EFFECTS OF PHOSPHORUS AND POTASSIUM ON THE GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus oleraceus*)

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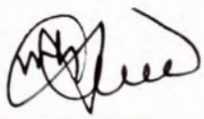

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This is to certify that thesis entitled, **"Effect of phosphorus and potassium on the growth and yield of stem amaranth"** submitted to the faculty of Agriculture, **Sher-e-Bangla Agricultural University (SAU), Dhaka,** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE,** embodies the result of a piece of *bona fide* research work carried out by **TANIA ROKSANA, REGISTRATION No. 25143/00288** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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Dedicated to

My
Parents, husband and teachers
Those who laid the
Foundation of my success

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ABSTRACT

EFFECTS OF PHOSPHORUS AND POTASSIUM ON THE GROWTH AND YIELD OF STEM AMARANTH (*Amaranthus oleraceus)*

By

Tania Roksana

An experiment was conducted at the Central Farm of Sher-e-Bangla Agricultural University, Dhaka during the period of April to June, 2005 to study the effects of four levels of phosphorus (P_2O_5) viz., control treatment (no phosphorus), P_1 (43.2 kg/ha), P_2 (48 kg /ha) and P_3 (52.8 kg /ha) and four levels of potassium (K_2O) viz., control treatment (no potassium), K_1 (114 kg /ha), K_2 (120 kg/ha) and K_3 (126kg/ha) on the growth and yield of stem amaranth. The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Most of the growth and yield parameters were significantly influenced by both phosphorus and potassium at 45 DAS. The maximum plant height (87.99 cm), plant diameter (2.43 cm), green yield per plant (285.54 g) and green yield per hectare (45.70t) were observed in the treatment of phosphorus applied at 48 kg/ha at 45 DAS. The minimum plant height (78.17 cm), plant diameter (1.50 cm), green yield per plant (187.27 g) and green yield per hectare (30.00t) were obtained from the control treatment at 45 DAS. The maximum plant height (87.49 cm), plant diameter (2.70 cm), green yield per plant (285.00g) and green yield per hectare (45.60t) were found from the plot receiving 120 kg K/ha at 45 DAS, while the control treatment gave the lowest plant height (78.51 cm), plant diameter (1.52 cm), green yield per plant (189.18g) and green yield per hectare (30.30t). Among the treatment combinations P_2K_2 (48kg P + 120 kg K/ha) gave the highest plant height (92.47cm), plant diameter (3.00 cm), green yield per plant (326.40g) and green yield per hectare (52.22t) at 45 DAS. The lowest plant height (48.47 cm), plant diameter (1.50 cm), green yield per plant (187.14g) and green yield per hectare (29.94t) were recorded from the control treatment.

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ACRONYMS

Full word	Abbreviation
Agro Ecological Zone	AEZ
And others (at elli)	*et al.*
At the rate of	@
Bangabandhu Skeikh Mujibar Rahman Agricultural University	BSMRAU
Benefit cost ratio	BCR
Centimeter	cm
Days after sowing	DAS
Degree of Celsius	^{0}C
Diammonium phosphate	DAP
Duncan's new Multiple Range Test	DMRT
Food and AgricultureOrganigation	FAO
Gram	g
Hectare	ha
Hydrogen ion concentration	p^H
Horticulture	Hort.
Kilogram	Kg
Least significant difference	LSD
Liter	L
Meter	m
Milligram	mg
Milliliter	ml
Millimeter	mm
Namely	viz.
Nitrogen	N
Parts per million	ppm
Percentile	%
Phosphorus	P
Phosphorus penta oxide	P_20_5
Potassium	K
Potassium dioxide	K_20
Square centimeter	cm2
Square meter	m2
Taka	Tk.
Ton	t
Versus	vs.

CHAPTER I

INTRODUCTION

INTRODUCTION

Amaranth (*Amaranthus oleraceus*) belongs to the family Amaranthaceae is grown mainly in the summer and the rainy season and very popular vegetables in Bangladesh for their quick growing and higher yield potential. It is usually grown in tropical and subtropical parts of Asia, Africa and Central America (Hardwood, 1980). Amaranth is considered as a potential upcoming subsidiary food crop for future (Teutonico and Knorr, 1985).

Amaranth plays a predominant role in nutrition as a cheapest source of minerals and vitamins. The leaves and stem of amaranth are rich in protein, fat, calcium, phosphorous, β-carotene, riboflavin, niacin, sodium, iron and ascorbic acid. Calcium, iron and phosphorus are the most important elements among the minerals present in amaranth (FAO, 2000). Again it contains food energy of 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 vegetables 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 vegetables production in Kharif season is very low. However, the maximum production of different vegetables is concentrated during the month of November and April. Thus there is a serious scarcity of vegetables during the month of May to September. As the nation runs with an acute shortage of vegetables, its production should be increased to meet up the shortage of vegetables to feed the ever increasing population of the country. As potentiality of year round production and soil type and weather are suitable, amaranth can play an important role to minimize the scarcity of vegetables during this period (Hossain, 1996; Talukder, 1999). At present cultivated area under this

crop in Bangladesh is 4000 hectares with production of 18,000 tons and the average yield is only about 35-40 tons per hectares (BBS, 2002). This amount is lower than the other amaranth growing countries.

Fertilizer application in appropriate time, appropriate dose and proper method is the prerequisite of amaranth cultivation (Islam, 2003). Among the chemical fertilizers phosphorus and potassium fertilizers i.e. triple superphosphate (TSP) and muriate of potash (MP) plays an excellent role to maximize the average yield of amaranth. Phosphorus helps in the development of stem of amaranth and it nourishes leaves. It elongates the internodes and makes fibre structure so firm that helps it to form as a single smooth attractive appearance avoiding branches and thus avoid from being bushy, which increases market price. It strengthens the fibre structures of stem that protect it from adverse effect of climatic factors such as storm, hail and logging.

Potassium is essential for cell organization and chloroplast. It helps in photosynthesis by maintaining iron supply and increases the body substrates. It improves root system of amaranth, so that the roots can absorb the minerals and irons from soil solution efficiently, resulting higher yield. Potassium also increases the plant diameter of amaranth which protects it from logging.

As our soil type and weather is suitable for cultivation of amaranth and it needs very low production cost and labour, there is a good scope to increase the production and yield of amaranth by manipulating different levels of essential fertilizers. Considering the above fact the study was undertaken with the following objectives:

i. To find out the yield performance of stem amaranth at different levels of phosphorus and potassium fertilizer.

ii. To determine the appropriate fertilizer dose of amaranth.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Fertilizers are indispensable for the production system of modern agriculture and play a vital role to increase the yield. Chemical fertilizers today hold the key to success of the crop production system of agriculture in Bangladesh, being contributed 50% of total production (Islam, 2003). The chemical fertilizer supplies available nutrients readily for proper growth and yield of plant. Among the macronutrients, NPK are used largely by the plants. Physiological, morphological and biological development of plants depends on the judicious application of NPK. An excess or deficiency of NPK causes remarkable effect on growth, development and yield of plant. Growth and yield performance of amaranth at different level of phosphorus and potassium fertilizer have not been studied adequately in Bangladesh. But some researcher works on different aspects of amaranth had been conducted in different parts of the world. Available literature related to the present study has reviewed in this chapter under following sections.

2.1. Effect of phosphorus on growth and yield

A study was carried out by Lian *et al.* (1997) to analyze fertilizer response and efficiency in vegetable production in Taiwan with three successive crops, mostly edible amaranth (*Amaranthus tricolor)*. Phosphate fertilizer showed yield increase with sufficient irrigation.

Ahmad (1995) reported that 30-40 ton/ha yield of *Amaranthus* spp. could be obtained at the phosphorus dose of 100 kg TSP/ha.

Portal (1992) carried out an experiment with different level of phosphorus on amaranth. Treatments were 20, 40, 60 or 80 kg P per hectare. Different growth parameters were

evaluated. Maximum plant height, number of leaves and number of branches were significantly increased with the highest level of phosphorus.

Amaranth collection showed variation in the growth parameters and productivity assessed by Jha *et al.* (1992). Plant of the same landrace exhibited variation in their height, inflorescence length, color and yield. Amaranth attained a height of 0.5 to 2.5 m at the rate of phosphorus 60 kg/ha. The crop production ability appeared to be 4 to5 times higher than average yield.

Shanmugavelu (1989) investigated two study on amaranth and reported that amaranth require high soil fertility, since their mineral uptake is very high. It responded well to nitrogen, phosphorus and potassium and particularly to high phosphorus.

Katyal and Chandna (1988) found in an experiment that amaranth grew well at 60 kg P/ha mixed with 10-15 ton cowdung and 85 kg N per hectare respectively.

In an experiment Joshi (1985) found the new amaranth cv. Annapurna in a trial of increasing levels of phosphorus and produces an average grain yield at 4 location is 2.23 t/ha. Its highest yield was 4.10 t/ha at Solan. It gave a three year average yield of 2.47 t/ha at Simla.

Bernejillo *et al.* (1994) reported that DAP solution treatment significantly increased total yield per plot (74.96 kg, compared with 58.66 kg in control treatment; equivalent to 49.973 and 39.226 kg/ha, respectively). In second trial they applied 30 or 60 kg/ha as solid DAP or DAP solution and resulted significantly higher early yield increase of liquid treatment than the corresponding solid DAP treatment. In case of total yield both liquid treatments gave significantly higher result than the both solid treatments (19.03-22.57 vs. 12.05-12.49 kg/ 15 m^2 plot, respectively).

Melton and Dafault (1991) stated that phosphorus level at g/liter increased fresh shoot weight, plant height, plant diameter, leaf number and leaf area compared with 5 as 1 mg P/liter.

Tindall, H.D. (1988) reported that nitrogen fertilizer in three equal split and phosphorus fertilizer in full dose as basal both significantly increased the production of *Amaranthus* spp.

Dufault (1988) found that increasing phosphorus rates increased floret number, total chlorophyll, plant height and root dry weight of crops to a lesser degree than did increase nitrogen.

Vijayakumar (1980) studied on the growth and development of nineteen types of amaranth in South India at a different fertilizer doses of phosphorus (0, 15, 30, or 60 kg/ha). The highest plant height was recorded as 122.15 cm and highest plant diameter was 2.38 cm at 60 kg/ ha.

Mathai (1978) evaluated some *Amaranthus* sp. in India. The cultivar Co.1 grown only for green have been reported to yield upto 16 t/ha and dual purpose types 12 t/ha greens and 10 t/ha grains by using 60 kg phosphorus per hectare.

The beneficial effects of phosphorus fertilizer on crop growth, yield and quality of different edible vegetables have been noticed by many scientists (Martin and Wilcox, 1963 and Winsor *et al.* 1967).

Wilson (1976) conducted an experiment with winter lettuce in which phosphorus was applied at the rate of 100, 200 or 300 kg/ha. He noted that maturity was advanced and the yield was increased by higher rates of phosphorus.

Sharma and Mann (1972) in an experiment worked with different phosphorus levels (30, 60 or 90 kg P_2O_5 /ha) in vegetables and reported that increasing levels of phosphorus increased the number of branches per plant and number of leaves per branch.

2.2. Effect of potassium on growth and yield

An experiment carried out by Romero (1999) in the village of Sella Cercado in Bolivia with four grain amaranth genotypes. Different variables of amaranth, plant height, plant diameter, inflorescence length, grain yield and 1000 seed weight were responsed well to the potassium at 60 kg/ha. Highest plant diameter was 2.2 cm and plant height was 102.5cm.

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

A field trial was conducted by Elbehri *et al.* (1993) in Minnesota, USA to study the response of *Amaranthus* spp. to fertilizers. There was no response to potassium application initial soil test was above 172 kg K/ha.

Zaman and Islam (1992) reported that at 15-20 cm X 10 cm spacing along with sufficient irrigation 15-16 ton/ ha stem yield of amaranth would be obtained from the fertilizer dose at the rate of 150 kg MP/ha in three equal split application.

According to George *et al.* (1989) a study was conducted on the source and variability for various nutritive aspects in amaranths (*Amaranthus* spp.) at five levels of potassium (0, 15, 30, and 60 kg/ha). Thirty germplasm lines belonging three species viz. *Amaranthus tricolor* L., *Amaranthus dubius* L. and *Amaranthus cruentus* L. were included in the trial. 'Acc 14' *Amaranthus cruentus* L. had the highest dry matter (17.17%, followed by 'Acc 65' *Amaranthus tricolor* L. (16.92%) at 60 kg/ha potassium.

Subhan (1989) applied potassium to *Amaranthus tricolor* as a single application at sowing, or as a split application at sowing and 10 days after sowing in a field trial at Lembang, Indonesia. The highest yield was obtained with split application.

Olufolaji and Tayo (1989) reported the effect of seedling rate on the performance of direct drilled amaranth. Two field trials were conducted by using 80kg MP/ha to determine the optimum sowing rate of *Amaranthus cruentus* required for a vegetative yield of about 20 t/ha. Seedling establishment, plant height, leaf area index, total plant yield and edible shoot yield were measured. The highest total and edible shoot yield (18.57 and 2.47 t/ha respectively) were obtained at a sowing rate of 6 kg/ha.

Bressani *et al.* (1987) conducted some experiment on *Amaranthus* spp. to response of chemical fertilizers in America, Peru and Guatemala. *Amaranthus* spp. were grown with potassium fertilizer at 0, 30, 60 and 90 kg/ha respectively. Highest plant height was ranged from 43 to 60 cm in different region.

