EFFECT OF NITROGEN AND SPACING ON THE GROWTH AND YIELD OF CABBAGE

Firoj Asadul Haque

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA 1207

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BY

Firoj Asadul Haque
Registration No. 11-04711

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Approved by:

Prof. Dr. Md. Nazrul Islam
Department of Horticulture
SAU, Dhaka
Supervisor

Shormin Choudhury
Assistant Professor
Department of Horticulture
SAU, Dhaka
Co-Supervisor

Prof. Md. Hassanuzzaman Akand
Chairman
Examination Committee

Dedicated

to

My Beloved Parents

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Bangladesh

PABX: +88029144270-9
Ext. 309 (Off.)
Fax: +88029112649
e-mail:
bioc_sau@ymail.com

Ref : **Date:**

CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF NITROGEN AND SPACING ON THE GROWTH AND YIELD OF CABBAGE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of *bona fide* research work carried out by **FIROJ ASADUL HAQUE**, Registration No. **11-04711** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2013
Place: Dhaka, Bangladesh

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Prof. Dr. Md. Nazrul Islam
Department of Horticulture
Sher-e-Bangla Agricultural University
Supervisor

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The author

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ABSTRACT

An experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from October 2012 to February 2013 to study the effect of nitrogen and spacing on the growth and yield of cabbage. The experiment was laid out in a Randomized Complete Block Design with three replications and includes of Factor A: four levels of urea; N_0: Control, N_1:150 kg ha^{-1}, N_2: 250 kg ha^{-1} and N_3: 350 kg ha^{-1}, and Factor B: three plant spacing; S_1 (50 cm x 30 cm), S_2 (50 cm x 40 cm) and S_3 (50 cm x 50 cm). At 80 DAT the highest plant height (37.2 cm), diameter of head (19.5 cm) from N_3 but fresh weight of head (2.1 kg from N_2) was found from N_2 and the lowest from N_0. On the other hand, at 80 DAT the highest plant height (35.3 cm), diameter of head (19.2 cm) and fresh weight of head (1.8 kg) were found in S_3 and the lowest from S_1. The highest fresh weight of head (2.3 kg from N_2S_3) and marketable yield (128.9 tha^{-1}) were recorded from N_2S_1 and, the lowest fresh weight of head (1.1 kg from N_0S_1) and marketable yield (53.3 tha^{-1}) from N_0S_3. The maximum benefit-cost ratio (4.7) was recorded in the treatment combination of 250 kg urea ha^{-1} with spacing 50 cm × 30 cm(N_2S_1) while the lowest in N_0S_3 (2.1). So, it can be concluded from economic point of view, 250 kg urea ha^{-1} with spacing 50 cm × 30 cm is suitable for growth and yield of cabbage.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	ELABORATIONS
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
cm	Centimeter
CV	Coefficient of Variation
cv.	Cultivar (s)
Dept.	Department
df	Degrees of Freedom
DMRT	Duncan’s Multiple Range Test
et al.	And others
FAO	Food and Agriculture Organization Of the United Nations
FYM	Farmyard manure
LSD	Least Significant Difference
MOA	Ministry of Agriculture
MSTAT	Michigan State University Statistical Package for Data Analysis
RCBD	Randomized Complete Block Design
RH	Relative Humidity
SAU	Sher-e-Bangla Agricultural University
SE	Standard Error
var.	Variety
Via	By way of
Viz.	Namely
WP	Wetable powder

Chapter I

Introduction

INTRODUCTION

Cabbage (*Brassica oleracea* var *capitata*) is an important vegetable of almost all parts of the world and belongs to the family Cruciferae. It is biennial and herbaceous in nature and is extensively grown during winter season in Bangladesh. A 100 g edible portion of cabbage contains 1.8 g protein, 0.1 g fat, 4.6 g carbohydrate, 0.6 g mineral, 29 mg calcium, 0.8 mg iron and 14.1 mg sodium (Singh and Naik, 1988). Moreover, it is a rich source of vitamins A and C (Prabhakar and Srinivas, 1990 and Tiwari *et al*., 2003). It may be served in slaw, salads or cooked dishes (Andersen, 2000).

Cabbage is one of the five best vegetables in the world (Rashid, 1999). It is an important winter leafy vegetables grown in Bangladesh. At present in Bangladesh, it is being cultivated in area of 16.6 thousand hectares which is increasing day by day with a production of 220 thousand metric tons and the average yield of cabbage in Bangladesh is 8.9 t/ha (BBS, 2010) which is very low compared to other countries (Japan 40.03 t/ha, South Korea 59.07 t/ha, and India 17.88 t/ha) of the world (FAO, 1994). This low yield may be attributed to a great extent on the method of low production management practices adopted by the farmers.

In order to maintain or even improve cabbage production, some factors have to be considered. Production of vigorous transplants is one such necessary factor for successful vegetable production (Cantliffe and Karchi, 1992). Again, correct cultural practices such as adequate application of fertilizers (Everaarts, 1998) and optimum plant population have to be adhered to in order to obtain good yields in cabbage production (Singh and Naik, 1988; Lecuona, 1996; Singh, 1996; Parmar, etal; 1999; Sandhu, etal; 1999; Kumar and Rawat, 2002).

Adequate application of nitrogen fertilizer promotes vigorous vegetative growth and dark green colour of cabbage (Ware and McCollum, 1980; Peck, 1981; Hadfield, 1995). Nitrogen is important in the formation of chlorophyll and is also a component of proteins. Lack of nitrogen causes slow, spindly growth and pale foliage, resulting in limited production (Hadfield, 1995).

Spacing is another factor that was reported to be having an influence on cabbage production. Widders and Price (1989) defined spacing as the distance between the plants in the row and between the rows of planted crops. Ghanti, etal; (1982) observed maximum results of yield contributing characters (head diameter, gross and net mass of cabbage head) at higher spacing and a decrease as spacing between plants decreased.

Bearing in mind that nitrogen plays a good role in production of vigorous transplants and that spacing and nitrogen levels influence cabbage head size produced. However, within a chosen cultivar, spacing and nitrogen levels can be manipulated in accordance with the required head size. Considering the above mentioned facts, the present study was undertaken with the following objectives:

1. To find out the optimum level of nitrogen for better growth and yield of cabbage.
2. To find out the suitable plant spacing for better growth and yield of cabbage.
3. To find out the combined effect of nitrogen along with suitable plant spacing for better growth and yield of cabbage.

Chapter II

Review of Literature

CHAPTER II
REVIEW OF LITERATURE

Cabbage is one of the important leafy vegetable. Crop species differ in their nutrient requirements depending on the stage of development and part of the plant that is of economic importance. Most leafy vegetables have a high requirement for nitrogen. Though, plants get major nutrients from the soil, they are not adequate to meet the increasing demand for higher production. The literature on the effect of nitrogen and spacing on growth and yield attributes of cabbage is included in this chapter for better understanding of the subject.

2.1 Effect of nitrogen on the growth and yield of cabbage

Pramanik (2007) carried out an experiment at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September 2006 to February 2007 to study the effect of nitrogen and phosphorus on the growth and yield of cabbage. Theexperiment was laid out by RCBD with three replications.The experiment consisted of two factors. Factor A: four levels of nitrogen (N_o = control, N_1 = 200 kg/ha, N_2= 260 kg/ha and N_3 = 320 kg/ha) and Factor B: four levels of phosphorus (P_o = control, P_1 = 110 kg/ha, P_2= 120 kg/ha and P_3 = 130 kg/ha). At harvest, the maximum plant height (34.76 cm), thickness of head (17.06 cm), gross and marketable yield of head were recorded in 260 kg N/ha while the control gave the lowest results.

Kumar and Rawat(2002) conducted an experiment on cabbage (*Brassica oleracea* L. Var *capitata*) CV. "Pride ofIndia" to study the effect of different levels of nitrogen (0,50, 100, 150 and 200 kg N/ha) and spacings(30 x 60 cm, 45 x 60 cm and 60 x 60 cm) on the quality and yield of cabbage. The nitrogen hadsignificant affect the TSS (%), dry matter per cent, chlorophyll content (mg g^{-1}), compactness ofhead (rank marks), head diameter (cm), head weight (g) and yield (q/ha). The maximum TSS, drymatter per cent, chlorophyll content, and head diameter were recorded in 200 kg N/ha. However, the highest head weight (1127.22 g) and yield (312.42 q/ha) was recorded in applicationof 150 kg N/ha. Spacing also affected the quality and yield of cabbage. The quality improved withincrease in spacing. Highest yield of 303.09 q/ha was recorded in 30 x 60 cm spacings.

