 14.23 t/ha under N_0 treatment (Table 1).

The different concentration of IAA singly influenced on the yield of red amaranth. The highest yield (17.19 t/ha) was obtained under I_2 treatment which was statistically similar to 16.70 t/ha under I_3 treatment and the minimum was 15.35 t/ha under I_0 treatment (Table 2).

The combined effect of different levels of nitrogen and IAA on yield (t/ha) was statistically significant and more prominent than nitrogen or IAA alone. The highest yield (19.5 ton/ha) was obtained under N_3I_2 treatment and the lowest was 12.83 t/ha under N_0I_0 treatment (Table 5).

Table 3. Combined effect of different levels of nitrogen and Indole -3- Acetic Acid on the plant height and stem diameter of red amaranth (*Amaranthus tricolor* L.) at different days after sowing.

Treatments	Plant height at different days after sowing (DAS)				Stem diameter at different days after sowing (DAS)			
	15 DAS	22 DAS	29 DAS	At harvest	15 DAS	22 DAS	29 DAS	At harvest
N_0I_0	9.16	17.20	27.59	37.00	3.12	4.33	6.23	8.04
N_0I_1	11.33	18.49	30.33	38.66	3.20	4.69	6.53	8.39
N_0I_2	13.66	20.13	33.69	43.66	4.10	4.93	7.13	8.98
N_0I_3	12.50	19.57	31.33	42.16	3.22	4.73	6.89	8.61
N_1I_0	11.43	20.69	32.48	42.20	4.11	5.13	7.33	9.21
N_1I_1	13.16	21.57	33.98	42.23	4.23	5.33	7.54	9.72
N_1I_2	14.26	23.15	34.80	43.13	4.30	5.46	8.16	10.40
N_1I_3	13.93	21.89	34.13	44.36	4.24	5.46	7.82	9.82
N_2I_0	13.33	23.00	34.93	43.28	4.40	5.31	8.02	9.92
N_2I_1	14.16	23.39	35.33	43.87	4.63	5.46	8.62	10.33
N_2I_2	15.06	24.27	36.27	44.64	4.81	6.12	9.22	10.78
N_2I_3	14.54	23.83	35.45	43.90	4.69	5.66	8.98	10.53
N_3I_0	14.12	23.19	35.22	44.53	5.33	5.77	8.77	10.93
N_3I_1	15.28	24.33	36.13	45.13	5.33	6.33	9.32	11.13
N_3I_2	16.66	26.34	36.64	46.33	5.64	8.33	10.03	12.33
N_3I_3	14.63	25.33	36.32	45.69	5.21	7.00	9.64	11.64
CV%	6.54	6.02	6.36	5.14	7.74	7.24	11.01	7.17
LSD 0.05	1.480	2.237	3.608	1.864	0.57	0.679	1.495	1.199
LSD 0.01	1.993	3.012	4.858	5.021	0.768	0.915	2.013	1.614

Where: N_0: 0 kg/ha nitrogen — I_0: 0 *ppm* IAA

N_1: 69 kg/ha nitrogen — I_1: 150 *ppm* IAA

N_2: 92 kg/ha nitrogen — I_2: 200 *ppm* IAA

N_3: 115 kg/ha nitrogen — I_3: 250 *ppm* IAA

DAS: Days after sowing — IAA: Indole -3- Acetic Acid

Table 4. Combined effect of different levels of nitrogen and growth regulator (IAA) on the growth rate of stem diameter, growth rate of height and growth rate of weight of red amaranth (*Amaranthus tricolor* L.).

