EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH YIELD AND POSTHARVEST ASSESMENT OF BROCCOLI (*Brassica oleracea* var. *botrytis* L.)

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A Thesis

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CERTIFICATE

This is to certify that thesis entitled, 'EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH YIELD AND POSTHARVEST ASSESMENT OF BROCCOLI (*Brassica oleracea* var. *botrytis* L.)' submitted to the Dept. of Horticulture and Postharvest Technology, 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 JASIM UDDAIN Registration Number 26233/00523 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 been duly acknowledged.

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June 2007 — The Author

DEDICATION

This work is dedicated to

My

Beloved parents

EFFECT OF PHOSPHORUS AND POTASSIUM ON GROWTH YIELD AND POSTHARVEST ASSESMENT OF BROCCOLI (*Brassica oleracea* var. *botrytis* L.)

ABSTRACT

An experiment was conducted at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2005 to February 2006 to study the effect of phosphorus and potassium on growth, yield and post harvest potential of broccoli. The experiment considered with two factors, factor A: four levels of Phosphorus (0, 30, 40 and 50 kg P/ha) and factor B: four levels of potassium (0, 50, 75 and 100 kg K/ha). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Incase of phosphorus, the highest plant height (55.85cm), stem diameter (5.69cm), number of leaves (13.78), leaf length (45.97cm) at 60 DAT, shoot length (39.93cm), root length (30.81cm), fresh shoot weight (793.9g), fresh root weight (83.42g) and main curd weight (264.3g) and curd yield (13.81 t/ha) were recorded from P_3. But the highest curd diameter (17.44cm), number of secondary curd (4.25), weight of secondary curd (155.3g) was found in P_2. Incase of potassium, the highest plant height (55.82cm), stem diameter (5.61cm), number of leaves (13.64), leaf length (46.03cm) at 60 DAT, shoot length (40.14cm), root length (30.94cm), fresh shoot weight (794.4g), fresh root weight (84.42g), main curd weight (260.0g), curd diameter (17.52cm), number of secondary curd (4.0), weight of secondary curd (166.0g) and curd yield (14.19 t/ha) were recorded from K_3. Incase of combined effect of phosphorus and potassium, the highest plant height (66.65cm), stem diameter (5.92cm), number of leaves (14.67), at 60 DAT, shoot length (44.93cm), root length (33.67cm), fresh shoot weight (899.3g), fresh root weight (96.0g), curd diameter (19.73cm) and main curd weight (295.0g) were recorded from $P_3 K_3$. But the highest leaf length (49.37cm) at 60 DAT, number of secondary curd (5.0), weight of secondary curd (215.0g), yield per plant (505.0g), yield per plot (9.09 kg) and yield per hectare (16.83 t) were found in $P_2 K_3$. Postharvest potential of broccoli was negatively correlated with the fertilizer combinations. The minimum amount of fertilizers (P_0K_0) showed the longest shelf life (17.87 days) of broccoli when kept in refrigerator with polyethylene bag at 4^0C. The highest net return (Tk. 287458.75/ha) and benefit cost ratio (5.84) were recorded from $P_2 K_3$.

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Some commonly used abbreviations:

Full word	Abbreviation	Full word	Abbreviation
Acre	A	Square meter	m^2
and others (at ell)	*et al.*	Month	mo
Centimeter	cm	Standard error	SE
Cubic Centimeter	cm^3	Ton	t
Foot, feet	ft	Year	yr
Degree Celsius	^0C	Phosphorus	P
Degree of freedom	df	Potassium	K
Gram	g	Nitrogen	N
Hectare	ha	Boron	B
Hour	hr	Magnesium	Mg
Hydrogen ion conc.	pH	Calcium	Ca
Inch	inch	Molybdenum	Mo
Kilogram	kg	Zinc	Zn
Kilometer	km	Microgram	µg
Pound	lb	Milligram	mg
Meter	m	Minute	min
Relative humidity	RH	Square centimeter	cm^2

CHAPTER-I

INTRODUCTION

Broccoli botanically referred to as the species *Brassica oleracia* var. *botrytis* L. and a member of Brassicaceae family. Broccoli is an Italian word and derived from Latin *brachium* meaning an arm or branch. There are three classes of sprouting broccoli, i.e., green, white and purple, but the green type is the most popular broccoli (Shoemaker, 1962).

Broccoli is one of the important cole crops in Europe and USA and it is a commercial crop in India (Tindall, 1983; Nonnecke, 1989) but it is a minor vegetable in Bangladesh and its production statistics is not available. A small-scale cultivation is found in the area of Dhaka and Gazipur districts. It has a good demand to some big hotels in the Dhaka city of Bangladesh to feed the foreigners. Broccoli contains a high amount of vitamin A, ascorbic acid and appreciable amounts of thiamin, riboflavin, niacin, calcium and iron (Thompson and Kelly, 1957; Lincolin, 1987). Analytical data presented by Nonnecke (1989) showed that sprouting broccoli contains more vitamins and minerals than those of other cole crops (Appendix III).Broccoli has high nutritive value especially vitamin A and vitamin C. Therefore, it can be met up some degree of vitamin A and vitamin C requirement and can contribute to solve malnutrition problem in Bangladesh.

The per capita production of vegetable in Bangladesh is very low as compared to that of other countries. Due to low production of vegetables, the present per capita consumption is only about 30g but it is 70g with potato and sweet potato. It is an alarming situation for vegetable consumption in Bangladesh. So, a large-scale production of broccoli can help to increase vegetable consumption.

Broccoli is environmentally better adapted than cauliflower and is reported to withstand comparatively at higher temperature than cauliflower (Rashid, 1976). Broccoli can be grown on a wide range of soil types, ranging from light sand to heavy loam or, even clay that are well supplied with organic matter (Katayal, 1994). Successful production of broccoli depends on various factors. Fertilizer management is one of the most important factors, which assured crop production.

Broccoli responds greatly to major essential elements like nitrogen, phosphorus and potassium in respect of its growth and yield (Mital *et al.*, 1975; Pieters, 1976; Sing *et al.*, 1976; Thompson and Kelly, 1957).

Phosphorus can influence curd initiation and growth of broccoli. Demchak and smith (1990) reported that phosphorus was the most responsible element for the increased yield of broccoli.

Potassium also has an important role in balancing physiological activities. Different levels of potassium influence the growth and yield of broccoli. Ying *et al.* (1997) observed that potassium was the most important element for yield and dry weight of broccoli. In our country farmers use fertilizers without following recommended dose and there were also a lack of fertilizer recommendation for newly introduced broccoli.

Vegetables are one of the perishable commodities due to high moisture contents. Most of the vegetables have very short shelf life. In our country about 70% vegetables are grown in rabi season. If we can increase shelf life of vegetables, the availability of vegetable in the off-season can be increased. Broccoli is an important vegetable having short shelf life, which hasten the post-harvest losses and make the crop unpopular even than it has a greater potential to improve the nutritional situation of our country. The post-harvest loss of broccoli due to the short shelf life results economic loss of the producers as well as the traders, which in turn affects over national economy. In order to have good return and avoid market glut it becomes essential to store the broccoli for a considerable period.

Considering the above-mentioned facts the present investigation was undertaken with the following objectives:

i) to determine the optimum doses of phosphorus fertilizer on growth and yield of broccoli

ii) to determine the optimum doses of potassium fertilizer on growth and yield of broccoli.

iii) to investigate the interaction effect of phosphorus and potassium fertilizer for proper growth and yield of broccoli.

iv) to investigate the shelf life of broccoli.

CHAPTER-II

REVIEW OF LITERATURE

Growth, yield and post harvest potential of broccoli have been studied in various parts of the world, but a little study has been done on this crop under the agro-ecological condition of Bangladesh. However, available information portioning to this study was reviewed in the following headings.

Fertilizer requirement:

Reddy *et al.* (2005) conducted a field experiment to study the effect of P (0, 50,100 and 200kg /ha) and Zn (0, 10, 20 and 40kg/ha) fertilizers, alone and in combination, on the yield and quality of cauliflower cv. snowball 16. Curd yield significantly increased with the increasing P and Zn rates up to 100kg P/ha and 20kg Zn/ha. However, an increase in Zn rate up to 40kg Zn/ha decrease curd yield. Curd yield was also highest with 100kg P +10kg Zn/ha. The ascorbic acid content significantly increased up to 100kg P/ha (83mg /100gm) and 10 kg Zn/ha (82mg/100gm) while it decreased significantly (80mg/100g) with 40 kg Zn/ha. Protein content significantly increased with 200kg P/ha (30.84%), 10kg Zn/ha (27.05%) and 100kg P/ha+10kg Zn/ha (31.28%).

Singh (2004) conducted a field experiment during 2001 and 2002 to evaluate the growth and yield of cauliflower c.v. Snowball-16 under different N (0, 60, 100 and 140kg/ha) and P levels (0, 60, 80 and 100 kg/ha). Increasing N and P levels advanced curd initiation and maturity and increased plant height, leaf length, lead width, curd diameter, curd depth, net curd weight and marketable curd yield. There were no significant differences between 100 and 140kgN/ha and between 80 and 100kg P/ha. Application of 140kg N/ha and 80kg p/ha recorded the highest values for number of leaves per plant (19.44), Curd diameter (16.42cm), Curd depth (10cm), net curd weight (740.38g), Curd solidity (66.84g/cm) and marketable curd yield (236.92 q/ha) as well as the highest net returns (Rs.101060/ha) and benefit cost ratio (6.81).

Brahma *et al.* (2002) conducted an experiment at Assam Agricultural University in India during rabi season of 1998-99 and 1999-2000 to study the effect of nitrogen, phosphorus and potassium on growth and yield of broccoli cv. Pusa Broccoli KTS-1. Treatments comprised: 0:0:0, 50:30:20, 100:60:40, 150:90:60 and 200:120:80 kg NPK/ha. The growth and yield of broccoli showed marked improvement with the application of 200:120:80 kg NPK/ha.

Sharma *et al.* (2002) were conducted an experiment and find out the response of sprouting broccoli 'Green head' to different levels of N (30, 60, 90 and 120 kgN/ha) and P (30, 60 and 90 kg P_2O_5 /ha). They were found when N and P are applied alone, maximum values with respects to plant height, plant frame, head size, head yield/plant and per hectare were obtained at 120 kg N and 60 kgP_2O_5/ha respectively. However, when N was applied in combination with P maximum head yield/plant as well as per hectare were obtained at a treatment combination of 90 kg N and 6kgP_2O_5/ha, resulting in a maximum cost: benefit cost ratio of 1: 2.35.

Pardeep-Kumar *et al.* (2001) conducted an experiment on performance of different broccoli cultivars (Green Head, Palam Samridhi, DPGB 12 and American Selection) under different N, P and K rates (0, 0 and 0; 60, 45 and 15 kg/ha; 90, 60 and 30 kg/ha; 120, 75 and 45 kg/ha and 150, 90 and 60 kg/ha, respectively) in India during 1998-99. Crop yield per plant (392.04 g/plant) and yield per hectare (13.05 t/ha), as well as vitamin C content (73.13 mg per 100 g), were highest in DPGB 12 compared to the other cultivars. The maximum values for growth, yield and quality characteristics were obtained at the highest N, P and K levels (150, 90 and 60 kg/ha, respectively). Treatment with these fertilizer levels combined with treatment with DPGB 12 resulted in the highest yield and benefit: cost ratio (2.71: 1).

Singh *et al.* (2000) reported a linear increased in plant height was observed with increasing N and K rates. K improved the development of roots and the utilization of N. Delay in marketable plant maturity was observed when N and K rates exceeded 150 and 50 kg/ha, respectively. The highest net head weight and yield were obtained when N at 150 kg/ha and K at 50 kg/ha were applied. Results indicate that these concentrations of N and K fertilizers are optimum for broccoli growth in Himachal Pradesh, and further increase in concentration may have negative effects on growth and yield.

Three field experiments were conducted with broccoli on clay loam to clay soils. In the first two experiments, N was applied at 0-400 kg/ha in split application (20% at planting, 40% at 30 DAT and 40 at 45 DAT) together with 80 kg P_2O_5/ha and 300 kg K_2O/ha during transplanting. In the third experiment, N and K were injected into the drip irrigation system as determined by the demand curve and P was applied at planting. In the third experiment, marketable yields were the highest (24.5 t/ha) at 400 kg N/ha. (Castellanos *et al.* 1999)

Cai *et al.* (1999) conducted an experiment on the amount of N and K application on broccoli raised in compound media. In this experiment broccoli was grown in compound media mixed with sawdust, slag and cotton seed coats. Results indicated that applying 15 g urea + 10 g potassium chloride per plant produced the earliest curds of high quality and high yields. Applying 30 urea + 10 g potassium chloride per plant produced the highest yields applying 30 g urea + 30 g potassium chloride per plant gave the least satisfactory results.

Sumiati (1998) stated that seedlings of broccoli cultivars Green King and Mikado were transplanted into Jiffy pots or into a mixture of stable manure and soil supplemented or not supplemented with NPK compound fertilizer (15:15:15) and/or Metalik. There were differences between cultivars in plant height, root length, LAI, NAR and RGR at 2, 3 or 4 weeks after transplanting. These factors were all highest at all stages in plants grown in manures + soil supplement with NPK+ Metallic and were generally lowest in plants grown in jiffy pots.

Ying *et al.* (1997) conducted a pot experiment to determine the effect of N P and K on yield and quality of broccoli. They observed K was the most important element for yield and dry weight. Additive effects were observed on yield and vitamin C (ascorbic acid) content when K was applied together with N or N + P. Application of N + P gave 110.8% higher yields than N alone. Nitrogen application advanced the harvesting date. Significant positive correlations were found between yield and dry weight of leaves and plant size. They also suggested that N, P and K application should be balanced to obtain high yields and quality of broccoli.

Everates *et al.* (1997) stated that application of a single dose of 260 kg N/ha (minus the amount of mineral N present in the top 0.60 cm layer of soil) by row application at the time of planting gave superior results. A high-yield crop uptook 200-250 kg N, 30 kg P and up to 250 kg K/ha.

A close relationship existed between the texture and quality of the head and N and K nutrition. Rational application of nitrogen and potash fertilizers regulated the absorption of N, P and K by plants, promoted nitrate accumulation in leaves and spears, and increased spear yields. (Yang. *et al.* 1995)

Steffen *et al.*(1994) observed the effect organic matter (spent mushroom compost at 64 mt/ha+rotten cattle manure at 57 mt/ha) applied in spring 1990 on growth and yield of broccoli. No fertilizer or other amendments were added to previously amended treatments, but 100% recommended NPK be added to all control treatments. Broccoli yield and head diameter were greater in the amended treatment

Simoes *et al.* (1993) investigated the effect of container size and substrate on growth and yield of broccoli in nursery and in field. It was found that containers of 21-31 mm wide and 71-75 mm deep, in combination with rich substrates (180-210 mg N, 120-240 mg P_2O_5 and 220-270 mg K_2O litre) produced the best result.

Magnifico-v *et al.* (1993) conducted a field trial on a silty clay soil at Policoro from January 1976 to September 1980 with broccoli, spinach, snap beans and pickling cucumbers grown in rotation comparing 12 NPK fertilizer rates and 3 herbicides (for each crop). Trifluralin, Chlorthal [-dimethyl] and Nitrofen were used on broccoli; Lenacil, Cyclote and Chlorbufam+Cycluron were applied on spinach; Trifluralin,Alachlor and Nitrofen were applied on snap beans; and Trifuralin, chlorthal and Asulam were applied on cucumbers. Over the 5 years, 17 crops were grown: 4 of broccoli, 3 of spinach, 5 of snap beans and 5 of cucumber. An average of 94 days were needed for broccoli, 85 for spinach, 65 for beans and 58 for cucumber, a total of 302 days/year. The effects of sowing/transplanting dates and harvesting and the residual effects of herbicides were examined. Yields of each species varied widely and were mainly influenced by fertilizer rates and not herbicides. Cucumber was the only crop to show phytotoxicity from herbicides used earlier on spinach. It was concluded that this intensive system could not be recommended to farmers since it required very careful planning and yields depended on a number of contingencies.

Bracy *et al.* (1995) conducted an experiment on direct-sown broccoli cv. Early dawn and the effects of pre-planting NPK fertilizer at a rate of 45 kg N+59 kg P +112 kg P and 90 kg N + 118 kg P _224 kg K /ha plus side dressed N fertilizer at 134, 196 or 258 kg/ha, either dropped onto or knifed into the bed were determined. The marketable yield, early yield, head weight and percentage of early to total yield were unaffected by fertilizer rate or method of application.

Mitra *et al.* (1990) obtained a yield of 51.5 tones broccoli/ha by applying nitrogen, phosphorus and potassium at the rate of 100, 50 and 50 kg/ha, respectively, compared with 33.5 tones/ha with 50 kg N, 25 kg P and 25 kg K/ha. They also reported that broccoli cv. Appollo produced average individual head weight of 0.87 lb by the application of N, P and K at the rate of 300, 100 and 150 kg/ha, respectively.

Magnifico *et al.* (1989) reported the growth and accumulation of macro and microelements in various stages of the cultural cycle of two cultivars of broccoli in Southern Italy. Plant samples were collected every two weeks beginning at the time of thinning and continuing for 112 and 126 days, respectively, for cultivars Di Gennaio and Di Marro. Despite the different cultural cycle, the cultivars were similar in yield and element uptake. On a per hectare basis the plants removed about 460 kg N, 140 kg P_2O_5, 692 kg K_2O, 33O kg Ca, 75 kg Na and 42 kg Mg.

Balyan *et al.* (1988) conducted an experiment on cauliflower of five levels of N (0, 40, 80, 120 and 160kgN/ha), two levels of P (0 and 50kg P_2O_5/ha) and four levels of zinc (0, 10, 20 and 30kg $Znso_4$/ha). It was found N application improved number of leaves per plant and leaf size index over control but delayed curd initiation. Curd compactness and marketable yield increased significantly up to 120kg N/ha. Phosphorus also improved number of leaves per plant and leaf size area index at 50kg P_2O_5/ha. Curd compactness and marketable yield were improved significantly up to 20kg $Znso_4$/ha. Interaction effect of these nutrients was found significant on marketable yield. Maximum yield was obtained at 160kg N, 50kg P_2O_5 and 20kg $Znso_4$/ha.

Nitrogen and phosphorus requirements of greenhouse broccoli cv. Southern Comet showed that increasing N rates increased head fresh weight stem diameter, floret total chlorophyll, root and top dry weight (stem, petiole, leaf and head), plant height, head quality and decreased days to heading and harvest. For quality broccoli production greenhouse, 5.6 g N, 0.21 g lkP and 16 g K per liter were required (Dufault, 1988).

Burghardt and Ellering (1986) observed that under sub-optimal total nutrient suplly, a foliar fertilizer (12N: 4P: 6K) at concentrations up to 15% was tolerated, without leaf damage by dwarf beans, carrots, beetroots, endives, broccoli, leeks and white cabbages. These concentrations were equivalent to 100 kg N/ha. Plant development and leaf color improved and yields increased by 12 to 74%.

A fertilizer experiment was carried out on growth and nutrient removed by broccoli in the United States of America and found that broccoli plants removed 559 kg N, 23 kg P_2O_5, and 723 kg K_2O/ha. The total yields were 1, 48,400 kg/ha fresh materials and 16,900 kg/ha of dry matter. (Magnifico *et al.* 1979)

Cuteliffe and Munro (1976) conducted an experiment to see the effect of N, P and K on cauliflower cv. Snowball. They found that yields were substantially increased by the application of N and P but only slightly affected by applied K. Maturity was slightly delayed by lack of P. Maximum yields were generally obtained where N was applied at 112-224 kg/ha, P_2O_5 at 49-98 kg/ha and K_2O at 93 kg /ha.