Parmar *et al.*(1999) reported higher yields in cabbage with increased nitrogen rates. The application of 200 kgha^{-1} N produced significantly higher yield over 150kg ha^{-1} N but at par with 250 kg ha^{-1} N. This was attributed to the fact that higher nitrogen levels favored the growth of plants with larger leaf area and it was more usefully utilized in head formation. Similar observations on cabbage were made by Ghanti *et al.*(1982), where yield contributing characters such as head diameter and gross mass of heads and number of marketable heads increased with increase in the levels of nitrogen up to 200 kgha^{-1} Gupta(1987) observed significantly higher cabbage yields at 150 kgha^{-1}N than yields at 0,50 and 100kg ha^{-1} N yet at par with yield at 200 kg ha^{-1} N.

Everaarts and De Moel(1998) reported increasing uniformity with increasing amounts of nitrogen applied. In cabbage production uniformity of heads is important. Increase in relative core length was observed when nitrogen application rate increased, whereas dry matter content of the heads decreased. This was associated with softer head tissue at higher nitrogen availability, thereby having less physical resistance to stalk elongation. The lower the relative core length, the better the head quality(AalbersbergandStolk,1993).

Peck(1981)observed decreases in percent dry mass of the heads, increased number of burst heads and increased tip burn in the heads with increasing fertilizer nitrogen rate. It was therefore concluded that high nitrogen fertilizer decreased the quality of cabbage heads.

Man and Sandhu (1956) carried out an experiment on the nitrogen requirement of cabbage in India. They found the optimum dose of nitrogen is about 168 kg/ha, which gave the maximum number and large size of outer leaves, bigger and heavier heads. The maximum sizes of marketable higher yield of head were also produced by the treatment.

Thomson and Kelly (1957) mentioned that cabbage is a heavy feeder of nitrogen. They also noted that in moist soil of California, 56-112 kg of nitrogen per hectare is considered adequate fertilization for cabbage. 308 kg N/ha, the higher dose reduced proportionately bigger head weights. Similarly Vleck and Polack (1977) found that application of 140 kg N/ha was effective for raising cabbage yields, but the maximum number outer leaves and yield were produced by 80 kg N/ha. It was reported by Batsei*et al*. (979) that nitrogen at the rate of 240 kg per hectare produced highest yield of cabbage on irrigated soil.

Csizinszky and Schyster (1985) conducted experiments to investigate the effect of N on the yield of cabbage with two years trail in Florida. The experiments were conducted ill spring and autumn winter they observed that the high N rate (257 kg/ha) increased head size in both seasons, but increased marketable yields in the spring.

Lawande*et al*. (1986) carried out an experiment to study the effects of spacing, nitrogen, phosphorus and potassium on yield and yield contributing characters of cabbage cv. Golden Acre. They found 240 kg N//ha was good for cabbage yield. Farooque and Mondol (1987) reported that the higher levels (336 kg/ha) of nitrogen increased the marketable yield of cabbage.

Khurana *et al*. (1987) conducted an experiment to investigate the effect of nitrogen and spacing on cabbage cv. Pride of India and found that the highest head yield and the average head weight were produced by 60 kg nitrogen per hectare in four splits. In another experiment, Prabhakar and Srinivas (1987) used three nitrogen levels (0, 75 and 150 kg/ha) and found that individual head yield was increased with increasing nitrogen up to 150 kg/ha (1.76 t/ha), compared with 1.04 t/ha with 75 kg N/ha and 0.23 t/ha in the control.

Gopal and Lal (1996) conducted an experiment to find out the effect of nitrogen and spacing on yield and quality of cabbage cv. Golden Acre, in India. They used different levels of nitrogen 0, 50, 75 and 100 kg/ha. Growth (number of leaves, plant height and weight of head) increased with increasing rates of N. The highest yield (254.85 q/ha) was observed at the rate of 100 kg N/ha compared with 168.73 q/ha in control.

Bhuiyan (1996) carried out an experiment to find out the effect of differentlevels of nitrogen and their time of application on the growth and yield of cabbage at horticulture farm, Bangladesh Agricultural University, Mymensingh in Bangladesh. There were six levels of nitrogen (0, 75, 150, 225 and 300 kg N/ha). He found that different levels of nitrogen had significantly influenced on growth and yield of cabbage. Yield contributing characters and yield such as plant height, diameter and thickness of the head were maximum at the rate of 150 kg N/ha. The highest gross yield (79.62 t/ha) was achieved by the application of 150 kg N/ha compared to the lowest yield (28.88 t/ha) in control.

According to Dixit (1997) the effects on N (0, 40, 80, 120 and 160 kg/ha) on the growth of cabbage cv. Pride of India was investigated in Himachal Pradesh, India. Yield increasing with increasing N rate (from 136.8 to 175.1 q/ha after addition of 0 and 160 kg N/ha respectively) .

Hossain (1998) studied the effect of different planting time, spacing and nitrogen level on the growth and yield of cabbage at the Horticulture farm of Bangladesh Agricultural University, Mymensingh in Bangladesh.The experiment consisted four levels nitrogen viz. 0, 50, 150 and 250 kg/ha. The maximum plant height, diameter of head, thickness of head, number of lateral roots, gross yield (108.60 t/ha), marketable yield (79.33 t/h) were obtained from 250 kg N/ha.

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.

2.2 Effect of plant spacing on growth and yield of cabbage

Moniruzzaman (2011) carried out a field experiment on cabbage (*Brassica oleracea* var. *capitata*) comprising two plant spacings viz. 60 × 40 cm and 60 × 45 cm and ten hybrid cabbage varieties viz. Green Rich, Green-621, Green Coronet, Summer Warrior, Rare Ball, Atlas-70, Southern treasure, Laurels, K-K Cross and K-S Cross was conducted during 15 October to 12 February of 2005-07 at the Agricultural Research Station, Raikhali, Rangamati Hill District to find out the optimum plant spacing and suitable cabbage variety(s). The wider spacing of 60 × 45 cm resulted in significantly maximum number of folded leaves and head weight (without unfolded leaves) in comparison to closer spacing of 60 × 30 cm. The variety Green Coronet took the highest duration (119 days), while Green-621 took the lowest duration for harvest (105 days). Although Green Coronet grew vigorously, it did not produce the highest head yield. All the varieties had good head compactness except Laurels and Green Coronet which had medium and less compactness, respectively. The combination of 60 × 30 cm spacing with variety Southern Treasure and K-S cross produced the highest head diameter, but wider spacing of 60 × 45 cm accompanied by Southern Treasure produced the highest head weight without unfolded leaves followed by K- K Cross in both the years. The pooled analysis showed the highest marketable head yield (73.32 t/ha) in the combination of 60 x 40 cm spacing with K-K Cross, which was closely followed by Southern Treasure (71.71 t/ha) and Laurels (71.56 t/ha). The variety Green-621 was found suitable for early harvest with reasonable yield (67.82 t/ha).

(Amreesh, 2002) conducted a field experiment at village Pemasar, in Bikaner district (Rajasthan, India) during the rabi season 2001-2002 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 cm × 60 cm spacing + 150 kg N ha^{-1}.

(Parmar*et al*., 1999) conducted a field experiment in 1999 in Gujarat to study the response of cabbage cv. Golden Acre to irrigation levels, plant spacing (30cm×30 cm or 40 cm ×30 cm) N application (150-250 kg/ha in clay soil. 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.

A field experiment was conducted in Mymensingh, Bangladesh, from October 1996 to March 1997 to study the effects of irrigation regime and spacing (50 cm×60 cm, 50 cm×50 and 50 cm×40 cm) on cabbage cv. Atlas-70. A spacing of 50 cm×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 cm × 50 cm. Net return (Tk. 128.026/ha) and benefit cost ratio (2.63) were highest with a spacing of 50 cm × 50 cm (Mannan*et al*., 2001).

(Aquino *et al*., 2005) undertook a field experiment 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 .

A trial from 1979 to 1981 with 25-day old cabbage (cv. capitata) seedlings was conducted with 3 spacing's (50 cm×30 cm, 50 cm×40 cm or 50 cm×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 (Probhakar and Srinivas 1990).

An experiment was carried out by Khatun (2008) at the farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from October 2007 to February 2008 to study theeffect of plant spacing and potassium on the growth and yield of cabbage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and includes of Factor A: three different plant spacing; S_1 (60 cm x 30 cm), S_2 (60 cm x 40 cm) and S_3 (60 cm x 60 cm) and Factor B: four levels of potassium; K_0 (control), K_1 (90 kg/ha), K_2 (120 kg/ha) and K_3 (150 kg). At 60 DAT the highest plant height (37.70 cm), maximum diameter of head (19.05 cm), fresh weight head (1.87 kg), gross yield (71.20 t/ha) and marketable yield (53.97 t/ha) was recorded from 60 cm x 40 cm spacing.

