EFFECT OF SPACING AND POTASSIUM ON GROWTH AND YIELD OF BROCCOLI *(Brassica oleracea* L. var. *italica)*

ALI AZIM SHARIF

DEPARTMENT OF HORTICULTURE AND POSTHARVEST TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

DECEMBER, 2008

EFFECT OF SPACING AND POTASSIUM ON GROWTH AND YIELD OF BROCCOLI *(Brassica oleracea* L. var. *italica)*

BY

ALI AZIM SHARIF

Registration No. : 07-02606

A Thesis
Submitted to the Department of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka, in partial
fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JULY-DECEMBER, 2008

Approved by:

Prof. M.A. Mannan Miah
Dept. of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka
Supervisor

Dr. Md. Ismail Hossain
Associate Professor
Dept. of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka
Co-Supervisor

Prof. A.K.M. Mahtabuddin
Chairman
Examination Committee

Department of Horticulture & Postharvest Technology
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

PABX: +88029144270-9
Fax: +88029112649
Web site: www.sau.edu.bd

Ref: **Date:**

……………...

CERTIFICATE

This is to certify that the thesis entitled, **" EFFECT OF SPACING AND POTASSIUM ON GROWTH AND YIELD OF BROCCOLI *(Brassica oleracea* L. var. *italica*)"** submitted to the Department of Horticulture and Postharvest Technology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment 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 **Ali Azim Sharif, Registration No.: 07-02606** under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.

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

(Prof. M.A. Mannan Miah)
Dept. Of Horticulture and Postharvest Technology
Sher-e-Bangla Agricultural University, Dhaka
Supervisor

Dated: December 2008

Place: Dhaka, Bangladesh

Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

All praises are due to Almighty "Allah" Who kindly enabled the author to complete the research work and the thesis leading to Master of Science.

*The author feels proud to express his profound respect, deepest sense of gratitude, heartful appreciation to Professor **M.A. Mannan Miah** ,Department of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his constant inspiration, scholastic guidance and valuable suggestions during the conduct of the research and for his constructive criticism and whole hearted co-operation during preparation of this thesis.*

*The author express his heartfelt gratitude and indebtness to, **Dr. Md. Ismail Hossain** Associate Professor, Department of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Dhaka for his assistance in planning and execution of the study and for his constructive instruction, critical reviews and heartiest co-operation during preparation of the manuscript.*

The author also express his heartfelt thanks to all the teachers of the Dept. of Horticulture and Postharvest Technology, Sher-e-Bangla Agricultural University, Dhaka for their help, valuable suggestions and encouragement during the period of study.

The Author also indebted to the Farm Division of Sher-e-Bangla Agricultural University and other staff of Sher-e-Bangla Agricultural University for their co-operation in the implementation of research works.

The Author is also thankful to Badal, Zakir, Kawsar, Raju, Asad, Sumon, Anjan, Zahid, Nasir , and Santos for their constant encouragement.

At last but not the least, the Author feel indebtedness to his beloved parents and relatives, whose sacrifice, inspiration, encouragement and continuous blessing paved the way to his higher education.

The Author

CONTENTS

CONT'D

LIST OF TABLES

LIST OF FIGURES

LISTS OF APENDICES

LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
et al.	=	And others
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days After Transplanting
/ha	=	Per hectare
g	=	Gram (s)
cm	=	Centimeter
Kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
Wt	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
i.e.	=	That is
NPK	=	Nitrogen, Phosphorus and Potassium
CV	=	Coefficient of Variation

EFFECT OF SPACING AND POTASSIUM ON GROWTH AND YIELD OF BROCCOLI *(Brassica oleracea* L. var. *italica)*

BY

ALI AZIM SHARIF

ABSTRACT

The experiment was conducted at experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2007 to February 2008 to determine the effect of spacing and potassium on the growth and yield of broccoli. The trial consists of 12 treatment combinations of 3 spacing and 4 levels of fertilizer application. Maximum plant height, number of leaves per plant, maximum fresh weight of leaves per plant, leaf dry weight per plant, primary curd weight, primary curd diameter, number of secondary curd per plant, weight of secondary curd per plant, curd dry weight per plant and yield per plant (372.80g) were recorded in widest spacing but the highest stem length, and yield/ha were recorded from the closest spacing. Maximum plant height, number of leaves per plant, length of largest leaf and largest leaf breadth per plant, fresh weight of leaves per plant, leaf dry weight per plant, highest stem length, primary curd weight, primary curd diameter, number of secondary curd per plant, weight of secondary curd per plant, curd dry weight per plant and yield per plant and yield/ha were obtained from 120 kg K/ha application. In combination of plant spacing and potassium fertilizer application, the highest primary curd weight per plant (252.20 g), primary curd diameter, number of secondary curd per plant, weight of secondary curd per plant (117.20 g), curd dry weight per plant and yield per plant (439.10g) were obtained from the combination of 60 cm x 60 cm and 120 kg K /ha and yield/ha (16.61t) were obtained from the combination of 60cm × 40cm and 120 kg K/ha. The highest net return (Tk.210514.00/ha) and benefit cost ratio (3.01) was obtained from 60cm × 40cm and 120 kg K /ha combination. From the result it may be concluded that treatment combination 60cm × 40cm and 120 kg K /ha was promising for application.

CHAPTER I

INTRODUCTION

CHAPTER I
INTRODUCTION

Broccoli (*Brassica oleracea* L. var. *italica*) is an important vegetable crop in Bangladesh. It is one of the non- traditional and relatively new cole crop which is a biennial and herbaceous crop belonging to the family Cruciferae. It is a biennial crop, while the annual cultivars are somewhat sensitive to frost (Mitra *et al.*, 1990). Morphologically, broccoli resembles cauliflower. Terminal head is rather loose, green in colour and flower stalks are larger than cauliflower. Broccoli originated from West Europe (Prasad and Kumer, 1999) and it is a very popular vegetable in the United States of America and very recently Japan has occupied a respectable position in the production of this crop.

Broccoli is fairly rich in vitamin A and C and contains appreciable amounts of calcium, phosphorus, riboflavin, thiamin, niacin, and iron (Thompson and Kelly, 1997). Analytical data presented by Nieuwhof (1999) showed that broccoli is more nutritious than other crop like cabbage, cauliflower and kohlrabi. So, it can contribute significantly to improve our diet.

Broccoli is grown by a small percentage of home gardeners in Bangladesh during the winter season. It is environmentally better adapted than cauliflower and reported to withstand comparatively higher temperature (Rashid, 1993). Growth and yield of broccoli in Bangladesh are seriously impeded compared to that of other countries. Main reason for such poor growth and yield might be due to lack of judicious application of fertilizers, proper cultural and management practices.

The cultivation of broccoli has not been extended much beyond the farms of different agricultural organizations in Bangladesh. The growth and yield of broccoli in Bangladesh are not good as in other countries. The reasons for such poor growth and yield of broccoli in this country are probably due to the lack of judicious application of fertilizers and sub-optimal management practices followed by the growers.

It is evident that balanced application of fertilizer is the prerequisite for obtaining higher yield and better quality of broccoli (Brahma *et al*., 2002a). Among the fertilizers, potassium appears to be an important factor for gaining higher yield. This nutrient acts in balancing physiological activities of plants (Mitra *et al*., 1990). Ying *et al.* (1997) observed that potassium was the most important element for yield and dry weight of broccoli.

Optimal plant spacing is very important for crop production through efficient utilization of light, nutrients and water by the plants. In some cases, higher plant population adversely affects on yield per unit area by hampering the vegetative and reproductive growth of plant. Closer spacing and higher densities of broccoli shows increased yield per hectare but the head and size and incidence of hollow stem were decreased i.e. quality of crops are decreased (Gorski and Armstrong, 1985).

The above statements indicate that a suitable combination of potassium fertilizer and also other fertilizers and plant spacing is important to get a higher yield of broccoli.

The present study has therefore, been undertaken with the following objectives:

1. to investigate the effect of different levels of potassium application on growth and yield of broccoli.

2. to determine the optimum spacing for higher yield and quality of broccoli under different levels of potassium.

CHAPTER II
REVIEW OF LITERATURE

Broccoli is one of the most prominent vegetables grown all over the world. It was introduced in Bangladesh recently but its cultivation has not yet been spread much. It is known as winter vegetable in Bangladesh because it is a cool loving crop. Its growth, yield and quality are remarkably influenced by mineral nutrition specially nitrogen and potassium. Different levels of potassium application influence the growth and yield of the crop. The plant spacing is also another important factor that influences the growth, yield and quality. To ensure better yield, the optimum levels of potassium and spacing are to be assessed. The requirements, however, varies with the soil and cultural conditions. The published information regarding the requirement of major nutrients for cultivation of this crop is very limited. However some of the important informative research findings available in this respect at home and abroad have been presented in this chapter.

2.1 Effects of K fertilizers

Wang *et al*. (2007) conducted a pot experiment to determine the effects of N, P and K on yield and quality of broccoli and reported that K was the most important element for yield. Additive effects were observed on yield and source-sink 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. N application advanced the harvest. Significant positive correlations were found between yield and dry weight of leaves and plant size. They suggested that to obtain high yields and quality, N, P and K applications should be balanced.

Yang *et al.* (2006) conducted a field experiment for two years to study the effect of nitrogen, phosphorus and potassium on growth and yield of broccoli. Treatments comprised: 60:40:30, 120:80:50, 150:80:70 and 200:100:80 kg NPK/ha. They observed that plant height was increased through stem length, leaf length and breadth with increasing NPK and the highest plant height and number of leaves were obtained with 200:120:80 kg NPK/ha, respectively. The highest yield per plot was also obtained from the same treatment.

Brahma *et al*. (2002a) carried out a field experiment to evaluate the effects of NPK fertilizers on the nutrient uptake, yield and quality of broccoli cv.KTS-1. The treatment comprised application of 80: 30: 20, 100: 60: 40, 150: 80: 60 and 200: 120: 80 kg NPK/ha. They reported that NPK at 200 : 120 : 80 kg /ha resulted in the highest values for head diameter (19.52 cm); cull head number (7.09); head yield (13.42 t/ha); cull head yield (4.70 t/ha); total yield (18.11 t/ha); leaf N (3.90%) and K (2.75%) content; and protein (3.36%), total chlorophyll (0.46 mg/g) and ascorbic acid content (128.05 mg/kg/ha) and K (72.37 kg/ha).

In another experiment Brahma *et al.* (2002b) found the effect of N, P and K on growth and yield of broccoli cv. Pusa broccoli KTS-1. They applied 0 : 0: 0, 50: 30: 20, 100 :60 :40 , 150 : 90 : 60 and 200 : 120 : 80 kg NPK/ha, respectively and found that the growth and yield of broccoli showed marked improvement with the application of 200 : 120 : 80 kg NPK/ha.

Guan and Chen (2001) reported that there was a significant effect of N and K on growth and yield of cauliflower and broccoli especially N on growth and K on yield. Higher amount of nitrogen increase plant height, leaf length and stem diameter at least at a certain range. On the other hand, higher amount of potassium contribute higher curd weight, curd diameter and secondary curd number per plant at least at a certain range of K application.

Cai *et al.* (1999) conducted an experiment in China on broccoli production and used different compound media mixed with sawdust, slag and cotton seed coats that are used for mushroom culture. The results of this experiment revealed that 15 g urea +10 g potassium chloride per plant produced the earliest curds of high quality and high yields and 30 g urea +

10 g potassium chloride per plant produced the highest yields. But 30 g urea + 30 g potassium chloride per plant gave the least satisfactory results.

Everaarts (1997) carried out an experiment on Brussels sprouts of the cv. Kudry planted in late April or early May, late May and late June or early July in Letystad at Netherlands. The uptake of N. P, K, and Mg was determined, and also the removal of N, P, K and Mg in the sprouts and reported that with latter planting, less N, P and K were required. Plant density had no effect on the uptake and removal of N and K.

Lu *et al.* (1997) reported that nutrient absorption and dry matter accumulation of broccoli cultivars, viz., 'Green Valiant', 'Yuguan' and 'Xinzengyanshui' grown under routine field fertilization. Amounts of N, P, K, Ca and Mg were absorbed for every 1000 kg of broccoli heads were 15.45-20.06, 1.45-2.51, 8.98-10.87, 7.32-9.48 and 1.65-2.40 kg, respectively.

Yang *et al.* (1994) carried out a field trials on cauliflower and found that the best plant growth, the highest curd yield, the highest curd yield per unit area were obtained with the lower N rate and the higher K rate. They used the combinations of 8 or 16 g urea per plant and 5 or 10 g potassium chloride per plant.

Csizinszky (1987) carried out field experiments on broccoli cv. 'Green Valiant', Cabbage cv. 'Market Prize' and cauliflower cv. 'Snow Crown' Hybrid with seepage or trickle irrigation and various rates of N and K fertilizers. Broccoli, cabbage and cauliflower yields were increased by increased rates of NK fertilizers with trickle irrigation. With trickle irrigation, high fertilizer rates were still needed for higher yields but irrigation water requirement was reduced by 50-60 percent.

Politanskaya (1985) studied the effects of 4 levels of N (120, 150, 180 and 210 kg/ha) in addition to 2 basal P, K treatment (P_2O_5, K_2O at 60: 90 or 120:180 kg/ha) applied on peaty-podzolic light-loamy soil. N at 120 or 150 kg /ha with P:K at 60:90 kg/ha greatly improved yields and curd quality compared with other variant in cauliflower.

Csizinszky and Stanley (1984) obtained satisfactory broccoli yields from trickle irrigation with three daily application of water. The highest marketable yield of 8.4 t/ha was recorded with 214 N, 56 P and 244 K kg/ha and yields with trickle irrigation were bellow those with seepage system.

Magnifico *et al.* (1979) conducted a fertilizer trial to study the effect of NPK on growth and nutrient removal 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_20/ha. The total yield was 148400 kg/ha and the total dry matter was 16800kg/ha.

Munro *et al.* (1978) carried out an experiment on broccoli and Brussels sprouts and analyzed the leaf tissue of broccoli *(Brassica oleracea* var. *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 were noted for applied N and 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 level for plants growth were within the ranges of 5.2-6.0% N, 0.35-0.60 P and 1.7-2.2% K.

Another experiment was conducted by Cutclifee and Munro (1976) to investigate the effects of nitrogen, phosphorus and potassium on the yield and maturity of broccoli and observed that yields were substantially increased by application of N and P_2O_5, but were only slightly affected by applied K_2O. Maturity was slightly delayed by a lack of P_2O_5. 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.

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

Singh *et al.* (1976) studied the effect of nitrogen and potassium on the curd yield of cauliflower cv. 'Snowball-16' and found that the curd yield increased with increasing N and K_2O application at each of 120 kg/ha. The interaction between N × K was highly significant.

Perez and Loria (1975) carried out two experiments on cauliflower. First one was conducted with cv. 'Snowball A' and found that the response to N, P and K was linear and there were no interactions. For each additional application of 75 kg N/ha, (0, 75 and 150 kg N/ha) 150 P_20_5/ha (0, 150 and 300 kg) and 60 kg K_2O/ha (0, 60 and 120 kg) production was increased by 1.54, 0.77 and 0.90 tons per ha, respectively. In the second experiment with the cv. Snowball `X', there was no response to N and K, but the effect of P was quadratic.

2.2 Effects of plant spacing

Plant spacing is an important factor for crop production of broccoli as light, nutrient, water etc, for plant growth and development. In some cases, lighter plant population adversely affects yield per unit area hampering vegetative and reproductive growth of plant. So, it is essential to maintain optimum plant spacing for maximum yield of broccoli.

