EFFECT OF GIBBERELLIC ACID (GA_3) ON GROWTH AND DEVELOPMENT OF RED AMARANTH (*Amaranthus sp.*)

BY

K. M. AHSAN HYDER

REGISTRATION NO. 06-02149

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SEMESTER: JANUARY-JUNE, 2015

Approved by:

Dr. Md. Ekramul Hoque
Professor
Department of Biotechnology
Sher-e Bangla Agricultural University
Dhaka-1207
Supervisor

Md. Abdul Halim
Assistant Professor
Department of Biotechnology
Sher-e Bangla Agricultural University
Dhaka-1207
Co-supervisor

Dr. Md. Ekramul Hoque
Chairman
Examination Committee
Department of Biotechnology
Sher-e Bangla Agricultural University
Dhaka-1207

DEPARTMENT OF BIOTECHNOLOGY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF GIBBERELLIC ACID (GA_3) ON GROWTH AND DEVELOPMENT OF RED AMARANTH (*Amaranthus sp.*)"** *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* **BIOTECHNOLOGY**, *embodies the result of a piece of bona fide research work carried out by* **K. M. AHSAN HYDER,** *Registration No.* **06-02149** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date: JUNE, 2015
Place: Dhaka, Bangladesh

(Dr. Md. Ekramul Hoque)
Professor
Department of Biotechnology
Sher-e Bangla Agricultural University
Dhaka-1207, Bangladesh
Supervisor

DEDICATION

This Thesis is dedicated to my father ***Md. Masud Hyder Khan****(late) and my mother* ***Khaleda Akhter****for their endless love, support and encouragement. Furthermore, I want to thank my younger brother* ***K. M. Shahrear Hyder****for his support and love that helped me to be motivated throughout my life.*

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The Author

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ABSTRACT

An experiment was conducted to find out the effects of different levels of GA_3 on the growth and yield of red amaranth at research farm, Sher-e-Bangla Agricultural University, Dhaka,during the period from October, 2014 to January, 2016.It revealed that, 500 ppm of GA_3 was best for lengthof stem (20.27 cm), stem diameter(10.13 mm), total numberof leaf (28.58),length of edible leaf(5.850cm), breath of edible leaf(2.883cm), and weight of ten plants(104.7gm). The experiment also shows that, maximum number of edible leaf was the highest 16.53, 21.04 and 24.12 in 12, 17 and 22 DASrespectively in the 400 ppm GA_3 treatment. Role of GA_3 on growth and development in red amaranth had also been studied under pot culture condition.It's noticed that,500 ppm GA_3 gave the highest stem length 32.18 cmhowever control treatment gave the lowest 26.18 cmresult at 12, 17 and 22 DAS. Maximum number of edible leaf 30.01 at 22 DAS was highest in 400 ppm GA_3. However control of GA_3 gave the minimum (17.26) result.GA_3 with 500 ppm exhibited maximum weight (66.33g) with maximum gain of weight (84.42%) against 100 ppm which showed minimum weight gain (19.27%). The highest stem length growth rate1.193, stem diameter growth rate0.4633 and stem weight growth rate 2.893 were obtained with 500 ppm of GA_3 treatment. In pot culturecondition treatment 500 ppm GA_3responded excellent in all the parameters under study.

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ABBREVIATIONS ANDACRONYMS

AEZ	:	Agro-ecological Zone
Agril.	:	Agriculture
BA	:	N6-benzyladenine
Biol.	:	Biological
Cm	:	Centimeter
CRD	:	CompletelyRandomizedDesign
Conc.	:	Concentration
df.	:	Degrees of freedom
DAG	:	Days after germination
DAS	:	Day after sowing
et al	:	And others (at elli)
FAO	:	Food and Agricultural Organization
GA_3	:	Gibberellic acid
g	:	Gram
gm	:	Gram
g/L	:	Gramperliter
Mg	:	Milligram
mg/g	:	Milligram per gram
Int.	:	International
J.	:	Journal
kg/ha	:	Kilogram per hectare
KIN	:	Kinetin
Mol.	:	Molecular
mg/L	:	Milligramperlitre
PGRs	:	PlantGrowthRegulators
ppm	:	parts per million
Res.	:	Research
RCBD	:	Randomized completely block design
SAU	:	Sher-e-Bangla Agricultural University
SRDI	:	Soil Resource Development Institute
Sci.	:	Science
CV	:	Co-efficient of Variation
°C	:	Degree Celsius
etc.	:	Etcetera
WHO	:	World Health Organization
UNDP	:	United Nations Development Programme

CHAPTER I
INTRODUCTION

CHAPTER I

INTRODUCTION

Amaranthus (*Amaranthus tricolor*) shows a wide variety of morphological diversity among and even within certain species. This complicate taxonomy and *Amaranthus* has generally been considered among systematists as a "difficult" genus (Costea and DeMason, 2001). *Amaranthus* (family: *Amaranthaceae*), collectively known as amaranth, is a cosmopolitan genus of annual or short-lived perennial plants, consisting of approximately 60 species, which according to the uses for human consumption can be divided into grain and vegetable *amaranthus* (Mlakar *et al.*,2010). *Amaranthus* (*Amaranthus tricolor*) plays an important role in nutrition among the leafy vegetables grown in Bangladesh. The leafy *amaranthus* is said to be the native of India (Shanmugavelu, 1989 and Nath, 1976). Among the leafy types, *Amaranthus tricolor* L. is the most commonly cultivated species in Bangladesh. However, during winter, its growth and development is slow than summer and rainy season (Bose *et al.*, 1993). Normally plants are harvested at 20 to 30 days after sowing to consume as tender greens. Yawalkar (1985) reported that good green tender leaves without spines, with stem green, medium thick and tender, petioles green, inflorescence terminal and medium sized, ready for first cutting after 30 days of sowing. Consumption of plants within 15 to 20 days as well as at the mature stages of 35 to 40 days after sowing is also not uncommon. Kader (1978) reported that the optimum stage of harvest in amarnathus could be fixed at the 25th days after sowing, as this stage the performance of the types was found to be superior with increase in leaf weight, stem weight, leaf length, leaf breadth, stem diameter and plant

height. According to Vijayakumar (1980), the optimum stage of harvest in most of the types of *amaranthus* could be fixed between 25-30 days after sowing to get the highest yield as well as nutritious and palatable greens. The optimum harvestable maturity stage of red amaranth when grown during winter season of Bangladesh is not available. Therefore, the present experiment was undertaken to find out the optimum harvestable stage to get maximum yield without being sacrificing the palatability.

Amaranth was important food crop in the Aztec, Mayan, and Incan civilizations; however, its production has declined remarkably, after collapsing of the Central American cultures (Bressani 2003; Schoenlechner *et al.*,2008; Alvarez-Jubete *et al.*,2010b).

The number of publications on various aspects of *Amaranthus* spp., such as cultivation, composition, applications, and health effects, has been steadily increasing; several review articles have summarized the output of expanding research. Teutonico and Knorr (1985) reviewed the results on amaranth composition, properties, and applications, while Stallknecht and Schulz-Schaeffer (1993) focused their review mainly on botany and agronomy of *Amaranthus* crops. Previously published review articles also discussed the history and uses of amaranth and revealed its potential; however, a lack of sufficient experimental data was indicated as a problem in commercialization of amaranth (Teutonico and Knorr, 1985). Therefore, currently amaranth cultivation remains relatively low.

Amaranth is a multipurpose crop supplying high nutritional quality grains and leafy vegetables for food and animal feed; as possessing attractive inflorescence coloration, it

also may be cultivated as an ornamental plant (Mlakar *et al.* 2009). Nowadays amaranth could be classified as a new, forgotten, neglected, and alternative crop of great nutritional value; in fact, amaranth has gained increased attention only since the 1970s (Lehmann1996). Crop importance, botany, and chemical composition were recently briefly reviewed focusing mainly on rheological properties of flours containing amaranth and their suitability for making bread (Mlakar *et al.*.2009).

Physicochemical and digestibility characteristics of starch present in *A. hypochondriacus* were reviewed by emphasizing the starch after the storage of starchy products, their cooking, and the potential of starch from unconventional sources in the production of resistant starch-rich goods using various treatments (Bello-Pérez and Paredes-López 2009). Health-promoting attributes of *A. cruentus* were briefly reviewed by Prokopowicz (2001). Most recently, a comprehensive review was published, which is focusing mainly on health effects, such as hypocholesterolemic activity, influence on the immune system, antitumor effect, action on blood glucose levels, effects on liver functions, hypertension, antienemic effect, antioxidant activity, celiac disease, and antiallergic action (Caselato-Sousa and Amaya-Farfán 2012). Plant growth hormone has great effect on growth and phenotypic development on leafy vegetable. Cytokinin group of hormones likes BAP, KIN, GA_3 has rapid influence on morphological traits. The hormone GA_3 has positive effect on growth and development in amaranth. Concentration and time of GA_3 application on leafy vegetable may increase the biomass production of that specific crop. The application of GA_3 can increase the size and phenotypic growth of red amaranth. Very few literature has been available on application of GA_3 in red amaranth for its yield potentiality study, Hence, considering the following importance of

red amaranth and role of GA_3 on morphological development the current experiment was set up for the below mentioned objectives:

- To identify the best concentration of GA_3 for growth and development of red amaranth.
- To find out the edible maturity period of red amaranth.
- To determine the growth rate of red amaranth after application of GA_3.
- To study the yield potentiality of red amaranth.

CHAPTER II
REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Red amaranth *(Amaranthus tricolor* L.) is widely used vegetable in Bangladesh. The number of published scientific article attained minimum attention for red amaranth research basically for good quality edible leaves and plant parts. There was less research work done with GA_3 treatment on red amaranth in different seasons which effects on the growth of that plant. The available sources of information which was most relevant to the present study have been reviewed here.