	Growth rate of stem diameter (mm/day)				Growth rate of height (cm/day)				Growth rate of weight (g/day)			
Treatments	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3
N_0	0.22	0.23	0.25	0.24	1.03	1.07	1.21	1.17	0.41	0.44	0.57	0.54
N_1	0.25	0.27	0.28	0.27	1.17	1.17	1.19	1.23	0.48	0.49	0.61	0.51
N_2	0.27	0.28	0.29	0.29	1.20	1.22	1.24	1.22	0.63	0.63	0.65	0.64
N_3	0.30	0.31	0.34	0.32	1.24	1.25	1.29	1.27	0.67	0.68	0.72	0.68
CV%	6.28				5.63				7.64			
LSD 0.05	0.01				0.09				0.07			
LSD 0.01	0.02				0.12				0.10			

Where:
N_0: 0 kg/ha nitrogen
N_1: 69 kg/ha nitrogen
N_2: 92 kg/ha nitrogen
N_3: 115 kg/ha nitrogen
IAA: Indole -3- Acetic Acid

I_0: 0 *ppm* IAA
I_1: 150 *ppm* IAA
I_2: 200 *ppm* IAA
I_3: 250 *ppm* IAA

Table 5. Combined effect of different levels of nitrogen and growth regulator (IAA) on weight of plant, leaf area and yield of red amaranth (*Amaranthus tricolor* L.).

	Weight of plant (g) at harvest				Leaf area (cm^2) at harvest				Yield at harvest							
									kg/plot				t/ha			
Treatments	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3	I_0	I_1	I_2	I_3
N_0	14.66	15.81	20.56	19.50	31.53	32.66	33.03	36.81	2.56	2.90	2.96	2.95	12.83	14.50	14.83	14.75
N_1	17.26	17.88	21.96	18.40	37.42	40.66	38.53	41.02	2.76	3.08	3.30	3.22	13.83	15.41	16.50	16.11
N_2	23.52	23.00	26.58	23.03	42.96	44.23	42.98	46.87	3.35	3.45	3.58	3.47	16.75	17.28	17.91	17.38
N_3	24.36	24.50	25.80	24.66	48.33	49.11	56.11	50.33	3.60	3.65	3.90	3.71	18.00	18.25	19.50	18.55
CV%	8.89				5.32				9.17				8.18			
LSD 0.05	3.16				3.73				0.5				2.23			
LSD 0.01	4.26				5.02				0.67				3.01			

Where:
N_0: 0 kg/ha nitrogen
N_1: 69 kg/ha nitrogen
N_2: 92 kg/ha nitrogen
N_3: 115 kg/ha nitrogen
IAA: Indole -3- Acetic Acid
At harvest: 36 days after sowing

I_0: 0 *ppm* IAA
I_1: 150 *ppm* IAA
I_2: 200 *ppm* IAA
I_3: 250 *ppm* IAA

4. 9. 1. Relationship between plant height and weight of red amaranth

It was perceived that there was a positive linear relationship between plant height and weight when data was regressed (Fig. 6). Here the equation was y= 1.2982 x - 34.706 and the value of the coefficient of determination (R^2 = 0.7257) gave a good fit and that the fitted regression line had a significant regression coefficient. So, it is evident that the weight increased with the increase in plant height.

4.9.2. Relationship between stem diameter and weight of red amaranth

A positive linear relationship was also observed between stem diameter and weight of red amaranth (Fig. 7). The equation was y =2.69x - 5.67 and the value of the coefficient of determination (R^2 = 0.7593) gave a good fit and that the fitted regression line had a significant regression coefficient. The regression line indicated that the weight of red amaranth depended on stem diameter. So, the weight increased with the increase in stem diameter.

