EFFECT OF PLANT DENSITY AND PHOSPHORUS ON THE GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus viridus*)

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CERTIFICATE

This is to certify that the thesis entitled **"Effect of Plant Density and Phosphorus on the Growth and Yield of Stem Amaranth (*Amaranthus viridus*)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by Mithu Kumer Saha, Registration No. 27573/00734 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:

Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED PARENTS

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EFFECT OF PLANT DENSITY AND PHOSPHORUS ON THE **GROWTH AND YIELD OF STEM AMARANTH** (*Amaranthus viridus*)

ABSTRACT

An experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka during the period from March 2007 to June 2007 to study the effect of different plant density and Phosphorus on growth and yield of stem amaranth. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Factor A: plant density (4 levels) i.e. 15 × 20 cm (S_1), 20 × 20 cm (S_2), 25 × 20 cm (S_3), 30 × 20 cm (S_4); Factor B: Levels of phosphorus (4 levels) i.e. 48 kg P_2O_5/ha (P_1), 52.8 kg P_2O_5/ha (P_2), 57.6 kg P_2O_5/ha (P_3), 62.4 kg P_2O_5/ha (P_4). Treatment S_3 (25 × 20 cm) gave the highest yield (68.06 t/ha) at 60 DAS, while S_1 (15 × 20 cm) gave the lowest yield (35.57 t/ha). All the levels of fertilizer, which was used in the experiment showed a regular increase in yield of stem amaranth start from 30 DAS to 60 DAS. At 60 DAS, the highest (60.51 t/ha) yield was recorded from P_4 (62.4 kg P_2O_5/ha) and the lowest (45.11 t/ha) was recorded from P_1 (48 kg P_2O_5/ha). At 60 DAS, the highest (74.94 t/ha) yield was recorded from S_3P_3 (30 × 20 cm + 57.6 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the lowest yield (31.35 t/ha). The highest benefit cost ratio (3.02) was obtained from the treatment combination of S_3P_4 and the lowest (0.84) was from S_1P_1.

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CHAPTER I

INTRODUCTION

Stem amaranth (*Amaranthus viridus*) commonly used as leafy as well as stem vegetable in our country belongs to the family Amaranthaceae. This type of vegetable mainly grown during summer and is one of the important popular vegetables for its quick growth and higher yield potentiality. It is widely grown in tropical and subtropical parts of Asia, Africa and Central America (Hardwood, 1980). It is also considered as to be the cheapest vegetable in the market and it could be rigidly described as a 'poor man's vegetable in Bangladesh (Shanmugavelu, 1989).

Stem amaranth may be harvested over a considerable period of time. Its wider environmental adaptability, higher nutritive value, good taste, less risk to crop failure and various biotic and abiotic factors specify that there is enough scope for its promotional cultivation. Stem amaranth is reasonably rich in vitamin A, ascorbic acid and contains considerable amounts of iron, calcium, Phosphorus, riboflavin, thiamine, niacin and iron (Thompson and Kelly, 1988). Again it contains about 43 calorie per 100 g edible portion which is higher than that of any other common vegetables except potato and taro (Chowdhury, 1967).

Total vegetable production in our country is about 1.29 million tons per year of which 69% is produced in Rabi season and 31% in Kharif season (BBS, 2002). So, it is clear that the vegetable production in Kharif season is very low. However, the maximum production of different vegetable is concentrated during the month of November to April. Thus there is a serious scarcity of vegetables during the month of May to September. As the nation runs with an acute shortage of vegetables, its production should be increased to meet up the shortage of vegetables to feed the ever increasing population of the country. As potentiality of year round production and soil type and weather are suitable, stem amaranth can play an important role to minimize the scarcity of vegetable (Hossain, 1990; Talukder, 1999).

At present, stem amaranth is being cultivated in an area of 4000 hectare with a total production of 18,000 metric tons of green stem amaranth and the average yield is only about 35-40 tons per hectare (BBS, 2002), which is much lower as compared to other stem amaranth growing countries. To attaining considerable production and quality yield for any crop it is necessary to proper management including ensuring the proper space and availability of essential nutrient components. Stem amaranth thrives well in a fertile, clay loam soil because it requires considerable amounts of nutrients to sustain rapid growth with in short period of time. But in our country most of the stem amaranth growers cultivate this crop in fallow land with broadcasting without following any spacing and management practices including fertilizers, resulting more seeds.

Plant density for stem amaranth cultivation is an important criterion for attaining maximum yield. Densely planted crop obstruct the proper growth and development with hampering the basic requirements of plant growth. On the other hand wider spacing ensure the basic requirements but decrease the total number of plant as well as total yield. Yield may be increased upto 25% by using optimum spacing (Bansal *et al.*, 1995).

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

Phosphorus is also one of the important essential macro elements for the normal growth and development of plant. The phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). Considering as a leafy vegetable lack of phosphorus restricted the plant growth and remains immature (Hossain, 1990). Stem amaranth is as a vegetable with short durated crops, for that easily soluble fertilizer like as phosphorus should be applied in the field. On the other hand nutrient availability in a soil depends on some factors among them balance fertilizer is the important one. The optimum proportion of nitrogen and phosphorus fertilizer enhances the growth and development of a crop as well as ensuring the availability of other essential nutrients for the plant. Again secondary mechanism of interference was the absorption of phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al*., 2004). Again secondary mechanism of interference was the absorption of Phosphorus from the soil through luxury consumption, increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al*., 2004). Considering the above circumstances, the present investigation has been undertaken with the following objectives:

1. To determine the optimum plant density for growth and higher yield of stem amaranth.
2. To determine the optimum levels of Phosphorus for growth and development considering over time.
3. To measure the combined effect of plant density and Phosphorus for attaining desirable yield of stem amaranth.

CHAPTER II

REVIEW OF LITERATURE

Stem amaranth is one of the important summer vegetable in Bangladesh and as well as many countries of the world. The crop has conventional less concentration by the researchers on various aspects because normally it grows without less care or management practices. For that a very few studies on the related to growth, yield and development of stem amaranth have been carried out in our country as well as many other countries of the world. So the research work so far done in Bangladesh and is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the plant density and Phosphorus so far been done at home and abroad on this crop have been reviewed in this chapter under the following headings-

2.1 Effect of plant density

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

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

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

Field trials were conducted in South Florida, United States, between 1996 and 1999 by Santos *et al.* (2003) to determine the extent of yield reduction due to population densities of amaranthus. They recorded yield reductions reached 24% with densities higher than 8 plants/6 m row.

Missinga and Currie (2002) conducted an experiment to assess the impact of plant densities of amaranth on yield and yield contributing characters and reported that spacing didn't affected the individual plant yield but yield per hectare was greatly affected by plant spacing.

Jaishree *et al.* (1996) conducted an experiment on effect of plant populations, nitrogen and phosphate on yield and quality of amaranth during the kharif season of 1991 at densities of 111,000, 146,000 or 222,000 plants/ha and recorded the highest yield with planting 146,000 plants/ha.

Peiretti and Gesumaria (1998) conducted an experiment on inter row spacing on growth and yield of amaranth with four different row spacing and the approximately densities were 100,000, 740,000, 550,000 and 470,000 plants/ha. Both the vegetative characters and yield per plant at harvest decreased with closer row spacing, particularly at 0.30 m spacing. Yield, however, was only slightly affected or tended to increase with increase in density. Spacing at 0.30 and 0.45 m were considered the most appropriate due to the rate of inter row coverage, which offers advantages for weed control by competition. Yield increase is also facilitated by these spacing.

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

2.2 Effect of phosphorus

A field trails were conducted to investigate the influence of P application method on the critical period of amaranth by Santos *et al.* (2004) with phosphorus fertilizer at rates of 125 or 250 kg ha^{-1}, respectively. Significant differences in respect of marketable yield, fresh yield and stem diameter were recorded at harvest. Fresh yield was 20% higher in 250 kg ha^{-1} compare with 125 kg/ha P in the method of broadcasting application.

Santos *et al.* (2004) conducted a greenhouse studies to determine the influence of phosphorus concentrations on the growth of amaranth and P-absorption rate over time. For the P-competition studies mixtures were established in P-less hydroponics solutions. No biomass changes were observed in amaranth as P concentration increased. From this experiment it was recorded that the plant absorbed P luxuriously.

Rana and Rameshwar (2003) conducted an experiment in Sangla, Kinnaur, Himachal Pradesh, India during the summer seasons of 2000 and 2001 to find out the response to phosphorus fertilizer at 20, 40 and 60 P_2O_5 kg/ha rate under irrigated conditions on amaranth. Yield and yield contributing characters increased significantly with the increase in the rate of fertilizer. But maximum net returns and benefit cost ratio were obtained from the Phosphorus fertilizer application @ 40 kg P_2O_5 per hectare under irrigated conditions.

Santos *et al.* (2003) carried out a field trails in South Florida, United States, between 1996 and 1999 to determine the extent of yield reductions under two P fertility regimes. Phosphorus was applied in two ways likely broadcast at 250 kg P/ha and banded at 125 kg/ha. When P was broadcasted, yield reductions were observed approximately 20% in no weeding condition whereas 24% reductions were occurred in banded condition. Maximum yield was recorded from 250 kg P/ha treatment. On another experiment Dusky *et al.* (1996) conducted an experiment to find out the influence of phosphorus fertility in greenhouse and field condition during 1992-1993 and reported that yield was affected by phosphorus fertility and its application method.

Efficiency indexes associated with growth assimilate partitioning and P utilization was studied to evaluate the ability of amaranth to recover from P deficiency by Blanco and Ascencio (2001). Pot grown plants were irrigated either with a nutrient solution containing adequate P from 16 to 32 days after sowing or with a nutrient solution deficient in P from 16 to 23 DAS followed by a nutrient solution sufficient in P from 24 to 36 DAS. P deficiency reduced dry matter accumulation by 70%, total leaf area by 60%, leaf number by 39%, and total relative growth rate by 36%. P deficiency also reduced leaf sucrose content by almost 100%. The recovery of plants from P deficiency was followed by in increase in sucrose concentrations. The results indicated that amaranth exhibited high potential for recovery from P deficiency.

Shrefler *et al.* (1994) conducted a field studies at Belle lade, Florida to determine the influence of phosphorus fertility and method of application on the competitive interaction of amaranth. Duration of interference had little or no effect on P content and inter-specific competition between the species probably was not due to competition for P but some other factor.

Effect of a compound NPK mineral fertilizer on the growth response of amaranths resulting from inorganic nutrient sources was investigated by Agele *et al.* (2004) in under sandy clay loam soil condition. The application rate of N 150 kg/ha from NPK fertilizer result the highest maximum yield as well as economic return.

Thapa and Maity (2002) carried out a field experiment in the sandy loan of West Bengal, India during the summer seasons of 1998 and 1999 to study the effect of different N @ 50, 100 and 150 kg/ha and K_2O @ 40 and 60 kg/ha on the growth and yield of Amaranthus sp. cv. local. The response in terms of growth components such as plant height, number of leaves, and number of branches, leaf area index, yield and dry matter production was highest at the highest nutrient levels. The highest yields of 100.75, 101.5 and 112.47 q/ha was obtained from treatments with N at 150, P_2O_5 at 60 kg K_2O /ha, respectively.

A field experiment in 1985-87 at Brahmvar, Karnataka carried out by Lingaiah *et al.* (1997) on response of fertilizers on yield of fertilizer in coastal area with 6 local amaranth cultivars were given 50:25:25 kg NPK/ha and found that yield increased with increasing rate of fertilizer comparative to the control condition.

Panda *et al.* (1991) carried out a field experiment during 1989-90 on amaranth growing on acid lateritic soils with N applied at 0, 20, 40 or 60 kg/ha and P_2O_5 and K_2O applied at 0 or 20 kg/ha. P_2O_5 and K_2O were applied as a basal dose at sowing time with N applied either as a full basal dose or 50% basal and 50% as a foliar spray. Highest fresh yield (12.7 t/ha) and protein content (4.9 g/100 g) were obtained with 60 kg N+20 kg P_2O_5+20 kg K_2O/ha with N applied as a full basal dose. The same treatment but with N applied as 50% basal + 50% foliar spray resulted in the next highest yield and protein content.

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

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

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

A comparative study on yield and quality of some amaranth genotypes was done by Hossain (1990) in the Bangabandhu Sheikh Mujibur Rahman Agricultural University. Fertilizer dose was cowdung, urea, triple super phosphate and muriate of potash as 20 t, 200, 100 and 200 kg/ha, respectively. Different growth and yield contributing characters were evaluated and found highest yield 81.24 t/ha with maximum doses of fertilizer combination.

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

An experiment was conducted by Quasem and Hossain (1995) to evaluate 16 germplasm of local stem amaranths in summer at the rate of fertilizer doses of 210 kg urea, 100 kg triple super phosphate band 200 kg muriate of potash per ha respectively . Plant height at last harvest was found the maximum in SAT 0034 as 88.3 cm and the highest yield was recorded in SAT 0054 as 54 t/ha .

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

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

Hamid *et al*. (1989) in a experiment use 200 kg urea, 100 kg triple super phosphate and 200 kg muriate of potash per ha and reported that significant variation were present among 12 amaranth lines (4 exotic and 8 local) for plant diameter were positively correlated with yield. The exotic germplasm AM0008 was the highest yielding, producing 234.40 t/ha.

Among the local germplasm highest yield produced 122.40 t/ha and lowest yield was 42.80 t/ha. Plant height of some exotic and local lines varied from 70.20 to 131.60 cm. The number of leaves and plant diameter per plant in local cultivars was ranged from 72 to 162 and 5.30 to 9.30 mm respectively.

Moniruzzman (1987) reported that optimum yield of amaranth could be found at the rate of 10-12 ton cowdung, 12 kg urea, 8-10 kg triple super phosphate and 5-7 kg muriate of potash per bigha respectively. A study was conducted by Mohyideen *et al.* (1983) to ascertain the yield potential of grain type's amaranth. Fertilizer dose were 85 kg N, 60 kg P and 60 kg per hectare respectively. Eight grain amaranth types were evaluated for yield and yield attributes. Highest plant height was recorded as 172.5 cm. In Himachal Pradesh, in a study NPK at rate of 60, 50 30 kg per hectare, respective4ly, were recommended for getting the best yield of vegetables.

Grubben *et al.* (1981) in an experiment on amaranth recommended fertilizer dose of amaranth as a mixture of 10-10-20 N-P-K applied at 400 kg/ha for plants to uprooted and at 600 kg/ha for plant to be harvest respectively.

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

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental Site

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

3.2 Characteristics of Soil

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

3.3 Weather Condition of the Experimental Site

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

3.4 Planting Materials

In this research work, the seeds of stem amaranth were used. It is a green stem and leafy type, quick growing short duration summer vegetable collected from Dhaka Seed Store, Siddique Bazar, Dhaka.

