EFFECT OF PLANT SPACING AND POTASSIUM ON GROWTH AND YIELD OF CABBAGE

BY

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF PLANT SPACING AND POTASSIUM ON GROWTH AND YIELD OF CABBAGE"** submitted to Department of Horticulture and Postharvest Technology of Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **Most. Shamima Khatun** bearing Registration No. 03-01152 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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The Author

Dedicated to
My
BELOVED PARENTS

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ABSTRACT

The experiment was conducted in Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during October 2007 to February 2008 to find out the effect of plant spacing and potassium on growth and yield of cabbage. The experiment consisted of Factor A: three plant spacing; S_1: 60 cm × 30 cm, S_2: 60 cm × 40 cm and S_3: 60 cm × 60 cm and Factor B: four levels of potassium fertilizer; K_0: 0 kg; K_1: 90 kg; K_2: 120 kg and K_3: 150 kg K_2O/ha respectively. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replication. Different treatments showed significant variations on growth, yield components and yield of cabbage. Highest plant height at 60 DAT (37.70cm), maximum diameter of head (19.05 cm) and fresh weight of head (1.87kg) were found from S_3 and lowest was observed from S_1. On the other hand, the tallest plant height at 60 DAT (39.51 cm), maximum diameter of head (18.81 cm) and fresh weight of head (1.62 kg) were found from K_3 and lowest was observed from K_0 treatment. For combined effect the highest plant height at 60 DAT (40.23 cm), maximum diameter of head (21.02 cm), highest fresh weight of head (2.21 kg) were found from S_3K_3 and lowest was observed from S_1K_0 treatment. The highest gross yield (81.89 t/ha), marketable yield (61.30 t/ha) and benefit cost ratio (1.98) was noted from S_2K_3 and lowest from S_1K_0. So, 60 cm × 40 cm spacing with 150 kg K_2O/ha was best for growth and yield of cabbage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleraceae* L. var *capitata)* botanically referred to as family Brassicaceae and the member of cole crops meaning that they are relatively resistant to frost and light freezes. The genus and species *Brassica oleraceae* was developed in western and central Europe from wild species which was found in the Mediterranean region (Nieuwhof, 1969). It had originated from the seacoast of England, Denmark, and Northwestern part of France (Thomson and Kelly, 1957). Although it was originated from temperate region, it has been distributed in both the sub-tropical and tropical area. It is one of the most important leafy vegetables in Bangladesh, and one of the five leading vegetables in the world (Rashid, 1999).

In Bangladesh, cultivation of cabbage is mainly limited in rabi season. The crop is cultivated in an area of 202 thousand acres with a production of 286 thousand metric tones (BBS, 2007). The yield of cabbage is very low (13.40 t/ha) in Bangladesh as compared to that of developed countries (80-100 t/ha) of the world (FAO, 2003). Cabbage has high nutritive value and high consumers demand. It has also some medicinal values furthermore cabbage juice was employed as a gargle against hoarseness and the leaves covered wounds and ulcers to haste healing.However,cabbages were eaten raw as well as cooked. It contains substantial amount of β-carotene (600 IU), phosphorus (0.38%), potassium (2.7%), calcium (0.73%) and 60 mg/100g of ascorbic acid (Bose and Som, 1986). Bogra, Jessore, Kustia, Meherpur and Tangail are the cabbage growing areas in Bangladesh.

Cabbage is a cole crop and prefers cool moist climate (Gilliuary and Parra, 1961). Cultivation of cabbage is done mainly on sandy to heavy soil rich in organic matter. Early crop prefers light soil while late crop thrive better on heavier soil due to retention of moisture. The growth and yield of cabbage largely depend on the soil, climatic conditions and different production practices. The total yield of cabbage could be raised by practicing improved production technology which includes judicious application of fertilizers, proper cultural management and optimum spacing.

Plant spacing is one of the factors that affects growth and yield of cabbage. It is well established that plant spacing has significant influence on growth and yield of cabbage. Yield is a function of inter plant and intra plant competition. Competition associated with different spacing alters plant morphology in various ways. Optimum plant spacing should be maintained to exploit maximum natural resources, such as nutrients, sunlight, soil moisture etc. and to ensure satisfactory yield and proper use of land. The optimum plant spacing depends on several factors including the growing environment, dose of fertilizer, source of nutrients, cultivars used, moisture availability and fertility status of the land. Early planting and wide spacing significantly enhanced the growth of cabbage (Shaker, 1999). The widest spacing (60 cm × 60 cm) resulted in the highest mean total soluble solid (8.77%) and chlorophyll (0.24 mg/g) contents and head diameter (13.95 cm) and weight (1184.33 g) (Mahesh-Kumar *et al.* 2002). Wider plant spacing ensures more leaf number, stem diameter, leaf area, where as closer spacing results in lower plant height, fresh weight, volume and decrease marketable yield of cabbage.

Cabbage is a heavy feeder, especially of potassium (Thompson and Kelly, 1957) for vegetative growth. Potassium fertilizer increases the yield of cabbage, head weight and leaf per plant. Potassium deficiency may affect such varied process as respiration, photosynthesis, chlorophyll development and water content of leaves (Nason and McElroy, 1963). Potassium fertilizers are used frequently for better yield. It was found that application of potassium fertilizer increase the nutrient contents in heads, leaves and increase growth, yield, quality of cabbage. Considering the above mentioned facts, the present study was undertaken with the following objectives:

i) to find out the suitable plant spacing for the maximum growth and yield of cabbage.

ii) to find out the optimum dose of potassium for better vegetative growth, maximum yield and economic return of cabbage, and

iii) to find out the suitable combination of plant spacing and potassium for ensuring the maximum growth and yield of cabbage.

CHAPTER II

REVIEW OF LITERATURE

2.1 Effect of plant spacing on growth and yield of cabbage

Singh *et al.* (2007) conducted an experiment in Allahabad, Uttar Pradesh, India during the winter season of 2000-01 to evaluate the effects of N (0, 40, 80 and 120 kg/ha) and spacing (30 × 45 and 30 × 60 cm) on the growth and yield of cabbage [*B. pekinensis*]. Yield and yield components increased with increasing N levels. Maximum curd weight/plant (1.68 kg) was obtained with N at 120 kg/ha. Spacing at 60 cm × 30 cm resulted in maximum values (38.20, 12.20, 12.20, 15.9 and 34.35 cm) for plant height, leaf number, leaf width, midrib length, and plant spread, respectively.

A field experiment was undertaken from September to December 2002 in Minas Gerais, Brazil to evaluate the effect of plant spacing (80 × 30, 60 × 30 and 40 × 30 cm) and N rate (0, 75, 150, 225 and 300 kg/ha) on the yield of cabbage cv. Kenzan. N was applied at 20% of the total during transplanting and 20% at 20 days after transplanting (DAT) and 30% at 35 and 50 DAT. Data were recorded for fresh head mass per area, fresh head mass, area of external leaves, leaf area index, harvest precocity and returns. Spacing at 80 × 30 cm and 253 kg N/ha were the most suitable treatments for cabbage cultivation under spring conditions (Aquino *et al.*, 2005).

Puiatti *et al.* (2005) studied the effects of three spacings (80 × 30, 60 × 30 and 40 × 30 cm and five rates of N (0, 75, 150, 225 and 300 kg ha^{-1}) on the qualitative aspects of cabbage cv. Kenzan in Minas Gerais, Brazil. The seedlings were produced in trays of 128 cells, under polyethylene cover greenhouse and transplanted 28 days after transplanting date (DAT). The rates of N were divided as follows: 20% of the total rate at transplantation and at 20 DAT, and 30% at 35 and 50 DAT. Plants were harvested from 65 to 83 DAT. The average fresh head weight, transverse and longitudinal diameters, volume of head and total protein content were evaluated, aside from the post harvest losses during storage. A reduction in spacing resulted in lower plant fresh weight, volume, transverse and longitudinal diameters and protein of the heads and increased loss in mass post harvest. Considering the qualitative aspects of the production, the spacing of 40 × 30 cm and the rate of 253 kg ha^{-1} of N, would be the most suitable for cabbage cultivation and commercialization. When the product is destined for processing, the largest spacing would be the most suitable.

Two field experiments were done to study the effect of 2 cultivars, 3 densities and 7 sowing dates on the growth and yield of Chinese cabbage in EL-Bahaira Governorate, Egypt in 2001-2002 and 2002-2003 seasons. The cultivars Chinese Express and Tropical Delight were raised from 7 sowing dates (5, 20 July; 5, 20 August; 5, 20 September and 5 October) and sown in the field on 10, 25 August; 10, 25 September; 10, 25 October and 15 November, respectively. Three different planting densities were compared for each cultivar, i.e. 20000 (70 × 30 cm^2), 15 000 (70 × 40 cm^2) and 12000 (70 × 50 cm^2) plants/feddan. Plant population had a significant effect on marketable yield. Head weight decreased as plant population increased. The most suitable density for this crop was 20000 plants/feddan. This density increased the marketable yield and decreased the percentage of unmarketable heads. The influence of sowing date on yield was mainly related to the duration of the growing period. However, under the condition of the experiments the 10, 25 September and 10, 25 October sowings were the most appropriate for cabbage. Sowing in these dates increased the length, width, weight and yield and gave rise to minimum values of total defects. There was a significant interaction between cultivar, plant density and sowing date. The most satisfactory result was observed on China Express at spacing of

70×30 cm^2 and sowing date of 25 September, which recorded the highest marketable yield, while the lowest value was obtained on Tropical Delight spaced at 70×50 cm^2 and sown on 15 November (Esmail, 2004).

Meena (2003) conducted an experiment in Rajasthan, India, during the rabi season of 1997-98. Three levels of spacing, (30×45 cm), (45×45 cm) and (60×45 cm) had 72,48,36 plants respectively. Plant height was not significantly affected by increasing levels of spacing at all crop growth stages. Leaf number per plant significantly increased with increasing levels of spacing at 30 and 60 days after transplanting (DAT). The percent increase in leaf number per plant was 8.33 at 30 DAT, and 9.98 at 60 DAT. Stem diameter significantly increased with increasing levels of spacing. Stem diameter was highest (1.28 cm) with recorded 1.15- and 1.00-cm diameters, respectively. Leaf area was highest with (315.41 cm^2), and lowest with (310.83 cm^2) at harvest. The average head weight was highest under (831.25 g), and lowest under (766.33 g). The percent increase in head weight was 8.47. A significant increase in biological and economical yield was observed. The percent harvest index was highest (71.25) and lowest (70.29). Closer spacings resulted in higher biological and economic yields.

Fujiwara *et al.* (2003) carried out an experimental a high uniformity of cabbage weight was obtained using a small-spreading and early-ripening cultivar despite high density planting because of shorter period of competition between plants and higher head weight/top weight ratio. A high uniformity of cabbage head weight in winter sowing-early summer harvesting cropping type (cropping type for rising temperatures) was successfully maintained despite the high density condition compared with summer sowing-winter harvesting cropping type (cropping type for decreasing temperatures) because of suppressed spreading of the initial growth.

A field experiment was conducted at village Pemasar, in Bikaner district (Rajasthan, India) during the rabi season 2001-02 to find out the economics of cabbage (Brassica oleracea var. capitata) production. The wider spacing recorded the maximum yield and highest net return in the crops. In cabbage, the highest net return was obtained in treatment combination of 60 × 60 cm spacing + 150 kg N ha^{-1} (Amreesh, 2002).

Ferreira *et al.* (2002) carried out a study on Brassica crops have been widely studied due to their importance as food for human consumption, especially in relation to their nutritional value. Both yield and consumption are high. *Brassica chinensis* var. parachinensis was introduced in Uberlandia, Minas Gerais, Brazil, in 1992, surpassing other Brassica due to its high content of vitamins A and C, calcium and iron, and for becoming ready for consumption in about 30 days. The yield of this variety was analyzed under three kinds of fertilizers and three spacings with a view to its production on a commercial scale. The leaf area, dry matter mass, and absolute growth rate were higher with mineral than organic fertilizer. High values for relative growth rate and net assimilation rate were recorded in plants growing in greater spacings (30 × 20 and 30 × 30 cm). The highest value of agronomic yield (21.5 t/ha) was reached in the smallest spacing (30 × 10 cm), with mineral fertilizer application. This value is near to that registered in Malaysia and China where this vegetable is cultivated on a large scale.

Mahesh-kumar (2002) conducted a field experiment in Udaipur, Rajasthan, India, in 1997/98 to study the effects of N (0, 50, 100, 150, and 200 kg/ha as urea) and spacing (30 × 60, 45 × 60, and 60 × 60 cm) on the quality and yield of cabbage cv. Pride of India. The highest total soluble solid (8.80%) and chlorophyll (0.29 mg/g) contents and head diameter (14.30 cm) were obtained with 200 kg N/ha. However, 150 kg N/ha gave the highest mean head weight (1127.22 g) and head yield (312.42 q/ha). The widest spacing

(60 × 60 cm) resulted in the highest mean total soluble solid (8.77%) and chlorophyll (0.24 mg/g) contents and mean head diameter (13.95 cm) and weight (1184.33 g). A spacing of 30 × 60 cm gave the highest head yield (303.09 q/ha).

A field experiment was conducted in Mymensingh, Bangladesh, from October 1996 to March 1997 to study the effects of irrigation regime and spacing (50 × 60, 50 × 50, and 50 × 40 cm) on cabbage cv. Atlas-70. A spacing of 50 × 40 cm resulted in the highest gross yield (118.72 t/ha). The widest spacing gave the highest fresh weight of individual head (2.376 kg). The highest marketable yield (79.69 t/ha) and harvest index (80.17) were obtained with a spacing of 50 × 50 cm. Net return (Tk. 128,026/ha) and benefit cost ratio (2.63) were highest with a spacing of 50 × 50 cm (Mannan *et al.*, 2001).

Tendaj and Kuzyk (2001) carried out that a research was to check whether greater plant density in cultivation of late red cabbage cultivars influence the size of yield and the weight of the forming heads. Seedlings of three cabbage cultivars - Langendijker Pol, Rodima and Roxy were planted at 30 × 45 cm, 40 × 45 cm, 50 × 45 cm and 60 × 45 cm spacing, what equaled the density of 7.4, 5.5, 4.4 and 3.7 plants m^{-2}. It was demonstrated that various plant density had no significant effect on the size of the marketable yield of heads but it was significant for their weight. The largest marketable yield was obtained at 4.4 and 5.5 plants m^{-2} density, i.e. at the spacing 40 × 45 cm, and 50 × 45 cm, (on average 61.9-63.9 tha^{-1}). Such plant density was advantageous for forming heads of rather low weight on average 1017-1250 g.)

Fujiwara *et al.* (2000) conducted an experiment to study the effects of planting densities of cabbage plant transplants in the field on the uniformity of their initial growth and head size at harvest. Head size uniformity decreased with small within-row spacing (WRS) from the beginning of head formation. Unevenness of initial-growth of high-density transplants resulted in a decrease of uniform head size at harvest. This lack of uniformity is attributed to the initial differences in growth which increased with time. Retarding harvest time did not improve growth uniformity. Gaps within the row and the slow growth of some plants promoted the growth of adjacent plants. This tendency was strong under high densities. Hence, growth uniformity was decreased with time. Head size uniformity at harvest decreased when WRS was small. The degree of the decrease was controlled by the initial-growth uniformity of transplants.

Mannana *et al.* (1999) undertaken an experiment on six water regime treatments (40, 60, 80 or 100% of field capacity, or switching between 40 and 100% capacity at different growth stages) were applied to cabbages grown at 50 × 60, 50 × 50 or 50 × 40 cm spacing. Among the water regime treatments, 80% field capacity gave the highest growth and dry matter of stem, leaf and head and total DM, and highest marketable yield per hectare. Severe stress produced the highest (19.19 g) dry matter of roots per plant and root shoot ratio. Growth, dry matter accumulation and yield were higher when stress was applied in vegetative growth than at heading. The maximum growth and dry matter of leaves, head, stem and root were obtained from the widest spacing (60 × 50 cm) and the lowest from the closest spacing (50 × 40 cm). Maximum marketable yield was obtained from the moderate spacing of 50 × 50 cm.

A field experiment was conducted in 1993-96 in Gujaratto study the response of cabbage cv. Golden Acre to irrigation levels, plant spacing (30 × 30 or 40 × 30 cm) and N application (150-250 kg/ha) in clay soil. Mean marketable head yield increased with irrigation at up to IW: CPE of 0.7 (18.3 t/ha). Mean marketable head yield was highest with 250 kg N (20.6 t), but was not significantly different at 2 spacings, but the yields were consistently higher at the narrow spacing (Parmar *et al.*, 1999).