Makus (1984) carried out an experiment on *Amaranthus tricolor* L, were fertilized at five levels of nitrogen corporate with potassium and produced between 10.00 to 18.40 t/ha of plant biomass. All treatments at split application of nitrogen and potassium gave the highest yield response.

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

According to Prasad *et al.* (1980) correlation co-efficient at phenotypic level showed that the yield has increased with an increase in leaf length and the leaf width at the rate of potassium 40-60 kg/ ha. The leaf length has also increased with an increase in leaf width. Cerne and Briski (1994) in an experiment showed that the combination of 400 kg K_20/ha, stable manure and irrigation gave the highest total yield of tomato in the 1st and 2nd years (1.03 and 2.25 kg/ plant, respectively).

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

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

2.3. Combined effect on growth and yield

A study was conducted by Linkui *et al.* (2002) in Shanghi, China to investigate the effect of different bio-organic fertilizers on the yield and quality of 3-coloured amaranth. Fertilizers applied at the rate of 1.9 kg/plot was: The big tri-element, N 10 bio-organic and exclusive vegetable fertilizers. Amaranth receiving bio-fertilizers showed a yield increase of 15-38% compared to those receiving exclusive vegetable fertilizers.

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 up to 50ton/ha.

Mazumdar (2004) reported that the optimum yield of amaranth was obtained from BARI Data-1 at Bangladesh Agricultural Research Institute, Gazipur. The highest yield 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 ha respectively.

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

A study was conducted on the effect of plant density on the green yield and seed production in different cultivars of stem amaranth by Talukdar (1999) at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. Different growth attributing characters were investigated. Fertilizer dose was 200-100-200 kg/ha as urea, triple super phosphate and muriate of potash respectively. The highest stem yield was 355.75 g/plant and green yield was 94.41 t/ha at wider spacing (30cmX10 cm).

Saini and Shekhar (1998) carried out an experiment on amaranth at different levels of nitrogen with phosphorus and potassium and found that yield and most yield components increased significantly upto 90 kg N/ ha, then decreased.

The effect of nitrogen fertilizer on amaranth *(Amaranthus* spp.) grain yield, yield components and growth and development was investigated by Myers (1998) in three Missouri environments with five levels of nitrogen fertilizer and three cultivars. Phosphorus and potassium fertilizers were also used in each treatment. Yield was responsive to nitrogen application, but high rates of nitrogen fertilizer can negatively affect grain harvest in terms of excessive plant height, increased lodging and crop maturity.

A comparative study on yield and quality of some amaranth genotypes was done by Hossain (1996) at the Bangabandhu Sheikh Mujibur Rahman Agricultural University. Fertilizer dose was cowdung, urea, triple super phosphate and muriate of potash as 20 t, 200 kg, 100 kg and 200 kg/ha respectively. Different growth and yield contributing characters were evaluated. The highest green yield was obtained from Ausdanta (81.24 t/ha) and minimum in Fire field (27.85 t/ha). The highest dry matter recorded as 10.07%.

A study was conducted by Apaza (1994) in representative areas of the cevtral valley of Tarija in Bolivia. Two species of amaranth were evaluated for their response to eight levels of fertilizer: control treatment, chemical (40-40-20) and (80-80-40) NPK, organic (7.5t/ ha, 15t/ha dried ovine manure), mixed (20-20-10+ 3.75 t/ha, 40-40-20+ 7.5 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 200 kg urea, 100 kg triple super phosphate and 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, *Amaranthus hypochondriacs1008, Amaranthus hypochondriacs* K 402, *Amaranthus cruentus* 17-GUA, *Amaranthus cruentus* 29-USA 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 height, number of leaves, plant

diameter and yield. Height and 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.

Moniruzzan (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 Mohideen *et al.* (1983) to ascertain the yield potential of grain type's amaranth. Fertilizer doses were 85 kg N, 60 kg P and 60 kg K per hectare respectively. Eight grain amaranth types were evaluated for yield and yield attributes. Highest plant height was recorded as 172.5 cm. The mean weight of 8 types of amaranth was 276.00 g at 35 DAS.

In Himachal Pradesh, in a study NPK at the rate of 60, 50 30 kg per hectare, respectively, were recommended for getting the best yield of vegetables (Anon, 1978).

Grubben (1977) in an experiment on amaranth recommended fertilizer doses of amaranth as a mixture of 10-10-20 N-P-K applied at 400 kg/ha for plants to be uprooted and at 600 kg/ha for plant to be harvested respectively.

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 other attributes form 1972 onwards. The Co.1 was used as standard for these evaluations.

Further work on the improvement program of this crop in Tamil Nadu Agricultural University by Department of Horticulture, resulted in 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 75 DAS. The length and breadth of leaves were ranged from 9.80 to 10.20 cm and 5.10 to 7.60 cm respectively at 40 DAS. Weight of stem and leaves after harvesting at 40 DAS were 110 to 140 g and 220 to 170 g respectively. Fertilizer doses of this study were 85 kg N, 60 kg P and 60 kg K per hectare respectively.

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

Mohideen *et al.* (1985) conducted an experiment for an evaluation program in amaranth under the all Indian coordinated vegetable improvement project at the Tamil Nadu Agriculture University. A promising clipping type (A.83) was released as Co.3 amaranth over local type after testing for five seasons. Fertilizer doses were 85 kg N, 60 kg P and 60 kg K per hectare respectively. The leaf stem ratio was 2.00 and the yield performance of this strain was recorded a mean yield of 30.716 kg/ha.

CHAPTER III

MATERIALS AND METHODS

MATERIELS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment.

3.1. Experimental site

The experiment was conducted at the Central Farm of the Sher-e-Bangla Agricultural University, Dhaka during the period from April to June, 2005. The experimental site was previously used as vegetable cultivation and recently developed for research works. The location of the site is situated in 23°72′ N latitude and 90°35′ E longitude with an elevation of 8.2 meter from sea level (Anon., 1989).

3.2. Climate

The climate of experimental site is sub-tropical, characterized by heavy rainfall during Kharif season (April to September) and scanty during the Rabi season (October to March). There was no rainfall during the month of December, January and February. The average maximum temperature of experimental site during the period of study was 31.6°C and the average minimum temperature was 21.5°C. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the period of the experiment were collected from Bangladesh Meteorogical Department (Climate Division), Sher-e-Bangla Nagar, Dhaka and have been presented in Appendix I.

3.3. Characteristics of soil

The soil of the experimental area belongs to the Madhupur Tract (UNDP, 1988). The experimental site was a medium high land. Soil texture was silty loam with a p^H of 6.3.

The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute, Soil Testing Laboratory, Khamar Bari, Dhaka and have been presented in Appendix II. The morphological characters of soil of the experimental plot as indicated by FAO (1988) are given below-

AEZ No. -28

Soil series - Tejgoan

General soil - Non- calcarious dark grey

3.4. Planting materials used for experiment

The variety name of amaranth used in the experiment was "Baspata". It was a high yielding variety and the seeds were collected from the sale center of Bangladesh Agricultural Development Corporation (BADC).

3.5. Treatments of the experiment

Experiment consists of two factors:

Factor-A:

Phosphorus (4 levels)

Triple super phosphate was used as the source of phosphorus.

1. P_0: Control treatment (No fertilizer)
2. P_1: 43.2 kg P_2O_5 /ha (90 kg TSP/ha)
3. P_2: 48 kg P_2O_5 /ha (100 kg TSP/ha)
4. P_3: 52.8 kg P_2O_5 /ha (110 kg TSP/ha)

Factor-B:

Potassium (4 levels)

Muriate of potash was used as the source of potassium.

1. K_0: Control treatment (No fertilizer)
2. K_1: 114 kg K_2O /ha (190 kg MP/ha)
3. K_2: 120 kg K_2O /ha (200 kg MP/ha)
4. K_3: 126 kg K_2O /ha (210 kg MP/ha)

There were altogether 16 treatments combination such as:

P_0K_0	P_1K_0	P_2K_0	P_3K_0
P_0K_1	P_1K_1	P_2K_1	P_3K_1
P_0K_2	P_1K_2	P_2K_2	P_3K_2
P_0K_3	P_1K_3	P_2K_3	P_3K_3

3.6. Layout and design of experiment

The two factors experiment was laid out following Randomized Complete Block Design (RCBD) with three replications. An area of 31.5m×8m was divided into three equal blocks. Each block was divided into 16 plots where 16 treatments were allotted at random. Thus there were 48 unit plots altogether in the experiment. The size of each plot was 3 m^2 (2 m×1.5 m). The distance between two blocks and two plots were kept 1m and 0.5m respectively. A layout of the experiment has been shown in figure 1.

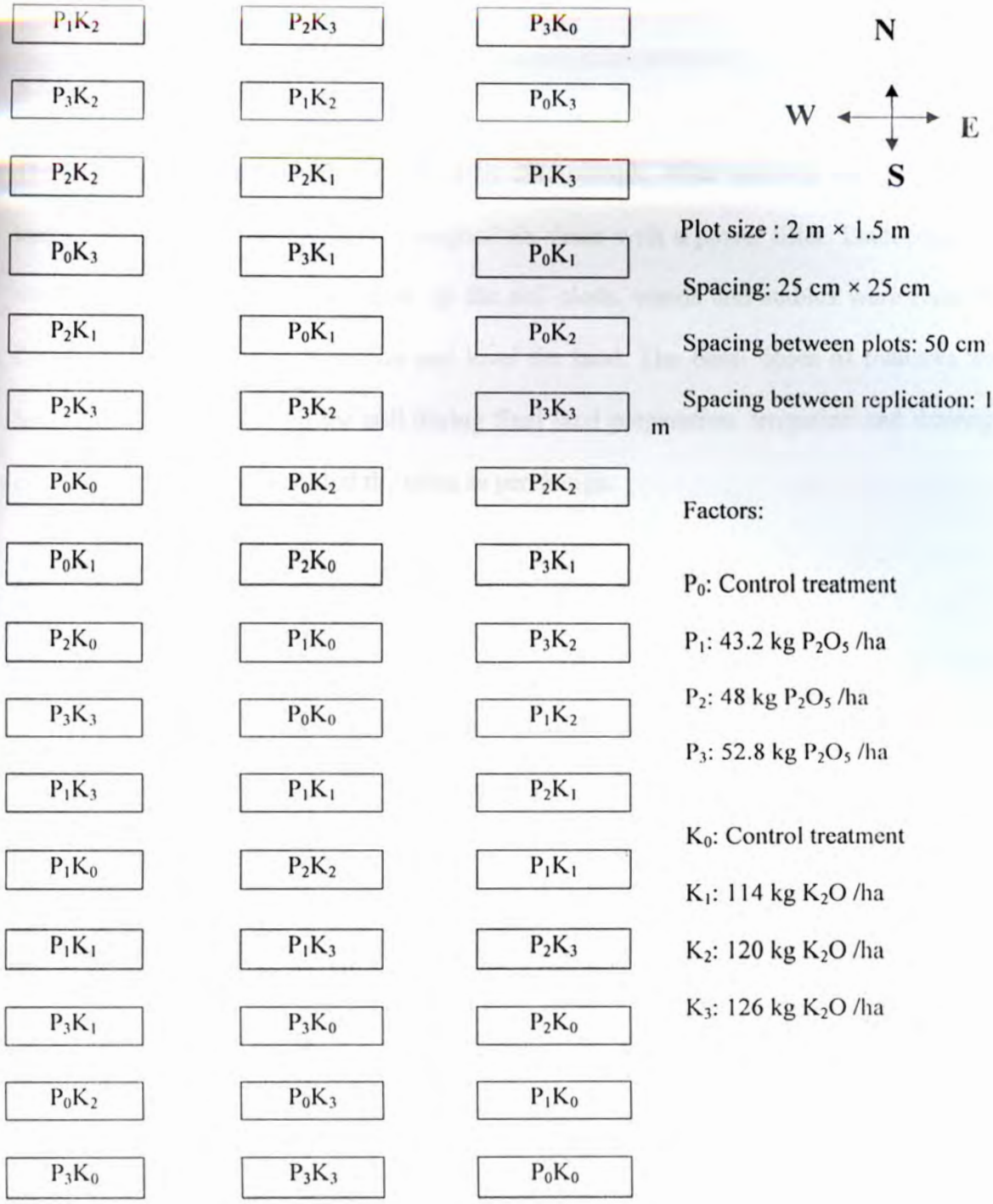

Figure 1. Field layout of the two fectors experiment in the Randomized Complete Block Design (RCBD)

3.7. Cultivation procedure

3.7.1. Land preparation

The experimental plot was first opened by disc plough. After opening the land with a tractor it was ploughed and cross ploughed six times with a power tiller. Each ploughed was followed by laddering to break up the soil clods, weeds and stables were removed from the field to obtain good tilth and level the land. The basal doses of manures and fertilizers were mixed into the soil during final land preparation. Irrigation and drainage channels were prepared around the plots as per design.

3.7.2. Manure and fertilizers and its methods of application

Urea, triple super phosphate (TSP) and muriate of potash (MP) were applied as the source of nitrogen, phosphorus and potassium respectively as per treatment in each plot.

Phosphorus and potassium was applied as per treatment and urea was applied at the rate of 200 kg/ha (Rashid, 1993). The quantity of manure, cow dung was also determined as recommended by Rashid (1993) at the rate of 10 t/ha.