Singh *et al.* (1976) reported that curd yield that curd yield of cauliflower increased with increasing application of N and K_2O, each at 120 kg/ha and N, K interactions were highly significant.

Borna (1976) conducted an experiment to study the effect of N, P_2O_5 and K_2O on cabbage, cauliflower broccoli, onions, leeks, carrots, parsley, celery, cucumber and tomatoes with different levels of fertilizers. He observed that irrigation generally increased the effectiveness of mineral fertilizers even at high rates. Fertilization and irrigation and their interactions had greater effects on marketable yield than total yield.

Munro *et al.* (1978) conducted an experiment on broccoli and Brussels sprouts and analyzed the leaf tissue of broccoli (*Brassica oleracea* spp.*italica*) cv. Waltham 29 and Brussels sprouts, cv. Jode Cross during the growing season. Plants were fertilized with 4 levels of N, P and K in factorial combination with and without FYM. Growth responses to applied N and P tended to lower tissue K levels. FYM had little effect on tissue N and only small effects on tissue P and K. Concentrations of all three nutrients declined during the growing season. Critical N, P and K levels for plants growth were within the ranges of 5.2-6.0% N, 0.35-0.60 P and 1.7-2.2% K.

Magnifico *et al.* (1979) conducted a trial to study the effect of NPK on growth and nutrient removal by broccoli plants removed 559 kg N, 23 kg P_2O_5 and 723 kg K_2O/ha. The total yield was 148400 kg/ha and dry matter was 16800 kg/ha.

An experiment was conducted in BARI to investigate the effect of chemical fertilizer and manure on the yield of cabbage, with the findings that the application of NPKS and cow dung increased the yield component and head yield significantly, whereas the effect of Zn and Mo was beneficial. The highest head yield of 75t/ha was recorded in treatment N_{120} P_{100} S_{30} Zn_5 M_{O1} kg/ha along with cow dung 5 t/ha (Anon. 1988).

An experiment was conducted in BARI at Joydebpur on cabbage. They used in this experiment was Atlas-70. There were five levels of nitrogen (O, 60, 120, 180 and 240kg N/ha), four levels of phosphorus (O, 60, 90 and 120 kg/ha) and four levels of potassium (O, 60, 120 and 180 kg/ha), two levels of each of sulphur (0 and 30 kg/ha), zinc (0 and 5 kg/ha), molybdenum, (0 and 1 kg/ha) and a constant dose of 5 t/ha cow dung as organic manure. The application of chemical fertilizer had a significant effect on growth and yield of cabbage. The highest cabbage yield (110.98 ton/ha) was obtained from the treatment N_{180} P_{120} K_{120} S_{30} Zn_5 MO_1 and the lowest (50.76 t/ha) from the absolute control treatment (Anon., 1982).

An experiment was carried out in Grey Terrace Soils of BARI at Joydebpur to find out the optimum rates of fertilizer for broccoli on the basis of soil test value and crop response data during the rabi season. There were five levels of N: O, 60, 90, 120 and 150 kg/ha; four levels each of P_2O_5: O, 40, 80, 120 kg/ha; and K_2O: O, 40, 80 and 120 kg/ ha and three levels each of S: O, 20 and 30 kg/ha and Mo: O, 1 and 3 kg/ha with a blanket rate of 5 t/ha of cow dung. The tested variety was green Sprout. Responses of Broccoli to N, P, K and S and Mo were significant. The highest vegetative growth and curd yield of 22.01 t/ha was produced by the combined effects of 120, 80, 20 and 1 kg of N, P_2O_5, K_2O, S and Mo, respectively and cow-dung 5 t/ha (Anon., 1992).

Magnifico *et al.* (1989) reported the growth and accumulation of macro and microelements in various stages of the cultural cycle of 2 cultivars of broccoli in Southern Italy. Plant samples were obtained every 2 weeks beginning at the time of thinning and contenting for 112 and 126 days, respectively, for cultivars Di Gennaio and Di Marzo. Despite the different cultural cycle, the cultivars were similar in yield and element uptake. On a per hectare basis the plants removed about 460 kg N, 140 kg P_2O_5, 692 kg K_2O, 330 kg Ca, 75 kg Na, and 42 kg Mg. Microelement removal by Di Gennaio was 77 kg S, 20 kg Al, 12 kg Fe, 1 kg Mn, 479g Zn, 443 g Sr, 411 g B, 72 g Cu, 26 g Mo, 23 g Ni, and 20 g Ca. Total growth averaged 136-t/ha fresh materials, which included 14 t/ha of main heads, 28t/ha of secondary heads, and 14-t/ha dry matters. The highest removal rates were recorded from flower stem emission to main head production.

Dufault (1988) studied nitrogen and phosphorus requirements of greenhouse broccoli cv. Southern Comet and showed that increasing N rates increased head fresh weight, stem diameter, floret total chlorophyll, root and top dry weight (stem, petiole, leaf, and head), plant height, and head quality, and decreased days to heading and harvest. For quality broccoli production in greenhouse, 5.6g N, 0.21g P and 1.6g K per 15-liter pot were required.

Karim *et al.* (1987) studied the response of cauliflower to NPK fertilizer at different levels of irrigations. The interaction effects of irrigation and nitrogen on yield and yield components were found to be significant. Five irrigations along with higher doses of fertilizers (N_{150}, P_{113}, K_{180}) produced the tallest plants (47.5 cm), maximum number of leaves (34.5/plant) and the heaviest curd (1070) g/plant).

Magnitico *et al.* (1979) carried out a fertilizer experiment on growth and nutrient removed by broccoli in the United States of America and found that broccoli plants removed 559 kg N, 23 kg P_2O_5 and 723 kg K_2O per ha. The total yield was 14840-kg/ha fresh materials and 1680 kg/ha of dry matter.

Simon (1976) conducted an experiment on the effect of graduated raters of nitrogen and irrigation on the yield of broccoli. He observed that N application had greater effect on yields than irrigation. Raising nitrogen rates increased yield. It has been reported that curd yield of broccoli increased with increasing application of N and K_2O, each at 120 kg/ha and NK interactions were slightly significant.

Kaniszewski and Jagoda (1975) conducted an experiment on the effect of increasing rates of mineral fertilizer and spacing on broccoli yields. They applied N, P_2O_5 and K_2O at the rates of 300, 600 and 900 kg/ha, respectively, and the plants were spaced at 50 X 50 cm and 50 X 70 cm. The highest NPK rates gave the best results. The highest yield per plant was obtained from wider spacing but the highest yields per hectare were obtained from closer spacing.

Sumiati (1988) stated that seedlings of broccoli cultivars Green King and Mikado were transplanted into Jiffy posts or into a 1: 1 mixture of stable manure and soil supplemented or not supplemented with NPK compound fertilizer (15:15:15) and/ or Metallic. There were no differences between cultivars in plant height, root length, LAI, NAR and RGR at 2,3 or 4 weeks after transplanting. These factors were all highest at all stages in plants grown in manure + soils supplemented with NPK+ Metallic and were generally lowest in plants grown in Jiffy pots. Interactions between cultivars and treatments on LAI. NAR and K uptake at 4 weeks after transplanting were noted.

Burghardt and Ellering (1986) observed that under sub-optimal total nutrient supply, a foliar fertilizer (12 N: 4 P: 6 K) at concentrations up to 15% was tolerated, without leaf damage by dwarf beans, carrots, beetroots, endives, broccoli, leeks and white cabbages. These concentrations were equivalent to >100 kg N/ha. Plant development and leaf color improved and yields increased by 12-74%. Crop quality was unchanged in most crops by foliar spraying, but it improved in beetroots and leeks. Leaf nitrate content was little affected by foliar spraying.

Effect of different storage condition on shelf-life o f broccoli:

King and Morris (1994) found that ethylene production during storage showed no consistent relationship to yellowing. However time until onset of yellowing was broadly related to the basal level of ethylene production. The maximum storage life at 20^0C is approximately 72 hrs. Branchless are useful model system for investigation of broccoli senescence.

Barth *et al.* (1993) observed that broccoli spears were packed using a semi permeable polymeric film and stored 96 hours at 20°C, CO_2 and O_2 concentration within the packages equilibrated to about 9 and 3 percent, respectively. Relative to non-packed spears, ascorbic acid, chlorophyll and moisture retention were greater.

Bastrash *et al.* (1993) carried out an experiment on storage of broccoli. They observed that the atmosphere consisting of 6% CO_2 and 2% O_2 resulted in extended storage of broccoli florets from 5 weeks in air to 7 weeks. This was demonstrated by delayed yellowing, prolonged chlorophyll retention, and reduced development of mold and offensive odors and better water retention. These beneficial effects were especially noticeable when the florets were returned from control atmosphere storage at 4°C to normal air 20°C.

Tan *et al.* (1993) conducted an experiment on storage characteristics and quality of 4 broccoli cultivars stored at 1^0C for three weeks in folded high-density polyethylene bags. After storage they were still green, compact and marketable. After exposure to 26°C for another two days, most of the heads turned yellow and were non-marketable.

An experiment was conducted in Kasetsart University, Bangkok, Thailand on modified atmosphere storage of broccoli. The vegetable (broccoli) stored either at 5^0C or 10% had a storage life of 16 days. The organoleptic test of the stored broccoli was as good as farming fresh ones (Anon., 1992).

Deschene *et al.* (1991) observed that when freshly cut heads of broccoli were stored in air control atmosphere at 23^0C or 10^0C the florets rapidly senescent. Chlorophyll levels declined by 80-90% within 4 days at 20^0C and within 10 days at 10^0C. Broccoli florets senescence those are sensitive, directly or indirectly to ambient CO_2 and O_2 concentrations.

Dazami *et al.* (1991) conducted an experiment on pre-storage hot water dipping of broccoli heads on shelf life and quality during storage. They found that harvested broccoli heads become yellow after two days when stored at 20^0C. However when the harvested heads were dipped in hot water (45^0C) for 14 minutes, head yellowing occurred after 4-5 days storage at 20^0C.

Kalieber and Wills (1991) reported that an optimum storage life about 8 weeks was attained at 0^0C and 100% relative humidity but close control of these conditions were required. Reducing the O_2 concentration and increasing Co_2 concentration could extend storage life.

Xue *et al.* (1991) conducted an experiment and observed that the effects of low density polyethylene (LDPE) films mixed with ethylene absorbent or far infrared radiation ceramics and of the moisture absorbent in an LDPE bag on freshness keeping of broccoli. The storage life of broccoli in LDPE bags was more than twice as long as for non-packaged broccoli. Yellowing and wilting of broccoli were observed without packaging and off flavor was observed in LDPE packaging.

Berard (1990) conducted an experiment with nitrogen fertilizer on stored cabbage. They found that maximum severity in storage head treated with high nitrogen and suggested that application of nitrogen fertilizer in excess of 180 kg N/ha must be avoided.

Makhlouf *et al.* (1989) carried out an experiment on long-term storage of broccoli under controlled atmosphere. The cv. Stolto was stored for 6 weeks at 1^0 C under the N containing the following percentages of Co_2/O_2 0/20%, 6/2.5%, 10/2.5% and 15/2.5%. Color and chlorophyll retention was better under control atmosphere then in air. Storage under control atmosphere also delayed the development of soft rot and mould. Among the atmosphere tested, 6% CO_2 and 2.5% O_2 was the best for long term (3 weeks) maintenance of broccoli quality while avoiding physiological injury.

The influence of several plastic film combined with low temperature (5^0C) was observed to prolonged marketability of broccoli up to two weeks. Plastic film prevented the development of unpleasant volatile compounds and reduced excessive loss of water (Anelli *et al.*, 1985).

Apelond (1985) carried out an experiment on storage of Chinese cabbage and found that the head were stored for 90 to 120 days respectively at 2.5°C or 5°C in 0.5, 2.5 or 5% CO_2 and 1-20.5% O_2 in different combination.

Mertens (1985) conducted an experiment on storage conditions of important Chinese cabbage and found that harvested head of the Chinese cabbage cv. WR-60, which was susceptible to vein browning were stored at 1^0, 2.50 or at 1^0 C with various Co_2/O_2 percentage for 3 or 4 weeks.

CHAPTER-III

MATERIALS AND METHODS

Experimental site

The plants of broccoli were grown at Horticulture Farm in Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. The experiment was carried out during rabi season (October 15, 2005 to February 15, 2006). It was located in 24.09^0N latitude and 90.26^0E longitude. The altitude of the location was 8m from the sea level (The Meteorological Department of Bangladesh, Agargoan, Dhaka-1207).

Climate

The experimental area was situated in the sub-tropical climatic zone, which was characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest period of the year. Details of weather data in respect of temperature (^{O}C), rainfall (cm) and relative humidity (%) for the study period were collected from the Meteorological Department of Bangladesh, Agargoan, Dhaka-1207 (Appendix IV).

Soil

The experimental site was located in the Modhupur Tract (AEZ-28) and it was medium high land with adequate irrigation facilities. The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100g soil respectively.

Plant materials used in the experiment

The hybrid variety 'Green Sprouting Broccoli' was used in the experiment. The seeds of the hybrid variety were produced by Royal Sluis, Holland, and were collected from Khustia seed store, Mirpur-11, Dhaka-1216.

Seedbed preparation

Seedbed was prepared on 26 October 2005 for raising seedlings of broccoli and the size of the seedbed was 3m×1m. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtained good tilth. Weeds, stubbles and dead roots were removed from the seedbed. Cow dung was applied to the prepared seedbed at the rate of 10 t/ha. The soil was treated by Seven 50WP @ 5kg/ha to protect the young plants from the attack of mole crickets, ants and cutworm.

Seed treatment

Seeds were treated by Vitavax-200 @ 5g/1kg seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

Seed sowing

Seeds were sown on 28 October 2005 in the seedbed. Sowing was done thinly in lines spaced at 5cm distance. Seeds were sown at a depth of 2cm and covered with a fine layer of soil followed by light watering by water can. Thereafter the beds were covered with dry straw to maintain required temperature and moisture. The cover of dry straw was removed immediately after emergence of seed sprout. When the seeds were germinated, shade by bamboo mat (Chatai) was provided to protect the young seedlings from scorching sunshine and rain.

Raising of seedlings

Light watering and weeding were done several times. No chemical fertilizers were applied for raising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 21 days old seedlings were transplanted into the experimental field on 27 November 2005.

Design of the experiment

A. Field experiment

The field experiment was conducted by split-plot Randomized Complete Block Design (RCBD) with three replications. Two factors were used in the experiment viz. four levels of phosphorus and four levels of potassium.

Factor A. Four levels of phosphorus coded as P

P_0 = Control (No P application) TSP= P × 5

P_1 =30 kg P/ ha or, 0.0162 kg P/ plot

P_2 = 40 kg P/ha or, 0.0216 kg P/plot

P_3 =50kg P/ ha or, 0.027 kg P/plot

Factor B. Four levels of potassium coded as K

K_0 = Control (No K application) MP = K × 2

K_1= 50 kg K/ ha or, 0.027 kg K/plot

K_2 = 75kg K/ ha or, 0.0405 kg K/plot

K_3 = 100kg K/ ha or, 0.054 kg K/plot

There the 16 treatment combinations were given below:

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

Layout

The experimental plot was first divided into three blocks. Each block consisted of 16 plots. Thus, the total numbers of plot were 48. Different combinations of phosphorus and potassium were assigned to each block as per design of the experiment. The size of a unit plot was 4.5m ×1.2m. A distance of 0.5 m between the plots and 1.0 m between the blocks were kept. Thus the total area of the experiment was 27.2m × 16.5m.

Land preparation

The experimental area was first opened on 15 October 2005 by a disc plough to open direct sunshine to kill soil born pathogens and soil inhabitant insects. It was prepared by several ploughing and cross ploughing with a power tiller followed by laddering to bring about a good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. The weeds, crop residues and stables were removed from the field. The basal doses of manure and fertilizers were applied and finally leveled. The soil of the plot was treated by Seven 50wp @ 5kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm. According to design and layout the plots were prepared.

Application of manure and fertilizers

Manure and fertilizers were given bellow:

Name of manure and nutrient elements	Amount		Name of fertilizers	Amount	
	Kg/ha	g/plot		Kg/ha	g/plot
N	140	75.6	Urea	303.8	164.1
P	As per treatment	As per treatment	TSP	As per treatment	As per treatment
K	As per treatment	As per treatment	MoP	As per treatment	As per treatment
S	24	12.96	Gypsum	133.44	72.1
Zn	3.0	1.62	$ZnSO_4$	8.37	4.52
B	1.8	0.972	Boric acid	10.52	5.72
Mo	0.6	0.324	Ammonim molybdate	1.11	0.60
Cow dung	8 T/ha	4.32kg	-	-	-

Source: Fertilizer Recommendation Guide -2003, BARC

Half of cow dung and full doses of phosphorus (according to treatment), sulfur, zinc, boron and molybdenum should be broadcasted and incorporated during final land preparation. Remaining cow dung should be applied in pits prior to planting. Nitrogen and potassium (according to treatment) should be applied in two equal installments at 21 November 2005 and 11 December 2005 as ring method around the plants followed by irrigation.

Transplanting

The seedbed was watered before uprooting the seedlings to minimize the damage of roots. At the time of uprooting, care was taken so that root damage become minimum and some soil remained with the roots. Twenty-one days-old healthy seedlings were transplanted at the spacing of 60cm × 50cm in the experimental plots on 6 November 2005. Thus the 18 plants were accommodated in each unit plot. Planting was done in the afternoon. Light irrigation was given immediately after transplanting around each seedling for their better establishment. The transplanting seedlings were shaded for five days with the help of white polythene to protect them from scorching sunlight, watering was done up to five days until they became capable of establishing on their own root system.

Intercultural operations

1. Gap filling

Very few seedlings have been damaged after transplanting and new seedlings from the same stock replaced these.

2. Weeding

The plants were kept under careful observation. Three times weeding were done during cropping period viz., 13th November, 28th November and 13th December, for proper growth and development.

3. Spading

After each irrigation soils of each plot were pulverized by spade for easy aeration.

4. Irrigation

Irrigation was given by observing the soil moisture condition. Four times irrigation were done during crop period viz., 14th November, 24th November, 5th December and 15th December, for proper growth and development of plants.

5. Earthing up

Earthing up was done by taking the soil from the space between the rows on 13th November 2005.

6. Insects and disease control

Few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Seven 80WP was dusted to the soil before irrigation to controlled mole crickets and cut worms on 12th November 2005. Some of the plants were infected by alternaria leaf spot disease caused by

Alternaria brassicae. Rovral 50WP @ 20g per 10 litre of water was sprayed to prevent the spread of the disease on 10th December 2005. Bird pests such as nightingale (bulbuli) were seen visiting the broccoli field very frequently. The nightingale visited the fields from 8 to 11 a.m. and 4 to 6 p.m. The birds were found to puncture the soft leaves and initiating curd and were controlled by striking of a metallic container.

Harvesting

Main curds and secondary curds were harvested at different dates according to maturity indices. Main curds were harvested when the plants formed compact curd. After harvesting the main curd, secondary curds were developed from the leaf axils, which also developed into small secondary curds and were harvested over a period. Harvesting was started on 26 December 2005 and was completed on 14 February 2005. The curds were harvested with 20 cm of stem attached with the sprouts.

Collection data

The data pertaining to following characters were recorded from ten plants randomly selected from each plot, except yield of curds, which was recorded plot wise.

Plant height (cm)

Plant height was measured from base to the tip of the longest leaf at 20, 40 and 60 days after transplanting (DAT). A meter scale was used to measure plant height of the plant and expressed in centimeter (cm).

Stem diameter (cm)

Diameter of the stem was measured at 20, 40 and 60 DAT. The diameter of the stem was recorded in three dimensions and finally the average of the three dimensions was recorded and expressed in centimeter (cm).