Sandhu *et al.* (1999) conducteda trial on plant growth characters in cabbage variety Golden Acre in Punjab, India during 1989-90 and 1990-91 under the influence of twelve combinations of spacing (30, 45, 60 and 75 cm row to row and 15, 30 and 45 cm plant to plant) and six levels of nitrogen (0, 62.5, 125, 187.5, 250 and 312.5 kg/ha). The application of 187.5 and 125 kg N/ha with wider spacing of 75 × 45 cm and 75 × 30 cm produced maximum plant spread. However, the application of 125 kg N/ha with closer spacing of 45 × 45 and 30 × 45 cm produced the highest total yield of cabbage heads with good head compactness, which may be due to more number of plants per unit area. Total yield and head compactness were reduced considerably with the increase in nitrogen level beyond 187.5 kg N/ha.

Shaker (1999) carried out two field experiments during two successive winter seasons (1996/97 and 1997/98) in Egypt to evaluate the effects of planting date (first week of November, December or January) and spacing (40, 50 and 60 cm between plants) on cabbage cv. Balady. Data were recorded for plant height, number of branches per plant, number of inflorescences per plant, inflorescence length, number of pods per inflorescence, pod length and seed yield. Early planting and wide spacing significantly enhanced the growth of cabbage. However, early planting and narrow spacing recorded the highest seed yield per feddan.

An experiment was carried out to study the effects of N (0, 50, 75 or 100 kg/ha) and spacing (30 × 60, 45 × 60 or 60 × 60 cm) on the growth and yield of cabbages (cv. Golden Acre), at K.V.K. Badgaon, Udaipur, India. Growth (number of leaves, height of plant and weight of head) increased with increasing rates of N. The highest yield (254.85 q/ha) was observed at 100 kg N/ha compared with 168.73 q/ha in control. Yield decreased with increasing plant density, from 245.22 q/ha at a spacing of 30 × 60 cm to 184.71 q/ha at a spacing of 60 × 60 cm (Gopal, 1996).

Mallik (1996) determined that the response of cabbage cv. Pusa Drum Head to N fertilizer application rate (0, 40, 80 or 120 kg/ha) and spacing (60 × 45 or 60 × 60 cm) in field trials conducted on a sandy loam soil during the winter season of 1989-90. Yield increased with increasing rate of N application (57.76 and 331.46 q/ha with 0 and 120 kg/ha, respectively) and was higher at the closer spacing than at the wider spacing (229.53 and 207.37 q/ha, respectively). Highest net profit and cost: benefit ratio were obtained at 120 kg N/ha and at the closer spacing

Balvoll (1994) conducted trials over 3 years, the hybrid cultivars Erdeno (vigorous), Apex (which has considerably less free [outer] leaf area than other cultivars) and Bartolo (intermediate growth). In addition to a basic dressing of 180-200 kg N/ha, some plots received one or 2 applications of 77 kg N/ha as a top dressing. The plants were spaced 30, 40 or 50 cm apart in rows 43 cm apart. Each kg of N top dressing gave a yield increase of 130 kg/ha, regardless of the cultivar or spacing. The closest spacing resulted in a higher yield/ha than the widest spacing, with no marked difference in response between the cultivars. Erdeno showed most variation, with a standard deviation in head weight of 500-600 g and a coefficient of variation of about 30%, compared with 300-400 g and about 27%, respectively, for the other cultivars. Plants were grown on a 3-row bed system. In 2 of the years the row direction was E-W and in these years the row in the bed facing S. gave a lower yield, probably because it received greater exposure to the sun than did the other 2 rows. The difference in yield response between rows was lowest at the highest level of N top dressing.

Freyman *et al.* (1992) carried out study on the effects of intra-row competition by C. bursa-pastoris, grown either 10 or 25 cm apart, with cabbages cv. Tucana grown on well-drained soil in single rows and spaced 20 or 50 cm apart within the rows. At 50 cm spacing, cabbage head weight was reduced by C. bursa-pastoris grown at either spacing. However, at 20 cm spacing, cabbage head weight was unaffected by C. bursa-pastoris grown 25 cm apart but was reduced in 1 of 2 years when the weed was grown 10 cm apart. When cabbages were grown weed-free in 3 rows at either 20 × 100 or 50 × 40 cm spacing, no differences in yield were measured. The results indicate that cabbages grown in wide rows with close within-row spacing should experience minimal intra-row weed competition.

Jaiswal *et al.* (1992) conducted an experiment on cabbage cv. Pride of India on 4 September 1985 and transplanted on 10 October 1985 at a spacing of 30 × 30 cm or 30 × 20 cm. N was applied at 125, 250 or 375 kg/ha. Half of the N was applied as a basal dose and as top dressing 2 weeks after transplanting (WAT). The remaining 1/4 of the N was applied as a top dressing 4 WAT (M_1) or as a foliar application at 4, 5, 6 or 7 WAT (M2). Plant growth and productivity increased with increasing level of N application and was highest under M2. Plant growth was highest at the wider spacing but productivity (yield/ha) was highest at the smaller spacing. Highest yield (770.77 q/ha) was obtained with 375 kg N/ha applied under M_2 at 30 × 20 cm.

Orowski (1991) studied in 3-year trials with the cultivar Amager; the seeds were sown at 6 or 0.6 g/m superscript 2 in rows 10, 15, 20 or 25 cm apart. The sowing treatments had no marked effect on transplant quality but the highest total 3-year marketable yield of head cabbage viz. 156.2 t/ha, were obtained by sowing at 0.6 g/m row with rows 20 cm apart. The transplant raising treatment had generally no adverse effect on crop quality.

Hill (1990) studied in an experiment at Manjimup Research Station on a sandy loam over clay at 60 cm, Chinese cabbage cv. Early Jade Pagoda was grown at spacing of 25 × 25, 30 × 30, 35 × 35 or 40 × 40 cm and given 0, 50, 100, 200, 300 or 400 kg N/ha. The highest marketable yields, 126.6 and 123.6 t/ha, were produced at the wider spacing, with N fertilizer rates of 200 and 300 kg/ha, respectively. Marketable yield for this spacing increased as N rate increased from 0 to 200 kg/ha, remained constant from 200 to 300 kg/ha and decreased when N rate was increased to 400 kg/ha. Soft rot damage was severe at the highest N rate and contributed to the reduced yield. The yield potential of Chinese cabbage was higher at wider spacing than at the close spacing. Plant height was not affected by any treatment, but plant width increased at the higher N rates.

A trial from 1979 to 1981 with 25-day-old cabbage (cv. Capitata) seedlings was conducted with 3 spacings (50 × 30 cm, 50 × 40 cm or 50 × 50 cm) and with 2 rates of N (75 or 150 kg N/ha) and P (40 or 80 kg /ha) fertilization, on a sandy clay loam. All of the P was applied at planting, half the N was applied at planting and rest half 25 days later. Without additional N and P, cabbage head yield was greatest (110.56 kg/ha) with the closest spacing. Yield increased with increasing rate of N application. P increased yield significantly only in the presence of additional N. High planting density and application of 150 kg N/ha and 80 kg P/ha were recommended (Prabhakar and Srinivas 1990).

Farooque and Islam (1989) conducted trials with the cultivar K-K Cross, between October 1987 and Mar. 1988, the plants spaced at 60 × 30, 60 × 45 or 60 × 60 cm were subjected to 3 different fertilization schedules. Marketable yields for the 3 spacings were 10.4, 10.3 and 8.9 t/ha, respectively. Of the fertilizer treatments, application (per ha) of 8.3 t FYM + 200 kg mustard oilcake + 326 kg urea + 125 kg triple super phosphate + 200 kg muriate of potash gave the highest marketable yield of 13.7 t/ha whereas, the control yield was 6.3 t/ha with no fertilizer treatment.

Islam *et al.* (1989) conducted a field trial in 1987/88 at Mymensingh,with 21, 28, 35 and 42 days old seedling, of the cultivar Atlas 70 and the plant were spaced at 60 × 30, 60 × 45 and 60 × 60 cm. The highest marketable yield of 39.3 t/ha was obtained with 42-day-old seedlings spaced 60 × 60 cm, and the lowest yield of 29.8 t/ha with 28-day-old seedlings spaced 60 × 30 cm.

Khadir *et al.* (1989) determined on this study for 2 consecutive seasons to investigate the effects of 3 levels of urea (0, 300 and 600 kg/ha) and 3 plant spacing (20, 30 and 40 cm within rows) on the growth and yield of cabbage. Yield, mean head weight and diameter were greatest at the maximum fertilizer level. Increasing the plant density increased total yield and decreased head weight and diameter. Increasing the nitrogen level to 600 kg urea/ha and the plant spacing to 40 cm resulted in an increase in leaf number/plant and leaf N and protein contents during the two seasons of vegetative growth, and at harvest. The highest yield (80.84 t/ha) was obtained from 600 kg urea/ha and a 20-cm within-row spacing, whereas the best quality was achieved using the same fertilizer level but with a 40-cm spacing.

2.2 Effect of different levels of potassium on growth and yield of cabbage

Sheng *et al.* (2006) carried out an experiment on the effects of K fertilizers on the yield, quality and nutrient uptake in cabbage in China. The application of K significantly increased the yield. The increments in yield due to MOP [muriate of potash] were correlated with K rate and soil properties. At the optimum K rate, plants supplied with MOP were superior in yield, nutrient use efficiency and quality to plants supplied with SOP [sulfate of potash]. The nutrient content of plants supplied with SOP was higher than that of plants treated with MOP. SOP enhanced the uptake of Ca, Mg, Fe and Mn, whereas MOP improved the uptake of P and K. The results suggested that MOP is the optimum K source for leafy vegetables such as cabbage.

Rajender (2005) studied that N (60, 120, 180 and 240 kg/ha), P (30, 60 and 90 kg/ha) and K (30 and 60 kg/ha) were supplied to cabbage hybrid Bajrang during the rabi seasons of 1998/99 and 1999/2000 in Nauni, Solan, Himachal Pradesh, India. In general, 120 kg N + 60 kg P + 60 kg K/ha and 240 kg N + 90 kg P and 60 kg K/ha recorded the highest head yields of 413.99 and 421.15 q/ha and BC ratios of 2.61 and 2.53, respectively.

The yield was increased by 23.67% (1234.5 kg/667 m2), quality was improved and NO content of autumn cabbage was decreased by using organic compound fertilizer. The N, P and K removal rates for 1000kg cabbage was 3.7, 1.07 and 6.0 kg, respectively. The N : P : K ratio was 1 : 0.29 : 1.60. The maximum nutrient absorption rate was recorded at 60-80 days after sowing (Jiang *et al.* 2005).

Gue, *et al.* (2004) studied that cabbage [Brassica oleracea var. capitata] was grown in two field trials in Hefei, Anhui, China. N-P-K was applied at rates of 0 - 60 -0, 350 - 60 -0, 450-60-0, 0-60-300, 350-60-300, and 450-60-300 kg/ha. Nitrogen and potassium and their proper combination significantly improved the yield and its nutrient use efficiency. Potassium sulfate markedly increased the content of ascorbic acid and sugars, and alleviated the unfavorable effect of irrational nitrogen application. Urea increased the content of amino acids, while nitrogen and potassium enhanced the nutritional value of the essential amino acids. Ascorbic acid and sugar contents were correlated negatively with N content in cabbage heads and positively with potassium content. It was concluded that adequate potassium and optimum combination of nitrogen and potassium will help ensure high quality and yield.

Wang *et al.* (2004) conducted a field trial in China to investigate the effects of N and K rates on the nutrient uptake and partitioning of cabbage. Sole N application increased the contents of N, B, Mn and Zn, but reduced the contents of K, Ca, Mg, Cu and Fe. Sole K increased the contents of K and other microelements in the heads, but reduced N, Ca and Mg contents. Application of N and K increased nutrient proportion in heads and leaves, which increased growth, yield, quality and nutritional value of cabbage.

Marsic *et al.* (2004) carried out an experiment to find out the effect of fertilization and broadcast mineral fertilizer application on yield and quality of 4 cabbage (*B. oleracea* var. capitata) cultivars in Ljubljana, Slovenia. Five treatments were formed: K=classical fertilization with 150 kg N ha-1 (broadcast incorporated); F< sub>NPK</ sub>=all nutrients (NPK) were applied via fertilization; F< sub>N</ sub>=P and K were added by classical methods and total N by fertilization; F< sub>NPK/30%</ sub>=30% of total N was incorporated before transplanting, total P and K and remaining N were applied via fertilization; F< sub>N/30%</ sub>=total P and K and 30% of total N were incorporated before transplanting, the remaining N was applied via fertilization. During the harvest, the height and width of the cabbage, length of stalk, weight of head with leaves and without leaves, height and width of cleaned head, firmness of head and core length were measured and the number of external trimmed leaves was counted. The highest average marketable yield was achieved by fertilization with soluble nutrients, combined with pre-plant broadcast N incorporation, with each individual cultivar as follows: Hermes F1 (38.7 t ha^{-1}), Parel F1 (71.1 t ha^{-1}) and Tropicana F1 (70.7 t ha^{-1}) and the lowest by fertilization with N, where the total amount of P and K were pre-plant broadcast incorporated, with cultivars as follows: Hermes F_1 (20.9 t ha^{-1}), Parel F_1 (50.4 ha^{-1}), Tropicana F_1 (63.0 t ha^{-1}) and Field winner F_1 (66.1 t ha^{-1}). The firmness of cabbage heads was also affected by the method of nutrient application.

Loncaric *et al.* (2003) carried out field experiments during 1999-2001 in two localities in eastern Croatia to determine the effects of fertilizers on the yield of early Savoy cabbage (*Brassica oleracea* var. sabauda). The yields of Savoy cabbage heads (fresh matter) were 29-31 t ha^{-1} under no fertilizer and 56-59 t ha^{-1} under the highest fertilizer rate. The average weights of Savoy cabbage heads were 469 and 947 g, and the dry matter contents of heads were 101 and 69 g kg ha^{-1} under no fertilizer and highest fertilizer level, respectively. The total dry matter production ranged from 4.6 t ha-1 in the control plots to approximately 7 t ha^{-1} in plots treated with the highest fertilizer rate; the uptake of 100-206 kg N ha^{-1}, 43-73 kg P ha^{-1} and 161-261 kg K ha^{-1} was also observed. Based on yield increase, total above ground mass, and head weight, the optimum nitrogen fertilizer rate for Savoy cabbage was between 200 and 300 kg ha-1. The yield response to fertilizer application was higher on soil with lower N, P and K contents before treatment. The increase in the N fertilizer rate resulted in the increase in yield, and N content and uptake, but the increase in the rate of P and K fertilizers did not affect yields. Increased fertilizer rate resulted in lower dry matter content but higher dry matter production. Nutrient removal per tonne of head yield was highest for K (4.2-5.6 kg), followed by N (3.3-3.5 kg) and P (1.2-1.5 kg). Crop residues of Savoy cabbage contained 42-83 kg N, 13-24 kg P and 51-96 kg K ha-1.

Salo and Suojala (2002) conducted trial on broadcast application of solid NPK fertilizer with cabbage (cv. Castello),). In the broadcast application, P and K were given as a single application in spring and N was split according to the existing recommendations. In the fertilization applications, nutrients were given according to the expected nutrient uptake rate based on previous experiments. Growth and nutrient uptake were monitored by monthly samplings. In 1998, growing season was extremely rainy, and N leaching from conventional broadcast application was expected. However, leaching seemed to have no impact in the sandy experimental soil, as broadcast application resulted in good growth of cabbage. In 1999, natural rainfall was low, and irrigation was applied according to tensiometer measurements. Treatments affect cabbage growth and nutrient uptake were still decreased by fertilization towards the middle of the growing period. At harvest, cabbage yields and nutrient uptakes were similar between the treatments. Cabbage yields averaged to over 90 t/ha in both years. At harvest, total nutrient uptakes were 213-243 kg N/ha, 36-40 kg P/ha and 302-345 kg K/ha.

Chaubey *et al.* (2001) did an experiment in Pantnagar, Uttar Pradesh, India, during winter of 1996/97 and spring-summer of 1997 to study the effect of N:P:K level (60:30:30, 120:60:60, 180:90:90, and 240:120:120 kg/ha) on the yield and yield-contributing characters (head gross and net weight, head shape index, core length, ascorbic acid, marketable head percentage, and marketability period of heads after maturity) of 23 cultivars. The analysis of variance revealed significant differences among cultivars and fertilizer levels in both seasons for all characters studied. The yield ranged from 105.61 to 590.82 q/h. Net head weight and size increased at higher fertility levels; however, head shape index was unaffected. The percentage of marketable heads and their durability also increased at higher levels of fertilizer. Winter-spring season proved to be favourable for higher cabbage productivity.

An experiment was determined in Tianjin, China [date not given] to determine the effect of potash application (at 0, 150, 225, 300 kg K/ha) on the time of ripening and yield of cabbage. Treatment with potash at 225 kg K/ha resulted in a more rapid heading, rapid maturation and improved cabbage quality compared to other treatments. This treatment produced the highest commercial yield increase of 17.4 t/ha and the highest profit for the farmer (9970 yuan/ha). In the Tianjin region, the rate of 225 kg K/ha, along with 225 kg N/ha and 60 kg P/ha is recommended for cabbage production on soils represented by this trial. This application should bring the farmer a net profit of 9000 to 10 000 yuan/ha, depending on local market prices (Zhou *et al.*, 2001).