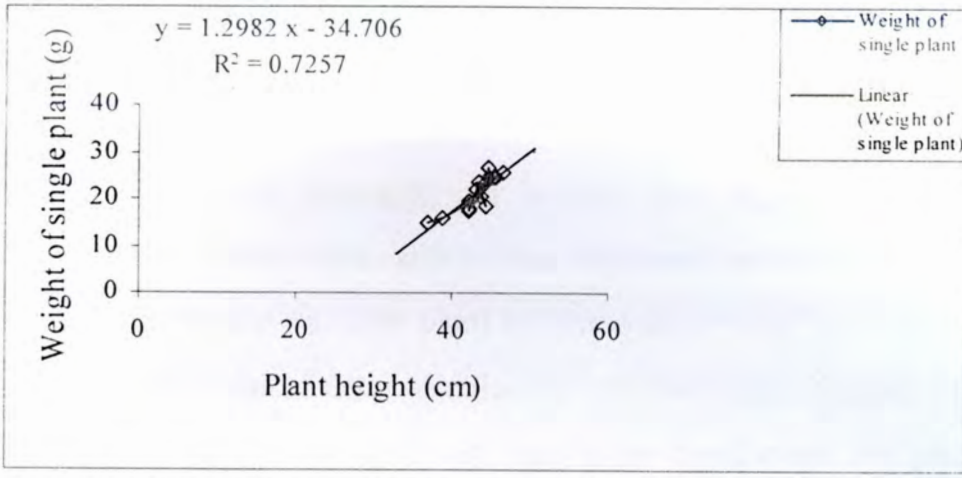


Fig. 6. Relationship between plant height and weight of red amaranth.

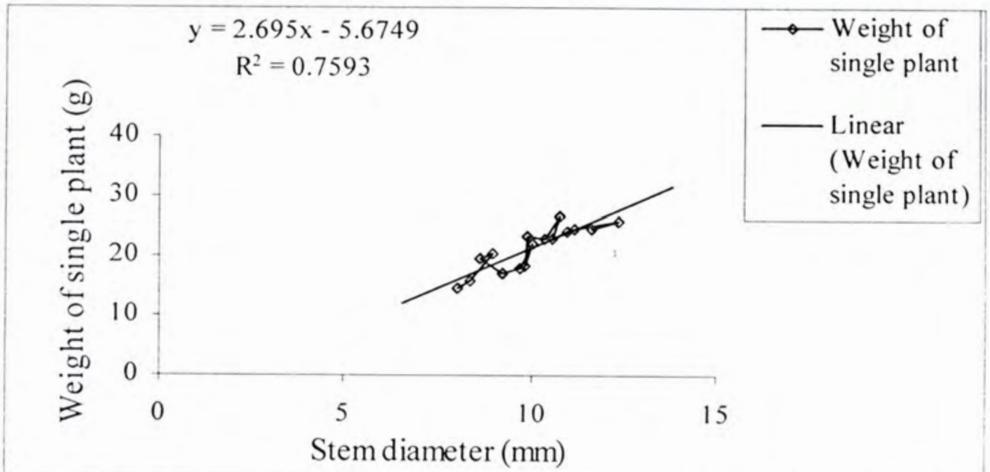


Fig. 7. Relationship between stem diameter and weight of red amaranth.

4.9.3. Relationship between plant height and yield (t/ha) of red amaranth

When the yield of red amaranth per hectare was regressed against plant height, a positive linear relationship was observed between them (Fig 8.). The equation under the variable plant height was y = 0.67 x - 12.58 and the value of the coefficient of determination R^2 = 0.7416 gave a good fit and the fitted regression line had a significant regression coefficient. So, yield (t/ha) was increased with the increase in plant height of red amaranth.

4.9.4. Relationship between stem diameter and yield (t/ha) of red amaranth

Here only two variable, one was independent variable i.e. stem diameter and the other was dependent variable i.e. yield (t/ha) of red amaranth were studied. A positive linear relationship was observed between the variables (Fig 9). The regression equation was y = 1.52 x + 1.12 and the value of the coefficient of determination R^2 = 0.9272 gave a good fit and the fitted regression line had a significant regression coefficient.