Aykroyd,(1963) reported that edible portion of leaves and tender stems of red 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 9200I.U. and vitamin C 99 mg.

According to Bressani & Garcia-Vela, (1990) red amaranth contains 5.20 g protein, 0.80 g fat, 341 mg calcium, 76 mg phosphorus, 4.10 mg iron, 0.37 mg riboflavin, 77.15 g 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 red 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 10.00t/ha 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 by Mohideen *et al.*,(1985) of red 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 liber, 0.47% phosphors, 3.20% potassium, 0.84% iron, 2.48% calcium and 1.35% magnesium.

Sealy *et al.*, (1988) reported that *Amaranthus dubius* L. cv. *ibondwe*, *A. hybridus* cultivars *Quilete* and *Vlete*, *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 mg/g) and moderate in Ibondwe (16.50/mg). 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. *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%) content. The lowest oxalate was recorded in 'Co.1', (3.04%). All the red and green-red types with high protein and β-carotene also had high oxalate.

Jhon (1992) reported that seedlings of Globe amaranth (*Gomphrena globose),* grown for cut flowers, were planted on 6 June in silty loam soil with a pH of 6.8, 26.79kg available P 205/ha, 316.80kg available K 20/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 ton manure, 100 kg P 205/ha and 100 kg K 20/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.

CHAPTER III
MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effects of different levels of GA_3 on the growth and yield of red amaranth at research farm Sher-e-Bangla Agricultural University, and Dhaka during the period from October, 2014 to January, 2016. The materials and methods of the research program is organised in different sub-headlines as noted below:

3.1. Climate

The climate is subtropical. The experimental period was from October, 2014 to January, 2016 characterized by plenty of sunshine and scarce rainfall. The average maximum and minimum temperatures were 29.30°C and 15.97°C 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 as per the followings:

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

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 determined in soil testing laboratory, SRDI, Khamarabari, Dhaka is presented below:

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
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

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 (2010) is shown as AEZ No.-28, Soil Series.-Tejgaon, General Soil.-Non calcareous dark grey.

3.3. Plant Materials

The seed of red amaranth belongs to the study was collected from Lal Teer Seed Ltd., Dhaka. and named Altapeti 20.

3.4. Plant growth regulator

Plant growth regulator Gibberellic Acid (GA_3) with different concentrations were used for this experiment.

3.5. Treatments of the experiment

Experiment was carried out with single factor. The concentration of GA_3 is given below. Analytical grade GA_3 was collected from Merck Germany Company.

i) T_0 = Control

ii) T_1 = 100 ppm

iii) T_2 = 200 ppm

iv) T_3 = 300 ppm

v) T_4 = 400 ppm

vi) T_5 = 500 ppm

3.6. Experimental design and layout

Forty-eight treatments (4 x 4 x 3) were accommodated followed by randomized complete block design with three replications. Four doses of GA_3 (including control) were assigned in the plots. The area of the experimental land was 20.5 m x 9.5 m. The size of each plot was 2 m x 1 m and the distance between two blocks and two plots was kept 0.5 m. A layout of the experiment has been shown in (Plate. 1.)

Design of the Field

Land = (20.5 x 9.5) m

No. of Plot = (4 x 4 x 3)

Plot = (2 x 1) m

Block to Block = 0.5 m

Plot to Plot = 0.5 m

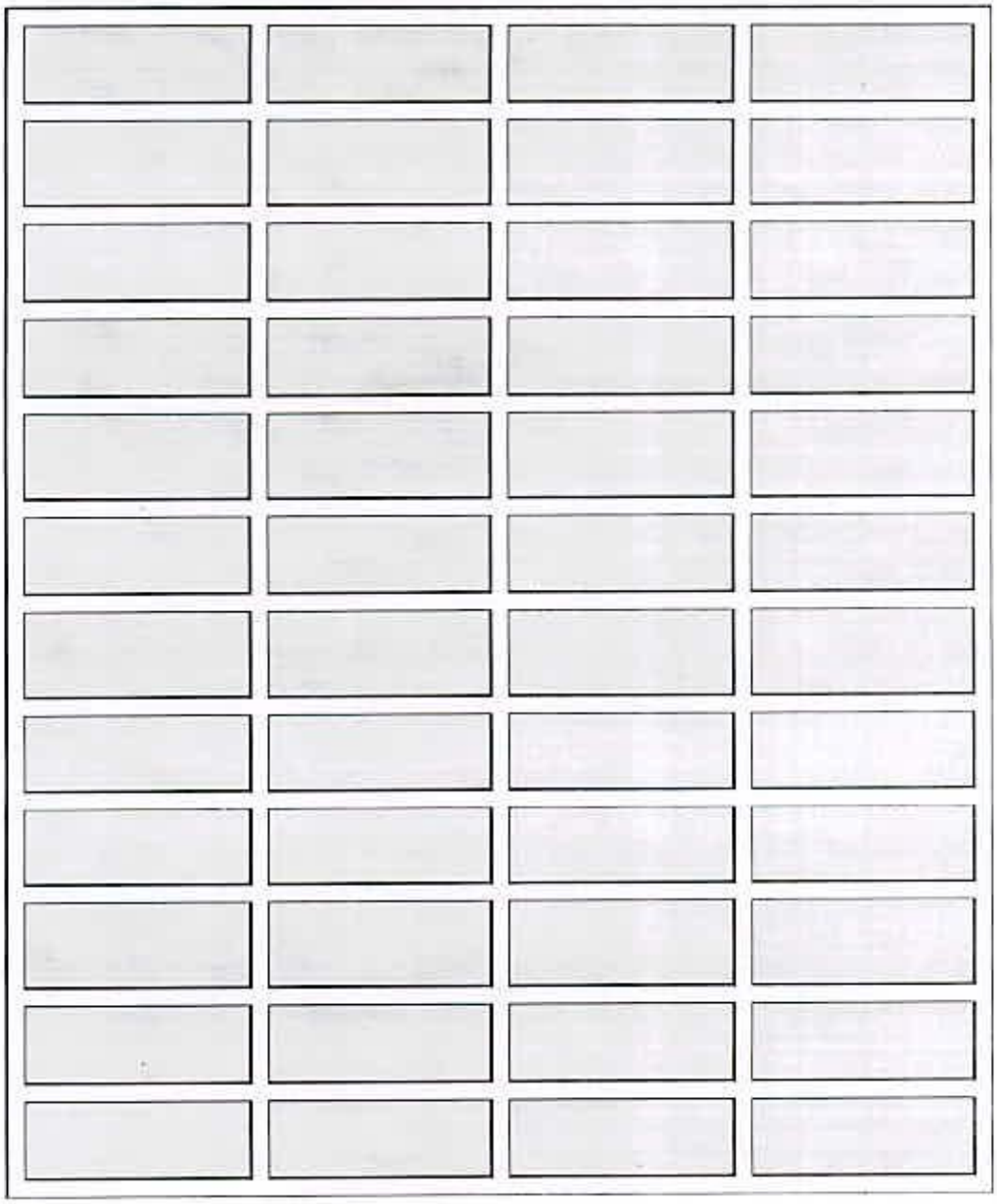


Plate. 1. Field design of the experiment

3.7. Land preparation

The selected land was opened on 15th September 2014 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. 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 10 October, 2014, 2nd June, 2015 and 22nd November, 2015 for first, second and third experiment respectively.

3.9. Application of manures and fertilizers

Following manures and fertilizers were used for this experiment:

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

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

Two experiments were conducted to fulfill the mentioned objective under different environmental conditions.

1. **Sub-experiment 1.**

   Role of GA_3 on red amaranth under field condition.

2. **Sub-experiment 2.**

   Effect of GA_3 in red amaranth under pot culture in net house condition.

3.10. Preparation of GA_3:

Stock solution of different treatments of GA_3 were prepared by following methods.

1. 500 ppm GA_3: 500 mg of GA_3 powder was dissolved in 0.1% NaOH and then the volume was made upto 1000 ml.
2. 400 ppm GA_3: 400 mg of GA_3 powder was dissolved in 0.1% NaOH and then the volume was made upto 1000 ml.
3. 300 ppm GA_3: 300 mg of GA_3 powder was dissolved in 0.1% NaOH and then the volume was made upto 1000 ml.
4. 200 ppm GA_3: 200 mg of GA_3 powder was dissolved in 0.1% NaOH and then the volume was made upto 1000 ml.
5. 100 ppm GA_3: 100 mg of GA_3 powder was dissolved in 0.1% NaOH and then the volume was made upto 1000 ml.

3.11. GA_3 Spraying

First treatment was sprayed after 2 days of 80% germination. With every 4 days interval rest of the treatments were applied and within 22 days of the application of GA_3 was completed.

3.13. Data collection

The morphological traits under study of two sub-experiments were similar and the parameters were as follows: stem length (cm), stem diameter (cm), number of total leaf, number of edible leaf, length of edible leaf (cm), breath of edible leaf (cm), weight of 10 selected plant (g), percentage of edibility of plant (%) and crop growth rate at 12, 17 and 22 DAS for both the experiments.

3.13.1. Plant height (cm)

Plant height was measured in centimeter (cm) by using a scale 12, 17 and 22 days after sowing from the point of ground level to the tip of the plant leaf. Randomly 10 plants were selected and data was recorded on average basis.

3.13.2. Stem diameter of plant (mm)

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

3.13.3. Number of total leaf

Randomly 10 plants were selected and measured, then the sum of number of leaf was divided by 10 to record number of leaf of plant.

3.13.4. Number of edible leaf

Randomly 10 plants were selected and measured, then the sum of number of edible leaf was divided by 10 to record number of edible leaf of plant on the basis of freshness and softness of leaf.