Yang *et al.* (2001) studied the effect of water uptake, accumulated dry matter content, and dry matter output per litre of water in cabbage plants grown under different soil water potentials and at different fertilizer application rates during October-December 1996. For the same range of soil water potential, an increase in N application rate increased N content in cabbage leaves and roots while P and K contents decreased. The amount of N, P and K absorbed was maximum at 300 kg N/m2, medium at 0 fertilizer application rate and minimum at 1200 kg N/m2. N/P and N/K values increased with increases in fertilizer application rate, leading to non-equilibrium of nutrient uptake and inhibition of normal growth.

Cubeta *et al.* (2000) developed three hypotheses that involved manipulation of soil calcium (Ca), potassium (K), and pH in relation to the occurrence of leaf tipburn of cabbage in eastern North Carolina, USA and tested: (1) adding K to soil will increase leaf tipburn; (2) adding Ca and K together to soil will block K-related tipburn induction, and (3) raising soil pH to levels of 6.0 to 6.5 will decrease leaf tipburn. Six experiments were conducted in commercial cabbage production fields in eastern North Carolina in 1996 and 1997 to test these hypotheses. Hypothesis 1 was accepted since higher rates of K significantly increased leaf K concentration, soil K content and leaf tipburn incidence compared with the control. Total cabbage yield increased as K rates increased, however, significant differences were only observed between the control and the highest rate (365 kg K/ha) in 1996. Hypothesis 2 was accepted since adding increased amounts of Ca and K did not significantly increase leaf tipburn incidence. Hypothesis 3 was rejected since a range of soil pH from 5.3 to 6.6 did not increase or decrease leaf tipburn incidence, nutrient uptake or total yield. The data suggest that leaf tipburn of cabbage can be increased (induced) with excessive K fertilization and that this practice may be associated with the disorder observed in North Carolina. The addition of Ca with K may potentially reduce the risk associated with K-related leaf tipburn of cabbage.

Liu *et al.* (1999) studied that the effect of different ratios of NPK combination on yield and nitrate accumulation of cabbage the levels of N were 0, 180, 360, and 540 kg/ha; the levels of P were 0, 90, 180, 270 kg/ha; the levels of K were 0, 90, 180, 270 kg/ha. The plant density of cabbage was 31 500/ha. The result was obtained with $N_{360} + P_{90} + K_{180}$. The nitrate accumulation was increased with the increase of the amount of N applied. Phosphate fertilizer had no significant effect on nitrate accumulation in plant; however, potassium fertilizer had a significant effect on nitrate content in plant. Thirty and 50 days after planting were two key periods for fertilizer application on cabbage.

Rutkauskiene and Poderys (1999) studied the influence of mineral fertilizer rates on the yield and quality of cabbage was studied in the field at the Experimental station of the Lithuanian University of Agriculture in 1997-98. The highest harvest of cabbage was obtained at fertilizer rates (kg/ha) of N 240 P 120 K 180 and N_{300} P_{120}, K_{180}. Increasing the dose of nitrogen fertilizers decreased the quantity of vitamin C [ascorbic acid] and increased the concentration of nitrates in cabbage heads. Phosphorus fertilizers had no significant impact on yield and quality of heads. Potassium fertilizers decreased the yield, but increased head quality.

Vanparys (1998) studied that the effects of potassium application rate (0, 100 and 200 kg k/ha) and cultivar (Bingo, Marathon and Zerlina) were compared in white cabbage in Belgium. Seeds were sown on 22 April 1997, seedlings planted out on 30 May, fertilized on 3 June, and harvested on 7 (Bingo and Zerlina) and 11 October (Marathon). Significant differences were found between cultivars for crop stand, uniformity, leaf color, stem and head height, head color (before and after cooking), structure, crop weight and percentage of marketable heads. Significant differences between fertilizer treatments at harvesting were found for crop stand, crop height, number of leaves, head form and width, cooking color and crop weight, as well as in dry matter, vitamin C and phosphorus contents. After storage, significant differences occurred in dry matter, nitrate, chloride, vitamin C, magnesium, phosphorus contents.

Zhong *et al.* (1997) carried out a field experiment in Zhejiang, China, to investigate the K requirement of cabbage and its relation to shoot DM accumulation. The seedling stage was identified as the critical stage for K nutrition and the heading stage as the most efficient. The shoot DM contents at the different growth stages were positively correlated with the amounts of K absorbed by the shoots during the same stages and the proportions of DM in the head or mesophyll, in relation to the total amount of DM in the shoot, increased with increasing K fertilizer application, indicating that K not only promotes DM accumulation but also affects its distribution. It was also observed that 66-77% of the total amount of K, and 76-82% of shoot DM were accumulated during the heading stage. The results suggest that K fertilizers should be applied at the start of the heading stage.

Chen (1996) conducted an experiment on the effects of NPK fertilizers (control, 20:20:20 and 31:10:10) on the quality of plug seedlings of 3 cabbage cultivars (K-Y, Kaiya, Chun-Chon No.1) during the summer season in central Taiwan. Good results with regard to growth, seedling index and the G value of the absolute growth rate (AGR) were obtained for plug seedlings of Chun-Chon No.1 and Kaiya. Significant differences among the fertilizer treatments were found for plant height, number of leaves, leaf area, shoot fresh weight, leaf length, and leaf width. The best results were obtained with the 31:10:10 fertilizers, followed by the 20:20:20 fertilizer. This latter treatment gave better results with regard to the balance of seedling index and G value of AGR.

Bubnova (1995) studied that fertilizer experiments with cabbage (cv. Slava) in pots (50 × 50 × 40 cm) of alluvial meadow soil with residual K contents of 10, 35 or 56 mg/kg soil. N was applied at 0, 2.25, 4.5 or 6.75 g/pot, and K at 0, 2.25, 4.5 or 9 g/pot. N had the greater effect on yield, 2.25-6.75 g N/pot giving a crop yield of 2183-3028 g/pot (an increase of 66-130%).

Tarata *et al.* (1995) observed that Autumn cabbages (cv. De Buzau) were grown with 8 different fertilizer treatments representing various combinations of N (50, 100, 200, 300 or 400 kg/ha), P (50, 100 or 150 kg/ha) and K (50, 100 or 150 kg/ha). Data are presented on leaf area per plant, foliar index (superscript 2/ha), rate of photosynthesis, photosynthetic potential (kg/ha), total biomass, and yield. The highest yields were obtained when the leaf area was 43000 superscript 2/ha and the photosynthetic potential was ~90 t/ha, i.e. with fertilizer treatments of 300 kg N + 100 kg P + 100 kg K/ha. The ratio of total biomass to harvested crop was constant at 3:1, and was unaffected by fertilizer treatment or yield level.

Halim *et al.* (1994) conducted a trial in 1990-91 at Jamalpur, N was applied at 0, 100, 150 or 200 kg/ha, P at 0, 50, 100 or 150 kg and K at 0, 75, 150 or 225 kg K /ha in 12 combinations to cabbage cv. K-K cross. Gross yield and marketable head weight per plant were highest with 150 kg N + 100 kg P+ 150 kg K or 200 kg N + 100 kg P+ 150 kg K.

Sarkar *et al.* (1994) conducted a field experiments during winter 1991-92 and 1992-93 on sandy loam soil of pH 5.1-5.8 at Kanke, cabbage cv. Pride of India was given 0, 50, 100, 150 or 200 kg K/ha. Head yield increased as K rate increased from 29.98 t/ha with no K to 47.36 t/ha with 200 kg K/ha. This was mainly due to increases in average head weight and equatorial diameter. Days to maturity declined significantly as K rate increased up to 100 kg K /ha.

Hardter *et al.* (1994) studied that cabbages on clay soil received potassium sulfate at 0, 150, 300 or 450 kg K/ha, with or without 30 kg MgO/ha, applied in the furrow. N and P were applied with all treatments. Yield was higher with 150 kg K/ha than with no K, but did not increase significantly with higher rates or with Mg. The best cash return (20% more than with no K) was obtained with 150 kg K/ha. Under all treatments, NO content of leaves and midribs decreased from the outermost to the innermost leaves, while K content increased.

Zhang *et al.* (1993) reported that they showed the absorption and distribution of mineral nutrient elements in leaves of cabbage cv. Lubai 8. The results indicated that the mineral nutrient element content increased with plant growth, most rapidly from 30 to 70 days after emergence.

Jothi *et al.* (1993) carried out a field trial in Tamil Nadu, India, and found a cabbage yield of 117.2 t/ha with the application of N,P,K at 100,125 and 250 kg/ha, respectively.

Samanta *et al.* (1992) investigated the balance fertilizer use for cabbage in clay loam soils of Orissa, India. It was reported that nitrogen (75 kg/ha) and potassium (150 kg/ha) gave the highest yield (17.42 t/ha), and it was the economic dose.

An experiment was carried out at Joydebpur, Gazipur on cabbage (var. Atlas-70) during the Rabi season to fiend out the effects of fertilizer doses and organic manure on the yield of cabbage. The application of 120 kg K/ha along with cow dung @ 5 t/ha produced highest head yield of 75 t/ha (Anonymous, 1991).

Yestistrin and Vural (1991) mentioned that the effects of various fertilizer applications on cabbage yield and quality. Nitrogen was applied at 10 or 20 kg/ha and K at 15 or 30 kg K_2O/ha. They reported that highest yield was obtained with 20 kg N + 30 kg K_2O/ha.

Rao and Subramanian (1991) conducted an experiment to fiend out the effect of potassium application on the yield and content of potassium, calcium and magnesium in cabbage at Bangalore in India. K_20 was applied @ 0, 25, 100, 150 and 200 kg/ha. They observed that the plant K concentration at all stages of growth increased significantly as the level of K_20 application dose was increased.

Farooque ad Islam (1989) reported that the cabbage cultivar K-K cross gave the highest marketable yield when 8.3 t FYM, 200 kg mustard oil cake, 326 kg urea, 125 kg TSP and 200 kg MP per hectare were applied.

Lawande *et al.* (1986) conducted an experiment on nitrogen, phosphorus, potassium fertilizer application in cabbage. Plant received N at 80-240 kg/ha P_2O_5 at 0-80 kg/ha and K_2O at 0-80 kg/ha. They noted that cabbage response to the highest N and P rates, but the responds to K was little. It was reported that the highest head of cabbage was obtained with 76.64 t/ha from the combined effect of 180 kg N/ha, 60 kg P/ha, 180 kg K/ha and cow dung @ 5t/ha (Anonymous, 1990) and it was stated that a combination of the fertilizer was important rather than application of a single fertilizer for the production of cabbage.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted at Horticulture Farm in Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The trial was carried out during rabi season (4 October 2007 to 15 February 2008). The site was located in 24.09^0 N latitude and 90.26^0E longitude. The altitude of the location was 8.2m from the sea level (The Meteorological Department, Agargaon, Dhaka – 1207).

3.2 Climate

The experimental plot was situated in the sub-tropical monsoon climate, which is characterized by heavy rainfall during the month of Kharif season (April to September) and scanty rainfall during the rabi season (October to March). Cabbage is grown in a cool and moist climate. A temperature range of 15–21^0C is considered as optimum for growth and head formation of the crop. Details of weather data in respect of temperature (^{0}C), rainfall (cm) and relative humidity (%) were collected from the Meteorological Department, Agargaon, Dhaka (Appendix I).

3.3 Soil

The soil condition as well as soil texture of the experimental area was sandy loam and belonged to the Modhupur Tract (AEZ – 28). The land was medium high with adequate irrigation facilities. The soil was having a texture of sandy loam with pH 5.6. Cultivation of cabbage was done mainly on sandy soils rich in organic matter. Physical and chemical properties of soil in the experimental field of Horticulture Farm in Sher-e-Bangla Agricultural University (SAU), Dhaka were given in Appendix II.

3.4 Planting materials used for the experiment

Seeds of "Atlas-70" variety of cabbage were used in the experiment. The seeds were F_1 hybrid produced by Sakata Seed Corporation, Japan and were collected from Kamal Seed Store, Fulbaria Dhaka, Bangladesh.

3.5 Seed bed preparation

Seed bed was made on 6 October for cabbage seedlings raising. The size of the seed bed was 3.2 m × 1.2 m. For making seed bed the soil was well ploughed and converted into loose friable and dried masses to obtain good tilth.Weed stubbles and dead roots were removed from the seed bed. The surface of the bed was made smooth and well leveled. Well decomposed FYM @ 2-3 kg/m^2 was added at the time of bed preparation. Raised beds are necessary to avoid problem of water logging in heavy soils.

3.6 Seed Treatment

Seeds were treated by vitavax 200 WP @ 2.5 g/kg of seed to protect some seed borne diseases such as damping off and leaf spot.

3.7 Seed Sowing

Seeds were sown on 6 October 2007 in the seedbed. The soil of the seed bed was well prepared and made into loose friable mass by spading. The bed was covered with dry straw or grass or sugarcane leaves to maintain required temperature and moisture. Sowing was done thinly in lines spaced at 5 cm distance and the seeds were sown at a depth of 2 cm and covered with a fine layer of soil followed by light watering with a water can. The watering should be done till germination is completed. The cover of dry straw or grass was removed immediately after emergence of seedlings.

3.8 Raising of Seedling

Light watering and weeding were done as a when needed. No chemical fertilizer was applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy 30 days old seedlings were transplanted on 6 November 2007.

3.9 Design of experiment

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. Two factors were used in this experiment where three types of spacing and four levels of potassium fertilizer.

Factor A

Three different spacing: denoted as (S)

S_1 : 60 cm × 30 cm

S_2 : 60 cm × 40 cm

S_3 : 60 cm × 60 cm

Factor B

Four levels of Potassium: denoted as (K)

K_0 : Control

K_1 : 90 kg K_2O/ha

K_2 : 120 kg K_2O/ha

K_3 : 150 kg K_2O/ha

Therefore, the treatment combinations are S_1K_0, S_1K_1, S_1K_2, S_1K_3, S_2K_0, S_2K_1, S_2K_2, S_2K_3, S_3K_0, S_3K_1, S_3K_2 and S_3K_3.

3.10 Layout of the field experiment

The experiment area was first divided into 3 blocks. Each block was divided into 12 plots for the treatment combinations. Therefore, total numberof plots were 36 and 12 treatment combinations were assigned to each block as per design of the experiment. The size of the unit plot was 3.2 m × 1.2 m. A distance of 50 cm was maintained between the plot and 1 m between the block. Thus, the total land area was 20.9 m × 13.6 m.

3.11 Land Preparation

The experimental field was ploughed to fine tilth by giving four to five ploughing. The land should be properly leveled, corner tiller followed by laddering to bring a good tilth. The weeds, crop residues and stables were removed from the field. The basal doses of manure and fertilizers were applied at the final ploughing after final preparation of the land, prepare 1m wide and 15cm high bed. Distance between two beds 50 cm wide were maintained wich helped in irrigating crop as well as drainage. According to design, layout plot was prepared on 20 October.