The entire amount of cowdung, TSP and half of MP were applied as basal during land preparation. Those were mixed with the soil of the individual plot 4 days before seed sowing. The full amount of urea and half of MP were used as top dressing in three equal splits 15, 25 and 35 days after sowing (DAS).

3.7.3. Sowing of seeds

After final land preparation, the seeds were sown at the rate of 5 kg/ha in row maintaining a spacing of 25 cm×25 cm (Rashid, 1993). Seeds were sown on 25 April,

2005. Each unit plot had 8 rows and each with 6 plants. So there were 48 plants per unit plot.

3.7.4. Intercultural operations

Necessary intercultural operations were done through the cropping season for proper growth and development of the plant.

3.7.4.1. Weeding

Two weeding were done at 15 days interval.

3.7.4.2. Irrigation and drainage

Irrigation was done every alternate day in the evening up to 1st weeding. Further irrigation was done as when needed. Stagnant water was effectively drained out at the time of heavy rain.

3.7.4.3. Pest management

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.

3.7.5. Harvesting

To evaluate growth rate and yield, three harvesting were done at different growth stage. First harvesting was done at 35 days after sowing. Second and third harvesting were done at 40 and 45 days after sowing respectively. Different yield contributing data have been recorded from the mean of 10 (ten) harvested plant which was selected at random of each unit plot of every harvesting stage.

3.8. Collection of data

Data were recorded on the following parameters from the sample plants during the course of experiment. Ten (10) 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 at the extreme end of the middle rows were excluded from the random selection to avoid the border effect.

i) Plant height

Plant height was measured in centimeter (cm) by a meter scale at 25, 35 and 45 days after sowing (DAS) from the point of attachment to the ground level up to the tip of the longest leaf from 10 selected plants.

ii) Number of leaves per plant

To estimate number of leaves per plant, leaves were counted at 25, 35 and 45 days after sowing (DAS) from 10 selected plants. All the leaves of selected plants were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting.

iii) Plant diameter

Diameter of the stem of ten selected plant from each plot at 25, 35 and 45 days after sowing (DAS) measured in centimeter (cm) by slide calipers.

iv) Weight of stem per plant

Weight of ten selected plant excluding roots and leaves were recorded during harvest from each plot at 35, 40 and 45 days after sowing (DAS) and measured in gram (g).

v) Weight of leaves per plant

Separating leaves from the stem, weight of leaves of ten selected plant were recorded during harvest from each plot at 35, 40 and 45 days after sowing (DAS) and measured in gram (g).

vi) Green yield per plant

Green yield of plant was recorded as weight of entire plant including leaves and stem from each plot at 35, 40 and 45 days after sowing (DAS) and measured in gram (g).

vii) Green yield per hectare

Green yield per hectare was calculated in ton (t) after harvest by computing green yield per plot (multiplying green yield per plant by 48 plant) and then converting it into hectare at 35, 40 and 45 days after sowing (DAS).

viii) Dry matter of stem per plant

After harvesting, randomly selected 100 gram of stem sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0 C 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 were computed by simple calculation from the weight recorded at 35, 40 and 45 days after sowing (DAS) by the following formula.

$$\text{Dry matter of stem \%} = \frac{\text{Dry weight of stem}}{\text{Fresh weight of stem}} \times 100$$

ix) Dry matter of leaves per plant

After harvesting, randomly selected 100 gram of leaf sample previously sliced into very thin pieces were put into envelop and placed in oven maintained at 60^0 C 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 were computed by simple calculation from the weight recorded at 35, 40 and 45 days after sowing (DAS) by the following formula.

$$\text{Dry matter of leaf \%} = \frac{\text{Dry weight of leaf}}{\text{Fresh weight of leaf}} \times 100$$

x) Benefit cost ratio

Total cost of production was calculated and has been presented in appendix IV. Gross return was calculated by selling amaranth @ 2500 Tk. per ton and net return was computed by deducting total cost of production from gross return. Benefit cost ratio (BCR) was computed by the following formula.

$$\text{Benefit cost ratio} = \frac{\text{Net return}}{\text{Total cost of production}}$$

3.9. Statistical analysis

The recorded data on various parameters were statistically analyzed using MSTAT package program. The means of all treatment was calculated and the analysis of variance for each of the characters under study was performed by F- test. Difference between treatment means were determined by Duncan's New Multiple Range Test (DMRT) according to Gomez and Gomez, (1984).

CHAPTER IV

RESULT AND DISCUSSION

The experiment was conducted to investigate the effect of different levels of phosphorus and potassium on the growth and yield of stem amaranth. The analysis of variances for different characters has been presented in Appendix III. Data on different parameters were analyzed statistically and the results have been presented in the Table 1 to 16 and Figures 2 to 7. The results of the present study have been presented and discussed in this chapter under the following headings.

4.1. Plant height

The plant height varied significantly due to the individual application of different level of phosphorus and potassium at 25 DAS, 35 DAS and 45 DAS (Figure 2 & 3). The tallest plant height at all observations were observed from the plot that received 48 kg P_2O_5 /ha. Phosphorus at a level of 48 kg P_2O_5 /ha of treatment P_2 gave the highest plant height (39.59 cm) at 25 DAS, while the control treatment (0 kg P_2O_5/ha) gave the lowest (32.86 cm) at 25 DAS. The tallest plant height (63.48 cm) was observed from treatment P_2, while the shortest (54.39 cm) was from the control treatment at 35 DAS. At 45 DAS the highest plant height was recorded 87.99 cm from treatment P_2 and the lowest was 78.17 cm from the control treatment (Figure 2).

It was observed that various level of potassium exhibited significant affect on the plant height at 25, 35 and 45 DAS (Figure 3). The tallest plant height was 39.13 cm from 120 kg K_2O/ ha and the shortest plant height 32.95 cm was from 0 kg K_2O/ ha at 25 DAS. At 35 DAS the tallest plant height (63.17 cm) was found from K_2 treatment, while the shortest (54.43 cm) was from the control treatment. The maximum plant height was recorded 87.49 cm from the treatment of K_2 (120 kg K_2O/ ha) and the minimum was

78.51 cm from the treatment of K_0 (0 kg K_2O/ha) at 45 DAS. So it is clear that plant height increases up to the potassium level of 120 kg K_2O/ ha.

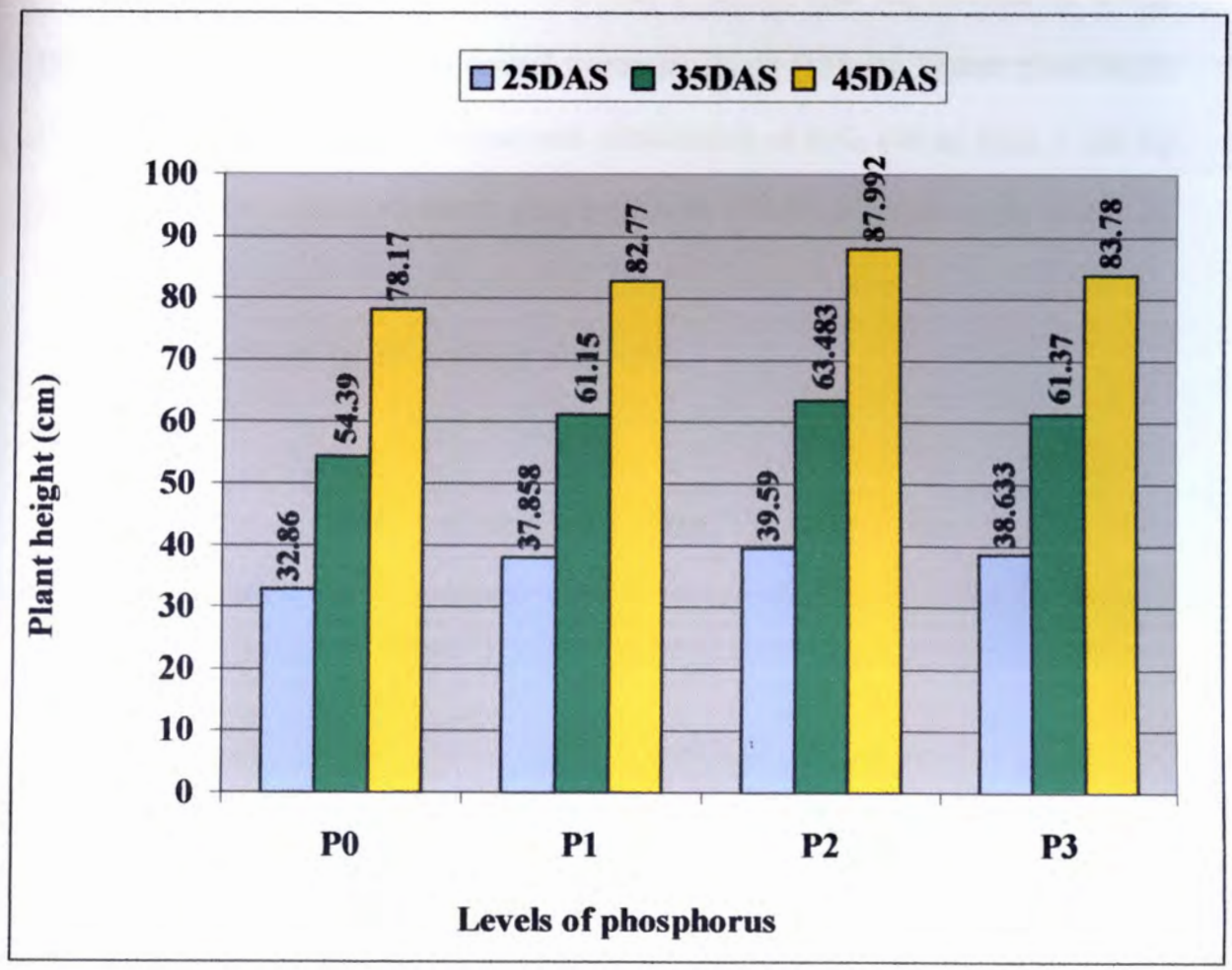

Figure 2. Effect of phosphorus on the plant height of stem amaranth at different days after sowing (DAS).

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

The plant height was significantly influenced by the interaction effect of phosphorus and potassium. The combined effect of phosphorus and potassium at different days after sowing was also significant (Appendix III). The highest plant height (41.5 cm) was recorded at 25 DAS from the combined effect of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha),

while the control treatment i.e. P_0K_0 (0 kg P_2O_5 / ha + 0 kg K_2O/ ha) gave the lowest plant height (33.07 cm) at 25 DAS. At 35 DAS significant variation in plant height was also observed among the treatments. The highest plant height (65.63 cm) was observed from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha) whereas the lowest (54.53 cm) was found from the control treatment. At 45 DAS the highest plant height (92.47 cm) was found from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha) and the control treatment gave the lowest (78.47 cm) plant height (Table 1). From the data it reveals that both phosphorus and potassium favored the plant height at a certain level then plant height gradually decreased.

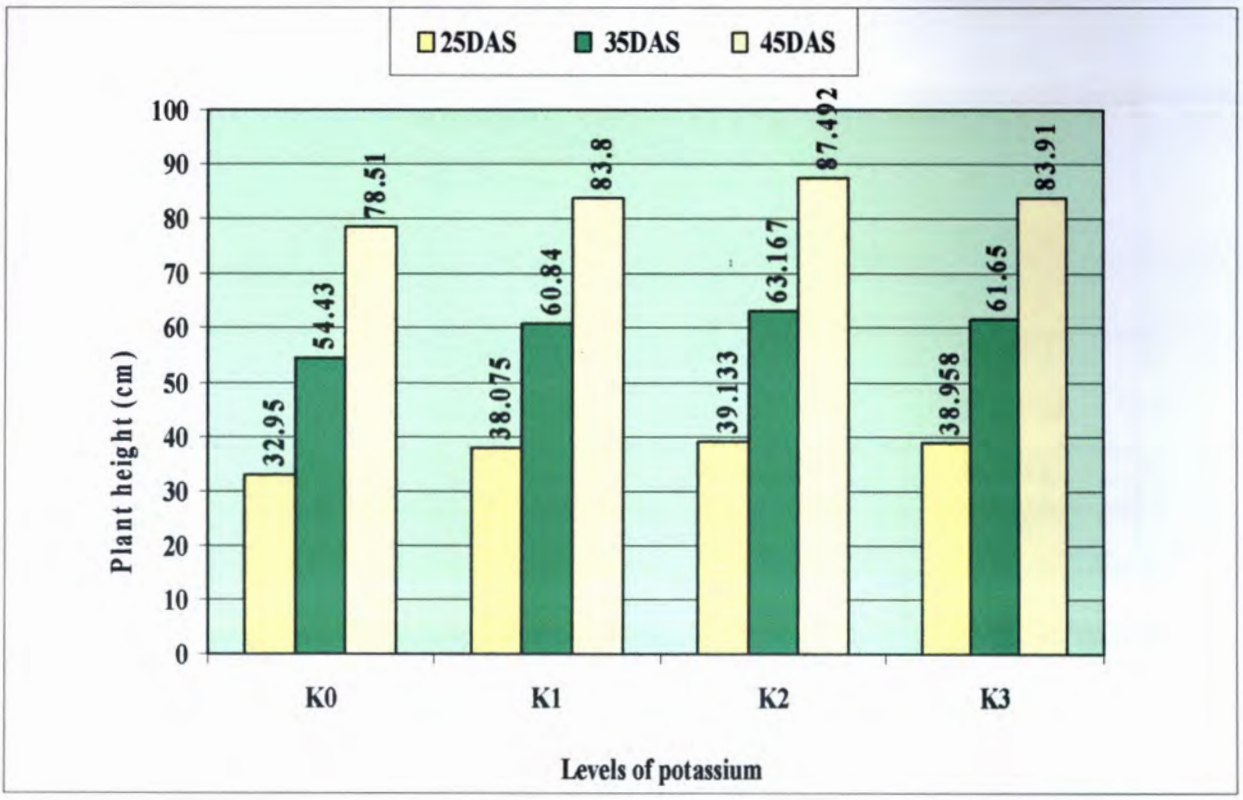

Figure 3. Effect of potassium on the plant height of stem amaranth at different days after sowing (DAS).