An experiment was carried out by Ullah (2011) at the farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from October 2010 to March 2011 to study theeffect of planting time and spacing on the growth and yield of cabbage. The experiment was laid out in a Randomized Complete

Block Design (RCBD) with three replications and includes of Factor A: three different planting times; T_1 (7 November), T_2 (21 November) and T_3 (5 December) in 2010, and Factor B: three different plant spacing; S_1 (60 cm x 40 cm), S_2 (60 cm x 45 cm) and S_3 (60 cm x 50 cm). At 80 DAT the highest plant height (31.5 cm), maximum diameter of head (19.4 cm) and the highest fresh weight (1.00 kg) were found from S_3 and the lowest weight (0.86 kg) from S_1. On the other hand, at 80 DAT the tallest plant height (35.9 cm), maximum diameter of head (20.4 cm) and highest weight of head (1.28 kg) were found from T_1 and the lowest weight (0.53 kg) from T_3 treatment. The highest fresh weight of head (1.36 kg) was recorded from T_1S_1 and the lowest fresh weight of head (0.4 kg) from T_3S_3. He concluded that, the spacing (60 cm x 40 cm) and 21 November planting time were found suitable for growth and yield of cabbage.

An experiment was carried out to study the effects of N (0,50,75 or 100 kg/ha) and spacing (30 cm×60 cm, 45 cm×60 cm or 60 cm×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 cm × 60 cm to 184.71 q/ha at a spacing of 60 cm×60 cm (Gopal, 1996).

Dufault and Waters(1985) reported that broccoli head mass decreased linearly when plant populations were increased from 24000 to72000 plants ha^{-1} with nitrogen kept constant at 112,169 or 224kgha^{-1}. It was however, observed that despite reduction of head mass, marketable yields increased due to increased numbers of heads. High broccoli yields were recorded at the highest plant populations of 72000 plants ha^{-1}. In cauliflower different results from those of broccoli were reported. It was observed that whenever plant populations were increased from 24 000 to 72 000 plants ha^{-1} , marketable yield of cauliflower decreased. The explanation given was that increasing plant populations increased competition among plants resulting in reduced marketable yield.

Farooque and Islam (1989) conducted trials with the cultivar K-K Cross, between October 1987 and Mar. 1988, the plants spaced at 60 cm×30 cm, 60 cm×45 cm or 60 cm×60 cm were subjected to 3 different fertilization schedules. Marketable yields for the 3 spacing's 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.

Ferreira *et al*. (2002) carried out a study on Brassica crop due to their importance as food for human consumption, especially in relation to their nutritional value. Both yield and consumption were 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 cm × 20 cm and 30 cm × 30 cm). The highest value of agronomic yield (21.5 t/ha) was reached in the smallest spacing (30 cm × 10 cm), with mineral fertilizer application. This value is near to that registered in Malaysia and China where this vegetable was cultivated on a large scale.

Freyman*et al*. (1992) carried out study on the effects of intra-row competition by C. bursa-pastoris, grown either 10 of 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 cm×100 cm or 50 cm×40 cm spacing, no differences in yield were found. The results indicate that cabbages grown in wide rows with close within-row spacing should experience minimal intra-row weed competition.

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.

Fujiwara *et al*. (2003) carried out an experiment where 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.

Ghanti *et al.*(1982) studied the response of 'Pusa Drumhead' cabbage to nitrogen, phosphorus and spacingin order to find a suitable combination of nitrogen, phosphorus and spacing for obtaining higher yield. They observed significant effects of different spacings on the yield contributing characters such as head diameter, and gross and net mass of head. Maximum results of head diameter, head gross and head net mass were obtained at 50x70cm spacing and decreased as intra-rows pacing(40x70cmand30 x70cm) decreased. Closer spacing increased competition for water and nutrients and subsequently reduced vegetative growth which led to a decrease in the diameter as well as mass of heads. Nonetheless,a closer spacing of 30x70cm produced maximum number of marketable heads which was 55% more than that of 50x70cms pacing. The maximum number of marketable heads from 30x70cm spacing contributed to higher yields of about 35% and 18% more than that recorded under50x70cm spacing for the first and the second year, respectively.

Guzman(1990) monitored the effect of 12,13,14 and 15 inch(30.5, 33.0,35.6 and 38.0cm) plant spacing in the row to maximize yield and quality of transplanted crisphead lettuce. Spacing did not have a significant influence on fresh mass and the number and percentage of marketable heads. This suggested that 12 to 15 inch (30.5to38.0cm) plant spacing gave similar productivity. Nevertheless, it was evident that 12 or 13 inch(30.5or33.0cm) spacing would probably maximize yields more than with wider spacings. All plant spacings under study provided good head mass and 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 cm×25 cm, 30 cm×30 cm, 35 cm×35 cm, or 40 cm×40 cm and given 0,50, 100, 200, 300 or 400 kg N/ha. The highest marketable yields were 126.6 and 123.6 t/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.

Islam *et al*. (1989) conducted a field trial in 1987/888 at Mymensingh, with 21, 28, 35 and 42 days old seedling, of the cultivar Atlas 70 and the plant were spaced at 60 cm×30 cm, 60cm×45 cm and 60 cm×60 cm. The highest marketable yield of 39.3 t/ha was obtained with 42-day-old seedlings spaced 60 cm×60 cm, and the lowest yield of 29.8 t/ha with 28-day-old seedlings spaced 60 cm×30 cm.

Jaiswal*et al*. (1992) conducted an experiment on cabbage cv. Pride of India on 4 September1985 and transplanted on 10 October 1985 at a spacing of 30 cm×30 cm or 30 cm×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 ¼ 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 (M_2). Plant growth and productivity increased with increasing level of N application and was highest under M_2. 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 cm×20 cm.

Khadir*et al.* (1989) carried out a study for 2 consecutive seasons to investigate the effects of 3 levels of urea (0, 300 and 600 kg/ha) and 3 plant spacings (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 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.

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 cm × 60 cm, 45 cm × 60 cm and 60 cm × 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 cm×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 cm×60 cm gave the highest head yield (303.09 q/ha).

Kumar and Rawat(2002) conducted a study during 1997-98 at the Horticulture Farm, Rajasthan College of Agriculture, Udaipur, to determine the effects of nitrogen and spacing on the quality and yield of cabbage (*Brassica oleracea*L.var. *capitata*). It was observed that spacing had no effect on dry matter percentage. Maximum head diameter and head mass were recorded at wider spacing. It was believed that wider spacing provided more sufficient space and less competition between available nutrients for plants. Therefore, there was increase in the head diameter and head mass.

Mallik (1996) determined the response of cabbage cv. Pusa Drum Head to N fertilizer application rate (0, 40, 80 or 120 kg/ha) and spacing (60 cm × 45 cm or 60 cm × 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.

Mannana*et al.* (1999) set up 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) applied to cabbages grown at 50 cm×60 cm, 50 cm×50 cm or 50 cm×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 cm×50cm) and the lowest from the closest spacing (50 cm×40 cm). Maximum marketable yield was obtained from the moderate spacing of 50 cm×50 cm.

Meena (2003) conducted an experiment in Rajasthan, India, during the rabi season of 1997-98. Three levels of spacing, (30 cm × 45 cm) (45 cm × 45 cm) and (60 cm × 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 8.3 at 30 DAT, and 9.9 at 60 DAT. Stem diameter significantly increased with increasing levels of spacing. Stem diameter was the highest 1.28cm compared with 1.15cm and 1.00cm diameters were recorded respectively. Leaf area was the highest with 315.41 cm^2 and lowest with 310.83 cm^2 at harvest. The average head weight was the highest 831.3 g and the lowest 766.3 g. The percent increase in head weight was 8.5. A significant increase in biological and economical yield was observed. The percent harvest index was the highest 71.3 and the lowest 70.3. Closer spacings resulted in higher biological and economic yield.

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 weight 0.6 g/m row with rows 20 cm apart. The transplant raising treatment had generally no adverse effect on crop quality.

Prabhakar and Srinivas(1990) recorded higher cabbage head yield(11t ha^{-1}) with closer spacing(50x30cm) than wider spacings(50x40cmand50x50cm). Parmar *et al.*,(1999)noted higher head yield(16to43%) in30x30cm over45x30cm during individual years of conducting experiments.