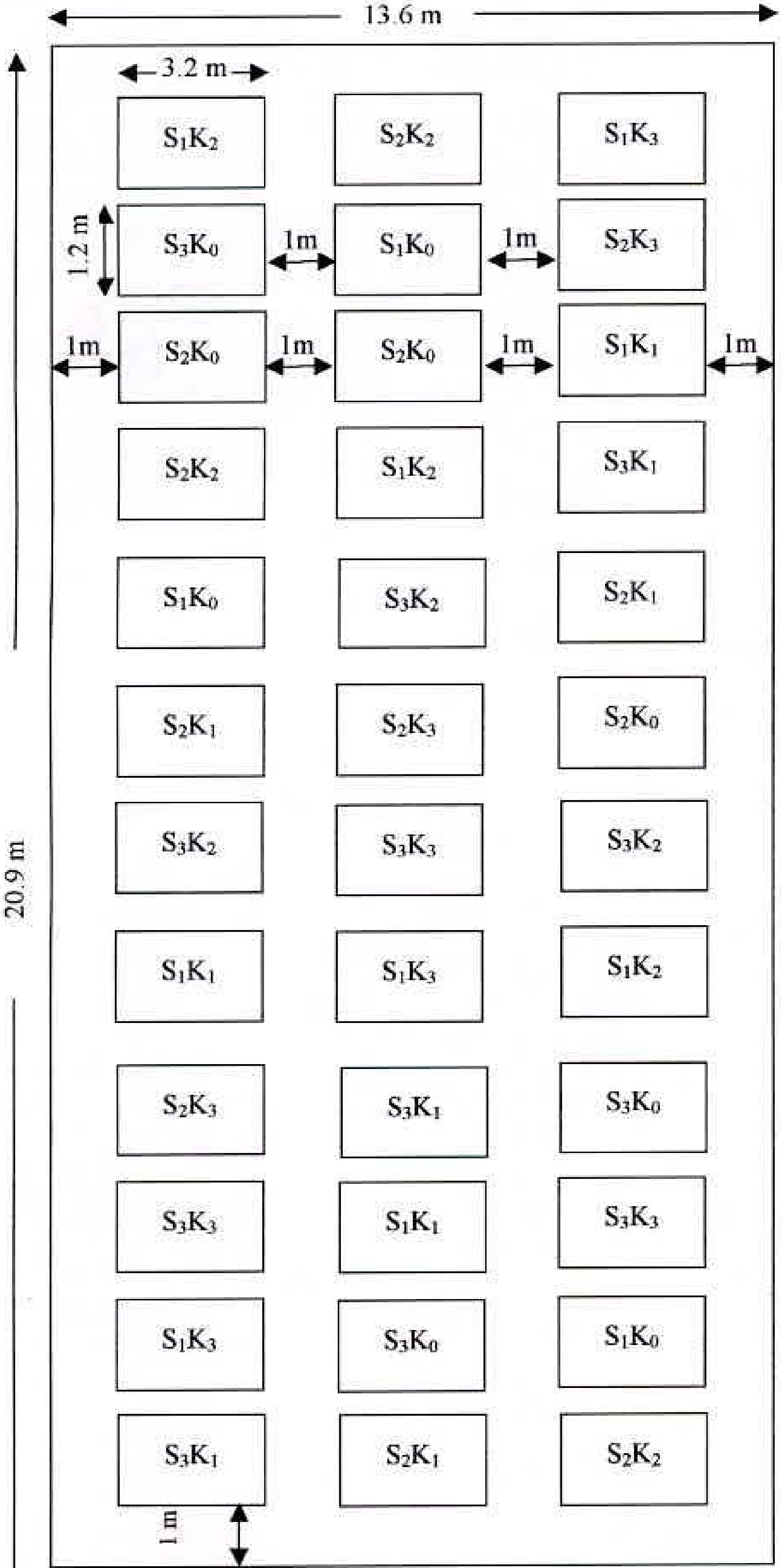
3.12 Application of Manure and Fertilizers

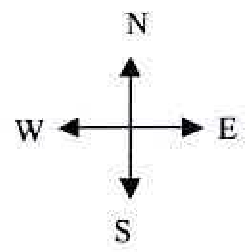
Manure and fertilizers were applied according to Fertilizer Recommendation Guide – 2005, BARC that presented in below-

Table 1. Fertilizer and manures applied in the experiment

Name of Fertilizers and Manure	Amount (kg/ha)
Urea	348
TSP	180
MOP	As per treatment
Zypsum	166
Boron	7
Cowdung	6 t/ha

Full dose of cowdung, TSP, Zypsum and Boron were applied during final land preparation. The total amount of Urea and MOP were applied in two installments. The first half was 15 and second half at 35 days after seedling were transplanted and light irrigation was applied followed by fertilizer application.





Plot size: 3.2 m × 1.2 m
Plot spacing: 50 cm
Between replication: 1.0 m

Factors A:

S_1: 60 cm × 30 cm
S_2: 60 cm × 40 cm
S_3: 60 cm × 60 cm

Factors B:

K_0: Control
K_1: 90 kg K_2O/ha
K_2: 120 kg K_2O/ha
K_3: 150 kg K_2O/ha

Figure 1. Layout of the experimental plot

3.13 Transplanting of Seedlings

The seed bed was watered before uprooting the seedling to minimize the root damage at the time of uprooting, care was taken so that root damage was minimum and some soil remain with the roots. Before transplanting, the root of the seedlings was dipped in solution of Bavistin (2gm/L of water). The 30 days older seedling having 5 – 6 true leaves were transplanted at the spacing 60 cm x 30 cm, 60 cm x 40 cm and 60 cm x 60 cm in a plot on 6 November. Transplanting was done in the afternoon to allow light irrigation.

3.14 Intercultural Operation

3.14.1 Gap filling

Very few seedlings were damaged after transplanting and these were replaced by the new seedling. For gap filling and light watering at every morning and afternoon was continued for seven days for well establishment of the seedlings into the soil.

3.14.2 Weeding

Crop was kept weeds free by 2 – 3 hand weeding and 1 –2 hoeing. The weeding was done during cropping period of 21 November, 6 December and 21 December of planting.

3.14.3 Earthing up

At the time of earthing up the plants were supported with soil to avoid toppling down of the plant during the head formation. Earthing up around the plants were done on 6 December and 6 January after transplanting.

3.14.4 Irrigation

Four times irrigation were given after transplanting of seedling and subsequent irrigation was given on 6 December, 16 December, 26 December and 5 January for proper growth and development. Care was taken to avoid water stress from the time of head formation to the head maturity period.

3.15 Insects and Diseases Management

Few plants were damaged by mole creckets and caterpillars feed on the leaf epidermis and later make holes just after transplanting. In the leaves so spraying the crop with Malathion 57EC @ 2ml per litre was sprayed to control mole cricket and caterpillar. Some time, the adult Cabbage borer female lay eggs, on the growing point or on the older leaves. Some plants were infected by Alternaria leaf spot disease caused by *Alternaria brassicae*. To prevent the spread of Alternaria leaf spot disease ,Rovral 50 WP @ 20g per 10 liter of the water was sprayed to control the disease. Bird pests such as Nightingale (common name is Bulbuli) was visiting the experimental field very frequently. The birds were found to puncture the soft leaves were controlled by striking of a metallic container.

3.16 Harvesting

The head of cabbage was harvested during the period from 12 to 15 February 2008. When the plants formed compact heads, the harvesting of the crop was done plot wise after testing the compactness of the cabbage head by hand. The compact head showed comparatively a hard feeling. Each head was cut by a sharp knife at the base of the plant.

3.17 Collection of data

The following data were recorded from the cabbage plants during the study period.

3.17.1 Plant height

Ten plants were randomly selected from each plot to measure the plant height and average plant height was calculated in centimeter (cm). Plant height was measured from base to the tip of the longest leaf at 30, 45, 60 days after transplanting (DAT). A meter scale was used to measure the plant height.

3.17.2 Stem length

Stem length was measured from base to the plant of the end point of stem at 30, 45, 60 days after transplanting (DAT) by a meter scale.

3.17.3 Number of leaves per plant

Total number of leaves produced by each plant was counted at 30, 45, 60 days after transplanting (DAT).

3.17.4 Leaf length

The length of the leaf was measured from the base of the petiole to the tip at 30, 45, 60 days after transplanting. A meter scale was used to measure the length of leaves and expressed in centimeter

3.17.5 Leaf breadth

Breadth of large leaf per plant was measured in cm with a meter scale at 30, 45, 60 days after transplanting.

3.17.6 Spreading of plant

Horizontal space covered by the plant was measured at 30, 45, 60 days after transplanting in cm with a meter scale for determining spread of plant.

3.17.7 Number of loose leaves per plant

Total number of loose leaves per plant was calculated by counting loose leaves after harvest of plant.

3.17.8 Number of compact leaves per plant

Total number of compact leaves per plant was calculated by counting compact leaves after harvest of plant.

3.17.9 Weight of loose leaves per plant

Weight of loose leaves per plant was recorded in grams.

3.17.10 Total dry matter in the loose leaves

Firstly, the fresh weight of loose leaves per plant was recorded. Then ten gms of loose leaves were taken and dried in the oven at 70 degree centigrade for 72 hours after sun drying for two days.

3.17.11 Diameter of head

Diameter of the head was measured in cm with a scale as the horizontal distance from one side to another side after sectioning the head vertically at the middle position.

3.17.12 Thickness of head

Thickness of the head was measured in cm with a scale as the vertical distance from the lower most level to the upper most level of the head after sectioning vertically at the middle position of head.

3.17.13 Fresh weight of head

The fresh weight of head was recorded at harvest including the roots and loose leaves were measured in kilogram.

3.17.14 Total dry matter of head per plant

First the fresh weight of head was recorded, and then ten grams of head were taken and dried in an oven at 70 °C for 72 hours after sun drying for two days.

3.17.15 Diameter of stem

Diameter of stem was measured in cm with a slide calipers as the horizontal distance from one side to another side of stem.

3.17.16 Length of stem

The length of stem was measured in cm with a meter scale from base of the folded leaves to the level of the root.

3.17.17 Fresh weight of stem

The fresh weight of stem was measured in grams.

3.17.18 Length of root

The distance from the base to the top of the root was measured in cm with the help of a scale for the determination of the length of root.

3.17.19 Fresh weight of root

The fresh weight of root was measured in grams.

3.17.20 Gross yield

The total weight of eight randomly selected cabbage plants was taken excluding the roots in kilogram for determination the gross yield per plot.

3.17.21 Marketable yield

Marketable yield of eight randomly cabbage plant per plot was measured in kilogram excluding the roots and loose leaves.

3.18 Statistical analysis

The recorded data on different parameters were statistically analyzed with the help of "MSTAT" program. The treatments mean were separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) at 5% level of significance for interpretation of the result.

3.19 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of spacing and potassium fertilizer. All input cost including the cost for lease of land and interests was on running capital in computing the cost of production. The interests were calculated @ 13%. The market price of cabbage was considered for estimating the cost and return. The benefit cost ratio (BCR) was calculated by the following formulae:

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

CHAPTER IV

RESULTS AND DISCUSSION

The results on the effect of plant spacing and potassium on growth and yield of cabbage were presented below:

4.1 Plant height

Significant variation was found in plant height at different days after transplanting (DAT) due to different spacing (Table 2 and Appendix III). The tallest plant at 30 DAT (17.22 cm), 45 DAT (32.17 cm) and 60 DAT (37.70 cm) were found in the widest spacing treatment (S_3), whereas, the shortest plant height at 30 DAT (16.08 cm), 45 DAT (29.84 cm) and 60 DAT (35.68 cm) were found in the closest spacing treatment (S_1). The results showed that the plant height at different DAT was increased with the increase in spacing. This might be due to receiving sufficient amount of light and nutrients. The trend of the present results was agreed to that of Singh *et al.* (2007).

Plant height varied significantly due to the application of different levels of potassium (Table 2 and Appendix III). The tallest plant at 30 DAT (17.14 cm), 45 DAT (33.29 cm) and 60 DAT (39.51 cm) were found from K_3 treatment and the shortest plants height at 30 DAT (15.84 cm), 45 DAT (27.84 cm) and 60 DAT (32.47 cm) were found in control treatment (K_0). The plant height increased with the increasing application of potassium fertilizer. Potassium fertilizer ensured favorable condition for the growth of cabbage with optimum cell division and elongation of cell and the ultimate results was the tallest plant. Similar findings also reported by Vanparys (1998).

The variation was recorded due to combined effect of plant spacing and different levels of potassium in terms of plant height at different DAT (Table 3 and Appendix III). The tallest plant at 30 DAT (17.97 cm), 45 DAT (34.43 cm) and 60 DAT (40.79 cm) was recorded from S_3K_3 treatment combination. On the other hand, the shortest plant height at 30 DAT (14.97 cm), 45 DAT (26.97 cm) and 60 DAT (31.92 cm) were recorded from S_1K_0 treatment combination.

4.2 Stem length

Statistically significant variation was recorded due to different plant spacings in respect of stem length of cabbage (Table 2 and Appendix III). The longest stem at 30 DAT (5.22 cm), 45 DAT (6.13 cm) and 60 DAT (6.55 cm) were found in widest spacing treatment (S_3), the shortest stem length at 30 DAT (4.65 cm), 45 DAT (5.45 cm) and 60 DAT (5.73 cm) was found in the closest spacing treatment (S_1). Wider spacing produced the longest stem length at different DAT.

Stem length showed statistically significant variation due to the application of different levels of potassium (Table 2 and Appendix III). The longest stems at 30 DAT (5.24 cm), 45 DAT (6.15 cm) and 60 DAT (6.54 cm) were found from K_2 treatment neverthless, the shortest stem at 30 DAT (4.68 cm), 45 DAT (5.52 cm) and 60 DAT (5.83 cm) were recorded from control treatment (K_0). The stem length increased with the increasing of days after transplanting i.e., 30, 45 and 60 DAT and revealed that stem length increased with the K_2 treatment. This could be due to the positive effect of potassium because it enhanced vegetative growth of cabbage. Potassium also helped proper growth and ultimate results were the longest stem length of cabbage. This finding was reported by Chaubey *et al.* (2001).

Table 2. Effect of spacing and potassium levels on plant height, stem length and number of leaves per plant of cabbage at different days after transplanting

Treatment(s)	Plant height (cm)			Stem length (cm)			Number of leaves per plant		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
Spacing									
S_1	16.08 c	29.84 c	35.68 c	4.65 b	5.45 b	5.73 b	14.85	18.22 b	14.46 c
S_2	16.58 b	31.25 b	36.75 b	5.06 a	5.93 a	6.33 a	14.81	18.53 ab	16.51 b
S_3	17.22 a	32.17 a	37.70 a	5.22 a	6.13 a	6.55 a	15.33	19.52 a	17.96 a
$LSD_{(0.05)}$	0.443	0.697	0.776	0.340	0.391	0.428	--	1.005	0.338
Significance level	**	**	**	**	**	**	NS	*	**
Potassium fertilizer									
K_0	15.84 c	27.84 c	32.47 c	4.68 b	5.52 c	5.83 b	14.51	17.87 b	14.14 d
K_1	16.48 b	30.51 b	35.96 b	5.09 a	5.98 ab	6.35 a	15.02	18.77 ab	16.30 c
K_2	17.04 a	32.70 a	38.89 a	5.24 a	6.15 a	6.54 a	15.51	19.61 a	16.99 b
K_3	17.14 a	33.29 a	39.51 a	4.89 ab	5.70 ab	6.09 ab	14.94	18.78 ab	17.80 a
$LSD_{(0.05)}$	0.512	0.805	0.892	0.392	0.451	0.495	--	1.160	0.390
Significance level	**	**	**	*	*	*	NS	*	**
CV (%)	8.17	6.63	10.50	8.07	7.91	8.15	5.75	6.33	7.41

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

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability; NS: Not significant

Table 3. Combined effect of spacing and potassium levels on plant height, stem length and number of leaves per plant of cabbage at different days after transplanting

Treatment(s)	Plant height (cm) at			Stem length (cm) at			Number of leaves per plant at		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
S_1K_0	14.97 c	26.97 g	31.92 h	4.52 c	5.34 d	5.65 b	14.60	17.56 b	11.67 g
S_1K_1	16.23 b	29.40 de	34.54 fg	4.70 bc	5.56 bcd	5.83 b	14.70	18.15 b	15.21 f
S_1K_2	16.78 b	31.40 bc	37.58 de	4.72 bc	5.48 cd	5.79 b	15.27	18.85 ab	15.17 f
S_1K_3	16.35 b	31.60 bc	38.68 bcd	4.68 bc	5.41 d	5.75 b	14.83	18.31 b	15.79 ef
S_2K_0	16.40 b	28.80 ef	33.02 gh	5.02 abc	5.93 abcd	6.30 ab	14.37	17.73 b	15.07 f
S_2K_1	16.77 b	31.50 bc	37.35 de	5.43 ab	6.33 abc	6.82 a	14.93	18.77 ab	16.43 de
S_2K_2	16.60 b	34.33 a	40.23 ab	5.57 a	6.59 a	6.99 a	15.33	19.27 ab	17.05 cd
S_2K_3	17.10 ab	33.93 a	39.64 abc	4.85 abc	5.67 bcd	6.09 ab	14.60	18.35 b	17.50 c
S_3K_0	16.17 b	27.77 fg	32.47 h	4.50 c	5.29 d	5.54 b	14.57	18.31 b	15.70 f
S_3K_1	16.43 b	30.63 cd	35.99 ef	5.15 abc	6.06 abcd	6.40 ab	15.43	19.40 ab	17.27 c
S_3K_2	17.73 a	32.27 b	38.30 cd	5.45 ab	6.38 ab	6.84 a	15.93	20.71 a	18.75 b
S_3K_3	17.97 a	34.43 a	40.79 a	5.13 abc	6.01 abcd	6.44 ab	15.40	19.69 ab	20.10 a
$LSD_{(0.05)}$	0.886	1.394	1.552	0.679	0.782	0.857	--	2.010	0.675
Significance level	**	*	*	*	*	*	NS	*	*
CV (%)	8.17	6.63	10.50	8.07	7.91	8.15	5.75	6.33	7.41

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

**: Significant at 0.01 level; *: Significant at 0.05 level; NS: Not significant

Combined effect of plant spacing and levels of potassium in terms of stems length showed variation at different DAT (Table 3 and Appendix III). The longest stem length at 30 DAT (5.57 cm), 45 DAT (6.59 cm) and 60 DAT (6.99 cm) were found from S_2K_2 treatment combination and the shortest stems length at 30 DAT (4.50 cm), 45 DAT (5.29 cm) and 60 DAT (5.54 cm) were found from S_3K_0 treatment combination.