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha , K_3: 126 kg K_2O /ha

Table 1. Combined effect of phosphorus and potassium on plant height at different days after sowing (DAS).

Treatment Combination	Plant height (cm) at different DAS		
	25 DAS	35 DAS	45 DAS
$P_0 K_0$	33.07 j	54.53 k	78.47 l
$P_0 K_1$	34.67 i	59.77 j	82.90 k
$P_0 K_2$	36.87 f	60.90 h	84.07 i
$P_0 K_3$	35.43 hi	60.40 i	83.43 j
$P_1 K_0$	34.07 i	59.20 j	82.93 k
$P_1 K_1$	40.90 e	62.07 f	85.57 g
$P_1 K_2$	38.13 e	62.23 ef	87.10 d
$P_1 K_3$	39.10 d	63.10 d	86.47 e
$P_2 K_0$	36.57 g	60.43 h	83.93 i
$P_2 K_1$	40.07 b	63.17 d	87.93 b
$P_2 K_2$	41.50 a	65.63 a	92.47 a
$P_2 K_3$	40.13 b	63.70 bc	87.63 bc
$P_3 K_0$	34.67 i	59.57 j	82.70 k
$P_3 K_1$	39.67 c	62.57 e	87.00 d
$P_3 K_2$	40.13 b	63.90 b	87.33 cd
$P_3 K_3$	40.17 b	63.43 cd	86.10 f
CV (%)	0.40	0.33	0.25

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

The result of the study are compared to Talukder (1999) who recorded plant height of three amaranth cultivars at 30 DAS ranged from 32.50 to 39.88 cm, at 40 DAS ranged from 57.99 to 61.30 cm and at 45 DAS ranged from 75.68 to 81.84 cm. Similar result was found by Hossain (1996).

4.2. Number of leaves per plant

Phosphorus individually played a significant positive role in increasing the number of leaves per plant (Table 2). The maximum number of leaves (31.42) was performed from the P_3 treatment (52.8 kg P_2O_5 /ha) and the minimum (19.25) was obtained from the control treatment at 25 DAS. The highest number of leaves (54.25) was recorded from the P_3 treatment and the lowest (33.5) was recorded from the control treatment at 35 DAS. At 45 DAS the maximum number of leaves (69.25) was found from P_3 treatment and the minimum number (40.5) was found from the control treatment.

Table 2. Main effect of phosphorus on number of leaves of stem amaranth at different days after sowing (DAS).

Treatment Combination	Number of leaves at different DAS		
	25 DAS	35 DAS	45 DAS
P_0	22.25b	33.5c	41.5d
P_1	25.5b	38.58c	46.5c
P_2	29a	44.33b	55.25b
P_3	32.42a	54.25a	69.25a
CV (%)	12.57	11.54	8.45

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

The result of this study favored the study of Portal (1992). He reported that number of leaves per plant increased with the increasing levels of phosphorus.

Number of leaves per plant increased up to the level of 120 kg K_2O /ha (K_2) and then decreased. The highest number of leaves was found 31.42 from K_2 treatment at 25 DAS, while the lowest number of leaves was found 19.08 from control treatment (Table 3). The highest number of leaves (46.75) was recorded from K_2 treatment at 35 DAS, while the lowest number of leaves was observed 32.75 from the control treatment. At 45 DAS the highest number of leaves (59.00) was from K_2 treatment and the lowest number of leaves (38.17) was found from control treatment.

Table 3. Main effect of potassium on number of leaves at different days after sowing (DAS).

Treatment Combination	Number of leaves at different DAS		
	25 DAS	35 DAS	45 DAS
K_0	24.08c	32.75c	41.17c
K_1	28.83ab	36.25c	55.67b
K_2	31.42a	46.75a	59.00a
K_3	26.83bc	41.92b	52.67b
CV (%)	12.57	11.54	8.45

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha , K_3: 126 kg K_2O /ha

Table 4. Combined effect of phosphorus and potassium on number of leaves at different days after sowing (DAS)

Treatment Combination	Number of leaves at different DAS		
	25 DAS	35 DAS	45 DAS
P_0 K_0	19.33 g	32.93 d	38.00 e
P_0 K_1	22.67 fg	36.33 d	43.67 c-e
P_0 K_2	25.67 e-g	38.67 d	45.33 c-e
P_0 K_3	23.33 fg	36.67 d	43.00 c-e
P_1 K_0	23.67 fg	38.33 d	43.33 c-e
P_1 K_1	26.00 d-g	39.67 d	46.67 c-e
P_1 K_2	27.00 c-g	42.67 d	49.00 cd
P_1 K_3	26.33 d-g	40.00 d	47.67 c-e
P_2 K_0	25.00 e-g	39.67 d	45.00 c-e
P_2 K_1	30.33 b-e	46.00 cd	58.00 bc
P_2 K_2	33.33 bc	51.33 c	63.00 b
P_2 K_3	31.33 b-d	43.33 d	59.67 bc
P_3 K_0	23.33 fg	40.67 d	49.00 cd
P_3 K_1	36.33 ab	56.00 b	73.33 a
P_3 K_2	39.667 a	63.00 a	78.33 a
P_3 K_3	35.33 bc	59.33 ab	74.67 a
CV (%)	12.57	11.54	8.

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

Number of leaves per plant was significantly influenced by the interaction effect of phosphorus and potassium. The combined effect of phosphorus and potassium at different days after sowing was also significant (Appendix III). Number of leaves per plant increased with the increasing combined levels of phosphorus and potassium. The highest number of leaves was found 39.67 from the treatment combination of P_3K_2 (52.8 kg P_2O_5 /ha +120 kg K_2O /ha) at 25 DAS, while the lowest number of leaves was found 19.33 from the control treatment. At 35 DAS maximum number of leaves (61.00) was counted from the treatment combination of P_3K_2, whereas the minimum number (32.93) was counted from the control treatment. The highest number of leaves was recorded 78.33 from the treatment combination of P_3K_2 at 45 DAS and the control treatment gave the lowest (38.00) (Table 4).

Hamid *et al.* (1989) found in an experiment that the maximum number of leaves per plant at 49 DAS in local cultivars was ranged from 72.3 to 162. The result of present study at 45 DAS was within the range of the report.

4.3. Plant diameter

The plant diameter per plant varied significantly due to the application of different levels of phosphorus and potassium at 25 DAS, 35 DAS and 45 DAS (Table 5 & 6). The maximum plant diameter per plant was observed in the plot that received 48 kg P_2O_5 /ha after then decreased. Phosphorus at a level of 48 kg P_2O_5 /ha (P_2) performed maximum plant diameter (1.50 cm), while the control treatment (0 kg P_2O_5/ha) gave the minimum plant diameter (0.91 cm) at 25 DAS. At 35 DAS the maximum plant diameter (2.06 cm) was obtained from P_2 treatment and the minimum (1.31 cm) was from the control

treatment. The maximum and the minimum plant diameter at 45 DAS was observed 2.43 cm and 1.5 cm from the P_2 treatment and the control treatment respectively (Table 5).

Table 5. Effect of phosphorus on plant diameter of stem amaranth

Treatment Combination	Plant diameter (cm) at different DAS		
	25 DAS	35 DAS	45 DAS
P_0	0.91d	1.31b	1.5db
P_1	1.22c	1.76b	2.295ab
P_2	1.5a	2.056a	2.43a
P_3	1.26b	1.8b	2.297ab
CV (%)	1.38	6.09	8.19

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

Table 6. Effect of potassium on plant diameter of stem amaranth at different days after sowing (DAS)

Treatment Combination	Plant diameter (cm) at different DAS		
	25 DAS	35 DAS	45 DAS
K_0	0.88d	1.23c	1.52c
K_1	1.23c	1.78b	2.411b
K_2	1.501a	2.08a	2.7a
K_3	1.27b	1.79b	2.428b
CV (%)	1.38	6.09	8.19

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha, K_3: 126 kg K_2O /ha

It was observed that various level of potassium exhibited significant affect on the plant diameter at 25, 35 and 45 DAS (Table 6). The maximum plant diameter was found in the plot that received 120 kg K_2O/ ha (K_2) then decreased. During the first observation maximum plant diameter (1.5 cm) was observed from K_2 treatment, the minimum plant diameter (0.88 cm) was observed from control treatment. At 35 DAS the maximum plant diameter (2.08 cm) was in K_2 treatment and the minimum (1.23 cm) was from the control treatment. At 45 DAS the maximum plant diameter was found 2.70 cm and the minimum was 1.52 cm from the K_2 treatment and the control treatment respectively.

Plant diameter per plant was significantly influenced by the interaction effect at different days after sowing (Appendix III). The maximum plant diameter was observed with the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha) after then gradually decreased. The maximum plant diameter was found 1.55 cm from the treatment combination of P_2K_2 at 25 DAS, while the minimum was observed 0.98 cm from the control treatment. The highest average plant diameter was obtained 2.33 cm found from the treatment combination of P_2K_2 and the lowest value was found 1.30 cm from the control treatment at 35 DAS. At 45 DAS the highest plant diameter was observed 3.00 cm from the treatment combination of P_2K_2 and the lowest plant diameter was determined 1.50 cm from the control treatment (Table 7). From the data it reveals that both phosphorus and potassium increase the plant diameter up to a certain level and then gradually decreased.

Talukder (1999) recorded the plant diameter of three cultivar of amaranth which was ranged from 1.22 to 1.5 cm at 30 DAS, 1.98 to 2.38 cm at 40 DAS and 2.35 to 2.98 cm at 45 DAS which was similar to the present study at 25, 35 and 45 DAS observations. Hossain (1996) also found the same result in 11 amaranth cultivars.

Table 7. Combined effect of phosphorus and potassium on plant diameter at different days after sowing (DAS)

Treatment Combination	Plant diameter (cm) at different DAS		
	25DAS	35DAS	45DAS
$P_0 K_0$	0.98 j	1.30 h	1.50 d
$P_0 K_1$	1.25 i	1.78 d-f	2.26 c
$P_0 K_2$	1.28 i	1.91 c-e	2.32 c
$P_0 K_3$	1.25 i	1.83 c-e	2.30 c
$P_1 K_0$	1.24 i	1.47 gh	2.27 c
$P_1 K_1$	1.36 g	1.89 c-e	2.41 bc
$P_1 K_2$	1.47 c	2.02 bc	2.53 bc
$P_1 K_3$	1.42 e	1.97 b-d	2.40 bc
$P_2 K_0$	1.26 i	1.61 fg	2.34 c
$P_2 K_1$	1.51 b	2.15 ab	2.50 bc
$P_2 K_2$	1.55 a	2.34 a	3.00 a
$P_2 K_3$	1.50 b	2.13 b	2.52 bc
$P_3 K_0$	1.27 i	1.78 d-f	2.22 c
$P_3 K_1$	1.45 cd	1.72 ef	2.47 bc
$P_3 K_2$	1.46 c	2.13 b	2.52 bc
$P_3 K_3$	1.44 cd	1.97 b-d	2.49 bc
CV (%)	1.38	6.09	8.19

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment

P_1: 43.2 kg P_2O_5 /ha

P_2: 48 kg P_2O_5 /ha

P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment

K_1: 114 kg K_2O /ha

K_2: 120 kg K_2O /ha

K_3: 126 kg K_2O /ha

4.4. Weight of stem per plant

Significant variation was observed among the treatments in respect of weight of stem per plant at different days of observation. The highest weight of stem per plant was observed in P_2 treatment (48 kg P_2O_5 /ha) at different stages of harvesting i.e., 35, 40 and 45 DAS, while the control treatment gave the lowest. During the first observation the highest weight of stem per plant was observed from P_2 treatment (52.21 g), while the lowest weight of stem was obtained from control treatment (33.56 g). At 40 DAS the highest weight of stem per plant was obtained 153.88 g from the P_2 treatment and the lowest was observed 125. g from the control treatment. The highest weight of stem per plant was observed 220.0 g from the P_2 treatment and 141.45 g was the lowest value that found from the control treatment at 45 DAS (Table 8).

It was observed that various level of potassium exhibited significant affect on the weight of stem per plant at 35, 40 and 45 DAS (Table 9). During the first observation the highest weight of stem per plant was observed from K_2 treatment (49.50 g). The lowest weight of stem was obtained from the control treatment (33.71 g). At 40 DAS the highest weight of stem per plant was found 151.50 g in K_2 treatment and the lowest was observed 125.00 g from the control treatment. The highest and the lowest weight of stem per plant at 45 DAS were 211.79 g from K_2 treatment and 140.39 g from the control treatment respectively.