Puiatti *et al*. (2005) studied the effects of three spacings (80 cm × 30 cm, 60 cm × 30 cm and 40 cm × 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 after 28 days. 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.

Sandhu*et al*. (1999) conducted a 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 cm×45 cm and 75 cm×30 cm produced maximum plant spread. However, the application of 125 kg N/ha with closer spacing of 45 cm× 45 cm and 30 cm×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 inflorescence 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.

Singh(1996) tested nitrogen, phosphorus and spacing for their impact on cabbage (cv. Pusa Drumhead) under Chotanagpur conditions. It was observed that with the increase in plant spacing from 30to60cm, there was a significant reduction in the number of marketable heads per unit area. The reductions were associated with higher plant densities in the closer spacings. Spacing did not have any significant in fluence on the head index, butan increasing trend was observed as spacing increased. Significant improvements in head volume were attained with an increase in spacing. Similar behavior was again observed with head mass a ssignificantly higher mass was recorded at 60cm spacing compared to 30 and 40cm inter-row spacings. This behavior was attributable to availability of enough space and more nutrients at the widest spacings, which encouraged the growth and development of plants.

Singh and Naik(1988) recorded significantly higher yields with closer spacing(45x30cm) than wider spacings (45x45cmand45x60cm) of cabbage. Yield from the closer spacing was approximately 49% and 45% more than yield recorded under 45x60cm spacing in the first and second year, respectively. Furthermore, 63% and 92% more marketable heads were obtained from the closer spacing than the widest spacing. More number of marketable heads per unit area in the case of closer spacing was attributed to increases in yield. As spacing was increased there was no significant increase in head mass even though the widest spacing recorded maximum head mass. This was attributable to the fact that with closer spacing competition for the growth factors increased.

Singh *et al*. (2007) conducted an experiment in Allahabad, Uttar Pradesh, India during winter season of 2000-2001 to evaluate the effects of N (0, 40, 80 and 120 kg/ha) and spacing (30 cm × 45 cm and 30 cm × 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 30 cm × 60 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.

Stepanovic *et al.*(2000) reported highest cabbage head diameter values in the case of lowest crop density .It was observed that head diameter decreased in parallel with increasing crop density. In the contrary, higher cabbageyields per hectare were recorded in the case of higher plant densities. The higher crop densities were as a result recommended for cabbage production. It is, however, important to compare the issue of profitability of such a production with the high costs of transplants and manual labour. The most suitable crop density is tha twhich ensures high yields, good quality and low production costs.

Tendaj and Kuzyk (2001) carried out a research to check whether greater plant density in cultivation of late red cabbage cultivars influence the size, yield and the weight of heads. Seedlings of three cabbage cultivars-Langenkijker Pol, Rodima and Roxy were planted at 30 × 45 cm, 40 cm×45cm, 50 cm×45 cm and 60 cm×45 cm spacing, what equaled the density of 7.4, 5.5, 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 cm × 45cm and 50 cm × 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).

Tendaj and Kuzyk(2001) initiated a study to investigate the influence of greater plant density on the yield and head mass of red cabbage cultivars. They reported highest yield of marketable heads from 50x45cm spacing.There was no significant difference between 50x45cm spacing and the lower spacings (30x45cmand40x45cm).As spacing was increased to60x45cm each cultivar used gave lower yields. Knavel and Herron(1981) observed that wide spacing increased head size while doubling plant population reduced it.

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 transplanted 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 cm × 30 cm), 15000 (70 cm × 40 cm) and 12000 (70 cm × 50 cm) 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 20000plant/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 10, 20 September and 10, 25 October sowing was 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 cm × 30 cm and sowing date of 25 September, which recorded the highest marketable yield, while the lowest value was obtained on Tropical Delight at 70 cm × 50 cm and sown on 15 November (Esmail, 2004).

Chapter III

Materials and Methods

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 (October 2012 to February 2013). The site was located in 24.09° N latitude and 90.26°E longitude (Appendix-I).

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°C is considered as optimum for growth and head formation of the crop. Details of weather data in respect of temperature (°C), rainfall (cm) and relative humidity (%) were collected from the Meteorological Department, Agargaon, Dhaka (Appendix-II).

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-III.

3.4 Planting materials used for the experiment

Seeds of “Autumn Queen” 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 15 October for raising cabbage seedlings. The size of the seed bed was 3 m × 1 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 seed bed on 15 October. The soil of the seed bed was well prepared and made into loose friable mass by spading. The bed was covered with dry straw to maintain required temperature and moisture. Sowing was done thinly 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 cover of dry straw was removed immediately after emergence of seedlings.

3.8 Raising of Seedling

Light watering and weeding were done as and when needed. No chemical fertilizer was applied for rising of seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy seedlings were transplanted.

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 is fourlevels of nitrogen and three types of spacing.

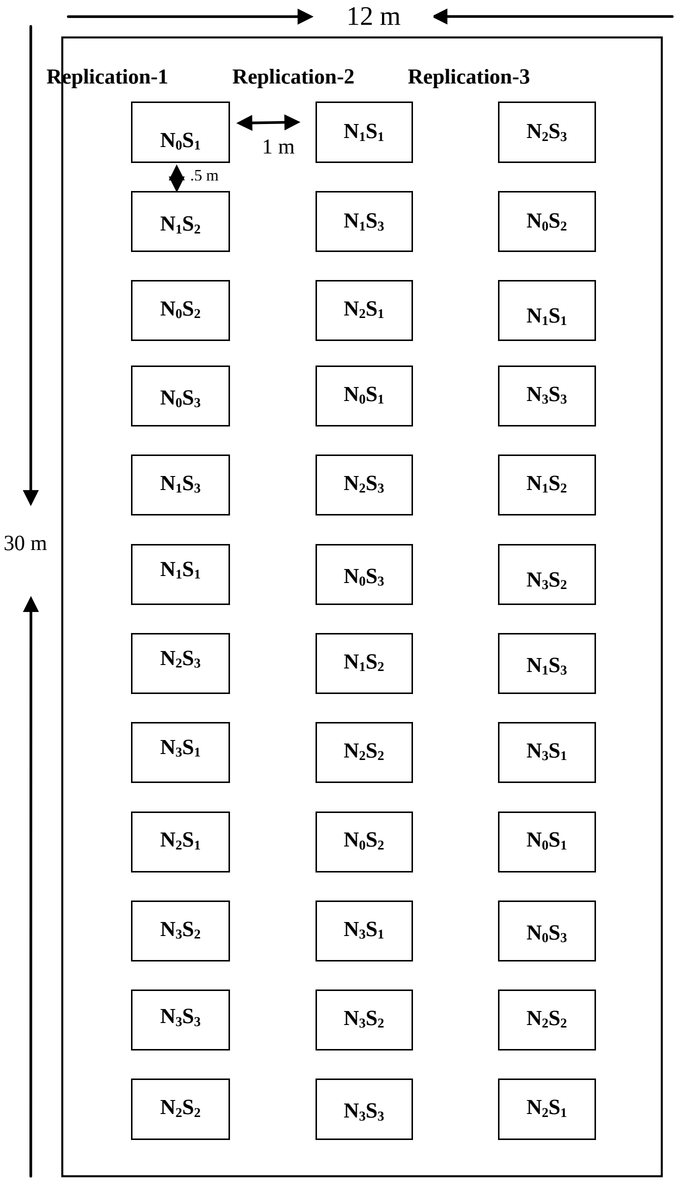
Factor A	**Factor B**
Four levels of nitrogen: given as urea and denoted as (N)	Three different spacing: denoted as (S)
N_0 : Control (No fertilizer)	
N_1 : 150 kg/ha	S_1 : 50 cm × 30 cm
N_2 : 250 kg/ha	S_2 : 50 cm × 40 cm
N_3 : 350 kg/ha	S_3 : 50 cm × 50 cm

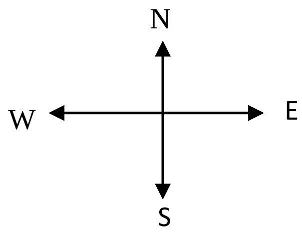
Therefore, the treatment combinations are N_0S_1,N_0S_2, N_0S_3, N_1S_1, N_1S_2, N_1S_3, N_2S_1, N_2S_2, N_2S_3, N_3S_1, N_3S_2 and N_3S_3.

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 combination. Therefore, the total numbers of plots were36 and 12 treatment combinations were assigned to each block as per design of the experiment. The size of the unit plot was 3 m×2 m. A distance of 50 cm was maintained between the plot and 1m between the block. Thus, the total land area was 360 m^2.