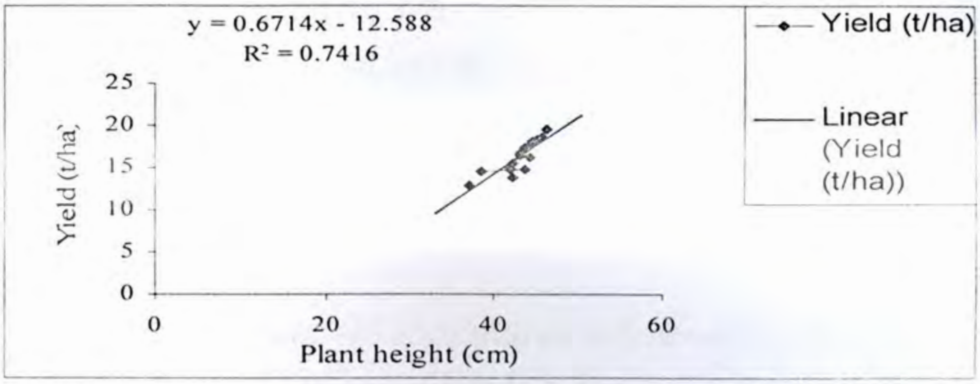


Fig. 8. Relationship between plant height and yield (t/ha) of red amaranth.

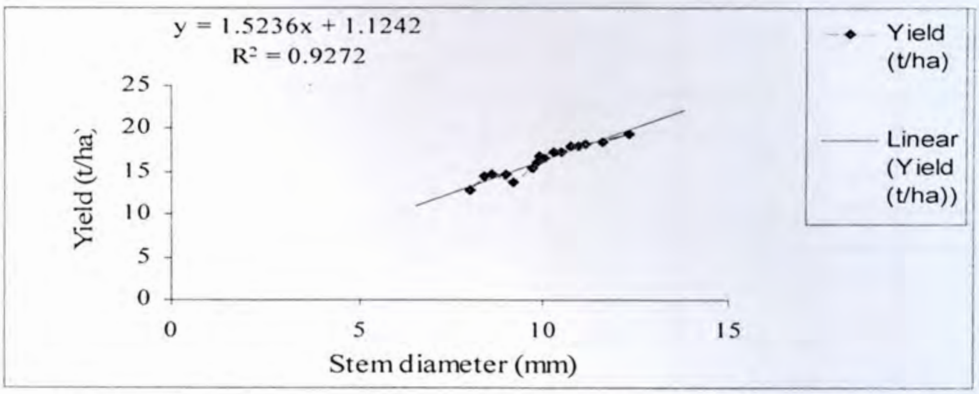


Fig. 9. Relationship between stem diameter and yield (t/ha) of red amaranth.

4.10. Cost and return analysis.

Total costs and returns for each treatment were calculated based on the prevailing market price during the study period. The detailed of cost analysis have been shown in Appendix IV. The benefit cost ratio was computed by dividing the gross return with the total cost of production. Net benefit was calculated by subtracting total cost of production gross return. The minimum benefit (47464 Tk/ha) was found under N_0I_0 treatment. The maximum (93720 Tk/ha) benefit was found with N_3I_2 treatment followed by 86424 Tk/ha under N_3I_0 treatment. The lowest benefit cost ratio (BCR) was 1.86 under N_0I_0 treatment and the highest was 2.5 under N_3I_2 treatment which was close to N_3I_0 treatment. Comparing the total cost of production and the net benefit of red amaranth under N_3I_2 and N_3I_0 level, it is said that N_3I_2 level was more prominent than others. The net benefit from N_3I_2 treatment was 93720 Tk/ha which was greater than that of 86424 Tk/ha under N_3I_0 treatment (Table 6).

Table 6. Cost and return of red amaranth as influenced by different levels of nitrogen and growth regulator (IAA).