Mourao *et al*. (2007) conducted an experiment during 2001-2003 in Odemis, Turkey, to investigate the effects of plant spacing (4 plant spacing; 50 cm × 45 cm, 50 cm × 50 cm, 60 cm × 45 cm and 60 cm × 60 cm) on the growth and yield of 3 cultivars of broccoli (‘Green Dome’, ‘KY-110’ and ‘Marathon’) with recommended fertilizer dose of NPK at 150: 100: 80 kg/ha, respectively. The trial was resulted that the lowest plant spacing (50 cm × 45 cm) showed higher stem length and lower stem diameter but the highest plant spacing (60 cm × 60 cm) process the highest leaf length and leaf breadth and as a result the highest plant height. The highest weight of primary curd and yield/plant was recorded from the highest plant spacing (60 cm × 60 cm) but the highest yield was obtained from the lowest spacing (50 cm × 45 cm).

Kunicki *et al.* (2005) conducted an experiment under the climatic conditions of SE Poland. The effect of plant densities of 3.2, 4.0, 5.3 or 8.0 plants/m^2 was investigated on the yield and quality of broccoli cultivars ‘Kermit’, ‘Montilla’ and ‘Skiff’. They reported that plant density had a significant effect on the marketable yield which ranged from 11.0 t/ha to 16.6 t/ha. Head weight increased by 46% as planting density decreased from 8.0 to 3.2 plants/m^2. On the other hand, higher plant spacing required the highest number of leaves and fresh weight and dry weight/plant.

Yoldas and Esiyok (2004) stated the effect of seedling (1, 2 and 3 month old), plant spacing (70 x 30 and 70 x 40cm) and growth stages of broccoli cultivars ‘Green Dome’, ‘KY-110’ and ‘Marathon’ F_1 on the yield and quality of the crop were determined in a field experiment conducted in Turkuy during 2001-03. The highest yield was observed in plants grown from 1-month old seedling (4910 kg/day).

Waltert and Theiler (2003) stated that predictions of plant development, potential and time of harvest are important. Nondestructive parameters are needed which can be easily measured in the field. The growth and yield of different cultivars of cauliflower and broccoli were analyzed by the diameters of curd and stem and weight of curd. They observed a strong correlation between the diameter of stem and plant biomass and the diameters of stem and curd with different planting spacing. Lower plant spacing showed higher curd diameter which resulting higher curd weight. The growth of stem and curd diameter were also dependent on the days after transplantation in the field. The growth of curd showed higher cultivar variation and was more sensitive to environmental factors than the growth of stem. Consequently, there was a higher variation between curds of one crop, which differs between cultivars. They reported that the harvest periods for cultivars can be predicted, depending on the correlations and variations.

Das *et al.* (2000) conducted an experiment to find out the effect of various N : P : K fertilizers (80:60:50, 120:90:75, 160:120:100 and 200:150:125 kg /ha) and plant densities (45 × 45, 60 × 45 and 60 × 60 cm) on production of cauliflower cv. ‘Pusa Katki’. Curd yield per plant was maximum at a spacing of 60 × 60 cm, and at a NPK rate of 160: 120:100 kg/ha.

Under the climatic condition of S.E. Polland the effect of plant densities of 3.2, 4.0, 5.3 or 8.0 plants/ m^2 on the yield and quality of broccoli cultivars ‘Kennit’, ‘Montilla’ and ‘Skif’, was investigated by Kunicki *et al.* (1999). Plant density had a significant effect on the marketable yield which ranged from 11.0 t/ha at 3.2 plant/m^2 to 16.6 t/ha, at 8.0 plants/m. Head weight increased by 46% as plant density decreased from 8.0 to 302 plants/ m^2.

Pornsuriya *et al,* (1997) conducted experiments to find out various cultural methods to increase yield and quality of broccoli in Thailand. The best spacing was 40 x 60 cm, which gave the highest yield and quality.

Sorensen and Grevsen (1994) planted broccoli at spacing of 40 x 50, 30 x 50, 20 x 50, 10 x 50 and 20 x 25 cm spacing and found little effect on uniformity in maturity in the early planting. In the late planting, a higher variability in maturity index occurred at increased plant density.

Griffith and Carling (1991) found that the maximum yield of individual heads for fresh market at a spacing of 45 x 30 cm using single plant transplants. At this spacing yields for ‘Green Valiant’ and ‘Emperor’ were 18.3 and 15.0 t/ha, respectively.

A trials in Cortago was carried out with the broccoli cultivar Green Valiant planted at densities of 70,000, 100,000 or 300,000 plants /ha and receiving nitrogen at 200, 250, 300, 350 or 400 kg/ha in the second year. The best combination with regard to yield (16.7 t/ha) and quality was 100,000 plants/ha receiving 350 kg/ha (Soto, 1991).

Khan *et al.* (1991) conducted field trails at Bixby, Oklahome at 1986-1988, with broccoli cv. Premium crop seedlings were planted 15 or 30 cm apart and given 4 N rates in split applications before and after (side dressing) planting. Although the 15 cm spacing sometimes produced the greatest total number of marketable heads, this spacing resulted in higher head production, lower average marketable head weight, delayed maturity.

Broccoli is generally sown on bed like cole crops. But more recently the seeds are drilled directly to soil in the USA. The spacing in such sowing is maintained at 30 x 75 cm between the plants and rows, respectively. Crops grown in such close spacing yield more though main heads are smaller and these mature slightly later than wide spacing (Bose and Som, 1990).

Mullins and Straw (1990) conducted trails at Crossville, Tennessee in 1988 and 1989 on a lily sandy loam soil. They observed that more heads and lower average weights were produced at 6 inch (15.24 cm) spacing in both years.

Cuocolo *et al.* (1988) conducted two-year trails to investigate the effects of nitrogen and plant density on production of cauliflower cv. ‘Gigontedi Napoli’ in the Scale river plains. Seed yield was found to be increased linearly with increase in plant population.

According to Dufault and Waters (1985) increasing the N rate from 56 to 224 kg/ha at any population (24,0000 to 72,000 plants/ha), linearly increased broccoli head weight and marketable yields, and decreased cull yields. Broccoli yields were the highest at 72,000 plants/ha and 224 kg/N.

Gorski and Armstrong (1985) reported that closer spacing (40 cm to 20 cm) and higher plant densities increased yield/ha but the head size and incidence of hollow stem were decreased. Increasing N rate (0 to 224 kg/ha) increased yield.

The effect of variety, spacing and levels of nitrogen fertilization on the yield of broccoli were investigated by Lewandowaka and Skapski (1977).The seedlings were planted at densities of 9, 7, 5, 4.5, and 3/ m^2 and applied N at the rate of 100, 200, 300 kg/ha and PK as basal dressing. They reported that the total marketable yields were increased with increasing N rate.

Mathur *et al.* (1996) conducted experiments in India to observe the effect of different spacing and nitrogen rates on the yield of broccoli. They found that plants spaced at 45 x 45, 61 x 61 and 76 x 76 cm yielded 14317, 10331 and 8077 kg/ha, respectively. They reported that the response of plants to N in the range of 50-150 kg/ha was insignificant.

Another experiment on the effect of different nitrogen levels and spacing was conducted by El-Behedi and Nansi (1995). The crop was planted at 50, 70 and 90 cm in the row and supplied with N at 0, 20, 40 and 60 kg. They stated that the highest N rate increased total and early yields.

Salter and James (1985) observed that the spacing of 86 cm x 86 cm to 15 cm x 15 cm (1.4 to 44.4 plants/m^2, respectively) had no effect in variation of time for curd initiation in cultivars 110 Hylite. However, in all spacing curd size for 110 decreased as the curd grew large in Hylite that did not occur at the close spacing.

In another two years trail, the effect of N at the rate of 40, 80 and 120 kg and row spacing of 30, 45 and 60 were observed by Mital *et al.* (1975). Yield was found the highest with 80 kg N/ha and 45 cm row spacing.

Nassar *et al.* (1982) investigated the effect of spacing on seed production of cauliflower cv. Snowball-M. The plant spacings were 40, 55 or 70 cm. They reported that increasing the plant number per plot lowered the seed yield per plant, but did not affect the seed yield per plot.

Zink and Akana (1991) grew broccoli in double rows 33.02 cm (13 inches) apart in beds 109 cm (43 inches) apart on centers. The spacing in the row varied from 20.32 cm (8 inches) to 50.8 cm (20 inches). The greatest yield of center heads was obtained with 20.30 cm spacing. As the plants were placed close together the size of the center head decreased and production of lateral heads decreased.

From the above review, it appears that spacing and K fertilizers affect the yield of broccoli. In most cases it was found that the higher doses of K fertilizers increase yield but in few cases higher doses of K fertilizers were not to be economic for broccoli production. In case of plant spacing, lower spacings were reported to produce lower individual weight of curd and higher total marketable yield per unit area. On the other hand, wider spacing produced higher individual curd weight and relatively lower yield per unit area.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the major information regarding materials and methods that were used in conducting the experiment. It consists of a short description of locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, economic and statistical analysis etc., which are presented as follows;

3. Experimental site

The research work relating to determine the effect of spacing and potassium on the growth and yield of broccoli was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during October 2007 to February 2008.

3.1 Location

3.1.1 Geographical Location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.2 Climate

Area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in Appendix II.

3.2 Characteristics of soil

Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.1- 6.3 and had organic matter 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. Physicochemical properties of the soil are presented in Appendix III.

3.3 Raising of seedlings

Seedlings of broccoli were raised at the Horticulture Farm SAU, Dhaka, under special care in two seedbeds of 3m x 1m size under the polythene tunnel. Soil of the seedbed was well ploughed with a spade and converted into loose friable and dried masses to obtain good tilth aiming to provide a favorable condition for the growth of young seedlings. All the weeds, stubbles and dead roots of the previous crop were removed. Seed bed was dried in the sun to destroy soil insect and protect the young seedlings from the infestation of damping off disease. Decomposed cow dung was applied to the prepared seedbed at the rate of 10 t/ha. Ten grams of seed were sown in each seedbed on October 30, 2007. After sowing the seeds were covered with finished light soil. At the end of germination, shading was done by polythene to protect the young seedlings from scorching sunshine and heavy rainfall. Light watering, weeding and mulching were done when necessary to provide seedlings with good or ideal conditions for better growth.

3.4 Treatments of experiment

The research work was conducted with two sets of treatment consisting of 3 levels of plant spacing and 4 levels of potassium fertilizers. The factors with their levels are as follows:

Factor A: Plant spacing (3)

S_1: 60cm x 40cm

S_2: 60cm x 50cm

S_3: 60cm x 60cm

Factor B: levels of potassium fertilizers (4)

K_0: 0 kg /ha (Control)

$K_{1:}$ 60 kg /ha

K_2: 90 kg /ha

K_3: 120 kg /ha

Treatments

Thus there were 12 treatment combinations, which are given below:

i.	S_1K_0	vii.	S_2K_2
ii.	S_1K_1	viii.	S_2K_3
iii.	S_1K_2	ix.	S_3K_0
iv.	S_1K_3	x.	S_3K_1
v.	S_2K_0	xi.	S_3K_2
vi.	S_2K_1	xii.	S_3K_3

3.5 Design of the experiment

Two-factor experiment consisting of 12 treatment combinations was laid out in the randomized complete block design (RCBD) with three replications. At first the whole experimental area was marked with the measuring tape and rope. Total experimental area (27.6m x 11.10m) was divided into three equal blocks, representing the replications. The total number of plots was 36. Size of each unit plot was 2.7m x 1.8m. There were 12 unit plots in each block. The distance between two adjacent blocks and plots were kept 100 cm and 50 cm, respectively.

3.6 Methods of broccoli cultivation

3.6.1 Land preparation

Experimental plot was fallow during land preparation. The land was first opened on October 20, 2007 with a power tiller and it was exposed to the sun for few days prior to next ploughing followed by laddering to obtain good tilth. Weeds were uprooted and stubbles were removed from the field with the help of spades. Big clods were broken into fine soil particles and the surface was leveled until the desired tilth obtained. The soil was treated with insecticides (Cinocarb 3G @ 4kg/ha) at the time of final land preparation to protect young plants from the attack of insects such as cutworm and mole cricket. Experimental field was made plain and the plots were laid out according to plan.

3.6.2 Application of manures and fertilizers

The following doses of manures and fertilizers recommended by Rashid (1999) were applied to the experimental plots to grow the crop as below:

Manure/ fertilizers	Dose/ha	Dose/plot*
Well decomposed cowdung	14ton	6.80kg
Urea	260kg	122gm
Triple Super Phosphate (TSP)	395kg	72gm

MP (potassium)	As per level of treatment	As per level of treatment

*Unit plot size was 2.7m x 1.8m

Potassium was applied at the rate of 0, 60, 90, 120 Kg per hectare in the form of muriate of potash as per treatments in different plots. The entire amount of cowdung was applied at the time of initial land preparation and the total amount of urea and TSP was applied during final land preparation. Potassium was applied as per treatment schedule.

3.6.3 Transplanting

Healthy and uniform sized twenty-nine days old seedlings were transplanted in the experimental plots on 29 November 2007. Seedlings were uprooted carefully from the seedbed to avoid damage the root system. To minimize the damage the roots of the seedlings, the seedbed were watered one hour before uprooting the seedlings. Transplanting was done in the afternoon according to the treatment. The seedlings were watered immediately after transplanting. The young transplants were shaded by banana leaf during day time to protect them from scorching sunshine up to 7 days until they were set in the soil. Transplants were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of the experimental plots for gap filling.

3.6.4 Intercultural operations

Following intercultural operations were done during the period of field experiment:

i) Gap filling

Transplanted seedlings in the experimental plot were kept under careful observation. Very few seedlings were damaged after transplanting and such seedling were replaced by new seedlings from the same stock planted earlier on the border of the experimental plots. Those seedlings were retransplanted with a big mass of soil with roots to minimize transplanting shock. Replacement was done with healthy seedlings having a boll of earth which were also planted on the same date by the side of the unit plot. Transplants were given shading and irrigation for 7 days for their proper establishment.

ii) Weeding

Hand weeding was done at 15, 30 and 45 days after transplanting to keep the plots free from weeds.

iii) Mulching

Mulching was done as soon as the soil became workable after irrigation by breaking the crust of the soil for easy aeration and to conserve soil moisture as and when needed. This operation was done by khurpi or nirani.

iv) Earthing up

Earthing up was done at 20 and 40 days after transplanting on both sides of rows by taking the soil from the space between the rows by a small spade.

v) Irrigation

Light watering was given at every morning and afternoon according to its requirements and was continued for a week for well establishment of the transplanted seedlings.

vi) Pest and disease control

Insect infestation was a serious problem during the period of establishment of seedling in the field. In spite of Cinocarb 3G applications during final land preparation few young plants were damaged due to the attack of mole cricket and cut worm. Cut worms were controlled both mechanically and spraying Darsban 29 EC @ 3%. Some of plants were infected by Alternaria leaf spot disease cased by *Alternaria brassicae*. To prevent the spread of the disease Rovral @ 2 g per liter of water was sprayed in the field. The diseased leaves were also collected from the infested plant and removed from the field. The nightingale visited the fields in the morning and afternoon. The birds were found to puncture the soft leaves and newly initiated curd and were controlled by striking kerosene tin frequently during day time.

3.7 Harvesting

Harvesting of the broccoli var. Premium crop was not possible on a certain or particular date because curd initiation as well as curd maturation period in different plants were not uniform or similar probably due to different management practices and genetic or other factors. Only the compact mature curds were harvested with 2-4 cm stalk by using a sharp knife. According to Thompson and Kelly (1997) the curds were harvested in compact condition before the flower buds opened. Before harvesting of the broccoli head, compactness of the head was tested by pressing with thumbs. After harvesting the main curd, secondary shoots were developed from the leaf axils, which also developed into small secondary curds and were harvested over a period of time. The crop under investigation was harvested for the first time on January 28, 2008 and the last harvesting was done on February 12, 2008.