Field layout of the two factors experiment in the Randomized complete Block Design:





Plot size: 3 m x 2 m
Spacing between plots: 50 cm
Spacing between replication: 1 m

Factor A:
Four levels of nitrogen: denoted as (N)

N_0 : Control (No fertilizer)

N_1 : 150 kg/ha

N_2 : 250 kg/ha

N_3 : 350 kg/ha

Factor B:
Three different spacing: denoted as (S)

S_1 : 50 cm × 30 cm

S_2 : 50 cm × 40 cm

S_3 : 50 cm × 50 cm

3.11 Land Preparation

The experimental field was ploughed to fine tilth by giving four to five ploughing. The land was properly leveled 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; prepared 1m wide and 15 cm high bed. Distance between two beds 50 cm wide were maintained which helped irrigating the crop as well as drainage. According to design, layout of plot was done on 05 November.

3.12 Application of manure and Fertilizers

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

Name of Fertilizers and manure	Quantity (kg/ha)
Urea	As per treatment
TSP	250
MoP	300
Cowdung	5 t/ha

Full doses of cowdung and TSP were applied during final land preparation. The total amounts 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.

3.13 Transplanting of Seedlings

The seed bed was watered before uprooting the seedling to minimize the root damage. Care was taken so that root damage was minimum and some soil should remain with the roots. Before transplanting, the root of the seedlings was dipped in solution of Bavistin (2g/l of water). The seedling having 5-6 true leaves were transplanted on 20 November at the spacing 50 cm × 30 cm, 50 cm × 40 cm and 50 cm × 50 cm in plots. Transplanting was done in the afternoon to the experimental plot and a light irrigation was given after transplanting.

3.14 Intercultural Operation

3.14.1 Gap filling

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

3.14.2 Weeding

Crop was kept weed free by 2-3 hand weeding and 1-2 hoeing. The weeding was done during cropping period.

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.

3.14.4 Irrigation

Irrigation was given as and when required after transplanting of seedlingfor 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 crickets and caterpillars which fed on the leaf epidermis and later made holes just after transplanting. In the leaves spraying with Malathion 57 EC@ 2ml per litre was done to control them. Some time, adult Cabbage borer female laid eggs on the growing point or on the older leaves. Some plants were infected by Alternaria leaf spot disease caused by *Alternariabrassicae*. To prevent the spread of Alternaria leaf spot disease, Rovral 50 WP @ 20 g/10 liter of water was sprayed.

3.16 Harvesting

The head cabbage was first harvested on 10 February 2013 at 85 DAT. Harvesting in completed 85-90 Days. 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 in cm and average plant height was calculated. Plant height was measured from base to the tip of the longest leaf at 20, 40, 60 and 80 days after transplanting (DAT). A meter scale was used to measure the plant height.

3.17.2 Spreading of plant

Horizontal space covered by the plant was measured at 20, 40, 60 and 80 days after transplanting in centimeter (cm) with a meter scale for determining spread of plant.

3.17.3Number of loose leaves per plant

Total number of loose leaves per plant was counted at harvest.

3.17.4 Weight of loose leaves per plant

Weight of loose leaves per plant was recorded in grams (g) with the help of a digital balance.

3.17.5Fresh weight of plant

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

3.17.6Number of lateral roots per plant

The number of lateral roots per plant was counted after harvest of the plant.

3.17.7 Length of root per plant

The distance from the base to the top of the root was measured after harvest of the plant in centimeter (cm) with the help of a scale for the determining the length of root.

3.17.8Fresh weight of root per plant

The fresh weight of root per plant was recorded in grams (g) with the help of a digital balance after harvest of the plant.

3.17.9 Length of stem per plant

The distance from the base of the folded leaves to the level of the root was measured after harvest of the plant in centimeter (cm) with the help of a scale for determining the length of stem.

3.17.10 Diameter of stem per plant

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

3.17.11 Fresh weight of stem per plant

The fresh weight of stem per plant was recorded in grams (g) with the help of a digital balance after harvest of the plant.

3.17.12 Diameter of head

Diameter of 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.

3.17.13 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.

3.17.14 Fresh weight of head per plant

The fresh weight of head per plant was recorded excluding the stem, roots and loose leaves at harvest in kilogram.

3.17.15Dry matter content of head per plant

First the fresh weight of head was recorded, and then 100 g of head were taken from central portion of each heads and dried in an oven at $70^{o}C$ for 72 hours after sun drying for two days.

3.17.16Gross yield per hectare

Gross yield of cabbage per plot was recorded in kilogram and per hectare was calculated in tonnes excluding the stem and roots.

3.17.17Marketableyield per hectare

Marketable yield of cabbage per plot was recorded in kilogram and per hectare was calculated in tonnes excluding the stem, roots and loose leaves.

3.17.18 Statistical analysis

The recorded data on different parameters were statistically analyzed with the help of MSTAT-C Program. The mean values of all the treatments were calculated and analyses of variance for all the characters were performed by the F-test. The significance of the difference among the treatment combinations of means was estimated by least significance difference (LSD) at 5% level of probability.

3.17.19 Economic analysis

The cost of production was analyzed with a view to find out the most profitable treatment combination. Analyses were done according to the procedure determining by Alam*et al.* (1989). The benefit cost ratio (BCR) was calculated as follows:

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

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The results on the effect of nitrogen and plant spacing 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 levels of nitrogen. The tallest plant at 20 DAT (7.5 cm)was recorded from N_3 which was statistically similar to N_2 and N_1, at 40 DAT tallest plant was recorded in N_3(16.8cm)which wasstatistically similar to N_2.At 60 DAT (32.0 cm) and 80 DAT (37.2cm) tallest plants were found in $N_{3,}$whereas, the shortest plant height at 20 DAT (7.1 cm), 40 DAT (13.7cm), 60 DAT (26.3 cm) and 80 DAT (29.0 cm) were found in control (Figure 1). The results showed that the plant height at different DAT was increased in N_3. This might be due to the fact that higher N uptake by plants possibly got favorable condition for better growth than those of other.This result is in agreement with the findings of (Khadir *et al*.,1989 and Singh *et al.,* 2007) where the author reported that plant height increase with increasing the doses of nitrogen.

Plant height varied significantly due to the different spacing (Figure 2). The tallest plant at 20 DAT (7.6 cm), 40 DAT (16.1 cm), 60 DAT (31.1cm) and 80 DAT (35.3cm) were found from S_3. whereas, the shortest plant height at 20 DAT (7.1 cm), 40 DAT (15.3 cm), 60 DAT (28.9 cm)and 80 DAT (32.2cm) were found in S_1. The results showed that the plant height at different spacing was increased with the increasing of spacing. This might be due to receiving sufficient amount of light and nutrients. The trend of the present results was agreed to that of Khadir *et al.,* 1989;Singh *et al*., 2007;Khatun, 2008 and Ullah, 2011. The present result does not agree with the finding of Meena (2003) where the author reported that there was no significant affect by increasing levels of spacing at all crop growth stages.

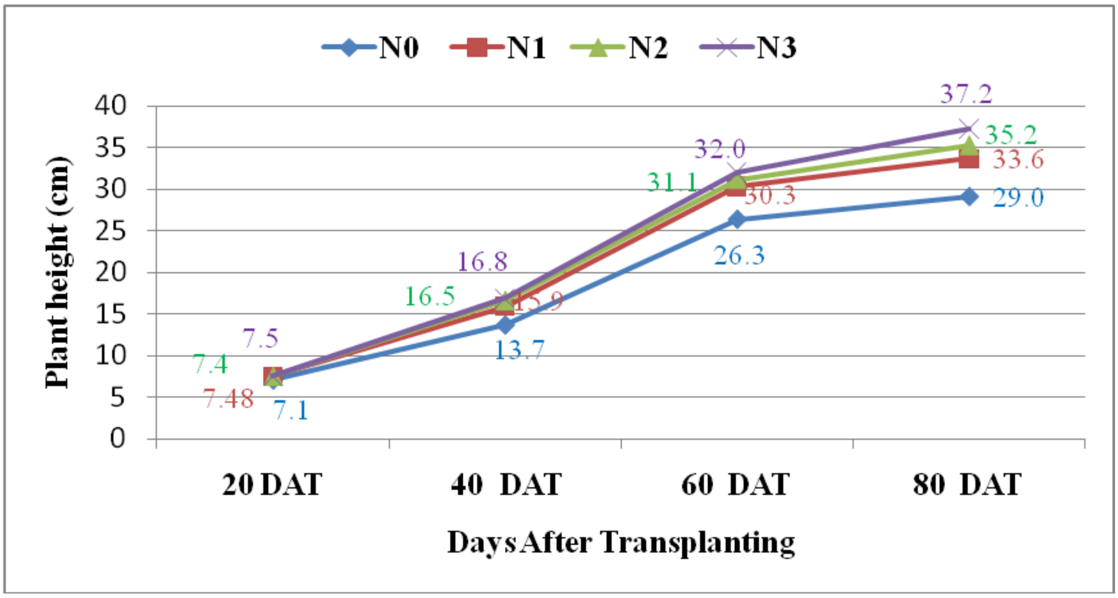


Figure1. Effect of nitrogen on plant height of cabbage at different days after transplanting.