3.13.5. Length of edible leaf (cm)

Randomly 10 plant's length of edible leaf (cm) were selected and measured by using scale, then the sum of number of leaf length was divided by 10 to record length of edible leaf of plant.

3.13.6. Breath of edible leaf (cm)

Randomly 10 plant's breath of edible leaf (cm) were selected and measured by using scale, then the sum of number of breath of leaf was divided by 10.

3.13.7. Weight of 10 selected plants (g)

Randomly 10 plants were selected and measured by using balance, then the sum of number of weight of plants was divided by 10 to recorded weight of 10 selected plant in gm.

3.13.8. Percentage of edibility (%)

Randomly 10 plant were selected, then the fresh part of plants were isolated and weighed. Then the percentage of edibility was measured by using the following formula:

$$\% \text{ edibility of plant} = \{ \text{Fresh weight which is edible (g)} \div \text{Total weight (g)} \} \times 100$$

3.13.9. Growth rate

At the date of harvesting, randomly selected 10 plants from each unit plot was measured against a roller having cm scale and individual sum of plant length, diameter and plant wt. were divided by total growing period (22 days). The growth rates were calculated by using the following formula.

- Stem length growth rate = Length of stem (cm) at harvest ÷ Total growing period (22 days)
- Growth rate of stem diameter = Diameter of the stem (mm) at harvest ÷ Total growing period (22 days)
- Weight growth rate = Weight of plant (g) at harvest ÷ Total growing period (22days)

3.14. Data analysis:

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

CHAPTER IV
RESULT AND DISCUSSION

CHAPTER IV

RESULT AND DISCUSSION

The role of GA_3 on morphological parameter were studied in the present experiment. Different concentration of GA_3 has great influence on phenotypic traits on red amaranth. The finding of different treatments are presented in the chapter.

Sub-experiment. 1.

Role of GA_3 in red amaranth under field condition

4.1.1. Length of Stem:

Length of stem was studied after application of GA_3 in different concentration. Three application was done at 12, 17 and 22 DAS. It revealed that, when the conc. of GA_3 increase then the length of stem also increased in all the treatment. 500 ppm of GA_3 showed highest length (13.90, 16.42 and 20.27 cm) (Table. 1) (Plate. 2) respectively at 12, 17 and 22 DAS.

Table.1. Effect of Gibberellic acid (GA_3) on stem length of red amaranth

Treatments	Stem length (cm)		
	12 DAS	17 DAS	22 DAS
T_0	7.197 f	9.233 f	12.95 d
T_1	8.333 e	10.53 e	13.62 d
T_2	10.12 d	11.65 d	15.15 c
T_3	12.12 c	13.05 c	15.55 c
T_4	13.18 b	15.37 b	18.37 b
T_5	**13.90 a**	**16.42 a**	**20.27 a**
$LSD_{0.05}$	0.5753	0.6169	0.7231
CV (%)	6.324	5.276	8.529

Plate.2. Stem length of red amaranth in the treatment 500 ppm GA_3 application at 22 DAS.

a. 100 ppm GA_3

b. 200 ppm GA_3

c. 300 ppm GA_3

d. 400 ppm GA_3

e. 500 ppm GA_3

4.1.2. Diameter of stem (mm)

Diameter of stem in red amaranth was measured in millimeter (mm). It is observed that, higher conc. of GA_3 has positive effect of diameter. When the conc. increase the diameter also increase. It is noticed that 500 ppm GA_3 showed highest diameter 5.93, 8.88 and 10.13 mm on 12, 17 İnd 22 DAS respectively. The lowest data 4.023, 4.727 and 6.113 were recorded in 100 ppm GA_3. (Table. 2)

Table.2. Effect of Gibberellic acid (GA_3) on stem diameter(mm) of red amaranth

Treatments	Stem diameter (mm)		
	12 DAS	17 DAS	22 DAS
T_0	**4.023 f**	**4.727 f**	**6.113 f**
T_1	4.770 d	6.090 d	7.570 d
T_2	4.320 e	5.483 e	7.227 e
T_3	5.040 c	7.347 c	8.123 c
T_4	5.277 b	7.623 b	8.477 b
T_5	**5.933 a**	**8.883 a**	**10.13 a**
$LSD_{0.05}$	0.05753	0.09965	0.1151
CV (%)	7.993	6.471	6.831

4.1.3. Total Number of Leaf:

Total number of leaf of red amaranth which was counted after 12, 17 and 22 DAS in amaranth with applying 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm of GA_3 revealed statistically significant variation. It showed that 500 ppm GA_3 gave the highest result at 12, 17 and 22 DAS and it were 17.48, 24.05 and 28.58 respectively. The lowest data 11.97, 13.02 and 14.90 were observed in control treatment. (Fig. 1)

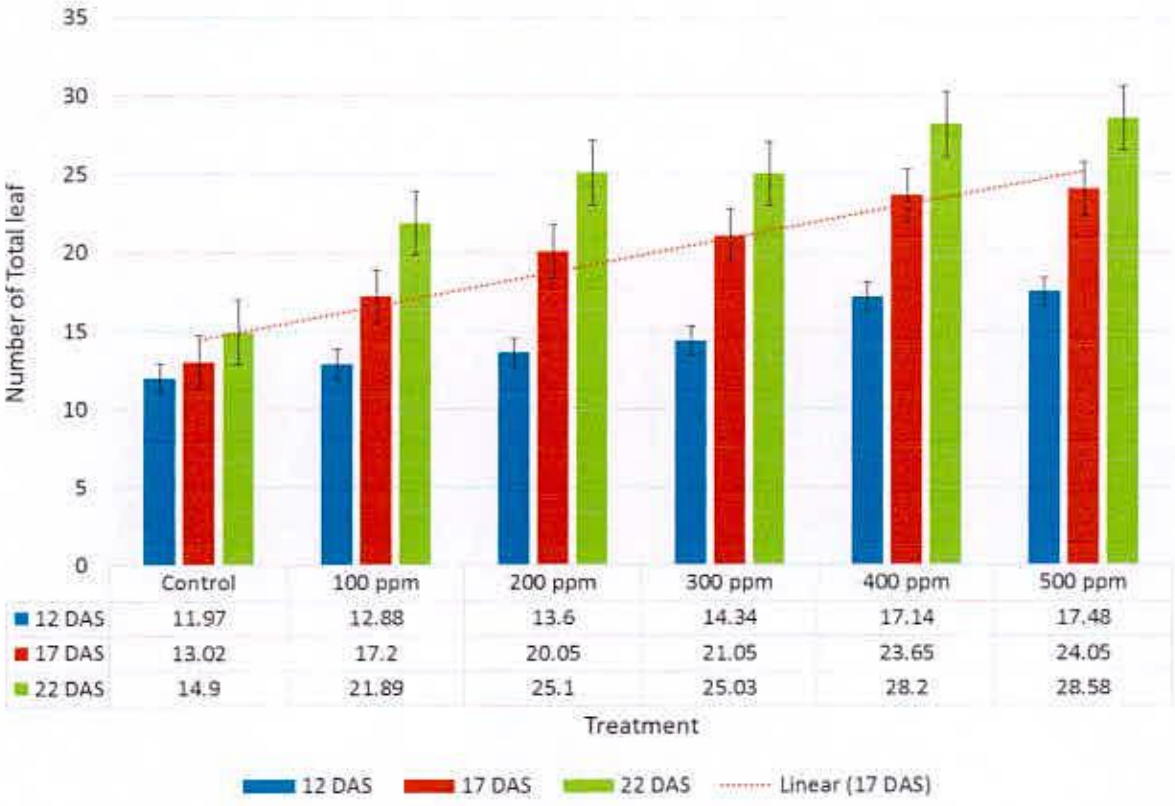


Fig.1. Effect of Gibberellic acid (GA_3) on number of total leaf

4.1.4. Number of edible Leaf:

Total number of edible leaf is an important trait for human consumption. Data were recorded on each treatment of GA_3 application. It was observed that 400 ppm GA_3 showed the highest number of edible leaf 16.53, 21.04 and 24.12 respectively on 12, 17 and 22 DAS. The control treatment showed the lowest result in three intervals of spraying. (Fig. 2)

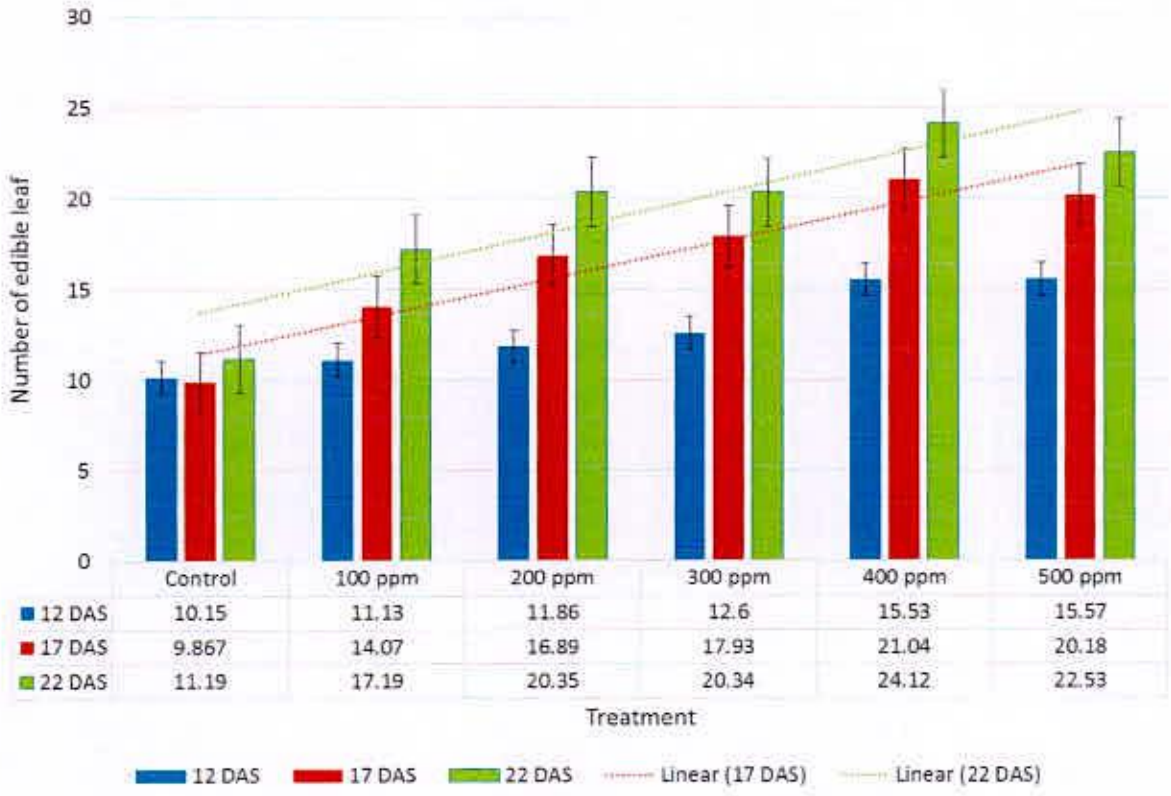


Fig.2. Effect of Gibberellic acid (GA_3) on number of edible leaf of red amaranth