3.8 Data collection

Ten plants were randomly selected from the middle rows of each unit plot for avoiding border effect except yields of curds, which was recorded plot wise. Data were collected in respect of the following parameters to assess plant growth, yield attributes and yields as affected by different treatments of the experiment. Data on height of the plant, number of leaves per plant and length of largest leaf and breadth of largest leaf were collected 20, 40 and 60 days after transplanting (DAT). All other parameters were recorded during harvest and after harvest. Data were recorded on the following parameters:

3.8.1 Growth parameters

3.8.1.1 Plant height

Height of the plant was measured with a meter scale from the ground level to tip of the longest leaf and data were recorded in centimeter (cm).

3.8.1.2 Number of leaves per plant

Number of leaves per plant was counted excluding the small leaves, which were produced by axillary shoots. The fallen leaves were counted on the basis of scar marks on the stem.

3.8.1.3 Length of leaves

Distance from the base of the petiole to the tip of leaf was considered as length of leaf. It was measured with a meter scale and was recorded in centimeter (cm).

3.8.1.4 Breadth of leaves

Breadth of leaves was recorded from 10 selected plants at 20, 40 and 60 days after transplanting and finally the mean values were calculated and was expressed in centimeter (cm).

3.8.1.5 Length of stem

Length of stem was taken from the ground level to base of the main curd of plant during harvesting. A meter scale was used to measure the length of stem and was expressed centimeter (cm).

3.8.1.6 Diameter of stem

Diameter of the stem was measured at the point where the central curd was cut off. Diameter of the stem was recorded in three dimensions with scale and the average of three values was taken into account and was expressed in centimeter (cm).

3.8.1.7 Length of roots

Length of roots was considered from the base of the plant to the tip of the root. It was measured in centimeter (cm) with a meter scale after harvesting the secondary curds.

3.8.1.8 Fresh weight of leaves per plant

Fresh weight of leaves was recorded in grams (g) from the average of ten (10) selected plants using an electric balance.

3.8.1.9 Dry weight of leaves

At first 100 g leaves of selected plant was collected, cut into pieces and dried under sunshine for a few days and then dried in an oven at 70°C for 72 hours till it was constant. Dry weight was recorded in gram (g) with an electric balance.

3.8.1.10 Fresh weight of roots per plant

Fresh weight of roots was recorded by weighing the total roots and was recorded in gram (g).

3.8.2Yield contributing Parameter

3.8.2.1 Days required for curd initiation

Each plant of the experiment plot was kept under close observation from 40 DAT to count days required for initiation. Total number of days from the date of transplanting to the visible curd initiation was recorded.

3.8.2.2 Primary curd weight

Weight of primary or central curd per plant was recorded in gram (g) by a beam balance.

3.8.2.3 Primary curd diameter

Diameter of primary curd was measured in several directions with meter scale and the average of all directions was finally recorded and expressed in centimeter (cm).

3.8.2.4 Number of secondary curds per plant

Numbers of secondary curds excluding the small shoots were counted when they reached at marketable size.

3.8.2.5 Weight of secondary curds per plant

Total marketable axillary curds of an individual plant were taken and weight was recorded in gram (g) by a weighing balance.

3.8.2.6 Curd dry weight

Sample of 100 g curd was taken, cut into pieces and dried under direct sunshine for 3 days and then dried in an oven at 70°C for 72 hours.The dry weight was recorded in gram (g) with an electric balance.

3.8.3Performance on yield

3.8.3.1 Yield/plant

Yield per plant was calculated by adding the weight of central curd and the weight of all secondary curds harvested and it was measured in gram (g).

3.8.3.2 Yield/plot

Yield per unit plot was calculated by adding the weight of all the central curds and secondary curds produced in the respective plot. Yield of all plants in each unit plot was recorded and was expressed in kilogram (kg).

3.8.3.3 Yield/hectare

Yield per hectare was calculated out by converting per plot yield data to per hectare and was measured in ton (t).

3.9 Statistical analysis

Data were collected from the experimental plot in respect of various characteristics were compiled and tabulated in proper form for statistical analysis. Collected data on different parameters were statistically analyzed using the MSTAT computer package program. Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

3.10 Economic analysis

Economic analysis was done in order to compare the profitability of the treatment combination of different levels of potassium fertilizer and spacing. All input costs including the cost for lease of land and interest on running capital were considered for computing the cost of production. Interests were calculated @ 8% for 6 months. Price of 1 kg broccoli at harvest was considered to be Tk 16.00. Cost and analysis were done in details according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

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

CHAPTER IV

RESULTS AND DISCUSSION

Present study was conducted to determine the effect of spacing and potassium on the growth and yield of broccoli. Data on the effect of spacing and potassium application on yield were recorded. The effect of spacing and potassium in figure 1-6 and tables 1-9 and discussed in this chapter. The analysis of variance (ANOVA) of the data on different plant characteristics yield of broccoli from the present investigation are presented in appendices I-VI. The results have been presented and discussed and possible interpretations have been made under the following sub-headings.

4.1 Growth parameters

4.1.1 Plant height

Plant height was significantly influenced by plant spacing at different days after transplanting (DAT) (Appendix IVa). The tallest (68.57cm) plant was recorded from S_3 (60 cm x 60 cm) spacing which was followed by (66.81 cm) at S_2 (60 cm x 50 cm) and the shortest (64.59 cm) plant was recorded from the closest spacing S_1 at 60 DAT (Fig. 1). The variation in plant height as influenced by spacing was probably due to the proper utilization of nutrient, more space, moisture and light. Similar result was obtained by Mourao *et al*. (2007).

The application of different levels of potassium markedly influenced the height of plants (Appendix IVa). An increasing trend in plant height was observed due to increase of potassium levels. The maximum plant height (69.24 cm) was recorded from the highest dose of potassium (K_3) which was followed by (68.02 cm) at K_2 treatment and minimum plant height (62.9 cm) was recorded from the control K_0 treatment at 60 DAT (Fig. 2). The plant height increased with the progress of time. This might be due to fertilizer supplied adequate plant nutrients for better vegetative growth of broccoli which ultimately increased plant height. Yang *et al.* (2006) also found the similar result in case of plant height.

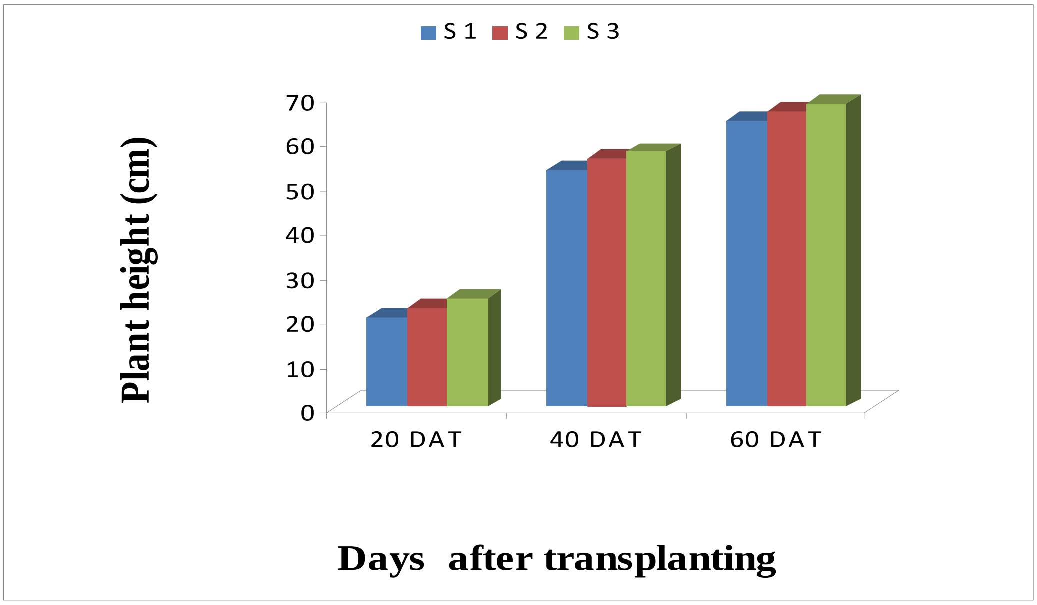


Fig.1. Effect of different plant spacing on plant height at different days after transplanting of broccoli.

Here,

S_1 = 60 × 40 cm^2 S_2 = 60 × 50 cm^2 S_3 = 60 × 60 cm^2

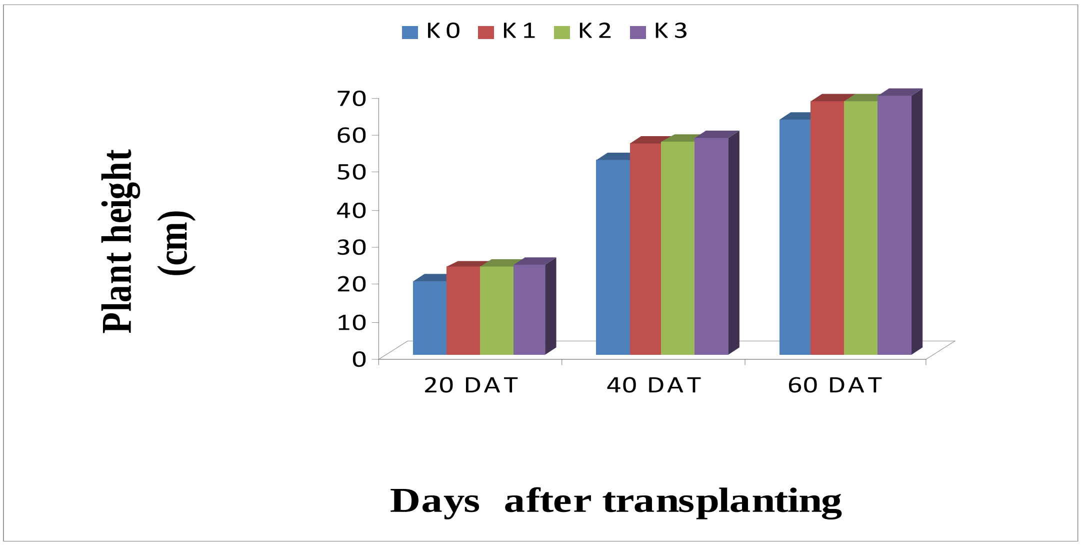


Fig.2. Effect of different levels of potassium application on plant height at different days after transplanting of broccoli.

Here,

K_0 = Control K_1 = 60 kg K/ha K_2 = 90 kg K/ ha K_3 = 120 kg K/ha

Plant height was significantly influenced by the interaction effect of spacing and potassium application (Appendix IVa). The highest plant height (68.68 cm) was observed 60 days after transplanting (DAT) from the treatment combination of S_3K_3 which was followed by treatment combination S_3K_2 (68.50 cm). On the other hand the lowest plant height (63.50cm) was recorded from the treatment combination of S_1K_0 which was significantly different with treatment combination S_2K_0 (Table 1). The results from the treatment combination S_1K_1, S_1K_2, S_1K_3, S_2K_1, S_2K_2 and S_2K_3 showed the intermediate level of plant height compared to other treatment combinations.

Table 1. Effect of different plant spacing and potash fertilizer levels on plant height at different days after transplanting of broccoli

Treatment	Plant height (cm)		
	20 DAT	40 DAT	60 DAT
S_1K_0	19.46 g	54.03 g	63.50 g
S_1K_1	23.07 e	56.47 f	67.42 e
S_1K_2	23.37 de	56.67 ef	67.67 de
S_1K_3	23.64 cd	56.89 de	67.87 cd
S_2K_0	19.10 g	52.32 h	63.40 g
S_2K_1	23.18 de	56.66 ef	67.68 de
S_2K_2	23.59 cd	56.95 de	67.89 cd
S_2K_3	23.97 bc	57.17 cd	68.17 bc
S_3K_0	20.40 f	53.74 g	64.79 f
S_3K_1	24.19 ab	57.37 bc	68.31 b
S_3K_2	24.37 ab	57.53 ab	68.50 ab
S_3K_3	24.59 a	57.74 a	68.68 a
$LSD_{(0.05)}$	0.4729	0.3076	0.3387
CV (%)	8.46	9.32	7.21

Here,

S_1: 60cm x 40cm
S_2: 60cm x 50cm
S_3: 60cm x 60cm

K_0: 0 kg K /ha (Control)
K_1: 60 kg K /ha
K_2: 90 kg K /ha
K_3: 120 kg K/ha

4.1.2 Number of leaves per plant

Number of leaves per plant was varied significantly by spacing at different days after transplanting (DAT) (Appendix IVb). The maximum number of leaves per plant (15.77) was recorded from S_3 (60 cm x 60 cm) spacing which was followed by (14.45) at S_2 (60 cm x 50 cm) and the minimum number of leaves per plant (13.92) was found from the closest spacing S_1 (60 cm x 40 cm) at 60 DAT (Fig. 3). It was observed that the number of leaves was higher in plant with wider plant spacing and was lower in closely spaced plants. It is probably due to inter plant competition having reduced access to nutrient and other resources. The result obtained from the experiment by Kunicki *et al.* (2005) supported this result under the present study.

The application of different levels of potassium markedly influenced the number of leaves per plant (Appendix IVb). The maximum number of leaves per plant (15.90) was recorded from the highest level K_3 of potassium which was followed by (14.72) at K_2 treatment and minimum number of leaves per plant (12.41) was recorded from the control K_0 treatment at 60 DAT (Fig. 4). The number of leaves per plant was increased mainly due to the increased vegetative growth of the plant. Yang *et al.* (2006) also found the similar result in case of number of leaves per plant.

Number of leaves was significantly influenced by the interaction effect of spacing and potassium application (Appendix IVb). Number of leaves per plant (16.33) was observed at 60 days after transplanting (DAT) from the treatment combination of S_3K_3 which was followed by treatment combination S_3K_2 (15.15). On the other hand, the lowest number of leaves per plant (13.09) was recorded from the treatment combination of S_1K_0 at 60 DAT (Table 2). The results from the treatment combination S_1K_1, S_1K_2, S_1K_3, S_2K_1, S_2K_2 and S_2K_3 showed intermediate level of number of leaves per plant compared to other treatment combination.

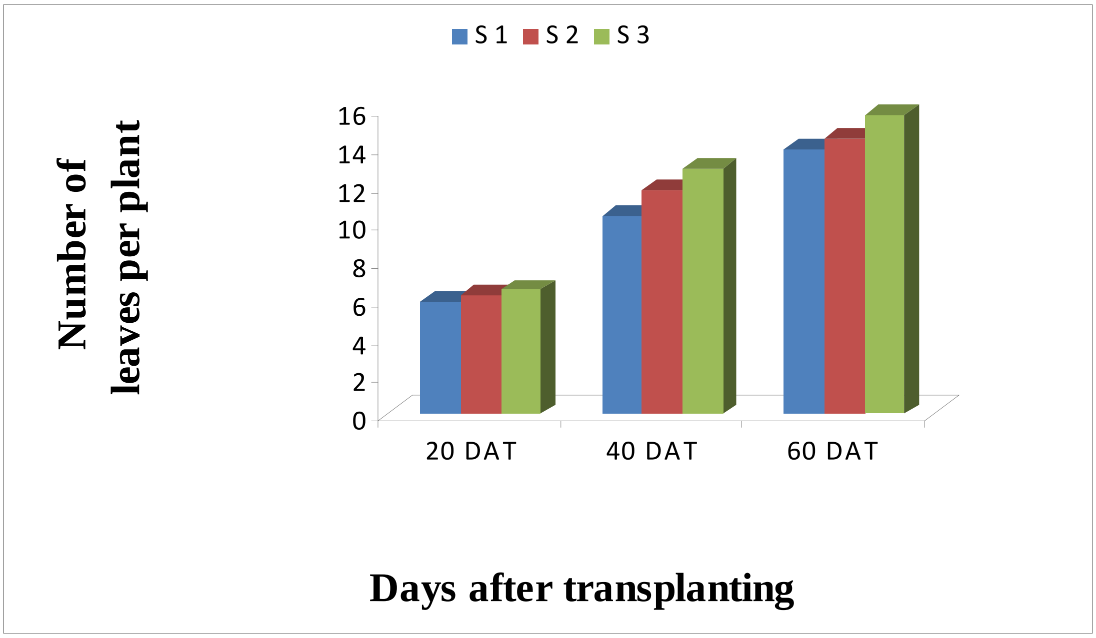


Fig.3. Effect of different plant spacing on number of leaves per plant at different days after transplanting of broccoli.