(N_0 = Control, N_1 = 150 kg urea ha^{-1}, N_2 = 250 kg urea ha^{-1} and N_3 = 350 kg urea ha^{-1})

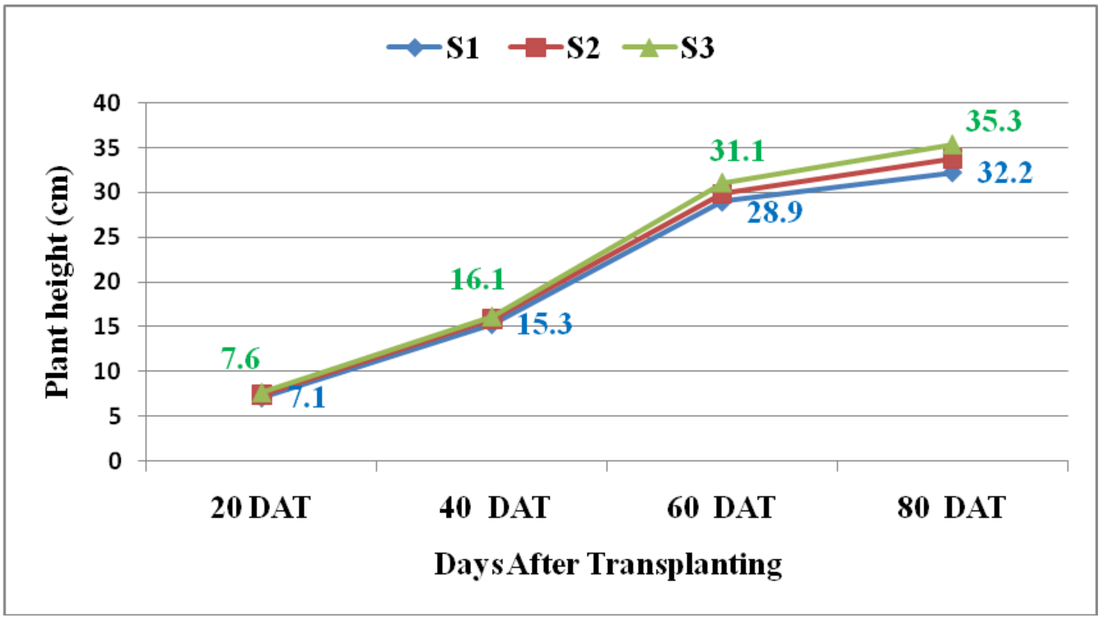


Figure 2. Effect of spacing on plant height of cabbage at different days after transplanting (S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm)

The significant variation was recorded due to combined effect of nitrogen and plant spacing in terms of plant height at different DAT except at 40 DAT (Table 1). The tallest plant at 20 DAT (8.1 cm), at 40 DAT (17.2 cm), 60 DAT (33.6 cm) and 80 DAT (39.8 cm) was recorded from N_3S_3 treatment combination. On the other hand, the shortest plant height at 20 DAT (6.8 cm), 40 DAT (12.9 cm), 60 DAT (25.3 cm)and 80 DAT (28.01 cm) were recorded from N_0S_1 treatment combination.This was due to receiving of sufficient amount of nutrients in the widest spacing. The trend of the present results was agreed to that of Khadir *et al.* (1989); Meena (2003) and Singh *et al*. (2007).

Table 1. Interaction effect of nitrogen and spacing on plant height of cabbage at different days after transplanting (DAT)

Treatmentcombinations	**Plant height (cm) at**			
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**
N_0S_1	6.8 d	12.9 e	25.3 h	28.01 i
N_0S_2	7.2 bcd	13.9 d	25.6 h	29.0 h
N_0S_3	7.2 bcd	14.2 d	28.1 g	30.2 g
N_1S_1	7.3 bcd	15.2 c	29.6 f	32.0 f
N_1S_2	7.6 b	16.1 bc	30.6 de	34.2 de
N_1S_3	7.6 b	16.4 ab	30.8 cde	34.6 cd
N_2S_1	7.3 bc	16.6 ab	30.0 ef	33.4 e
N_2S_2	7.5 bc	16.5 ab	31.6 bc	35.4 c
N_2S_3	7.5 bc	16.6 ab	31.8 b	36.8 b
N_3S_1	7.1 cd	16.5 ab	30.9 bcde	35.4 c
N_3S_2	7.2 bcd	16.8 ab	31.5 bcd	36.4 b
N_3S_3	8.1 a	17.2 a	33.6 a	39.8 a
$LSD_{(0.05)}$	0.48	0.95	0.92	0.94
F-test	*	*	**	**
CV%	3.84	3.55	1.81	1.64

* = Significant at 5% probability, ** = Significant at 1% probability, N_0 = Control, N_1 = 150 kg urea ha^{-1}, N_2 = 250 kg urea ha^{-1},N_3 = 350 kg urea ha^{-1},S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm

4.2 Spreading of plant

Significant variation was found in spreading of plant at different days after transplanting due to different levels of nitrogen (Table 2). The maximum spreading of plant at 20 DAT (26.3 cm) and at 40 DAT (42.9 cm), 60 DAT (47.6 cm) and 80 DAT (55.4 cm) were found from N_3 but it was statistically similar to N_2. Whereas, the minimum spreading of plant at 20 DAT (17.5 cm), 40 DAT (35.7 cm), 60 DAT (39.9 cm) and 80 DAT (48.1 cm) were found in control (N_0). The results showed that higher N uptake by plants increase the length of leaf with created favorable condition for better growth. The trend of the present results was agreed to that of Pramanik and Singh *et al*. (2007).

Spreading of plant at different days after transplanting varied significantly due to the different spacing (Table 2). The maximum spreading of plant at 20 DAT (24.5 cm), 40 DAT (42.3 cm), 60 DAT (47.4 cm) and 80 DAT (55.7 cm) were found in S_3. Whereas, the minimum spreading of plant at 20 DAT (22.5 cm), 40 DAT (38.2 cm), 60 DAT (42.4 cm) and 80 DAT (50.2 cm) were found in S_1. This result is in agreement with the earlier findings of Sandhu (1999) and Singh *et al*. (2007) where they reported that plant spread exceedingly with higher spacing.

The significant variation was recorded due to combined effect of nitrogen and plant spacing in terms of spreading of plant at different (Table 2). The maximum spreading of plant at 20 DAT (27.8 cm), 40 DAT (45.3 cm), 60 DAT (51.1 cm) and 80 DAT (58.7 cm) were found in N_3S_3. Whereas, the minimum spreading of plant at 20 DAT (17.2 cm), 40 DAT (35.2 cm), 60 DAT (38.9 cm) and 80 DAT (47.5cm) were found in N_0S_1.This was due to receiving of sufficient amount of nutrients in the widest spacing.