Plate.3. Field view of experimental plot

4.1.5. Length (cm) and breadth (cm) of edible Leaf:

Length and breadth of edible leaf was measured at 12, 17 and 22 DAS. It recorded that 500 ppm GA_3 responded best as 3.54, 4.04 and 5.85 cm (Table. 4) length and 2.27, 2.49 and 2.88 cm (Table. 5) breadth respectively among all other treatments. Similar trend of poor performance was noticed in control treatment. (Plate. 4)

Table.3. Effect of Gibberellic acid (GA_3) on length of edible leaf (cm) of red amaranth

Treatments	Length of edible leaf (cm)		
	12 DAS	17 DAS	22 DAS
T_0	1.934 d	4.367 a	3.700 f
T_1	2.273 cd	3.267 cd	4.060 e
T_2	2.563 c	3.050 d	4.367 d
T_3	2.530 c	3.330 c	4.843 c
T_4	2.990 b	3.330 c	5.537 b
T_5	3.540 a	4.047 b	5.850 a
$LSD_{0.05}$	0.3684	0.2228	0.2228
CV (%)	4.562	5.397	5.248

Table.4. Effect of Gibberellic acid (GA_3) on breadth of edible leaf (cm) of red amaranth

Treatments	Breadth of edible leaf (cm)		
	12 DAS	17 DAS	22 DAS
T_0	1.113 f	1.603 f	1.917 b
T_1	1.270 e	1.790 e	2.067 b
T_2	1.407 d	2.027 d	2.557 a
T_3	1.887 c	2.200 c	2.517 a
T_4	2.137 b	2.400 b	2.797 a
T_5	2.273 a	2.490 a	**2.883** a
$LSD_{0.05}$	0.09965	0.08136	0.4108
CV (%)	5.831	6.793	6.482

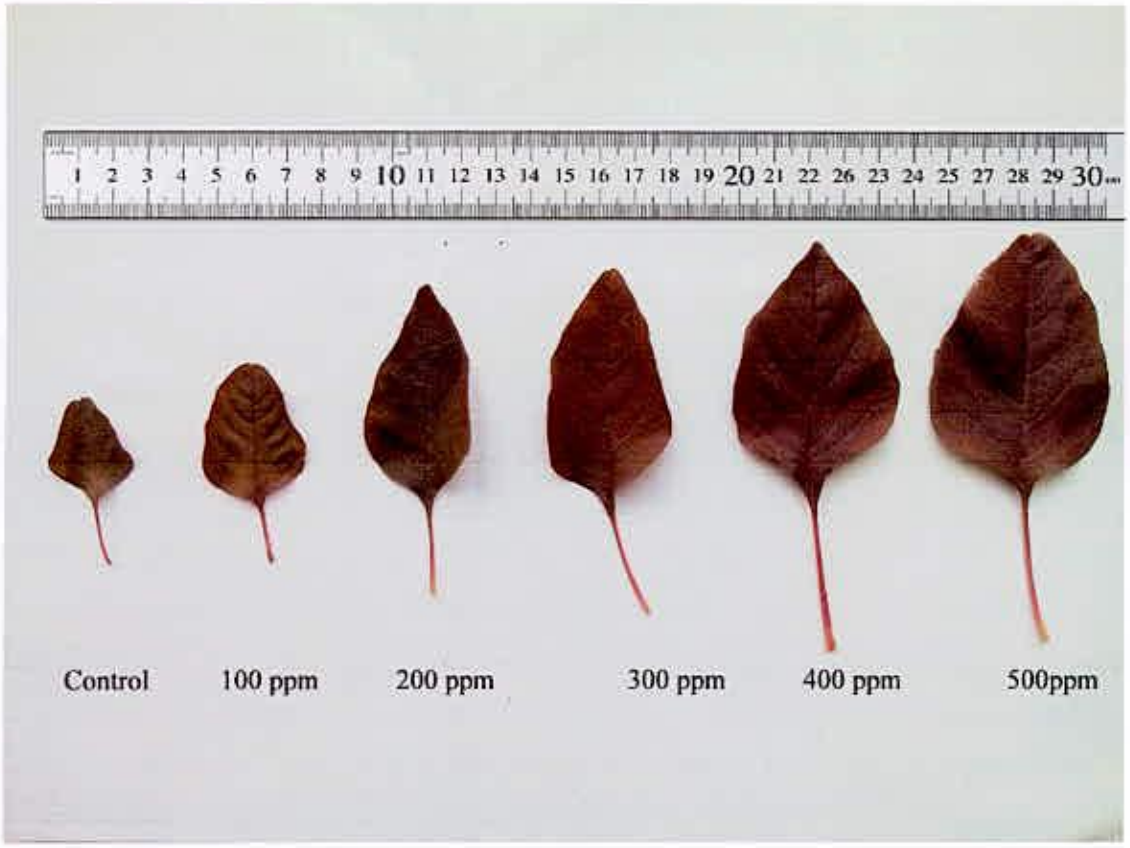


Plate.4. Leaf breadth of red amaranth in different conc. of GA_3

a. Control treatment

b. 100 ppm GA_3

c. 200 ppm GA_3

d. 300 ppm GA_3

e. 400 ppm GA_3

f. 500 ppm GA_3

4.1.6. Weight of plant (gm) over control treatment:

Plant of red amaranth which was calculated at 22 DAS. The results was statistically significant. Which showed 500 ppm GA_3 exhibited maximum weight (104.7 g) with maximum percent of weight 85.03 of weight against control and 100 ppm showed minimum percent of weight 14.16 (Table. 5). Result showed that higher concentration of GA_3 gives more weight gain of red amaranth compared to less concentration of GA_3. Roy and Amaranth (2012) showed the same consequence in cabbage.

Table.5. Percent of weight increase due to application of GA_3 on red amaranth

Treatments with GA_3 Conc. (ppm)	Weight of ten plant (at 22 DAS) (gm)	% increase of weight over control
Control	56.67 d	--
100	64.67 c	14.16 c
200	69.67 c	23.09 bc
300	77.00 b	36.22 b
400	103.7 a	84.11 a
500	104.7 a	85.03 a
$LSD_{0.05}$	5.113	13.56
CV (%)	7.493	4.629

4.1.7. Growth rate of red amaranth:

Growth rate of stem length, diameter and weight in red amaranth were measured at 22 DAS by applying 100, 200, 300, 400 and 500ppm of GA_3 which were statistically significant. It was observed that 500 ppm GA_3 gave the highest result at 12 DAS and 22 DAS. The highest stem length growth rate, stem diameter growth rate and plant weight growth rate were obtained at 500 ppm GA_3 as 1.19, 0.46 and 2.89 (Table. 6) respectively. It can be said that higher the GA_3 concentration stimulates the stem length growth rate, stem diameter growth rate and overall plant weight growth rate. (Plate. 5)

Table.6. Effect of Gibberellic acid (GA_3) on growth rate of red amaranth

Treatments with GA_3 Conc. (ppm)	Stem length growth rate	Stem diameter growth rate	Plant weight growth rate
Control	**0.8567 d**	**0.2800 e**	**1.637 e**
100	0.9267 c	0.3500 c	1.947 d
200	0.9600 c	0.3300 d	2.067 c
300	0.9767 c	0.3833 b	2.150 c
400	1.113 b	0.426 ab	2.793 b
500	**1.193 a**	**0.4633 a**	**2.893 a**
$LSD_{0.05}$	0.05753	0.01819	0.09797
CV (%)	4.352	5.329	4.977