Number of leaves per plant

Total number of leaves produced by each plant was counted at the time of main curd harvesting excluding the small leaves, which produced auxiliary shoots.

Leaf length (cm)

The length of the leaf was measured from the base of the petiole to the tip at 20, 40 and 60 DAT. A meter scale was used to measure the length of the leaves and expressed in centimeter (cm).

Days required for curd initiation

Total number of days from the date of transplanting to the date of visible curd initiation was recorded.

Curd diameter (cm)

Curd diameter was taken by using a meter scale at the final harvest. Diameter of the curd was measured at different directions and finally the average of all directions was recorded and expressed in centimeter (cm).

Average curd weight (g)

Weight of the central curd was recorded excluding the weight of all secondary marketable curds.

Number of secondary curds

When the secondary curds reached marketable size, they were counted the small shoots were taken into consideration.

Average secondary curd weight (g)

Weight of secondary curd was recorded by weighing the total marketable auxiliary curds of an individual plant.

Yield per plant (g)

The yield per plant was calculated by averaging the weights of ten randomly harvested curds and secondary curds.

Yield per plot (kg)

The yield per unit plot was calculated by adding the yields of all plants of each unit plot.

Yield per hectare (t)

The yield per hectare was calculated out from the per plot yield data.

B. Post harvest potential

Laboratory experiment was carried out after harvesting the curds to find out the shelf life of curd at different storage condition. The experiment was laid out in two factors Completely Randomized Design (CRD) with sixteen fertilizer combinations and three storage conditions. The storage conditions were as follows:

i) Stored in open condition at room temperature (24^0C)
ii) Stored in perforated polythene bags at room temperature (24^0C)
iii) Stored in perforated polythene bags at 4^0 C in refrigerator

The three mature broccoli curds were selected for each treatment. The selected broccoli curds were kept in a perforated polythene bag. The changes of florets color (just started to yellowish) were recorded by eye estimation. Laboratory trail comprised of sixteen-fertilizer combination with three storage conditions.

Data collection

Data on post harvest duration (days) was estimated until yellowing of florets under different storage condition.

Economic analysis

Economic analyses were done in order to compare the profitability of the treatment combination. All the non-material and material input costs and interests on running capital were considered for computing the cost of production. The interests were calculated for six months @ 13% per year. The price of one kg broccoli at harvest was considered to be Tk. 20.00.

The Benefit cost ratio (BCR) was calculated by the following formula:

Benefit cost ratio (BCR) = Gross return (Tk/ha) ÷ Total cost of production

Statistical analysis

The recorded data on different parameters were statistically analyzed with the help of MSTAT program. The treatment means were separated by Duncan's Multiple Range Test (DMRT) [Gomez and Gomez (1983)] at 5% level of significance for interpretation of the results.

CHAPTER-IV

RESULTS AND DISCUSSION

Plant height

Application of phosphorus exhibited a significant influence on the height of broccoli plants at 20, 40 and 60 days after transplanting (DAT) (Figure 1& Appendix-VI). At 20 DAT, the plant height ranged from 16.93cm to 28.73cm. The tallest plant (28.73cm) was found in the highest dose of phosphorus application (P_3) and the shortest plant (16.93cm) in $P_{1,}$ which was statistically similar to that of P_0. At 40 DAT, plant height ranged from 24.09cm to 38.68cm. The highest plant height (38.68cm) was recorded from P_3, which was statistically similar to that of P_2, while the lowest (24.09cm) was recorded from $P_{0.}$ At 60 DAT, the plant height ranged from 33.99cm to 55.85cm. The highest plant height (55.85cm) was recorded from $P_{3,}$ which was statistically similar to that of P_2, and the lowest (33.99cm) was recorded from P_0. It was revealed that the plant height increased with the increased in days after transplanting (DAT) i.e., 20, 40 and 60 DAT and also revealed that the plant height increased with the increased in P application as well. This could be due to the synergistic effect of P because it helped the efficiency of nitrogen uptake, which enhanced vegetative growth of broccoli plants (Leaflet, IPI, 2005). Mishra and Indulkarl(1993); Sharma *et al.* (2002), Singh (2004) and Reddy *et al.* (2005) found the same trend of the present investigation.

Application of potassium showed significant influence on the height of broccoli plants at 20, 40 and 60 DAT (Figure 2 & Appendix-VI). At 20 DAT, plant height ranged from 18.00cm to 27.60cm. K_3 produced the highest plant height (27.60cm), which was statistically similar to that of K_2 (22.36cm) and the lowest plant height (18.00cm) was found in K_1, which was statistically similar to that of K_0 (18.32cm). At 40 DAT, plant height ranged from 23.51cm to 39.13cm. The highest plant height (39.13m) was recorded from $K_{3,}$ which was statistically similar to that of K_2, while the lowest (23.51cm) was recorded from $K_{0.}$

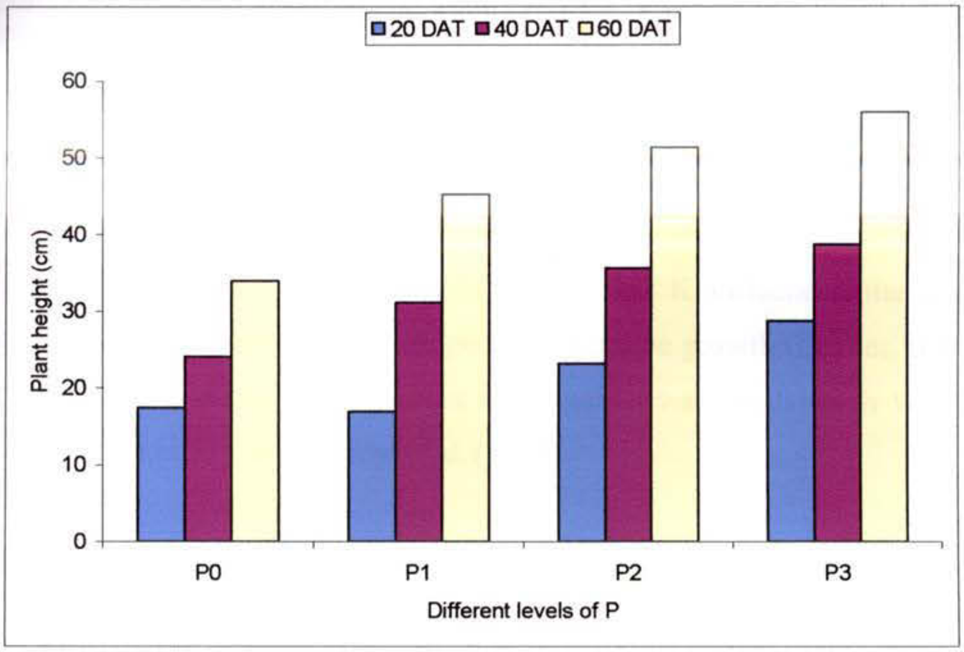

Figure 1 Effect of different levels of P and DAT on plant height

P_0 = 0 kg/ha, P_1 = 30 kg/ha, P_2 = 40 kg/ha and P_3 = 50 kg/ha.

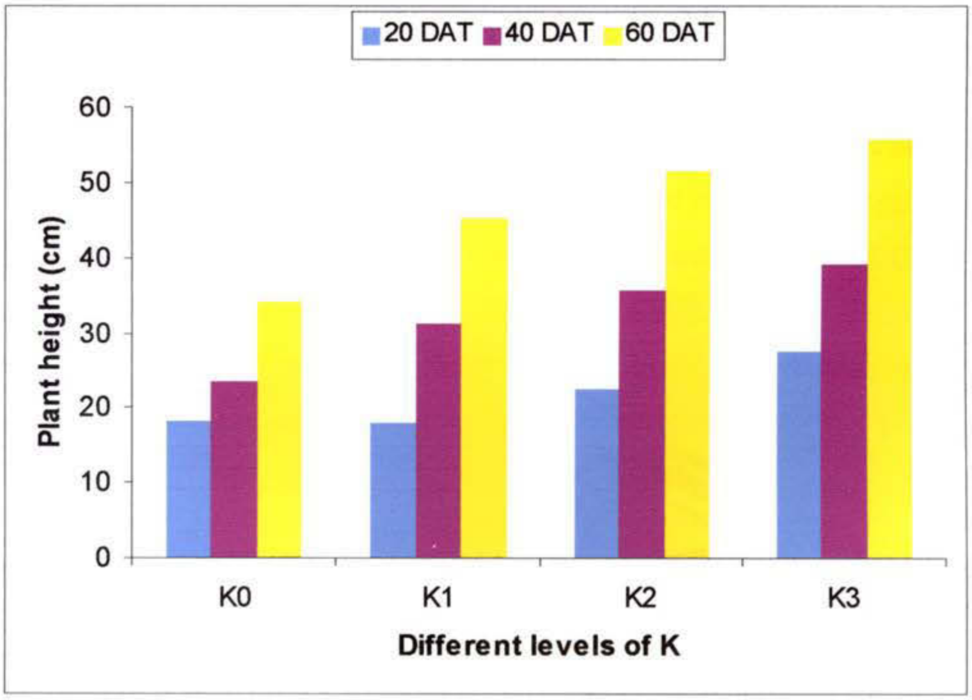

Figure 2. Effect of different levels of K and DAT on plant height

K_0 = 0 kg/ha, K_1 = 50 kg/ha, K_2 = 75 kg/ha and K_3 = 100 kg/ha

At 60 DAT, plant height ranged from 33.98cm to 55.82cm. The highest plant height (55.82 cm) was recorded from K_3, which was statistically similar to that of K_2 (51.51cm) and the lowest (33.98cm) was recorded from K_0. Similar to phosphorus the plant height was increased with the increased in K application and it was also observed that the plant height increased with the increased in DAT i.e., 20, 40, and 60 DAT. This might be caused that K influenced the uptake of nitrogen and phosphorus, which helped in vegetative growth (Leaflet, IPI, 2005). The trend of the result of the present investigation was similar with Wyatt *et al.* (1989), Singh (2004) and Reddy *et al.* (2005).

The plant height was significantly influenced by the treatment combinations at 20, 40 and 60 DAT (Table 3 & Appendix-VI). At 20 DAT, plant height ranged from 12.07cm to 35.15cm. The highest plant height (35.15cm) was observed in P_3K_3 and the lowest (12.07cm) was recorded from P_0K_1. At 40DAT, plant height ranged from 19.17cm to 46.57cm. The highest plant height (46.57cm) was observed in P_3K_3 and the lowest (19.17cm) was recorded from P_0K_0. At 60 DAT, plant height ranged from 27.36cm to 66.65cm.The highest plant height (66.65cm) was observed in P_3K_3 and the lowest (27.36cm) was recorded from P_0K_0. It was reveled that the plant height increased with the increased in DAT and increased in the application both of P and K as well. Similar trend of the result was found by other scientists like Wyatt *et al.* (1989), Singh (2004) and Reddy *et al.* (2005).

Table 3. Combined effect of phosphorus and potassium on plant height and stem diameter of broccoli

Treatments	Plant height (cm)			Stem diameter (cm)		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
P_0K_0	13.23 gh	19.17 h	27.36 i	0.72 g	2.24 ef	5.134 a
P_0K_1	12.07 h	22.11 gh	32.56 hi	1.10 ef	2.16 f	5.235 a
P_0K_2	17.60 ef	26.43 fg	35.60 gh	1.11 ef	2.54 de	5.352 a
P_0K_3	26.93 bc	28.63 ef	40.42 fg	1.10 ef	2.64 cd	5.186 a
P_1K_0	13.90 fg	22.07 gh	31.50 hi	0.90 fg	2.38 ef	5.185 a
P_1K_1	14.60 fg	31.40 de	44.36 ef	1.55 d	2.81 bc	5.452 a
P_1K_2	19.83 de	33.67 cd	50.50 de	1.61 cd	2.76 bc	5.302 a
P_1K_3	19.40 de	37.22 bc	54.53 cd	1.77 bc	3.06 ab	5.837 a
P_2K_0	18.40 de	24.97 fg	36.36 gh	1.10 ef	2.50 de	5.186 a
P_2K_1	21.40 cd	34.07 cd	49.81 de	1.65 cd	2.80 bc	5.722 a
P_2K_2	23.93 bc	39.26 bc	57.56 bc	1.97 ab	3.25 ab	5.553 a
P_2K_3	28.93 b	44.10 ab	61.67 ab	1.91 ab	3.39 ab	5.520 a
P_3K_0	27.77 b	27.85 ef	40.72 fg	1.24 e	2.37 ef	5.169 a
P_3K_1	23.93 bc	37.22 bc	53.64 d	1.85 bc	3.16 ab	5.773 a
P_3K_2	28.07 b	43.08 ab	62.39 ab	2.01 ab	3.42 ab	5.903 a
P_3K_3	35.15 a	46.57 a	66.65 a	2.13 a	3.57 a	5.920 a
CV (%)	15.41	12.06	9.04	9.11	12.62	15.13

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Stem diameter

The stem diameter of broccoli was significantly influenced by different DAT (i.e., 20, 40 and 60) due to application of phosphorus (Figure 3 & Appendix-VI). At 20 DAT, stem diameter ranged from 1.01cm to 1.81cm. The maximum diameter (1.81cm) was found in P_3, which was statistically similar to that of P_2 (1.66cm) and the minimum (1.01cm) was found in P_0. At 40 DAT, the stem diameter ranged from 2.40cm to 3.13cm. The highest stem diameter (3.13cm) was recorded from P_3, which was statistically similar to that of P_2 (3.00cm), while the lowest figure (2.40cm) was recorded from P_0. At 60 DAT, the stem diameter was statistically insignificant due to the application of different levels of phosphorus. The maximum stem diameter (5.69 cm) was found in P_3 and the minimum (5.22 cm) was found in P_0. This result revealed that the stem diameter increased significantly up to 40 DAT as well as increased in phosphorus application. This might be due to the synergistic effect of P and N. Phosphorus increased the nitrogen uptake efficiency, which ultimately stimulated the stem growth (Leaflet, IPI, 2005). Dufault (1988) found the same trend of the present investigation.

Marked variation was found in different levels of K application in respect of stem diameter of broccoli plants at 20, 40 and 60 DAT (Figure 4 & Appendix-VI). At 20 DAT, stem diameter ranged from 0.99cm to 1.73cm. K_3 produced the highest stem diameter (1.73cm) and the lowest (0.99cm) was found in K_0. At 40 DAT, stem diameter ranged from 2.37cm to 3.16cm. The highest stem diameter (3.16cm) was recorded from K_3, while the lowest figure (2.37cm) was recorded from K_0. At 60 DAT, stem diameter ranged from 5.16cm to 5.61cm. The maximum stem diameter (5.61 cm) was found in K_3 and the minimum (5.16 cm) was found in K_0. The stem diameter was statistically insignificant due to the application of different levels of potassium. It was revealed that the stem diameter increased up to 40 DAT at the increased in K application.

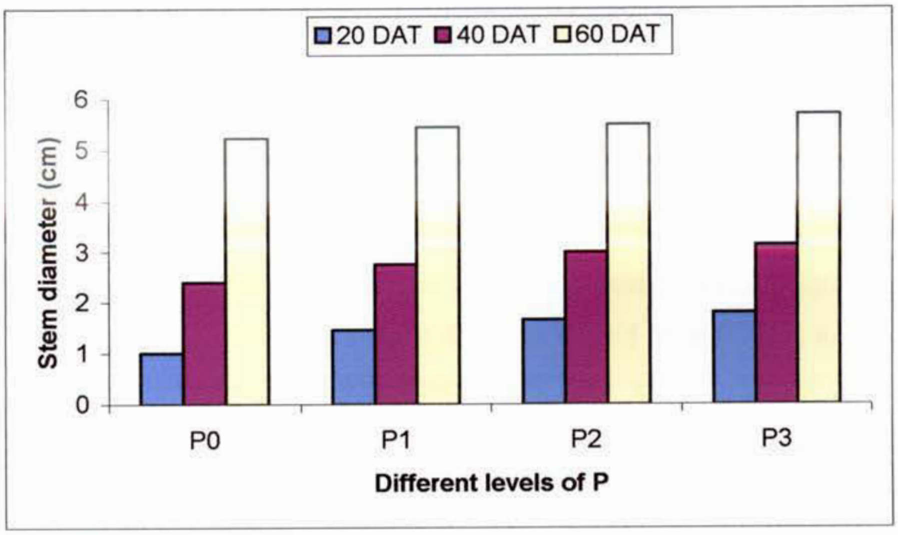

Figure 3. Effect of different levels of P and DAT on stem diameter

P_0 = 0 kg/ha, P_1 = 30 kg/ha, P_2 = 40 kg/ha and P_3 = 50 kg/ha.

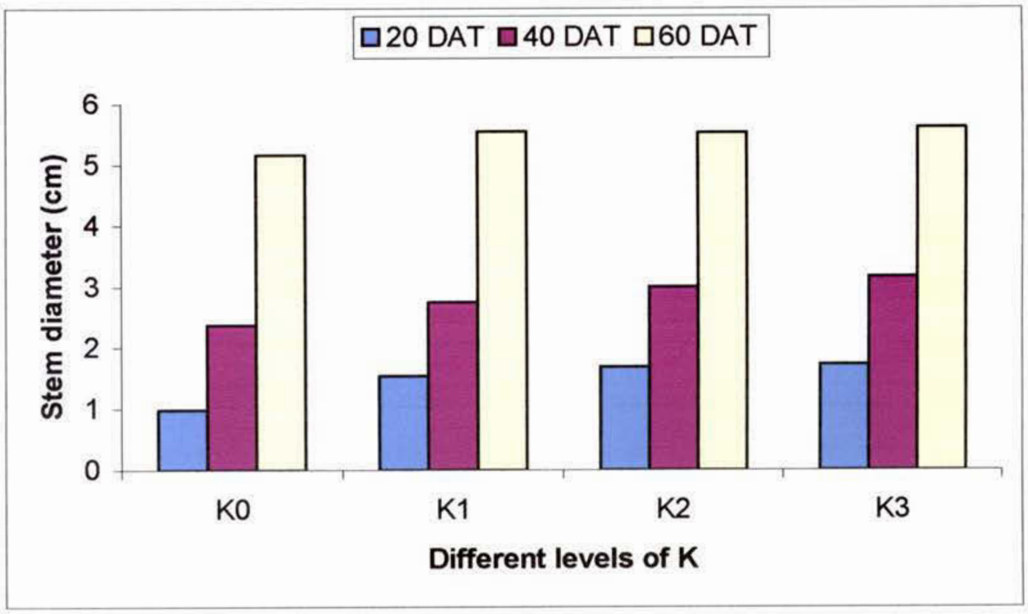

Figure 4. Effect of different levels of K and DAT on stem diameter

K_0 = 0 kg/ha, K_1 = 50 kg/ha, K_2 = 75 kg/ha and K_3 = 100 kg/ha

This might be due to K increased in other nutrients uptake efficiency in the plant, thus increasing the efficiency of applied urea and TSP, which ultimately stimulated stem growth (Leaflet, IPI, 2005). Similar trend of the result was found by other scientists like Wyatt *et al.* (1989), Ruan *et al.* (1991) and Singh *et al.* (2000).

There had significant variation was found among the treatment combinations at 20, 40 and 60 DAT (Table 3). At 20 DAT, stem diameter ranged from 0.72cm to 2.13cm. The highest stem diameter (2.13cm) was observed in P_3K_3 and the lowest (0.72cm) was recorded from P_0K_0. At 40 DAT, stem diameter ranged from 2.16cm to 3.57cm.The highest stem diameter (3.57cm) was observed in P_3K_3 and the lowest (2.16cm) was recorded from P_0K_1. At 60 DAT, it was found that stem diameter did not differ significantly due to the combined application of different levels of phosphorus and potassium. The maximum stem diameter (5.92 cm) was found in P_3K_3 and the minimum (5.13 cm) was found in P_0K_0. It was found that the stem diameter increased with the highest dose of P and K and the stem diameter also increased up to 40 DAT.