Table 2. Effect of nitrogen and spacing on spreading of plant at different days after transplanting

Treatment	Spreading of plant(cm)at			
	20 DAT	**40 DAT**	**60 DAT**	**80 DAT**
Nitrogen				
N_0	17.5 c	35.7 c	39.9 c	48.1 c
N_1	25.2 b	40.3 b	44.2 b	52.8 b
N_2	25.3 b	42.5 a	47.6 a	55.4 a
N_3	26.3 a	42.9 a	47.5 a	55.4 a
$LSD_{(0.05)}$	0.49	0.74	0.56	0.79
F-test	**	**	**	**
Spacing				
S_1	22.5 c	38.2 c	42.4 c	50.2 c
S_2	23.8 b	40.5 b	44.5 b	52.9 b
S_3	24.5 a	42.3 a	47.4 a	55.7 a
$LSD_{(0.05)}$	0.43	0.64	0.49	0.69
F-test	**	**	**	**
Treatment combinations				
N_0S_1	17.2 e	35.2 e	38.9 h	47.5 g
N_0S_2	17.6 e	35.8 e	39.3 h	47.6 g
N_0S_3	17.7 e	36.1 e	41.5 g	49.2 f
N_1S_1	23.5 d	36.4 e	40.5 g	47.4 g
N_1S_2	25.8 bc	41.0 d	44.5 f	53.7 de
N_1S_3	26.3 b	43.6 bc	47.6 c	57.3 b
N_2S_1	24.3 d	40.8 d	45.6 de	53.3 e
N_2S_2	25.7 bc	42.4 c	47.6 c	55.4 c
N_2S_3	26.1 b	44.4 ab	49.5 b	57.4 ab
N_3S_1	25.2 c	40.6 d	44.8 ef	52.5 e
N_3S_2	25.9 bc	42.9 c	46.5 d	54.9 cd
N_3S_3	27.8 a	45.3 a	51.1 a	58.7 a
$LSD_{(0.05)}$	0.86	1.29	0.98	1.37
F-test	**	**	**	**
CV%	2.14	1.88	1.29	1.53

** = Significant at 1% probability,N_0 = Control, N_1 = 150 kgurea ha^{-1}, N_2 = 250 kgurea ha^{-1}, N_3 = 350 kgurea ha^{-1}, S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm

4.3 Number of loose leaves per plant

Number of loose leaf per plant showed statistically significant variation due to the applications of different levels of nitrogen (Table 3). The maximum number of loose leaf per plant (19.3) was recorded from N_3 and the minimum (14.10) was recorded in N_2. Number of loose leaf increased with the increasing of nitrogen. The trend of the present results was agreed to that of Sandhu*et al*. (1999), Pramanik (2007) and Singh *et al*. (2007).

Due to use of different plant spacing the number of loose leaf per plant of cabbage varied significantly (Table 4). The maximum number of loose leaf per plant (19.22) was observed in S_3 and the minimum (13.98) was recorded in S_1. The number of loose leaf per plant increased with the increasing of spacing. The trend of the present results was agreed to that of Sandhu*et al*. (1999), Pramanik (2007) and Singh *et al*. (2007).

Combined effect of nitrogen and plant spacing in terms of number of loose leaf per plant in cabbage showed statistically significant differences (Table 5).The maximum number of loose leaf per plant (25.1) was found from N_3S_3 treatment and the minimum (13.3) from N_1S_1 treatment combination. The trend of the present results was agreed to that of Sandhu*et al*. (1999).

4.4 Weight of loose leaves per plant

Weight of loose leaves per plant showed statistically significant variation due to the different doses of nitrogen (Table 3). The highest weight of loose leaves per plant (862.2 g) was recorded from N_3, while the minimum (647.8 g) was recorded from N_1. Higher doses of nitrogen increases the number of loose leaf per plant that ultimately increased the weight of loose leaves per plant. The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Due to different plant spacing the weight of loose leaves per plant of cabbage varied significantly (Table 4). The maximum weight of loose leaves per plant (869.4 g) was observed in S_3 and the minimum (617.5 g) was recorded in S_1.

Widest spacing increases the number of loose leaf per plant that ultimately increased the weight of loose leaves per plant. The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Combined effect of nitrogen and plant spacing in terms of weight of loose leaves per plant in cabbage showed statistically significant differences (Table 5). The maximum weight of loose leaves per plant (1124.0 g) was found from N_3S_3 and the minimum (588.4 g) from N_1S_1 treatment combination.

4.5 Fresh weight of plant

Fresh weight of plant showed statistically significant differences due to the different doses of nitrogen (Table 3). The maximum fresh weight of plant (3.0kg) was recorded from $N_2$and the minimum fresh weight of plant (2.0kg) was recorded in control (N_0). Optimum nitrogen ensured proper growth of plant and consequently the maximum fresh weight of plant. The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Fresh weight of plant varied significantly due to different plant spacing (Table 4). The maximum fresh weight of plant (2.8kg) was recorded in S_3 and the minimum fresh weight of plant (2.3kg) was observed in S_1. Fresh weight of plant was increased with the increasing in spacing. This might be due to availability of sufficient amount of light and nutrients.

Significant variation was recorded due to the combined effect of different doses of nitrogen and plant spacing in terms of fresh weight of plant in cabbage (Table 5). The maximum fresh weight of plant (3.4kg) was observed from N_2S_3 treatment combination and the minimum (1.9kg) in $N_0S_1$and N_0S_2treatment combination.

4.6 Number of lateral roots per plant

Number of lateral roots per plant showed statistically significant differences due to the different levels of nitrogen (Table 3). The maximum number of lateral roots per plant (14.6) was recorded from N_3 but it was statistically similar to N_2 and N_1.The minimum number of lateral roots per plant (12.5) was recorded in control (N_0). The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Number of lateral roots per plant varied significantly due to different plant spacing (Table 4). The maximum number of lateral roots per plant (14.68) was recorded from widest spacing (S_3) and the minimum number of lateral roots per plant (13.18) was observed from closest spacing (S_1).

Significant variation was recorded due to the combined effect of different doses of nitrogen and plant spacing in terms of number of lateral roots per plant in cabbage (Table 5). The maximum number of lateral roots per plant (15.4) was observed from N_3S_3 treatment combination but it was statistically similar to N_2S_3, N_2S_3andN_1S_3while the minimum (10.9) in N_0S_1 treatment combination.

4.7 Length of root per plant

There were no significant differences due to different levels of nitrogen, spacing but their combination showed significant variation on length of leaf per plant. The maximum length of root per plant was obtained from N_3S_3 while the minimum (9.3 cm) was found from N_1S_1 and $N_3S_{1.}$

4.8 Fresh weight of root per plant

Fresh weight of root per plant showed statistically significant differences due to the different doses of nitrogen (Table 3). The maximum fresh weight of root per plant (45.0 g) was recorded from N_3 while the minimum fresh weight of root per plant (39.4 g) was observed in control (N_0). Optimum nitrogen ensured proper growth of plant and consequently the maximum fresh weight of plant. The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Table 3.Effect of nitrogen on number of loose leaves, weight of loose leaves,fresh weight of plant, number of lateral roots, length of root and fresh weight of root per plant

Treatments	Number of loose leaves plant^{-1}	Weight of loose leaves plant^{-1} (g)	Fresh weight of plant (kg)	Number of lateral roots plant^{-1}	Length of root plant^{-1} (cm)	Fresh weight of root plant^{-1} (g)
N_0	15.3 c	679.2 c	2.0 d	12.5 b	9.8 a	39.4 c
N_1	14.1 d	647.8 c	2.4c	14.5 a	9.5 a	43.0 b
N_2	17.6 b	783.3 b	3.0 a	14.1 a	9.6 a	43.4 b
N_3	19.3 a	862.2 a	2.9b	14.6 a	9.5 a	45.0 a
$LSD_{(0.05)}$	0.93	35.26	0.03	0.43	0.47	0.98
F-test	**	**	**	**	**	**
CV%	5.73	4.85	2.54	3.17	4.96	2.34

** = Significant at 1% probability, N_0 = Control, N_1 = 150 kg urea ha^{-1}, N_2 = 250 kg urea ha^{-1} and N_3 = 350 kg urea ha^{-1}

Table 4.Effect of spacing on number of loose leaves, weight of loose leaves,fresh weight of plant, number of lateral roots, length of root and fresh weight of root per plant

Treatments	Number of loose leaves plant^{-1}	Weight of loose leaves plant^{-1} (g)	Fresh weight of plant (kg)	Number of lateral roots plant^{-1}	Length of root plant^{-1} (cm)	Fresh weight of root plant^{-1} (g)
S_1	13.98 c	617.50 c	2.3 c	13.18 c	9.48 a	40.55 c
S_2	16.74 b	742.40 b	2.5 b	14.06 b	9.63 a	42.99 b
S_3	19.22 a	869.40 a	2.8 a	14.68 a	9.78 a	44.66 a
$LSD_{(0.05)}$	0.81	30.53	0.03	0.37	0.40	0.85
F-test	**	**	**	**	**	**
CV%	5.73	4.85	2.54	3.17	4.96	2.34

** = Significant at 1% probability,S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm

Fresh weight of root per plant varied significantly due to different plant spacing (Table 4). The maximum fresh weight of root per plant (44.6 g) was recorded from widest spacing (S_3) and the minimum fresh weight of root per plant (40.55 g) was observed from the closest spacing (S_1).

Significant variation was recorded due to the combined effect of different doses of nitrogen and plant spacing in terms of fresh weight of root per plant in cabbage (Table 5). The maximum fresh weight of root per plant (48.9 g) was observed in N_3S_3 and the minimum (38.6 g) in N_0S_2 treatment combination.