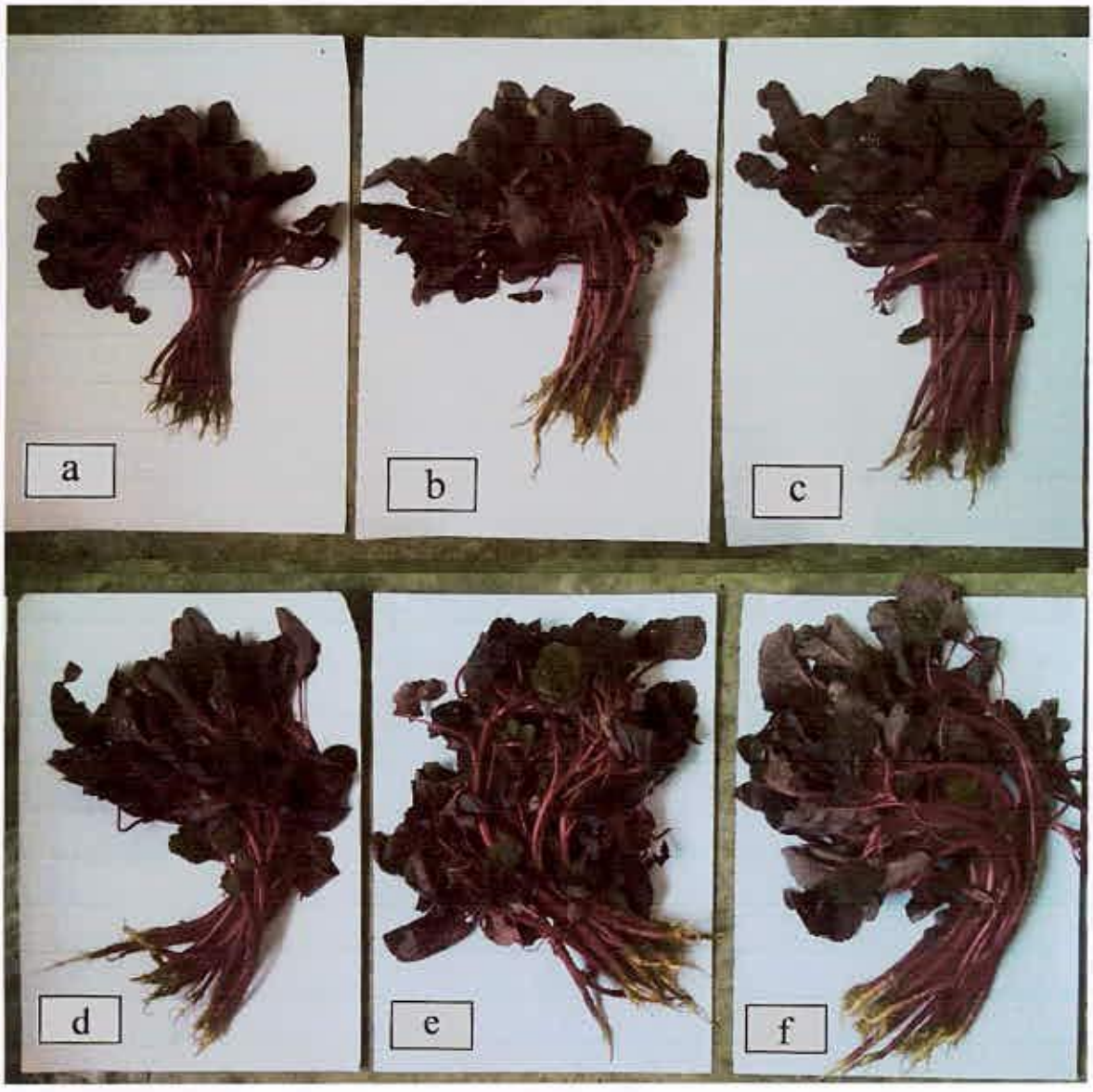


Plate.5. Leaf and stem biomass of red amaranth in different treatments

a. Control treatment
b. 100 ppm GA_3
c. 200 ppm GA_3
d. 300 ppm GA_3
e. 400 ppm GA_3
f. 500 ppm GA_3

Sub-experiment. 2.

Effect of GA_3 in red amaranth under pot culture in net house condition

Another set of experiment was conducted in plastic pot under net house condition to study the effect of GA_3 in red amaranth. The same morphological traits were evaluated as like previous experiment. The major finding of the experiments were given below.

4.2.1. Whole Plant height (cm):

Length of stem in red amaranth varied significantly in all treatment under studied. It was observed that, there was a positive relation between conc. of GA_3 and length of stem, at lower conc. of GA_3 the length of stem also low and it was gradually increase in relation to higher dose of GA_3 The 500 ppm GA_3 showed the highest 16.30, 21.45 and 26.18 cm length respectively at 12, 17 and 22 DAS. The control treatment showed the lowest of result in all the treatments. (Table. 7) (plate. 6)

Table.7. Effect of Gibberellic acid (GA_3) in stem length on red amaranth under pot culture condition

Treatments with GA_3 Conc. (ppm)	Stem length (cm)		
	12 DAS	17 DAS	22 DAS
Control	10.03 c	14.24 d	18.88 d
100	11.15 d	15.53 cd	20.37 c
200	13.31 c	16.66 bc	21.08 c
300	15.38 b	18.11 b	21.48 c
400	16.28 a	20.39 a	24.52 b
500	16.30 a	21.45 a	26.18 a
$LSD_{0.05}$	0.4149	1.925	1.175
CV (%)	9.337	8.299	6.453

Plate.6. Red amaranth under pot culture in net house condition with GA_3 treatments at 12 DAS

a. 100 ppm GA_3
b. 200 ppm GA_3
c. 300 ppm GA_3
d. 400 ppm GA_3
e. 500 ppm GA_3

4.2.2. Diameter of stem (mm):

Stem diameter of red amaranth which was measured in centimeter (mm) unit and data were recorded at 12, 17 and 22 DAS. The result showed significant variation among the treatments with 500 ppm giving the maximum outcome at 12, 17 and 22 DAS which were 5.93 cm, 8.88 cm and 10.13 cm respectively whereas control of GA_3 gave the minimum output 4.023 cm, 4.727cm and 6.113cm respectively at all three observation dates. It was noted that higher concentration of GA_3 applying in plants responded well in respect of stem diameter of red amaranth. (Table. 8)

Table.8. Effect of Gibberellic acid (GA_3) on stem diameter of red amaranth

Treatments with GA_3 Conc. (ppm)	Stem diameter (mm)		
	12 DAS	17 DAS	22 DAS
Control	4.053 d	4.708 e	6.107 f
100	4.577 c	6.143 c	7.623 d
200	4.350 cd	5.423 d	7.260 e
300	5.223 b	7.677 b	8.427 cd
400	5.203 b	8.347 ab	9.365 b
500	6.300 a	8.930 a	10.22 a
$LSD_{0.05}$	0.4108	0.7139	0.05753
CV (%)	4.562	4.853	5.284

4.2.3. Total Number of Leaf:

The parameter total number of leaf showed significant variation among the conc. of GA_3. It was observed that 500 ppm GA_3 gave maximum number of leaf was (20.25, 28.45 and 34.38) at three times (12, 17 and 22 DAS) of interval and the (Fig. 3) treatment showed minimum leaf control (14.85, 17.69 and 20.70) in the same study period.

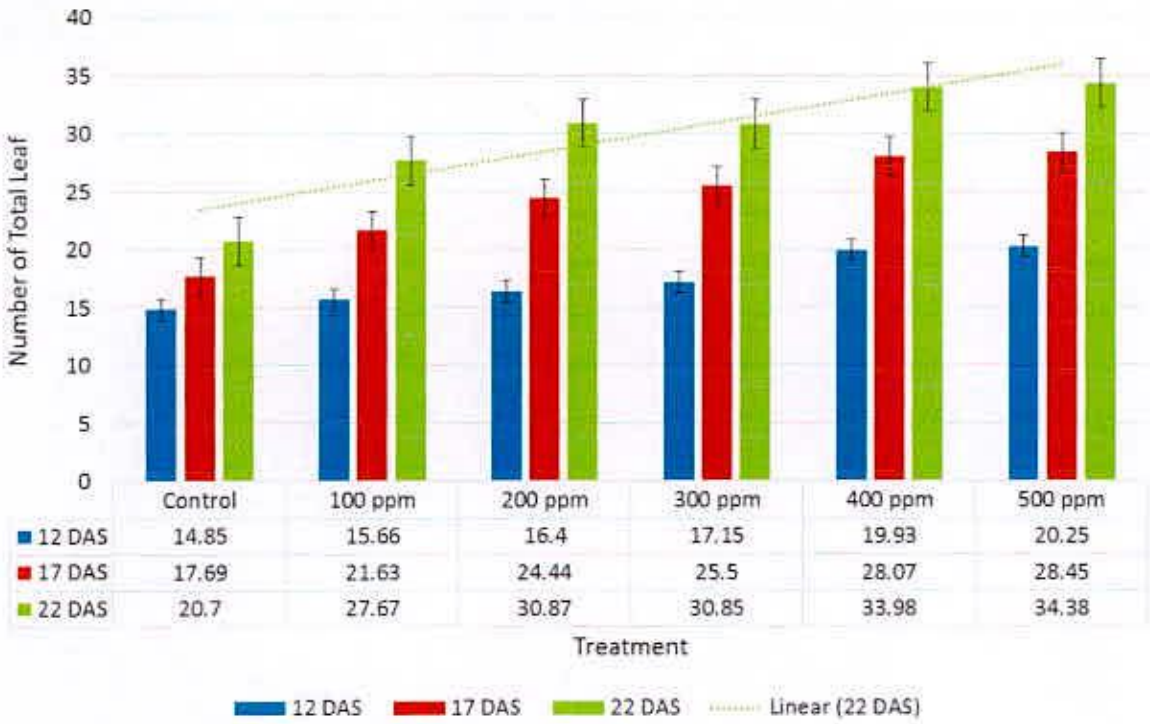


Fig.3. Effect of Gibberellic acid (GA_3) on number of total leaf under pot culture in net house condition

4.2.4. Number of edible leaf:

Number of edible leaf of red amaranth was recorded at 12, 17 and 22 DAS for all the treatment and it showed significant variation with GA_3 400 ppm giving maximum number of edible leaf 30.01 (Fig.4.) at 22 DAS. However control of GA_3 gave the negligible consequence 13.21, 15.03 and 17.26 (Fig. 4) in all three times of data collection.