Significant variation was also observed among the treatments in respect of weight of stem at all stages of harvesting i.e., 35, 40 and 45 DAS (Appendix III). The highest weight of stem per plant was observed in the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha) then gradually

decreased. The highest weight of stem per plant was found 60.00 g from the treatment combination of P_2K_2 at 35 DAS, while the control treatment gave the lowest (33.12 g). At 40 DAS the highest weight was found 163.11 g from the treatment combination of P_2K_2 and the lowest was 125.19 g from the control treatment. The highest weight of stem per plant at 45 DAS was obtained 243.70 g from the treatment combination of P_2K_2 and the lowest was found 141.00 g from the control treatment (Table 10).

The results on stem green yield of plant at different stages obtained in this study are comparable to the findings of Talukder (1999) who recorded the stem weight of 25.93 to 41.55 g at 35 DAS, 119.07 to 180.02 g at 40 DAS and 193.56 to 291.68 g at 45 DAS respectively in three amaranth cultivars.

4.5. Weight of leaves per plant

Significant variation was observed among the treatments in respect of weight of leaves per plant at different days of observation. The highest weight of leaves per plant was observed in P_2 treatment (48 kg P_2O_5 /ha) at different stages of harvesting i.e., 35, 40 and 45 DAS, while the control treatment gave the lowest. During the first observation the highest weight of leaves per plant (36.58 g) was observed from P_2 treatment and the lowest weight of leaves was obtained 20.67 g from the control treatment. At 40 DAS the highest weight of leaves per plant was recorded 59.00 g from P_2 treatment and the lowest was found 36.43 g from the control treatment. The highest weight (81.16 g) was observed from P_2 treatment and the lowest weight of leaves per plant (51.45 g) was recorded from the control treatment at 45 DAS (Table 8).

Table 8. Effect of phosphorus on weight of stem and weight of leaves at different days after sowing (DAS)

Treatment Combination	Weight of stem per plant (g) at different DAS			Weight of leaves per plant (g) at different DAS		
	35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
P_0	33.56d	125.45c	141.44d	20.67c	36.43c	51.44d
P_1	43.736c	146.53b	193.58c	31.72b	50.918b	65.999b
P_2	52.21a	153.88a	220.00a	36.58a	59.00a	81.163a
P_3	46.396b	146.07b	199.05b	30.02b	51.17b	62.642c
CV (%)	3.01	1.07	1.27	2.76	9.43	2.46

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

Table 9. Effect of potassium on weight of stem and weight of leaves at different days after sowing (DAS)

Treatment Combination	Weight of stem per plant (g) at different DAS			Weight of leaves per plant (g) at different DAS		
	35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
K_0	33.71c	125.04c	140.39c	19.58c	37.97c	51.52d
K_1	46.495b	147.32b	198.56b	29.8b	48.01b	61.32b
K_2	49.511a	151.5a	211.79a	35.072a	56.926a	73.636a
K_3	46.183b	148.10b	200.31b	31.45b	50.6b	60.8c
CV (%)	3.01	1.07	1.27	2.76	9.43	2.46

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha, K_3: 126 kg K_2O /ha

Table 10. Combined effect of phosphorus and potassium on weight of stem and weight of leaves at different days after sowing (DAS)

Treatment Combination	Weight of stem per plant (g) at different DAS			Weight of leaves per plant (g) at different DAS		
	35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
$P_0 K_0$	33.12 i	125.19 h	141.00 j	19.74 f	35.47 f	51.24 h
$P_0 K_1$	41.25 gh	132.95 fg	164.31 I	25.14 e	41.68 e	54.41 g
$P_0 K_2$	42.55 f-h	136.61 e	174.85 fg	25.21 e	43.67 e	57.59 f
$P_0 K_3$	41.32 e-g	133.06 fg	169.58 h	24.22 e	42.92 e	54.54 g
$P_1 K_0$	41.01 h	134.31 ef	171.12 gh	24.22 e	41.43 e	54.41 g
$P_1 K_1$	43.78 e-g	148.84 d	194.18 e	35.41 cd	51.97 d	68.14 d
$P_1 K_2$	45.91 de	153.73 c	212.36 c	36.37 cd	57.87 c	75.39 c
$P_1 K_3$	44.24 ef	149.24 d	196.66 e	34.89 d	52.41 cd	66.06 de
$P_2 K_0$	42.92 f-h	135.56 ef	176.24 f	25.21 e	46.46 e	57.88 f
$P_2 K_1$	52.83 b	157.81 b	229.16 b	39.46 b	54.08 c	86.77 b
$P_2 K_2$	60.00 a	163.11 a	243.70 a	42.12 a	70.73 a	94.10 a
$P_2 K_3$	53.07 b	159.04 b	230.88 b	39.53 b	64.66 b	85.90 b
$P_3 K_0$	41.78 f-h	131.12 g	169.26 h	25.14 e	42.55 e	54.54 g
$P_3 K_1$	48.13 cd	149.69 d	206.60 h	35.19 cd	52.28 cd	63.94 e
$P_3 K_2$	49.57 c	152.42 c	216.23 c	36.59 c	55.43 c	67.47 d
$P_3 K_3$	46.11 b-e	151.06 cd	204.12 d	35.17 cd	54.44 c	64.61 e
CV (%)	3.01	1.07	1.27	2.76	9.43	2.46

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

It was observed that various level of potassium exhibited significant affect on the weight of leaves per plant at 35, 40 and 45 DAS (Table 9). The highest weight of leaves per plant was observed in the plot that received 120 kg K_2O/ ha (K_2), while the control treatment gave the lowest. At 35 DAS the highest weight of leaves per plant was observed 35.10 g from K_2 control treatment. At 40 DAS the highest weight of leaves per plant was found 56.93 g from treatment and the lowest weight of leaves was obtained 19.58 g from K_2 treatment and the lowest was 40.97 g from the control treatment. At 45 DAS the highest weight of leaves per plant was 73.64 g from K_2 treatment and the lowest weight was recorded 51.52 g from the control treatment.

Significant variation was observed among the treatments in respect of weight of leaves at different stages of harvesting i.e., 35, 40 and 45 DAS (Appendix III). The highest weight of leaves per plant was observed 42.12 g from the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha), while the control treatment gave the lowest weight (19.74 g) at 35 DAS. The highest weight of leaves per plant was 70.73 g in the treatment combination of P_2K_2 and the lowest was 35.47 g from the control treatment at 40 DAS. At 45 DAS the highest weight of leaves per plant was 94.10 g from the treatment combination of P_2K_2 and the lowest weight was 51.24 g from the control treatment (Table 10).

The results on weight of leaves at different stages obtained in this study are comparable to the findings of Talukder (1999) who recorded the leaves weight of 49.53 to 78.90 g at 40 DAS and 61.54 to 92.02 g at 45 DAS in three amaranth cultivars.

4.6. Green yield per plant

Significant variation was observed among the treatments in respect of green yield per plant at different days of observation. At 35 DAS the highest green yield per plant (88.22 g) was observed in P_2 treatment, while the lowest green yield per plant (52.82 g) was obtained from control treatment. At 40 DAS the highest green yield per plant was 211.15 g from P_2 treatment and the lowest was 153.70 g from the control treatment. At 45 DAS the highest green yield per plant was found 285.54 g from the P_2 treatment and lowest green yield per plant was recorded 187.27 g from the control treatment (Figure 4).

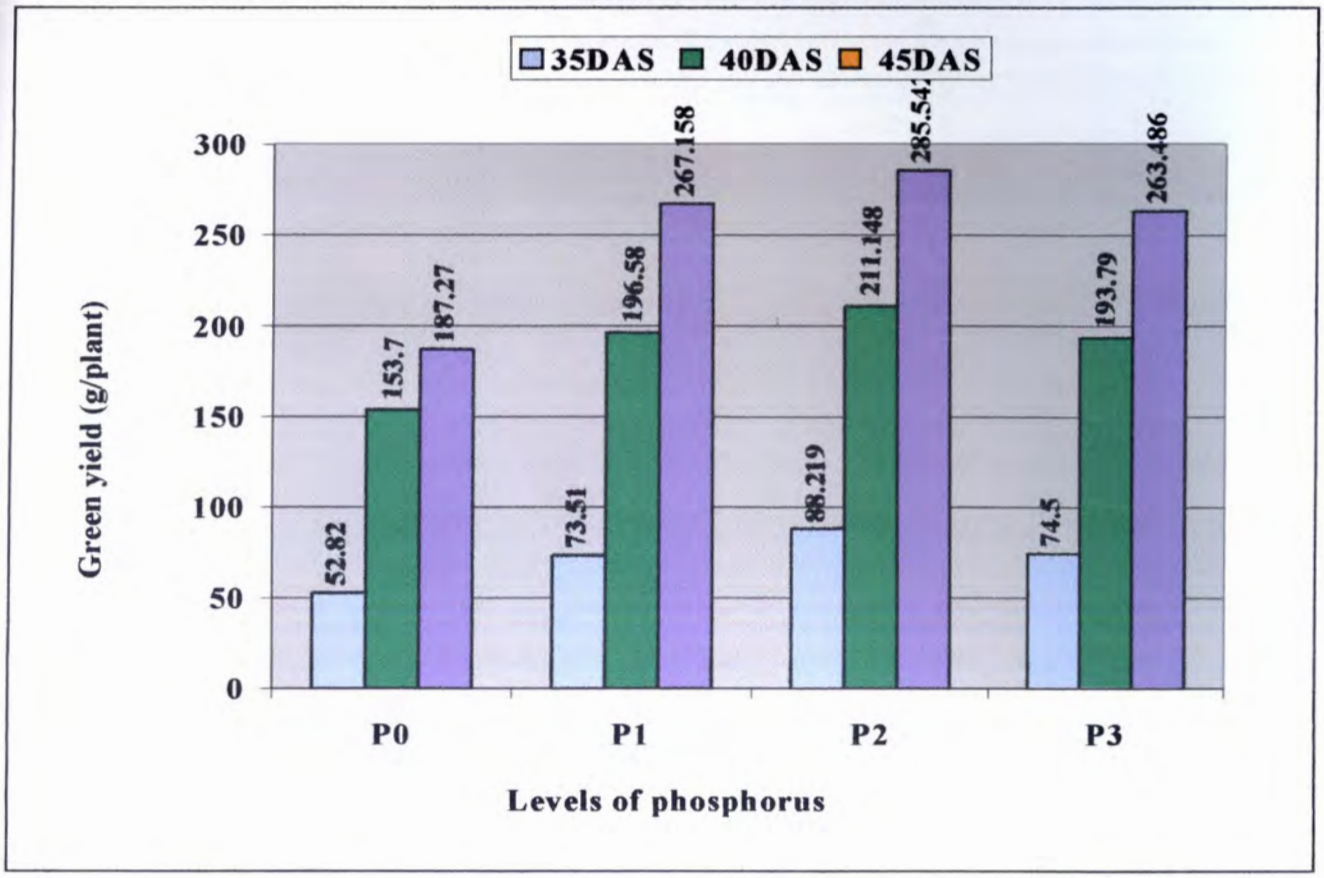

Figure 4. Effect of phosphorus on green yield per plant at different days after sowing (DAS)

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

It was observed that various level of potassium exhibited significant effect on the green yield per plant at 35, 40 and 45 DAS (Figure 5). The highest green yield per plant was observed 85.40 g from the plot that received 120 kg K_2O/ ha (K_2), while the control treatment gave the lowest (52.82 g) at 35 DAS. At 40 DAS the highest green yield per plant was recorded 210.57 g from K_2 treatment and the lowest green yield per plant was obtained 153.70 g from control treatment. At 45 DAS the highest green yield per plant was 285.00 g from K_2 treatment and the lowest was 189.18 g from the control treatment.