Number of leaves per plant

Application of phosphorus exhibited a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT (Figure 5 & Appendix-VII). At 20 DAT, number of leaves per plant ranged from 7.63 to 10.88. The maximum number of leaves (10.88) was found in P_3 that was statistically similar to that of P_1 and P_2 and the minimum (7.63) was found in P_0. At 40 DAT, The maximum number of leaves (12.98) was found in P_3 and the minimum (11.25) was found in P_0. At 60 DAT, there were no significant difference was found in number of leaves due to the application of different levels of phosphorus. The maximum number of leaves (13.78) was found in P_3 and the minimum (12.18) was found in P_0. It was revealed that the number of leaves per plant increased with the increased in P application and with the advanced of DAT as well. This might be caused that phosphorus has a significant role in photosynthesis, energy storage, cell division and cell enlargements, which enhanced the number of leaves (Leaflet, IPI, 2005).

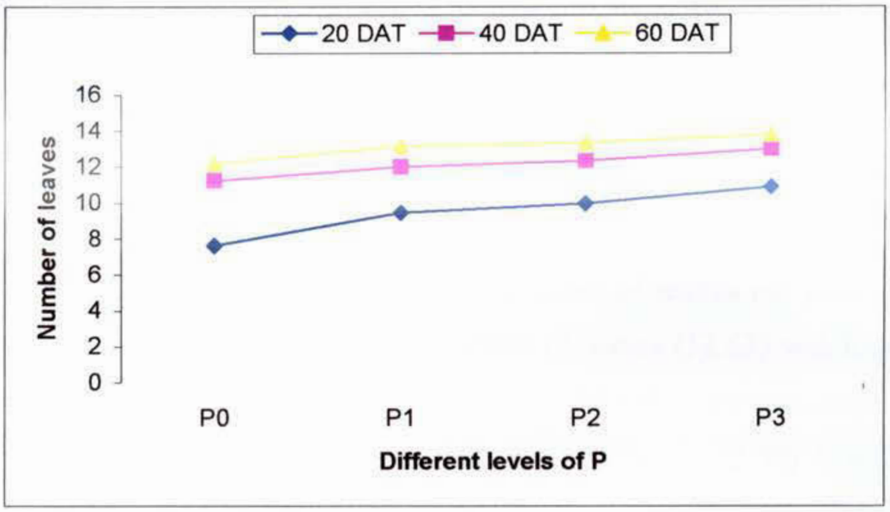

Figure 5 Effect of different levels of P and DAT on number of leaves

P_0 = 0 kg/ha, P_1 = 30 kg/ha, P_2 = 40 kg/ha and P_3 = 50 kg/ha.

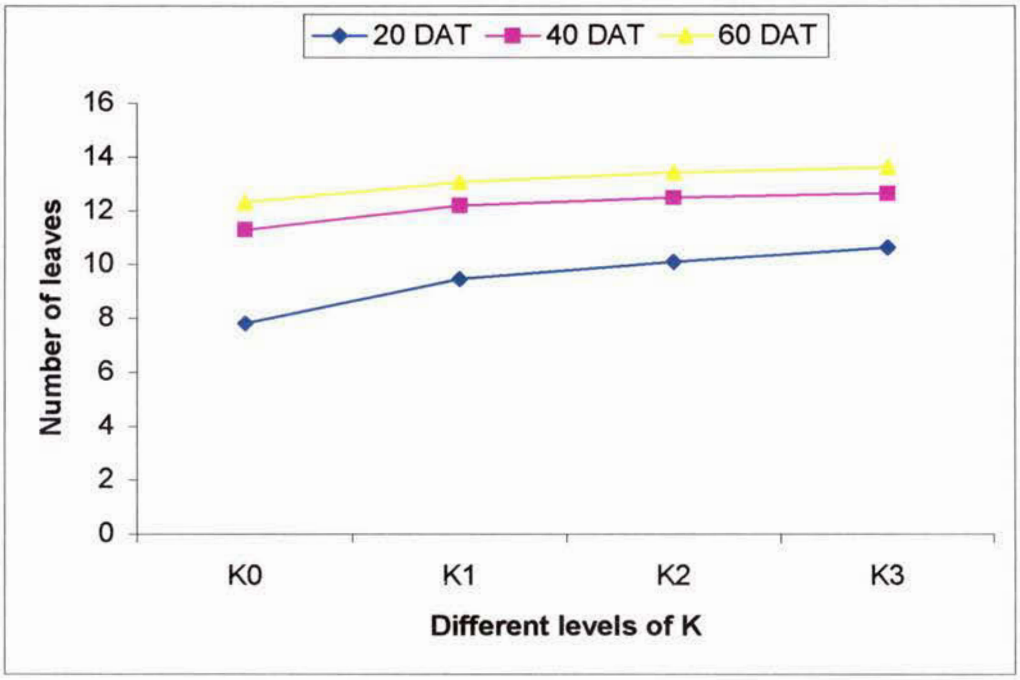

Figure 6 Effect of different levels of K and DAT on number of leaves

K_0 = 0 kg/ha, K_1 = 50 kg/ha, K_2 = 75 kg/ha and K_3 = 100 kg/ha

Application of potassium exhibited a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT (Figure 6 & Appendix-VII). At 20 DAT, number of leaves per plant ranged from 7.80 to 10.62. The maximum number of leaves (10.62) was found in K_3 that was statistically similar to that of K_1 and K_2 while the minimum (7.8) was found in K_0. Similar to phosphorus there was no significant difference was found in number of leaves per plant due to K application at 40 DAT, the maximum number of leaves (12.63) was found in K_3 while the minimum (11.28) was found in K_0. At 60 DAT, the maximum number of leaves (13.63) was found in K_3 while the minimum (12.30) was found in K_0.The number of leaves per plant increased with the increased in K application and with the advanced of DAT as well. This might be caused that K enhanced the photosynthesis process in plant.

The number of leaves was significantly influenced by the treatment combinations at 20, 40 and 60 DAT (Table 4 & Appendix-VII). At 20 DAT, number of leaves per plant ranged from 7.00 to 12.20. The maximum number of leaves (12.20) was observed in P_3K_3, which was statistically similar to that of P_3K_2, P_3K_1, P_2K_3, P_2K_2 and P_1K_3 while the minimum (7.00) was recorded from P_0K_0. At 40 DAT, number of leaves per plant ranged from 10.47 to 13.80. The maximum number of leaves (13.80) was observed in P_3K_1, which was statistically similar to that of P_3K_3 (13.73) and the minimum (10.47) was recorded from P_0K_1. At 60 DAT, number of leaves per plant ranged from 11.46 to 14.67. The maximum number of leaves (14.67) was observed in P_3K_3 and the minimum (11.46) was recorded from P_0K_1. It was appeared that number of leaves did not differ significantly due to the combined application of different levels of phosphorus and potassium. Corroborative results were obtained by Raut and keder (1981), Balyan *et al.* (1988) and Wyatt *et al.* (1989).

Leaf length

Phosphorus had a significant influence on the length of leaves of broccoli plants at 20, 40 and 60 DAT (Figure 7 & Appendix-VII). At 20 DAT, leaf length ranged from 31.67cm to 41.97cm. P_3 produced the longest leaf (41.97cm), which was statistically similar to that of P_1 and P_2 while the lowest (31.67cm) was found in P_0. At 40 DAT, leaf length ranged from 35.52cm to 45.21cm. The largest leaf (45.21cm) was recorded from P_3, which was statistically similar to that of $P_1$and P_2, while the smallest leaf (35.52cm) was recorded from P_0. At 60 DAT, leaf length ranged from 36.53cm to 45.87cm. The longest leaf (45.87cm) was recorded from P_3, which was statistically similar to that of $P_1$and P_2 while the smallest (36.53cm) was recorded from P_0. It was revealed that the leaf length increased with the increased in P application and DAT as well. This might be due to the synergistic effect of P and N. Phosphorus helped the nitrogen uptake efficiency, which stimulated the vegetative growth of broccoli plant. Similar results were found by other scientists like Singh (2004) and Reddy *et al.* (2005).

There had a significant influence of potassium on broccoli plants in respect of leaf length at 20, 40 and 60 DAT (Figure 8 & Appendix-VII). At 20 DAT, leaf length ranged from 31.26cm to 42.45cm. K_3 produced the longest leaf (42.45cm), which was statistically similar to that of K_1 and K_2 whereas K_0 produced the smallest leaf (31.26cm). Similar trend of result was found at 40 DAT and 60 DAT. At 40 DAT, K_3 produced the longest leaf (44.91cm) whereas K_0 produced the smallest leaf (34.64cm). At 60 DAT, the largest leaf (46.03 cm) was found in K_3 and the smallest leaf (35.47 cm) was found in K_0.

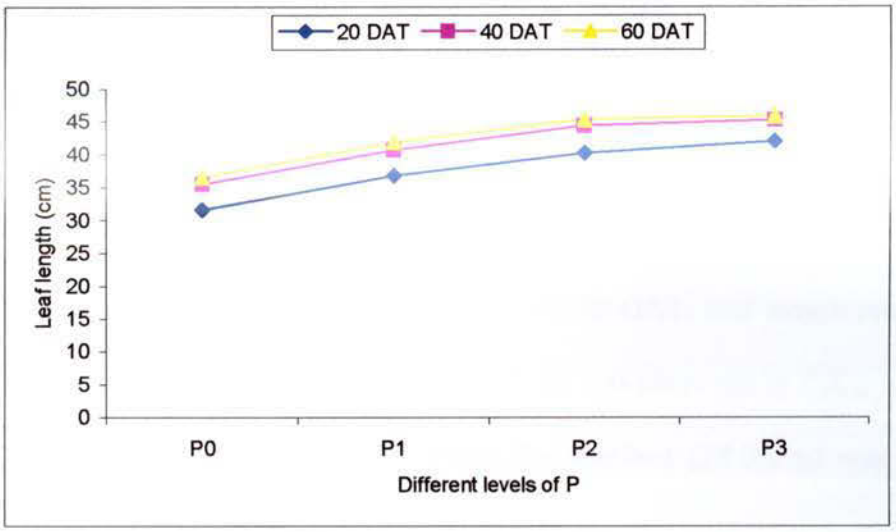

Figure 7 Effect of different levels of P and DAT on leaf length

P_0 = 0 kg/ha, P_1 = 30 kg/ha, P_2 = 40 kg/ha and P_3 = 50 kg/ha.

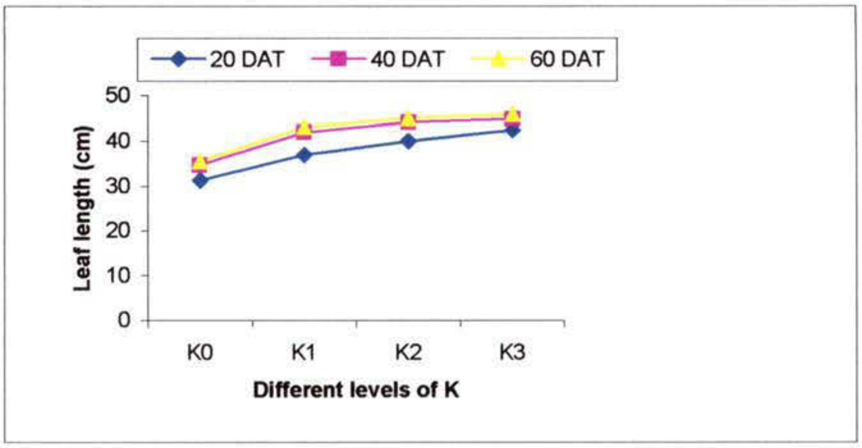

Figure 8 Effect of different levels of K and DAT on leaf length

K_0 = 0 kg/ha, K_1 = 50 kg/ha, K_2 = 75 kg/ha and K_3 = 100 kg/ha

It was found that the leaf length increased with the increased in K application and increased in DAT as well. This might be due to K stimulated the nitrogen uptake by broccoli plant.

The leaf length was significantly influenced by the treatment combinations at 20, 40 and 60 DAT (Table 4 & Appendix-VII). At 20 DAT, leaf length ranged from 28.00cm to 46.55cm. The largest leaf (46.55cm) was observed in P_2K_3, which was statistically similar to that of P_3K_3 while the smallest (28.00cm) was recorded from P_0K_0.

At 40 DAT, leaf length ranged from 32.13cm to 48.43cm. The longest leaf (48.43cm) was observed in P_3K_3, which was statistically similar to that of P_2K_3 and while the smallest (32.13cm) was recorded from P_0K_0.

At 60 DAT, leaf length ranged from 32.80cm to 49.13cm. The largest leaf (49.13cm) was observed in P_3K_3, which was statistically similar to that of P_2K_3 and while the smallest (32.80 cm) was recorded from P_0K_0. Similar results were reported by Ram and Sharma (1969) and Mal and Shandhu (1955).

Table 4. Combined effect of phosphorus and potassium on number of leaf and leaf length of broccoli

Treatments	Number of leaf			Leaf length		
	20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
P_0K_0	7.00 g	11.40ab	12.3a	28.00f	32.13 g	32.80 f
P_0K_1	7.36 fg	10.47 b	11.46 a	31.37ef	33.87 fg	34.90 f
P_0K_2	7.90 ef	11.73ab	12.73 a	32.37de	35.47 ef	36.60 ef
P_0K_3	8.26 ef	11.40ab	12.20 a	34.93cd	40.60 cd	41.83 cd
P_1K_0	8.30 ef	11.33ab	12.67 a	30.30ef	32.40 g	34.10 f
P_1K_1	9.33 cd	11.80ab	12.73 a	36.67bc	41.53 bc	42.63 bc
P_1K_2	9.73 bc	12.2 ab	13.33 a	38.43ab	46.40 ab	47.27 ab
P_1K_3	10.47ab	12.73ab	13.87 a	41.80ab	42.42 ab	43.77 ab
P_2K_0	7.26 fg	10.80ab	11.80 a	32.30de	35.57 ef	36.53 ef
P_2K_1	9.80 bc	12.67ab	13.60 a	38.27ab	46.27 ab	47.40 ab
P_2K_2	11.33ab	13.20ab	14.13 a	43.57ab	47.53 ab	48.40 ab
P_2K_3	11.53ab	12.67ab	13.80 a	46.55 a	48.21 a	49.37 a
P_3K_0	8.63 de	11.60ab	12.40 a	34.43cd	38.47 de	38.43 de
P_3K_1	11.33ab	13.80 a	14.53 a	41.47ab	46.40 ab	47.67 ab
P_3K_2	11.37ab	12.80ab	13.53 a	45.47ab	47.53 ab	48.23 ab
P_3K_3	12.20 a	13.73 a	14.67 a	46.53 a	48.43 a	49.13 a
CV (%)	11.66	12.82	13.64	13.16	9.18	10.71

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Shoot length

The shoot length of broccoli plant is important morphological character that influences the yield, because it is correlated with photosynthesis by the higher leaf area. Application of phosphorus exhibited a significant influence on shoot length of broccoli plants (Table 5 & Appendix-VIII). Shoot length ranged from 29.08cm to 39.93cm. The maximum shoot length (39.93cm) was recorded from P_3, which was statistically similar to that of P_1 and P_2 while the minimum shoot length (29.08cm) was observed in P_0. It was revealed that shoot length increased with the increased in phosphorus application. This might be due to its role in photosynthesis, energy storage, cell division and cell enlargement. Similar results were reported by Saimbhi *et al.* (1969), Raut (1980) and Keder (1981).

Application of potassium showed a significant influence on shoot length of broccoli plants (Table 6 & Appendix-VIII). Shoot length ranged from 28.96cm to 40.14cm. The maximum shoot length (40.14cm) was recorded from K_3, which was statistically similar to that of K_1 and K_2 while the minimum shoot length (28.96cm) was observed in $K_{0.}$ Shoot length increased with higher levels of potassium application. This might be caused that potassium regulated plant metabolism ensuring a healthy and sturdy which enhance the shoot length of broccoli plants (Leaflet, IPI, 2005). Similar trend were found by other scientists like Singh *et al.* (2002) and Wyatt *et al.* (1989).

The shoot length was significantly influenced by treatment combinations (Table 7 & Appendix-VIII). . Shoot length ranged from 25.72cm to 44.93cm. The longest shoot (44.93cm) was observed in P_3K_3 while the shortest (25.72cm) was recorded from $P_0K_{0.}$ It was revealed that the shoot length was increased with the increased in phosphorus and potassium application.

Table 5. Effect of different levels of phosphorus on vegetative growth of broccoli

Treatments	Shoot length (cm)	Root length (cm)	Fresh shoot weight (g)	Fresh root weight (g)	Total weight (g)
P_0	29.08 b	24.62 b	581.3 b	57.92 c	647.9 b
P_1	34.53 ab	27.86 ab	688.1 ab	71.50 b	759.6 ab
P_2	37.63 a	29.37 a	752.8 a	77.17 ab	830.7 a
P_3	39.93 a	30.81 a	793.9 a	83.42 a	877.4 a
CV (%)	14.55	9.28	14.23	10.23	10.13

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, P_0= 0 kg P/ ha, P_1=30kg P/ ha, P_2=40kg P/ ha and P_3= 50kg P / ha

Table 6. Effect of different levels of potassium on vegetative growth of broccoli

Treatments	Shoot length (cm)	Root length (cm)	Fresh shoot weight (g)	Fresh root weight (g)	Total weight (g)
K_0	28.96 b	24.48 b	582.9 b	58.58 c	642.3 c
K_1	34.28 ab	27.54 ab	682.4ab	68.92 bc	751.3 bc
K_2	37.80 a	29.70 a	756.3 a	78.08 ab	834.4 ab
K_3	40.14 a	30.94 a	794.4 a	84.42 a	887.6 a
CV (%)	14.55	9.28	14.23	10.23	10.13

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, K_0= 0 kg K/ ha, K_1= 50kg K / ha, K_2=75kg K /ha and K_3= 100kg K/ha

Root length

Phosphorus exhibited a significant influence on root length of broccoli plants (Table 5 & Appendix+-VIII). Root length ranged from 24.62cm to 30.81cm. The maximum root length (30.81cm) was recorded from P_3, which was statically similar to that of P_1 and P_2 while the minimum root length (24.62cm) was observed in P_0. It was revealed that root length increased with the increased in phosphorus application. This might be caused that phosphorus increased physiological processes in the plant system leading to increased rate of growth, which ultimately stimulated the root length of broccoli plants. The root length of broccoli plant is important morphological character that influences the yield, because it is correlated with nutrient uptake for proper growth and development by the larger root length. Kumar *et al.* (1993) found the same trend of the present investigation.

Application of potassium exhibited a significant influence on root length of broccoli plants (Table 6 & Appendix-VIII). The maximum root length (30.94cm) was recorded from K_3, which was statistically similar to that of K_1 and K_2 while the minimum root length (24.48cm) was observed in control K_0. It was revealed that root length increased with the increased in potassium application. This might be caused that potassium improved the development of roots and the utilization of nitrogen (Leaflet, IPI, 2005). Singh *et al.* (2000) also reported a similar trend of root length affected by the application of potassium fertilizer.

The root length was significantly influenced by the treatment combinations (Table 7 & Appendix-VIII). The largest root length (33.67cm) was observed in P_3K_3, which was statistically similar to that of P_3K_2, P_3K_1, P_2K_3, P_2K_2, P_1K_3, P_1K_2 while the smallest (22.49cm) was recorded from P_0K_0.