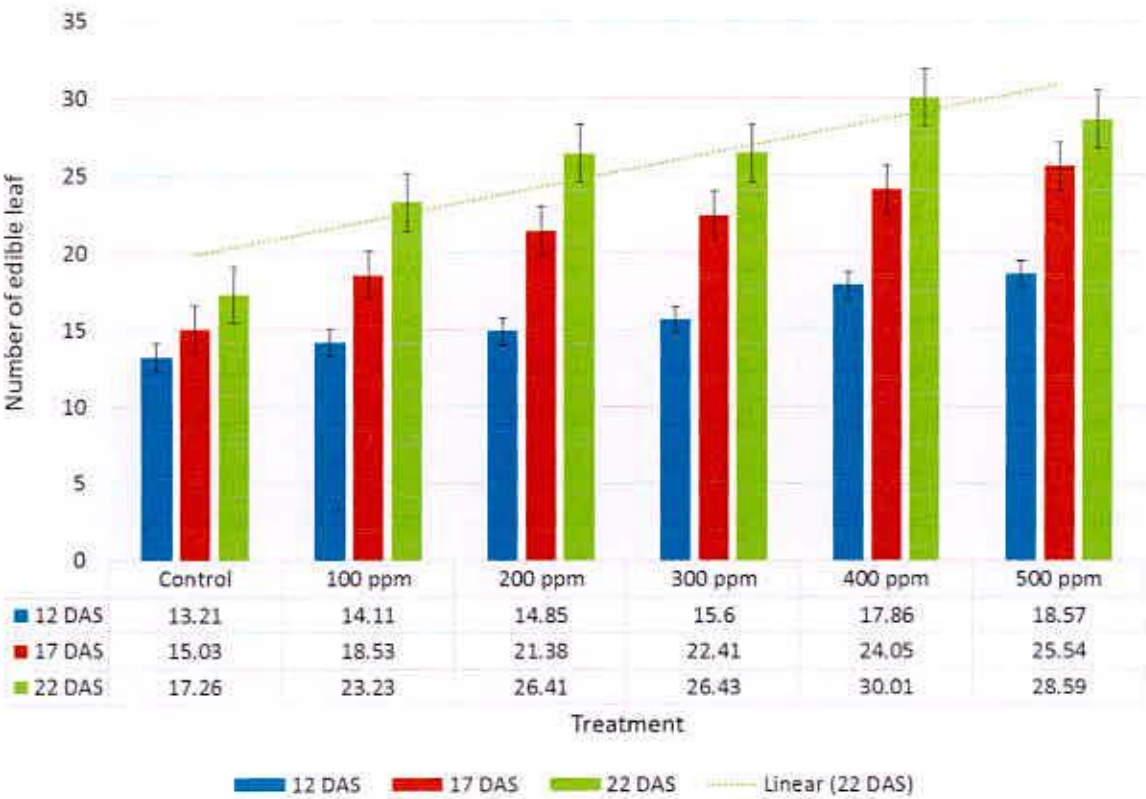


Fig.4 Effect of Gibberellic acid (GA_3) on number of edible leaf of red amaranth under pot culture in net house condition

4.2.5. Length (cm) and breadth (cm) of edible Leaf:

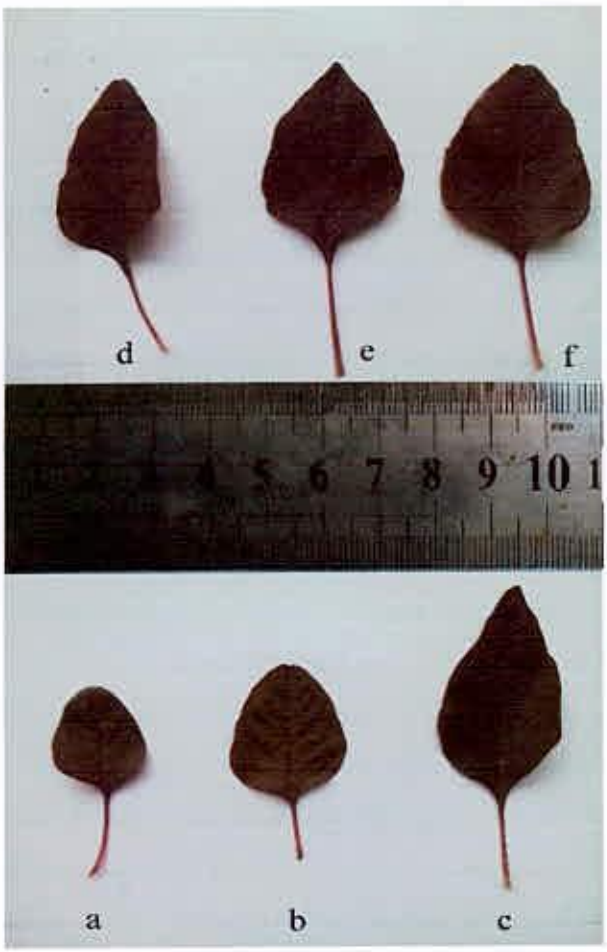
The phytohormone GA_3 regulate the major traits of red amaranth. All the parameters showed positive effect with GA_3 treatment. With the increase of GA_3 conc. the trait also increased. The 500 ppm GA_3 gave maximum length 6.317cm (Table. 9) and breadth 3.123cm (Table. 10) in red amaranth at 22 DAS. The minimum results were recorded in control treatment.

Table.9. Effect of Gibberellic acid (GA_3) on length of edible leaf (cm) of red amaranth

Treatments GA_3 Conc. (ppm)	Length of edible leaf (cm)		
	12 DAS	17 DAS	22 DAS
Control	2.190 e	3.117 e	4.133 f
100	2.530 d	3.477 d	4.530 e
200	2.817 c	3.750 c	4.867 d
300	2.817 c	3.763 c	5.327 c
400	3.540 b	4.497 b	6.023 b
500	3.827 a	4.807 a	**6.317** a
$LSD_{0.05}$	0.2153	0.2301	0.2153
CV (%)	5.392	5.386	4.295

Table.10. Effect of Gibberellic acid (GA_3) on breadth of edible leaf (cm) of red amaranth

Treatments GA_3 Conc. (ppm)	Breadth of edible leaf (cm)		
	12 DAS	17 DAS	22 DAS
Control	1.200 f	1.783 e	2.157 c
100	1.373 e	1.990 d	2.407 bc
200	1.537 d	2.217 c	2.830 a
300	2.023 c	2.383 b	2.740 ab
400	2.260 b	2.567 a	3.047 a
500	2.377 a	2.660 a	**3.123** a
$LSD_{0.05}$	0.1151	0.09965	0.3773
CV (%)	5.423	4.838	6.277



a. Control treatment
b. 100 ppm GA_3
c. 200 ppm GA_3
d. 300 ppm GA_3
e. 400 ppm GA_3
f. 500 ppm GA_3

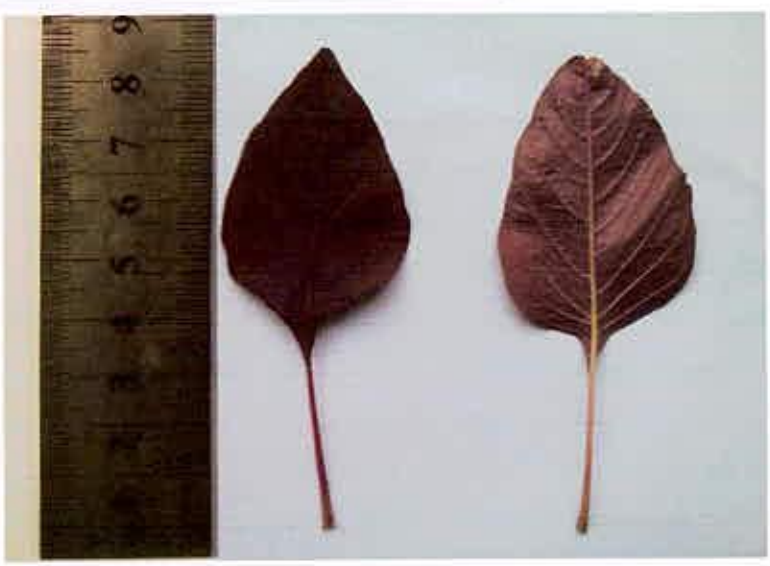


Plate.7. Leaf morphology (length and breadth) of red amaranth in different conc. of GA_3 under pot culture in net house condition

4.2.6. Weight of Plnt:

Weight of red amaranth was calculated at 22 DAS. The result was statistically significant which showed 500 ppm GA_3 exhibited maximum weight (66.33 g) and maximum of weight (84.42%) against control. The treatment 100 ppm GA_3 showed minimum weight (19.27%) (Table. 11) The calculated results showed that higher concentration of GA_3 gives more weight of red amaranth compared to less concentration of GA_3. Roy and Amaranth (2012) showed the same consequence in cabbage.

Table.11. Percent of weight increase due to application of GA_3 on red amaranth under pot culture in net house condition

Treatments with GA_3 Conc. (ppm)	Weight (at 22 DAS)	% increase of weight over control
Control	36.00 e	--
100	42.83 d	**19.27** d
200	45.50 cd	26.82 cd
300	47.33 c	31.91 c
400	61.50 b	71.24 b
500	66.33 a	**84.42** a
$LSD_{0.05}$	3.962	10.43
CV (%)	6.428	8.357

4.2.7. Growth rate of red amaranth:

Growth rate of stem length, diameter and weight in red amaranth were measured at 22 DAS by applying 100, 200, 300, 400 and 500ppm of GA_3 which were statistically significant. It is observed that 500 ppm GA_3 gave the highest result at 12 DAS and 22 DAS. The highest stem length growth rate, stem diameter growth rate and plant weight growth rates were obtained at 500 ppm GA_3 (1.19, 0.46 and 2.89) respectively. On the other hand, control of GA_3 exhibited the lowest results (0.85, 0.28 and 1.63) (Table. 12) It is concluded to tell that higher the GA_3 concentration enhanced the stem length growth rate, stem diameter growth rate and growth rate of plants.