3.5 Treatment of the Experiment

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

Factor A: Four levels of plant density

i. $S_1 = 15 \times 20$ cm
ii. $S_2 = 20 \times 20$ cm
iii. $S_3 = 25 \times 20$ cm
iv. $S_4 = 30 \times 20$ cm

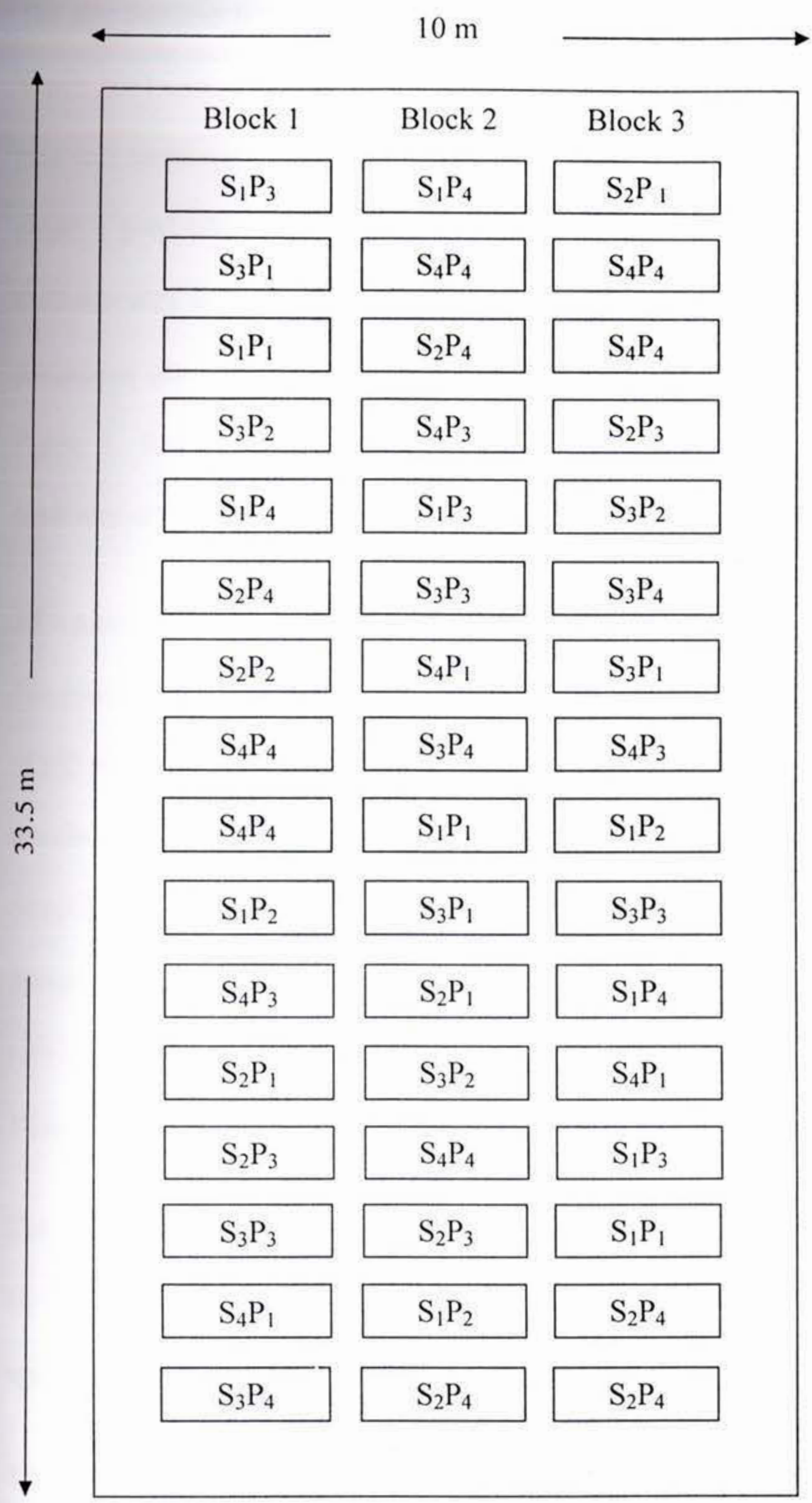
Factor B: Four levels of phosphorus

i. $P_1 = 48$ kg P_2O_5/ha
ii. $P_2 = 52.8$ kg P_2O_5/ha
iii. $P_3 = 57.6$ kg P_2O_5/ha
iv. $P_4 = 62.4$ kg P_2O_5/ha

There were 16 (4 × 4) treatment combinations such as S_1P_1, S_1P_2, S_1P_3, S_1P_4, S_2P_1, S_2P_2, S_2P_3, S_2P_4, S_3P_1, S_3P_2, S_3P_3, S_3P_4, S_4P_1, S_4P_2, S_4P_3 and S_4P_4.

3.6 Design and Layout of the Experiment

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



Plot size = 2.0 m × 1.5 cm
Plot spacing = 0.5 m
Between replication = 1.0 m

Factors A:

S_1 = 15 × 20 cm
S_2 = 20 × 20 cm
S_3 = 25 × 20 cm
S_4 = 30 × 20 cm

Factors B:

P_1 = 48 kg P_2O_5/ha
P_2 = 52.8 kg P_2O_5/ha
P_3 = 57.6 kg P_2O_5/ha
P_4 = 62.4 kg P_2O_5/ha

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

3.7 Land preparation

The plot selected for conducting the experiment first was opened in the second week of March 2007 with a power tiller, and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth condition. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil for sowing of stem amaranth seeds. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in Figure 1. Recommended doses of well-decomposed cowdung manure and chemical fertilizers as indicated in below were mixed with the soil of each unit plot.

3.8 Application of Manure and Fertilizers

The sources of N and K_2O as urea and MP were applied, respectively. The entire amounts of MP were applied during the final preparation of land. Urea was applied in three equal installments at 15, 30 and 45 days after seed sowing of stem amaranth. Well-rotten cowdung 10 t/ha also applied during final land preparation. The following amount of manures and fertilizers were used which shown as tabular form recommended by Rashid (1993).

Dose and method of application of fertilizers in stem amaranth field

Cow dung 10 ton/ha, phosphorus (P_2O_5) as per treatments and murate of potash (K_2O) 120 Kg/ha were applied as basal dose during land preparation. Nitrogen 200 Kg/ha were applied in three equal installments of fifteen days interval as top dressing.

3.9 Intercultural operation

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

3.9.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening upto 1st thinning. Further irrigation was provided and when needed. Stagnant water was effectively drained out at the time of heavy rain.

3.9.2 Thinning

First thinning were done 15 days after sowing (DAS), 2nd thinning were done 15 days after the first and 3rd and 4th were done 15 days interval for proper growth and development of stem amaranth seedlings.

3.9.3 Weeding

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

3.9.4 Top Dressing

After basal dose, the remaining doses of urea were top-dressed in 3 equal installments at 15 DAS, 30 DAS and 45 DAS. The fertilizers were applied on both sides of plant rows and mixed well with the soil. Eathing up operation was done immediately after top-dressing with nitrogen fertilizer.

3.10 Plant Protection

For controlling leaf caterpillars Nogos @ 1 ml/L water were applied 2 times at an interval of 10 days starting soon after the appearance of infestation. There was no remarkable attack of disease.

3.11 Harvesting

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

3.12 Data Collection

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

3.12.1 Stem length

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

3.12.2 Stem diameter

Stem diameter of stem amaranth plant was measured in centimeter (cm) with a thread and then in a meter scale as the outer surface of the stem. Data were recorded as the average of

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

3.12.3 Number of leaves per plant

The total number of leaves arise from the main stem of a plant was counted as the number of leaves per plant. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot starting from 30 DAS to 60 DAS at 10 days interval.

3.12.4 Length of leaf

The length of leaves was measured by using a meter scale. The measurement was taken from base to tip of the leaf. Data were recorded as the average of 10 leaves selected at random from the inner rows plant of each plot starting from 30 DAS to 60 DAS at 10 days interval. Thus mean was recorded and expressed in centimeter (cm).

3.12.5 Leaf breadth

The breadth of leaves was measured by using a meter scale. The measurement was taken from one side to another side of the leaf. Data were recorded as the average of 10 leaves selected at random from the inner rows plant of each plot starting from 30 DAS to 60 DAS at 10 days interval. Thus mean was recorded and expressed in centimeter (cm).

3.12.6 Petiole length

The length of petiole was measured by using a meter scale. The measurement was taken from junction to the stem to the starting point of leaf base. Data were recorded as the average of 10 petiole selected at random from the plant of inner rows of each plot starting from 30 to 60 DAS at 10 days interval. Thus mean was recorded and expressed in centimeter (cm).

3.12.7 Fresh weight of stem per plant

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

3.12.8 Fresh weight of leaves per plant

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

3.12.9 Dry matter of stem per plant

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

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

3.12.10 Dry matter of leaves per plant

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

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

3.12.11 Green Yield

Yield of stem amaranth per plot was recorded as the whole plant in every harvest within a plot (2.0 m × 1.5 m) and was expressed in kilogram. Yield included weight of stem with leaves and total at different harvested time.

3.12.12 Green Yield

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

3.13 Statistical Analysis

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

3.14 Economic analysis

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

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

Chapter IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of plant density and phosphorous on growth and yield of stem amaranth. Data on different yield contributing characters and yield at different days after sowing (DAS) was recorded for find out the optimum plant density and levels of phosphorous. The analysis of variance (ANOVA) of the data on different yield components and yield of stem amaranth are given in Appendices. The results have been presented and discussed, and possible interpretations have been given in this chapter.

4.1 Stem length

Stem length varied statistically due to the plant density at 30, 40, 50 and 60 (Figure 2). The longest stem length (39.60 cm) at all observations was observed from the plot where plant density was 30 × 20 cm (S_4) at 30 DAS, while the shortest (29.28 cm) was recorded for spacing 15 × 20 cm at 30 DAS (Figure 1). The longest stem (65.71 cm) was observed from 30 × 20 cm plant density, while the shortest (52.55 cm) was observed from 15 × 20 cm at 40 DAS. At 50 DAS the longest stem (85.93 cm) was recorded from S_4 and the shortest (72.69 cm) was from S_1. The longest (100.37 cm) stem length was found from S_4 at 60 DAS, while S_1 (15 × 20 cm) gave the shortest (87.55 cm). The results indicated wider spacing increases the growth and development of plant which ensure the maximum stem length of plant. The results of this study are comparable to the findings of Vijayakumar *et al.* (1982) who recorded stem height at 30 DAS and ranged from 16.05-57.25 cm, at 40 DAS it ranged from 34.95-70.25 cm and 60 DAS ranged from 65 -122.15 cm.

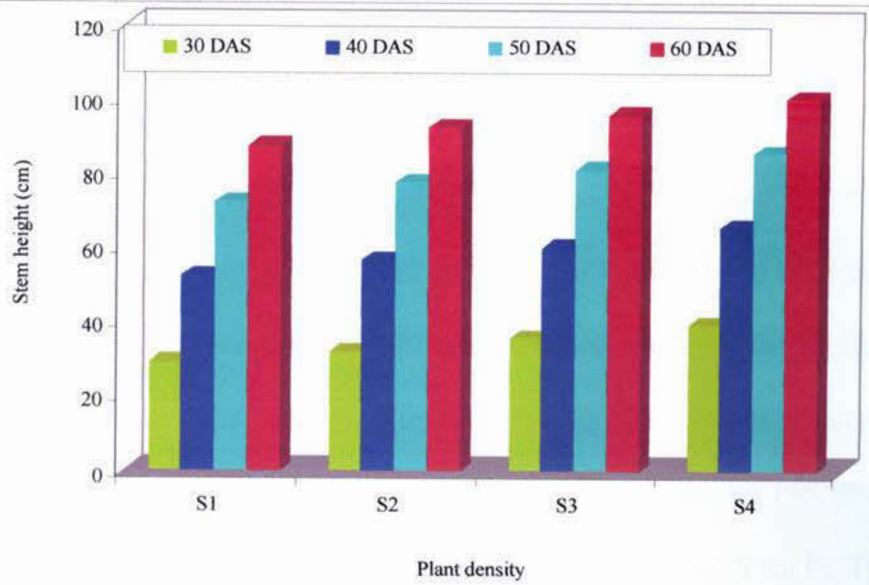


Figure 2. Effect of plant density on the stem height of stem amaranth

$S_1 = 15 \times 20$ cm $S_2 = 20 \times 20$ cm

$S_3 = 25 \times 20$ cm $S_4 = 30 \times 20$ cm

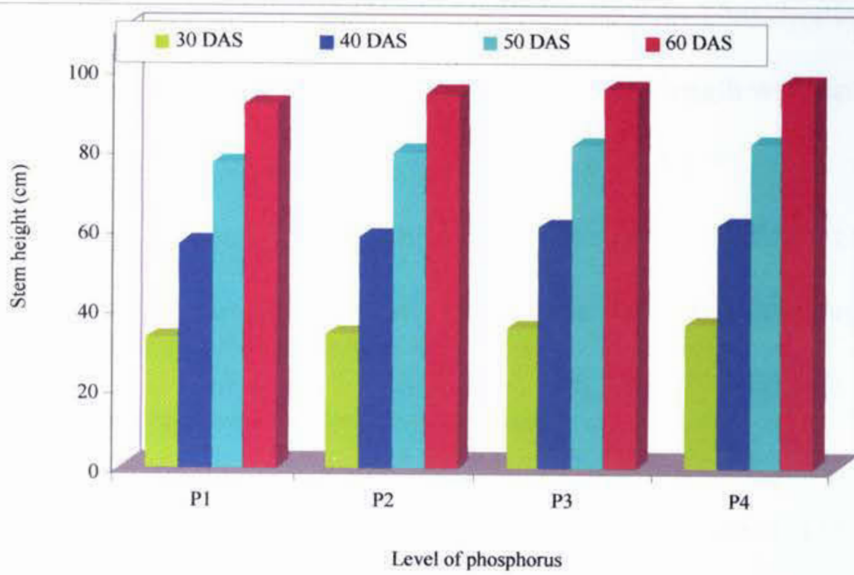


Figure 3. Effect of phosphorus on stem height of stem amaranth

$P_1 = 48$ kg P_2O_5/ha $P_2 = 52.8$ kg P_2O_5/ha

$P_3 = 57.6$ kg P_2O_5/ha $P_4 = 62.4$ kg P_2O_5/ha

A statistically significant variation was recorded in respect of stem length with different levels of Phosphorus (Figure 3). Although all the levels of fertilizer, which was used in the present experiment, showed an increasing trend in height of stem amaranth start from 30 to 60 DAS. The longest (35.85 cm) stem length was recorded from P_4 (62.4 kg P_2O_5) at 30 DAS and the shortest (32.52 cm) was recoded in P_1 (48 kg P_2O_5). At 40 DAS the longest (60.94 cm) stem length was recorded from P_4 treatment and the shortest (56.18 cm) was found from P_1. The longest (81.34 cm) gave the stem length at 50 DAS was recorded from P_4, while P_1 showed the shortest (76.61 cm). At 60 DAS the longest (96.50 cm) stem length was recorded from P_4 and the shortest (91.17 cm) was recorded from P_1. The results indicated that Phosphorus fertilizer increases the growth and development as well as ensure the availability of other nutrients for plant and the ultimate results is the maximum stem length than other condition. Similar results also reported by Agele *et al.* (2004) from their experiment.