Here,

S_1 = 60 × 40 cm^2 S_2 = 60 × 50 cm^2 S_3 = 60 × 60 cm^2

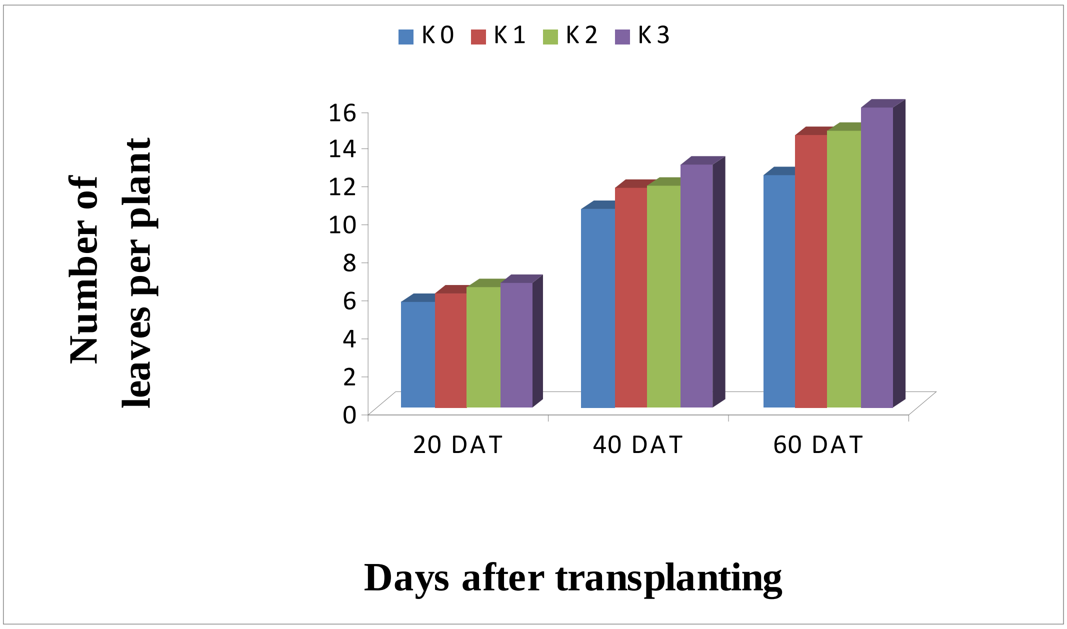


Fig.4. Effect of different levels of potassium application on number of leaves per plant at different days after transplanting of broccoli.

Here,

K_0 = Control K_1 = 60 kg K/ha K_2 = 90 kg K/ha K_3 = 120 kg K/ ha

Table 2. Effect of different plant spacing and potash fertilizer levels on number of leaves per plant at different days after transplanting of broccoli

Treatment	Number of leaves per plant

	20 DAT	40 DAT	60 DAT
S_1K_0	5.38 f	11.27 g	13.09 j
S_1K_1	5.83 e	11.35 fg	13.97 g
S_1K_2	6.02 de	11.48 e-g	14.21 fg
S_1K_3	6.25 cd	11.57 ef	14.40 ef
S_2K_0	5.84 e	11.60 de	13.44 i
S_2K_1	6.05 de	11.69 c-e	14.59 de
S_2K_2	6.48 bc	11.80 b-d	14.81 cd
S_2K_3	6.62 bc	11.98 ab	14.96 bc
S_3K_0	5.67 ef	11.69 c-e	13.70 h
S_3K_1	6.57 bc	11.87 bc	14.88 c
S_3K_2	6.82 b	12.09 b	15.15 b
S_3K_3	8.10 a	13.17 a	16.33 a
$LSD_{(0.05)}$	0.3671	0.2074	0.2395
CV (%)	8.45	6.19	9.06

4.1.3 Length of Leaves

Leaf length of leaf was significantly influenced by spacing at different days after transplanting (DAT) (Appendix IVc). The maximum length of leaf (53.76 cm) was obtained from S_3 (60 cm x 60 cm) spacing which was followed by (51.69 cm) at S_2 (60 cm x 50 cm) and minimum (49.66 cm) leaf length was recorded from the closest spacing S_1 (60 cm x 40 cm) at 60 DAT (Fig. 5). Similar result was obtained by Mourao *et al*. (2007).

The length of leaf was significantly influenced by different levels of potassium (Appendix IVc). The length of leaf was increased with the increasing rate of potassium. The maximum leaf length (53.35 cm) was obtained with the application of the highest level of potassium and it was the lowest (49.45 cm) in the control treatment at 60 DAT (Fig. 6).

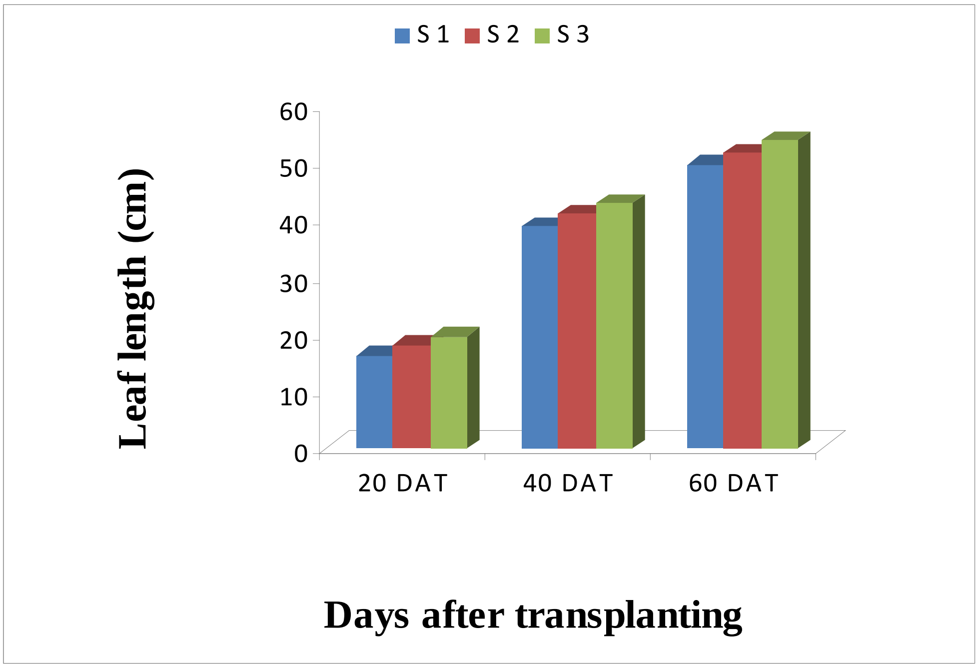


Fig.5. Effect of different plant spacing on leaf length at different days after transplanting of broccoli.

Here,

S_1 = 60 × 40 cm^2 S_2 = 60 × 50 cm^2 S_3 = 60 × 60 cm^2

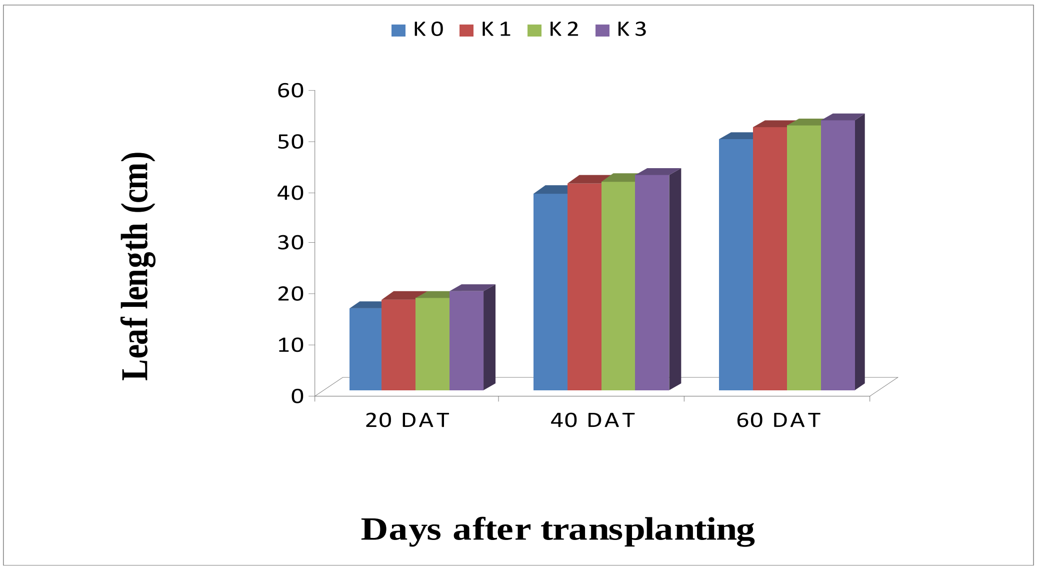


Fig.6. Effect of different levels of potassium application on leaf length at different days after transplanting of broccoli.

Here,

K_0 = Control K_1 = 60 kg K /ha K_2= 90 kg K /ha K_3= 120 kg K / ha

Leaf length was significantly influenced by the interaction effect of spacing and potassium application (Appendix IVc). The longest length of leaf (53.44 cm) was observed 60 days after transplanting (DAT) from the treatment combination of S_3K_3 which was followed by treatment combination S_3K_2 (53.24 cm). On the other hand, the shortest length (49.44 cm) was recorded from the treatment combination of S_1K_0 at 60 DAT (Table 3). The results from the treatment combination S_1K_1, S_1K_2, S_1K_3, S_2K_1, S_2K_2 and S_2K_3 showed the intermediate level of length of leaves compared to other treatment combinations.

Table 3. Effect of different plant spacing and potash fertilizer levels on leaf length per plant at different days after transplanting of broccoli

Treatment	Length of leaf (cm)		
	20 DAT	40 DAT	60 DAT
S_1K_0	16.59 h	38.93 h	49.44 i
S_1K_1	17.21 fg	39.96 g	50.85 g
S_1K_2	17.39 efg	40.18 fg	51.03 fg
S_1K_3	17.62 e	40.38 f	51.31 ef
S_2K_0	17.16 g	40.00 g	50.47 h
S_2K_1	18.26 d	41.11 de	51.84 d
S_2K_2	18.45 cd	41.34 cd	52.13 cd
S_2K_3	18.63 bcd	41.55 c	52.31 c
S_3K_0	17.55 ef	40.85 e	51.44 e
S_3K_1	18.73 abc	41.93 b	52.94 b
S_3K_2	18.95 ab	42.15 ab	53.24 ab
S_3K_3	19.10 a	42.30 a	53.44 a
$LSD_{(0.05)}$	0.3592	0.2782	0.3344
CV (%)	10.11	6.59	7.04

4.1.4 Breadth of Leaves

Leaf breadth was not significantly influenced by spacing at different days after transplanting (DAT) (Appendix IVd). It was observed that the highest (17.24 cm) leaf breadth was recorded from S_3 (60 cm x 60 cm) at all stages. On the other hand, the lowest (16.83 cm) leaf breadth was recorded from S_1 (60 cm x 40 cm) at all stages. It was also observed that S_2 gave intermediate results at all stages (Table 4).

Leaf breadth was significantly influenced by potassium application at different days after transplanting (DAT) except 20 DAT (Appendix IVd). The highest leaf breadth (23.35 cm) was recorded from K_3 treatment 40 days after transplanting

(DAT) which was followed by (18.53 cm) was recorded 60 DAT. On the other hand, the lowest leaf breadth, 19.19 and 15.56 cm was recorded from K_0 40 and 60 days after transplanting (DAT), respectively. It was also observed that K_1 and K_2 at all stages gave the results which indicate intermediate level compared to other levels of potassium application (Table 4). Yang *et al.* (2006) also found the similar result in case of leaf breadth.

Leaf breadth was significantly influenced by the interaction effect of spacing and potassium application (Appendix IVd). It was observed that at 20 DAT there was no significant effect was found but at 40 and 60 DAT significant effect was observed. Highest leaf breadth, 23.40 and 18.00 cm at 40 and 60 days after transplanting (DAT), respectively were recorded from S_3K_3 treatment combinations. On the other hand, the lowest leaf breadth, 19.63 and 15.98 cm were recorded from S_1K_0 at 40 and 60 DAT, respectively. The results from the treatments, S_2K_2, S_2K_3, and S_3k_2 showed higher leaf breadth and S_2K_0 and S_3K_0 showed lower leaf breadth and rest of the treatment showed intermediate results compared to the highest and lowest value of leaf breadth at different days after transplanting (DAT) (Table 4).

Table 4. Effect of different plant spacing and potash fertilizer levels on leaf breadth per plant at different days after transplanting of broccoli

Treatment	Breadth of leaves(cm)		
	20 DAT	40 DAT	60 DAT
Spacing			
S_1	8.172	21.11	16.83
S_2	8.327	21.43	16.95
S_3	8.653	21.93	17.24
LSD $_{(0.05)}$	NS	NS	NS
Potassium			

K_0	7.97	19.19 c	15.56 c
K_1	8.21	21.43 b	17.15 b
K_2	8.45	21.98 b	17.29 b
K_3	8.90	23.35 a	18.53 a
LSD $_{(0.05)}$	NS	0.5761	0.5429
Interaction			
S_1K_0	7.79	19.63 f	15.98 e
S_1K_1	8.17	21.17 e	17.03 d
S_1K_2	8.22	21.27 e	17.13 cd
S_1K_3	8.50	21.36 e	17.19 cd
S_2K_0	8.06	19.45 g	16.02 e
S_2K_1	8.21	21.88 d	17.17 cd
S_2K_2	8.30	22.09 cd	17.23 cd
S_2K_3	8.73	22.29 bc	17.39 bc
S_3K_0	8.07	20.48 f	16.17 e
S_3K_1	8.25	21.25 e	17.26 b-d
S_3K_2	8.84	22.57 b	17.52 b
S_3K_3	9.45	23.40 a	18.00 a
LSD $_{(0.05)}$	NS	0.3710	0.2568
CV (%)	4.59	6.38	7.11

4.1.5 Length of stem

Stem length was significantly influenced by plant spacing during the cropping season (Appendix IVe). It was observed that higher plant spacing; S_1 (60 cm x 40 cm) showed the highest stem length (33.36 cm) and lower plant spacing S_3 (60 cm x 60 cm) showed the lowest stem length (31.57 cm). It was also observed that medium plant spacing S_2 (60 cm x 50 cm) showed intermediate result (32.29 cm) (Table 5). The present result was supported by Mourao *et al.* (2007). This result was supported by Mourao *et al*. (2007).

Stem length was significantly influenced by potassium application during the cropping season (Appendix IVe). It was observed that the highest stem length (32.99 cm) was recorded from K_3 which was significantly similar (32.73 cm) with K_2 and the lowest stem length (31.44 cm) was recorded from K_0. Again K_1 (32.46 cm) showed intermediate result but significantly different from both K_0 and K_3 (Table 5).

Stem length was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix IVe). Highest stem length (33.88 cm) was recorded from S_1K_3 which was significantly similar (33.69 cm) with S_1K_2. On the other hand the lowest stem length (30.62 cm) was recorded from S_3K_0 which was not significantly different (99.40 g) from S_1K_1 and similar (103.80 g) with S_1K_2. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest values of leaf dry weight per plant but significantly different (Table 5).

4.1.6 Diameter of stem

Stem diameter was not significantly influenced by plant spacing during the cropping season (Appendix IVe). But it was observed that higher plant spacing; S_3 (60 cm x 60 cm) showed the highest stem diameter (2.85 cm) and lower plant spacing; S_1 (60 cm x 40 cm) showed the lowest stem diameter (2.72 cm). It was also observed that medium plant spacing; S_2 (60 cm x 50 cm) showed intermediate result (2.80 cm) (Table 5). This result was supported by Mourao *et al*. (2007).