Table.12. Effect of Gibberellic acid (GA_3) on crop growth rate of red amaranth

Treatments	Stem length growth rate	Stem diameter growth rate	Plant weight growth rate
T_0	**0.8567 d**	**0.2800 e**	**1.637 e**
T_1	0.9267 c	0.3500 c	1.947 d
T_2	0.9600 c	0.3300 d	2.067 c
T_3	0.9767 c	0.3833 b	2.150 c
T_4	1.113 b	0.426 ab	2.793 b
T_5	**1.193 a**	**0.4633 a**	**2.893 a**
$LSD_{0.05}$	0.05753	0.01819	0.09797
CV (%)	4.352	5.329	4.977

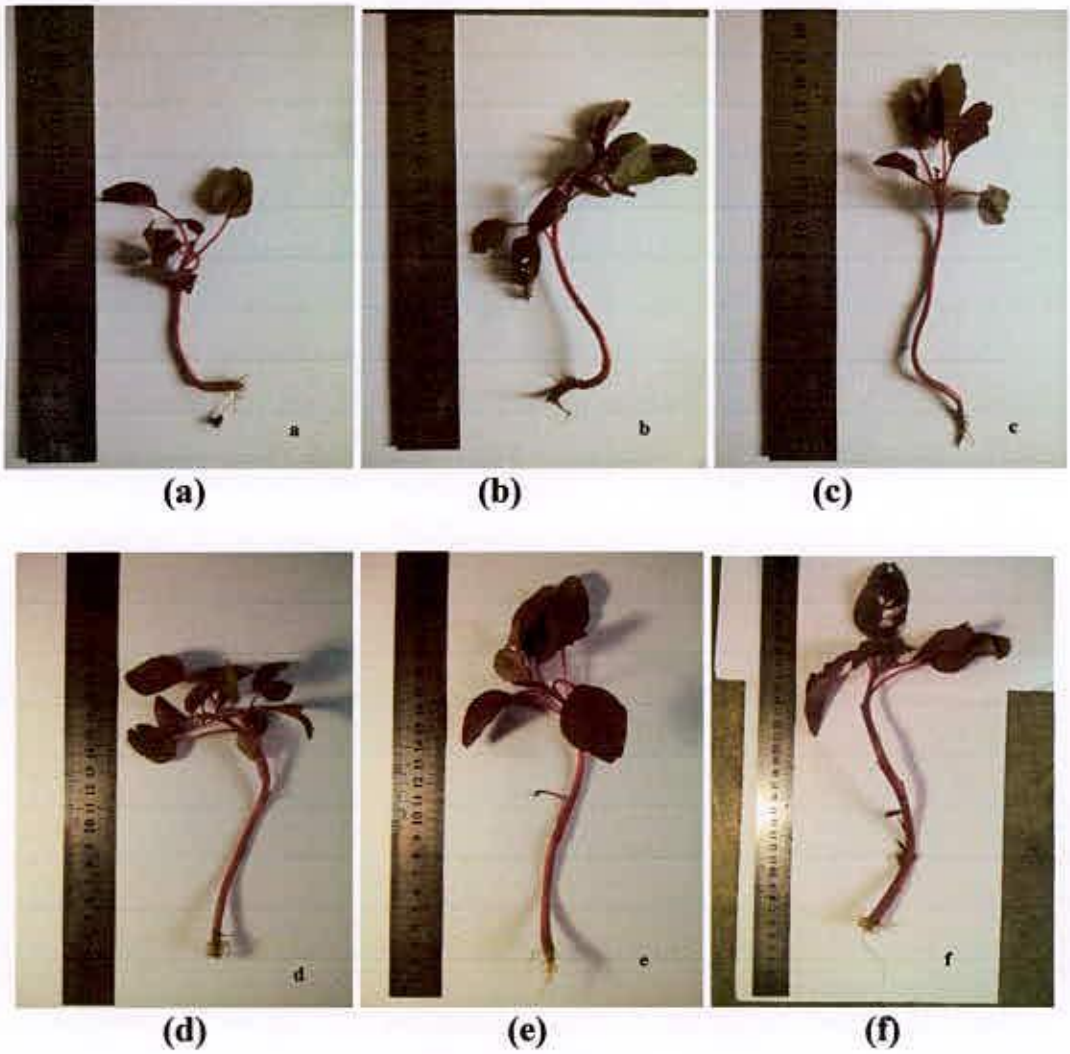


Plate.8. Leaf and stem biomass of red amaranth under different treatments with GA_3

a. Control treatment
b. 100 ppm GA_3
c. 200 ppm GA_3
d. 300 ppm GA_3
e. 400 ppm GA_3
f. 500 ppm GA_3

CHAPTER V
SUMMERY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment were conducted to study the effect of different levels of GA_3 on the growth and yield of red amaranth. The experiment comprised of five levels of GA_3 100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm concentration. The experiment was laid out in the randomized complete block design with three replications. GA_3 were applied in three equal split installments at 4 days interval that was started from 12 days after germination. The key findings were given below,

Effect of GA_3 in field condition of red amaranth

The treatment 500 ppm GA_3 showed the highest result in respect of stem length at 12, 17 and 22 DAS and it was 13.90 cm, 16.42 cm and 20.27 cm respectively whereas control of GA_3 gave the minimum output in all three times schedule.

The same treatment 500 ppm GA_3 gave the maximum outcome after 12, 17 and 22 DAS and it was 5.933 mm, 8..883 mm and 10.13 mm respectively whereas control of GA_3 gave the minimum output 4.023 mm, 4.727 mm and 6.113 mm respectively after all three times of data collection date in stem diameter.

Maximum number of edible leaf 16.53, 21.04 and 24.12 in 12, 17 and 22 DAS was observed in 400 ppm of GA_3 and it was minimum in control treatment

500 ppm GA_3 exhibited maximum weight (104.7 g) of weight against 100 ppm showed minimum weight gain (14.16g).

The highest stem length Growth rate, stem diameter growth rate and stem weight growth rate were obtained with 500 ppm of GA_3 spraying those were 1.193, 0.4633 and 2.893 respectively. On the other hand, control of GA_3 exhibited the lowest result.

Role of GA_3 in pot culture of red amaranth

Another set of experiment was conducted in polyethene pot under net house condition. The key finding were as follows,

500 ppm GA_3 gave the highest stem length at 12, 17 and 22 DAS and it was 16.30, 21.45 and 32.18 accordingly however control of GA_3 gave the lowest consequence viz. 10.03, 14.24 and 26.18 after all three times of data collection in respect of stem length.

Maximum number of edible leaf 30.01 at 22 DAS was highest in 400 ppm GA_3. However control of GA_3 gave the minimum result (13.21, 15.03 and 17.26) at all three times of data collection.

GA_3 with 500 ppm exhibited maximum weight (66.33g) with maximum gain of weight (84.42%) against 100 ppm showed minimum weight gain (19.27%).

The highest stem length growth rate, stem diameter growth rate and stem weight growth rate were obtained with 500 ppm of GA_3 spraying those were 1.193, 0.4633 and 2.893 respectively. On the other hand, control of GA_3 exhibited the lowest result (0.8467, 0.28, and 1.637) in pot culture under net house condition of red amaranth.

Conclusion:

In first experiment 500 ppm of GA_3 is the best for length of stem, diameter of stem, number of total leaf , length and breadth of edible leaf, weight gain over control of GA_3 treatment and Growth rate of red amaranth but it showed minimally for percentage of edible portion of red amaranth. Both the experiments show maximum number of edible leaf at 22 DAS which was the highest in 400 ppm GA_3 treatment.

Like first experiment, second showed the similar response with 100, 200,300,400 and 500 ppm of GA_3 spraying.

CHAPTER VI
RECOMMENDATION

CHAPTER VI

RECOMMENDATION

Plant growth regulators has position effect on edible yield and biomass increase in leafy vegetable. The present study also reported the similar trends of finding. Hence, the following recommendation may be carried out for further research.

1. More specific higher dose can be applied to study the growth pattern of red amaranth.
2. Some other phytohormones like BA, KIN or any Cytokinin group of growth regulator can be used.
3. The experiment can be repeated in other growing season of the year to study the variation of seasonal effect.
4. Biochemical study of treated and non-treated leaf of red amaranth can be studied for nutritional quality analysis.

CHAPTER VII
REFERENCE

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REFERENCES

Alvarez-Jubete L, Auty M, Arendt EK, gallagher E. 2010b. Baking properties and microstructure of pseudocereal flours in gluten-free bread formulations. Eur. Food. Res. Technol. 230:437–45.

Aykaryood.1963. the effect of amaranth grain flour on the quality of bread. Int. J. Food. Prop 4:341–51.

Bello-Pérez LA, Paredes-López O. 2009. Starches of some food crops, changes during processing and their nutraceutical potential.Food Eng Rev 1:50–65.

Bose M, Filipčev B, Kevrešan Z, Mandić A, Šimurina O. 1999. Quality of bread supplemented with popped *Amaranthus* cruentus grain. J. Food. Process Eng. 31:602–18.

Bressani R. 2003. Amaranth. In: Caballero B, editor, Encyclopedia of food sciences and nutrition. Oxford, UK: Elsevier/Academic Press. P 66–173.

Bressani, R., & Garcia-Vela, L. A. (1990). Protein fractions in amaranth grain and their chemical characterization. Journal of Agricultural and Food Chemistry. 38(5), 1205-1209.

Caselato-Sousa, V. M., & Amaya-Farfán, J. (2012). State of knowledge on amaranth grain: a comprehensive review. Journal of Food Science, 77(4), R93-R104.