Treatments	Yield (t/ha)	Gross return (Tk/ha)	Total cost of production (Tk/ha)*	Net Benefit(Tk/ha) = GR-TCP	Benefit-Cost Ratio = GR/TCP
N_0I_0	12.83	102640	55176	47464	1.86
N_0I_1	14.50	116000	58704	57296	1.97
N_0I_2	14.83	118640	59880	58760	1.98
N_0I_3	14.75	118000	61056	56944	1.93
N_1I_0	13.83	110640	56616	54024	1.95
N_1I_1	15.41	123280	60144	63136	2.04
N_1I_2	16.50	132000	61320	70680	2.15
N_1I_3	16.11	128880	62496	66384	2.06
N_2I_0	16.75	134000	57096	76904	2.34
N_2I_1	17.28	138240	60624	77616	2.28
N_2I_2	17.91	143280	61800	81480	2.31
N_2I_3	17.38	139240	62976	76064	2.20
N_3I_0	18.00	144000	57576	86424	2.49
N_3I_1	18.25	146000	61104	84896	2.38
N_3I_2	19.50	156000	62280	93720	2.50
N_3I_3	18.55	148400	63456	84944	2.33

Gross return = Yield (t/ha) × Price @ 8000 Tk/t.
* Refer Appendix IV.

CHAPTER – V

SUMMARY AND CONCLUSION

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SUMMARY AND CONCLUSION

An experiment was conducted to study the effect of different levels of nitrogen and Indole-3-Acetic Acid (IAA) on the growth and yield of red amaranth at the Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November to December 2006.

The experiment comprised of four levels of nitrogen viz. N_0: 0 kg/ha, N_1: 69 kg/ha, N_2: 92 kg/ha & N_3: 115 kg/ha supplied through urea and four levels of Indole-3-Acetic Acid (IAA) viz. I_0: 0 *ppm*, I_1: 150 *ppm*, I_2: 200 *ppm* and I_3: 250 *ppm* concentration. The experiment was laid out in the randomized complete block design with three replications. The unit plot size was 1m x 2m, distance between plots was 0.5 m. The land was supplied with 10 ton of well decomposed cowdung per hectare at the beginning of the ploughing operation. Triple Supper Phosphate and Muriate of Potash was applied at the rate of 100 kg/ha and 200 kg/ha to supply P_2O_5 and K_2O, respectively during final land preparation. Urea and IAA were applied in three equal split installments at 7 days interval that was started from 7 days after germination.

The height of plants and stem diameter were taken at 15, 22, 29 and 36 days after sowing from randomly selected ten plants. The weight of ten plants, weight of plant, leaf area and yield (t/ha) were recorded at the time of harvest.

The effect of nitrogen on plant height, stem diameter, leaf size, weight of single plant, yield (t/ha) were significant. More or less, all the characters mentioned above attained highest value when N_3 treatment was applied. The highest plant was 15.17cm, 24.8 cm, 36.08 cm and 45.42 cm under N_3 treatment at 15, 22, 29, and 36 days after sowing respectively. The maximum stem diameter was observed also under N_3 treatment which was 5.37 mm, 6.85 mm, 9.44 mm and 11.50 mm at 15, 22, 29 and 36 days after sowing respectively. The leaf size under N_3 treatment was 50.97 cm^2 and under I_2 treatment was 43.75 cm^2 at harvest.

The maximum plant height (44.02 cm), stem diameter (10.53 mm), leaf area (43.75 cm^2), weight of plant (23.72 g), yield per plot (3.46 kg/plot) and yield per hectare (17.18 t/ha) were under I_2 treatment at harvest.

The maximum yield was 18.57 t/ha with the application of N_3 level. The maximum growth rate in stem diameter, growth rate in height and growth rate in weight were 0.319 mm/day, 1.26 cm/day and 0.68 g/day under N_3 treatment and 0.292 mm/day, 1.23 cm/day and 0.63 g/day under I_2 treatment respectively.

The maximum plant height, stem diameter, growth rate in height, growth rate in stem diameter, growth rate in weight, leaf size and yield (t/ha) were 46.33 cm, 12.33 mm, 1.286 cm/day, 0.342 mm/day, 0.716 g/day, 56.11 cm^2 and 19.50 t/ha under N_3I_2 treatment at harvest respectively. The minimum values of all the parameter under N_0I_0 treatment.