4.3 Number of leaves per plant

Number of leaves per plant of cabbage showed statistically insignificant variation at 30 DAT but at 45 DAT and 60 DAT varied significantly (Table 2 and Appendix III). At 30 DAT, the maximum number of leaves per plant (15.33) was observed from S_3 treatment and the minimum number of leaves per plant (14.81) was found from S_2 treatment. The maximum number of leaves per plant at 45 DAT (19.52) and 60 DAT (17.96) was recorded from S_3 treatment and the minimum number of leaves per plant at 45 DAT (18.22) and 60 DAT (14.46) was recorded from S_1 treatment. The results were observed that the number of leaves per plant at different DAT was increased with the widest spacing. This was due to receiving of sufficient amount nutrients in the widest spacing. The trend of the present results was agreed to that of Meena (2003).

Application of different levels of potassium in cabbage was statistically insignificant at 30 DAT but at 45 DAT and 60 DAT varied significantly in respect of number of leaves per plant (Table 2 and Appendix III). At 30 DAT, the maximum number of leaves per plant (15.51) was observed from K_2 treatment and the minimum (14.51) was recorded from K_0 treatment. On the other hand, the maximum number of leaves per plant at 45 DAT was recorded from K_2 treatment which was statistically similar to that of K_3 and K_1 treatments, and the minimum (17.87) was recorded from K_0 treatment. At 60 DAT, the maximum number of leaves per plant (17.80) was found from K_3 treatment followed by others and the minimum (14.14) was recorded from K_0 treatment. It was noted that the plant height increased with the applications of the higher doses of potassium. Spacings and optimum level of potassium produced the maximum number of leaves per plant by ensuring appropriate soil moisture and essential nutrients.

Number of leaves per plant did not vary significantly at 30 DAT but at 45 DAT and 60 DAT varied significantly due to combined effect of plant spacing and levels of potassium (Table 3 and Appendix III). At 30 DAT, the maximum number of leaves per plant (15.40) was recorded from S_3K_3 treatment combination and the minimum (14.60) was recorded from S_1K_0 treatment combination. At 45 DAT, the maximum number of leaves per plant (20.71) was observed from S_3K_2 treatment combination and the minimum (17.56) was recorded from S_1K_0 treatment combination. At 60 DAT, the highest number of leaves per plant (20.10) was recorded from S_3K_3 treatment combination and the minimum (11.67) was found from S_1K_0 treatment combination.

4.4 Leaf length

Statistically insignificant variation was found in leaf length at 30 DAT but at 45 DAT and 60DAT varied significantly due to different plant spacings (Figure 2 and Appendix IV). At 30 DAT, the highest leaf length (18.58 cm) was found from S_2 treatment and the lowest (18.21 cm) was recorded from S_3 treatment. The highest leaf length at 45 DAT (28.17 cm) and 60 DAT (32.87 cm) were reported from the closest spacing treatment (S_1.), moreover, the lowest leaf length at 45 DAT (26.54 cm) and 60 DAT (30.61 cm) was observed from S_3 treatment. It was found that the leaf length increased with the decreased in plant spacing.

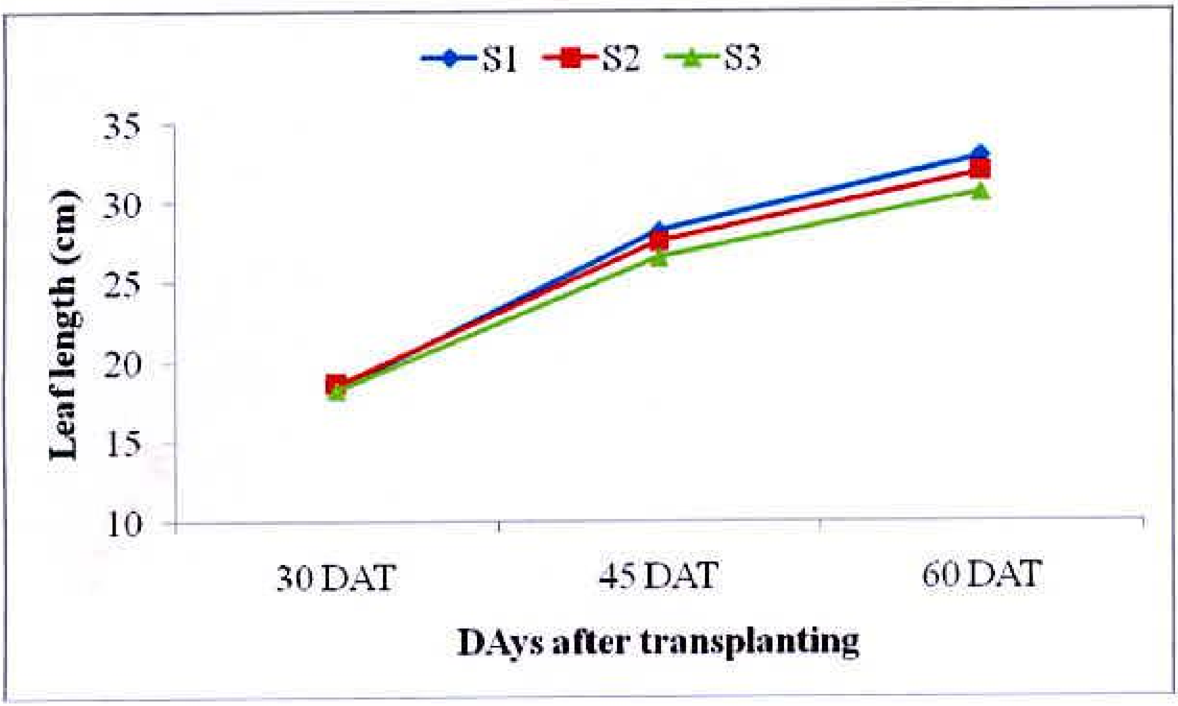


Figure 2. Effect of different spacing on leaf length of cabbage

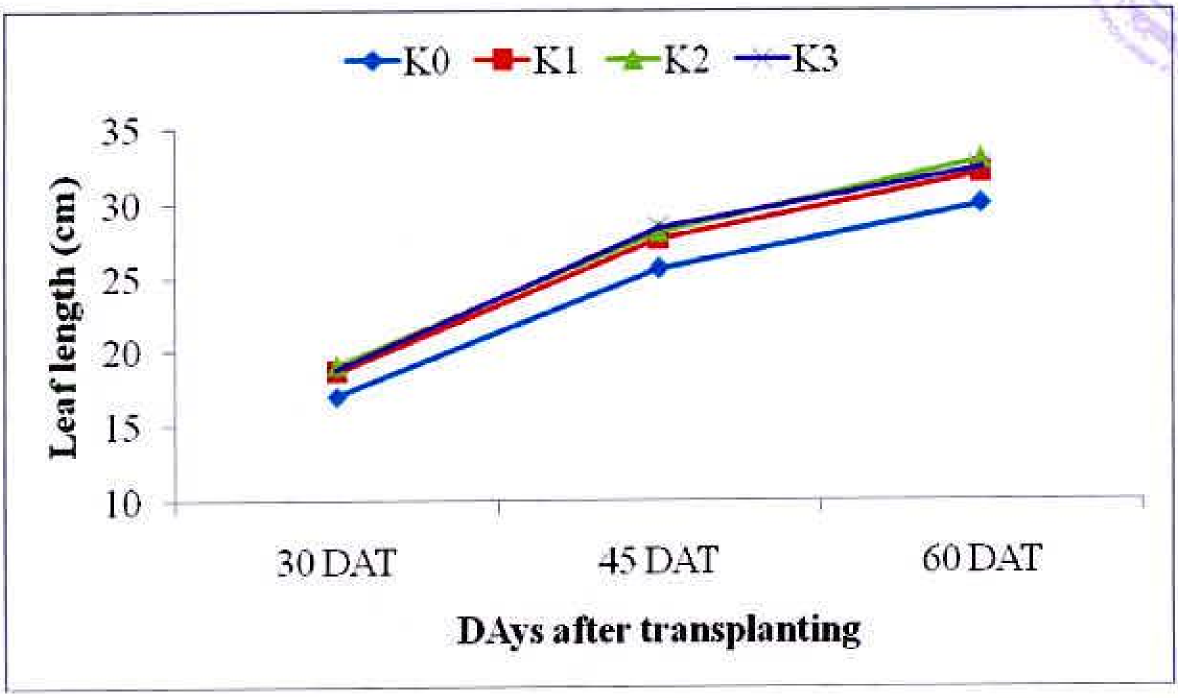


Figure 3. Effect of different level of potassium on leaf length of cabbage

Leaf length of cabbage varied significantly due to the application of different levels of potassium at 30 DAT, 45 DAT and 60 DAT (Figure 3 and Appendix IV). The highest leaf length at 30 DAT (19.11 cm), 45 DAT (28.37 cm) and 60 DAT (32.90 cm) were found from K_2 treatment. In contrast, the lowest leaf length at 30 DAT (17.02 cm), 45 DAT (25.57 cm) and 60 DAT (29.95 cm) were noted from K_0 treatment. It was reported that potassium helped vegetative growth that ensured maximum leaf length.

Statistically significant variation was recorded due to combined effect of plant spacing and different levels of potassium in terms of leaf length at 30, 45 and 60 DAT (Table 4 and Appendix IV). The highest leaf length at 30 DAT (19.33 cm), 45 DAT (28.98 cm) and 60 DAT (33.84 cm) were observed from S_1K_2 treatment combination. Moreover, the lowest leaf length at 30 DAT (16.53 cm), 45 DAT (24.41 cm) and 60 DAT (28.37 cm) were showed in S_3K_0 treatment combination.

4.5 Leaf breadth

Significant variation was found in leaf breadth at different days after transplanting (DAT) due to different plant spacing (Figure 4 and Appendix IV). The highest leaf breadth at 30 DAT (11.51 cm), 45 DAT (17.61 cm) and 60 DAT (23.35 cm) were observed from widest spacing treatment (S_3) whereas, the lowest leaf breadth at 30 DAT (10.58 cm), 45 DAT (16.00 cm) and 60 DAT (21.03 cm) were found in closest spacing treatment (S_1). The results noted that the leaf breadth at different DAT was increased with wider spacing treatment (S_3).

Leaf breadth differed significantly due to the application of different levels of potassium (Figure 5 and Appendix IV). The highest cabbage leaf breadth at 30 DAT (11.64 cm), 45 DAT (17.70 cm) and 60 DAT (23.22 cm) were found from K_2 treatment

Table 4. Combined effect of spacing and potassium levels on leaf length, leaf breadth and spreading of plant of cabbage at different days after transplanting

Treatment(s)	Leaf length (cm) at			Leaf breadth (cm) at			Spreading of plant (cm) at		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
S_1K_0	17.07 ab	26.52 bc	31.50 abc	10.22 e	15.35 d	19.70 e	21.00 c	30.45 f	45.43 e
S_1K_1	18.27 ab	28.30 ab	32.89 ab	10.60 cde	15.93 bcd	21.55 cd	26.53 b	35.90 e	51.67 d
S_1K_2	19.33 a	28.98 a	33.84 a	11.08 abcde	17.10 abc	21.33 cd	26.77 b	37.79 e	53.43 d
S_1K_3	18.73 ab	28.87 a	33.25 ab	10.39 de	15.61 cd	21.53 cd	26.83 b	37.12 e	54.43 d
S_2K_0	17.47 ab	25.78 cd	29.97 bc	10.65 bcde	16.34 abcd	21.10 de	25.97 b	36.26 e	52.77 d
S_2K_1	18.90 ab	27.90 ab	32.43 ab	10.82 abcde	16.59 abcd	21.79 cd	26.80 b	44.01 c	64.30 b
S_2K_2	18.87 ab	27.85 abc	32.37 ab	11.90 ab	17.99 a	22.99 bc	27.67 ab	44.41 c	66.13 b
S_2K_3	19.10 a	28.53 ab	32.77 ab	11.52 abcd	17.34 ab	22.96 bc	28.53 ab	45.87 c	66.40 b
S_3K_0	16.53 b	24.41 d	28.37 c	10.72 abcde	16.44 abcd	21.19 de	26.38 b	40.40 d	59.50 c
S_3K_1	18.70 ab	26.60 bc	30.59 abc	11.75 abc	18.01 a	24.26 ab	27.97 ab	51.82 b	76.50 a
S_3K_2	19.13 a	27.57 abc	32.50 ab	11.94 a	18.02 a	25.32 a	28.83 ab	53.87 ab	77.53 a
S_3K_3	18.47 ab	27.59 abc	30.97 abc	11.65 abcd	17.98 a	22.64 cd	31.37 a	54.47 a	79.97 a
$LSD_{(0.05)}$	2.141	1.857	3.000	1.105	1.482	1.486	3.792	2.381	3.732
Significance level	*	*	*	**	**	*	*	**	**
CV (%)	6.88	8.02	5.57	9.88	5.18	7.22	8.27	6.67	8.34

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

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability; NS: Not significant

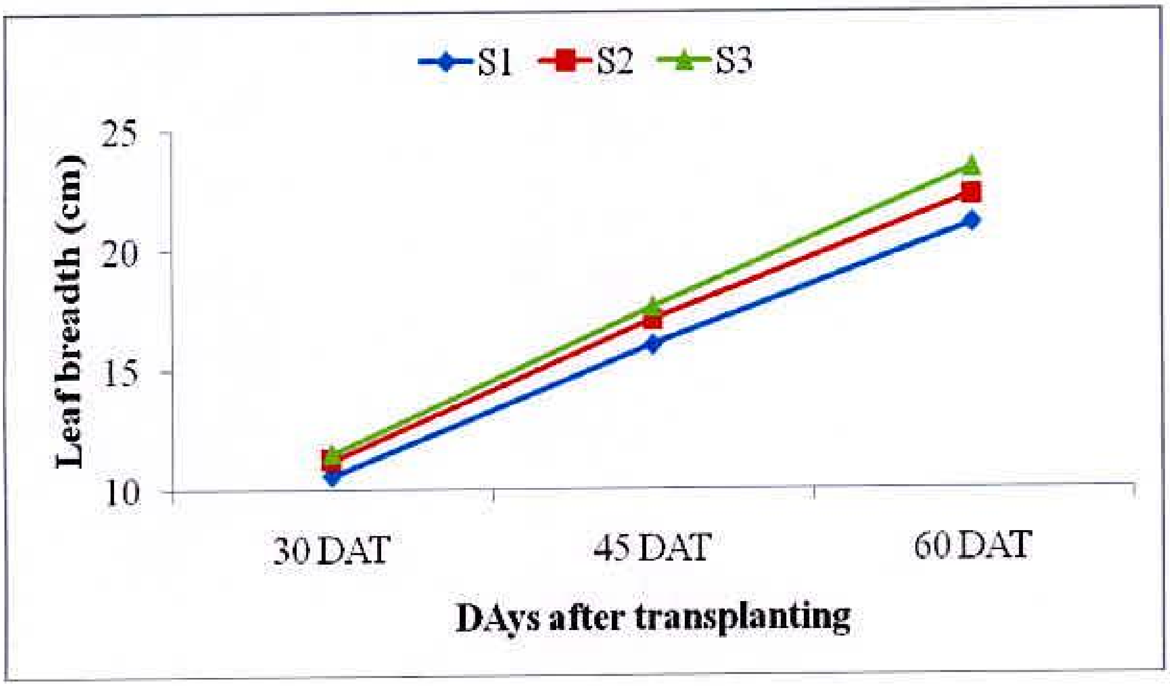


Figure 4. Effect of different spacing on leaf breadth of cabbage

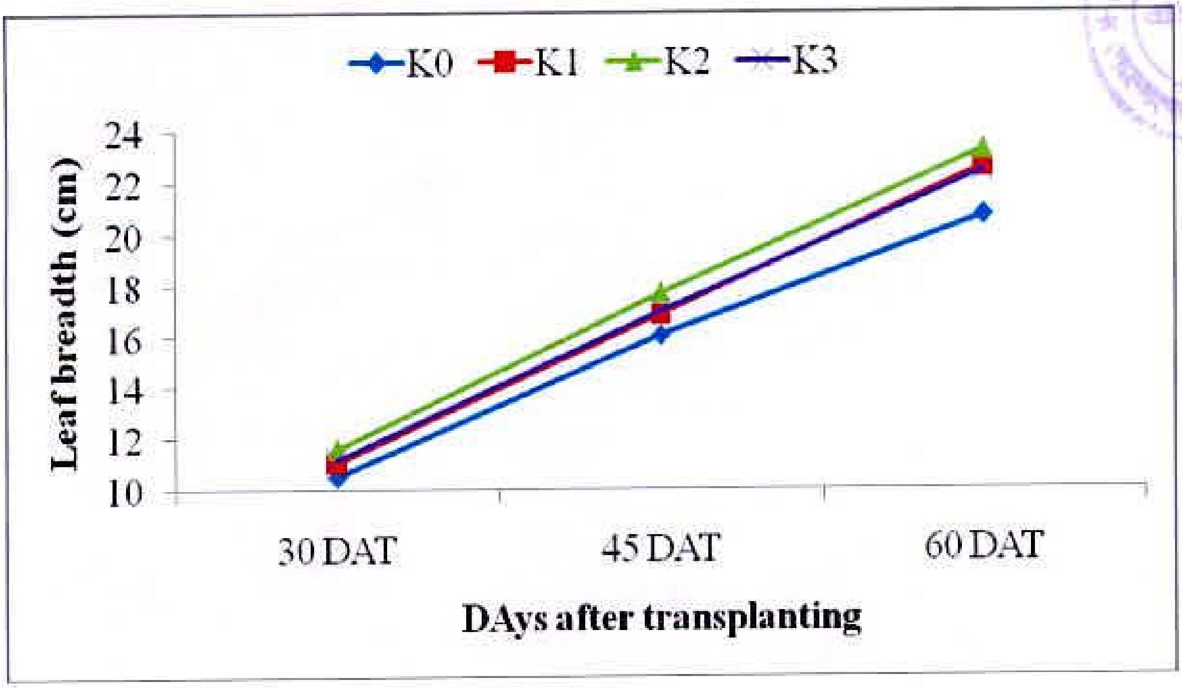


Figure 5. Effect of different level of potassium on leaf breadth of cabbage

Again, the lowest leaf breadth at 30 DAT (10.53 cm), 45 DAT (16.04 cm) and 60 DAT (20.66 cm) were observed from K_0 treatment. It was reported that leaf breadth increased with the increasing of potassium level due to optimum cell elongation.