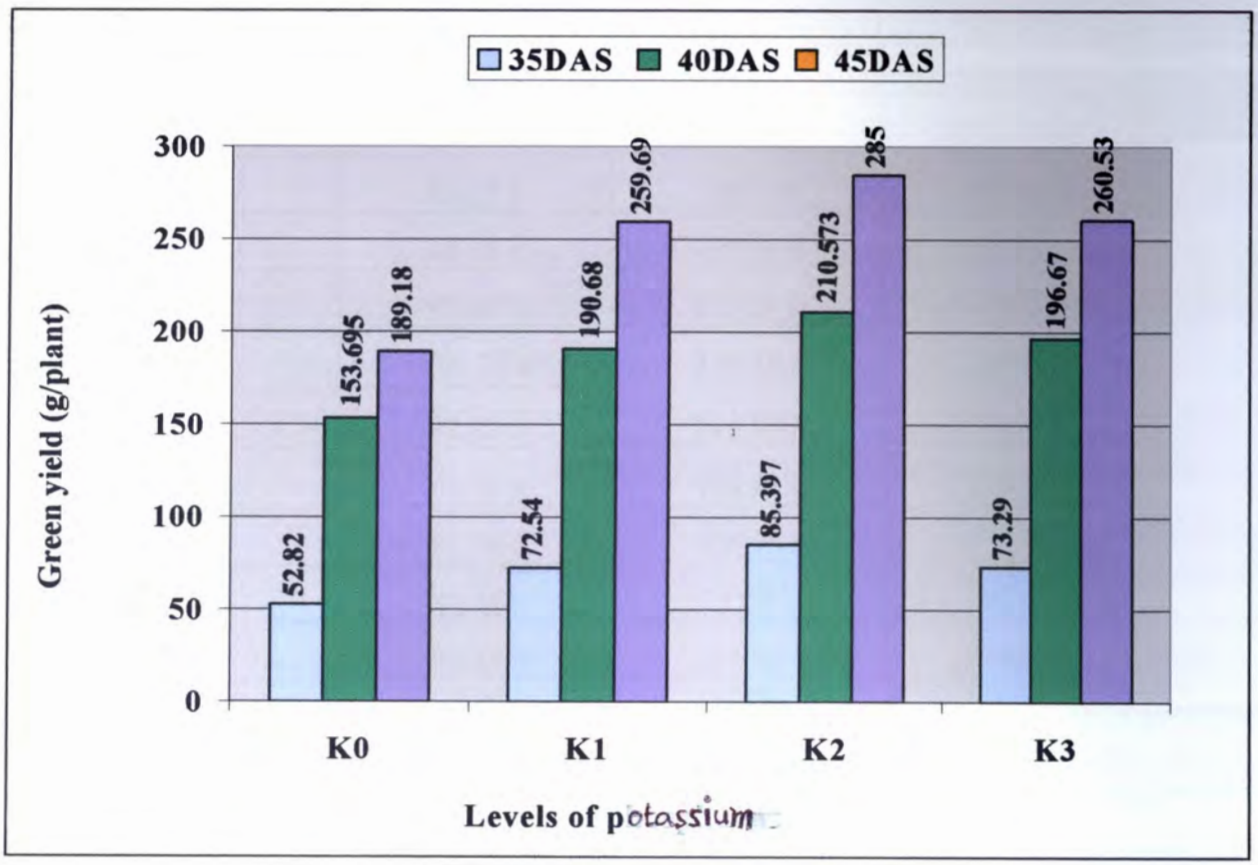

Figure 5. Effect of potassium on green yield per plant at different days after sowing (DAS)

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha, K_3: 126 kg K_2O /ha

Table 11. Combined effect of phosphorus and potassium on green yield per plant (g) at different days after sowing (DAS)

Treatment Combination	Green yield per plant (g) at different DAS		
	35 DAS	40 DAS	45 DAS
$P_0 K_0$	52.86 f	153.08 e	187.14 g
$P_0 K_1$	66.39 e	170.81 d	204.79 f
$P_0 K_2$	68.15 e	175.74 d	223.71 e
$P_0 K_3$	67.87 e	174.15 d	216.99 ef
$P_1 K_0$	67.87 e	174.15 d	216.99 ef
$P_1 K_1$	82.03 d	207.65 c	276.88 d
$P_1 K_2$	85.11 cd	214.8 b	293.27 bc
$P_1 K_3$	83.03 d	208.7 c	281.49 cd
$P_2 K_0$	68.15 e	175.74 d	223.71 e
$P_2 K_1$	91.66 b	217.51 b	298.17 b
$P_2 K_2$	101.05 a	236.46 a	326.40 a
$P_2 K_3$	92.02 b	214.89 b	293.89 bc
$P_3 K_0$	66.39 e	170.81 d	204.79 f
$P_3 K_1$	82.10 d	206.75 c	274.91 d
$P_3 K_2$	87.28 c	215.3 b	296.61 b
$P_3 K_3$	82.24 d	204.95 c	277.63 d
CV (%)	2.66	10.83	3.21

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

Green yield per plant was significantly influenced by the interaction effect at different days after sowing (Appendix III). The highest green yield per plant was observed 101.05 g from the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha), while the control treatment gave the lowest green yield (52.86 g) at 35 DAS. The highest green yield per plant was recorded 236.46 from the treatment combination of P_2K_2 at 40 DAS and the lowest was recorded 153.08 g from the control treatment. The highest green yield per plant at 45 DAS was 326.40g from the treatment combination of P_2K_2 and the control treatment gave the lowest yield (187.14 g) (Table 11).

The results on green yield per plant at different stages obtained in this study is within the range of the findings of Talukder (1999) who recorded the green yield per plant of 168.60 to 259.10 g at 40 DAS and 255.10 to 383.70 g at 45 DAS in three amaranth cultivars. Rajagopal *et al.* (1977) reported the similar findings at 35 DAS and 40 DAS.

4.7. Green yield per hectare

Significant variation was observed among the treatments in respect of green yield per hectare at different days of observation. The highest green yield per hectare was observed from P_2 treatment (48 kg P_2O_5 /ha) at different stages of harvesting i.e., 35, 40 and 45 DAS, while the control treatment gave the lowest. At 35 DAS the highest weight per hectare was observed 14.16 t from P_2 treatment and the lowest green yield per hectare was obtained 8.45 t from control treatment. At 40 DAS the highest green yield per hectare was 33.80 t from treatment P_2 and the lowest was 27.80 t from the control treatment. The highest green yield per hectare at 45 DAS was 45.70 t from treatment P_2 and the lowest was 30.00 t from the control treatment (Figure 6).

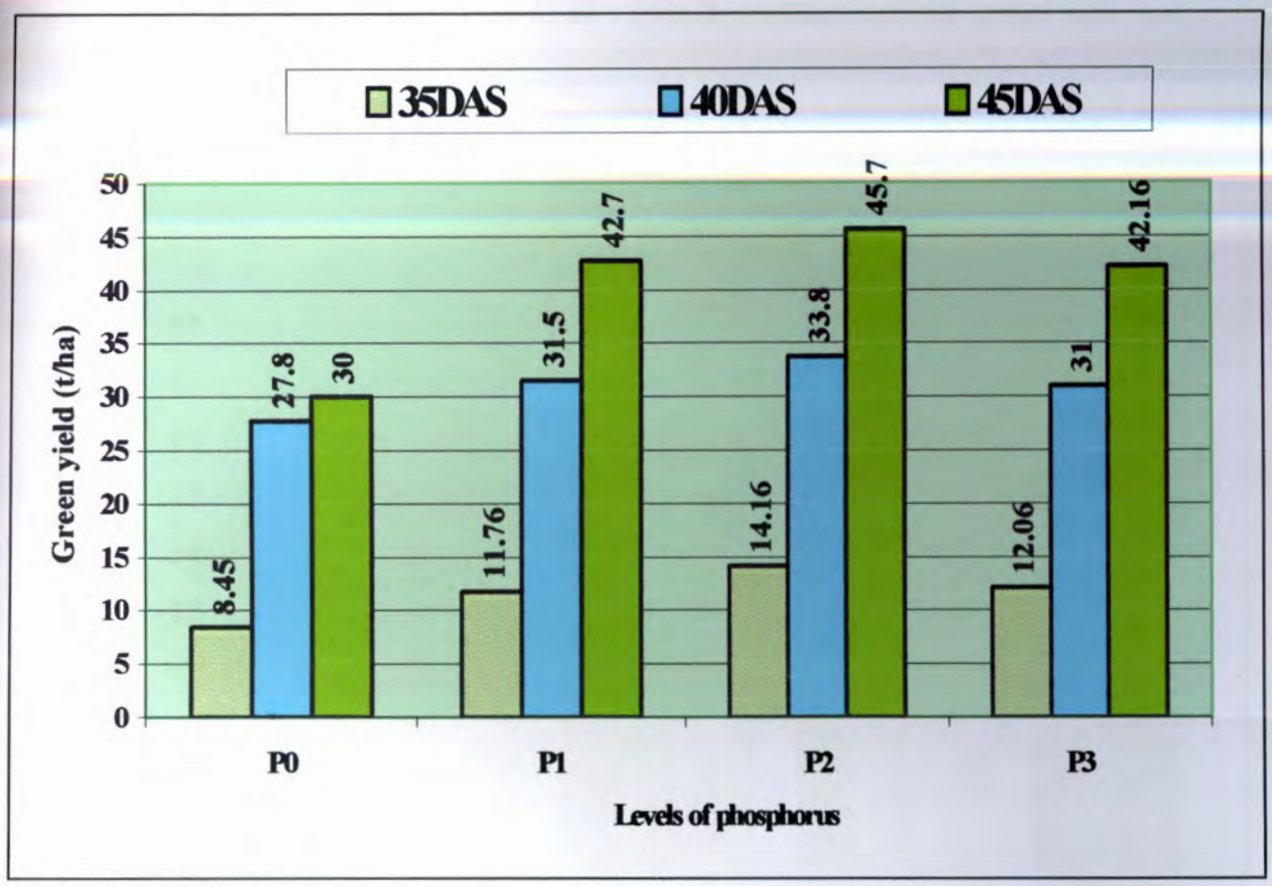

Figure 6. Effect of phosphorus on green yield per hectare at different days after sowing (DAS)

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

It was observed that various level of potassium exhibited significant affect on the green yield per hectare at 35, 40 and 45 DAS (Figure 7). The highest green yield per hectare was observed from the plot that received 120 kg K_2O/ ha (K_2), while the control treatment gave the lowest. At 35 DAS the highest green yield per hectare was observed 13.70 t from K_2 treatment and the lowest green yield per hectare was obtained 8.45 t from the control treatment. At 40 DAS the highest green yield per hectare was 33.70 t from treatment K_2 and the lowest was obtained 27.80 t from the control treatment. At 45 DAS the highest

green yield per hectare was recorded 45.60 t from K_2 treatment and the lowest yield was obtained 30.30 t from the control treatment.

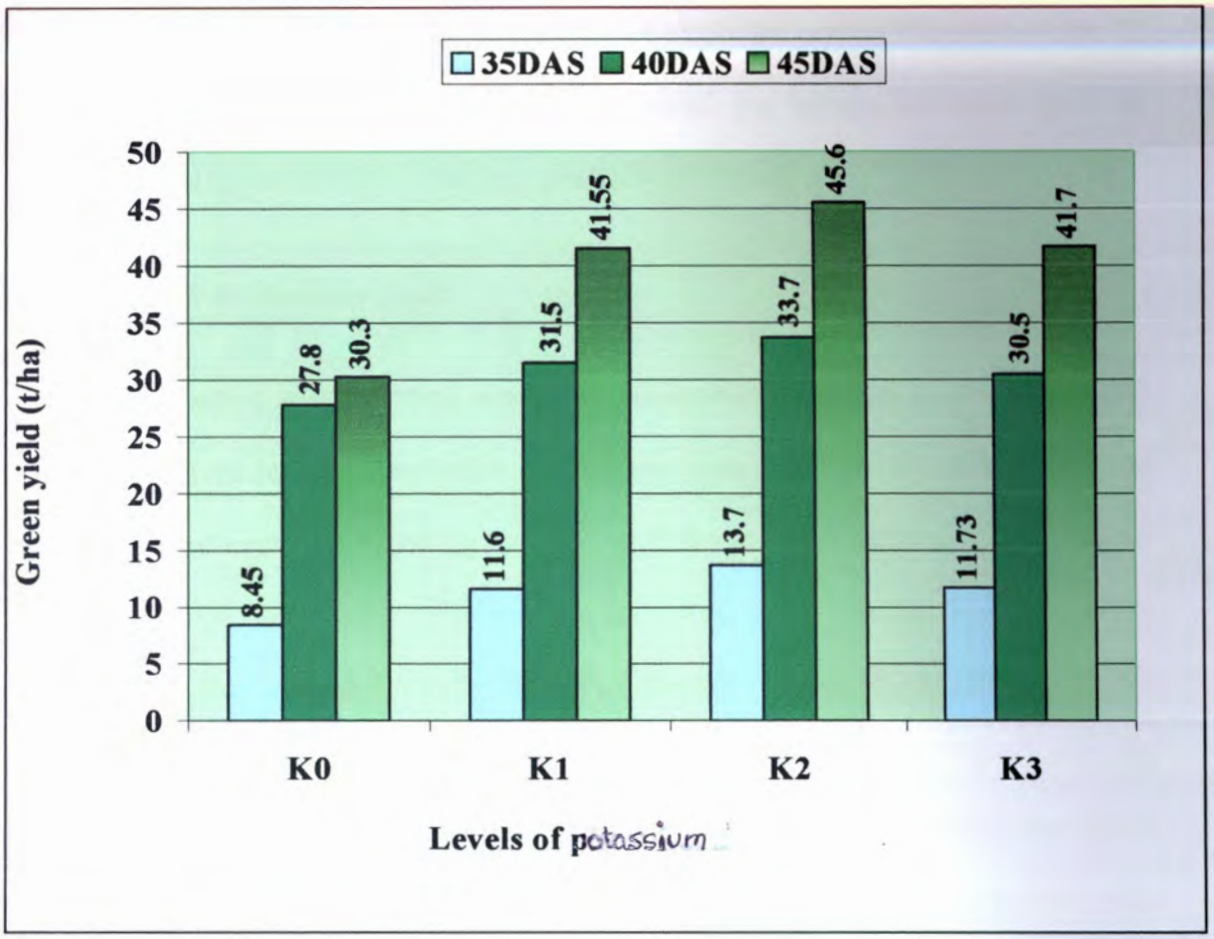

Figure 7. Effect of potassium on green yield per hectare at different days after sowing (DAS)

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha, K_3: 126 kg K_2O /ha

Green yield per hectare was significantly influenced by the interaction effect at different days after sowing (Appendix III). The highest green yield per hectare was observed with the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha), while the control treatment gave the lowest. The highest green yield per hectare was calculated 16.17 t from the treatment combination of P_2K_2 at 35 DAS and lowest was recorded 8.46 t from the control treatment. The highest green

yield per hectare was observed 37.83 ts from the treatment combination of P_2K_2 and the lowest was recorded 24.50 t from the control treatment at 40 DAS. At 45 DAS the maximum green yield per hectare was calculated 52.22 t from the treatment combination of P_2K_2, while the lowest yield was recorded 29.94 t from the control treatment (Table 7). From the data it reveals that green yield of amaranth per hectare increased up to the treatment combination of P_2K_2, after then gradually decreased.