The results of correlation indicated that the yield of red amaranth was positive and significantly correlated with plant height, stem diameter and other parameter tested.

From the results of the present study, it may be concluded that 115 kg/ha with 200 *ppm* IAA can effectively be used for the maximum growth and yield of red amaranth.

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APENDICES

Appendix I. Monthly record of air temperature, rainfall, relative humidity, soil temperature, and sunshine of the experimental site during the period from 15th November 2006 to 28th December 2006

Year	Month	*Air temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Soil temperature (^{0}c)			*Sunshine (hr)
		Maximum	Minimum	Mean			5 cm depth	10 cm depth	20 cm depth	
2006	November	29.30	18.21	23.75	64.06	0.125	23.18	24.60	25.43	7.57
	December	27.20	15.97	21.58	63.03	00	20.46	21.92	22.65	5.77

* Monthly average

Source: Bangladesh Meteorological Department (Climate Division)
Agargoan, Dhaka.

Appendix II. Characteristics of horticultural farm soil were analyzed by Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field.

Morphological features	Characteristics
Location	Horticultural Farm, S.A.U., Dhaka.
AEZ	Modhupur Tract (28)
General soil type	Shallow red brown soil
Land type	High land
Soil series	Tejgoan
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fellow - red amaranth

B. Physical and chemical properties of the initial soil.

Characteristics	Value
Partical size analysis	27
% Sand	43
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbone(%)	0.45
Organic matter(%)	0.78
Total N(%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100gm soil)	0.10
Available S (ppm)	45

Appendix III. Mean sum of square values of analysis of variance of the data on the growth and yield contributing characters of red amaranth as influenced by different levels of nitrogen and growth regulator (IAA)

Source of variation	Degrees of Freedom	Mean sum of squares							
		Plant height (cm)				Stem diameter (mm)			
		At 15 DAS	At 22 DAS	At 29 DAS	At 36 DAS	At 15 DAS	At 22 DAS	At 29 DAS	At 36 DAS
Replication	2	4.521**	9.00*	21.438*	25.00*	0.25 ns	0.526*	3.950*	2.250*
Treatment	15	9.689**	19.668**	18.593**	17.626**	1.79**	2.863**	3.936**	4.279**
Factor - A	3	27.373**	80.516**	68.919**	54.019**	8.10**	10.037**	17.151**	18.995**
Factor - B	3	17.372**	13.049**	15.98*	19.376*	0.521*	2.483**	2.428*	2.163*
Interaction - AB	9	1.231 **	0.481**	2.689 **	4.913 **	0.111 **	0.60**	0.034 **	0.08 **
Error	30	0.7.88	1.800	4.682	5.00	0.117	0.166	0.804	0.517

* and **, significant at 5% and 1% level of probability, respectively; ns, non-significant.
DAS: Days after sowing
Factor - A: Levels of nitrogen
Factor - B: Different concentrations of Indole -3- Acetic Acid (IAA)

Appendix III.(Contd.) Mean sum of square values of analysis of variance of the data on the growth and yield contributing characters of red amaranth as influenced by different levels of nitrogen and growth regulator (IAA)

Source of variation	Degrees of Freedom	Mean sum of squares						
		Weight of single plant	Growth rate in stem diameter (mm/day)	Growth rate in height (cm/day)	Growth rate in weight (g/day)	Leaf size (cm^2)	Yield	
							(kg/plot)	(t/ha)
Replication	2	16.776*	0.001*	0.021**	0.010*	25.025*	0.202 ns	9.00*
Treatment	15	40.949**	0.0003**	0.0137**	0.0273**	145.907**	0.428**	10.715**
Factor A	3	157.059**	0.015**	0.042**	0.107**	657.514**	1.788**	44.767**
Factor B	3	34.839**	0.002**	0.015**	0.018**	29.567**	0.289*	7.225*
Interaction AB	9	4.283 **	0.0001 **	0.004 **	0.004*	14.153*	0.021 **	0.528 **
Error	30	3.599	0.0001	0.003	0.002	5.005	0.090	1.800

* and ** , significant at 5% and 1% level of probability, respectively; ns, non-significant.