Costea M, DeMason D (2001). "Stem morphology and anatomy in *Amaranthus* L. (*Amaranthaceae*) Taxonomic significance". J. Tor. Bot. Soci. 128 (3): 254–281

FAO. 2005. The state of food insecurity in the world 2004. Rome: FAO.

FAO. 2010. The state of food insecurity in the world 2009. Rome: FAO.

George GN, Platel K, Prakash J, Srinivasan K. 1989. Influence of antioxidant spices on the retention of β-carotene in vegetables during domestic cooking processes. Food Chem 84:35–43.

Gomez and Gomez. 1984. Statistical Analysis. LWT-Food Sci Technol 40:136–43.

Gupta VK, Thimba D. 1992. Grain amaranth – a promising crop for marginal areas of Kenya. Food Rev Intl 8:51–69.

Johns T, Eyzaguirre PB. 2007. Biofortification, biodiversity and diet: a search for complementary applications against poverty and malnutrition. Food Policy 32:1–24.

Kader J.1978. Rutin and total quercetin content in amaranth (*Amaranthus* spp.). Plant Food Hum Nutr 64:68–74.

Lehmann JW. 1996. Case history of grain amaranth as an alternative crop. Cereal Foods World 41:399–411.

Makus EA.1984. Effect of organic, organ mineral and NPK fertilizer on nutritional quality *amaranthus* in Lagos, Nigeria. Researcher 2:32–6.

Malkar A, Shajan A, Dua S. 2009. Salts and pH induced changes in functional properties of amaranth (*Amaranthus tricolor* L.) seed meal.Cereal Chem 79:834–7.

Malkar A, Shajan A, Dua S. 2010. Salts and pH induced changes in functional properties of amaranth (*Amaranthus tricolor* L.) seed meal.Cereal Chem 81:844–7.

Mlakar SG, Turinek M, Jakop M, Bavec M, Bazvec F. 2010. Grain amaranth as an alternative and perspective crop in temperate climate. Revija za geografijo – J. for Geo. 5:135–45.

Mohiuddeen AG, Turinek M, Tasner L, Jakop M, Bavec M, Bavec F. 1985. Organically produced grain amaranth-wheat composite flours: II. Bread quality. In: Hardi ZU, editor. Proceedings of the 4th International Congress on Flour – Bread '07. J Strossmayer Univ Osijek-Croatia, Fac Food. P 172–6.

Nath F. 1976. Grain amaranth as an alternative and perspective crop in temperate climate. Revija za geografijo – Journal for Geography 5:135–45.

National Academy of Sciences. 1985. Amaranth: modern prospects for an ancient crop. Washington, DC: Natl Acad Sci.

Prakash D, Pal M. 1991. Nutritional and antinutritional composition of vegetable and grain amaranth leaves. J Sci Food Agric57:573–83.

Prokopowicz D. 2001. Health promoting attributes of *amaranthus* (*Amaranthus cruentus*). Med Weter 57:559–61.

Schoenlechner R, Siebenhandl S, Berghofer E. 2008. Pseudocereals. In: Arendt EK, Dal Bello F, editors. Gluten-free cereal products and beverages. London: Elsevier/Academic Press. P 149–90.

Sealy M.1988.Characterization of amaranth (*Amaranthus hypochondriacus* L.) seed proteins. J Agric Food Chem 40:1553–8.

Shanmugavelu SK.1989. Variations in the polyphenol content of seeds of field grown *Amaranthus* genotypes.Food Chem 129:131–8.

Subbiah A, Dziwulska-Hunek A, Kornarzynski K. 1983. Compositional and nutritional values of amaranth seeds after pre-sowing He-Ne laser light and alternating magnetic field treatment. Intl Agrophys 23:81–6.

Teutonico RA, Knorr D. 1985. Amaranth: composition, properties and applications of a rediscovered food crop. Food Technol 39:49–61.

United Nations Development Programme.1988. Cyclodextrin production from amaranth starch by cyclodextrin glycosyltransferase produced by Paenibacillus macerans CCM 1987.

Vijayakumar P.1980. Screening of medicinal plant extracts for antioxidant activity. J Med Plants Res 3:608–12.

Winer, B. J., Brown, D. R., & Michels, K. M. (1971). Statistical principles in experimental design (Vol. 2, p. 596). New York: McGraw-Hill.

Ywalker AM. 1985. Chemical and nutritional characterization of *amaranthus* (*Amaranthus cruentus*). Arch. Lat. Nutr. 44:57–62.

CHAPTER VIII
APPENDICES

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APPENDICES

Appendix I: Analysis of variance table for stem length (cm) 12 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.786	0.393	3.9111	0.0556
2	Factor A	5	109.675	21.935	218.3483	0.0000
-3	Error	10	1.005	0.100		
Total		17	111.466			

Appendix II: Analysis of variance table for stem length (cm) 17 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	3.247	1.623	14.1514	0.0012
2	Factor A	5	116.570	23.314	203.2395	0.0000
-3	Error	10	1.147	0.115		
Total		17	120.964			

Appendix III: Analysis of variance table for stem length (cm) at 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	2.571	1.285	1.1104	0.3669
2	Factor A	5	119.074	23.815	20.5737	0.0001
-3	Error	10	11.575	1.158		
Total		17	133.220			

Appendix IV: Analysis of variance table for stem diameter at 12 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.001	0.001	0.4459	
2	Factor A	5	7.053	1.411	1010.7270	0.0000
-3	Error	10	0.014	0.001		
Total		17	7.068			

Appendix V: Analysis of variance table for stem diameter 17 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.001	0.000	0.1308	
2	Factor A	5	35.351	7.070	2189.6785	0.0000
-3	Error	10	0.032	0.003		
Total		17	35.384			

Appendix VI: Analysis of variance table for stem diameter 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.001	0.000	0.1044	
2	Factor A	5	27.344	5.469	1300.3957	0.0000
-3	Error	10	0.042	0.004		
Total		17	27.387			

Appendix VII: Analysis of variance table for number of total leaf 12 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	2.691	1.346	54.0362	0.0000
2	Factor A	5	77.106	15.421	619.2679	0.0000
-3	Error	10	0.249	0.025		
Total		17	80.046			

Appendix VIII: Analysis of variance table for number of total leaf 17 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.457	0.229	0.1072	
2	Factor A	5	261.639	52.328	24.5518	0.0000
-3	Error	10	21.313	2.131		
Total		17	283.409			

Appendix IX: Analysis of variance table for number of total leaf 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	2.156	1.078	0.3259	
2	Factor A	5	384.476	76.895	23.2395	0.0000
-3	Error	10	33.088	3.309		
Total		17	419.721			

Appendix X: Analysis of variance table for number of edible leaf 12 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	4.137	2.068	69.9684	0.0000
2	Factor A	5	77.475	15.495	524.1900	0.0000
-3	Error	10	0.296	0.030		
Total		17	81.907			

Appendix XI: Analysis of variance table for number of edible leaf 17 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.071	0.035	0.0339	
2	Factor A	5	258.396	51.679	49.5941	0.0000
-3	Error	10	10.420	1.042		
Total		17	268.887			

Appendix XII: Analysis of variance table for number of edible leaf 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	7.778	3.889	1.4532	0.2792
2	Factor A	5	318.219	63.644	23.7825	0.0000
-3	Error	10	26.761	2.676		
Total		17	352.758			

Appendix XIII: Analysis of variance table for length of edible leaf 12 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.060	0.030	0.7379	
2	Factor A	5	4.751	0.950	23.2556	0.0000
-3	Error	10	0.409	0.041		
Total		17	5.220			

Appendix XIV: Analysis of variance table for length of edible leaf 17 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.118	0.059	2.0842	0.1751
2	Factor A	5	4.018	0.804	28.3794	0.0000
-3	Error	10	0.283	0.028		
Total		17	4.419			

Appendix XV: Analysis of variance table for length of edible leaf 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.005	0.002	0.1617	
2	Factor A	5	10.679	2.136	143.5462	0.0000
-3	Error	10	0.149	0.015		
Total		17	10.833			

Appendix XVI: Analysis of variance table for breadth of edible leaf 12 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.054	0.027	8.7373	0.0064
2	Factor A	5	3.502	0.700	228.6997	0.0000
-3	Error	10	0.031	0.003		
Total		17	3.586			

Appendix XVII: Analysis of variance table for breadth of edible leaf 17 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.034	0.017	8.0880	0.0081
2	Factor A	5	1.797	0.359	172.4852	0.0000
-3	Error	10	0.021	0.002		
Total		17	1.851			

Appendix XVIII: Analysis of variance table for breadth of edible leaf 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	0.113	0.057	1.1082	0.3675
2	Factor A	5	2.265	0.453	8.8651	0.0019
-3	Error	10	0.511	0.051		
Total		17	2.889			

Appendix XIX: Analysis of variance table for wt. of 10 selected plant (g) 22 DAS

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	867.444	433.722	33.3918	0.0000
2	Factor A	5	6184.944	1236.989	95.2344	0.0000
-3	Error	10	129.889	12.989		
Total		17	7182.278			

Appendix XX: Analysis of variance table for % increase over control

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	171.855	85.927	1.5457	0.2601
2	Factor A	5	19621.353	3924.271	70.5920	0.0000
-3	Error	10	555.909	55.591		
Total		17	20349.116			

Appendix XXI: Analysis of variance table for % of edible portion(wt. basis)

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	33.333	16.667	4.3103	0.0447
2	Factor A	5	3190.500	638.100	165.0259	0.0000
-3	Error	10	38.667	3.867		
Total		17	3262.500			

Appendix XXII: Analysis of variance table for wt. of edible portion from 10 selected plant

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	523.256	261.628	23.6917	0.0002
2	Factor A	5	1508.352	301.670	27.3177	0.0000
-3	Error	10	110.430	11.043		
Total		17	2142.039			