Fresh weight of shoot

Application of phosphorus exhibited a significant influence on fresh shoot weight of broccoli plants (Table 5 & Appendix-VIII). Fresh weight of shoot ranged from 581.30g to 793.90g. The maximum fresh weight of shoot (793.90g) was recorded from P_3, which was statistically similar to that of P_1 and P_2 and the minimum fresh weight of shoot (581.30g) was observed in P_0. It was revealed that fresh shoot weight increased with the increased in phosphorus application. This might be due to its role in photosynthesis, energy storage, cell division and cell enlargement. Similar effects of phosphorus have been reported by Singh (2004) and Sharma *et al.* (2002).

Application of potassium exhibited a significant influence on fresh shoot weight of broccoli plants (Table 6 & Appendix-VIII). Fresh weight of shoot ranged from 582.90g to 794.40g. The maximum fresh weight of shoot (794.40g) was recorded from K_3, which was statistically similar to that of K_1 and K_2 while the minimum fresh shoot weight (582.90g) was observed in K_0. It was revealed that fresh shoot weight increased with the increased in potassium application. This might be caused that potassium regulated plant metabolism ensuring a healthy and sturdy, which enhance the fresh shoot weight of broccoli. Similar trend of the result was found by other scientists like Wyatt *et al.* (1989) and Singh *et al.* (2000).

Fresh weight of shoot was significantly influenced by the treatment combinations (Table 7 & Appendix-VIII). Fresh weight of shoot ranged from 520.00g to 899.30g. The maximum fresh weight of shoot (899.30g) was observed in P_3K_3, which was statistically similar to that of P_3K_2, P_3K_1, P_2K_3, P_2K_2, P_2K_1 and P_1K_2 while the minimum (520.00g) was recorded from P_0K_0. Fresh shoot weight of broccoli plant is important morphological characters that influence the yield, because it is correlated with photosynthesis by the higher leaf area.

Fresh weight of root

Application of phosphorus exhibited a significant influence on fresh root weight of broccoli plants (Table 5 & Appendix-VIII). Fresh weight of root ranged from 57.92g to 83.42g. The maximum fresh weight of root (83.42g) was recorded from P_3, which was statistically similar to that of P_2 while the minimum fresh weight of root (57.92g) was observed in P_0. It was revealed that the fresh root weight increased with the increased in phosphorus application. This might be due to its role of cell division and cell enlargement.

Application of potassium exhibited a significant influence on fresh root weight of broccoli plants (Table 6 & Appendix-VIII). Fresh weight of root ranged from 58.58g to 84.42g. The maximum fresh weight of root (84.42g) was recorded from K_3, which was statistically similar to that of K_2 and while the minimum fresh weight of root (58.58g) was observed in K_0. It was revealed that the fresh weight of root increased with the increased in potassium application. This might be caused that potassium improved the development of roots and the utilization of nitrogen. Singh *et al.* (2000) found the same trend of the present investigation.

Fresh weight of root was significantly influenced by the treatment combinations (Table 7 & Appendix-VIII). Fresh weight of root ranged from 53.33g to 96.00g. The maximum fresh root weight (96.00g) was observed in P_3K_3, which was statistically similar to that of P_3K_2, P_2K_3 and P_2K_2 while the minimum (53.33g) was recorded from P_0K_0. Fresh root weight of broccoli plant is important morphological characters that influence the yield, because it is correlated with nutrient uptake for proper growth and development by root.

Total fresh weight

Phosphorus had a significant influence on total fresh weight of broccoli plants (Table 5& Appendix-VIII). Total fresh weight ranged from 647.90g to 877.40g. The maximum fresh weight (877.40g) was recorded from P_3, which was statistically similar to that of P_1 and P_2 and the minimum fresh weight (647.90g) was observed in P_0.

Application of potassium exhibited a significant influence on total weight of broccoli plants (Table 6 & Appendix-VIII). Total fresh weight ranged from 642.30g to 887.60g. The maximum fresh weight (887.60g) was recorded from K_3, which was followed by other treatments. The minimum fresh weight (642.30g) was observed in K_0.

Total fresh weight was significantly influenced by the treatment combinations (Table 7 & Appendix-VIII). Total fresh weight ranged from 573.30g to 997.00g. The maximum fresh weight (997.00g) was observed in P_3K_3, which was

Table 7. Combined effect of phosphorus and potassium on vegetative growth of broccoli

Treatments	Shoot length	Root length	Fresh shoot weight	Fresh root weight	Total weight
P_0K_0	25.72 g	22.49 f	520.0 f	53.33 h	573.3 g
P_0K_1	28.23 fg	24.27 ef	556.7 ef	55.00 gh	611.7 fg
P_0K_2	30.08 ef	25.50 de	606.7 de	60.00 fg	668.3 ef
P_0K_3	32.30 cd	26.23 cd	641.7 cd	63.33 ef	738.3 de
P_1K_0	27.47 fg	23.85 ef	564.0 ef	55.33 gh	619.3 fg
P_1K_1	34.37 bc	27.87 bc	683.3 bc	70.67 de	754.0 de
P_1K_2	36.23 ab	28.87 ab	735.0 ab	75.00 cd	810.0 bc
P_1K_3	40.07 ab	30.87 ab	770.0 ab	85.00 ab	855.0 ab
P_2K_0	30.37 de	25.15 ef	605.0 de	60.33 fg	668.3 ef
P_2K_1	35.40 ab	27.80 bc	719.3 ab	69.00 de	788.3 cd
P_2K_2	41.50 ab	31.53 ab	820.0 ab	86.00 ab	906.0 ab
P_2K_3	43.27 ab	33.00 a	866.7 ab	93.33 ab	960.0 a
P_3K_0	32.30 cd	26.43 cd	642.7 cd	65.33 ef	708.0 de
P_3K_1	39.10 ab	30.23 ab	770.3 ab	81.00 bc	851.3 ab
P_3K_2	43.37 ab	32.90 a	863.3 ab	91.33 ab	953.3 ab
P_3K_3	44.93 a	33.67 a	899.3 a	96.00 a	997.0 a
CV (%)	14.55	9.28	14.23	10.23	10.13

Means in the column followed by different letter(s) differed significantly by DMRT at 5% levels of significance.

statistically similar to that of P_3K_2, P_2K_3 and P_2K_2 while the minimum (573.3g) was recorded from P_0K_0. Total weight of broccoli plant is important for total production. Different fertilizer combinations resulted in an increase in total fresh weight ranging from 6.28 % to 42.50 % over the control.

Days to required for curd initiation

The number of days was required for curd initiation was not significantly influenced by phosphorus application (Table 8 & Appendix-IX). It was ranged from 52.00 to 59.92 days. The lowest (52days) days were required curd initiation by P_0 and the highest (59.92) days were required by P_3. The result indicated that phosphorus might have retarded vegetative growth and forced the plants to reach reproductive stages earlier. Such, effect of phosphorus due to the fact that phosphorus is mainly responsible for improving the quality and quantity of produce by way of increasing metabolic activities in the plant system. Mitra *et al.* (1990) reported that application of phosphorus hastened the crop to reach reproductive stage, which was agreed with the present finding.

The application of potassium was not significantly influenced the number of days required for curd imitation (Table 9 & Appendix-IX). It was ranged from 53.17 to 58.42 days. The lowest (53.17days) days were required for curd initiation by K_0 and the highest (58.42) days were required by K_3.

There was significant variation among the treatment combinations in days to curd initiation (Table 10 & Appendix-IX). The maximum days (63.00 days) were required in the P_3K_3 treatment that was statistically similar to that of P_0K_2, P_0K_3, P_1K_2, P_1K_3, P_2K_0, P_2K_1, P_2K_2, P_2K_3, P_3K_0, P_3K_1 and P_3K_2 while the minimum (47.33 days) days were required for curd initiation in P_0K_0 treatment followed by P_0K_1. The same trend of the result was found by other scientist like Sharma *et al.* (2002).

Table 8. Effect of different levels of phosphorus on curd diameter, curd wt., number of secondary curd and wt. of secondary curd of broccoli

Treatments	Days required for curd initiation	Main curd diameter (cm)	Main curd weight (g)	Number of secondary curd	Weight of secondary curd (g)
P_0	52.00 a	13.27 b	181.7 c	2.08 b	60.00 c
P_1	54.00 a	15.48 ab	222.3 b	3.25 a	105.5 b
P_2	57.00 a	16.43 a	245.8 ab	4.25 a	155.3 a
P_3	59.92 a	17.44 a	264.3 a	4.00 a	150.0 a
CV (%)	9.11	11.84	11.68	20.21	8.97

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, P_0= 0 kg P/ ha, P_1=30kg P/ ha, P_2=40kg P/ ha and P_3= 50kg P / ha

Table 9. Effect of different levels of potassium on curd diameter, curd weight, number of secondary curd and weight of secondary curd of broccoli

Treatments	Days to curd initiation	Curd diameter (cm)	Main curd weight (g)	Number of secondary curd weight	Weight of Secondary curd (g)
K_0	53.17 a	13.12 b	184.0 c	2.58 b	67.50 d
K_1	53.42 a	15.27 ab	219.2 bc	3.50 ab	110.3 c
K_2	57.92 a	16.72 a	250.8 ab	3.50 ab	127.0 b
K_3	58.42 a	17.52 a	260.0 a	4.00 a	166.0 a
CV (%)	9.11	11.84	11.68	20.21	8.97

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, K_0= 0 kg K/ ha, K_1= 50kg K / ha, K_2=75kg K /ha and K_3= 100kg K/ha

Main curd diameter

Application of phosphorus exhibited a significant influence on curd diameter of broccoli plants (Table 8 & Appendix-IX). Main curd diameter ranged from 13.27cm to 17.44cm. The maximum curd diameter (17.44 cm) was recorded from $P_{3,}$ which was statistically similar to that of P_1 and P_2 while the minimum (13.27 cm) was observed in P_0. It was revealed that the curd diameter increased with the increased in phosphorus application. This might be due to its role of energy storage, cell division and cell enlargement. Sharma *et al.* (2002) and Singh (2004) were found same trend of the present investigation.

Application of potassium should a significant influence on curd diameter of broccoli plants (Table 9 & Appendix-IX). Main curd diameter ranged from 13.12cm to 17.52cm.The maximum curd diameter (17.52 cm) was recorded from $K_{3,}$ which was statistically similar to that of K_1 and K_2 while the minimum (13.12 cm) was observed in $K_{0.}$ This result was revealed that the curd diameter increased with the increased in potassium application. Watt *et al.* (1989) was found the same trend of the present investigation.

Curd diameter was significantly influenced by the treatment combinations (Table 10 & Appendix-IX). Main curd diameter ranged from 11.93cm to 19.73cm.The maximum curd diameter (19.73cm) was observed in $P_3K_{3,}$ which was statistically similar to that of $P_2K_{3,}$ P_1K_2, P_1K_3, P_2K_2, P_3K_1 and P_3K_2 while the minimum (11.93 cm) was recorded from P_0K_0. Main curd diameter is important for curd yield. Diameter of the curd was significantly influenced by different fertilizer treatments. Different fertilizer combinations resulted in an increase in curd diameter ranging from 6.80 % to 39.53 % over the control.

Main curd weight

Phosphorus exhibited a significant influence on main curd weight of broccoli plants (Table 8 & Appendix-IX). Main curd weight ranged from 181.70g to 264.30g. The maximum main curd weight (264.30g) was recorded from $P_{3,}$ which was statistically similar to that of P_2 while the minimum main curd weight (181.70g) was observed in P_0. It was revealed that the increased of main curd weight with the increased in phosphorus application. Such effect of phosphorus was due to the fact that phosphorus was mainly responsible for improving the quality and quantity of curd by the way of increasing metabolic activities in broccoli plant. Similar trend of the result was found by other scientists like Saimbhi *et al.* (1969), Balyan *et al.* (1988) and Singh (2004).

Potassium had a significant influence on main curd weight of broccoli plants (Table 9 & Appendix-IX). Main curd weight ranged from 184.00g to 260.00g. The maximum main curd weight (260.00g) was recorded from K_3, which was statistically similar to that of K_2 and while the minimum main curd weight (184.00g) was observed in K_0. It was revealed that the main curd weight increased with the increased in potassium application. This might be caused that potassium promoted growth and increased yield. It regulated plant metabolism ensuring a healthy and sturddy that was stimulated ultimately main curd weight of broccoli plant. Corroborative results were obtained by other scientists like Wyatt *et al.* (1989), Singh *et al.* (2000); Pardeep *et al.* (2001) and Brahma *et al.* (2002).

Main curd weight was significantly influenced by the treatment combinations (Table 10 & Appendix-IX). Main curd weight ranged from 160.00g to 295.00g. The maximum main curd weight (295.00g) was observed in P_3K_3, which was statistically similar to that of P_1K_3, P_2K_2, P_3K_1, P_2K_3 and P_3K_2 while the smallest (160.00g) was recorded from P_0K_0. Main curd weight of broccoli plant is important for increasing total production. Different fertilizer combinations resulted in an increase in curd yield ranging from 7.67 % to 45.76 % over the control.

Number of secondary curd per plant

The secondary curds were those, which develop after harvest of the main curd. Number of secondary curd of broccoli plant is important for increasing total production. Application of phosphorus exhibited a significant influence on number of secondary curd of broccoli plants (Table 8 & Appendix-IX). Number of secondary curd per plant ranged from 2.08 to 4.00. The maximum numbers of secondary curds (4.00) were recorded from P_3, which was statistically similar to that of P_1 and P_2 while the minimum (2.08) were observed in P_0. It was revealed that the number of secondary curd increased with the increased in phosphorus application. This might be caused that its role of photosynthesis, cell division and cell enlargement. Similar effect of phosphorus has been reported by Sharma *et al.* (2002).

Potassium exhibited a significant influence on number of secondary curds of broccoli plants (Table 9 & Appendix-IX). Number of secondary curd per plant ranged from 2.58 to 4.00. The maximum numbers of secondary curds (4.0) were recorded from K_3, which was statistically similar to that of K_1 and K_2 while the minimum number of secondary curds (2.58) was observed in K_0. It was revealed that the number of secondary curd increased with the increased in potassium application. This might be caused that potassium regulates the photosynthesis and also translocation of metabolites, which ultimately increased the number of secondary curd. Corroborative results were obtained by other scientists like Wyatt *et al.* (1989); Cai *et al.* (1999) and Singh *et al.* (2000). Number of secondary curds was significantly influenced by the treatment combinations (Table 10 & Appendix-IX). Number of secondary curd per plant ranged from 1.33 to 5.00. The maximum number of secondary curds (5.00) was observed in P_2K_2 that was statistically similar to that of P_1K_2, P_1K_3, P_2K_1, P_3K_0, P_2K_3, P_3K_1 and P_3K_3 while the minimum (1.33) were recorded from P_0K_0. Different fertilizer combinations resulted in an increase in number of secondary curds ranging from 33.5 % to 73.4% over the control.

Secondary curd weight

Secondary curd weight of broccoli plant is important for increasing total yield. Phosphorus had a significant influence on secondary curd weight of broccoli plants (Table 8 & Appendix-IX). Secondary curd weight ranged from 60.00g to 155.30g. The maximum secondary curd weight (155.30g) was recorded from P_2, which was statistically similar to that of P_3 and the minimum (60g) was observed in P_0. It was revealed that the weight of secondary curd increased with the increased in phosphorus application. This might be caused that its role of photosynthesis, cell division and cell enlargement. Similar effects of phosphorus have been reported by Sharma *et al.* (2002).

Application of potassium exhibited a significant influence on secondary curd weight of broccoli plants (Table 9 & Appendix-IX). Secondary curd weight ranged from 67.50g to 166.00g. The maximum secondary curd weight (166.00g) was recorded from K_3 while the minimum (67.50g) was observed in $K_{0.}$ It was revealed that the weight of secondary curd increased with the increased in potassium application. This might be caused that potassium regulates the photosynthesis and also translocation of metabolites, which ultimately increased the weight of secondary curd. Corroborative results were obtained by other scientists like Wyatt *et al.* (1989); Cai *et al.* (1999) and Singh *et al.* (2000).

Secondary curd weight was significantly influenced by the treatment combinations (Table 10 & Appendix-IX). Secondary curd weight ranged from 20.00g to 215.00g. The maximum secondary curd weight (215.00g) was observed in P_2K_3 and the minimum (20g) was recorded from P_0K_0. Different fertilizer combinations resulted in an increase in secondary curd weight ranging from 60.0 % to 90.70 % over the control.

Table 10. Combined effect of phosphorus and potassium on curd diameter, curd weight, number of secondary curd and weight of secondary curd of broccoli

Treatments	Days required for curd initiation	Main curd diameter (cm)	Main curd weight (g)	Number of secondary curd weight	Secondary curd weight (g)
P_0K_0	47.33 d	11.93f	160.0 f	1.33 d	20.00 h
P_0K_1	49.33 cd	13.27 ef	173.3ef	2.00 cd	50.00 g
P_0K_2	54.67 ab	13.40 ef	191.7de	2.00 cd	62.00 g
P_0K_3	56.67 ab	14.47 cd	201.7de	3.00 bc	108.0 e
P_1K_0	52.00 bc	12.80 f	174.3ef	2.00 cd	46.00 g
P_1K_1	52.33 b	15.23 bc	221.7cd	3.00 bc	84.00 f
P_1K_2	55.67 ab	17.07 ab	240.0bc	4.00 ab	136.0 d
P_1K_3	56.00 ab	16.8 ab	253.3ab	4.00 ab	156.0 c
P_2K_0	56.33 ab	13.50 ef	191.3de	3.00 bc	84.00 f
P_2K_1	53.67 ab	15.37 bc	221.7cd	4.00 ab	132.0 d
P_2K_2	60.00 ab	17.80 ab	280.0ab	5.00 a	190.0 b
P_2K_3	58.00 ab	19.07 a	290.0a	5.00 a	215.0 a
P_3K_0	57.00 ab	14.23 de	210.3cd	4.00 ab	120.0de
P_3K_1	58.33 ab	17.20 ab	260.0ab	5.00 a	175.0 b
P_3K_2	61.33 ab	18.60 ab	291.7a	3.00 bc	120.0de
P_3K_3	63.00 a	19.73 a	295.0a	4.00 ab	185.0 b
CV (%)	9.11	11.84	11.68	20.21	8.97

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Yield per plant

Yield per plant is important for increasing total yield. Application of phosphorus exhibited a significant influence on yield per plant (Table 11& Appendix-X). Yield per plant ranged from 241.70g to 414.50g. The maximum yield (414.50g) was recorded from P_3, which was statistically similar to that of P_2 while the minimum (241.70g) was observed in P_0. It was revealed that yield per plant increased with the increased in phosphorus application. This might be caused that P had a role in photosynthesis, cell division and cell enlargement. Similar trend of the results were found by scientists like Balyan *et al.* (1988); Sharma *et al.* (2002); Singh (2004) and Reddy *et al.* (2005).

Application of potassium exhibited a significant influence on total yield per plant (Table 12 & Appendix-X). Yield per plant ranged from 251.50g to 425.80g. The maximum yield (425.80g) was recorded from K_3 while the minimum (251.50g) was observed in K_0. It was revealed that the yield per plant increased with the increased in potassium application. This might be caused that potassium regulates the photosynthesis and also translocation of metabolites, which ultimately increased the yield per plant. Corroborative results were obtained by other scientists like Wyatt *et al.* (1989); Ruan *et al.* (1991); Cai *et al.* (1999) and Singh *et al.* (2000).

Yield per plant was significantly influenced by the treatment combinations (Figure 9 & Appendix-X). Yield per plant ranged from 180.00g to 505.00g. The maximum yield (505.00g) was observed in P_2K_3, which was statistically identical with those of P_2K_2 and P_3K_3 while the minimum (180.00g) was recorded from P_0K_0. Different fertilizer combinations resulted in an increase in yield per plant ranging from 18.29 % to 64.35 % over the control.