Plant density and Phosphorus showed significant differences in consideration of stem length of stem amaranth (Table 1). The longest (41.80 cm) stem length was recorded at 30 DAS from the combination of S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), which was statistically similar with S_4P_2 and S_4P_3 and the treatment combination of S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (27.91 cm) stem length. At 40 DAS the longest (70.15 cm) stem length was recorded from the combination of S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while the combination S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (48.52 cm) stem length. The longest (88.53 cm) stem length was recorded at 50 DAS from the combination of S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while the combination of S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (67.25 cm) stem length. At 60 DAS the longest (104.43 cm) stem length was recorded from the combination of S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while the combination of S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (81.48 cm) stem length. From 30 DAS to 60 DAS stem length showed an increasing trend under the trial. With the higher spacing and higher level of Phosphorus fertilizer ensure the availability of nutrients in the soil and the ultimate results maximum photosynthesis as well as highest growth of the plant.

4.2 Stem diameter

Due to the plant density stem diameter varied statistically at 30, 40, 50 and 60 DAS (Figure 4). At 30 DAS the maximum (14.51 mm) stem diameter was observed from the plot where the widest plant density (30 × 20 cm) and the minimum (10.78 mm) were recorded from the closed spacing (15 × 20 cm). The maximum (18.73 mm) stem diameter was observed from S_4 (30 × 20 cm), while the minimum (14.55 mm) was recorded from S_1 (15 × 20 cm) at 40 DAS. At 50 DAS the maximum (23.05 mm) stem diameter was recorded from S_4 and the minimum (18.66 mm) was from S_1. From the widest plant density (30 × 20 cm) S_4 gave the maximum stem diameter (25.89 mm), while S_1 gave the minimum (21.28 mm) at 60 DAS. The results indicated that the wider spacing increases the growth and development of plant which ensure the maximum stem diameter of plant.

A statistically significant variation was recorded in terms of stem diameter in relation with different levels of Phosphorus (Figure 5). Although all the levels of Phosphorus showed a regular increase in diameter of stem amaranth start from 30 to 60 DAS. At 30 DAS the maximum (13.06 mm) stem diameter was recorded in P_4 and the minimum (11.94 mm) was recoded in P_1. At 40 DAS the maximum (17.22 mm) stem diameter was observed from P_4 and the minimum (15.85 mm) was observed from P_1. Treatment P_4 gave the maximum (21.56 mm) stem diameter at 50 DAS, while P_1 gave the minimum (20.21 mm). At 60 DAS the maximum (24.22 mm) stem diameter was recorded from P_4 and the

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Table 1. Combined effect of plant density and phosphorus on stem length and diameter of stem amaranth

Treatment Combination	Stem length (cm) at				Stem diameter (mm) at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1P_1	27.91 j	48.52 g	67.25 g	81.48 j	10.26 h	13.67 g	17.29 g	19.91 h
S_1P_2	29.01 j	53.22 efg	75.22 def	90.10 hi	10.77 gh	14.84 efg	19.37 def	22.07 efg
S_1P_3	30.29 hij	55.68 def	74.68 ef	89.64 i	11.04 fgh	14.60 fg	18.74 fg	21.34 gh
S_1P_4	29.92 ij	52.79 fg	73.59 f	89.01 i	11.03 fgh	15.07 efg	19.25 ef	21.80 fgh
S_2P_1	30.12 ij	55.04 def	76.37 def	91.02 ghi	11.89 efg	15.92 def	20.54 cde	23.06 defg
S_2P_2	31.27 ghij	56.11 def	77.36 cdef	91.98 fghi	11.18 fgh	15.12 efg	19.66 def	22.27 efg
S_2P_3	32.74 fghi	57.49 cdef	78.60 bcdef	93.28 efgh	12.24 ef	16.31 de	20.82 bcdef	23.46 cdef
S_2P_4	33.76 fghi	58.47 cde	79.47 de	94.12 defg	11.91 efg	16.07 def	20.57 cdef	23.22 cdefg
S_3P_1	34.29 fgh	58.95 cd	79.92 bcde	94.60 def	12.39 def	16.37 de	21.03 bcde	23.68 bcdef
S_3P_2	34.78 defg	59.41 cd	80.33 bcde	94.99 cdef	12.76 de	16.90 cd	21.40 bcd	24.10 cde
S_3P_3	36.06 cdef	60.60 cd	81.45 bcd	96.12 cde	12.70 de	16.88 cd	21.38 bcd	24.06 bcde
S_3P_4	37.92 bcd	62.37 bc	83.75 ab	98.45 bc	13.79 bcd	17.99 bc	22.52 abc	25.21 abc
S_4P_1	37.77 bcde	62.24 bc	82.89 abc	97.58 cd	13.23 cde	17.42 cd	21.98 abc	24.67 abcd
S_4P_2	38.70 abc	63.09 bc	83.66 ab	98.36 bc	14.18 abc	18.39 abc	22.82 ab	25.63 ab
S_4P_3	40.15 ab	67.35 ab	88.63 a	101.12 b	15.12 ab	19.35 ab	23.50 a	26.62 a
S_4P_4	41.80 a	70.15 a	88.53 a	104.43 a	15.50 a	19.75 a	23.90 a	26.66 a
$LSD_{(0.05)}$	3.254	4.901	5.426	3.225	1.271	1.462	1.827	1.833
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.71	4.99	4.09	2.05	6.10	5.30	5.24	4.66

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

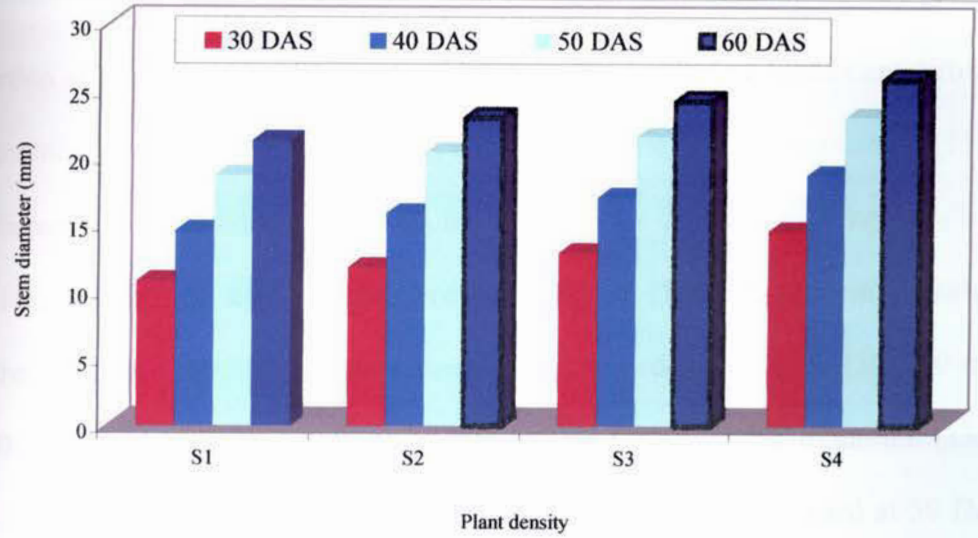

Figure 4. Effect of plant density on stem diameter of stem amaranth

$S_1 = 15 \times 20$ cm $S_2 = 20 \times 20$ cm
$S_3 = 25 \times 20$ cm $S_4 = 30 \times 20$ cm

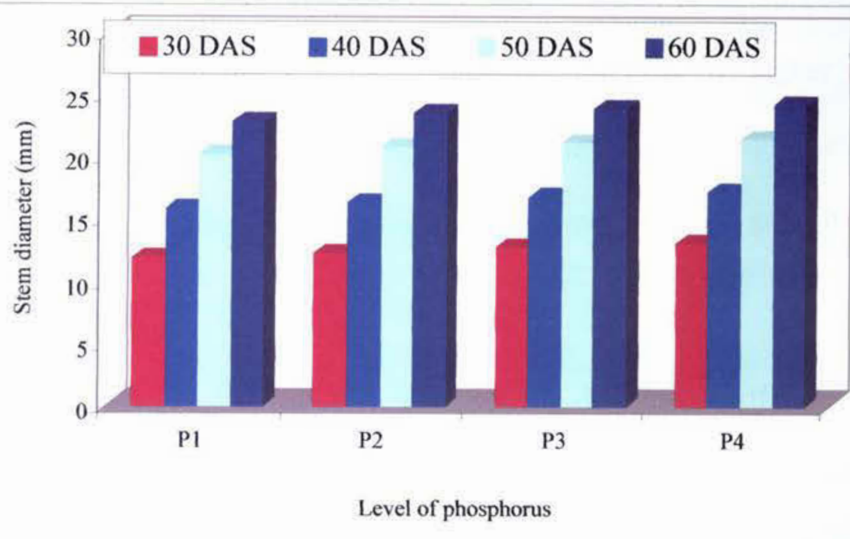

Figure 5. Effect of phosphorus on stem diameter of stem amaranth

$P_1 = 48$ kg P_2O_5 /ha...............$P_2 = 52.8$ kg P_2O_5 /ha
$P_3 = 57.6$ kg P_2O_5/ha $P_4 = 62.4$ kg P_2O_5 /ha

minimum (20.21 mm) was recorded from P_1. The results indicated that Phosphorus fertilizer increases the growth and development as well as ensure the availability of other nutrients for plant and the ultimate results is the maximum stem diameter.

Interaction effect between plant density and Phosphorus showed significant differences in consideration of stem diameter of stem amaranth (Table 1). The maximum (15.50 mm) stem diameter was recorded at 30 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (10.26 mm) stem diameter. At 40 DAS the maximum (19.75 mm) stem diameter was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (13.67 mm) stem diameter. The maximum (23.93 mm) stem diameter was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (17.29 mm) stem diameter. At 60 DAS the maximum (26.66 cm) stem diameter was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (19.91 mm) stem diameter. From 30 DAS to 60 DAS stem diameter showed an increasing trend under the trial. With the higher spacing and higher level of Phosphorus fertilizer ensure the availability of nutrients materials in the soil and the ultimate results maximum photosynthesis as well as highest growth of the plant.

4.3 Number of leaves

Number of leaves per plant varied significantly due to the different plant density at 30 DAS, 40 DAS, 50 DAS and 60 DAS (Figure 6). The maximum (19.40) number of leaves was observed from the plot where plant density was 30 × 20 cm, while the minimum (10.74) was found from the plot where the spacing 15 × 20 cm at 30 DAS. The maximum (24.81) number of leaves was observed from S_4 (30 × 20 cm), while the minimum (16.70) was found from S_1 (30 × 20 cm plant density) at 40 DAS. At 50 DAS the maximum

(37.01) number of leaves was recorded from S_4 and the minimum (29.16) was found from S_1. Treatment S_4 gave the maximum (44.96) number of leaves, while S_1 (15 × 20 cm) gave the minimum (36.70) at 60 DAS. The results indicated wider spacing increases the growth and development of plant which ensure the maximum number of leaves of plant.

A significant variation was recorded in respect of number of leaves in relation with different levels of Phosphorus (Figure 7). The maximum number of leaves (16.65) was recorded in P_4 at 30 DAS and the minimum (13.85) was recoded in P_1. At 40 DAS the maximum (22.45) number of leaves was recorded from P_4 and the minimum (20.08) was observed from P_1. Treatment P_4 gave the maximum (34.95) number of leaves, while P_1 gave the minimum (32.06) at 50 DAS. At 60 DAS the maximum (43.18) number of leaves was recorded from P_4 and the minimum (39.36) was recorded from P_1. The results indicated that Phosphorus fertilizer increases the growth and development. Similar trends of results also reported by Agele *et al.* (2004) from their experiment.