4.8. Dry matter of stem per plant

Significant variation was observed among the treatments in respect of stem dry matter content at different days of observation. The highest content of stem dry matter was found from the plant of treatment P_2 (48 kg P_2O_5 /ha) at different stages of harvesting i.e., 35, 40 and 45 DAS, while the control treatment gave the lowest. At 35 DAS the highest stem dry matter content was observed 8.59 % from P_2 treatment and the lowest stem dry matter content was found 4.54 % from the control treatment. At 40 DAS the highest stem dry matter content was 10.93 % in treatment P_2 and the lowest was 6.87 % from the control treatment. The highest and lowest stem dry matter contents at 45 DAS were 12.95 % from P_2 treatment and 8.64 % from the control treatment respectively (Table 13).

It was observed that various level of potassium exhibited significant effect on the stem dry matter content at 35, 40 and 45 DAS (Table 14). The highest stem dry matter content was observed from the plot that received 120 kg K_2O/ ha (K_2), while the control treatment gave the lowest. At 35 DAS the highest stem dry matter content was observed 8.13 % from K_2 treatment, while the lowest stem dry matter content was obtained 4.35 % from the control treatment. At 40 DAS the highest stem dry matter content was 10.81 % from treatment K_2 and the lowest was 6.84 % from the control treatment. The highest and

lowest stem dry matter contents were 12.85 % from treatment K_2 and 8.99 % from the control treatment respectively at 45 DAS.

Table 12. Combined effect of phosphorus and potassium on green yield per hectare at different days after sowing (DAS)

Treatment Combination	Green yield (t/ha) at different DAS		
	35 DAS	40 DAS	45 DAS
$P_0 K_0$	8.46 g	24.50 g	29.94 h
$P_0 K_1$	10.62 f	27.33 f	32.77 g
$P_0 K_2$	10.90 e	28.12 d	35.80 e
$P_0 K_3$	10.86 e	27.85 e	34.72 f
$P_1 K_0$	10.86 e	27.86 e	34.72 f
$P_1 K_1$	13.12 cd	33.22 cd	44.30 d
$P_1 K_2$	13.52 c	34.37 bc	46.92 bc
$P_1 K_3$	13.28 cd	33.40 cd	45.08 d
$P_2 K_0$	10.90 e	28.12 d	35.80 e
$P_2 K_1$	14.66 b	34.80 b	47.71 b
$P_2 K_2$	16.17 a	37.83 a	52.22 a
$P_2 K_3$	14.72 b	34.38 bc	47.02 bc
$P_3 K_0$	10.62 f	27.33 f	32.77 g
$P_3 K_1$	13.14 cd	33.08 cd	44.00 d
$P_3 K_2$	13.96 c	34.45 bc	47.46 b
$P_3 K_3$	13.16 cd	34.45 bc	44.42 d
CV (%)	2.6	2.61	2.78

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

Stem dry matter content was significantly influenced by the interaction effect at different days after sowing (Appendix III). The highest stem dry matter content was observed in the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha), while the control treatment gave the lowest. The highest stem dry matter content (9.76 %) was estimated from the treatment combination of P_2K_2 at 35 DAS and the lowest (4.75 %) was estimated from the control treatment. At 40 DAS the highest dry matter content was calculated 12.08 % from the treatment combination of P_2K_2 and the lowest stem dry matter content was recorded 6.38 % from the control treatment. At 45 DAS the highest dry matter content was found 13.70 % from the treatment combination of P_2K_2 and the lowest stem dry matter content was recorded 7.16 % the control treatment (Table 15).

Hossain (1996) recorded the dry matter content of 11 amaranth genotypes and it was ranged from 7.26 to 10.07% at 55 DAS, which is lower than present study.

4.9. Dry matter of leaves per plant

Significant variation was observed among the treatments in respect of leaf dry matter content at different days of observation. The highest content of leaf dry matter was found in the plant of treatment P_2 (48 kg P_2O_5 /ha) at different stages of harvesting i.e., 35, 40 and 45 DAS, while the control treatment gave the lowest. At 35 DAS the highest leaf dry matter content was observed 10.93 % from P_2 treatment and the lowest leaf dry matter content was found 6.87 % from the control treatment. At 40 DAS the highest leaf dry matter content (13.57 %) was from treatment P_2 and the lowest (8.462 %) was from the control treatment. The highest and lowest leaf dry matter contents were 16.65 % from treatment P_2 and 10.96 % from the control treatment respectively at 45 DAS (Table 13).

Table 13. Main effect of phosphorus on dry matter % of stem and leaves at different days after sowing (DAS)

Treatment Combination	Dry matter % of stem at different DAS			Dry matter % of leaves at different DAS		
	35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
P_0	4.54 c	6.87 c	8.64 c	6.87 c	8.46 c	10.96 c
P_1	7.21 b	9.88 b	12.46 b	9.88 b	12.77 b	15.70 b
P_2	8.59 a	10.93 a	12.95 a	10.93 a	13.66 a	16.65 a
P_3	7.21 b	9.95 b	12.19 b	9.95 b	12.60 b	15.85 b
CV (%)	3.56	4.41	2.14	4.41	2.73	2.92

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment, P_1: 43.2 kg P_2O_5 /ha, P_2: 48 kg P_2O_5 /ha, P_3: 52.8 kg P_2O_5 /ha

Table 14. Main effect of potassium on dry matter % of stem and leaves at different days after sowing (DAS)

Treatment Combination	Dry matter % of stem at different DAS			Dry matter % of leaves at different DAS		
	35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
K_0	4.31 c	6.84 c	8.99 c	6.84 c	8.69 c	10.98 a
K_1	7. b	9.99 b	12.09 b	9.99 b	12.64 b	15.73 b
K_2	8.13 a	10.81 a	12.85 a	10.81 a	13.33 a	16.53 a
K_3	7.64 b	9.99 b	12.32 b	9.99 b	12.74 b	15.92 b
CV (%)	3.56	4.41	2.14	4.41	2.73	2.92

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

K_0: Control treatment, K_1: 114 kg K_2O /ha, K_2: 120 kg K_2O /ha, K_3: 126 kg K_2O /ha

Table 15. Combined effect of phosphorus and potassium on dry matter % of stem and leaves at different days after sowing (DAS)

Treatment Combination	Dry matter % of stem at different DAS			Dry matter % of leaves at different DAS		
	35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
$P_0 K_0$	4.75 h	6.38 f	7.16 h	6.38 f	8.61 f	10.70 f
$P_0 K_1$	5.78 f	7.71 e	9.57 g	7.71 e	10.76 e	12.90 e
$P_0 K_2$	6.38 e	9.46 d	11.34 e	9.46 d	11.31 d	14.54 d
$P_0 K_3$	5.23 g	7.94 e	10.49 e	7.94 e	11.16 e	13.69 de
$P_1 K_0$	5.17 gh	7.93 e	10.76 f	7.93 e	11.34 e	13.51 d
$P_1 K_1$	7.16 d	10.55 bc	12.80 c	10.55 bc	13.08 bc	16.24 bc
$P_1 K_2$	8. b	10.68 bc	13.08 bc	10.68 bc	13.53 bc	16.61 bc
$P_1 K_3$	8.05 bc	10.36 c	13.18 bc	10.36 c	13.15 c	16.43 c
$P_2 K_0$	5.80 f	9.34 d	11.43 e	9.34 d	12.12 d	14.34 d
$P_2 K_1$	9.46 a	11.08 bc	13.18 bc	11.08 bc	13.7 bc	16.92 bc
$P_2 K_2$	9.76 a	12.08 a	13.70 a	12.08 a	14.9 a	17.82 a
$P_2 K_3$	9.34 a	11.23 b	13.50 ab	11.23 b	13.54 b	17.53 b
$P_3 K_0$	5.50 fg	7.71 e	10.60	7.71 e	10.7 e	13.38 e
$P_3 K_1$	7.42 d	10.60 bc	12.79 c	10.60 bc	13.03 bc	16.85 bc
$P_3 K_2$	7.94 c	11.02 bc	13.27	11.02 bc	13.56 bc	17.16 bc
$P_3 K_3$	7.96 c	10.46 bc	12.13 d	10.46 bc	13.1 bc	16.02 bc
CV (%)	3.56	4.41	2.14	4.41	2.73	2.92

Means followed by common letters are not significantly different from each other by DMRT at 5% level.

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

It was observed that various level of potassium exhibited significant affect on the leaf dry matter content at 35, 40 and 45 days after sowing (DAS) (Table 14). The highest leaf dry matter content was observed from the plot that received 120 kg K_2O/ ha (K_2), while the control treatment gave the lowest. At 35 DAS the highest leaf dry matter content was observed 10.81 % from K_2 treatment. The lowest stem dry matter content was obtained 6.84 % from the control treatment. At 40 days after sowing (DAS) the highest leaf dry matter content was 13.33 % from treatment K_2 and the lowest was 8.69 % from the control treatment. The highest (16.53 %) and lowest (10.98 %) leaf dry matter contents were found from treatment K_2 and the control treatment respectively at 45 DAS.

Leaf dry matter content was significantly influenced by the interaction effect at different days after sowing (Appendix III). The highest leaf dry matter content was observed in the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha), while the control treatment gave the lowest. The highest leaf dry matter content was 12.08 % from the treatment combination of P_2K_2 and the lowest dry matter content was estimated 6.38 % from the control treatment at 35 DAS. At 40 DAS the highest dry matter content was calculated 14.9 % from the treatment combination of P_2K_2, while the lowest was obtained 8.61 % from the control treatment. The highest (17.82 %) and lowest (10.70 %) leaf dry matter contents was found from the treatment combination of P_2K_2 and the control treatment respectively at 45 DAS.

4.10. Benefit cost ratio

The cost and return analysis were done and have been presented in table 16 and appendix IV. Materials (1A), non-materials (1B) and overhead cost were recorded for all the treatment combinations. Local market was considered to calculate the price of amaranth per hectare.

The total cost of production ranges between Tk. 67437 to 62257 per hectare among the different treatment combination. The variation was due to different cost of fertilizer, manure and others. The highest cost of production of Tk. 67437 per ha was recorded in the treatment combination of P_3K_3 while the lowest cost of production of Tk. 62257 per ha was recorded from the combination of P_0K_0 treatment.

Gross return of the different treatment combination ranged between Tk. 130550 to Tk. 74850 per ha. Gross return was calculated from sale of harvested amaranth @ Tk. 2500 per ton. Among the different treatment combinations of P_2K_2 gave the highest net return Tk. 63917 per ha, while the lowest was obtained Tk. 12593 from treatment combination of P_0K_0.

The highest Benefit Cost Ratio (BCR) (0.96) was recorded from the treatment combination of P_2K_2 and the lowest BCR (0.20) was recorded from the combination of P_0K_0.

Thus it was apparent that the treatment combination of P_2K_2 gave the highest marketable yield, the highest gross return and the BCR. Therefore it may be suggested that phosphorus level at 48 kg /ha and potassium levels at 120 kg /ha can be used successfully for commercial stem amaranth production.

Table 16. Cost and return of stem amaranth due to combined effect of phosphorus and potassium.

Treatment Combination	Marketable yield (t/ha)	Gross return (Tk./ha)	Total cost of production (Tk./ha)	Net return (Tk./ha)	Benefit Cost Ratio (BCR)
$P_0 K_0$	29.94	74850	62257	12593	0.20
$P_0 K_1$	32.77	81925	63806	18119	0.28
$P_0 K_2$	35.80	89500	64854	24646	0.38
$P_0 K_3$	34.72	86800	65568	21232	0.32
$P_1 K_0$	34.72	86800	64683	22117	0.34
$P_1 K_1$	44.30	110750	65773	44977	0.68
$P_1 K_2$	46.92	117300	66486	50814	0.76
$P_1 K_3$	45.08	112700	66785	45915	0.69
$P_2 K_0$	35.80	89500	64871	24629	0.38
$P_2 K_1$	47.71	119275	65919	53356	0.81
$P_2 K_2$	52.22	130550	66633	63917	0.96
$P_2 K_3$	47.02	117550	66872	50678	0.76
$P_3 K_0$	32.77	81925	65023	16902	0.26
$P_3 K_1$	44.00	110000	66071	43929	0.66
$P_3 K_2$	47.46	118650	66409	52241	0.77
$P_3 K_3$	44.42	111050	67437	43593	0.65

P_0: Control treatment
P_1: 43.2 kg P_2O_5 /ha
P_2: 48 kg P_2O_5 /ha
P_3: 52.8 kg P_2O_5 /ha

K_0: Control treatment
K_1: 114 kg K_2O /ha
K_2: 120 kg K_2O /ha
K_3: 126 kg K_2O /ha

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An experiment was conducted at the Central Farm of Sher-e- Bangla Agricultural University, Dhaka during the period of April to June 2005 to study the effect of phosphorus and potassium on the growth and yield of stem amaranth. The experiment consisted of four levels of phosphorus (P_2O_5) viz., control treatment (no phosphorus), P_1 (43.2 kg /ha), P_2 (48 kg /ha) and P_3 (52.8 kg /ha) and four levels of potassium (K_2O) viz., control treatment (no potassium), K_1 (114 kg /ha), K_2 (120 kg /ha) and K_3 (126 kg /ha).