Stem diameter was not significantly influenced by potassium application during the cropping season (Appendix IVe).Highest stem diameter (2.91cm) was recorded from K_3 and the lowest stem diameter (2.69 cm) was recorded from K_0. It was also observed that K_1 (2.76 cm) and K_2 (2.82 cm) showed intermediate result (Table 5).

Stem diameter was not significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix IVe). Highest stem diameter (3.01 cm) was recorded from S_3K_3 and the lowest stem length (2.62 cm) was recorded from S_1K_0. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest values of stem diameter (Table 5).

4.1.7 Length of root

Length of root was significantly influenced by plant spacing during the cropping season (Appendix IVe). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed the highest length of root (28.66 cm) which was not significantly different from medium plant spacing S_2 (60 cm x 50 cm) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest length of root (26.41 cm) (Table 5).

Length of root was significantly influenced by potassium application during the cropping season (Appendix IVe). It was observed that the highest length of root (28.51 cm) was recorded from K_3 which was significantly different (28.18 cm) from K_2 and the lowest length of root (26.62 cm) was recorded from K_0. It was also observed that K_1 (27.70 cm) showed intermediate result but significantly different from both K_0 and K_3 (Table 5).

Length of root was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix IVe). It was observed that the highest length of root (29.56 cm) was recorded from S_3K_3 which was not significantly different (29.26 cm) from S_3K_2. On the other hand, the lowest leaf dry weight per plant (25.33 cm) was recorded from S_1K_0. The results from the treatments, S_2K_2 (28.60 cm), S_2K_3 (28.85 cm) and S_3K_1 (28.54 cm) showed higher length of root and S_1K_1 (26.47 cm) and S_1K_2 (26.69 cm) showed lower length of root but significantly different from highest and lowest results, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of length of root but significantly different (Table 5).

4.1.8 Fresh weight of leaves per plant

Leaf fresh weight per plant was significantly influenced by plant spacing during the total cropping season (Appendix IVf). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed the highest leaf fresh weight per plant (1244.00 g) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest leaf fresh weight per plant (1223.00 g). It was also observed that medium plant spacing S_2 (60 cm x 50 cm) showed intermediate result (1233.00 g) (Table 6).

The result obtained from the experiment by Kunicki *et al.* (2005) which supported this result under the present study.

Leaf fresh weight per plant was significantly influenced by potassium application during the cropping season (Appendix IVf). It was observed that the highest leaf fresh weight per plant (1238.00 g) was recorded from K_3 which was significantly similar with K_2 (1234.00 g). On the other hand, the lowest leaf fresh weight per plant (1230.00 g) was recorded from K_0 which was significantly similar with K_1 (1231.00 g) (Table 6).

Leaf fresh weight per plant was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix IVf). It was observed that the highest leaf fresh weight per plant (1248.14 g) was recorded from S_3K_3 which was not significantly different (1246.12 g) from S_3K_2 and significantly similar (1243.11 g) with S_3K_1. On the other hand the lowest leaf fresh weight per plant (1220.10 g) was recorded from S_1K_0 which was significantly similar (1222.07 g) with S_1K_1. The results from the treatments, S_2K_3 (1239.10 g) and S_3K_0 (1238.09 g) showed higher leaf fresh weight per plant and S_1K_2 (1223.13 g), S_1K_3 (1227.07 g) and S_2K_0 (1229.06 g) showed lower leaf fresh weight per plant but significantly different from highest and lowest results, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest values of leaf fresh weight per plant but significantly different (Table 6).

Table 5. Effect of different plant spacing and potash fertilizer levels on growth parameters of broccoli

Treatment	Length of stem (cm)	Diameters of stem (cm)	Length of root (cm)
Spacing			
S_1	33.36 a	2.72	26.41 b
S_2	32.29 b	2.80	28.19 a
S_3	31.57 c	2.85	28.66 a
LSD $_{(0.05)}$	0.4367	NS	0.5610
Potassium			

K_0	31.44 c	2.69	26.62 c
K_1	32.46 b	2.76	27.70 b
K_2	32.73 ab	2.82	28.18 a
K_3	32.99 a	2.91	28.51 a
LSD $_{(0.05)}$	0.3983	NS	0.3645
Interaction			
S_1K_0	32.96 c	2.62	25.33 f
S_1K_1	33.41 b	2.69	26.47 e
S_1K_2	33.69 ab	2.77	26.69 e
S_1K_3	33.88 a	2.81	27.13 d
S_2K_0	32.62 cd	2.71	27.24 d
S_2K_1	32.45 de	2.78	28.09 c
S_2K_2	32.34 de	2.83	28.60 b
S_2K_3	32.13 ef	2.89	28.85 b
S_3K_0	30.62 i	2.73	27.29 d
S_3K_1	31.63 gh	2.79	28.54 b
S_3K_2	31.88 fg	2.86	29.26 a
S_3K_3	31.25 h	3.01	29.56 a
LSD $_{(0.05)}$	0.4350	NS	0.3344
CV (%)	8.28	4.14	7.88

4.1.9 Dry weight of leaves

Leaf dry weight per plant was significantly influenced by plant spacing during the cropping season (Appendix IVf). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed the highest leaf dry weight per plant (141.10 g) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest leaf dry weight per plant (102.20 g). Medium plant spacing; S_2 (60 cm x 50 cm) showed intermediate result (128.40 g) (Table 6). The result obtained from the experiment by Kunicki *et al.* (2005) supported this result under the present study.

Leaf dry weight per plant was significantly influenced by potassium application during the cropping season (Appendix IVf). It was observed that the highest leaf dry weight per plant (134.80 g) was recorded from K_3 and the lowest leaf dry weight per plant (112.60 g) was recorded from K_0. It was also observed that K_1 (122.20 g) and K_2 (126.00 g) showed intermediate result but significantly different from both K_0 and K_3 (Table 6).

Leaf dry weight per plant was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (IVf). It was observed that the highest leaf dry weight per plant (154.80 g) was recorded from S_3K_3. On the other hand, the lowest leaf dry weight per plant (95.25 g) was recorded from S_1K_0 which was not significantly different (99.40 g) from S_1K_1 and significantly similar (103.80 g) with S_1K_2. The results from the treatments, S_2K_3 (139.30 g), S_3K_1 (139.80 g) and S_3K_2 (144.20 g) showed higher leaf dry weight per plant and S_1K_2 (103.80 g), S_1K_3 (110.40 g) and S_2K_0 (116.80 g) showed lower leaf dry weight per plant but significantly different from highest and lowest result respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest values of leaf dry weight per plant but significantly different (Table 6).

4.1.10 Fresh weight of root per plant

Fresh weight of root per plant was significantly influenced by plant spacing during the cropping season (Appendix IVf). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed the highest fresh weight of root per plant (91.33 g) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest leaf dry weight per plant (81.42 g). Medium plant spacing S_2 (60 cm x 50 cm) showed intermediate result (87.25 g) (Table 6).

Fresh weight of root per plant was significantly influenced by potassium application during the cropping season (Appendix IVf). It was observed that the highest fresh weight of root per plant (91.33 g) and the lowest fresh weight of root per plant (80.89 g) were recorded from K_0. It was also observed that K_1 (85.44 g) and K_2 (89.00 g) showed intermediate result but significantly different from both K_0 and K_3 (Table 6).

Fresh weight of root per plant was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix IVf). Highest fresh weight of root per plant (95.67 g) was recorded from S_3K_3 and the lowest fresh weight of root per plant (74.67 g) was recorded from S_1K_0. The results from the treatments, S_2K_3 (91.67 g), S_3K_1 (90.33 g) and S_3K_2 (92.67 g) showed higher fresh weight of root per plant and S_1K_1 (79.67 g) and S_2K_0 (81.33) showed fresh weight of root per plant but significantly different from highest and lowest result respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of fresh weight of root per plant but significantly different (Table 6).

Table 6. Effect of different plant spacing and potash fertilizer levels on growth parameters of broccoli

Treatment	Fresh weight of leaf per plant (g)	Dry weight of leaf per plant (g)	Fresh weight of root per plant (g)
Spacing			
S_1	1223.00 c	102.20 c	81.42 c
S_2	1233.00 b	128.40 b	87.25 b
S_3	1244.00 a	141.10 a	91.33 a
LSD $_{(0.05)}$	3.469	4.160	1.170
Potassium			
K_0	1230.00 c	112.60 c	80.89 d
K_1	1231.00 bc	122.20 b	85.44 c
K_2	1234.00 ab	126.00 b	89.00 b
K_3	1238.00 a	134.80 a	91.33 a
LSD $_{(0.05)}$	4.006	4.803	1.351
Interaction			
S_1K_0	1220. 10 g	95.25 f	74.67 f
S_1K_1	1222.07 fg	99.40 f	79.67 e
S_1K_2	1223.13 e-g	103.80 ef	84.67 d
S_1K_3	1227.08 d-f	110.40 de	86.67 d
S_2K_0	1229.06 d-f	116.80 d	81.33 e
S_2K_1	1231.12 de	127.40 c	86.33 d

S_2K_2	1234.14 cd	130.20 c	89.67 c
S_2K_3	1239.10 bc	139.30 b	91.67 bc
S_3K_0	1238.09 bc	125.70 c	86.67 d
S_3K_1	1243.11 ab	139.80 b	90.33 bc
S_3K_2	1246.12 a	144.20 b	92.67 b
S_3K_3	1248.14 a	154.80 a	95.67 a
$LSD_{(0.05)}$	6.938	8.320	2.341
CV (%)	9.29	8.78	10.11

4.2 Yield contributing Parameter

4.2.1 Days required for curd initiation

Days required for curd initiation was not significantly influenced by plant spacing during the cropping season (Appendix Va). It was observed that the highest duration (45.76 days) of curd initiation was recorded from S_1 (60 cm x 40 cm) and the lowest (44.16 days) was in S_3 (60 cm x 60 cm). It was also observed that S_2 (60 cm x 50 cm) showed intermediate result (Table 7).

Days required curd initiation was not significantly influenced by potassium application during the total cropping season (Appendix Va). It was observed that the highest duration (45.74 days) of curd initiation was recorded from K_0 and the lowest (44.02 days) from K_3. Treatments K_1 and K_2 showed intermediate result (Table 7).

Days required curd initiation was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix Va). It was observed that the highest duration (46.47 days) of curd initiation was recorded from S_1K_0 which was significantly same with S_1K_1 (46.33 days) and S_2K_0 (46.26 days) and significantly similar with S_1K_2 (45.53 days), S_2K_1 (45.90 days) and S_2K_2 (45.64 days). On the other hand, the lowest duration (43.00 days) of curd initiation was recorded from S_1K_3 which was significantly similar (43.86 days) with S_3K_3 (44.02 days). Results from the treatments, S_2K_3, S_3K_0, S_3K_1 and S_3K_2 showed intermediate results compared to the highest and lowest values of days required curd initiation (Table 7).

4.2.2 Primary curd weight

Primary curd weight was significantly influenced by plant spacing during the cropping season (Appendix Va). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed highest primary curd weight (253.80 g) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest primary curd weight (244.00 g). S_2 (60 cm x 50 cm) showed intermediate result (249.50 g) compared to the highest and lowest value (Table 7). This finding was also supported by Waltert and Theiler (2003).

Primary curd weight was significantly influenced by potassium application during the total cropping season (Appendix Va). Highest primary curd weight (253.00 g) was recorded from K_3 and the lowest (243.50 g) from K_0. Treatments K_1 and K_2 showed intermediate result (Table 7). Similar finding was reported by Guan and Chen (2001).

Primary curd weight was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix Va). It was observed that the highest primary curd weight (252.20 g) was recorded from S_3K_3 which was significantly same with S_3K_2 (251.00 g) and significantly similar with S_2K_3 (250.10 g) and S_3K_1 (249.80 g). On the other hand, the lowest primary curd weight (244.80 g) was recorded from S_1K_0. The results from the treatments, S_2K_2 (249.70 g) and S_3K_0 (249.30 g) showed higher primary curd weight and S_1K_1 (246.10 g) and S_2K_0 (246.50 g) showed lower primary curd weight but significantly different from highest and lowest result, respectively. It was also observed that rest of the treatments showed intermediate results compared to the highest and lowest values of primary curd weight (Table 7).

4.2.3 Primary curd diameter

Primary curd diameter was significantly influenced by plant spacing during the cropping season (Appendix Va). Higher plant spacing S_3 (60 cm x 60 cm) showed the highest primary curd diameter (14.78 cm) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest primary curd diameter (13.77 cm) which was not significantly different from medium plant spacing S_2 (60 cm x 50 cm) (Table 7). This finding was also supported by Waltert and Theiler (2003).

Primary curd diameter was significantly influenced by potassium application during the total cropping season (Appendix Va). Highest primary curd diameter (14.84 cm) was recorded from K_3 which was significantly similar with K_2 and the lowest curd diameter (13.15 cm) was recorded from K_0. It was also observed that K_1 showed intermediate result (Table 7). Similar result was found by Brahma *et al*. (2002) and they observed that application of 80: 30: 20, 100: 60: 40, 150: 80: 60 and 200: 120: 80 kg NPK/ha; NPK at 200: 120: 80 kg /ha resulted in the highest values for head diameter (19.52 cm).

Primary curd diameter was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix Va). It was observed that the highest primary curd diameter (15.31 cm) was recorded from S_3K_3 which was significantly similar with S_3K_2 (15.10 cm). On the other hand the lowest primary curd diameter (12.44 cm) was recorded from S_1K_0. The results from the treatments, S_2K_3 (14.69 cm) and S_3K_1 (14.91 cm) showed higher primary curd diameter and S_1K_1 (13.91 cm), S_2K_0 (13.20 cm) and S_3K_0 (13.80 cm) showed lower primary curd diameter but significantly different from highest and lowest results, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest values of primary curd weight (Table 7).

4.2.4 Number of secondary curds per plant

Number of secondary curd per plant was significantly influenced by plant spacing during the cropping season (Appendix Va). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed the highest number of secondary curd per plant (4.96) which was not significantly different from medium plant spacing S_2 (60 cm x 50 cm) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest number of secondary curd per plant (4.23) (Table 7).

Number of secondary curd per plant was significantly influenced by potassium application during the total cropping season (Appendix Va). Highest number of secondary curd per plant (4.84) was recorded from K_3 which was significantly similar with K_1 (4.55) and K_2 (4.68) and the lowest number of secondary curd per plant (4.38) was recorded from K_0 (Table 7). Similar finding was reported by Guan and Chen (2001).

Number of secondary curd per plant was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix Va). It was observed that the highest number of secondary curd (5.23) was recorded from S_3K_3 which was significantly similar with S_3K_2 (5.01). On the other hand the lowest number of secondary curd (4.01) was recorded from S_1K_0 which was significantly similar with S_1K_1 (4.18). The results from the treatments, S_2K_3 (4.86) and S_3K_1 (4.85) showed higher number of secondary curd and S_1K_2 (4.30), S_1 K_3 (4.41) and S_2K_0 (4.36) showed lower number of secondary curd but significantly different from highest and lowest result, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest values of number of secondary curd. (Table 7)

4.2.5 Weight of secondary curds per plant

Weight of secondary curd per plant was significantly influenced by plant spacing during the cropping season (Appendix Va). It was observed that higher plant spacing S_3 (60 cm x 60 cm) showed the highest secondary curd weight per plant (115.4 g) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest secondary curd weight per plant (108.40 g). Medium plant spacing S_2 (60 cm x 50 cm) showed intermediate (111.30 g) result (Table 7).