Interaction effect between plant density and Phosphorus showed significant differences in consideration of number of leaves of stem amaranth (Table 2). The maximum (21.02) number of leaves was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (9.42) number of leaves at 30 DAS. At 40 DAS the maximum (26.93) number of leaves was found from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (15.55). The maximum (38.03) number of leaves was recorded at 50 DAS from S_4P_3 (30 × 20 cm + 57.6 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (28.07). At 60 DAS the maximum (46.51) number of leaves was recorded

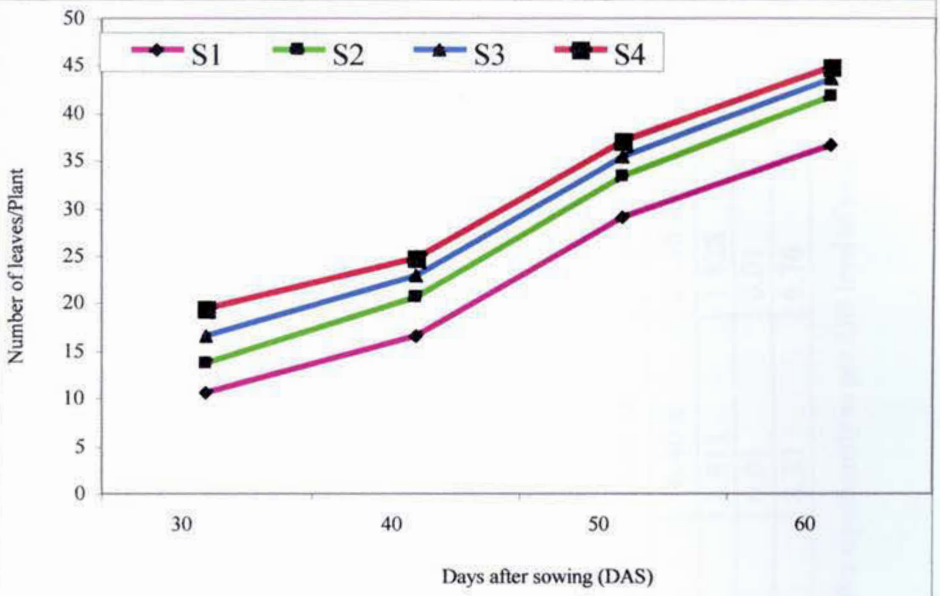

Figure 6. Effect of plant density on number of leaves of stem amaranth

$S_1 = 15 \times 20$ cm $S_2 = 20 \times 20$ cm

$S_3 = 25 \times 20$ cm $S_4 = 30 \times 20$ cm

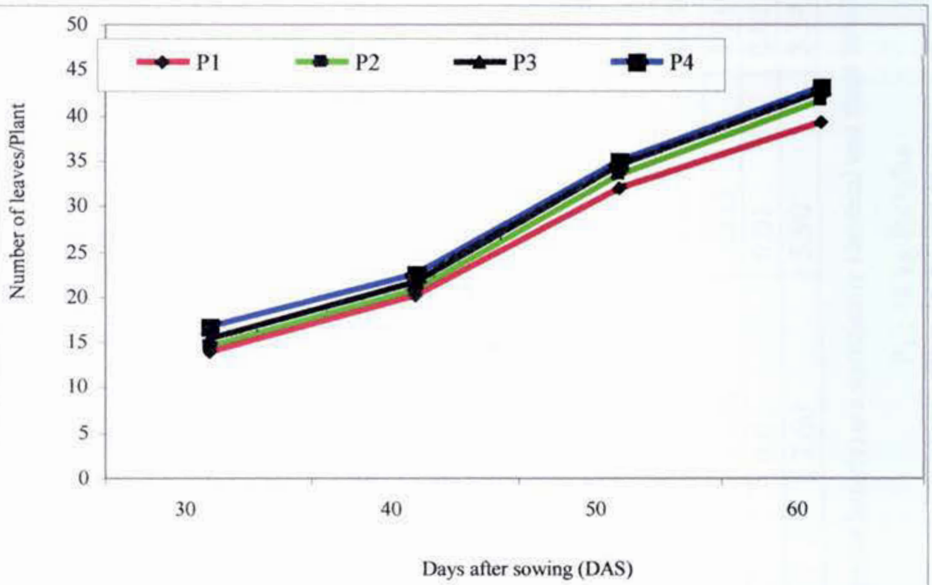

Figure 7. Effect of phosphorus on number of leaves of stem amaranth

$P_1 = 48$ kg P_2O_5/ha $P_2 = 52.8$ kg P_2O_5/ha

$P_3 = 57.6$ kg P_2O_5/ha $P_4 = 62.4$ kg P_2O_5/ha

Table 2. Combined effect of plant density and phosphorus on number and length of leaves of stem amaranth

Treatment Combination	Number of leaves				Length of leaves (cm)			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1P_1	9.42 j	15.55 h	28.07 d	34.55 g	6.34 i	10.13 h	13.30 i	16.50 g
S_1P_2	10.39 ij	16.35 h	28.62 d	36.35 fg	6.87 hi	10.56 gh	13.70 hi	17.93 fg
S_1P_3	10.84 hij	17.08 gh	29.32 d	37.60 efg	7.51 ghi	11.18 fgh	14.31 ghi	18.53 ef
S_1P_4	12.29 ghi	17.83 fgh	30.63 cd	38.30 efg	8.27 fghi	11.96 efgh	14.99 fghi	19.56 def
S_2P_1	12.44 ghi	19.48 efg	31.06 cd	39.56 def	8.50 fgh	12.19 defg	15.24 efghi	19.51 def
S_2P_2	13.28 fgh	20.27 def	33.29 bc	41.72 bcde	7.26 fgh	11.05 fgh	14.07 ghi	8.29 efg
S_2P_3	14.36 efg	21.28 cde	34.27 abc	42.66 abcd	8.99 ghi	12.63 def	15.67 fgh	20.00 def
S_2P_4	15.11 ef	21.99 cde	34.95 ab	43.32 abcd	8.64 efgh	12.31 defg	15.34 efghi	19.65 def
S_3P_1	15.50 ef	22.36 bcde	33.54 bc	40.83 cde	9.26 efg	12.89 def	15.95 efg	20.22 de
S_3P_2	15.86 de	22.69 bcd	35.63 ab	43.98 abc	9.84 def	13.43 cde	16.47 def	20.79 cd
S_3P_3	16.80 cde	23.58 bc	36.48 ab	44.80 abc	9.79 def	13.38 cde	16.43 def	20.77 cd
S_3P_4	18.16 bcd	23.04 bcd	36.55 ab	44.58 abc	11.46 bcd	14.96 abc	17.98 bcd	22.50 abc
S_4P_1	18.06 bcd	22.94 bcd	35.57 ab	42.51 abcd	10.66 cde	14.21 bcd	17.24 cde	21.65 bcd
S_4P_2	18.74 abc	24.18 abc	36.78 ab	44.80 abc	12.04 abc	15.50 ab	18.50 abc	22.91 ab
S_4P_3	19.80 ab	25.18 ab	38.03 a	46.02 ab	12.90 ab	15.83 ab	19.81 ab	23.73 a
S_4P_4	21.02 a	26.93 a	37.67 a	46.51 a	13.51 a	16.40 a	20.36 a	23.98 a
$LSD_{(0.05)}$	2.323	2.698	3.323	3.718	1.850	1.811	1.828	1.864
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	9.21	7.60	5.90	5.34	11.69	8.33	6.76	5.48

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (34.55) number of leaves. From 30 DAS to 60 DAS number of leaves showed an increasing trend under the trial. With the wider spacing and higher levels of Phosphorus fertilizer resulted the maximum trends of growth.

4.4 Length of leaf

Length of leaf varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Figure 8). The longest (12.28 cm) length of leaf was observed from the plot where plant density was 30 × 20 cm at 30 DAS, while the shortest (7.25 cm) was recorded for spacing 15 × 20 cm at 30 DAS. At 40 DAS the longest (15.48 cm) length of leaf was observed from S_4, while the shortest (10.96 cm) was from S_1. The longest (18.98 cm) length of leaf was recorded from S_4 and the shortest (14.07 cm) was found from S_1 at 50 DAS. Treatment S_4 gave the longest length of leaf (23.07 cm) at 60 DAS, while S_1 (15 × 20 cm) gave the shortest (18.13 cm). The results indicated wider spacing increases the growth and development of plant which ensures the maximum length of leaf of plant.

A statistically significant variation was recorded in terms of length of leaf in relation with different levels of Phosphorus (Figure 9). Although all the level of this fertilizer, which was used as in the present experiment, showed a regular increase in length of leaf of stem amaranth start from 30 to 60 DAS. The longest length of leaf (10.47 cm) was recorded in P_4 at 30 DAS and the shortest (8.69 cm) was observed in P_1. At 40 DAS the longest (13.26 cm) length of leaf was recorded from P_4 and the shortest (12.35 cm) was from P_1. Treatment P_4 gave the longest (17.17 cm) length of leaf at 50 DAS, while the P_1 gave the shortest (15.43 cm). At 60 DAS the longest (21.42 cm) length of leaf was recorded from P_4 and the shortest (19.47 cm) was recorded from P_1 . The results indicated

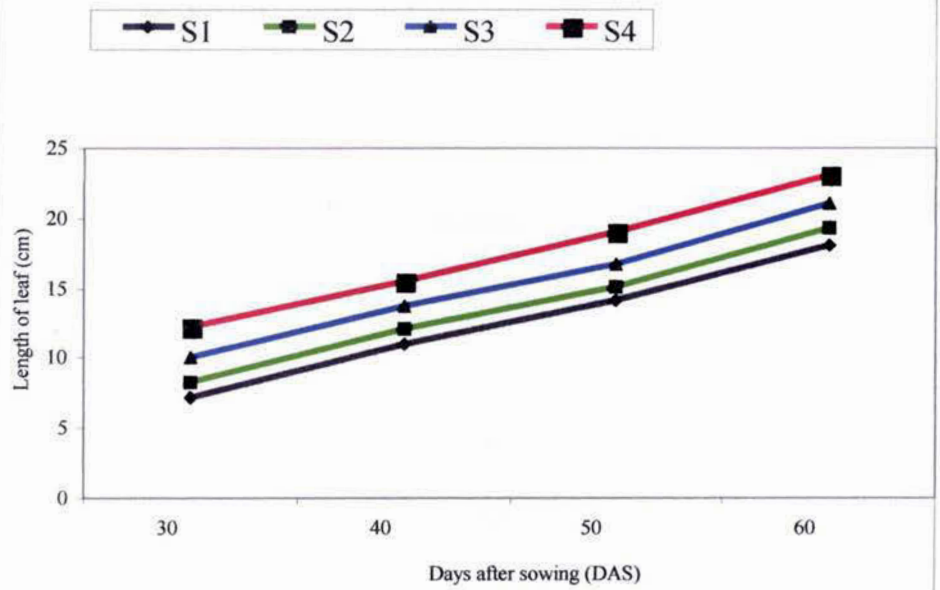

Figure 8. Effect of plant density on length of leaf of stem amaranth

S_1 = 15 × 20 cm S_2 = 20 × 20 cm

S_3 = 25 × 20 cm S_4 = 30 × 20 cm

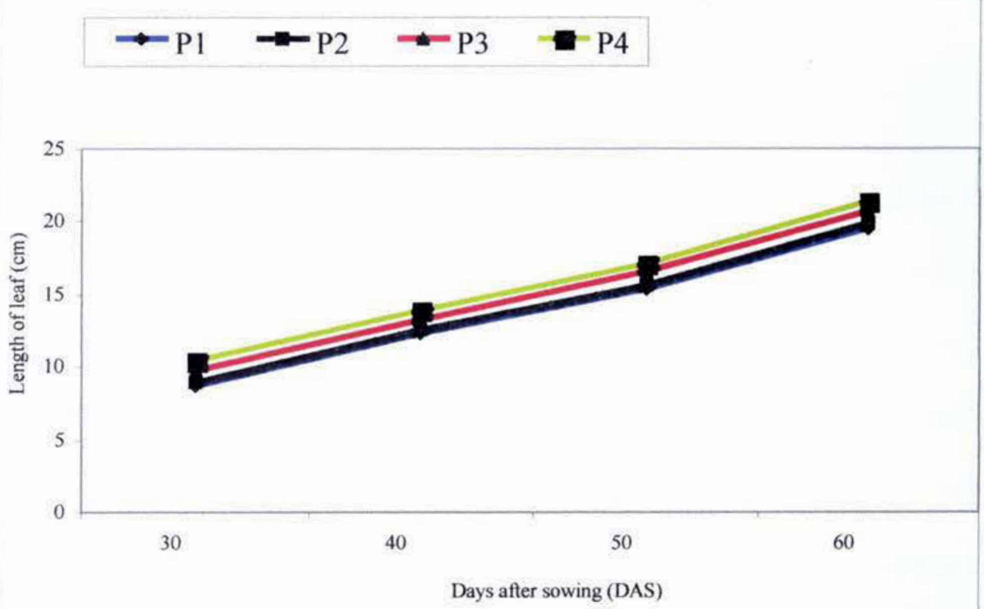

Figure 9. Effect of phosphorus on length of leaf of stem amaranth

P_1 = 48 kg P_2O_5/ha P_2 = 52.8 kg P_2O_5/ha

P_3 = 57.6 kg P_2O_5/ha P_4 = 62.4 kg P_2O_5/ha that Phosphorus fertilizer increases the growth and development of the plants which enhanced the maximum length of leaves.

Interaction effect between plant density and Phosphorus showed a significant differences in consideration of length of leaf of stem amaranth (Table 2). The longest (13.51 cm) length of leaf was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (6.34 cm) length of leaf at 30 DAS. At 40 DAS the longest (16.40 cm) length of leaf was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (10.13 cm) length of leaf. The longest (20.36 cm) length of leaf was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (13.30 cm) length of leaf at 50 DAS. The longest (23.98 cm) length of leaf was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (16.50 cm) length of leaf at 60 DAS.

4.5 Breadth of leaf

Breadth of leaf varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Figure 10). The longest (6.45 cm) breadth of leaf at all observations was observed from the plot where plant density was 30 × 20 cm at 30 DAS, while the shortest (4.63 cm) was recorded from the spacing 15 × 20 cm (S_1) at 30 DAS. The longest (7.31 cm) breadth of leaf was observed from S_4, while the shortest (5.56 cm) was found from S_1 at 40 DAS. At 50 DAS the longest (8.25 cm) breadth of leaf was recorded from S_4 and the shortest (6.66 cm) was from S_1. Treatment S_4 gave the longest breadth of leaf (8.60 cm) at 60 DAS, while S_1 (15 × 20 cm) gave the shortest (7.39 cm). The results indicated wider spacing increases the growth and development of plant which ensure the maximum breadth of leaf of plant.