Table 11. Effect of different levels of phosphorus on yield of broccoli

Treatments	Yield / plant (g)	Yield / plot (kg)	Yield/ha (t)
P_0	241.7 c	4.347 c	8.046 c
P_1	327.4 b	5.890 b	10.91 b
P_2	401.0 a	7.217 a	13.36 a
P_3	414.5 a	7.460 a	13.81 a
CV (%)	8.10	13.82	14.63

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, P_0= 0 kg P/ ha, P_1=30kg P/ ha, P_2=40kg P/ ha and P_3= 50kg P / ha

Table 12. Effect of different levels of phosphorus on yield of broccoli

Treatments	Yield/ plant (g)	Yield/ plot (kg)	Yield/ ha (t)
K_0	251.5 d	4.524 c	8.373 c
K_1	329.4 c	5.928 b	10.98 b
K_2	377.8 b	6.799 ab	12.59 ab
K_3	425.8 a	7.662 a	14.19 a
CV (%)	8.10	13.82	14.63

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, K_0= 0 kg K/ ha, K_1= 50kg K / ha, K_2=75kg K /ha and K_3= 100kg K/ha

Yield per plot

The yield per plot in sprouting broccoli consists of the main curd and the secondary curd those develop after the removal of the main one. Application of phosphorus exhibited a significant influence on yield per plot of broccoli plants (Table 11 & Appendix-X). Yield per plot ranged from 4.34kg to 7.46 kg. The maximum yield (7.46kg) was recorded from P_3, which was statistically similar to that of P_2 while the minimum (4.34kg) was observed in P_0. It was revealed that yield per plot increased with the increased in phosphorus application. This might be caused that P had a role in photosynthesis, cell division and cell enlargement. Similar trend of the results were found by scientists like Balyan *et al.* (1988); Sharma *et al.* (2002); Singh (2004) and Reddy *et al.* (2005).

Application of potassium exhibited a significant influence on total yield per plot of broccoli plants (Table 12 & Appendix-X). The maximum yield (7.66kg) was recorded in K_3, which was statistically significant in K_2 while the minimum (4.52kg) was observed in control treatment (K_0). It was revealed that the yield per plot increased with the increased in potassium application. This might be caused that potassium regulates the photosynthesis and also translocation of metabolites, which ultimately increased the yield per plot. Corroborative results were obtained by other scientists like Wyatt *et al.* (1989); Ruan *et al.* (1991); Cai *et al.* (1999) and Singh *et al.* (2000).

Total yield per plot was significantly influenced by the treatment combinations (Figure 10 & Appendix-X). Yield per plot ranged from 3.23kg to 9.09kg. The maximum yield per plot (9.09kg) was observed in P_2K_3, which was statistically identical with those of P_2K_2, P_3K_1 and P_3K_3 while the minimum (3.23kg) was recorded from P_0K_0. Different fertilizer combinations resulted in an increase in yield per plot ranging from 18.32% to 64.39 % over the control.

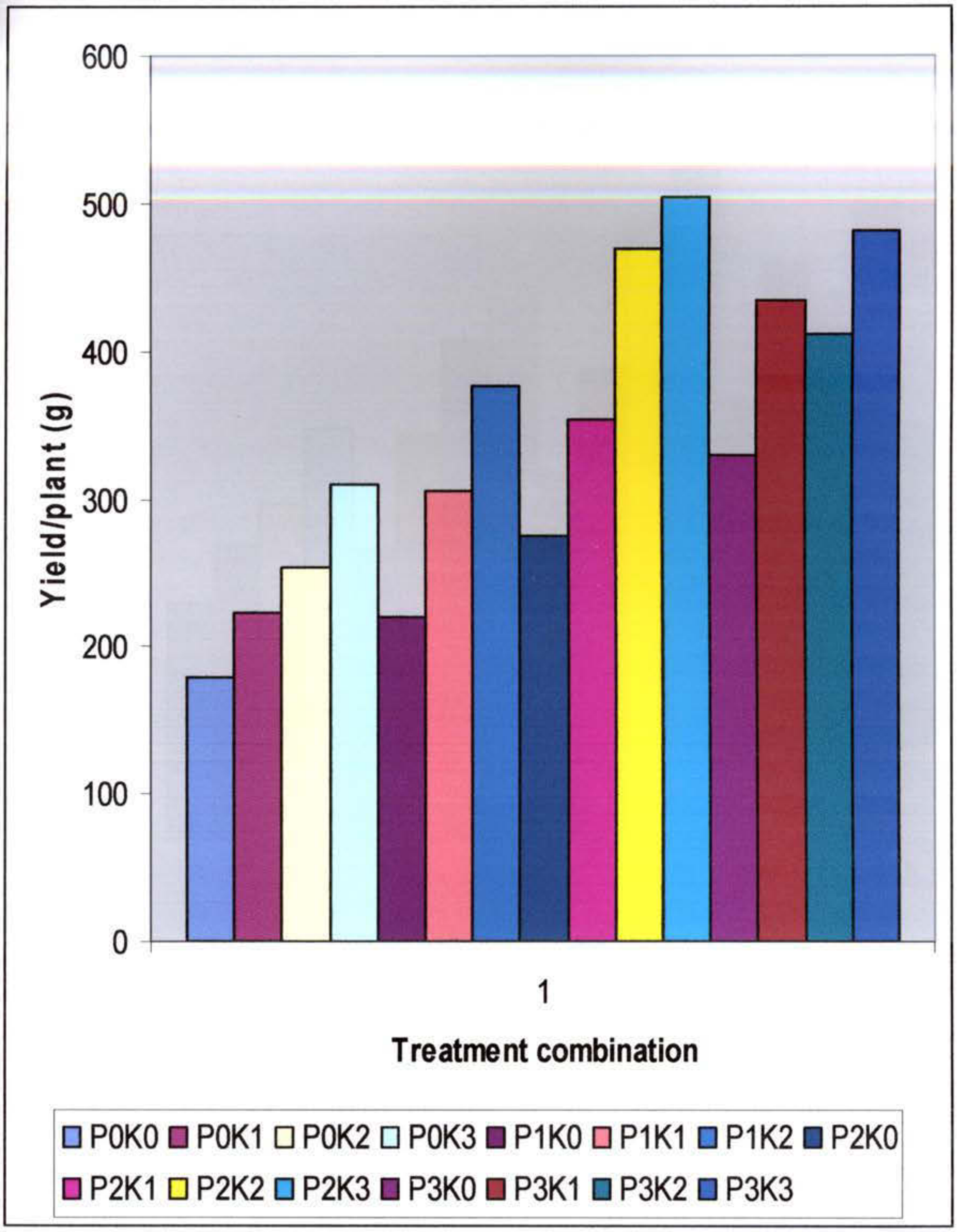

Figure 9 Effect of different treatment combinations on yield/plant of broccoli

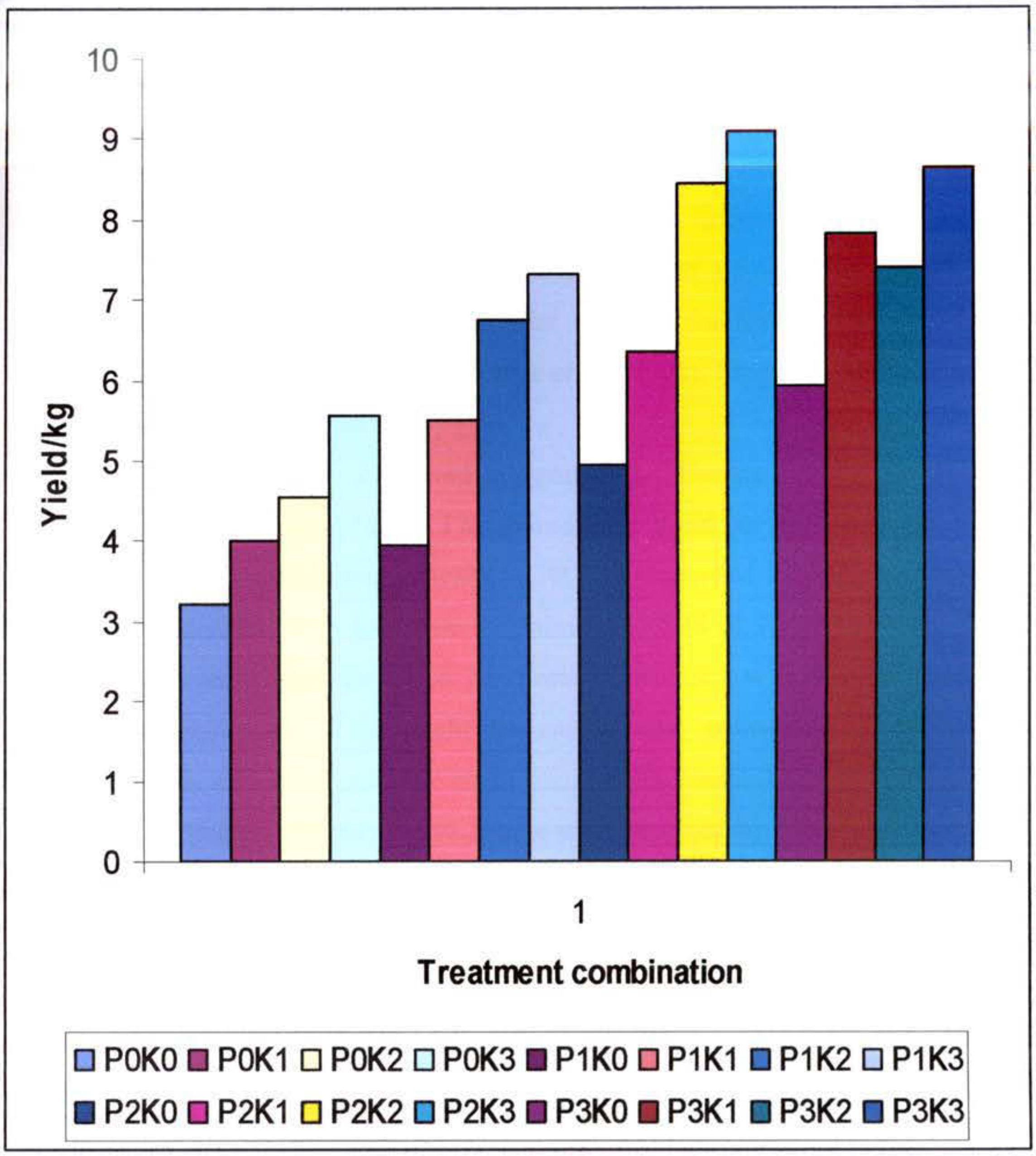

Figure 10 Effect of different treatment combinations on yield/plot of broccoli

Yield per hectare

Application of phosphorus exhibited a significant influence on yield per hectare of broccoli plants (Table 12 & Appendix-X). Yield per hectare ranged from 8.04t to 13.81t. The maximum yield (13.81t) was recorded from P_3, which was statistically similar to that of P_2 while the minimum yield (8.04t) was observed in P_0. It was revealed that yield per hectare increased with the increased in phosphorus application. This might be caused that Phosphorus had a role in photosynthesis, cell division and cell enlargement. Similar trend of the results were found by scientists like Balyan *et al.* (1988); Sharma *et al.* (2002); Singh (2004) and Reddy *et al.* (2005).

Application of potassium exhibited a significant influence on total yield per hectare of broccoli plants (Table 13 & Appendix-X). Yield per hectare ranged from 8.37t to 14.19t. The maximum yield (14.19t) was recorded from K_3, which was statistically identical with K_2 while the minimum yield (8.37t) was observed in K_0. It was revealed that the yield per hectare increased with the increased in potassium application. This might be caused that potassium regulates the photosynthesis and also translocation of metabolites, which ultimately increased the yield per hectare. Corroborative results were obtained by other scientists like Wyatt *et al.* (1989); Ruan *et al.* (1991); Cai *et al.* (1999) and Singh *et al.* (2000).

Yield per hectare was significantly influenced by the treatment combinations (Figure 11 & Appendix-X). Yield per hectare ranged from 5.98t to 16.83t. The maximum yield per hectare (16.83t) was observed in P_2K_3, which was statistically identical with those of P_2K_2, P_3K_1, P_3K_2 and P_3K_3 while the minimum (5.98t) was recorded from P_0K_0. Different fertilizer combinations resulted in an increase in yield per hectare ranging from 18.45 % to 64.45 % over the control.

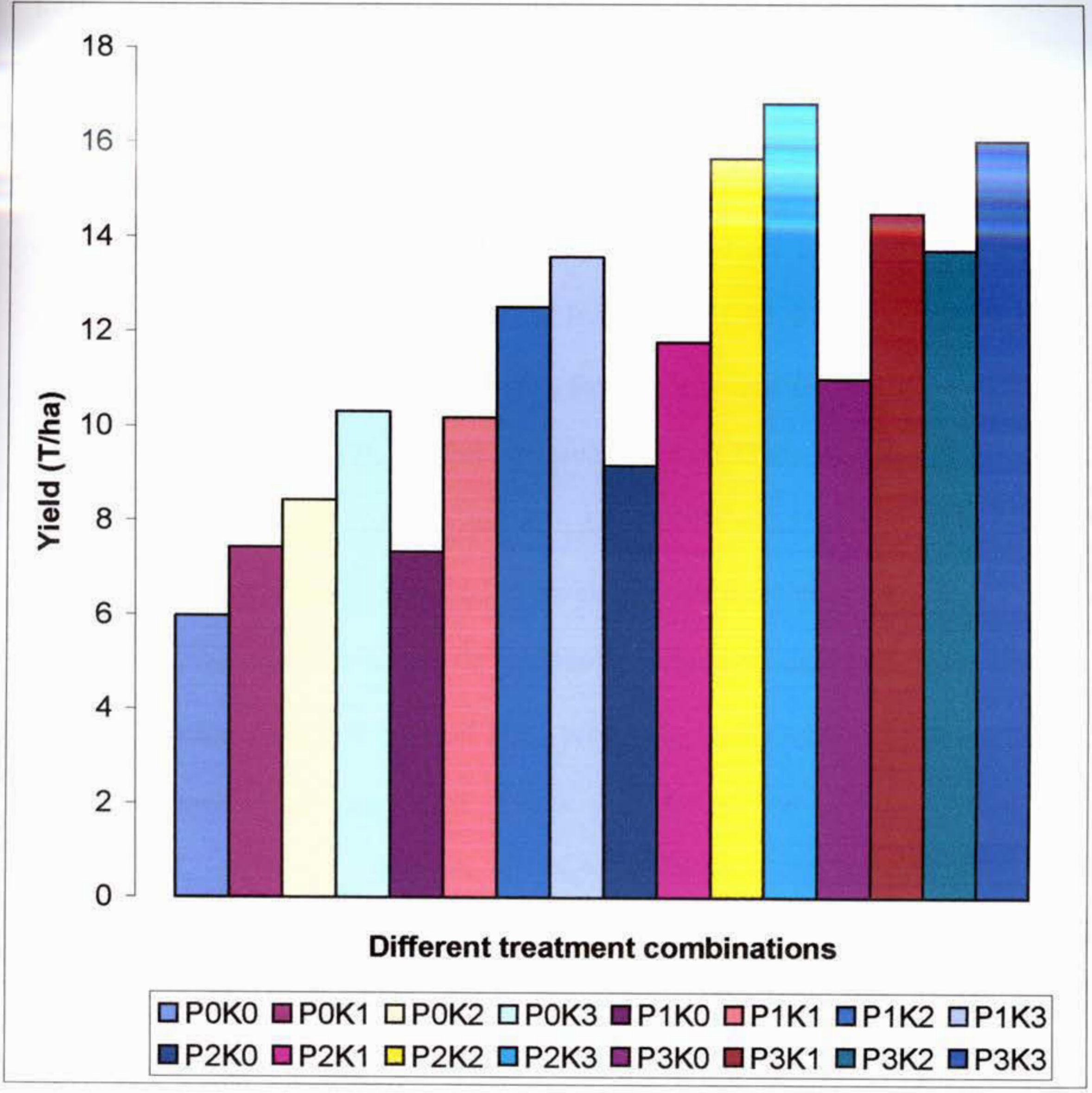

Figure 11 Effect of different treatment combinations on yield/ha of broccoli

Relationship of different characters of broccoli with yield

The yield of broccoli was positively correlated (Figure 1-15) with curd diameter (R^2 = 0.6258), curd weight (R^2 = 0.9386), number of secondary curd (R^2 = 0.5668), weight of secondary curd (R^2 = 0.6691), yield per plant (R^2 = 0.695), Days to curd initiation (R^2 = 0.7040), shoot length (R^2 = 0.9376), root length (R^2 = 0.9276), fresh shoot weight (R^2 = 0.9327), fresh root weight (R^2 = 0.9174), total fresh weight (R^2 = 0.9347), number of leaves (R^2 = 0.7285), leaf length (R^2 = 0.8723), plant height (R^2 = 0.9301) and stem diameter (R^2 = 0.5544),

This indicated that with the increased in the above mentioned characters the yield positively increased. Curd weight (R^2=0.9386) had the most intimate relationship with yield, suggesting that broccoli plant producing higher curd diameter, curd weight, number of secondary curd, weight of secondary curd, yield per plant, shoot length, root length, fresh shoot weight, fresh root weight, total weight, number of leaves, leaf length, plant height and stem diameter will produce high economic yield and vice-versa.

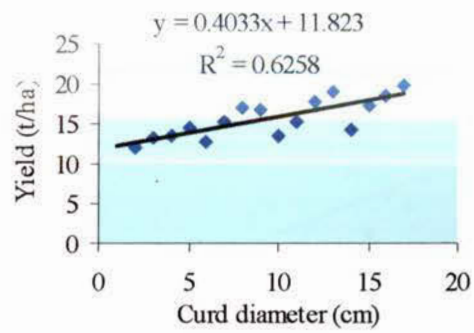

Figure 12. Relationship between curd diameter and yield in broccoli.

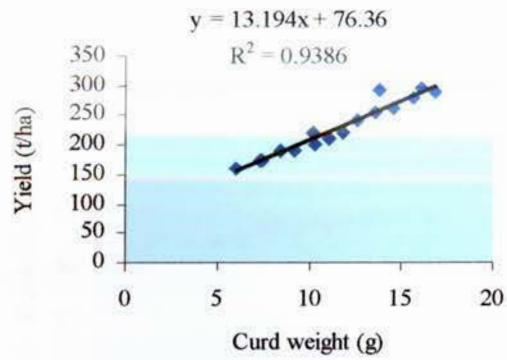

Figure 13. Relationship between curd weight and yield of broccoli.

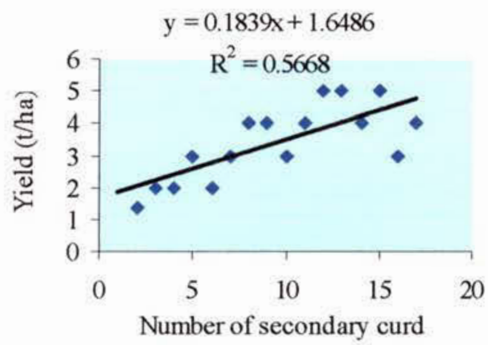

Figure 14. Relationship between no. of secondary curd and yield of broccoli.

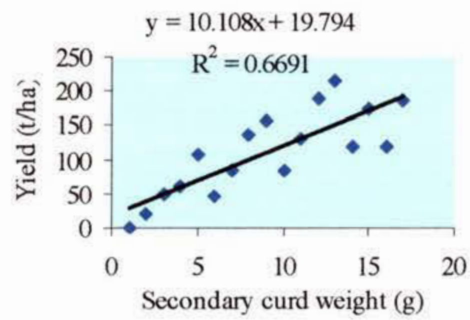

Figure 15. Relationship between secondary curd weight and yield of broccoli.