The variation was recorded due to combined effect of plant spacing and levels of potassium in terms of leaf breadth at different DAT (Table 4 and Appendix IV). The highest leaf breadth at 30 DAT (11.94 cm), 45 DAT (18.02 cm) and 60 DAT (25.32 cm) were recorded from S_3K_2 treatment combination, the lowest leaf breadth at 30 DAT (10.22 cm), 45 DAT (15.35 cm) and 60 DAT (19.70 cm) were observed from S_1K_0 treatment combination.

4.6 Spreading of plant

Statistically significant variation was recorded due to different plant spacings recorded in respect of spreading of cabbage (Figure 6 and Appendix IV). The highest spreading of plant at 30 DAT (28.64 cm), 45 DAT (50.14 cm) and 60 DAT (73.38 cm) were observed in widest spacing treatment (S_3), moreover, the lowest spreading of plant at 30 DAT (25.28 cm), 45 DAT (35.31 cm) and 60 DAT (51.24 cm) were observed in closest spacing treatment (S_1). The results noted that the spreading of plant at different DAT was increased with the Spacing S_3. This similar finding was found to that Sandhu (1999).

Spreading of plant varied significantly due to the application of different levels of potassium (Figure 7 and Appendix IV). The highest spreading of plant 30 DAT (28.91 cm), 45 DAT (45.82 cm) and 60 DAT (66.93 cm) were found in K_3 treatment. On the contrary, the lowest speeding of plant 30 DAT (24.45 cm), 45 DAT (35.70 cm) and 60 DAT (52.57 cm) was observed from K_0 treatment. It was stated that spreading of plant increased with the higher levels of potassium.

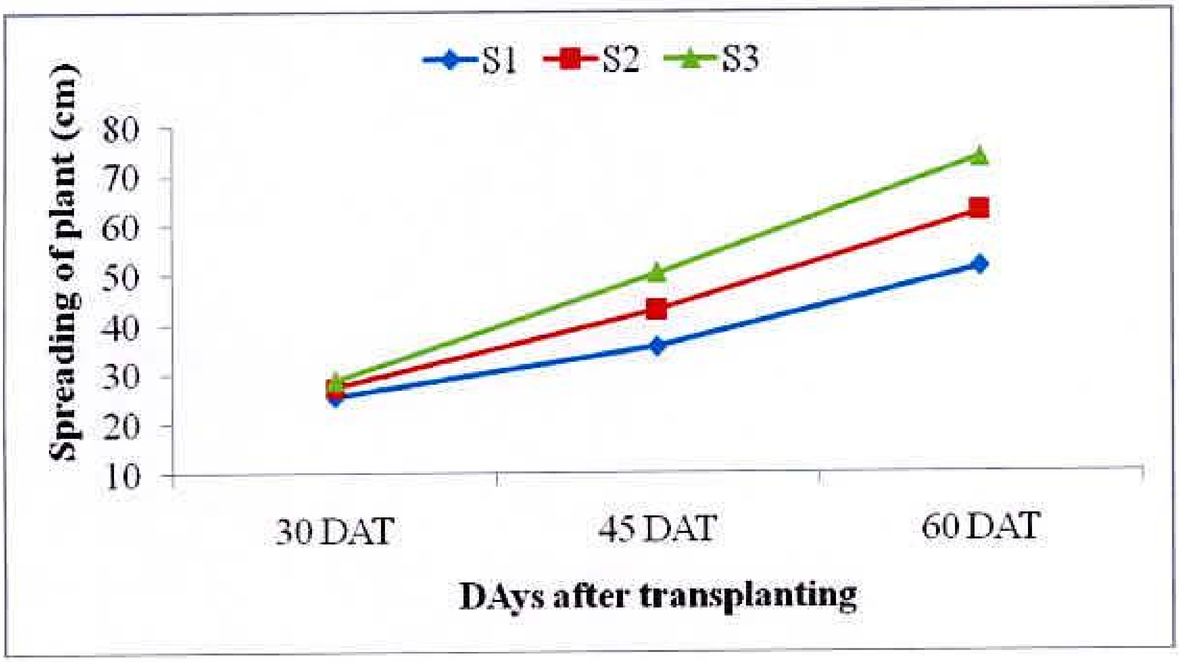


Figure 6. Effect of different spacing on spreading of plant of cabbage

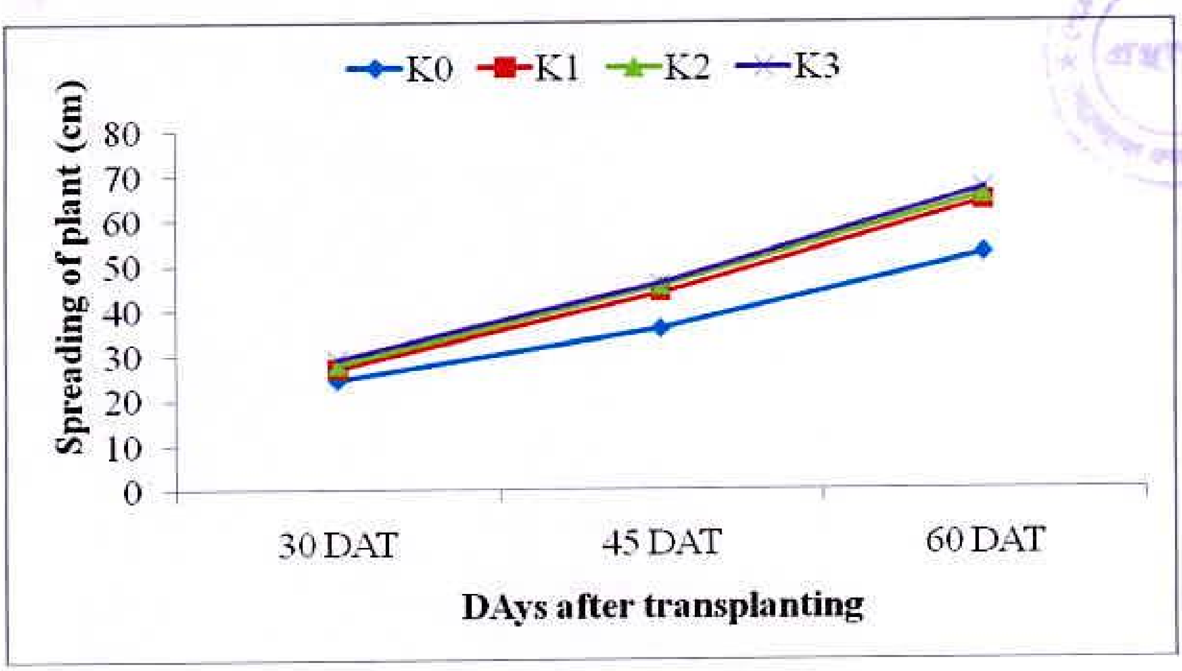


Figure 7. Effect of different level of potassium on spreading of plant of cabbage

The variation was observed due to the combined effect of plant spacing and levels of potassium in terms of spreading of plant at different DAT (Table 4 and Appendix IV). The highest spreading of plant 30 DAT (31.37 cm), 45 DAT (54.47 cm) and 60 DAT (79.97 cm) were noted from S_3K_3 treatment combination. Nevertheless, the lowest spreading of plant 30 DAT (21.00 cm), 45 DAT (30.45 cm) and 60 DAT (45.43 cm) were recorded from S_1K_0 treatment combination.

4.7 Number of loose leaf per plant

Due to different plant spacing the number of loose leaf per plant of cabbage varied significantly (Table 5 and Appendix V). The maximum number of loose leaf per plant (18.12) was observed from widest spacing treatment (S_3) and the minimum (16.21) was recorded from closet spacing treatment (S_1). The results observed that the number of loose leaf per plant was increased with the increasing in spacing.

Number of loose leaf per plant showed statistically variation due to the application of different levels of potassium (Table 5 and Appendix V). The maximum number of loose leaf per plant (18.32) was recorded from K_3 treatment. Again, the minimum (15.93) was observed from K_0 treatment. Loose leaf increased with K_3 treatment

Combined effect of plant spacing and levels of potassium in terms of number of loose leaf per plant in cabbage showed statistically significant differences (Table 6 and Appendix V). The maximum number of loose leaf per plant (19.46) was found from S_3K_3 treatment and the minimum (14.47) was recorded from S_1K_0 treatment combination.

Table 5. Effect of spacing and potassium levels on yield contributing characters of cabbage

Treatment(s)	Number of loose leaf per plant	Number of compact leaf per plant	Weight of loose leaf (gm/plant)	Total dry matter of loose leaf (gm/plant)	Fresh weight of head (kg/plant)	Total dry matter of head (g/plant)
Spacing						
S_1	16.21 b	32.17 b	639.67 c	6.25 c	0.81 c	5.77 c
S_2	18.11 a	39.23 a	779.17 b	7.43 b	1.52 b	9.88 b
S_3	18.12 a	39.44 a	868.33 a	8.46 a	1.87 a	11.70 a
$LSD_{(0.05)}$	0.753	1.417	71.82	0.471	0.120	0.509
Significance level	**	**	**	**	**	**
Potassium fertilizer						
K_0	15.93 b	34.03 c	627.33 c	5.83 c	1.04 d	6.83 d
K_1	17.60 a	36.98 b	761.11 b	7.45 b	1.44 c	8.94 c
K_2	18.07 a	38.00 a	816.67 ab	8.21 a	1.53 b	10.00 b
K_3	18.32 a	38.76 a	844.44 a	8.03 a	1.62 a	10.69 a
$LSD_{(0.05)}$	0.869	1.636	82.94	0.543	0.138	0.587
Significance level	**	**	**	**	**	**
CV (%)	5.07	9.11	11.09	7.48	5.99	6.83

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

**: Significant at 0.01 level; *: Significant at 0.05 level; NS: Not significant

Table 6. Combined effect of spacing and potassium levels on yield contributing characters of cabbage

Treatment(s)	Number of loose leaf per plant	Number of compact leaf per plant	Weight of loose leaf (gm/plant)	Total dry matter of loose leaf (gm/plant)	Diameter of head (cm)	Thickness of head (cm)	Fresh weight of head (kg/plant)	Total dry matter of head (g/plant)
S_1K_0	14.47 e	29.01 g	532.00 f	5.13 g	14.62 e	9.56 e	0.64 g	4.51 f
S_1K_1	16.67 cd	32.30 f	680.00 def	6.56 ef	16.80 d	10.72 bcde	0.82 f	5.95 e
S_1K_2	16.77 cd	33.83 ef	656.67 def	6.67 ef	16.97 d	10.00 de	0.87 f	6.00 e
S_1K_3	16.93 bcd	33.53 ef	690.00 cdef	6.65 ef	17.16 cd	10.95 bcd	0.92 f	6.62 e
S_2K_0	16.99 bcd	37.53 cd	646.67 ef	5.90 fg	16.66 d	10.56 cde	1.26 e	7.83 d
S_2K_1	18.33 abc	39.91 abc	710.00 cde	7.18 de	17.71 bcd	11.00 bcd	1.42 d	9.22 c
S_2K_2	18.56 ab	39.06 bc	950.00 ab	8.83 ab	18.20 bcd	11.72 bc	1.69 c	10.98 b
S_2K_3	18.56 ab	40.40 abc	810.00 bcd	7.81 cd	18.24 bcd	11.33 bc	1.72 c	11.48 b
S_3K_0	16.33 d	35.56 de	703.33 cde	6.45 ef	17.26 cd	10.72 bcde	1.20 e	8.14 d
S_3K_1	17.79 bcd	38.73 bc	893.33 ab	8.61 bc	18.81 bc	11.89 b	2.07 ab	11.66 b
S_3K_2	18.89 a	41.12 ab	843.33 bc	9.13 ab	19.12 b	11.67 bc	2.01 b	13.03 a
S_3K_3	19.46 a	42.36 a	1033.33 a	9.63 a	21.02 a	13.06 a	2.21 a	13.98 a
$LSD_{(0.05)}$	1.505	2.834	143.6	0.941	1.546	1.119	0.240	1.017
Significance level	**	**	**	*	**	**	**	**
CV (%)	5.07	9.11	11.09	7.48	5.14	5.94	5.99	6.83

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

**: Significant at 0.01 level; *: Significant at 0.05 level; NS: Not significant

4.8 Number of compact leaves per plant

Number of compact leaves per plant of cabbage differed significantly due to different plant spacings (Table 5 and Appendix V). The maximum number of compact leaf per plant (39.44) was noted in widest spacing treatment (S_3) and the minimum (32.17) was found in closest spacing treatment (S_1). Number of compact leaf per plant was increased with the increasing in spacing.

Number of compact leaves per plant varied significantly due to the application of different levels of potassium in cabbage (Table 5 and Appendix V). The maximum number of compact leaf per plant (38.76) was recorded from K_3 treatment. However, the minimum number of compact leaf per plant (34.03) was observed from K_0 treatment. It was revealed that the number of compact leaf increased with the increased in potassium levels.

Statistically significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of number of compact leave per plant in cabbage (Table 6 and Appendix V). The maximum number of compact leaves per plant (42.36) was recorded from S_3K_3 treatment and the minimum (29.01) from S_1K_0 treatment combination.

4.9 Weight of loose leaves per plant

Weight of loose leaves per plant of cabbage differed significantly due to different plant spacings (Table 5 and Appendix V). The highest weight of loose leaf per plant (868.33 g) was found from widest spacing treatment (S_3) and the lowest (639.67 g) was observed from closet spacing treatment (S_1). The results revealed that the weight of loose leaf per plant was increased with the increased in spacing. This was due to uptake of more available nutrient and sufficient amount of light, water and with minimum competition among the plant population.

Due to the application of different levels of potassium in cabbage weight of loose leaves per plant varied significantly (Table 5 and Appendix V). The highest weight of loose leaves per plant (844.44 g) was found from K_3 treatment and the lowest weight (627.33 g) was observed from K_0 treatment. It was decided that the weight of loose leaves per plant increased with the highest levels of potassium.

The variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of weight of loose leaves per plant in cabbage (Table 6 and Appendix V). The highest weight of loose leaves per plant (1033.33 g) was recorded from S_3K_3 and the lowest (532.00 g) was observed from S_1K_0 treatment combination.

4.10 Total dry matter of loose leaf

In cabbage total dry matter of loose leaves varied significantly due to different plant spacings (Table 5 and Appendix V). The highest total dry matter of loose leaves (8.46 g) was recorded from widest spacing treatment (S_3) and the lowest (6.25 g) from closest spacing treatment (S_1). The finding showed that the total dry matter of loose leaves was increased with the widest spacing (S_3).

Statistically significant variation was recorded for total dry matter of loose leaves due to the application of different levels of potassium (Table 5 and Appendix V). The highest total dry matter of loose leaves (8.21 g) was observed from K_2 treatment. In contrast, the lowest total dry matter of loose leaves (5.83 g) was observed from K_0 treatment. It was noted that the dry matter of loose leaf increase with the increased in potassium. The trend of the present results was agreed to that of Tarata *et al.* (1995).