Weight of secondary curd per plant was significantly influenced by potassium application during the total cropping season (Appendix Va). Highest weight of secondary curd per plant (116.20 g) was recorded from K_3 and the lowest weight of secondary curd per plant (109.20 g) was recorded from K_0. It was also observed that K_1 and K_2 showed intermediate result (Table 7).

Weight of secondary curd per plant was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season

(Appendix Va). Highest secondary curd weight per plant (117.20 g) was recorded from S_3K_3 and the lowest secondary curd weight per plant (108.10 g) was recorded from S^1K_0. The results from the treatments, S_3K_1 (115.30 g) and S_3K_2 (115.70 g) showed higher secondary curd weight per plant and S_1K_1 (110.50 g), S_1K_2 (111.80 g) and S_2K_0 (109.30 g) showed lower secondary curd weight per plant but significantly different from highest and lowest result, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of secondary curd weight per plant (Table 7).

4.2.6 Curd dry weight

Curd dry weight per plant was significantly influenced by plant spacing during the cropping season (Appendix Va). Higher plant spacing S_3 (60 cm x 60 cm) showed the highest curd dry weight per plant (10.47 g) and lower plant spacing; S_1 (60 cm x 40 cm) showed the lowest curd dry weight per plant (7.20 g). Medium plant spacing S_2 (60 cm x 50 cm) showed intermediate (9.19 g) result (Table 7).

Curd dry weight per plant was significantly influenced by potassium application during the total cropping season (Appendix Va). Highest curd dry weight per plant (10.64 g) was recorded from K_3 and the lowest curd dry weight per plant (7.25 g) was recorded from K_0. It was also observed that K_1 and K_2 showed intermediate result (Table 7).

Curd dry weight per plant was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix Va). Highest curd dry weight per plant (11.50 g) was recorded from S_3K_3 and the lowest curd dry weight per plant (7.52 g) was recorded from S_1K_0. The results from the treatments, S_3K_1 (10.67 g) and S_3K_2 (10.75 g) showed higher curd dry weight per plant and S_1K_1 (8.18 g), S_1K_2 (8.44), S_2K_0 (8.57 g) and S_3K_0 (8.66 g) showed lower curd dry weight per plant but significantly different from highest and lowest result, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of curd dry weight per plant (Table 7).

Table 7. Effect of different plant spacing and potash fertilizer levels on the performance of yield contributing characters of broccoli

Treatment	Days required for curd initiation	Primary curd weight per plant (g)	Primary curd diameter (cm)	Number of secondary curd per plant	Weight of secondary curd per plant (g)	Curd dry weight (g)
Spacing						
S_1	45.76	244.00 c	13.77 b	4.23 b	108.40 c	7.20 c
S_2	45.33	249.50 b	14.15 b	4.64 a	111.30 b	9.19 b
S_3	44.16	253.80 a	14.78 a	4.96 a	115.40 a	10.47 a
LSD $_{(0.05)}$	NS	0.3953	0.4472	0.4007	0.2981	0.3355
Potassium						
K_0	45.74	243.50 d	13.15 c	4.38 b	109.20 d	7.25 c
K_1	45.49	247.50 c	14.36 b	4.55 ab	112.30 bc	8.78 b
K_2	45.07	249.70 b	14.60 ab	4.68 ab	112.70 b	9.15 b
K_3	44.02	253.00 a	14.84 a	4.84 a	116.20 a	10.64 a
LSD $_{(0.05)}$	NS	0.3358	0.4136	0.3443	0.4627	0.3874
Interaction						
S_1K_0	46.47 a	244.80 e	12.44 g	4.01 f	108.10 f	7.52 f
S_1K_1	46.33 a	246.10 d	13.91 e	4.18 ef	110.50 e	8.18 e
S_1K_2	45.53 ab	247.40 c	14.23 de	4.30 e	111.80 de	8.44 de
S_1K_3	43.00 e	247.70 c	14.50 cd	4.41 de	112.20 c-e	9.05 de
S_2K_0	46.26 a	246.50 cd	13.20 f	4.36 de	109.30 ef	8.57 d
S_2K_1	45.90 ab	248.50 bc	14.25 de	4.62 cd	111.30 d	9.13 cd
S_2K_2	45.64 ab	249.70 a-c	14.46 cd	4.73 bc	112.70 cd	9.33 cd
S_2K_3	45.21 bc	250.10 ab	14.69 b-d	4.86 bc	113.10 c	9.67 c
S_3K_0	44.50 cd	249.30 b	13.80 e	4.77 bc	113.20 c	8.66 d
S_3K_1	44.24 d	249.80 ab	14.91 a-c	4.85 bc	115.30 b	10.67 b
S_3K_2	44.03 d	251.00 a	15.10 ab	5.01 ab	115.70 b	10.75 b
S_3K_3	43.86 de	252.20 a	15.31 a	5.23 a	117.20 a	11.50 a
LSD $_{(0.05)}$	0.8700	1.708	0.4759	0.2623	0.5963	0.4043
CV (%)	9.68	10.59	8.23	7.88	11.20	7.44

4.3 Performance on yield

4.3.1 Yield per plant

Yield per plant was significantly influenced by plant spacing during the cropping season (Appendix Vb). Higher plant spacing S_3 (60 cm x 60 cm) showed the highest yield per plant (372.80 g) and lower plant spacing S_1 (60 cm x 40 cm) showed the lowest yield per plant (323.50 g) which was not significantly different from medium plant spacing S_2 (60 cm x 50 cm) (Table 8). The result obtained from the experiment was similar with another finding by Mourao *et al*. (2007).

Yield per plant was significantly influenced by potassium application during the cropping season (Appendix Vb). Highest yield per plant (400.10 g) was recorded from K_3 and the lowest yield per plant (298.60 g) was recorded from K_0. The results from K_1 (314.90 g) and K_2 (347.40 g) showed intermediate result of yield per plant but significantly different from both K_0 and K_3 (Table 8). This may cause probably for the availability of nutrients, lights etc. due to lack of population.

Yield per plant (g) was significantly influenced by the interaction effect of spacing and potassium application during the total cropping season (Appendix Vb). It was observed that the highest yield per plant (439.10 g) was recorded from S_3K_3. On the other hand, the lowest yield per plant (288.40 g) was recorded from S_1K_0 which was not significantly different from S_1K_1 (300.30 g), S_2K_0 (293.90 g) and S_2K_1 (295.00 g) and significantly similar with S_1K_2 (324.60 g), S_2K_2 (328.10 g) and S_3K_0 (313.60 g). The results from the treatments, S_1K_3 (384.30 g), S_2K_3 (376.90 g) and S_3K_2 (389.30 g) showed higher yield per plant but significantly different from S_3K_3. It was also found that treatments S_3K_1 (349.30 g) showed intermediate results compared to the highest and lowest values of yield per plant but significantly different (Table 8).

4.3.2 Yield per unit plot

Significant variation was observed in case of yield per unit plot by plant spacing during the cropping season (Appendix Vb). Lower plant spacing S_1 (60 cm x 40 cm) showed the highest yield per unit plot (6.81 kg) and higher plant spacing S_3 (60 cm x 60 cm) showed the lowest yield per unit plot (5.59 kg) and medium plant spacing S_2 (60 cm x 50 cm) showed intermediate (5.76 kg) result of yield per unit plot (table 8).

Yield per unit plot was significantly influenced by potassium application during the cropping season (Appendix Vb). Highest yield per unit plot (7.15 kg) was recorded from K_3. On the other hand, the lowest yield per unit plot (5.26 kg) was recorded from K_0 which was not significantly different from K_1 (5.62 kg). The results from K_2 (6.19 kg) showed intermediate result of yield per unit plot but significantly different from both K_0 and K_3 (Table 8). This result was similar with another finding by Yang *et al.* (2006).

Significant variation was observed on yield per unit plot with the interaction effect of spacing and potassium application during the total cropping season (Appendix Vb). Highest yield per unit plot (8.07 kg) was recorded from S_1K_3. On the other hand, the lowest yield per unit plot (4.70 kg) was recorded from S_3K_0. The results from the treatments, S_1K_2 (6.82 kg), S_2K_3 (6.78 kg) and S_3K_3 (6.59 kg) showed higher yield per unit plot and S_2K_0 (5.03 kg), S_2K_1 (5.31 kg), S_3K_1 (5.24 kg) and S_3K_2 (5.84 kg) showed lower yield per unit plot but significantly different from highest and lowest result, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of yield per unit plot but significantly different (Table 8).

4.3.3 Yield (t/ha)

Significant variation was observed on yield (t/ha) by plant spacing during the cropping season (Appendix Vb). Lower plant spacing S_1 (60 cm x 40 cm) showed the highest yield (14.02 t/ha) and higher plant spacing S_3 (60 cm x 60 cm) showed the lowest yield (11.51 t/ha) which was not significantly different from medium plant spacing S_2 (60 cm x 50 cm) (Table 8). Similar result was found by Brahma *et al*. (2002) and they observed that application of 80: 30: 20, 100: 60: 40, 150: 80: 60 and 200: 120: 80 kg NPK/ha; NPK at 200: 120: 80 kg /ha resulted in the highest values total yield (18.11 t/ha). Everaarts *et al.* (1997) also reported that N (200-250 kg/ha), P (30 kg/ha) and K (350 kg/ha) gave the best yield of broccoli and Singh *et al.* (1976) studied that the curd yield increased with increasing N and potassium application.

Yield (t/ha) was significantly influenced by potassium application during the cropping season (Appendix Vb). Highest yield (14.70 t/ha) was recorded from K_3. On the other hand, the lowest yield (10.83 t/ha) was recorded from K_0. The results from K_1 (11.56 t/ha) and K_2 (12.74 t/ha) showed intermediate result of yield (t/ha) but significantly different from both K_0 and K_3 (Table 8). This result was similar with another finding by Everaarts *et al.* (1997).

Significant variation was observed on yield (t/ha) with the interaction effect of spacing and potassium application during the total cropping season (Appendix Vb). It was observed that the highest yield (16.61 t/ha) was recorded from S_1K_3. On the other hand the lowest yield (9.69 t/ha) was recorded from S_3K_0. The results from the treatments, S_1K_2 (14.04 t/ha), S_2K_3 (13.96 t/ha) and S_3K_3 (13.54 t/ha) showed higher yield per unit plot and S_2K_0 (10.35 t/ha), S_2K_1 (10.93 t/ha) and S_3K_1 (10.78 t/ha) showed lower yield but significantly different from highest and lowest result, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of yield (t/ha) but significantly different (Table 8).

Table 8. Effect of different plant spacing and potash fertilizer levels on yield and economic performance of broccoli

Treatment	Yield per plant (g)	Yield per unit plot (kg)	Yield (t/ha)
Spacing			
S_1	324.40 b	6.81 a	14.02 a
S_2	323.50 b	5.76 b	11.85 b
S_3	372.80 a	5.59 c	11.51 b
LSD $_{(0.05)}$	6.751	0.1629	1.3387
Potassium			
K_0	298.60 c	5.26 c	10.83 d
K_1	314.90 c	5.62 c	11.56 c
K_2	347.40 b	6.19 b	12.74 b
K_3	400.10 a	7.15 a	14.70 a
LSD $_{(0.05)}$	22.86	0.3619	0.3911
Interaction			
S_1K_0	288.40 d	6.05 de	12.45 de
S_1K_1	300.30 d	6.31 cd	12.98 cd
S_1K_2	324.60 cd	6.82 b	14.04 b
S_1K_3	384.30 b	8.07 a	16.61 a
S_2K_0	293.90 d	5.03 f	10.35 fg
S_2K_1	295.00 d	5.31 f	10.93 f
S_2K_2	328.10 cd	5.91 e	12.16 e
S_2K_3	376.90 b	6.78 b	13.96 b
S_3K_0	313.60 cd	4.70 g	9.69 g
S_3K_1	349.30 bc	5.24 f	10.78 f
S_3K_2	389.30b	5.84 e	12.02 e
S_3K_3	439.10 a	6.59 bc	13.54 bc
LSD $_{(0.05)}$	39.60	0.3257	0.6773
CV (%)	7.49	8.22	9.31

4.4 Performance on economic return

4.4.1 Total cost of production

Significant variation was observed on total cost of production according to different plant spacing (Appendix VI). Lower plant spacing S_1 (60 cm x 40 cm) showed the highest cost of production (100755.25 Tk./ha) and higher plant spacing S_3 (60 cm x 60 cm) showed the lowest cost of production (96335.25 Tk./ha) and medium plant spacing S_2 (60 cm x 50 cm) showed intermediate result in accordance with total cost of production (98705.25 Tk./ha) (Table 9).

Significant variation was observed in case of total cost of production in accordance with potassium application during the cropping season (Appendix VI). Highest cost of production (102919.33Tk./ha) was recorded from K_3. On the other hand, the lowest cost of production (93043.33Tk./ha) was recorded from K_0. The results from K_1 (97981.33 Tk./ha) and K_2 (100450.33 Tk./ha) showed intermediate result of total cost of production (Tk./ha) but significantly different from both K_0 and K_3 (Table 9).

Significant variation was observed on total cost of production (Tk./ha) with the interaction effect of spacing and potassium application during the total cropping season (Appendix VI). Highest cost of production (105076.00 Tk./ha) was recorded from S_1K_3. On the other hand, the lowest cost of production (90780.00Tk./ha) was recorded from S_3K_0. The results from the treatments, S_1K_2 (102607.00 Tk./ha) and S_2K_3 (103026.00 Tk./ha) showed higher cost of production and S_1K_0 (95200.00 Tk./ha), S_2K_0 (93150.00 Tk./ha) and S_3K_1 (95718.00 Tk./ha) showed lower cost of production but significantly different from highest and lowest result, respectively. The rest of the treatments showed intermediate results compared to the highest and lowest values of total cost of production (Tk. /ha) but significantly different (Table 9).

4.4.2 Gross return

Significant variation was observed on gross return (Tk./ha) according to different plant spacing (Appendix VI). Lower plant spacing S_1 (60 cm x 40 cm) showed the highest gross return (257333.33 Tk./ha) and higher plant spacing S_3 (60 cm x 60 cm) showed the lowest gross return (218642.50 Tk./ha) and medium plant spacing S_2 (60 cm x 50 cm) showed intermediate (223867.50 Tk./ha) result in accordance with gross return (Table 9).

Significant variation was observed in case of gross return (Tk./ha) in accordance with potassium application during the cropping season (Appendix VI). Highest gross return (277653.33 Tk./ha) was recorded from K_3. On the other hand, the lowest gross return (205770.00 Tk./ha) was recorded from K_0. The results from K_1 (219703.33 Tk./ha) and K_2 (229997.78 Tk./ha) showed intermediate result of gross return (Tk./ha) but significantly different from both K_0 and K_3 (Table 9).

Significant variation was observed on gross return (Tk./ha) with the interaction effect of spacing and potassium application during the total cropping season (Appendix VI). Highest gross return (315590.00 Tk./ha) was recorded from S_1K_3. On the other hand, the lowest gross return (184110.00 Tk./ha) was recorded from S_3K_0. The results from the treatments, S_1K_1 (246620.00 Tk./ha), S_2K_3 (260110.00 Tk./ha) and S_3K_0 (257260.00 Tk./ha) showed higher gross return and S_2K_0 (196650.00 Tk./ha), S_2K_1 (207670.00 Tk./ha) and S_3K_1 (204820.00 Tk./ha) showed lower gross return but significantly different from highest and the lowest result, respectively. It was also found that the rest of the treatments showed intermediate results compared to the highest and lowest value of gross return (Tk./ha) but significantly different (Table 9).

4.4.3 Net return

Significant variation was observed on net return (Tk./ha) according to different plant spacing (Appendix VI). Lower plant spacing S_1 (60 cm x 40 cm) showed the highest net return (164912.25 Tk./ha) and higher plant spacing S_3 (60 cm x 60 cm) showed the lowest net return (122307.25 Tk./ha) and medium plant spacing S_2 (60 cm x 50 cm) showed intermediate(125162.25 Tk./ha) result in accordance with net return (Table 9).