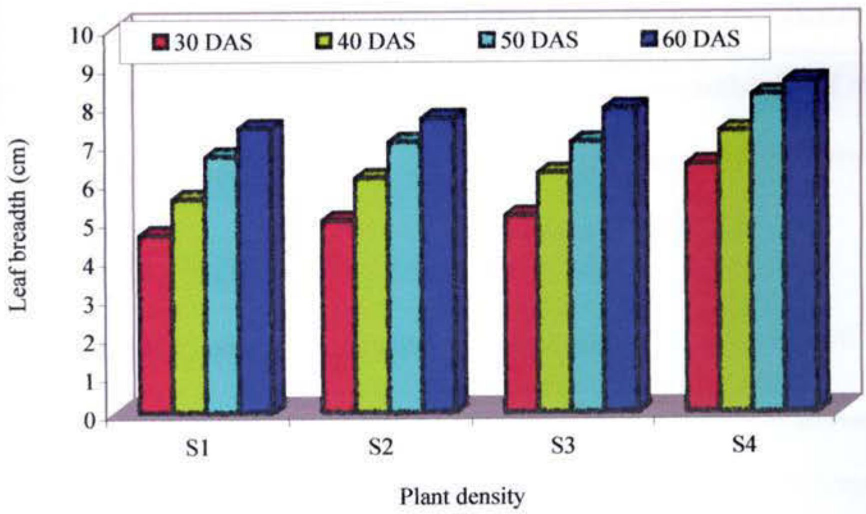

Figure 10. Effect of plant density on breadth of leaf of stem amaranth

$S_1 = 15 \times 20$ cm $S_2 = 20 \times 20$ cm
$S_3 = 25 \times 20$ cm $S_4 = 30 \times 20$ cm

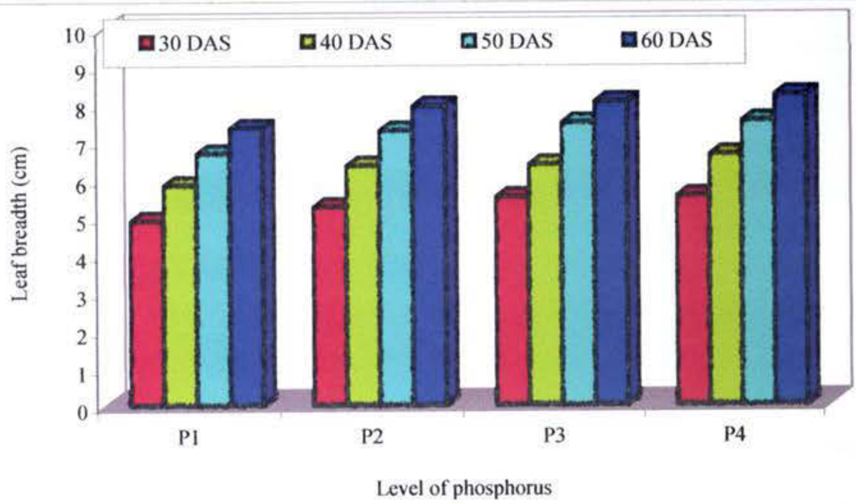

Figure 11. Effect of phosphorus on breadth of leaf of stem amaranth

$P_1 = 48$ kg P_2O_5/ha $P_2 = 52.8$ kg P_2O_5/ha
$P_3 = 57.6$ kg P_2O_5/ha $P_4 = 62.4$ kg P_2O_5/ha

A statistically significant variation was recorded in terms of breadth of leaf in relation with different levels of Phosphorus (Figure 11). The longest breadth of leaf (5.54 cm) was recorded in P_4 at 30 DAS and the shortest (4.90 cm) was recoded in P_1. At 40 DAS the longest (6.63 cm) breadth of leaf was recorded from P_4 and the shortest (5.84 cm) was found from P_1. Treatment P_4 gave the longest (7.52 cm) breadth of leaf at 50 DAS, while P_1 gave the shortest (6.68 cm). At 60 DAS the longest (8.21 cm) breadth of leaf was recorded from P_4 and the shortest (7.35 cm) was observed from P_1.

Interaction effect between plant density and Phosphorus showed a significant differences in consideration of leaf breadth of stem amaranth (Table 3). The longest (6.83 cm) breadth of leaf was recorded at 30 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (4.24 cm) breadth of leaf. At 40 DAS the longest (7.92 cm) breadth of leaf was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (5.00 cm) breadth of leaf. The longest (8.66 cm) breadth of leaf was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (6.27 cm) breadth of leaf. At 60 DAS the longest (9.07 cm) breadth of leaf was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (6.82 cm) breadth of leaf.

4.6 Petiole length

Petiole length varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Figure 12). The longest (5.83 cm) petiole length was observed from the plot where plant density was 30 × 20 cm, while the shortest (4.64 cm) was recorded for spacing 15 × 20 cm at 30 DAS. The longest (8.09 cm) petiole length was observed from S_4, while the shortest (6.54 cm) petiole length was from S_1.

Table 3. Combined effect of plant density and phosphorus on breadth of leaf and petiole length of stem amaranth

Treatment Combination	Breadth of leaf (cm) at				Petiole length (cm) at			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1P_1	4.24 g	5.00 g	6.27 g	6.82 h	4.30 ef	6.21 h	7.30 i	7.43 h
S_1P_2	4.54 efg	5.64 efg	6.57 def	7.36 efgh	4.09 f	6.37 gh	7.36 hi	7.61 gh
S_1P_3	4.96 def	5.72 cdefg	6.99 def	7.78 efg	5.09 bcdef	6.62 efgh	7.61 fghi	7.86 fgh
S_1P_4	4.78 cdef	5.88 cdefg	6.81 def	7.60 efghi	5.07 bcdef	6.97 cdefgh	7.99 defghi	8.23 defg
S_2P_1	4.93 defg	6.03 def	6.96 def	7.39 fgh	4.68 cdef	6.58 fgh	7.42 ghi	7.61 gh
S_2P_2	4.80 defgh	5.88 cdefg	6.83 def	7.62 efg	4.53 def	6.81 defgh	7.82 efghi	8.06 efgh
S_2P_3	5.25 efg	6.35 de	7.28 abc	7.73 defg	5.04 bcde	7.31 bcdef	8.34 cdef	8.57 cdef
S_2P_4	5.02 def	6.13 de	7.05 defg	7.84 fghi	5.15 bcde	7.42 bcdef	8.46 cde	8.69 cde
S_3P_1	4.76 defg	5.86 cdefg	6.28 cdef	7.42 fgh	4.48 def	6.39 gh	7.37 hi	7.62 gh
S_3P_2	5.13 cdef	6.23 cdef	7.16 abc	7.95 defg	4.90 bcdef	7.17 bcdefg	8.20 cdefg	8.43 cdef
S_3P_3	5.10 cdefg	6.24 cde	7.13 abc	7.92 defg	4.86 bcdef	7.14 bcdefg	8.16 cdefgh	8.40 cdef
S_3P_4	5.51 efg	6.61 ab	7.54 bcde	8.33 ab	5.33 abcd	7.60 abcd	8.65 bcd	8.88 bcd
S_4P_1	5.66 efgh	6.45 ab	7.22 cdef	7.78 defg	5.50 abc	7.76 abc	8.82 abc	9.04 abc
S_4P_2	6.55 ab	7.65 a	8.58 ab	8.81 ab	6.13 a	8.38 a	9.47 a	9.69 a
S_4P_3	6.77 b	7.21 ab	8.54 ab	8.73 ab	5.63 ab	7.88 ab	8.95 abc	9.17 abc
S_4P_4	6.83 a	7.92 a	8.66 a	9.07 a	6.06 a	8.32 a	9.41 ab	9.62 ab
LSD $_{(0.05)}$	0.127	0.214	0.184	0.213	0.759	0.715	0.708	0.698
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	7.35	8.07	5.33	6.95	9.01	5.98	5.16	4.96

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

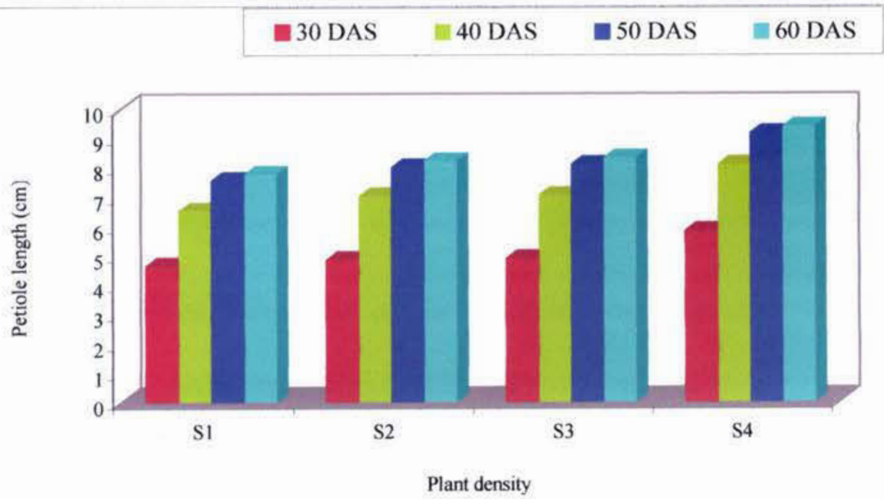

Figure 12. Effect of plant density on petiole length of stem amaranth

$S_1 = 15 \times 20$ cm $S_2 = 20 \times 20$ cm
$S_3 = 25 \times 20$ cm $S_4 = 30 \times 20$ cm

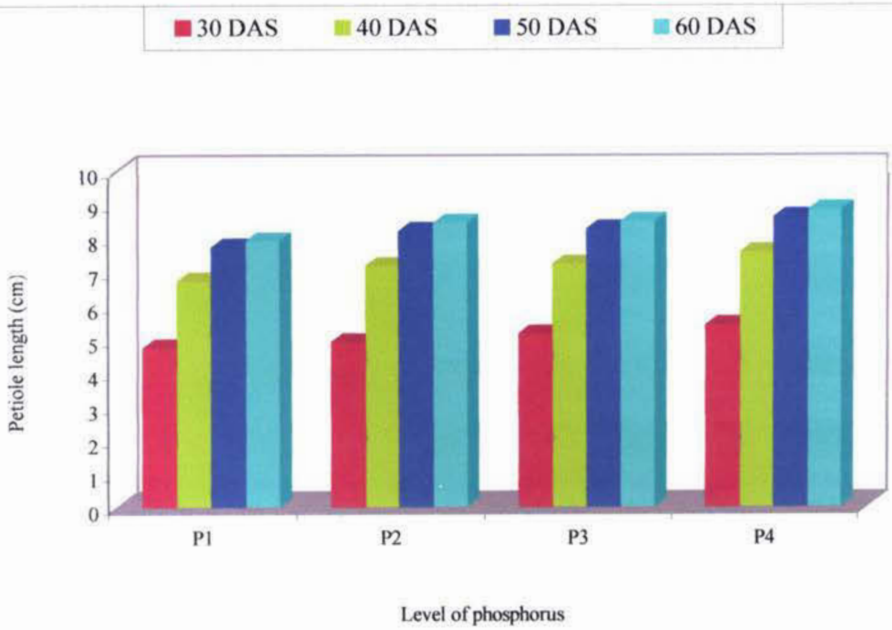

Figure 13. Effect of phosphorus on petiole length of stem amaranth

$P_1 = 48$ kg P_2O_5/ha $P_2 = 52.8$ kg P_2O_5/ha
$P_3 = 57.6$ kg P_2O_5/ha $P_4 = 62.4$ kg P_2O_5/ha

at 40 DAS. At 50 DAS the longest (9.16 cm) petiole length was recorded from S_4 and the shortest (7.56 cm) was from S_1. Treatment S_4 gave the longest petiole length (9.38 cm) at 60 DAS, while S_1 (15 × 20 cm) gave the shortest (7.78 cm). The results indicated wider spacing increases the growth and development of plant which ensure the maximum petiole length of plant.

A statistically significant variation was recorded in terms of petiole length in relation with different levels of phosphorus (Figure 13). Although all the level of this fertilizer, which was used as in the present experiment, showed a regular increase in length of petiole of stem amaranth start from 30 DAS to 60 DAS. The longest (5.41 cm) petiole length was recorded in P_4 at 30 DAS and the shortest (4.74 cm) was recoded in P_1. At 40 DAS the longest (7.58 cm) petiole length was recorded from P_4 and the shortest (6.73 cm) was from P_1. Treatment P_4 gave the longest (8.63 cm) petiole length at 50 DAS, while P_1 gave the shortest (7.73 cm). At 60 DAS the longest (8.85 cm) petiole length was recorded from P_4 and the shortest (7.93 cm) was recorded from P_1. The results indicated that Phosphorus fertilizer increases the growth and development as well as ensure the availability of other nutrients for plant and the ultimate results is the highest petiole length.

Interaction effect between plant density and phosphorus showed a significant differences in consideration of petiole length of stem amaranth (Table 3). The combined effect at different days after sowing showed significant differences. The longest (6.06 cm) petiole length was recorded at 30 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (4.30 cm) petiole length. At 40 DAS the longest (8.32 cm) petiole length was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (6.21 cm) petiole length. The longest (9.41 cm) petiole length was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg

P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (7.30 cm) petiole length. At 60 DAS the longest (9.62 cm) petiole length was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (7.43 cm) petiole length.

4.7 Fresh weight of stem

Fresh weight of stem varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Table 4). The maximum (48.32 g) fresh weight of stem at all observations was observed from the plot where plant density was 30 × 20 cm (S_4), while the minimum (35.72 g) was recorded for spacing 15 × 20 cm at 30 DAS. The maximum (87.39 g) fresh weight of stem was observed from S_4, while the minimum (69.89 g) was from S_1 at 40 DAS. At 50 DAS the maximum (122.02 g) fresh weight of stem was recorded from S_4 and the minimum (103.22 g) was from S_1. Treatment S_4 gave the maximum fresh weight of stem (156.58 g) at 60 DAS, while S_1 (15 × 20 cm) gave the minimum (136.59 g) fresh weight of stem. The results indicated wider spacing increases the growth and development of plant which ensure the maximum fresh weight of stem of plant.

A statistically significant variation was recorded in terms of fresh weight of stem in relation with different levels of phosphorus (Table 4). The maximum fresh weight of stem (43.74 g) was recorded in P_4 at 30 DAS and the minimum (39.68 g) was recoded in P_1. At 40 DAS the maximum (81.06 g) fresh weight of stem was recorded from P_4 and the minimum (74.73 g) was from P_1. At P_4 gave the maximum (115.50 g) fresh weight of stem at 50 DAS, while P_1 gave the minimum (108.78 g). At 60 DAS the maximum (150.54 g) fresh weight of stem was recorded from P_4 and the minimum (142.22 g) was recorded from P_1.

Interaction effect between plant density and phosphorus showed a significant differences in consideration of fresh weight of stem of amaranth (Table 5). The combined effect at different days after sowing showed significant differences. The maximum (51.00 g) fresh weight of stem was recorded at 30 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (34.05 g) fresh weight of stem (Table 6). At 40 DAS the maximum (93.30 g) fresh weight of stem was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (64.53 g) fresh weight of stem. The maximum (125.72 g) fresh weight of stem was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (95.50 g) fresh weight of stem. At 60 DAS the maximum (162.91 g) fresh weight of stem was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) showed the minimum (127.10 g) fresh weight of stem.

4.8 Fresh weight of leaves

Fresh weight of leaves varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Table 4). The maximum (29.71 g) fresh weight of leaves at all observations was observed from the plot where plant density was 30 × 20 cm at 30 DAS, while the minimum (16.43 g) was recorded for S_1 (15 × 20 cm) at 30 DAS. The maximum (40.93 g) fresh weight of leaves was observed from S_4, while the minimum (27.56 g) was from S_1 at 40 DAS. At 50 DAS the maximum (52.19 g) fresh weight of leaves was recorded from S_4 and the minimum (41.11 g) was from S_1. Treatment S_4 gave the maximum fresh weight of leaves (66.09 g) at 60 DAS, while S_1 (15 × 20 cm) gave the minimum (53.95 g). The results indicated wider spacing increases the growth and development of plant which ensure the maximum fresh weight of leaves of plant.