The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were altogether 16 treatment combinations in this experiment. Each plot was of 2 m ×1.5 m where distance between two blocks and two plots were kept 1m and 0.5 m respectively. The amaranth seed of Baspata were sown on 25 April, 2005. Data were recorded on growth and yield contributing parameters and collected data were statistically analyzed for evaluation of the treatments effects. The mean differences were adjusted by Duncan's New Multiple Range Test (DMRT).

Entire experimental plots were fertilized with 10t of cowdung and 200 kg urea. Phosphorus and potassium applied as per treatment. The entire amount of cowdung, TSP and half of MP were applied as basal during land preparation. Those were mixed with the soil of the individual plot 4 days before seed sowing. The full amount of urea and half of MP were top dressed in three equal splits 15, 25 and 35 days after sowing (DAS).

Most of the parameters like plant height, number of leaves, plant diameter, weight of stem, weight of leaves, green yield per plant, green yield of hectare, dry matter content of stem and dry matter content of leaves were significantly influenced by both phosphorus

and potassium. The tallest plant (87.99 cm) was observed in the treatment of phosphorus applied at 48 kg/ha. Plant had better vegetative growth in this treatment. The highest green yield at all observation also obtained at 48 kg phosphorus /ha.

The maximum plant diameter (2.43 cm), weight of stem per plant (220.0 g), weight of leaves per plant (81.16 g), green yield per plant (285.54 g), green yield per hectare (45.70t), dry matter content of stem (12.95 %) and dry matter content of leaves (16.65 %) were found from the plot receiving 48 kg P_2O_5 /ha at 45 DAS. But the highest number of leaves (69.25) was obtained from P_3 treatment. Minimum data of all parameters were recorded from the control treatment (0 kg P_2O_5 /ha). The lowest plant height (78.17 cm), number of leaves (40.5), weight of stem per plant (145.45 g), weight of leaves per plant (51.45 g), green yield per plant (187.27 g), green yield per hectare (30.00t), dry matter content of stem (8.64 %) and dry matter content of leaves (10.96 %) were found from the control treatment.

All the parameters were also influenced by the four levels of potassium. Better vegetative growth was obtained from the potassium level up to 120 kg/ ha. It was revealed that the tallest plant (87.49 cm), highest number of leaves (59.00), maximum plant diameter (2.70 cm), weight of stem per plant (211.79 g), weight of leaves per plant (73.64 g), green yield per plant (285.0 g), green yield per hectare (45.60t), dry matter content of stem (12.85 %) and dry matter content of leaves (16.53 %) were found from the plot receiving 120 kg K_2O /ha at 45 DAS. The minimum data of all parameters were recorded from control treatment (0 kg K_2O /ha). The lowest plant height (78.51 cm), number of leaves (38.17), plant diameter (1.52 cm), weight of stem per plant (140.39 g), weight of leaves per plant (51.52 g), green yield per plant (189.18 g), green yield per hectare (30.30t), dry

matter content of stem (8.99 %) and dry matter content of leaves (10.98 %) were found from the control treatment.

In case of combined effect, the highest results were observed with the combined effect of phosphorus and potassium from the treatment combination of P_2K_2 (48 kg P_2O_5 + 120 kg K_2O/ ha), while the control treatment gave the lowest. The tallest plant (92.47 cm), maximum plant diameter (3.00 cm), weight of stem per plant (243.70 g), weight of leaves per plant (94.10 g), green yield per plant (326.40 g), green yield per hectare (52.22t), dry matter content of stem (13.70 %) and dry matter content of leaves (17.82 %) were found from treatment combination of P_2K_2 at 45 DAS. The highest number of leaves (78.33) was recorded from the treatment combination of P_3K_2. The lowest plant height (78.47 cm), number of leaves (38.0), plant diameter (1.50 cm), weight of stem per plant (141.00 g), weight of leaves per plant (51.24 g), green yield per plant (187.14 g), green yield per hectare (29.94t), dry matter content of stem (7.16 %) and dry matter content of leaves (10.70 %) were found from the control treatment.

Among the different treatment combinations of P_2K_2 gave the highest net return Tk. 63917 per ha while the lowest was obtained Tk. 12593 from treatment combination of P_0K_0. The highest Benefit Cost Ratio (BCR) was recorded 0.96 from the treatment combination of P_2K_2 and the lowest BCR was recorded 0.20 from the combination of P_0K_0.

Conclusion

Therefore it may be suggested that phosphorus level at 48 kg /ha and potassium level at 120 kg /ha can be used to obtain higher growth and higher green yield for successful production of stem amaranth. However, further studies in this relation should be carried out in other region of the country before final recommendation.

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APPENDICES

Appendix I. Monthly records of rainfall, relative humidity, soil temperature and sun shine of the experimental site during the period from April to June, 2005

Month	Air Temperature (^{0}c)			Relative Humidity (%)	Rainfall (mm)	Soil Temperature (^{0}c)			Sun Shine (hr)
	Maximum	Minimum	Mean			5 cm depth	10 cm depth	20 cm depth	
April	35.97	20.	25.71	65.05	159	14.1	14.1	14.9	215.2
May	31.57	21.55	26.56	67.2	162.3	14.5	14.5	15.1	212.2
June	32.3	22.5	27.4	68.9	165.5	14.9	14.9	15.7	208.3

Appendix II. Characteristics of soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari , Farmgate , Dhaka.

A . Morphological Characteristics of the experimental field

Morphological Feature	Characteristics
Location	Central farm SAU Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Non-calcareous soil
Land Type	Medium high Land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above Flood Level
Drainage	Well Drained
Cropping Pattern	Fellow Amaranth

B . Physical and Chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
% Sand	27
%Silt	43
%Clay	35
Textural class	Silty loam
P^H	6.3
Organic Carbon (%)	0.78
Organic Matter (%)	0.03
Total N (%)	20.00
Available P (ppm)	35
Exchangeable K (me/100 gm soil)	0.10
Available S (ppm)	

Appendix III. Analysis of variance of growth and yield contributing characters of amaranth

Source of variation	DF	Mean sum of square					
		Plant height (cm)			Number of leaves		
		25 DAS	35 DAS	45 DAS	25 DAS	35 DAS	45 DAS
Replication	2	2.026	0.028	0.146	42.27	13.27	21.94
Factor A	3	41.10**	36.27**	69.80**	197.25**	1075.61**	1892.25**
Factor B	3	40.86**	27.42**	52.61**	115.58**	504.67**	789.42**
Interaction AB	9	2.2**	1.69**	6.01**	34.31**	138.10**	216.398**
Error	35	.023	0.041	0.0	12.20	23.38	19.76

** Significant at 1 % level

* Significant at 5 % level

Appendix III. (cont'd 1)

Source of variation	DF	Mean sum of square					
		Plant diameter (cm)			Green yield per plant (g)		
		25 DAS	35 DAS	45 DAS	35 DAS	40 DAS	45 DAS
Replication	2	0.001	0.015	0.003	9.679	418.403	47.681
Factor A	3	0.0**	0.254**	0.142**	1239.71**	7900.1**	13368.53**
Factor B	3	0.075**	0.679**	0.607**	1091.90**	78.46**	13284.32**
Interaction AB	9	0.026**	0.047**	0.105**	32.035**	341.411**	527.474**
Error	35	0.001	0.013	0.040	128.599	429.647	67.5

** Significant at 1 % level

* Significant at 5 % level

Appendix III. (cont'd 2)

Source of variation	DF	Mean sum of square					
		Weight of stem per plant (g)			Weight of leaves per plant (g)		
		35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
Replication	2	0.240	1.519	20.786	2.548	1.298	6.269
Factor A	3	336.875**	1792.68**	6789.43**	369.484**	618.664**	1498.81**
Factor B	3	204.223**	1755.28**	5010.03**	338.484**	495.174**	794.65**
Interaction AB	9	15.735**	50.573**	156.35**	13.434**	61.694**	103.39**
Error	35	1.869	2.358	6.025	0.755	2.28	2.642

** Significant at 1 % level

* Significant at 5 % level

Appendix III. (cont'd 3)

Source of variation	DF	Mean sum of square					
		Green yield (t/ha)			Dry matter content of stem (%)		
		35 DAS	40 DAS	45 DAS	35 DAS	40 DAS	45 DAS
Replication	2	0.125	0.714	0.842	0.151	0.296	0.028
Factor A	3	25.655**	246.18**	290.332**	18.728**	19.778**	26.322**
Factor B	3	8.936**	77.89**	91.854**	18.810**	19.408**	18.952**
Interaction AB	9	0.392**	3.47**	4.092**	1.205**	0.429*	0.675**
Error	35	0.107	1.179	1.179	0.065	0.181	0.064

** Significant at 1 % level

* Significant at 5 % level

Appendix III. (cont'd 5)

Source of variation	DF	Mean sum of square		
		Dry matter content of leaves (%)		
		35 DAS	40 DAS	45 DAS
Replication	2	2.026	0.028	0.146
Factor A	3	41.10**	36.27**	69.80**
Factor B	3	40.86**	27.42**	52.61**
Interaction AB	9	2.245**	1.69**	6.01**
Error	30	.023	0.041	0.045

** Significant at 1 % level

* Significant at 5 % level

Appendix IV. Production cost of amaranth per hectare

(A) Material cost (Tk. /ha)

Treatment Combination	Seed (5 kg /ha) Tk.	Fertilizer and Manure				Subtotal 1(A)
		Cow dung	Urea	TSP	MP	
$P_0 K_0$	500	6000	1280	--	--	7780
$P_0 K_1$	500	6000	1280	--	640	8420
$P_0 K_2$	500	6000	1280	--	1280	9060
$P_0 K_3$	500	6000	1280	--	1920	9700
$P_1 K_0$	500	6000	1280	1480	--	9260
$P_1 K_1$	500	6000	1280	1480	640	9900
$P_1 K_2$	500	6000	1280	1480	1280	10540
$P_1 K_3$	500	6000	1280	1480	1920	11180
$P_2 K_0$	500	6000	1280	1600	--	9380
$P_2 K_1$	500	6000	1280	1600	640	10020
$P_2 K_2$	500	6000	1280	1600	1280	10660
$P_2 K_3$	500	6000	1280	1600	1920	11300
$P_3 K_0$	500	6000	1280	1720	--	9500
$P_3 K_1$	500	6000	1280	1720	640	10140
$P_3 K_2$	500	6000	1280	1720	1280	10780
$P_3 K_3$	500	6000	1280	1720	1920	11420

Appendix IV. (contd. 1)

(B) Non- material cost (Tk./ha)

Treatment Combination	Land Preparation	Fertilizer and manure application	Seed Sowing	Intercultural Operation	Harvesting	Subtotal 1(B)	Total Input Cost 1(A)+1(B)
$P_0 K_0$	10500	--	5250	10000	7500	33250	41030
$P_0 K_1$	10500	750	5250	10000	7500	34000	42420
$P_0 K_2$	10500	1050	5250	10000	7500	34300	43360
$P_0 K_3$	10500	1050	5250	10000	7500	34300	44000
$P_1 K_0$	10500	750	5250	10000	7500	34000	43260
$P_1 K_1$	10500	1050	5250	10000	7500	34300	44200
$P_1 K_2$	10500	1050	5250	10000	7500	34300	44840
$P_1 K_3$	10500	750	5250	10000	7500	34000	45180
$P_2 K_0$	10500	750	5250	10000	7500	34000	43380
$P_2 K_1$	10500	1050	5250	10000	7500	34300	44320
$P_2 K_2$	10500	1050	5250	10000	7500	34300	44960
$P_2 K_3$	10500	750	5250	10000	7500	34000	45300
$P_3 K_0$	10500	1050	5250	10000	7500	34000	43500
$P_3 K_1$	10500	1050	5250	10000	7500	34300	44440
$P_3 K_2$	10500	750	5250	10000	7500	34000	44780
$P_3 K_3$	10500	1050	5250	10000	7500	34300	45720

Appendix IV. (contd. 2)

(C) Overhead cost and total cost of production (Tk.)

Treatment Combination	Cost of Lease Land	Miscellaneous Cost (5% of Input cost)	Interest on running Capital for 6 Months(13% of total input cost)	Total	Total cost of production(Input cost + Interest on running Capital (Tk./ha)
$P_0 K_0$	16000	2052	3175	21227	62257
$P_0 K_1$	16000	2121	3265	21386	63806
$P_0 K_2$	16000	2168	3326	21494	64854
$P_0 K_3$	16000	2200	3368	21568	65568
$P_1 K_0$	16000	2163	3260	21423	64683
$P_1 K_1$	16000	2210	3363	21573	65773
$P_1 K_2$	16000	2242	3404	21646	66486
$P_1 K_3$	16000	2259	3346	21605	66785
$P_2 K_0$	16000	2169	3322	21491	64871
$P_2 K_1$	16000	2216	3383	21599	65919
$P_2 K_2$	16000	2248	3425	21673	66633
$P_2 K_3$	16000	2265	3307	21572	66872
$P_3 K_0$	16000	2175	3348	21523	65023
$P_3 K_1$	16000	2222	3409	21631	66071
$P_3 K_2$	16000	2239	3390	21629	66409
$P_3 K_3$	16000	2286	3451	21737	67457