Significant variation was observed in case of net return (Tk./ha) in accordance with potassium application during the cropping season (Appendix VI). Highest net return (174734.00 Tk./ha) was recorded from K_3. On the other hand, the lowest net return (112726.67 Tk./ha) was recorded from K_0. The results from K_1 (121722.00 Tk./ha) and K_2 (140659.67 Tk./ha) showed intermediate result of net return (Tk./ ha) but significantly different from both K_0 and K_3 (Table 9).

Significant variation was observed on net return (Tk./ha) with the interaction effect of spacing and potassium application during the total cropping season (Appendix VI). Highest net return (210514.00 Tk./ha) was recorded from S_1K_3. On the other hand the lowest net return (93330.00 Tk./ha) was recorded from S_3K_0. The results from the treatments, S_1K_2 (161303.00 Tk./ha), S_2K_3 (157084.00 Tk./ha) and S_3K_3 (156604.00 Tk./ha) showed higher net return and S_2K_0 (196650.00 Tk./ha), S_2K_0 (103500.00 Tk./ha), S_2K_1 (109582.00 Tk./ha) and S_3K_1 (109102.00 Tk./ha) showed lower net return but significantly different from the highest and the lowest result, respectively. Rest of the treatments showed intermediate results compared to the highest and lowest value of net return (Tk./ha) but significantly different (Table 9).

4.4.4 Benefit cost ratio (BCR)

Significant variation was observed on benefit: cost ratio (BCR) according to different plant spacing (Appendix VI). Lower plant spacing S_1 (60 cm x 40 cm) showed the highest BCR (2.63) and higher plant spacing S_3 (60 cm x 60 cm) showed the lowest BCR (2.25) which was not significantly different from medium plant spacing S_2 (60 cm x 50 cm) (Table 9).

Significant variation was observed on benefit cost ratio (BCR) in accordance with potassium application during the cropping season (Appendix VI). Highest BCR (2.69) was recorded from K_3. On the other hand, the lowest BCR (2.20) was recorded from K_0 which was not significantly different from K_1 (2.24). The results from K_2 (2.40) showed intermediate result of BCR but significantly different from both K_0 and K_3 (Table 9).

Significant variation was observed on benefit: cost ratio (BCR) with the interaction effect of spacing and potassium application during the total cropping season (Appendix VI). Highest BCR (3.01) was recorded from S_1K_3. On the other hand, the lowest BCR (2.02) was recorded from S_3K_0 which was not significantly different from S_2K_0 (2.11), S_2K_1 (2.12) and S_3K_1 (2.13). The results from the treatments, S_2K_2 (2.30) and S_3K_2 (2.32) showed lower BCR but significantly different from the highest and the lowest result, respectively. Rest of the treatments, S_1K_0 (2.48), S_1K_1 (2.46), S_1K_2 (2.57), S_2K_3 (2.52) and S_3K_3 (2.55) showed intermediate results compared to the highest and the lowest values of BCR (Tk. /ha) but significantly different (Table 9).

Table 9. Effect of different plant spacing and potash fertilizer levels on yield and economic performance of broccoli

Treatment	Total cost of production (Tk./ha)	Gross return (Tk./ha)	Net return (Tk./ha)	BCR
Spacing				
S_1	100755.25 a	257333.33 a	164912.25 a	2.63 a
S_2	98705.25 b	223867.50 b	125162.25 b	2.26 b
S_3	96335.25 c	218642.50 c	122307.25 c	2.25 b
LSD $_{(0.05)}$	67.86	4470.00	95.21	0.066
Potassium				
K_0	93043.33 d	205770.00 d	112726.67 d	2.20 c
K_1	97981.33 c	219703.33 c	121722.00 c	2.24 c
K_2	100450.33 b	229997.78 b	140659.67 b	2.40 b
K_3	102919.33 a	277653.33 a	174734.00 a	2.69 a
LSD $_{(0.05)}$	78.36	5161.00	109.90	0.076
Interaction				
S_1K_0	95200.00 h	236550.00 d	141350.00 f	2.48 b
S_1K_1	100138.00 e	246620.00 c	146482.00 e	2.46 b
S_1K_2	102607.00 c	230573.33 d	161303.00 b	2.57 b
S_1K_3	105076.00 a	315590.00 a	210514.00 a	3.01 a
S_2K_0	93150.00 i	196650.00 f	103500.00 k	2.11 d
S_2K_1	98088.00 f	207670.00 e	109582.00 i	2.12 d
S_2K_2	100557.00 d	231040.00 d	130483.00 g	2.30 c
S_2K_3	103026.00 b	260110.00 b	157084.00 c	2.52 b
S_3K_0	90780.00 j	184110.00 g	93330.00 l	2.02 d
S_3K_1	95718.00 g	204820.00 ef	109102.00 j	2.13 d
S_3K_2	98187.00 f	228380.00 d	130193.00 h	2.32 c
S_3K_3	100656.00 d	257260.00 b	156604.00 d	2.55 b
LSD $_{(0.05)}$	236.00	8939.11	190.40	0.1312
CV (%)	8.88	7.93	9.81	7.55

CHAPTER V

SUMMARY AND CONCLUSION

Broccoli is a newly introduced winter cole crop in Bangladesh. The field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from October 2007 to February 2008 to determine the effect of spacing and potassium on the growth and yield of broccoli under the Modhupur Tract (AEZ-28). The experiment consisted of two level of treatments, viz. A. Plant spacing (3): S_1 (60 × 40cm^2), S_2 (60 × 50cm^2) and S_3 (60 ×60 cm^2) and B. potassium levels (4): K_0 (0 kg/ha), K_1 (60 kg/ha), K_2 (90 kg/ha) and K_3 (120 kg/ha).

Thirty days old seedlings were transplanted in the plots on 29 November, 2007 and harvested from 28 January to 12 February, 2008. Yield was recorded from all the plants of each plot. An economic analysis was also done to evaluate the profitability of the crop.

The collected data were statistically analyzed and the means were compared with the least significant difference (LSD) values. The result of the experiment revealed that almost all the parameters studied were significantly influenced by the different levels of spacing and potassium fertilizer application.

All parameters were also significantly influenced by plant spacing except leaf breadth, days required for curd initiation and stem diameter of broccoli. The maximum plant height (68.57 cm), number of leaves/plant (15.77), length of largest leaf (53.76 cm) was found in widest spacing S_3 (60 cm x 60 cm) at 60 DAT. The maximum fresh weight of leaves per plant (1244.00 g), leaf dry weight per plant

(141.10 g), length of root (28.66 cm) and fresh weight of roots per plant (91.33 g) were also recorded in widest spacing S_3 (60 cm x 60 cm) at harvest but highest stem length (33.36 cm) was recorded from S_1 (60 cm × 40 cm).

The primary curd weight (253.80 g), primary curd diameter (14.78 cm), number of secondary curd per plant (4.96), weight of secondary curd per plant (115.40 g), curd dry weight per plant (10.47 g) and yield per plant (372.80 g) were also recorded from widest spacing S_3 (60 cm x 60 cm) but the highest yield unit per plot (6.81 kg) and yield per hectare (14.02 t) were obtained from the closest spacing S_1(60 cm x 40 cm) due to accommodation of higher number of plants. The lowest yield unit per plot (5.59 kg) and yield per hectare (11.51 t) were found in the widest spacing (60 cm x 60 cm).

The maximum parameters were significantly influenced by potassium except stem diameter and days required curd initiation of broccoli. The maximum plant height (69.24 cm), number of leaves per plant (15.90), length of the largest leaf (53.35 cm) and the largest leaf breadth (18.53 cm) per plant was found in K_3 (120 kg K/ha) at 60 DAT. The maximum fresh weight of leaves per plant (1238.00 g), leaf dry weight per plant (134.80 g), stem length (32.99 cm), length of root (28.51 cm) and fresh weight of roots per plant (91.33 g) were also recorded in K_3 (120 kg K/ha) at harvest.

Primary curd weight (253.00 g), primary curd diameter (14.84 cm), number of secondary curd per plant (4.84), weight of secondary curd per plant (116.20 g), curd dry weight per plant (10.64 g) and yield per plant (400.10 g), the highest yield unit per plot (7.15 kg) and yield per hectare (14.70 t) were obtained from K_3 (120 kg K/ha) due to higher amount of potassium fertilizer. The lowest yield per unit plot (5.26 kg) and yield per hectare (10.83 t) were found in K_0 (0 kg K/ha).

The combined effect of plant spacing and potassium fertilizer showed significant effect on all parameters except stem diameter. The maximum plant height (68.68 cm), number of leaves per plant (16.33), length of the largest leaf (53.44 cm) and breadth of the largest leaf (18.00 cm) were found in the treatment combination of S_3K_3 (60 cm x 60 cm and 120 kg K/ha) at 60 DAT. The highest leaf fresh weight per plant (1248.14 g), leaf dry weight per plant (154.80 g), length of root (29.56 cm), fresh weight of root per plant (95.67 g) were also found from the same treatment combination at harvest but the highest stem length (33.88 cm) was obtained from the combination of S_1K_3 (60 × 40 cm^2 and 120 kg K/ha). On the other hand, the highest primary curd weight per plant (252.20 g), primary curd diameter (15.31 cm), number of secondary curd per plant (5.23), weight of secondary curd per plant (117.20 g) and curd dry weight per plant (11.50 g) were obtained from the combination of S_3K_3 (60 cm x 60 cm and 120 kg K/ha) but incase of the lowest days required for curd initiation (43.00), the highest yield per unit plot (8.07 kg) and yield/ha (16.61 t) were obtained from the combination of S_1K_3 (60 × 40 cm^2 and 120 kg K/ha). The highest yield per plant (439.10 g) was obtained from S_3K_3 (60 × 60 cm^2 and 120 kg K/ha).

From the economic point of view, it was evident that the highest cost of production Tk. 105076.00/ha, gross return Tk. 315590.00/ha and net return Tk. 210514.00/ha were obtained from the treatment combination of S_1K_3 (60 × 40 cm^2 and 120 kg K/ha). The maximum benefit cost ratio (3.01) was also obtained from the same treatment combination.

Considering all the conditions economic analysis from the present experiment, it can be concluded that application of K_3 (120 kg K/ha) with closest spacing S_1 (60 cm x 40 cm) i.e. S_1K_3 (60 × 40 cm^2 and 120 kg K/ha) was found to be profitable for broccoli production. Further investigation is needed in different agro-ecological zones of Bangladesh. Under variable field condition to confirm the result of the present experiment before recommending it to the growers.

REFERENCES

Alam, M.S., Iqbal, M.T., Amin, M.S. and Gaffer, M.A. 1989. Krishitattik Fasaler Utpadan O Unnayan (in Bengali) T.M. Jubair Bin Iqbal, Manik Potal, Meghai, Sirajgonj. pp. 231-239.

Anonymous, 1988a. Review of vegetable crop programme Memmonite Central Committee (MCC), Bangladesh. pp. 26-35.

Anonymous, 1988b. Crop Status Report. Christian Reformed Worlds Relief Committee, Bogra. pp. 124-127.

Anonymous, 2004. FAO Irrigation and Drainage Paper. Food and Agriculture Organization of the United Nations, Rome, Italy, **3**: 80-82.

Borna, Z. 1976. The effect of high rates of mineral fertilizers and irrigation on the growth of some brassica, root bulb and non-hardy vegetables. Roczniki Akademii Rolniczej w. Poznaniu, Ogrodnictwo. **85**(6): 5-20.[Cited from Hort. Abst., **47**(6): 5456, 1977].

Bose, T. K. and Som, M. G. 1990. Vegetable Crops in India. Naya Prokash, Calcutta, India. pp. 50-51.

Brahma, S., Phookan, D. B. Gautam B. P. and Bora. D. K. 2002a. The effects of NPK fertilizers on the nutrient uptake, yield and quality of broccoli *(Brassica oleracea* L. var *.italica)* cv. KTS-l. Veg. Sci., **29**(2): 154-156.

Brahma, S., Phookan, D. B. Gautam B. P. and Bora. D. K. 2002b. Effect of nitrogen, phosphorus and potassium on growth and yield of broccoli *(Brassica oleracea* L. var. *italica)* cv. Pusa broccoli KTS-l. *Indian J. Agric. Sci. Soc.*, **15**(l): 104-

106.

Cai, Y. P., Liu M. Y. and Liu, Z. M. 1999. A study on N, K application amount on broccoli raised in compound media. *J. Human Agric. Univ*., **25** (2): 99-102.

Csizinszky, A. A. 1987. Nutrition of Cole crops with the full bed polythene mulch system in West-Central Florida. *J. Plant Nutrition*, **10**(9): 1489-1497.

Csizinszky, A. A. and Stanley, C. D. 1984. Effect of trickle tubers per bed N and K rates on spring broccoli and cabbage yields. Soc. Flo. *Pro. Soil and Crop*. **43**: 51-55.

Cuocolo, L. and Duranti, A. 1988. The effect of nitrogen fertilization and plant density on seed yield of cauliflower *(Brassica oleracea var.botrytis)*. Rivistadi Agronomia. **22**(3): 203-207. [Cited from Hort. Abst., 60 (10): 8074, 1990].

Cutclifee, J.A. and Munro, D. C. 1976. Effects of nitrogen, phosphorus and potassium on yield and maturity of cauliflower. *Canadian J. Pl. Sci*., **56** (1): 127-131.

Das, J., Phookan D. B. and Gautam, B. P. 2000. Effect of levels of NPK and plant densities for curd production of early cauliflower *(Brassica oleracea* var. *botrytis) cv.* Pusa Katki. Haryana *J. Hort. Sci*., **29**(3-4): 265-266.

Dufault, R. J. and Waters, J. L. 1985. Interaction of nitrogen fertility and plant populations on transplanted broccoli and cauliflower yields. HortScience, **20**(1): 127-128.

El-Behedi, M. and Nansi, A. A. 1975. The effect of nitrogen level and spacing on cabbage yield. Beitrage for Tropis. Lundwi and Veterinar, **11**(3): 291-297. [Cited from Hort. Abst., **46**(2): 1108, 1976].

Everaarts, A. P., Moel, C. P. D. and Willigen, P. D. 1997. Nitrogen fertilization and nutrient uptake of broccoli. PAV Bul. **2**:16-17. [Cited from Hort. Abst., **68**(7): 5846, 1998].

Gomez. K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural

Research. 2nd edition. John Willy and Sons, New York. pp. 28-192.

Gorski, S. F. and Armstrong, D. M. 1985. The influence of spacing and nitrogen rate on yield and hollow stem in broccoli. Res. Circular, Ohio Agric. Res. and Dev. Center, **288**: 16-18. [Cited from Hort. Abst., **57**(9): 6991, 1987].

Griffith, M. and Carling, D. E. 1991. Effects of plant spacing on broccoli yield and hollow stem in Alaska. *Canadian J. Plant Sci*., **71**(2): 579-585.

Guan, P. C. and Chen, R. Y. 2001. Evaluation of N, K application on plant growth, curd yield characteristics of cauliflower and broccoli. Department of Horticulture, Acta Horticulturae Sinica. **23** (4): 115-119. [Cited from Hort. Abst., **57**(9): 6891, 2003].

Khan, B. A., Shilling, P. G. and Brusewitz, G. H. 1991. Force to shear the stalk, stalk diameter and yield of broccoli in response to nitrogen fertilization and within row spacing. *J. Amer. Soc. Hort Sci*., **116**(2): 222 -227.

Kunicki, E., Capecka, E. Siwek, P. and Kalisz, A. 1999. The effect of plant spacing on the yield and quality of the three broccoli cultivars in autumn growing. Folia Hort., **11**(2): 67-69. [Cited from CAB Abst., 1998-2000].

Kunicki, E., Capecka, E., Siwek, P. and Kalisz, A. 2005. The effect of plant spacing on the yield and quality of three broccoli cultivars in autumn growing. Folia Horticulturae. **11**(2): 69-79. [Cited from CAB Abst., 1998-2000].