Table 4. Main effect of plant density and phosphorus on fresh weight of stem and leaves of stem amaranth

Treatment Combination	Fresh weight stem (g)				Fresh weight leaves (g)			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Plant density								
S_1	35.72 d	69.89 d	103.22 d	136.59 d	16.43 d	27.56 d	41.11 c	53.95 d
S_2	39.01 c	75.52 c	110.69 c	144.46 c	20.93 c	34.25 c	47.08 b	61.47 c
S_3	43.63 b	80.24 b	115.54 b	149.82 b	25.23 b	37.81 b	50.13 a	64.01 b
S_4	48.32 a	87.39 a	122.02 a	156.58 a	29.71 a	40.93 a	52.19 a	66.09 a
$LSD_{(0.05)}$	1.124	1.685	1.847	2.125	2.175	1.452	1.985	1.562
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.71	4.99	4.09	2.05	8.26	7.60	5.90	5.34
Level of Phosphorus								
P_1	39.68 b	74.73 d	108.78 c	142.22 d	21.06 d	33.14 d	45.20 c	57.86 b
P_2	40.79 b	77.08 c	112.38 b	146.42 c	22.11 c	34.44 c	47.34 b	61.32 ab
P_3	42.47 ab	80.18 b	114.79 a	148.26 b	23.72 b	35.94 b	48.68 a	62.87 a
P_4	43.74 a	81.06 a	115.50 a	150.54 a	25.42 a	37.04 a	49.28 a	63.47 a
$LSD_{(0.05)}$	1.125	1.118	1.045	1.756	1.748	0.583	1.125	2.146
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.71	4.99	4.09	2.05	8.26	7.60	5.90	5.34

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

Table 5. Combined effect of plant density and phosphorus on fresh weight of stem and leaves of stem amaranth

Treatment Combination	Fresh weight stem (g)				Fresh weight leaves (g)			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1P_1	34.05 j	64.53 g	95.50 g	127.10 j	14.20 j	25.66 h	39.57 d	50.79 g
S_1P_2	35.39 j	70.78 efg	106.81 def	140.55 hi	15.67 ij	26.98 h	40.35 d	53.44 fg
S_1P_3	36.95 hij	74.05 def	106.05 ef	139.84 i	17.03 hij	28.18 gh	41.34 d	55.27 efg
S_1P_4	36.51 ij	70.21 fg	104.50 f	138.85 i	18.83 ghi	29.42 fgh	43.19 cd	56.30 efg
S_2P_1	36.75 ij	73.20 def	108.45 def	141.99 ghi	18.82 ghi	32.15 efg	43.79 cd	58.16 def
S_2P_2	38.15 ghij	74.63 def	109.85 def	143.49 fghi	20.11 fgh	33.45 def	46.94 bc	61.32 bcde
S_2P_3	39.94 fgh	76.47 cdef	111.61 bcdef	145.51 efgh	21.87 efg	35.12 cde	48.32 abc	62.71 abcd
S_2P_4	41.19 fgh	77.77 cde	112.85 bcdef	146.83 defg	22.93 def	36.29 cde	49.28 ab	63.68 abcd
S_3P_1	41.83 efg	78.40 cd	113.48 bcde	147.57 def	23.57 de	36.89 bcde	47.30 abc	60.02 cde
S_3P_2	42.43 defg	79.01 cd	114.07 bcde	148.18 cdef	24.09 de	37.44 bcd	50.24 ab	64.64 abc
S_3P_3	43.99 cdef	80.60 cd	115.66 bcd	149.94 cde	25.53 cd	38.90 bc	51.44 ab	65.86 abc
S_3P_4	46.26 bcd	82.95 bc	118.93 ab	153.58 bc	27.74 bc	38.01 bcd	51.53 ab	65.54 abc
S_4P_1	46.08 bcde	82.77 bc	117.70 abc	152.22 cd	27.68 bc	37.85 bcd	50.16 ab	62.48 abcd
S_4P_2	47.21 abc	83.91 bc	118.79 ab	153.44 bc	28.59 bc	39.90 abc	51.85 ab	65.86 abc
S_4P_3	48.98 ab	89.58 ab	125.85 a	157.74 b	30.43 ab	41.55 ab	53.63 a	67.64 ab
S_4P_4	51.00 a	93.30 a	125.72 a	162.91 a	32.16 a	44.43 a	53.11 a	68.38 a
$LSD_{(0.05)}$	3.970	6.518	7.704	5.031	3.177	4.451	4.685	5.467
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.71	4.99	4.09	2.05	8.26	7.60	5.90	5.34

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

A statistically significant variation was recorded in terms of fresh weight of leaves in relation with different levels of phosphorus (Table 4). The maximum fresh weight of leaves (25.42 g) was recorded in P_4 at 30 DAS and the minimum (21.06 g) was recoded in P_1. At 40 DAS the maximum (37.04 g) fresh weight of leaves was recorded from P_4 and the minimum (33.14 g) was from P_1. Treatment P_4 gave the maximum (49.28 g) fresh weight of leaves at 50 DAS, while P_1 gave the minimum (45.20 g). At 60 DAS the maximum (63.47 g) fresh weight of leaves was recorded from the P_4 and the minimum (57.86 g) was recorded from P_1.

Interaction effect between plant density and phosphorus showed a significant differences in consideration of fresh weight of leaves of stem amaranth (Table 5). The combined effect at different days after sowing showed significant differences. The maximum (32.16 g) fresh weight of leaves was recorded at 30 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (14.20 g) fresh weight of leaves (Table 6). At 40 DAS the maximum (44.43 g) fresh weight of leaves was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (25.66 g) fresh weight of leaves. The maximum (53.11 g) fresh weight of leaves was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (39.57 g) fresh weight of leaves. At 60 DAS the maximum (68.38 g) fresh weight of leaves was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (50.79 g) fresh weight of leaves.

4.9 Dry weight of stem

Dry weight of stem varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Table 6). The maximum (5.84 g) dry weight of stem at all observations was observed from the plot where plant density was 30 × 20 cm at 30 DAS, while the minimum (4.31 g) was recorded for spacing 15 × 20 cm at 30 DAS. The maximum (11.13 g) dry weight of stem was observed from S_4, while the minimum (8.66 g) was from S_1 at 40 DAS. At 50 DAS the maximum (14.67 g) dry weight of stem was recorded from S_4 and the minimum (12.27 g) was from S_1. Treatment S_4 gave the maximum dry weight of stem (18.71 g) at 60 DAS, while S_1 (15 × 20 cm) gave the minimum (16.24 g). The results indicated wider spacing increases the growth and development of plant which ensure the maximum dry weight of stem of plant.

Significant variation was recorded in terms of dry weight of stem in relation with different levels of phosphorus (Table 6). The maximum dry weight of stem (5.27 g) was recorded in P_4 at 30 DAS and the minimum (4.78 g) was recoded in P_1. At 40 DAS the maximum (10.23 g) dry weight of stem was recorded from P_4 and the minimum (9.41 g) was from P_1. Treatment P_4 gave the maximum (13.83 g) dry weight of stem at 50 DAS, while P_1 gave the minimum (12.98 g). At 60 DAS the maximum (18.10 g) dry weight of stem was recorded from P_4 and the minimum (16.96 g) was recorded from P_1.

Interaction effect between plant density and phosphorus showed a significant differences in consideration of dry weight of stem of amaranth (Table 7). The combined effect at different days after sowing showed significant differences. The maximum (36.13 g) dry weight of stem was recorded at 30 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (14.20 g) dry weight of stem (Table 8). At 40 DAS the maximum (11.89 g) dry weight of stem was recorded from S_4P_4 (30 ×

20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (8.12 g) dry weight of stem. The maximum (15.17 g) dry weight of stem was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (11.27 g) dry weight of stem. At 60 DAS the maximum (19.67 g) dry weight of stem was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (15.15 g) dry weight of stem.

4.10 Dry weight of leaves

Dry weight of leaves varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Table 6). The maximum (4.11 g) dry weight of leaves at all observations was observed from the plot where plant density was 30 × 20 cm at 30 DAS, while the minimum (2.25 g) was recorded for the spacing 15 × 20 cm at 30 DAS. The maximum (5.07 g) dry weight of leaves was observed from S_4, while the minimum (3.41 g) was from S_1 at 40 DAS. At 50 DAS the maximum (6.24 g) dry weight of leaves was recorded from S_4 and the minimum (4.94 g) was from S_1. Treatment S_4 gave the maximum dry weight of leaves (7.88 g) at 60 DAS, while S_1 (15 × 20 cm) gave the minimum (6.44 g). The results indicated wider spacing increases the growth and development of plant which ensure the maximum dry weight of leaves of plant.

A statistically significant variation was recorded in terms of dry weight of leaves in relation with different levels of phosphorus (Table 6). The maximum dry weight of leaves (3.50 g) was recorded in P_4 at 30 DAS and the minimum (2.89 g) was found in P_1. At 40 DAS the maximum (4.60 g) dry weight of leaves was recorded from P_4 and the minimum (4.12 g) was from P_1. Treatment P_4 gave the maximum (5.91 g) dry weight of leaves at 50 DAS, while P_1 gave the minimum (5.43 g). At 60 DAS the maximum (7.56 g) dry weight of leaves was recorded from P_4 and the minimum (6.90 g) was recorded from P_1.

Table 6. Main effect of plant density and phosphorus on dry weight of stem and leaves of stem amaranth

Treatment	Dry weight stem (g)				Dry weight leaves (g)			
Combination	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Plant density								
S_1	4.31 b	8.66 d	12.27 c	16.24 c	2.25 d	3.41 d	4.94 d	6.44 b
S_2	4.68 b	9.41 c	13.19 b	17.32 b	2.87 c	4.24 c	5.66 c	7.31 a
S_3	5.29 a	10.08 b	13.79 b	17.93 b	3.46 b	4.70 b	6.02 b	7.65 a
S_4	5.84 a	11.13 a	14.67 a	18.71 a	4.11 a	5.07 a	6.24 a	7.88 a
$LSD_{(0.05)}$	0.625	0.475	0.845	0.465	0.685	0.338	0.125	0.127
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.82	5.42	4.79	2.71	10.47	8.17	6.71	5.25
Level of Phosphorus								
P_1	4.78 b	9.41 b	12.98 b	16.96 c	2.89 c	4.12 b	5.43 c	6.90 c
P_2	4.96 b	9.63 b	13.38 a	17.45 a	3.06 b	4.24 b	5.68 b	7.30 b
P_3	5.12 a	10.00 a	13.74 a	17.69 a	3.24 a	4.45 a	5.84 a	7.51 a
P_4	5.27 a	10.23 a	13.83 a	18.10 a	3.50 a	4.60 a	5.91 a	7.56 a
$LSD_{(0.05)}$	0.452	0.268	0.325	0.456	0.256	0.364	0.745	0.521
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.82	5.42	4.79	2.71	10.47	8.17	6.71	5.25

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

Table 7. Combined effect of plant density and phosphorus on dry weight of stem and leaves of stem amaranth

Treatment Combination	Dry weight stem (g)				Dry weight leaves (g)			
	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1P_1	4.15 h	8.12 h	11.27 e	15.15 h	2.00 j	3.18 h	4.74 d	6.06 g
S_1P_2	4.28 gh	8.75 gh	12.75 cd	16.49 g	2.20 ij	3.33 gh	4.80 d	6.37 fg
S_1P_3	4.47 gh	8.92 fgh	12.62 cd	16.70 fg	2.25 ij	3.45 gh	5.02 cd	6.54 efg
S_1P_4	4.35 gh	8.84 gh	12.43 d	16.64 g	2.55 hij	3.68 fgh	5.18 bcd	6.79 def
S_2P_1	4.32 gh	9.22 efg	13.01 bcd	16.92 efg	2.58 ghij	3.96 efg	5.25 bcd	6.95 cdef
S_2P_2	4.62 fgh	9.21 efg	13.02 bcd	17.16 defg	2.76 fghi	4.12 def	5.70 abc	7.20 bcde
S_2P_3	4.74 efg	9.58 defg	13.30 bcd	17.57 cdef	2.96 efgh	4.38 cde	5.78 ab	7.50 abcd
S_2P_4	5.03 def	9.61 defg	13.45 bcd	17.63 cde	3.19 efg	4.50 bcde	5.88 ab	7.58 abc
S_3P_1	5.10 def	9.76 cdefg	13.52 bcd	17.56 cdef	3.17 efg	4.65 bcd	5.71 abc	7.14 bcde
S_3P_2	5.17 de	9.89 cdef	13.56 bcd	17.83 bcd	3.32 def	4.65 bcd	6.00 a	7.70 ab
S_3P_3	5.33 cd	10.10 cde	13.82 bc	17.88 bcd	3.55 cde	4.82 bc	6.14 a	7.94 a
S_3P_4	5.57 bcd	10.57 bcd	14.25 ab	18.45 bc	3.81 bcde	4.69 bcd	6.23 a	7.82 ab
S_4P_1	5.55 bcd	10.54 bcd	14.10 ab	18.22 bc	3.79 bcd	4.69 bcd	6.03 a	7.46 abcd
S_4P_2	5.76 abc	10.69 bc	14.19 ab	18.33 bc	3.97 abc	4.88 bc	6.20 a	7.94 a
S_4P_3	5.93 ab	11.41 ab	15.21 a	18.62 b	4.22 ab	5.17 ab	6.40 a	8.06 a
S_4P_4	6.13 a	11.89 a	15.17 a	19.67 a	4.47 a	5.55 a	6.35 a	8.06 a
$LSD_{(0.05)}$	0.489	0.887	1.076	0.795	0.553	0.594	0.639	0.642
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	5.82	5.42	4.79	2.71	10.47	8.17	6.71	5.25

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

Interaction effect between plant density and phosphorus showed a significant differences in consideration of dry weight of leaves of stem amaranth (Table 7). At 30 DAS the maximum (4.47 g) dry weight of leaves was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (2.00 g) dry weight of leaves. At 40 DAS the maximum (5.55 g) dry weight of leaves was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (3.18 g) dry weight of leaves. The maximum (6.35 g) dry weight of leaves was recorded at 50 DAS from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (4.74 g) dry weight of leaves. At 60 DAS the maximum (8.06 g) dry weight of leaves was recorded from S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the minimum (6.06 g) dry weight of leaves.

4.11 Yield per plot

Yield per plot varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Figure 14). The highest (5.44 kg) yield per plot at all observations was observed from the plot where plant density was 25 × 20 cm at 30 DAS, while the lowest (3.93 kg) was recorded for spacing 15 × 20 cm at 30 DAS. The highest (8.74 kg) yield per plot was observed from S_3, while the lowest (6.13 kg) was from S_1 at 40 DAS. At 50 DAS the highest (13.04 kg) yield per plot was recorded from S_3 and the lowest (7.79 kg) was found from S_1. Treatment S_3 gave the highest (20.42 kg) yield per plot at 60 DAS, while S_1 (15 × 20 cm) gave the lowest (10.66 kg). The results indicated wider spacing increases the growth and development of plant which ensure the maximum yield per plot of plant.