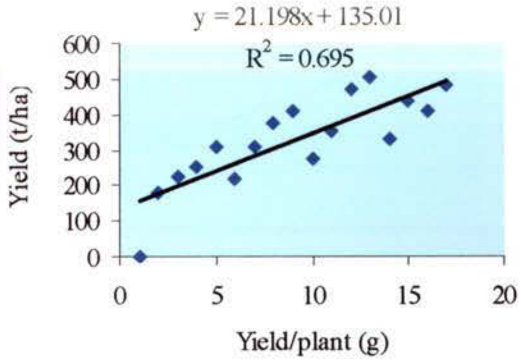

Figure 16. Relationship between yield per plant and yield of broccoli.

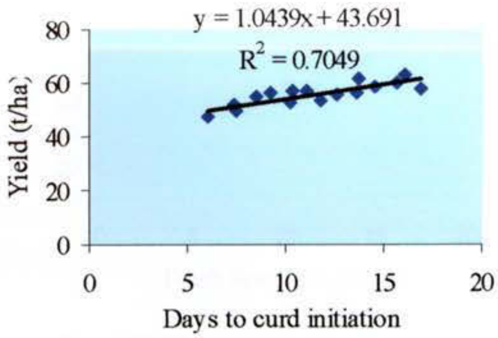

Figure 17. Relationship between days to curd initiation and yield of broccoli.

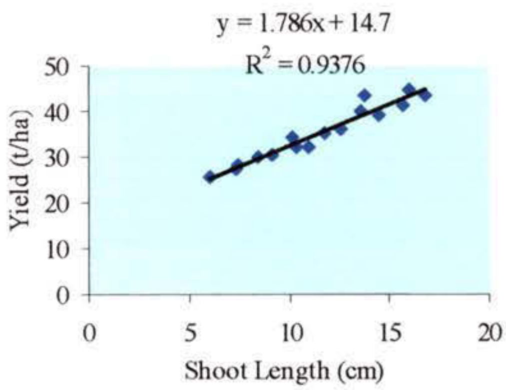

Figure 18. Relationship between shoot length and yield of broccoli

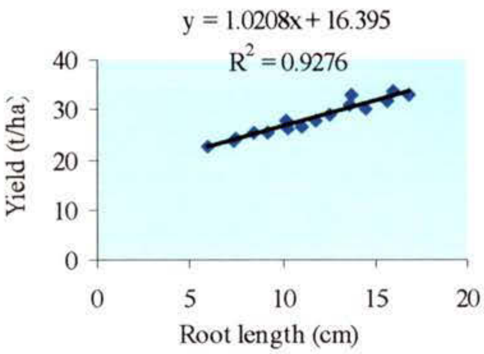

Figure 19. Relationship between root length and yield of broccoli

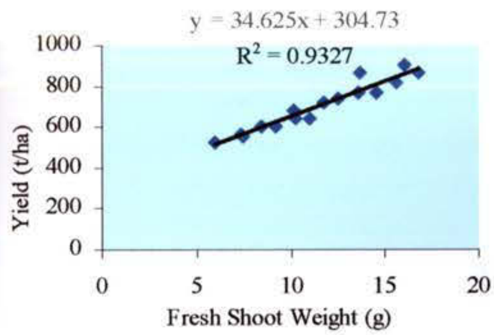

Figure 20. Relationship between fresh shoot weight and yield of broccoli

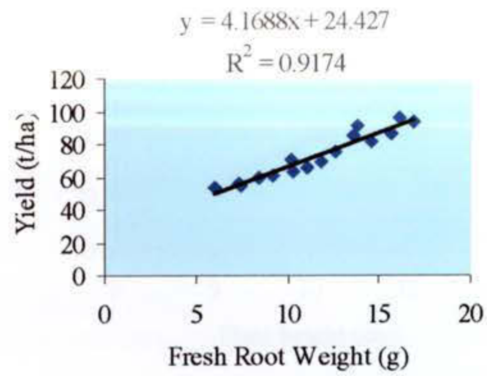

Figure 21. Relationship between fresh root weight and yield of broccoli

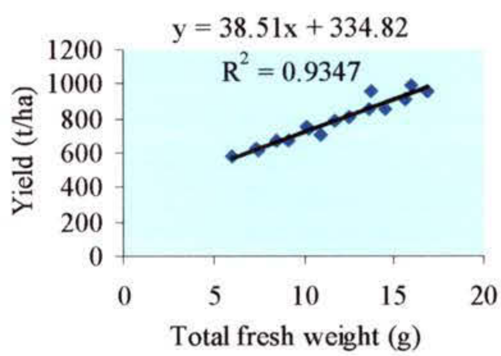

Figure 22. Relationship between total fresh weight and yield of broccoli

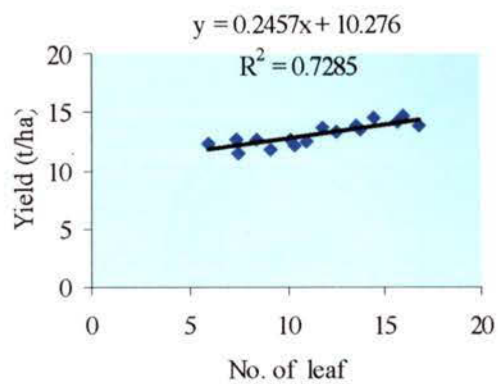

Figure 23. Relationship between no. of leaf and yield of broccoli

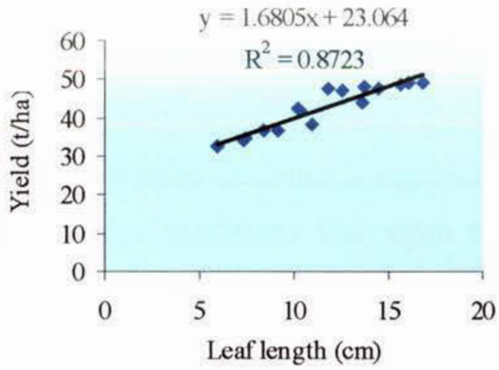

Figure 24. Relationship between leaf length and yield of broccoli

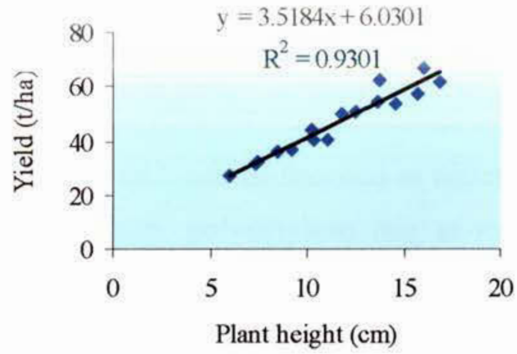

Figure 25. Relationship between Plant height and yield of broccoli

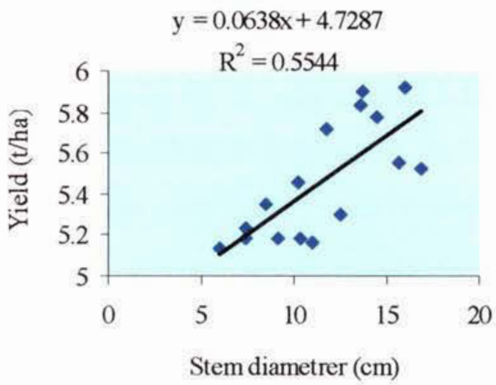

Figure 26. Relationship between stem diametrer and yield of broccoli

Post-harvest preservation

Almost all vegetable are known to exhibit a rise in respiration after harvest. A high rate of respiration deteriorates the storage quality of vegetable. Post-harvest changes i.e. yellowing of florets take place rapidly in broccoli and make it unsuitable for consumption if appropriate storage conditions are not maintained.

Phosphorus exhibited a significant influence on shelf life of broccoli at different storage conditions viz., open at room temperature, polyethylene bag at room temperature and polyethylene bag at refrigerator (Table 13).

Shelf life of broccoli in open at room temperature condition ranged from 1.69 to 2.62 days. The maximum shelf life (2.62 days) of broccoli was found in P_0 and minimum (1.69 days) was found in P_3.

Shelf life of broccoli in polyethylene bag at room temperature condition ranged from 3.70 to 6.02 days. The maximum shelf life (6.02 days) of broccoli was found in P_0 and minimum (3.70 days) was found in P_3.

Shelf life of broccoli in polyethylene bag at refrigerator condition ranged from 13.30 to 17.01 days. The maximum shelf life (17.01 days) of broccoli was found in P_0 which was statistically similar to that of P_1 and minimum (13.30 days) was found in P_3. It was revealed that the shelf life of broccoli increased with the decreased in P application in all the three storage condition. Among the three storage condition it was found that the shelf life of broccoli increased in the polyethylene bag at refrigerator condition. This could be due the effect of low temperature in refrigerator. Low temperature minimizes the respiration of broccoli as well as polyethylene bag also minimize the respiration process. Anelli *et al.* (1985), Kazmi *et al.* (1991), Makhlouf *et al.* (1989) and Tan *et al.* (1993) reported that the cv. Stolto was stored up to 6 weeks at 1^0C under different Co_2 and O_2 concentrations.

Potassium exhibited a significant influence on shelf life of broccoli at different storage conditions viz., open at room temperature, polyethylene bag at room temperature and polyethylene bag at refrigerator (Table 14).

Table 13. Effect of different levels of phosphorus and storage condition on shelf life (days) of broccoli

Treatments	Storage condition on shelf life (days) of broccoli.		
	Open at room temperature (24^{0}C)	Polyethylene bag at room temperature (24^{0}C)	Polyethylene bag at refrigerator (4^{0}C)
P_0	2.62 a	6.02 a	17.01 a
P_1	2.18 b	4.83 b	15.49 ab
P_2	1.90 c	4.52 b	14.10 b
P_3	1.69 c	3.70 c	13.30 b
CV (%)	7.33	7.33	7.33

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, P_0= 0 kg P/ ha, P_1=30 kg P/ ha, P_2=40 kg P/ ha and P_3= 50 kg P / ha

Table 14. Effect of different levels of potassium and storage condition on shelf life (days) of broccoli

Treatments	Storage condition on shelf life (days) of broccoli.		
	Open at room temperature (24^{0}C)	Polyethylene bag at room temperature (24^{0}C)	Polyethylene bag at refrigerator (4^{0}C)
K_0	2.55 a	5.63 a	16.64 a
K_1	2.17 b	4.87 b	15.23 ab
K_2	1.91 c	4.50 bc	14.37 ab
K_3	1.77 c	4.07 c	13.65 b
CV (%)	7.38	7.38	7.38

Means in the column followed by different letter(s) differed significantly by DMRT at 5% level of significance

Where, K_0= 0 kg K/ ha, K_1= 50 kg K / ha, K_2=75 kg K /ha and K_3= 100 kg K/ha

Shelf life of broccoli in open at room temperature condition ranged from 1.77 to 2.55 days. The maximum shelf life (2.55 days) of broccoli was found in K_0 and minimum (1.77 days) was found in K_3.

Shelf life of broccoli in polyethylene bag at room temperature condition ranged from 4.07 to 5.63 days. The maximum shelf life (5.63 days) of broccoli was found in K_0 and minimum (4.07 days) was found in K_3.

Shelf life of broccoli in polyethylene bag at refrigerator condition ranged from 13.65 to 16.64 days. The maximum shelf life (16.64 days) of broccoli was found in K_0 which was statistically similar to that of K_1 and minimum (13.65 days) was found in K_3. It was revealed that the shelf life of broccoli increased with the decreased in K application in all the three storage condition. Among the three storage condition it was found that the shelf life of broccoli increased in the polyethylene bag at refrigerator condition. This could be due the effect of low temperature in refrigerator. Low temperature minimizes the respiration of broccoli as well as polyethylene bag also minimize the respiration process. The positive effect of polymeric film was also reported by Barth *et al.* (1993).

Combined application of potassium and phosphorus exhibited a significant influence on shelf life of broccoli at different storage conditions viz., open at room temperature, polyethylene bag at room temperature and polyethylene bag at refrigerator (Table 15). Shelf life of broccoli in open at room temperature condition ranged from 1.35 to 3.0 days. The maximum shelf life (3.0 days) of broccoli was found in P_0K_0 which was statistically similar to that of P_0K_1 and the minimum (1.35 days) was found in P_3K_3.

Table 15. Combined effect of phosphorus, potassium and storage condition on shelf life (days) of broccoli

Treatments	Storage condition on shelf life (days) of broccoli.		
	Open at room temperature (24^{0}C)	Polyethylene bag at room temperature (24^{0}C)	Polyethylene bag at refrigerator (4^{0}C)
P_0K_0	3.00 a	6.41 a	17.87 a
P_0K_1	2.75 ab	6.16 ab	17.33 ab
P_0K_2	2.50 bc	5.95 ab	16.67 ab
P_0K_3	2.25 cd	5.56 bc	16.17 ab
P_1K_0	2.66 b	5.33 cd	16.95 ab
P_1K_1	2.23 cd	4.91 ef	15.50 ab
P_1K_2	1.93 fg	4.66 fg	15.00 bc
P_1K_3	1.91 g	4.41 fg	14.50 cd
P_2K_0	2.33 cd	5.78 bc	16.07ab
P_2K_1	1.96 ef	4.50 fg	14.15 de
P_2K_2	1.75 gh	4.16 gh	13.50 ef
P_2K_3	1.56 hi	3.66 ij	12.67 fg
P_3K_0	2.20 de	5.00 de	15.68 ab
P_3K_1	1.76 gh	3.91 hi	13.93 ef
P_3K_2	1.46 i	3.23 jk	12.32 gh
P_3K_3	1.35 i	2.66 k	11.25 h
CV (%)	9.04	9.04	9.04

Means in the column followed by different letter(s) differed significantly by DMRT at 5% levels of significance

Shelf life of broccoli in polyethylene bag at room temperature condition ranged from 2.66 to 6.41 days. The maximum shelf life (6.41 days) of broccoli was found in P_0K_0 which was statistically similar to that of P_0K_1 and P_0K_2 and minimum (2.66 days) was found in P_3K_3.

Shelf life of broccoli in polyethylene bag at refrigerator condition ranged from 11.25 to 17.87 days. The maximum shelf life (17.87 days) of broccoli was found in P_0K0 which was statistically similar to that of P_0K_1, P_0K_2, P_0K_3, P_1K_0, P_1K_1, P_2K_0 and P_3K_0 and the minimum (11.25 days) was found in P_3K_3.

It was revealed that the shelf life of broccoli increased with the decreased in P and K application in all the three storage condition. Among the three storage condition it was found that the shelf life of broccoli increased in the polyethylene bag at refrigerator condition. This could be due the effect of low temperature in refrigerator. Low temperature minimizes the respiration of broccoli as well as polyethylene bag also minimize the respiration process. Storage life was decreased with increasing P and K. Similar results reported by Beard (1990) and suggested that application of P fertilizer in excess of 180 kg/ha must be avoided for better storage in cabbage.

Table 16. Economic analysis of broccoli considering different levels of phosphorus and potassium

Treatments combination	Yield (ton ha^{-1})	Gross income (Tk. ha^{-1})	Total cost of production (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
P_0K_0	5.98	119600	42873.25	76726.75	1.79
P_0K_1	7.44	148800	44455.25	104344.75	2.35
P_0K_2	8.44	168800	45200.75	123599.25	2.73
P_0K_3	10.31	206200	45946.25	160253.75	3.49
P_1K_0	7.33	146600	45269.50	101330.50	2.24
P_1K_1	10.19	203800	46851.50	156948.50	3.35
P_1K_2	12.52	250400	47597.00	202803.00	4.26
P_1K_3	13.58	271600	48342.50	223257.50	4.61
P_2K_0	9.17	183400	46068.25	137331.75	2.98
P_2K_1	11.78	235600	47650.25	187949.75	3.94
P_2K_2	15.66	313200	48395.75	264804.25	5.47
P_2K_3	16.83	336600	49141.25	287458.75	5.84
P_3K_0	11.00	220000	46867.00	173133.00	3.69
P_3K_1	14.50	290000	48449.00	241551.00	4.98
P_3K_2	13.72	274400	49194.50	225205.50	4.58
P_3K_3	16.03	320600	49940.00	270660.00	5.42

Where,

P_0 = 0 kg P/ha
P_1 = 30 kg P/ha
P_2 = 40 kg P/ha
P_3 = 50kg P/ha

K_0 = 0 kg K/ha
K_1 = 50 kg K/ha
K_2 = 75 kg K/ha
K_3 = 100 kg K/ha

Economic analysis

Cost and return analysis in details were done according to the procedure of Alam *et al.* (1989). The details of economic analyses have been shown in Table 16 and Appendix I. Material, Non-material and overhead cost including harvesting of curds were recorded for all treatments according to unit plot basis and calculated per hectare. The total cost of production ranged between Tk. 42873.25 to Tk.49940.00 among the treatment combination (Appendix I). The variation was due to cost of different levels of TSP and MoP. It was found that the highest cost of production (Tk. 49940.00) was found in P_3K_3 while the lowest (TK. 42873.25) was found in P_0K_0.

The net return from different treatment combination ranged from Tk. 76726.75 to Tk. 287458.75 per hectare. Gross income were the total income through sale of broccoli curds @ Tk 20000/T. It was found from the economic analysis that the highest net return (Tk. 287458.75) was found in P_2K_3, Which was about near to that of P_2K_2 and P_3K_3 while the lowest (Tk. 76726.75) in P_0k_0.

The highest benefit cost ratio (BCR) was found in P_2K_3 (5.84) which was about near to that of P_2K_2 and P_3K_3 while the lowest (1.79) was found in P_0K_0. Singh (2004) was found the same trend of the present results. There was a wide gap between the lowest and highest BCR. However, the cost and return analyses were varied on crop yield as well as other factors such as cost of input and market price of harvested material, which might vary from year to year, therefore, the cost and return analyses for a crop grown in a particular year might not represent exactly the same with crop grown in another year. The present experiment revealed that the application of 40 kg P/ha and 100 kg K/ha was found to be conducive to higher economic return from broccoli under the soil and climatic condition of Dhaka.

CHAPTER-V

SUMMARY AND CONCLUSION

An experiment was conducted on "Effect of phosphorus and potassium on growth yield and post harvest assessment of broccoli" at Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2005 to February 2006. The experiment comprised of four levels of phosphorus viz., 0, 30, 40 and 50 kg P/ha and four levels of potassium viz., 0, 50, 75 and 100 kg K/ha. The experiment was laid out in split plot Randomized Complete Block Design with three replications.

Application of phosphorus exhibited a significant influence on the height of broccoli plants at 20, 40 and 60 days after transplanting (DAT). At 20 DAT, the tallest plants (28.73cm) were found in the highest dose of phosphorus application P_3 and the shortest plant (16.93cm) in P_1. At 40 DAT, the highest plant height was recorded at P_3 (38.68cm) and the lowest (24.09cm) was recorded from P_0. At 60 DAT, the highest plant height (55.85cm) was recorded from P_3 and the lowest (33.99cm) was recorded from P_0.

Application of potassium exhibited significant influence on the height of broccoli plants at 20, 40 and 60 DAT. At 20 DAT, K_3 treatment produced the highest plant height (27.60 cm) and the lowest plant height (18.00cm) was found in K_1. At 40 DAT, the highest plant height (39.13cm) was recorded from K_3 and the lowest (23.51cm) was recorded from K_0. At 60 DAT, the highest height (55.82cm) was recorded from K_3 and the lowest was (33.98cm) recorded from K_0.