Lewandowaka, A.M. and Skapski, H. 1977. The effect of variety, spacing and level of nitrogen fertilization on the quantity and quality of broccoli yield. Biul. Warzywn., **20** : 99-118. [Cited from Hort. Abst., **49** (1): 398, 1979].

Lu H., Jun, X.U., Ren, Z.J., Ping, C.Y. and Yan, M. 1997. Study on features of nutrient absorption and dry matter accumulation in broccoli. *Acta Agric. Shanghai*., **13** (4): 47-50.

Magnifico, V., Lattanzio V., and Sarli, G. 1979. Growth and nutrient removed by broccoli. *J. Amer. Soc. Hort. Sci*., **104** (2): 201-203.

Mathur, M.M. and Vashistha, K.S. 1996. Effect of different spacing cum- nitrogen doses on the yield of broccoli. Udayanika, **2**: 45-47.

Mital, S. P., Singh, R. P., Bhugat, N. R. and Maheswari, M. L. 1975. Response of celery to nitrogen and row spacing. *Indian J. Agron*. **20**(3): 278-279.

Mitra, S. K., Shadu, M. L. and Bose, T. K. 1990. Nutrition of Vegetable Crops. Naya Prokash, Calcutta, India. pp. 157-160.

Mourao, I. M. G., Hadley, P. and Esiyok, D. 2007. Effects of plant spacing on growth and yield of some quality parameters of broccoli. Ziraat Fakultesi Dergisi. **41**(2): 37-48.[Cited from CAB Abst., 2000-2006].

Mullins, C. A. and Straw, R. A. 1990. Broccoli cultivar and spacing trials. Tennese Farm and Home Sci., **156**:11-15. [Cited from Hort. Abst., **57**(6): 6981, 1995].

Munro, D. C., Mackay, D. C. and Cutcliffe, J. A. 1978. Relation of nutrient content of broccoli and brussels sprouts leaves to maturity and fertilization with N, P and K fertilizer. *Canadian J. Plant Sci*., **58** (2): 385-394.

Nassar, S. H., EI-Sherbni, M., Abdelgawad, M. G. and Nasr, M. S. 1982. Effect of some factors on cauliflower seed production. Agric. Res. Rev., **50**(4): 15-23. [Cited from Hort. Abst., **43**(3): 1523, 1974].

Nieuwhof, M. 1999. Cole Crops, Botany, Cultivation and Utilization. Leonard Hill Book Co., England. pp. 100-120.

Perez, A. O. A., Loria. M. W. 1975. Effect of nitrogen, phosphorous, potassium and their interactions on the production of cauliflower in Costa Rica. Boletin Tenhnico, **8**(5): 19. [Cited from Hort. Abst., **47**(6): 521, 1977].

Politanskaya, V. V. 1985. Effect of fertilizers on cauliflower growth and productivity. In: Sovershentvovanie Technologicheskogo Vyrashchivaniya Ovoschnykh kulture V. Otkrytom. RSFSR Leningrad USSR. **57**(5):33-53. [Cited from Hort. Abst., **57**(5): 3356, 1987].

Pornsuriya, P., Pornsuriya, P. and Teeraskulchon, S. 1997. Studies on broccoli production in Chonburi Province, Thailand. Kasetsart *J. Natural Sci*., **32**(4,): 81-85.

Prasad S. and Kumar, U. 1999. Principles of Horticulture. Agrobotanica, 4E 176. J. N. Vyas Nagar, India. p. 6.

Rashid. M. M. 1993. Shabji Biggan (in Bengali). Text Book Division. Bangla Academy, Dhaka, Bangladesh. p. 205.

Rashid. M. M. 1999. Shabji Biggan (in Bengali), (2nd edition).Rashid Pub. House,Dhaka. p.526.

Salter, P. J. and James, J. M. 1985. The effect of plant density on the initiation, growth and maturity of curds of two cauliflower varieties. *J. Hort Sci*. **50**(3): 239-248.

Singh, R. D., Tiwari, S. N., Singh, B. B. and Seth, J. N. 1976. Effect of nitrogen and potash on growth and curd yield of cauliflower variety Snowball-16. Prog. Hort., 7(4): 31-34. [Cited from Hort. Abst., **47**(7): 6508,1977].

Sorensen, L. and Grevsen, K. 1994. Effect of plant spacing on uniformity in broccoli for once-over harvest. Gartenbau wissenschaft, **59**(3): 102-105. [Cited from Hort. Abst., **65**(5): 39-43].

Soto, J. A. 1991. Effect of nitrogen fertilization and spacing on the yield and quality of broccoli during two growing cycles in Cartago. Agonomia Costarricense. **15**(1-2): 19-27. [Cited from Hort. Abst., **64**(9): 1716, 1994].

Thompson, H. C. and Kelly, W. C. 1997. Vegetable Crops. McGraw-Hill Book Company, Inc, New York. p. 308.

Waltert, B. and Theiler, R. 2003. Cauliflower and broccoli: growth pattern and potential yield variation with spacing. **10** (7), pp. 276-281.

Wang, G. Y., Zhang, C.Z. and Zhang, F. S. 2007. Effect of nitrogen, phosphorus and potassium fertilizer on the yield and physiology target of broccoli. China Vegetables. **1**(14-17): 36.

Yang, X. and Guar, P. 1994. Influence of N, K nutrients on texture, quality and nutrient accumulation in heads of green flowered broccoli. Guangdong Agri. Sci., **6**: 21-23. [Cited from Hort. Abst., **67**(2): 1222, 1997].

Yang, X., Guan, P. C. and Chen. R. Y. 2006. Effect of nitrogen, phosphorus and potassium on growth and yield of broccoli (*Brassica oleracea* L. var. italica). China Vegetables. **3**(44-47): 39.

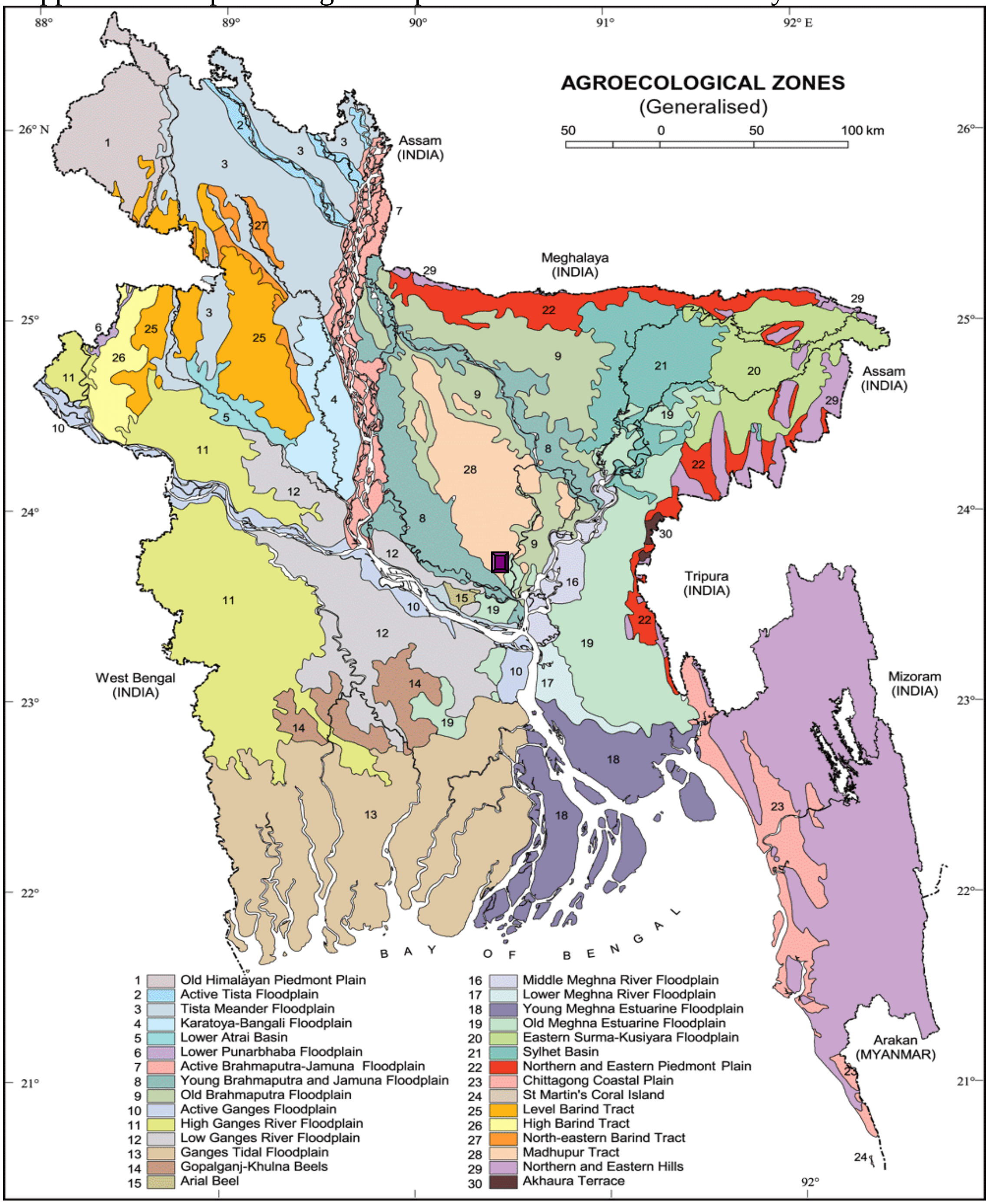
Ying, W. G., Zheng, Z. C. and Shan, Z. F. 1997. Effect of nitrogen, phosphorus and potassium fertilizer on the yield and physiology target of broccoli. China. Vegetables. **1**: 14-17.

Yoldas, S. and Esiyok, D. 2004. Effect of seedling age and plant spacing on yield and quality of broccoli varities in plateau condition. Anadolu, **14** (2): 81-104. [Cited from CAB Abst. 2005].

Zink, F. W. and Akana, F. W. 1991. The effect of spacing on the growth of sprouting broccoli. *Amer. Soc. Hort. Sci., Proc.*, **58**: 160-164.

APPENDICES

Appendix I. Map showing the experimental site under the study



APPENDICES

Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October 2007 to February 2008

Month	Air temperature (^0C)			Average RH (%)	Total rainfall (mm)
	Maximum	Minimum	Mean		
October 07	35.6	19.5	27.55	64.5	320
November 07	31.8	16.8	24.3	67.0	111
December 07	28.2	11.3	19.75	63.0	0
January 08	29.0	10.5	19.75	61.5	23
February 08	30.6	10.8	27.0	54.5	56

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil Characteristics	**Analytical results**
Agrological Zone	Madhupur Tract
P^H	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46

Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix IVa. Analysis of variance of the data on growth parameters of broccoli as influenced by different plant spacing and different levels of Potassium application

Source of variation	Mean some of square			
	Degrees of freedom	Plant height at 20 DAT	Plant height at 40 DAT	Plant height at 60 DAT
Replication	2	5.15	5.74	6.724
Spacing	2	3.92**	3.10**	3.175**
Potassium	3	38.68**	30.81**	38.539**
Spacing and potassium	6	0.034**	0.41**	0.105*
Error	22	0.478	0.533	3.74

Appendix IVb. Analysis of variance of the data on growth parameters of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Mean some of square			
	Degrees of freedom	Number of leaves per plant at 20 DAT	Number of leaves per plant at 40 DAT	Number of leaves per plant at 60 DAT
Replication	2	0.263	0.566	1.391
Spacing	2	1.347**	0.889**	2.208**
Potassium	3	1.777**	0.258**	4.015**
Spacing and Potassium	6	0.091*	0.008**	0.022**
Error	22	1.047	0.105	0.120

* = Significant at 5% level
** = Significant at 1% level

Appendix IVc. Analysis of variance of the data on growth parameters of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Mean some of square			
	Degrees of freedom	Length of leaf at 20 DAT	Length of leaf at 40 DAT	Length of leaf at 60 DAT
Replication	2	1.078	2.179	2.899
Spacing	2	5.934**	11.42*	13.31*
Potassium	3	3.273**	3.976*	6.615*
Spacing and Potassium	6	0.069**	0.002**	0.007**
Error	22	0.245	0.427	0.539

Appendix IVd. Analysis of variance of the data on growth parameters of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Mean some of square			
	Degrees of freedom	Breadth of leaf (cm) at 20 DAT	Breadth of leaf (cm) at 40 DAT	Breadth of leaf (cm) at 60 DAT
Replication	2	0.10	0.14	0.025
Spacing	2	0.72 NS	2.05 NS	0.52 NS
Potassium	3	1.40 NS	8.02*	3.84*
Spacing and Potassium	6	0.15 NS	1.37*	1.48*
Error	22	0.235	0.348	0.523

* = Significant at 5% level
** = Significant at 1% level
NS = Not significant

Appendix IVe. Analysis of variance of the data on growth parameters of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Degrees of freedom	Mean some of square		
		Stem length (cm)	Stem diameter (cm)	Length of root (cm)
Replication	2	1.434	0.038	0.56
Spacing	2	9.78*	0.049^{NS}	17.01*
Potassium	3	4.15*	0.078^{NS}	6.14*
Spacing and Potassium	6	0.51*	0.002^{NS}	5.10**
Error	22	1.166	1.121	3.039

Appendix IVf. Analysis of variance of the data on growth parameters of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Mean some of square			
	Degrees of freedom	Fresh weight of leaf per plant (g)	Dry weight of leaf per plant (g)	Fresh weight of root per plant (g)
Replication	2	25.528	49.043	40.58
Spacing	2	1313.36*	4726.49*	298.08*
Potassium	3	129.81*	764.07*	186.30*
Spacing and Potassium	6	8.58*	26.97*	12.49*
Error	22	3.679	2.414	3.911

* = Significant at 5% level
** = Significant at 1% level
NS = Not significant

Appendix Va. Analysis of variance of the data on yield of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Mean some of square						
	Degrees of freedom	Days required for curd initiation	Primary curd weight (g)	Primary curd diameter (cm)	Number of secondary curd per plant	Weight of secondary curd per plant	Curd dry weight per plant (g)
Replication	2	0.815	3.453	1.632	0.27	3.39	0.20
Spacing	2	8.206^{NS}	2.10*	3.13**	1.64**	47.59*	5.34**
Potassium	3	5.182^{NS}	3.61*	5.06**	0.34**	6.05*	3.09**
Spacing and Potassium	6	1.70*	4.17*	6.07*	3.01**	8.03*	5.15*
Error	22	0.264	3.018	0.307	1.024	2.124	2.057

* = Significant at 5% level
** = Significant at 1% level
NS = Not significant

Appendix Vb. Analysis of variance of the data on yield of broccoli as influenced by different plant spacing and different levels of potassium application

Source of variation	Mean some of square			
	Degrees of freedom	Yield per plant (g)	Yield per unit plot (kg)	Yield (t/ha)
Replication	2	64.61	6.29	26.71
Spacing	2	67.39*	5.24*	22.27*
Potassium	3	25.85*	6.09*	25.73*
Spacing and Potassium	6	63.82*	7.05*	21.12*
Error	22	46.942	3.037	3.161

Appendix VI. Analysis of variance of the economic data on of broccoli from different plant spacing and different levels of potassium application

Source of variation	Mean some of square				
	Degrees of freedom	Total cost of production (Tk./ha)	Gross return (Tk./ ha)	Net return (Tk./ha)	BCR
Replication	2	2143.00	2768.78	901.33	0.06
Spacing	2	5870.00*	52889.44*	6806.00*	0.58**
Potassium	3	1676.25*	87626.00*	6777.58*	0.45**
Spacing and Potassium	6	1128.25*	61589.33*	11109.33*	1.01*
Error	22	6441.45	2786.14	1264.78	1.006

* = Significant at 5% level
** = Significant at 1% level