A statistically significant variation was recorded in terms of yield per plot in relation with different levels of phosphorus (Figure 15). The highest (4.94 kg) yield per plot was recorded in P_4 at 30 DAS and the lowest (4.30 kg) was recoded in P_1. At 40 DAS the highest (7.95 kg) yield per plot was recorded from P_4 and the lowest (6.61 kg) was from P_1. Treatment P_4 gave the highest (11.53 kg) yield per plot at 50 DAS, while P_1 gave the lowest (9.76 kg). At 60 DAS the highest (18.15 kg) yield per plot was recorded from P_4 and the lowest (13.52 kg) was recorded from P_1.

Interaction effect between plant density and Phosphorus showed a significant differences in consideration of yield per plot of stem amaranth (Table 8). The highest (5.72 kg) yield per plot was recorded at 30 DAS from S_3P_2 (25 × 20 cm + 52.8 kg P_2O_5/ha), while S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the lowest (3.61 kg) yield per plot. At 40 DAS the highest (9.31 kg) yield per plot was recorded from S_3P_2 while S_1P_1 gave the lowest (5.53 kg) yield per plot. The highest (13.76 kg) yield per plot was recorded at 50 DAS from S_3P_2 and S_1P_1 gave the lowest (5.93 kg) yield per plot. At 60 DAS the highest (22.48 kg) yield per plot was recorded from S_3P_3, while S_1P_1 gave the lowest (9.34 kg) yield per plot.

4.12 Yield per hectare

Yield per hectare varied statistically due to the plant density at 30, 40, 50 and 60 DAS (Figure 16). The highest (18.12 t/ha) yield at all observations was observed from the hectare where plant density was 25 × 20 cm (S_3) at 30 DAS, while the lowest (13.20 t/ha) was recorded for spacing 15 × 20 cm (S_1) at 30 DAS. The highest (29.15 t/ha) yield was observed from S_3, while the lowest (20.42 t/ha) was from S_1 at 40 DAS. At 50 DAS the highest (43.45 t/ha) yield was recorded from S_3 and the lowest (25.96 t/ha) was from S_1. Plant density S_3 gave the highest (68.06 t/ha)

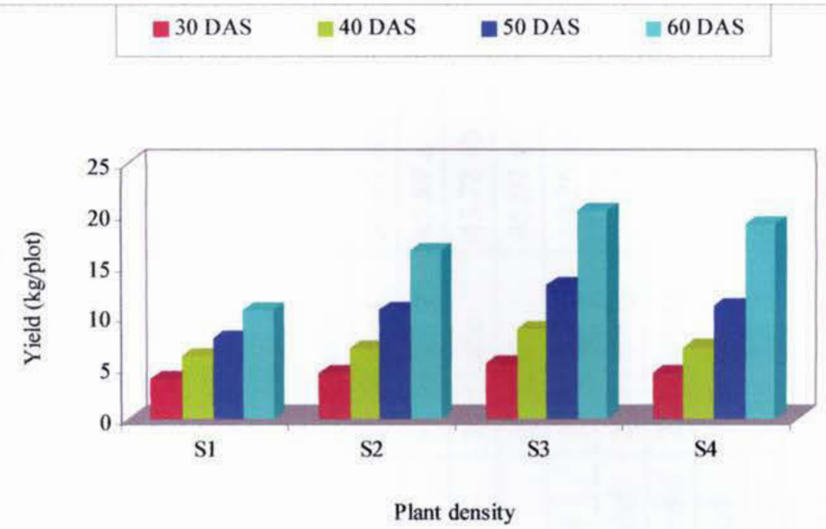

Figure 14. Effect of plant density on yield per plot of stem amaranth

$S_1 = 15 \times 20$ cm $S_2 = 20 \times 20$ cm

$S_3 = 25 \times 20$ cm $S_4 = 30 \times 20$ cm

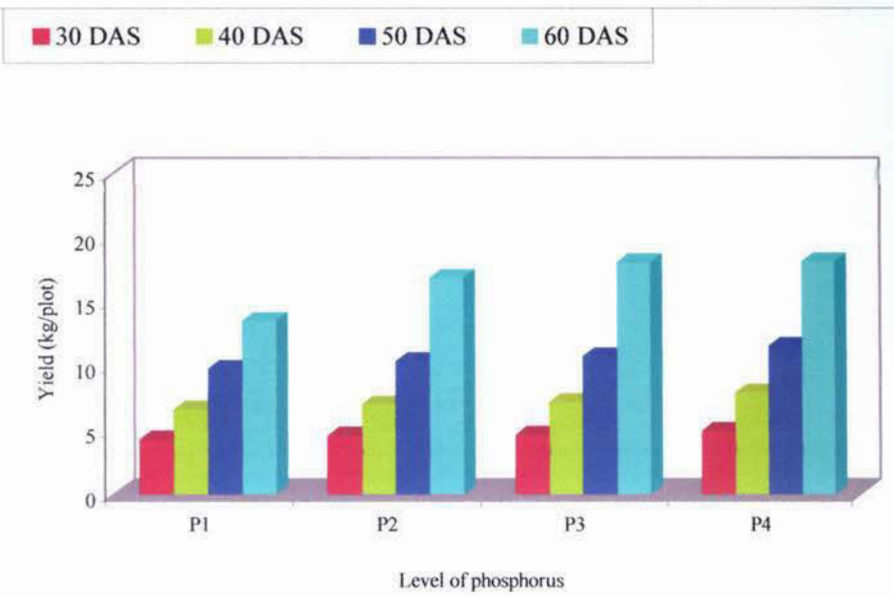

Figure 15. Effect of phosphorus on yield per plot of stem amaranth

$P_1 = 48$ kg P_2O_5/ha $P_2 = 52.8$ kg P_2O_5/ha

$P_3 = 57.6$ kg P_2O_5/ha $P_4 = 62.4$ kg P_2O_5/ha

Table 8. Combined effect of plant density and phosphorus on yield/plot and hectare of stem amaranth

Treatment	Yield (kg/plot)				Yield (t/ha)			
Combination	30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
S_1P_1	3.61 g	5.53 f	5.90 f	9.34 e	12.36 f	18.33 g	19.62 f	31.35 e
S_1P_2	3.77 fg	5.47 f	7.06 ef	10.83 e	12.57 f	18.24 g	23.55 ef	36.09 e
S_1P_3	4.01 efg	6.20 ef	8.39 de	11.12 e	13.36 ef	20.68 fg	27.96 de	37.06 e
S_1P_4	4.35 cdefg	7.32 bcde	9.82 cd	11.34 e	14.51 cdef	24.41 cdef	32.72 cd	37.79 e
S_2P_1	4.34 cdefg	6.58 cdef	9.62 cd	11.84 e	14.45 cdef	21.94 defg	32.08 cd	39.47 e
S_2P_2	4.19 defg	6.30 def	10.27 cd	16.54 d	13.97 def	20.99 efg	34.25 cd	55.13 d
S_2P_3	4.68 bcde	7.25 bcde	10.93 c	18.22 bcd	15.59 bcde	24.18 cdef	36.43 c	60.74 bcd
S_2P_4	4.79 bcde	7.48 bcde	11.37 bc	19.26 bc	15.97 bcde	24.92 cdef	37.91 bc	64.19 bc
S_3P_1	5.12 abc	8.12 abc	11.72 abc	16.95 cd	17.07 abc	27.08 abcd	39.07 abc	56.51 cd
S_3P_2	5.72 a	9.31 a	13.77 a	19.99 ab	19.08 a	31.03 a	45.89 a	66.63 ab
S_3P_3	5.24 ab	8.36 ab	13.13 ab	22.48 a	17.47 ab	27.87 abc	43.78 ab	74.94 a
S_3P_4	5.66 a	9.18 a	13.52 a	22.25 a	18.87 a	30.62 ab	45.07 a	74.16 a
S_4P_1	4.15 defg	6.21 ef	11.78 abc	15.94 d	13.82 def	20.69 fg	39.26 abc	53.13 d
S_4P_2	4.55 bcdef	7.00 bcdef	10.42 cd	20.05 ab	15.16 bcdef	23.33 cdefg	34.74 cd	66.82 ab
S_4P_3	4.51 abcdef	6.93 bcdef	10.59 c	20.41 ab	15.04 abcdef	23.09 cdefg	35.31 c	68.02 ab
S_4P_4	4.96 abcd	7.81 abcd	11.42 bc	19.78 ab	16.54 abcd	26.04 bcde	38.05 bc	65.92 ab
$LSD_{(0.05)}$	0.735	1.355	1.875	2.438	2.463	4.499	6.239	8.143
Significance level	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV (%)	9.56	11.29	10.60	8.22	9.56	11.29	10.60	8.22

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

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

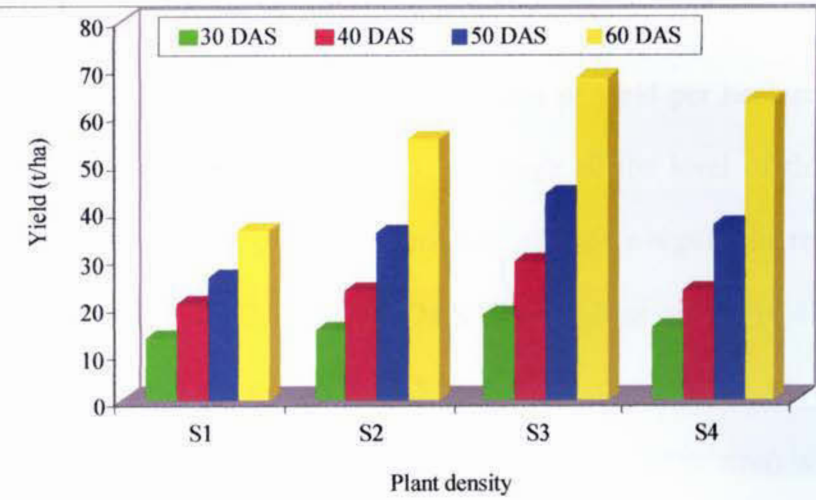

Figure 16. Effect of plant density on yield per ha of stem amaranth

S_1 = 15 × 20 cm S_2 = 20 × 20 cm
S_3 = 25 × 20 cm S_4 = 30 × 20 cm

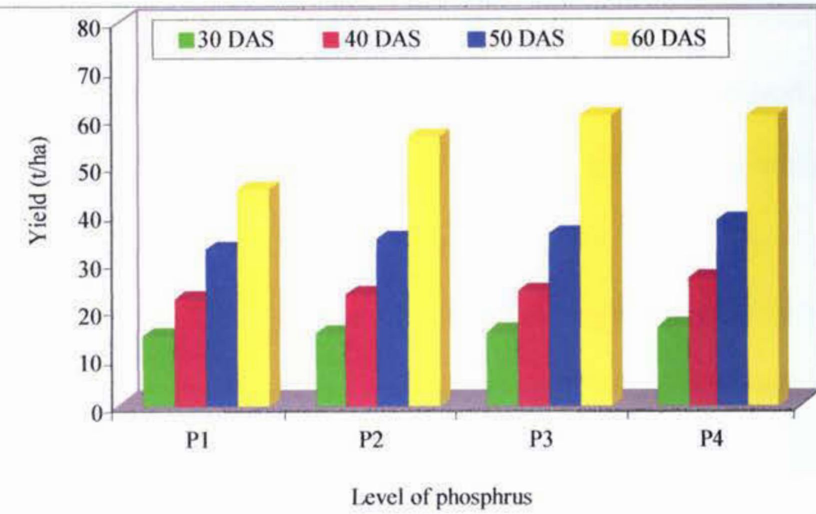

Figure 17. Effect of phosphorus on yield per ha of stem amaranth

P_1 = 48 kg P_2O_5/ha P_2 = 52.8 kg P_2O_5/ha
P_3 = 57.6 kg P_2O_5/ha P_4 = 62.4 kg P_2O_5/ha

yield at 60 DAS, while S_1 gave the lowest (35.57 t/ha). The results indicated wider spacing increases the growth and development of plant which ensure the maximum yield per hectare of plant.

A statistically significant variation was recorded in terms of yield per hectare in relation with different levels of phosphorus (Figure 17). Although all the level of this fertilizer, which was used as treatment in the present experiment, showed a regular increase in yield of stem amaranth start from 30 DAS to 60 DAS. The highest yield (16.47 t/ha) was recorded in P_4 at 30 DAS and the lowest (14.43 t/ha) was recoded in P_1. At 40 DAS the highest (26.50 t/ha) yield was recorded from P_4 and the lowest (22.01 t/ha) was from P_1. Treatment P_4 gave the highest (38.44 t/ha) yield at 50 DAS, while P_1 gave the lowest (32.51 t/ha). At 60 DAS the highest (60.51 t/ha) yield was recorded from P_4 and the lowest (45.11 t/ha) was recorded from P_1.

Interaction effect between plant density and phosphorus showed a significant differences in consideration of yield per hectare of stem amaranth (Table 8). The highest (19.08 t/ha) yield was recorded at 30 DAS from S_3P_2 (25 × 20 cm + 52.8 kg P_2O_5/ha), while S_1P_1 gave the lowest (12.36 t/ha) yield. At 40 DAS the highest (31.03 t/ha) yield was recorded from S_3P_2, while S_1P_1 gave the lowest (18.33 t/ha) yield. The highest (45.89 t/ha) yield was recorded at 50 DAS from S_3P_2, while S_1P_1 gave the lowest (19.62 t/ha) yield. At 60 DAS the highest (74.94 t/ha) yield was recorded from S_3P_3, while S_1P_1 gave the lowest (31.35 t/ha) yield.

4.13 Economic analysis

The economic analysis in the present experiment was done to find out the gross, net return and the benefit cost ratio and presented in this section.

4.13.a Gross return

In the combination of plant density and phosphorus, the highest gross return (Tk. 843,705) was obtained from S_3P_4 and the second highest (Tk. 820,300) gross return was obtained in S_3P_3. The lowest gross return (Tk. 408,350) was obtained in S_1P_1 (Table 9).

4.13.b Net return

In case of net return different treatment combination showed different types of net return. In the combination of plant density and phosphorus, the highest net return (Tk. 633,611) was obtained from S_3P_4 and the second highest net return (Tk. 610,489) was obtained in S_3P_3. The lowest (Tk. 186,007) net return was obtained in S_1P_1 (Table 9).

4.13.c Benefit cost ratio

In the combination of plant density and phosphorus the highest benefit cost ratio (3.02) was obtained from S_3P_4 and the second highest benefit cost ratio (2.91) was found from S_3P_3. The lowest befit cost ratio (0.84) was recorded from S_1P_1 (Table 9).