Factor - A: Levels of nitrogen

Factor - B: Different concentrations of growth regulator (IAA)

Appendix IV. Cost of production of red amaranth per hectare under different treatment combinations

A. Input cost (excluding the cost of nitrogen and IAA).

SL. No.	Item of cost	Number/ Unit/ Person	Rate	Amount of cost (Tk)
1.	Non material costs			
i.)	Land preparation including removal of weeds, stubbles	-	-	4000
ii.)	Making seed beds/ plots	21	60.00	1260
iii.)	Spraying insecticide and fungicide	18	60.00	1080
iv.)	Spreading manures and fertilizers	25	60.00	1500
v.)	Harvesting	30	60.00	1800
vi.)	Others cost up to marketing	-	-	5000
		Total non material cost		14640
2.	Material cost			
i.)	Seeds	2.5 kg	400.00 Tk/kg	1000
ii.)	Manures and fertilizer			
	► Cow dung	10 ton/ha	700.00 Tk/ton	7000
	► Murate of potash	200 kg/ha	16.00 Tk/kg	3200
	► Triple super phosphate	100 kg/ha	16.00 Tk/kg	1600
iii.)	Irrigation and drainage	3 person, 14 days	60.00	2540
iv.)	Insecticide and fungicide	-	-	1000
		Total material cost		16340
	Total input cost			30980

Appendix IV. (Contd.) Cost of production of red amaranth per hectare under different treatment combinations

B. Total variable and overhead cost:

Treatments	Variable cost (Tk)			Total variable cost (A= a+b+c)	Overhead cost (Tk)		Total overhead cost (B = p+q)	Total Cost of production (A+B)
	Input cost * (a)	Cost of urea (b)	Cost of IAA (c)		Hiring of land for 6 months (p)	Interest on running capitals (q)		
N_0I_0	30980	-	-	30980	15000	9196	24196	55176
N_0I_1	30980	-	2940	33920	15000	9784	24784	58704
N_0I_2	30980	-	3920	34900	15000	9980	24980	59880
N_0I_3	30980	-	4900	35880	15000	10176	25176	61056
N_1I_0	30980	1200	-	32180	15000	9436	24436	56616
N_1I_1	30980	1200	2940	35120	15000	10024	25024	60144
N_1I_2	30980	1200	3920	36100	15000	10220	25220	61320
N_1I_3	30980	1200	4900	37080	15000	10416	25416	62496
N_2I_0	30980	1600	-	32580	15000	9516	24516	57096
N_2I_1	30980	1600	2940	35520	15000	10104	25104	60624
N_2I_2	30980	1600	3920	36500	15000	10300	25300	61800
N_2I_3	30980	1600	4900	37480	15000	10496	25496	62976
N_3I_0	30980	2000	-	32980	15000	9596	24596	57576
N_3I_1	30980	2000	2940	35920	15000	10184	25184	61104
N_3I_2	30980	2000	3920	36900	15000	10380	25380	62280
N_3I_3	30980	2000	4900	37880	15000	10576	25576	63456

*Excluding the cost of urea and IAA.

Where

N_0: 0 kg/ha nitrogen ≈ 0 kg/ha urea @ 8 Tk/kg N_1: 69 kg/ha nitrogen ≈ 150 kg/ha urea @ 8 Tk/kg N_2: 92 kg/ha nitrogen ≈ 200 kg/ha urea @ 8 Tk/kg N_3: 115 kg/ha nitrogen ≈ 250 kg/ha urea @ 8Tk/kg	I_0: 0 *ppm* I_1: 150 *ppm* IAA; 980 Tk/5g×15 g/ha I_2: 200 *ppm* IAA; 980 Tk/5g×20 g/ha I_3: 250 *ppm* IAA; 980 Tk/5g×25 g/ha