The treatment combinations at 20, 40 and 60 DAT significantly influenced the plant height. At 20 DAT, the highest plant height (35.15cm) was observed in P_3K_3 and the lowest (12.07cm) was recorded from P_0K_1. At 40 DAT, the highest plant height (46.57cm) was observed in P_3K_3 and the lowest (19.17cm) was recorded from P_0K_0. At 60 DAT, the highest plant height (66.65cm) was observed in P_3K_3 and the lowest (27.36cm) was recorded from P_0K_0 treatment. The stem diameter of broccoli was significantly influenced on 20, 40 and 60 DAT. At 20 DAT, the maximum diameter (1.81cm) was found in P_3 and the minimum (1.01cm) was found in P_0. At 40 DAT, the highest stem diameter (3.13cm) was recorded from P_3 and the lowest figure (2.40 cm) was recorded from P_0. At 60 DAT, the stem diameter was statistically insignificant due to the application of different levels of phosphorus.

Marked variation was found in different levels of K application in respect of stem diameter of broccoli plants at 20, 40 and 60 DAT. At 20 DAT, K_3 produced the highest stem diameter (1.73cm) and lowest in K_0 (0.99cm). At 40 DAT, the highest stem diameter (3.16cm) was recorded from K_3, while the lowest figure (2.37cm) was recorded from K_0. At 60 DAT, the stem diameter was statistically insignificant due to the application of different levels of potassium. There had significant variation was found among the treatment combinations at 20, 40 and 60 DAT. At 20 DAT, the highest stem diameter (2.13cm) was observed in P_3K_3 and the lowest was (0.72cm) recorded from P_0K_0. At 40 DAT, the highest stem diameter (3.57cm) was observed in P_3K_3 and the lowest (2.16cm) was recorded from P_0K_1. At 60 DAT, it appeared that stem diameter did not differ significantly due to the combined application of different levels of phosphorus and potassium.

Application of phosphorus exhibited a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT. At 20 DAT, the maximum number of leaves (10.8) was found in P_3 and the minimum (7.63) was found in P_0. At 40 DAT and 60 DAT, there were no significant difference was found in number of leaves due to the application of different levels of phosphorus. Application of potassium exhibited a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT. At 20 DAT, the maximum numbers of leaves (10.62) were found in K_3 and the minimum (7.8) was found in K_0. Similar to phosphorus there was no significant difference was found in number of leaves per plant due to K application at 40 and 60 DAT. The treatment combinations at 20, 40 and 60 DAT significantly influenced the number of leaves. At 20 DAT, the highest numbers of leaves (12.20) were observed in P_3K_3 and the lowest (7.00) were recorded from P_0K_0. At 40 DAT, the highest number of leaves (13.80) was observed in P_3K_1 and the lowest (10.47) was recorded from P_0K_1. At

60 DAT, it appeared that number of leaves did not differ significantly due to the combined application of different levels of phosphorus and potassium. Application of phosphorus exhibited a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT. At 20 DAT, P_3 produced the longest leaf (41.97cm) and the lowest (31.67cm) was found in P_0. At 40 DAT, the largest leaf (45.21cm) was recorded from P_3 while the smallest leaf (24.09 cm) was recorded from P_0. At 60 DAT, the longest leaf (45.87cm) was recorded from P_3 while the smallest (36.53cm) was recorded from $P_{0.}$

Application of potassium exhibited a significant influence on the number of leaves of broccoli plants at 20, 40 and 60 DAT. At 20 DAT, K_3 produced the longest leaf (42.45 cm) whereas K_0 produced the smallest leaf (31.26 cm). Similar trend of result was found at 40 DAT and 60 DAT. The treatment combinations at 20, 40 and 60 DAT significantly influenced the number of leaves. At 20 DAT, the largest leaf (46.55cm) was observed in P_2K_3 while the smallest (28.00cm) was recorded from P_0K_0. At 40 DAT, the longest leaf (48.43cm) was observed in P_3K_3 while the smallest (32.13cm) was recorded from P_0K_0. At 60 DAT, the largest leaf (49.37cm) was observed in P_2K_3 while the smallest (32.80 cm) was recorded from P_0K_0. The number of days to curd initiation was not significantly influenced by phosphorus application. The application of potassium was not significantly influenced the number of days to curd imitation. There was significant variation among the treatment combinations in days to curd initiation. The maximum days (63 days) were required in P_3K_3 while the minimum days (47.33 days) were required for curd initiation in P_0K_0.

Application of phosphorus exhibited a significant influence on shoot length of broccoli plants. The maximum shoot length (39.93cm) was recorded from P_3 while the minimum shoot length (29.08cm) was observed in P_0.

Application of potassium exhibited a significant influence on shoot length of broccoli plants. The maximum shoot length (40.14cm) was recorded from K_3 and the minimum shoot length (28.96cm) was observed in $K_{0.}$ The treatment combinations significantly influenced the shoot length. The longest shoot (44.93cm) was observed in P_3K_3 while the smallest (25.72cm) was recorded from

P_0K_0. Application of phosphorus exhibited a significant influence on root length of broccoli plants. The maximum root length (30.81cm) was recorded from P_3 and the minimum root length (24.62cm) was observed in P_0. Application of potassium exhibited a significant influence on root length of broccoli plants. The maximum root length (30.94cm) was recorded from K_3 while the minimum root length (24.48cm) was observed in $K_{0.}$ The treatment combinations significantly influenced the root length. The maximum root length (33.67cm) was observed in P_3K_3 while the smallest (22.49cm) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on fresh shoot weight of broccoli plants. The maximum fresh shoot weight (793.90g) was recorded from P_3 and the minimum fresh shoot weight (581.30g) was observed in P_0. Application of potassium exhibited a significant influence on fresh shoot weight of broccoli plants. The maximum fresh shoot weight was (794.40g) recorded from K_3 while the minimum fresh shoot weight (24.48g) was observed in $K_{0.}$ The treatment combinations significantly influenced fresh shoot weight. The maximum fresh shoot weight (899.30g) was observed in P_3K_3 while the smallest (520.00g) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on fresh root weight of broccoli plants. The maximum fresh root weight (83.42g) was recorded from P_3 while the minimum fresh root weight (57.92g) was observed in P_0. Application of potassium exhibited a significant influence on fresh root weight of broccoli plants. The maximum fresh root weight (84.42g) was recorded from K_3 while the minimum fresh root weight (58.58g) was observed in $K_{0.}$ The treatment combinations significantly influenced fresh root weight. The maximum fresh root weight (96.00g) was observed in P_3K_3 while minimum (53.33g) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on total fresh weight of broccoli plants. The maximum fresh weight (877.40g) was recorded from P_3 and the minimum fresh weight (647.90g) was observed in P_0. Application of potassium exhibited a significant influence on total fresh weight of broccoli plants. The maximum fresh weight (887.60cm) was recorded from K_3 and the minimum fresh weight (642.30g) was observed in $K_{0.}$ Total fresh weight was significantly influenced by the treatment combination. The maximum fresh weight (997g) was observed in P_3K_3 while the minimum (573.3g) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on curd diameter of broccoli plants. The maximum curd diameter (17.44cm) was recorded from P_3 while the minimum (13.27cm) was observed in P_0. Application of potassium exhibited a significant influence on curd diameter of broccoli plants. The maximum curd diameter (17.52cm) was recorded from K_3 while the minimum (13.12cm) was observed in K_0. The treatment combinations significantly influenced curd diameter. The maximum curd diameter (19.73cm) was observed in P_3K_3 while the minimum (11.93cm) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on curd weight of broccoli plants. The maximum curd weight (264.30g) was recorded from P_3 while the minimum curd weight (181.70g) was observed in P_0. Application of potassium exhibited a significant influence on curd weight of broccoli plants. The maximum curd weight (260.00g) was recorded from K_3 and while the minimum curd weight (184.00g) was observed in K_0. The treatment combinations significantly influenced curd weight. The maximum curd weight (291.70g) was observed in P_3K_2 while the smallest (160.00g) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on number of secondary curd of broccoli plants. The maximum number of secondary curds (4.00) was recorded from P_3 while the minimum (2.08) was observed in P_0. Application of potassium exhibited a significant influence on number of secondary curds of broccoli plants. The maximum numbers of secondary curds (4.0) were recorded from K_3 while the minimum number of secondary curd (2.58) was observed in K_0. The treatment combinations were significantly influenced the number of secondary curds. The maximum number of secondary curds (5.0) was observed in P_2K_2 while the minimum (1.33) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on secondary curd weight of broccoli plants. The maximum secondary curd weight (155.30g) was recorded from P_2 and while the minimum (60g) was observed in P_0. Application of potassium exhibited a significant influence on secondary curd weight of broccoli plants. The maximum secondary curd weight (166g) was recorded from K_3 while the minimum (67.50g) was observed in K_0. The treatment combinations significantly influenced curd weight. The maximum secondary curd weight (215.0g) was observed in P_2K_3 and while the minimum (20g) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on yield per plant. The maximum yield (414.5g) was recorded from P_3 while the minimum (241.7g) was observed in P_0. Application of potassium exhibited a significant influence on yield per plant. The maximum yield (425.8g) was recorded from K_3 while the minimum (251.5g) was observed in K_0. The treatment combinations significantly influenced yield per plant. The maximum yield (505.0g) was observed in P_2K_3 while the minimum (180.0g) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on total yield per plot of broccoli plants. The maximum yield (7.46kg) was recorded from P_3 while the minimum (4.34kg) was observed in P_0. Application of potassium exhibited a significant influence on yield per plot of broccoli plants. The maximum yield (7.66kg) was recorded from K_3 while the minimum (4.52kg) was observed in K_0. The treatment combinations significantly influenced yield per plot. The maximum yield per plot (9.09kg) was observed in the P_2K_3 while the minimum (3.23kg) was recorded from P_0K_0. Application of phosphorus exhibited a significant influence on yield per hectare of broccoli plants. The maximum yield (13.81t) was recorded from P_3 while the minimum yield (8.04t) was observed in P_0. Application of potassium exhibited a significant influence on yield per hectare of broccoli plants. The maximum yield (14.19t) was recorded from K_3 while the minimum yield (8.37t) was observed in K_0. The treatment combinations significantly influenced yield per hectare. The maximum yield per hectare (16.83t) was observed in P_2K_3 while the minimum (5.98t) was recorded from P_0K_0.

In case of storage conditions broccoli curds kept in polyethylene bag in refrigerator at 4^0C showed highest shelf life (17.87 days) while the lowest shelf life (1.35 days) was observed when the curds were open at room temperature without polyethylene bag.

The economic analysis showed that the highest gross return (TK. 2, 87,405.50/ha) and benefit cost ratio (5.84) were obtained from the treatment combination of

P_2K_3 (40 kg p/ha and 100 kg k/ha) while the lowest gross return (TK. 76726.75/ha) and benefit cost ratio (1.79) was found in P_0K_0.

The following conclusions could be drawn:

(1) Phosphorus and potassium up to certain level had significant influence on growth and yield of broccoli and P_2K_3 (40 kg p/ha and 100 kg k/ha) gave the highest yield whereas economic return decreased in excess use of phosphorus fertilizer i.e., P_3K_3 (50 kg p/ha and 100 kg k/ha). So, P_2K_3 was the best fertilizer combination for broccoli production.

(2) Among the storage condition, the highest shelf life of broccoli was observed when the curd was kept in polyethylene bag in refrigerator at 4^0C.

(3) The present study was conducted in an individual soil type and further regional trials should be needed for fertilizer recommendation of broccoli.

CHAPTER-VI

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APPENDICES

Appendix I Cost of production of broccoli per hectare under different treatment combination.

A. Input costs excluding the cost of TSP and MoP

SL. No.	Item of Input cost	Cost (Tk.)
1.	Non material cost:	
i)	Land preparation including removal of weed, stubbles	3250
ii)	Making irrigation channel and drains	750
iii)	Making seed bed for seedling raising	500
iv)	Seedling transplanting	2000
v)	Weeding, mulching and earthing up	2500
vi)	Bird driving	2500
vii)	Spraying of insecticides and fungicides	500
viii)	Spreading of manures and fertilizers	2500
ix)	Harvesting	2250
2.	Material cost	
i)	Seeds @TK. 1000/kg seed	1000
ii)	Cow dung (20 T/ha, @ TK. 250/T)	5000
iii)	Fertilizer (Urea 300kg/ha, @ Tk. 6/kg)	1800
iv)	Irrigation (3 times)	2000
v)	Insecticides and fungicides	1500
vi)	Total materials cost	11300
3.	Total input cost	28050

B. **Total variable and overhead cost**

Treatments combination	Variable cost (Tk.)				Overhead cost (Tk.)			Total cost of production (A+B)	Gross income (Tk./ha)	Net return	BCR (%)
		TSP	MOP	Total Variable cost (A)	Hiring of land for six months	Interest on running capitals	Total overhead cost (B)				
P_0K_0	28050	-	-	28050	13000	1823.25	14823.25	42873.25	119600	76726.75	1.79
P_0K_1	28050	-	1400	29450	13000	2005.25	15005.25	44455.25	148800	104344.75	2.35
P_0K_2	28050	-	2100	30150	13000	2050.75	15050.75	45200.75	168800	123599.25	2.73
P_0K_3	28050	-	2800	30850	13000	2096.25	15096.25	45946.25	206200	160253.75	3.49
P_1K_0	28050	2250	-	30300	13000	1969.50	14969.50	45269.50	146600	101330.50	2.24
P_1K_1	28050	2250	1400	31700	13000	2151.50	15151.50	46851.50	203800	156948.50	3.35
P_1K_2	28050	2250	2100	32400	13000	2197.00	15197.00	47597.00	250400	202803.00	4.26
P_1K_3	28050	2250	2800	33100	13000	2242.50	15242.50	48342.50	271600	223257.50	4.61
P_2K_0	28050	3000	-	31050	13000	2018.25	15018.25	46068.25	183400	137331.75	2.98
P_2K_1	28050	3000	1400	32450	13000	2200.25	15200.25	47650.25	235600	187949.75	3.94
P_2K_2	28050	3000	2100	33150	13000	2245.75	15245.75	48395.75	313200	264804.25	5.47
P_2K_3	28050	3000	2800	33850	13000	2291.25	15291.25	49141.25	336600	287458.75	5.84
P_3K_0	28050	3750	-	31800	13000	2067.00	15067.00	46867.00	220000	173133.00	3.69
P_3K_1	28050	3750	1400	33200	13000	2249.00	15249.00	48449.00	290000	241551.00	4.98
P_3K_2	28050	3750	2100	33900	13000	2294.50	15294.50	49194.50	274400	225205.50	4.58
P_3K_3	28050	3750	2800	34600	13000	2340.00	15340.00	49940.00	320600	270660.00	5.42

TSP @Tk.15/kg and MoP @ Tk. 14/kg

Appendix II. Physical properties of soil in the experimental field

Soil physical properties	Analytical data
Soil texture	Sandy loam
Sand (%)	30.65
Silt (%)	38.19
Clay (%)	31.16
Soil Type	Shallow Red Brown Terrace soil
Soil Series	Tejgoan

Source: SRDI, Farmgate, Dhaka

Appendix III. Chemical properties of soil in the experimental field

Soil chemical properties	Analytical data
Soil pH	5.6
Total N (%)	0.078
Available P (ppm)	0.0015
Available K (ppm)	0.0053
Organic matter (%)	0.88
C: N ratio	12: 1

Source: SRDI, Farmgate, Dhaka

Appendix IV. Monthly air temperature, Rainfall, Relative humidity and Sunshine of the experimental site during the study period (October, 2005 to February, 2006)

Year	**Month**	**Air temperature (^0C)**			**** Rainfall**	*** Relative humidity (%)**	****Sunshine (hours)**
		Max.	Min.	Mean			
2005	October	31.40	21.50	26.45	205.90	86.16	185.20
	November	29.56	19.55	24.55	10.70	84.27	222.70
	December	26.52	13.90	20.21	0.00	80.84	220.20
2006	January	22.44	12.92	17.68	0.00	78.00	213.20
	February	27.31	16.41	21.86	11.1	74.71	169.40

* Monthly average

** Monthly total

Source: The Meteorological Department (Weather division) of Bangladesh, Agargoan, Dhaka.

Appendix V. Nutritive value of 1 lb of selected Cole crops for comparison

Kind of product	Broccoli	Cauliflower	Cabbage
Refuse percent	39.00	55.00	27.00
Food energy (cal.)	103.00	63.00	49.00
Protein (g)	9.10	4.90	4.60
Fat (g)	0.60	0.40	0.70
Carbohydrate (g)	15.20	10.00	17.50
Calcium (mg)	360.00	45.00	152.00
Phosphorus (mg)	211.00	147.00	103.00
Iron (mg)	3.60	2.20	1.70
Vitamin (i.u)	9700.00	200.00	270.00
Ascorbic acid (mg)	327.00	141.00	173.00
Riboflavin (mg)	0.59	0.22	0.21
Thiamin	0.26	0.21	0.23
Niacin	2.50	1.20	0.90

Source: Thomson and Kelly (1985)

Appendix VI. Analysis of variance of the data on plant height and stem diameter

Source of variation	Degrees of freedom	Plant height (cm)			Stem diameter (cm)		
		20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	3.806	22.294	50.580	0.022	0.029	0.039
Factor A	3	368.782*	481.945*	1076.661*	1.448*	1.243*	0.437NS
Factor B	3	241.190*	544.002*	1082.308*	1.367*	1.417*	0.484NS
Ax B	9	16.633*	12.661*	25.600*	0.040*	0.107*	0.104NS
Error	30	11.049	15.237	17.736	0.018	0.127	0.684

* Significant at 5% level of probability

Appendix VII. Analysis of variance of the data on number of leaf and leaf length

Source of variation	Degrees of freedom	Number of leaf			Leaf length (cm)		
		20 DAT	40 DAT	60 DAT	20 DAT	40 DAT	60 DAT
Replication	2	0.653	3.961	1.908	58.411	0.479	28.223
Factor A	3	22.532*	6.223NS	5.454NS	246.332*	234.296*	223.157*
Factor B	3	17.914*	4.387NS	4.141NS	279.054*	265.688*	276.772*
Ax B	9	1.450*	1.356*	1.417NS	7.828*	15.947*	14.567*
Error	30	1.225	2.425	3.200	24.565	14.491	20.677

* Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data on shoot length, root length, fresh shoot weight, fresh root weight and total weight

Source of variation	Degrees of freedom	Shoot length	Root length	Fresh shoot weight	Fresh root weight	Total weight
Replication	2	19.241	14.454	6198.938	189.063	5809.771
Factor A	3	264.299*	84.352*	103129.889*	1418.500*	119660.354*
Factor B	3	283.532*	96.135*	104129.000*	1518.778*	137309.243*
Ax B	9	7.865*	2.733*	2888.074*	81.426*	3166.410*
Error	30	26.389	6.832	10029.560	55.040	6224.349

* Significant at 5% level of probability

Appendix IX. Analysis of variance of the data on days required to curd initiation, curd weight, curd diameter and no. of secondary curd

Source of variation	Degrees of freedom	Days required to curd initiation	Curd weight	Curd diameter	No. of secondary curd
Replication	2	4.021	672.063	7.586	1.271
Factor A	3	144.188NS	15228.056*	38.138*	11.354*
Factor B	3	95.688NS	14233.556*	44.748*	4.188*
Ax B	9	6.576*	559.167*	1.827*	1.576*
Error	30	25.754	712.218	3.437	0.471

* Significant at 5% level of probability

Appendix X. Analysis of variance of the data on wt. of secondary curd, total weight yield per plot and yield per hectare

Source of variation	Degrees of freedom	Wt. of secondary curd	Total weight	Yield per plot	Yield per hectare
Replication	2	325.688	1094.083	0.773	2.951
Factor A	3	23725.688*	75791.799*	24.583*	84.351*
Factor B	3	19979.688*	66367.576*	21.507*	73.788*
Ax B	9	1852.021*	2941.243*	0.954*	3.264*
Error	30	111.354	785.550	0.741	2.844

* Significant at 5% level of probability