The variation was recorded due to the combined effect of plant spacing and levels of potassium in respect of total dry matter of loose leaves in cabbage (Table 6 and Appendix V). The highest total dry matter of loose leaf (9.63 g) was observed from S_3K_3 and the lowest (5.13 g) was found from S_1K_0 treatment combination.

4.11 Diameter of head

Statistically significant variation was recorded due to different plant spacings in respect of diameter of head (Figure 8 and Appendix V). The maximum diameter of head (19.05 cm) was recorded from widest spacing treatment (S_3) and the minimum (16.39 cm) was observed from closest spacing treatment (S_1). The results revealed that the diameter of head increased with the increase in spacing. This finding was similar to that of Mahesh-Kumar (2002).

Diameter of head varied significantly due to the application of different levels of potassium (Figure 9 and Appendix V). The maximum diameter of head (18.81 cm) was found from K_3 treatment and the minimum diameter of head (16.18 cm) was observed from K_0 treatment. It was reported that the diameter of head increased with highest doses of potassium. Potassium fertilizer ensures maximum plant nutrients for proper growth and the results were the maximum diameter of head. This trend of present result agreed with that of Zhong *et al* (1999).

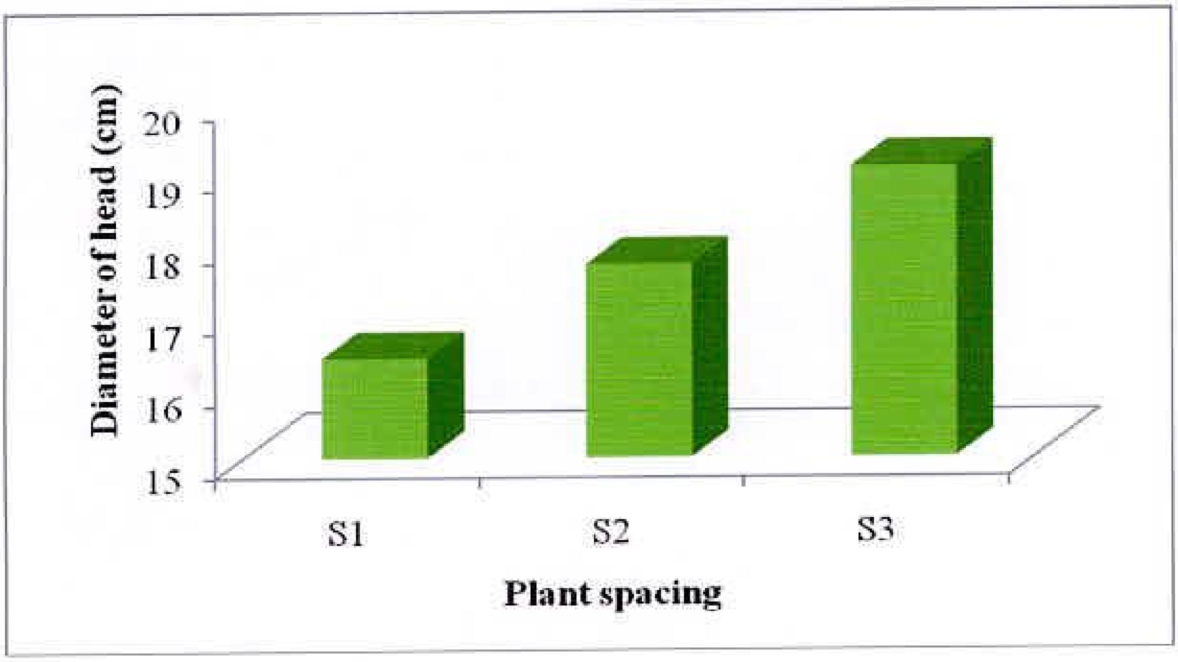


Figure 8. Effect of different spacing on diameter of head of cabbage

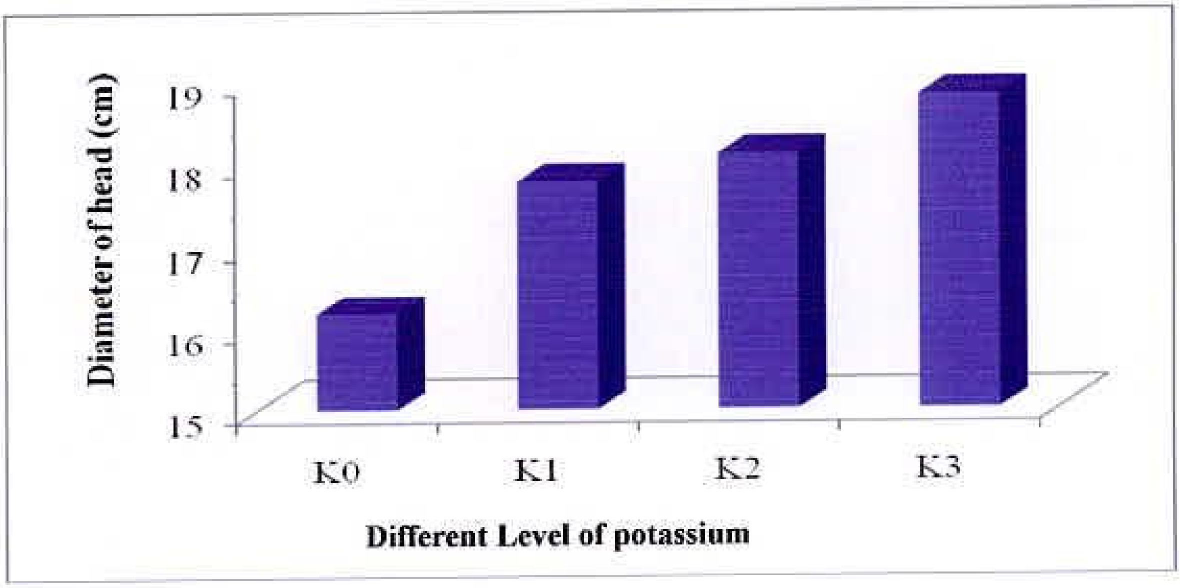


Figure 9. Effect of different level of potassium on diameter of head of cabbage

Combined effect of plant spacing and levels of potassium showed significant differences in respect of diameter of head (Table 6 and Appendix V). The maximum diameter of head (21.02 cm) was recorded from S_3K_3 treatment and the minimum (14.62 cm) was found from S_1K_0 treatment combination.

4.12 Thickness of head

Head thickness of cabbage differed significantly due to different plant spacings (Figure 10 and Appendix V). The maximum thickness of head (11.83 cm) was observed from widest spacing treatment (S_3) and the minimum (10.31 cm) was recorded from closest spacing treatment (S_1). From this finding it was observed that the thickness of head increased with the increase in spacing.

Thickness of head differed significantly due to the application of different levels of potassium in cabbage (Figure 11 and Appendix V). The maximum thickness of head (11.78 cm) was recorded from K_3 treatment. Alternatively, the minimum thickness of head (10.28 cm) was observed from K_0 treatment. Thickness of head increased with the increase in potassium levels.

Significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of thickness of head in cabbage (Table 6 and Appendix V). The maximum thickness of head (13.06 cm) was recorded from S_3K_3 treatment combination and the minimum (9.56 cm) was found from S_1K_0 treatment combination.

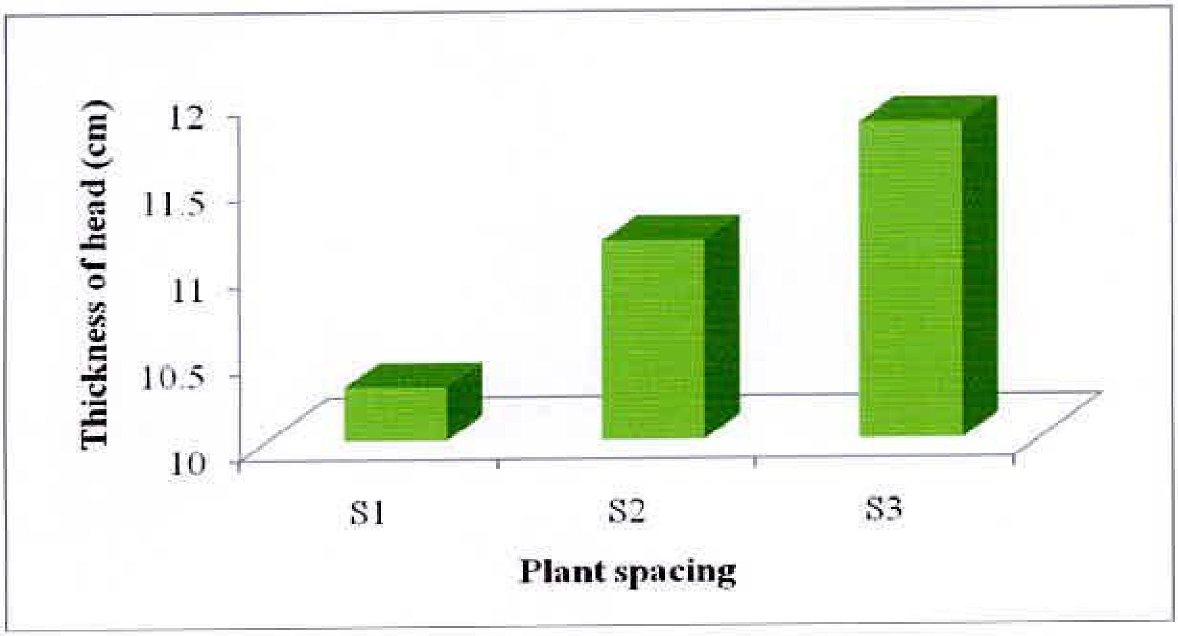


Figure 10. Effect of different spacing on thickness of head of cabbage

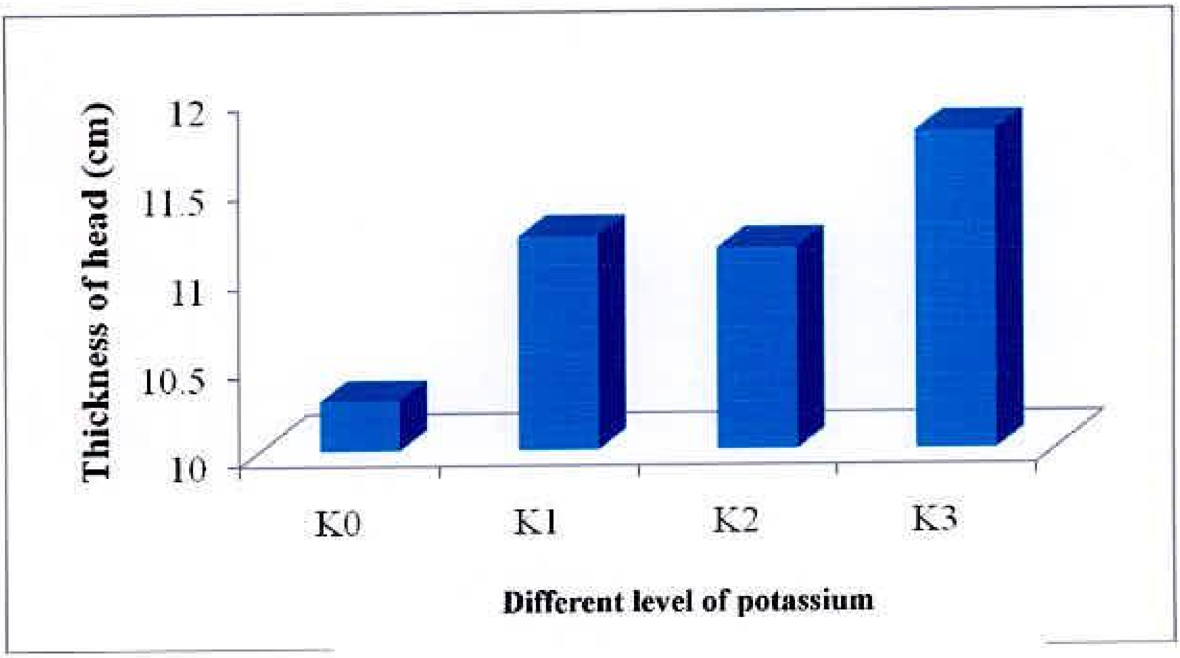


Figure 11. Effect of different level of potassium on thickness of head of cabbage

4.13 Fresh weight of head

In cabbage, fresh weight of head varied significantly due to different plant spacings (Table 5 and Appendix V). The highest fresh weight of head (1.87 kg) was recorded from widest spacing treatment (S_3) and the lowest (0.81 kg) was observed from closest spacing treatment (S_1). Fresh weight of head was increased with the increase in spacing. This might be due to availability of sufficient amount of light and nutrients. The trends of these present results were noted to that of Mahesh-Kumar (2002).

Fresh weight of head showed statistically significant differences due to the application of different levels of potassium in cabbage (Table 5 and Appendix V). The highest fresh weight of head (1.62 kg) was recorded from K_3 treatment and the lowest fresh weight of head (1.04 kg) was found from K_0 treatment. Potassium fertilizer ensures maximum plant nutrients which help proper growth of plant and the results are the highest yield per plant. This finding was found similar to that of Sarkar *et al.* (1994).

Significant variation was recorded due to combined effect of plant spacing and levels of potassium in terms of fresh weight of head in cabbage (Table 6 and Appendix V). The highest fresh weight of head (2.21 kg) was observed from S_3K_3 treatment combination and the lowest (0.64 kg) was found in S_1K_0 treatment combination.

4.14 Total dry matter of head per plant

Total dry matter of head per plant of cabbage differed significantly due to different plant spacings (Table 5 and Appendix V). The highest total dry matter of head per plant (11.70 g) was recorded from widest spacing treatment (S_3) and the lowest (5.77 g) was observed from closest spacing treatment (S_1). The results revealed that the total dry matter of head per plant was increased with widest spacing. Mannana *et al.* (1999) avobe obtained the maximum dry matter of head from the widest spacing.

Due to the application of different levels of potassium in cabbage total dry matter of head per plant varied significantly (Table 5 and Appendix V). The highest total dry matter of head per plant (10.69 g) was recorded from K_3 treatment and the lowest total dry matter of head per plant (6.83 g) was observed from K_0 treatment.

Statistically significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of total dry matter of head per plant in cabbage (Table 6 and Appendix V). The highest total dry matter of head per plant (13.98 g) was recorded from S_3K_3 treatment combination and the lowest (4.51 g) was found from S_1K_0 treatment combination.

4.15 Diameter of stem

Diameter of stem of cabbage differed significantly due to different plant spacings (Table 7 and Appendix VI). The maximum diameter of stem (3.74 cm) was recorded from widest spacing treatment (S_3) and the minimum (3.40 cm) from closest spacing treatment (S_1). The results revealed that the diameter of stem was increased with the increased in spacing.

Diameter of stem varied significantly due to the application of different levels of potassium in cabbage (Table 7 and Appendix VI). The maximum diameter of stem (3.83 cm) was observed from K_2 treatment. On the other hand, the minimum diameter of stem (3.22 cm) was observed from K_0 treatment, the variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of diameter of stem in cabbage (Table 8 and Appendix VI). The maximum diameter of stem (3.95 cm) was recorded from S_3K_3 and the minimum (2.93 cm) was found from S_1K_0 treatment combination.

4.16 Length of stem

Length of stem of cabbage showed significant variation due to different plant spacings (Table 7 and Appendix VI). The maximum length of stem (9.08 cm) from closest spacing treatment (S_1) whereas, the minimum (8.27 cm) was recorded from S_2 treatment. The results revealed that the length of stem was decreased with the increase in spacing. Optimum spacing ensured optimum amount of light and nutrients for the plant which lead to cell elongation and optimum vegetative growth of plant and the ultimate results was the maximum length of stem. The trend of the present results was reported to Mannan *et al.* (2001).

Statistically significant differences were recorded for length of stem due to the application of different levels of potassium in cabbage (Table 7 and Appendix VI). The maximum length of stem (8.93 cm) was recorded from K_3 treatment and the minimum length of stem (8.01 cm) was found from K_0 treatment.

Combined effect of plant spacing and levels of potassium showed significant difference in respect of length of stem (Table 8 and Appendix VI). The maximum length of stem (9.56 cm) was recorded from S_1K_3 treatment combination and the minimum (7.80 cm) was found from S_2K_0 treatment combination.