Table 9. Cost and return of stem amaranth as influenced by plant density and phosphorus

Treatment Combination	Cost of production (Tk./ha)	Yield (t/ha) at				Price (Tk./ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
		30 DAS	40 DAS	50 DAS	60 DAS				
S_1P_1	222342	12.36	18.33	19.62	31.35	408300	408350	186007	0.84
S_1P_2	209733	12.57	18.24	23.55	36.09	452250	452304	242571	1.16
S_1P_3	209914	13.36	20.68	27.96	37.06	495300	495358	285444	1.36
S_1P_4	210094	14.51	24.41	32.72	37.79	547150	547212	337118	1.60
S_2P_1	209553	14.45	21.94	32.08	39.47	539700	539761	330209	1.58
S_2P_2	209733	13.97	20.99	34.25	55.13	621700	621776	412043	1.96
S_2P_3	209914	15.59	24.18	36.43	60.74	684700	684785	474871	2.26
S_2P_4	210094	15.97	24.92	37.91	64.19	714950	715039	504945	2.40
S_3P_1	209553	17.07	27.08	39.07	56.51	698650	698734	489181	2.33
S_3P_2	209733	19.08	31.03	45.89	66.63	813150	813248	603515	2.88
S_3P_3	209914	17.47	27.87	43.78	74.94	820300	820403	610489	2.91
S_3P_4	210094	18.87	30.62	45.07	74.16	843600	843705	633611	3.02
S_4P_1	209553	13.82	20.69	39.26	53.13	634500	634574	425021	2.03
S_4P_2	209733	15.16	23.33	34.74	66.82	700250	700340	490607	2.34
S_4P_3	209914	15.04	23.09	35.31	68.02	707300	707391	497477	2.37
S_4P_4	210094	16.54	26.04	38.05	65.92	732750	732842	522748	2.49

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha

Chapter V

SUMMARY AND CONCLUSION

A field experiment was conducted in the experimental field of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from March 2007 to June 2007 to study the effect of different plant density and Phosphorus on growth and yield of stem amaranth. The experiment considered of two factors. Four level of plant density i.e. 15 × 20 cm (S_1), 20 × 20 cm (S_2), 25 × 20 cm (S_3), 30 × 20 cm (S_4); Four levels of Phosphorus i.e. 48 kg P_2O_5/ha (P_1), 52.8 kg P_2O_5/ha (P_2), 57.6 kg P_2O_5/ha (P_3), 62.4 kg P_2O_5/ha (P_4). There were 16 (4 × 4) treatments combinations. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the stem amaranth. Data were collected in respect of the plant growth characters and green yield of stem amaranth. The data obtained for different characters were statistically analyzed to find out the significance of the plant density and Phosphorus fertilizers on yield and yield contributing characters of stem amaranth.

The longest (100.37 cm) stem length was found from S_4 at 60 DAS, while S_1 gave the shortest (87.55 cm). The widest plant density S_4 gave the maximum (25.89 mm) stem diameter, while S_1 gave the minimum (21.28 mm) at 60 DAS. Treatment S_4 gave the maximum (44.96) number of leaves, while S_1 gave the minimum (36.70) at 60 DAS. Treatment S_4 gave the longest (23.07 cm) length of leaf at 60 DAS, while S_1 gave the shortest (18.13 cm). Treatment S_4 gave the longest (8.60 cm) breadth of leaf at 60 DAS, while S_1 gave the shortest (7.39 cm). Treatment S_3 gave the highest (20.42 kg) yield per plot at 60 DAS, while S_1 gave the lowest (10.66 kg) yield. Treatment S_3 gave the highest (68.06 t/ha) yield at 60 DAS, while S_1 gave the lowest (35.57 t/ha).

At 60 DAS the longest (96.50 cm) stem length was recorded from P_4 and the shortest (91.17 cm) was recorded from P_1. At 60 DAS the maximum (24.22 mm) stem diameter was recorded from P_4 and the minimum (20.21 mm) was recorded from P_1. At 60 DAS the maximum (43.18) number of leaves was recorded from P_4 and the minimum (39.36) was recorded from P_1. At 60 DAS the longest (21.42 cm) length of leaf was recorded from P_4 and the shortest (19.47 cm) was recorded from P_1. At 60 DAS the longest (8.21 cm) breadth of leaf was recorded from P_4 and the shortest (7.35 cm) was recorded from P_1. At 60 DAS the highest (18.15 kg) yield per plot was recorded from P_4 and the lowest (13.52 kg) was recorded from P_1. At 60 DAS the highest (60.51 t/ha) yield was recorded from P_4 and the lowest (45.11 t/ha) was recorded from P_1.

Plant density and Phosphorus showed significant differences in consideration of stem length of stem amaranth. At 60 DAS the longest (104.43 cm) stem length was recorded from the combination of S_4P_4 (30 × 20 cm + 62.4 kg P_2O_5/ha), while the combination of S_1P_1 (15 × 20 cm + 48 kg P_2O_5/ha) gave the shortest (81.48 cm) stem length. At 60 DAS the maximum (26.66 cm) stem diameter was recorded from S_4P_4, while S_1P_1 gave the minimum (19.91 mm) stem diameter. At 60 DAS the maximum (46.51) number of leaves was recorded from S_4P_4, while S_1P_1 gave the minimum (34.55) number of leaves. The longest (23.98 cm) length of leaf was recorded from S_4P_4, while S_1P_1 gave the shortest (16.50 cm) length of leaf at 60 DAS. At 60 DAS the longest (9.07 cm) breadth of leaf was recorded from S_4P_4, while S_1P_1 gave the shortest (6.82 cm) breadth of leaf. At 60 DAS the highest (22.48 kg) yield per plot was recorded from S_3P_3, while S_1P_1 gave the lowest (9.34 kg) yield per plot. At 60 DAS the highest (74.94 t/ha) yield was recorded from S_3P_3, while S_1P_1 gave the lowest (31.35 t/ha) yield.

In the combination of plant density and Phosphorus highest gross return (Tk. 843,705) was obtained from the treatment combination of S_3P_4 and lowest gross return (Tk. 408,350) was obtained in S_1P_1. In case of net return different treatment combination showed different types of net return. In the combination of plant density and Phosphorus highest (Tk. 633,611) net return was obtained from the treatment combination of S_3P_4 and the lowest net return (Tk. 186,007) was obtained in S_1P_1. Highest benefit cost ratio (3.02) was attained from the treatment combination of S_3P_4 and the lowest befit cost ratio (0.84) was obtained in S_1P_1.

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

- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
- Another combination of plant density may also included for further study
- Phosphorus up to certain level had significant influence on the growth and yield of stem amaranth. So, for growing stem amaranth Phosphorus may be included in the fertilization program upto another highest level.

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APPENDICES

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

Mechanical analysis

Constituents	Percent
Sand	33.65
Silt	60.05
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.18
Organic carbon (%)	1.25
Total nitrogen (%)	0.08
Available P (ppm)	20
Exchangeable K (%)	0.2

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

Month	Air temperature (^0C)		RH (%)	Total rainfall (mm)
	Maximum	Minimum		
March 2007	27.05	19.25	23.15	41
April 2007	32.98	23.72	88.24	65
May 2007	34.00	24.65	79.55	155
June 2007	33.85	26.15	69.05	184

Source : Dhaka metrological center

Appendix III. Analysis of variance of the data on stem length and stem diameter of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Stem length (cm) at				Stem diameter (mm) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	5.039	13.602	4.645	8.860	0.537	0.869	1.688	1.751
Plant density (A)	3	243.130**	372.663**	374.359**	352.556**	30.619**	37.890**	41.351**	45.789**
Phosphorus (B)	3	25.917**	57.376**	54.665**	61.193**	3.079**	4.229**	3.841*	4.247**
Interaction (A×B)	9	0.781^{NS}	8.133^{NS}	9.662^{NS}	10.731*	0.701^{NS}	0.786^{NS}	1.020^{NS}	1.108^{NS}
Error	30	3.808	8.638	10.587	3.741	0.581	0.769	1.200	1.208

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix 1V. Analysis of variance of the data on number and length leaf of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Number of leaves at				Length of leaf (cm) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	6.375	3.265	4.985	19.809	0.799	1.213	0.857	1.270
Plant density (A)	3	165.818**	145.291**	140.344**	156.094**	57.878**	46.773**	54.956**	55.169**
Phosphorus (B)	3	17.403**	12.835**	19.708**	35.176**	7.734**	5.744**	7.638**	8.851**
Interaction (A×B)	9	0.104^{NS}	1.005^{NS}	0.713^{NS}	0.275^{NS}	1.116^{NS}	0.865^{NS}	1.205^{NS}	1.316^{NS}
Error	30	1.941	2.617	3.971	4.974	1.231	1.179	1.202	1.250

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix III. Analysis of variance of the data on stem length and stem diameter of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Stem length (cm) at				Stem diameter (mm) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	5.039	13.602	4.645	8.860	0.537	0.869	1.688	1.751
Plant density (A)	3	243.130**	372.663**	374.359**	352.556**	30.619**	37.890**	41.351**	45.789**
Phosphorus (B)	3	25.917**	57.376**	54.665**	61.193**	3.079**	4.229**	3.841*	4.247**
Interaction (A×B)	9	0.781^{NS}	8.133^{NS}	9.662^{NS}	10.731*	0.701^{NS}	0.786^{NS}	1.020^{NS}	1.108^{NS}
Error	30	3.808	8.638	10.587	3.741	0.581	0.769	1.200	1.208

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix 1V. Analysis of variance of the data on number and length leaf of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Number of leaves at				Length of leaf (cm) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	6.375	3.265	4.985	19.809	0.799	1.213	0.857	1.270
Plant density (A)	3	165.818**	145.291**	140.344**	156.094**	57.878**	46.773**	54.956**	55.169**
Phosphorus (B)	3	17.403**	12.835**	19.708**	35.176**	7.734**	5.744**	7.638**	8.851**
Interaction (A×B)	9	0.104^{NS}	1.005^{NS}	0.713^{NS}	0.275^{NS}	1.116^{NS}	0.865^{NS}	1.205^{NS}	1.316^{NS}
Error	30	1.941	2.617	3.971	4.974	1.231	1.179	1.202	1.250

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix VII. Analysis of variance of the data on dry weight of stem and leaves of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Dry weight of stem (g) at				Dry weight of leaves (g) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.046	0.364	0.390	1.156	0.448	0.070	0.073	0.500
Plant density (A)	3	5.456**	13.243**	12.267**	12.977**	7.623**	6.151**	3.930**	4.812**
Phosphorus (B)	3	0.534**	1.597**	1.797**	2.710**	0.839**	0.553*	0.533*	1.078**
Interaction (A×B)	9	0.031^{NS}	0.170^{NS}	0.383^{NS}	0.335^{NS}	0.006^{NS}	0.064^{NS}	0.019^{NS}	0.026^{NS}
Error	30	0.086	0.283	0.416	0.227	0.110	0.127	0.147	0.148

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix VIII. Analysis of variance of the data on yield (kg/plot) and yield (t/ha) of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Yield (kg/plot) at				Yield (t/ha) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.120	0.591	0.662	5.035	1.059	6.928	7.490	54.833
Plant density (A)	3	4.630**	14.632**	56.125**	221.688**	49.945**	163.312**	624.366**	2474.923**
Phosphorus (B)	3	0.830*	3.765**	6.622**	55.288**	8.557**	42.244**	73.804**	621.707**
Interaction (A×B)	9	0.110^{NS}	0.573^{NS}	2.494^{NS}	3.765^{NS}	1.220^{NS}	6.371^{NS}	27.803^{NS}	42.292^{NS}
Error	30	0.194	0.660	1.264	1.868	2.181	7.281	13.998	23.847

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix VII. Analysis of variance of the data on dry weight of stem and leaves of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Dry weight of stem (g) at				Dry weight of leaves (g) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.046	0.364	0.390	1.156	0.448	0.070	0.073	0.500
Plant density (A)	3	5.456**	13.243**	12.267**	12.977**	7.623**	6.151**	3.930**	4.812**
Phosphorus (B)	3	0.534**	1.597**	1.797**	2.710**	0.839**	0.553*	0.533*	1.078**
Interaction (A×B)	9	0.031^{NS}	0.170^{NS}	0.383^{NS}	0.335^{NS}	0.006^{NS}	0.064^{NS}	0.019^{NS}	0.026^{NS}
Error	30	0.086	0.283	0.416	0.227	0.110	0.127	0.147	0.148

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix VIII. Analysis of variance of the data on yield (kg/plot) and yield (t/ha) of amaranth as influenced by plant density and Phosphorus

Source of variation	Degrees of freedom	Mean square							
		Yield (kg/plot) at				Yield (t/ha) at			
		30 DAS	40 DAS	50 DAS	60 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.120	0.591	0.662	5.035	1.059	6.928	7.490	54.833
Plant density (A)	3	4.630**	14.632**	56.125**	221.688**	49.945**	163.312**	624.366**	2474.923**
Phosphorus (B)	3	0.830*	3.765**	6.622**	55.288**	8.557**	42.244**	73.804**	621.707**
Interaction (A×B)	9	0.110^{NS}	0.573^{NS}	2.494^{NS}	3.765^{NS}	1.220^{NS}	6.371^{NS}	27.803^{NS}	42.292^{NS}
Error	30	0.194	0.660	1.264	1.868	2.181	7.281	13.998	23.847

** : Significant at 1% level of probability; * : Significant at 5% level of probability; NS : Non significant

Appendix IX. Contd.
B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13% of value of land Tk. 6,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 12 months (Tk. 13% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
S_1P_1	78000	13663	25579	117242	222342
S_1P_2	78000	13683	12801	104483	209733
S_1P_3	78000	13702	12812	104514	209914
S_1P_4	78000	13722	12823	104544	210094
S_2P_1	78000	13663	12790	104453	209553
S_2P_2	78000	13683	12801	104483	209733
S_2P_3	78000	13702	12812	104514	209914
S_2P_4	78000	13722	12823	104544	210094
S_3P_1	78000	13663	12790	104453	209553
S_3P_2	78000	13683	12801	104483	209733
S_3P_3	78000	13702	12812	104514	209914
S_3P_4	78000	13722	12823	104544	210094
S_4P_1	78000	13663	12790	104453	209553
S_4P_2	78000	13683	12801	104483	209733
S_4P_3	78000	13702	12812	104514	209914
S_4P_4	78000	13722	12823	104544	210094

S_1 : 15 × 20 cm
S_2 : 20 × 20 cm
S_3 : 25 × 20 cm
S_4 : 30 × 20 cm

P_1 : 48 kg P_2O_5/ha
P_2 : 52.8 kg P_2O_5/ha
P_3 : 57.6 kg P_2O_5/ha
P_4 : 62.4 kg P_2O_5/ha