Table 7. Effect of spacing and potassium levels on yield contributing characters and yield of cabbage

Treatment(s)	Diameter of stem (cm)	Length of stem (cm)	Fresh weight of stem (g)	Length of root (cm)	Fresh weight of root (g)	Gross yield (t/ha)	Marketable Yield (t/ha)
Spacing							
S_1	3.40 b	9.08 a	43.58 b	16.00	24.42 b	56.36 c	42.82 c
S_2	3.72 a	8.27 b	46.42 a	15.66	29.92 a	71.20 a	53.97 a
S_3	3.74 a	8.31 b	47.89 a	15.96	31.08 a	68.67 a	51.30 b
$LSD_{(0.05)}$	0.230	0.409	2.529	--	2.027	3.511	3.986
Significance level	*	**	**	NS	**	**	**
Potassium fertilizer							
K_0	3.22 b	8.01 b	36.99 b	15.01	23.60 b	51.23 c	39.63 c
K_1	3.70 a	8.67 a	48.41 a	16.00	29.07 a	65.40 b	48.96 b
K_2	3.83 a	8.62 a	48.78 a	16.01	29.96 a	71.12 a	53.31 a
K_3	3.72 a	8.93 a	49.66 a	16.48	31.26 a	73.88 a	55.54 a
$LSD_{(0.05)}$	0.266	0.472	2.920	--	2.341	4.054	4.603
Significance level	**	*	**	NS	**	**	**
CV (%)	7.47	5.62	6.48	7.60	8.38	5.53	5.07

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

**: Significant at 0.01 level; *: Significant at 0.05 level; NS: Not significant

Table 8. Combined effect of spacing and potassium levels on yield contributing characters and yield of cabbage

Treatment(s)	Diameter of stem (cm)	Length of stem (cm)	Fresh weight of stem (g)	Length of root (cm)	Fresh weight of root (g)	Gross yield (t/ha)	Marketable Yield (t/ha)
S_1K_0	2.93 d	8.22 de	35.31 c	14.46	20.79 d	45.22 h	35.47 h
S_1K_1	3.61 abc	9.33 ab	46.44 b	16.56	25.89 c	56.32 fg	42.44 fg
S_1K_2	3.72 abc	9.22 abc	46.11 b	16.45	25.11 c	60.41 ef	45.52 ef
S_1K_3	3.33 cd	9.56 a	46.44 b	16.55	25.89 c	63.48 de	47.84 de
S_2K_0	3.39 bcd	7.80 e	37.11 c	15.22	23.67 cd	55.40 fg	43.42 efg
S_2K_1	3.66 abc	8.17 de	48.22 ab	15.40	30.22 ab	67.34 cd	50.74 cd
S_2K_2	3.94 a	8.33 cde	50.11 ab	15.45	32.44 a	80.18 a	60.43 a
S_2K_3	3.89 ab	8.78 abcd	50.22 ab	16.58	33.33 a	81.89 a	61.30 a
S_3K_0	3.33 cd	8.01 de	38.55 c	15.34	26.33 bc	53.08 g	40.00 g
S_3K_1	3.83 abc	8.50 bcde	50.56 ab	16.05	31.11 a	72.56 bc	53.71 bc
S_3K_2	3.83 abc	8.30 de	50.11 ab	16.13	32.33 a	72.76 bc	53.99 bc
S_3K_3	3.95a	8.44 bcde	52.33 a	16.33	34.55 a	76.28 ab	57.48 ab
$LSD_{(0.05)}$	0.461	0.817	5.058	--	4.055	7.021	7.973
Significance level	**	*	**	NS	**	*	**
CV (%)	7.47	5.62	6.48	7.60	8.38	5.07	5.49

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

**: Significant at 0.01 level; *: Significant at 0.05 level; NS: Not significant

4.17 Fresh weight of stem

Fresh weight of stem of cabbage differed significantly due to different plant spacings (Table 7 and Appendix VI). The maximum fresh weight of stem (47.89 g) was observed from widest spacing treatment (S_3) and the minimum (43.58 g) was recorded from closest spacing treatment (S_1). Fresh weight of stem was increased with the increased in Spacing.

Fresh weight of stem varied significantly due to the application of different levels of potassium in cabbage (Table 7 and Appendix VI). The maximum fresh weight of stem (49.66 g) was found from K_3 treatment. In contrast, the minimum fresh weight of stem (36.99 g) was observed from K_0 treatment. It was revealed that fresh weight of stem increased with K_3 treatment.

Significant differences were observed due to combined effect of plant spacing and levels of potassium in terms of fresh weight of stem (Table 8 and Appendix VI). The maximum fresh weight of stem (52.33 g) was recorded from S_3K_3 treatment combination and the minimum (35.31 g) was found from S_1K_0 treatment combination.

4.18 Length of root

Length of root of cabbage did not vary significantly due to different plant spacings (Table 7 and Appendix VI). The maximum length of root (16.00 cm) was recorded from closest spacing treatment (S_1) again; the minimum (15.66 cm) was showed in S_2 treatment. It was found that the length of root was decreased with the increase in spacing.

Length of root showed non significant differences due to the application of different levels of potassium in cabbage (Table 7 and Appendix VI). The maximum length of root (16.48 cm) was recorded from K_3 treatment alternatively, the minimum length of root (15.01 cm) was observed from K_0 treatment. The length of root increased with highest levels of potassium.

Non significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of length of root in cabbage (Table 8 and Appendix VI). The maximum length of root (16.58 cm) was recorded from S_2K_3 and the minimum (14.46 cm) was observed from S_1K_0 treatment combination.

4.19 Fresh weight of root

Due to different plant spacings for fresh weight of root of cabbage differed significantly (Table 7 and Appendix VI). The maximum fresh weight of root (31.08 g) was recorded from widest spacing treatment (S_3) and the minimum (24.42 g) was found from closest spacing treatment (S_1). The results revealed that the fresh weight of root was increased with the increase in spacing.

Fresh weight of root varied significantly due to the application of different levels of potassium in cabbage (Table 7 and Appendix VI). The maximum fresh weight of root (31.26 g) was recorded from K_3 treatment. Moreover, the minimum fresh weight of root (23.60 g) was found from K_0 treatment. It was revealed that fresh weight of root increased with the increase in potassium.

Statistically significant variation was recorded due to the combined effect of plant spacing and levels of potassium in terms of fresh weight of root in cabbage (Table 8 and Appendix VI). The maximum fresh weight of root (34.55 g) was recorded from S_3K_3 similarly, the minimum (20.79 g) was found from S_1K_0 treatment combination.

4.20 Gross yield

Statistically significant variation was recorded for gross yield of cabbage due to different plant spacings (Table 7 and Appendix VI). The highest gross yield (71.20 t/ha) was found in S_2 treatment and the lowest (56.36 t/ha in closest spacing treatment (S_1). The results revealed that gross yield was increased with the increase in spacing. In optimum spacing plant received sufficient amount of light and nutrients that lead to optimum vegetative growth and on that condition plant gave the highest gross yield of cabbage. The trend of the present results was agreeable to that of Fujiwara *et al.* (2003) and Mannan *et al.* (2001).

Gross yield varied significantly due to the application of different levels of potassium in cabbage (Table 7 and Appendix VI). The highest gross yield (73.88 t/ha) was recorded from K_3 treatment. On the other hand, the lowest gross yield (51.23 t/ha) was found from K_0 treatment. It was noted that the gross yield increased with highest doses of potassium. Gue, *et al.* (2004) reported that adequate potassium supply and optimum combination of nitrogen and potassium will help ensure high quality and yield of cabbage.

Combined effect of plant spacing and levels of potassium in terms of gross yield in cabbage showed significant differences (Table 8 and Appendix VI). The highest gross yield (81.89 t/a) was recorded from S_2K_3 and the lowest (45.22 t/ha) was found from S_1K_0 treatment combination.

4.21 Marketable yield

Marketable yield of cabbage differed significantly due to different plant spacings (Table 7 and Appendix VI). The highest marketable yield (53.97 t/ha) was observed from S_2 treatment and the lowest (42.82 t/ha) was recorded from closest spacing treatment (S_1). The results showed that the number of marketable yield was increase with the increased in Spacing. This might be due to receiving of sufficient amount of light and nutrients. The trend of the present results was reported to that of Esmail (2004).

Due to the application of different levels of potassium in cabbage marketable yield varied significantly (Table 7 and Appendix VI). The highest marketable yield (55.54 t/ha) was found from K_3 treatment and the lowest marketable yield (39.63 t/ha) was observed from K_0 treatment. Marketable yield increased with the increase in potassium. Potassium fertilizer ensures maximum plant nutrients which help proper growth and the results are the highest yield. This finding agreed to that of Zhou *et al.* (2001).

Significant differences were observed due to combined effect of plant spacing and levels of potassium in terms of marketable yield (Table 8 and Appendix VI). The highest marketable yield (61.30 t/a) was recorded from S_2K_3 treatment combination and the lowest (35.47 t/ha) was observed from S_1K_0 treatment combination.

4.22 Economic analysis

Input costs for land preparation, seed cost, fertilizer, irrigation and manpower required for all the operations from transplanting to harvesting of cabbage were recorded for unit plot and converted into cost per hectare. Price of cabbage was considered as per market rate. The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under the following headings-

4.22.1 Gross return

The combination of plant spacing and level of potassium showed different gross return under the trial. The highest gross return (Tk. 306,500) was obtained from the treatment combination S_2K_3 treatment combination and the second highest gross return (Tk. 302,150) was obtained in S_2K_2 treatment combination. The lowest gross return (Tk. 177,350) was obtained from S_1K_0 treatment combination.

4.22.2 Net return

In case of net return different treatment combination showed different levels of net return. The highest net return (Tk. 151,868) was obtained from the treatment combination S_2K_3 and the second highest net return (Tk. 149,530) was obtained from the combination S_2K_2. The lowest (Tk. 32,782) net return was obtained S_1K_0.

4.22.3 Benefit cost ratio

In the combination of plant spacing and different level of potassium highest benefit cost ratio (1.98) was noted from the combination of S_2K_3 and the second highest benefit cost ratio (1.97) was estimated from the combination of S_2K_2. The lowest benefit cost ratio (1.23) was obtained from S_1K_0 (Table 9). From economic point of view, it is apparent from the above results that the combination of S_2K_3 was more profitable than rest of the combination.

Table 9. Cost and return of cabbage cultivation as influenced by spacing and potassium levels

Treatment Combination	Cost of production (Tk./ha)	Yield of cabbage (t/ha)	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
S_1K_0	144568	35.47	177350	32782	1.23
S_1K_1	150607	42.44	212200	61593	1.41
S_1K_2	152620	45.52	227600	74980	1.49
S_1K_3	154632	47.84	239200	84568	1.55
S_2K_0	144568	43.42	217100	72532	1.50
S_2K_1	150607	50.74	253700	103093	1.68
S_2K_2	152620	60.43	302150	149530	1.97
S_2K_3	154632	61.30	306500	151868	1.98
S_3K_0	144568	40.00	200000	55432	1.38
S_3K_1	150607	53.71	268550	117943	1.78
S_3K_2	152620	53.99	269950	117330	1.77
S_3K_3	154632	57.48	287400	132768	1.86

Price of cabbage @ Tk. 5000/ton

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APPENDICES

Appendix I. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from October 2007 to February 2008

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
October, 2007	29.18	18.26	81	39	6.4
November, 2007	25.82	16.04	78	00	6.8
December, 2007	22.4	13.5	74	00	6.3
January, 2008	24.5	12.4	68	00	5.7
February, 2008	27.1	16.7	67	30	6.7

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka - 1207

Appendix II. Physical, chemical and morphological charactiristics of the experimental site soils :

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Garden , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

* **Source**: SRDI

Appendix III. Analysis of variance of the data on plant height, stem length and number of leaves per plant of cabbage at different days after transplanting as influenced by plant spacing and potassium levels

Source of variation	Degrees of freedom	Mean square								
		Plant Height (cm)			Stem length (cm)			Number of leaves per plant		
		30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
Replication	2	0.457	3.564	5.565	0.170	0.465	0.346	0.642	0.433	0.633
Plant spacing (A)	2	4.445**	7.500**	15.559**	1.010**	1.477**	2.186**	1.022	5.591*	22.448**
Potassium (B)	3	2.273**	36.199**	51.904**	0.548*	0.712*	0.864*	1.511	4.551*	8.559**
Interaction (A × B)	6	0.507**	1.945*	2.323*	0.650*	0.823*	0.736*	0.120	4.243*	0.422*
Error	22	0.274	0.678	0.840	0.161	0.213	0.256	0.744	1.409	0.159

**: Significant at 0.01 level; *: Significant at 0.05 level

Appendix IV. Analysis of variance of the data on leaf length, leaf breadth and spreading of plant of cabbage at different days after transplanting as influenced by plant spacing and potassium levels

Source of variation	Degrees of freedom	Mean square								
		Leaf length (cm)			Leaf breath (cm)			Spreading of plant (cm)		
		30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
Replication	2	3.217	1.102	4.789	0.092	0.101	1.727	4.376	1.333	6.082
Plant spacing (A)	2	0.430	5.823*	15.470**	2.773**	8.095**	16.196**	6.470*	580.432**	1350.45**
Potassium (B)	3	7.759**	12.513**	14.882**	1.880**	4.155**	10.624**	5.282*	101.301**	237.780**
Interaction (A × B)	6	2.337*	2.710*	6.889*	1.233**	4.574**	2.122*	5.269*	14.801**	27.200**
Error	22	1.598	1.203	3.139	0.426	0.766	0.770	3.014	1.978	4.857

**: Significant at 0.01 level; *: Significant at 0.05 level

Appendix V. Analysis of variance of the data on yield contributing characters of cabbage as influenced by plant spacing and potassium levels

Source of variation	Degrees of freedom	Mean square							
		Number of loose leaf per plant	Number of compact leaf per plant	Weight of loose leaf (gm/plant)	Total dry matter of loose leaf (gm/plant)	Diameter of head (cm)	Thickness of head (cm)	Fresh weight of head (kg/plant)	Total dry matter of head (g/plant)
Replication	2	0.710	1.513	2436.11	0.636	0.192	0.295	0.069	0.381
Plant spacing (A)	2	11.737**	184.169**	149286.11**	13.710**	18.352**	5.903**	11.252**	21.248**
Potassium (B)	3	8.160**	30.420**	76395.370**	9.776**	8.878**	2.689**	1.520**	14.576**
Interaction (A × B)	6	6.535**	13.978**	21189.82**	0.880*	13.924**	2.746**	0.438**	1.231**
Error	22	0.790	2.801	7196.717	0.307	0.834	0.437	0.020	0.361

**: Significant at 0.01 level; *: Significant at 0.05 level

Appendix VI. Analysis of variance of the data on yield contributing characters and yield of cabbage as influenced by plant spacing and potassium levels

Source of variation	Degrees of freedom	Mean square						
		Diameter of stem (cm)	Length of stem (cm)	Fresh weight of stem (g)	Length of root (cm)	Fresh weight of root (g)	Gross yield (t/ha)	Marketable yield (t/ha)
Replication	2	0.035	0.091	22.227	4.051	4.310	15.873	114.491
Plant spacing (A)	2	0.342*	3.248**	45.207**	0.870 NS	138.875**	192.881**	652.950**
Potassium (B)	3	0.558**	0.924*	291.825**	2.292 NS	91.954**	1709.116**	1119.730**
Interaction (A × B)	6	0.453**	0.877*	43.083**	0.326 NS	46.163**	50.427*	74.486**
Error	22	0.074	0.233	8.921	1.467	5.734	17.192	22.168

**: Significant at 0.01 level; *: Significant at 0.05 level NS=Non-significant

Appendix VII. Production cost of cabbage per hectare

A. Input cost

Treatment Combination	Labour cost	Ploughing cost	Seed Cost	Water for plant Establishment	Manure and fertilizers				Insecticide/ pesticides	Sub Total (A)
					Cowdung	Urea	TSP	MP		
S_1K_0	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	0.00	8000.00	67376.00
S_1K_1	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	5400.00	8000.00	72776.00
S_1K_2	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	7200.00	8000.00	74576.00
S_1K_3	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	9000.00	8000.00	76376.00
S_2K_0	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	0.00	8000.00	67376.00
S_2K_1	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	5400.00	8000.00	72776.00
S_2K_2	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	7200.00	8000.00	74576.00
S_2K_3	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	9000.00	8000.00	76376.00
S_3K_0	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	0.00	8000.00	67376.00
S_3K_1	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	5400.00	8000.00	72776.00
S_3K_2	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	7200.00	8000.00	74576.00
S_3K_3	12000.00	9000.00	4000.00	3000.00	20000.00	4176.00	7200.00	9000.00	8000.00	76376.00

Appendix VII. Contd.

B. Overhead cost (Tk./ha)

Treatment Combination	Cost of lease of land for 6 months (13% of value of land Tk. 10,00000/year	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 13% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
S_1K_0	65000	3369	8823	77192	144568
S_1K_1	65000	3639	9192	77831	150607
S_1K_2	65000	3729	9315	78044	152620
S_1K_3	65000	3819	9438	78256	154632
S_2K_0	65000	3369	8823	77192	144568
S_2K_1	65000	3639	9192	77831	150607
S_2K_2	65000	3729	9315	78044	152620
S_2K_3	65000	3819	9438	78256	154632
S_3K_0	65000	3369	8823	77192	144568
S_3K_1	65000	3639	9192	77831	150607
S_3K_2	65000	3729	9315	78044	152620
S_3K_3	65000	3819	9438	78256	154632