Table 5. Combined effect of nitrogen and spacing on number of loose leaves, weight of loose leaves,fresh weight of plant, number of lateral roots, length of root and fresh weight of root per plant

Treatment combinations	**Number of loose leaves plant^{-1}**	**Weight of loose leaves plant^{-1} (g)**	**Fresh weight of plant (kg)**	**Number of lateral roots plant^{-1}**	**Length of root plant^{-1} (cm)**	**Fresh weight of root plant^{-1} (g)**
N_0S_1	15.2 de	674.2 de	1.9 i	10.9 g	9.8 ab	39.3 ef
N_0S_2	15.2 de	671.2 de	1.9 i	13.3 f	10.1 a	38.6 f
N_0S_3	15.6 d	692.1 de	2.1 h	13.3 ef	9.6 ab	40.3def
N_1S_1	13.3 f	588.4 f	2.1h	13.8 def	9.3 b	40.8 de
N_1S_2	14.4def	637.3 ef	2.4g	14.7 abc	9.6 ab	43.2 c
N_1S_3	14.7 def	717.6 d	2.6 e	15.1 a	9.5 ab	44.9 bc
N_2S_1	13.5 f	598.3 f	2.6 e	13.6 def	9.4 ab	40.9 de
N_2S_2	18.1 c	807.6 c	3.0 c	14.0 cdef	9.6 ab	44.8 bc
N_2S_3	21.3 b	944.1 b	3.4 a	14.8 ab	9.6 ab	44.4 bc
N_3S_1	13.8 ef	609.2 f	2.5 f	14.3 bcd	9.3 b	41.0 d
N_3S_2	19.2 c	853.5 c	2.9 d	14.1b-e	9.0 b	45.1 b
N_3S_3	25.1 a	1124.0 a	3.2 b	15.4 a	10.2 a	48.9 a
$LSD_{(0.05)}$	1.62	61.07	0.05	0.75	0.81	1.69
F-test	**	**	**	**	*	**
CV%	5.73	4.85	2.54	3.17	4.96	2.34

** = Significant at 1% probability, N_0 = Control, N_1 = 150 kg urea ha^{-1}, N_2 = 250 kg urea ha^{-1}, N_3 = 350 kg urea ha^{-1}, S_1 = 50 cm × 30 cm, S_2 = 50 cm × 40 cm and S_3 = 50 cm × 50 cm

4.9 Length of stem per plant

Significant variation was found in length of stem per plant due to different doses of nitrogen (Table 6). The maximum length of stem per plant (9.1 cm) was found in N_3 but it was statistically similar to N_2. whereas, the minimum length of stem per plant (8.6 cm) was found in N_1 but it was statistically similar 8.8 cm to N_0.

Length of stem per plant varied insignificantly due to the different spacing (Table 7).

The significant variation was recorded due to combined effect of nitrogen and plant spacing in terms of length of stem per plant (Table 7). The maximum length of stem per plant (9.4cm) was found in N_3S_3 whereas, the minimum length of stem per plant (8.3 cm) was found in N_1S_3.

4.10 Diameter of stem per plant

Significant variation was found in diameter of stem per plant due to different doses of nitrogen (Table 6). The maximum diameter of stem per plant (3.0 cm) was found in N_2but it was statistically similar to N_3 and the minimum diameter of stem per plant (2.4 cm) was found in N_0. The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Diameter of stem per plant varied significantly due to the different spacing (Table 7). The maximum diameter of stem per plant (2.9 cm) was found in widest spacing 50 cm × 50 cm (S_3) while the minimum diameter of stem per plant (2.7 cm) was found in closest spacing 50 cm × 40 cm (S_2) but it was statistically similar to the spacing 50 cm × 30 cm (S_2). The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

The significant variation was recorded due to combined effect of nitrogen and plant spacing in terms of diameter of stem per plant (Table 8). The maximum diameter of stem per plant (3.1 cm) was found in N_3S_3 and it was statistically similar to N_2S_3 and N_2S_1 whereas, the minimum diameter of stem per plant (2.4cm) was found in N_0S_1 which was similar to N_0S_2.

4.11 Fresh weight of stem per plant

Fresh weight of stem per plant showed statistically significant differences due to the different doses of nitrogen (Table 6). The maximum fresh weight of stem per plant (65.6 g) was recorded from N_3 while the minimum fresh weight of stem per plant (53.9 g) was observed in control (N_0). Optimum nitrogen ensured proper growth of plant and consequently the maximum fresh weight of stem per plant. The trend of the present results was agreed to that of Pramanik (2007) and Singh *et al*. (2007).

Fresh weight of stem per plant varied significantly due to different plant spacing (Table 7). The maximum fresh weight of stem per plant (63.4 g) was recorded from widest spacing 50 cm × 50 cm (S_3) and the minimum fresh weight of stem per plant (60.1 g) was observed from closest spacing 50 cm × 30 cm (S_1) which was similar (609 gm) to S_2.

Significant variation was recorded due to the combined effect of different doses of nitrogen and plant spacing in terms of fresh weight of stem per plant in cabbage (Table 8). The maximum fresh weight of stem per plant (69.3 g) was observed from $N_3S_3$and the minimum (53.4 g) in N_0S_1 treatment combination.

4.12 Diameter of head

Diameter of head showed statistically significant differences due to different doses of nitrogen (Table 6). The maximum diameter of head (19.5 cm) was recorded from $N_3$and the lowest (15.0cm) was found from control. Higher doses of nitrogen ensured vigorous growth of plant and consequently the highest diameter of head but it makes lesser compactness of leaves. The trend of the present results were agreed to that of Ghanti*et al.*(1982), Csizinszky and Schyster (1985), Gupta(1987), Parmar*et al.* (1999), Pramanik (2007) and Singh *et al*. (2007) reported higher diameter in cabbage with increased nitrogen rates that favored the growth of plants and it was more usefully utilized in head diameter.

Diameter of plant varied significantly due to different plant spacing (Table 7). The highest diameter of head (19.2 cm) was recorded from widest spacing (S_3) and the lowest (15.6 cm) was observed from closest spacing (S_1). Diameter of plant was increased with the increasing of spacing. This might be due to availability of sufficient amount of light and nutrients. The trend of the present results was agreed to that of Ghanti*et al.*(1982), Kumar and Rawat (2002), Mahesh-Kumar (2002), Pramanik (2007) and Singh *et al*. (2007) where reported that diameter of head increase with the increases of spacing.

Significant variation was recorded due to combined effect of nitrogen and plant spacing in terms of diameter of head in cabbage (Table 8). The highest diameter of head (22.2 cm) was observed from N_3S_3 and the lowest (14.3 cm) in N_0S_1 treatment combination. The trend of the present results was agreed to that of Kumar and Rawat (2002) where they reported that nitrogen and pacing affected the diameter of head of cabbage, quality and yield of cabbage

4.13 Thickness of head

Thickness of head showed statistically significant differences due to different doses of nitrogen (Table 6). The maximum thickness of head (12.5 cm) was recorded from N_3but it was statistically similar to N_2 and the lowest (10.0 cm) was found from control. Optimum nitrogen ensured proper growth of plant and consequently the maximum thickness of head. The trend of the present results was agreed to that of Csizinszky and Schyster (1985), Pramanik (2007) and Singh *et al*. (2007) where they observed that the high N rate (257 kg/ha) increased head size in both seasons.

Thickness of plant varied significantly due to different plant spacing (Table 7). The highest thickness of head (12.3 cm) was recorded from widest spacing 50 cm × 50 cm (S_3) and the lowest (11.1 cm) from the closest spacing 50 cm × 30 cm (S_1). Thickness of plant was increased with the increase in spacing. This might be due to availability of sufficient amount of light and nutrients. The trend of the present results was agreed to that of Pramanik (2007).

Significant variation was recorded due to combined effect of nitrogen and plant spacing in terms of thickness of head in cabbage (Table 8). The highest thickness of head (13.6 cm) was observed from N_3S_3but it was statistically similar to$N_2S_3$and the lowest (9.8 cm) in N_0S_1 treatment combination.

Table 6. Effect of nitrogen on length of stem, diameter of stem, fresh weight of stem, diameter of head and thickness of head of cabbage

Treatments	**Length of stem plant^{-1} (cm)**	**Diameter of stem plant^{-1} (cm)**	**Fresh weight of stem plant^{-1} (g)**	**Diamete r of head (cm)**	**Thickness of head (cm)**
N_0	8.8 bc	2.4 c	53.9 c	15.0 d	10.0 c
N_1	8.6 c	2.7 b	62.6 b	15.8 c	11.9 b
N_2	8.9 ab	3.0 a	63.6 b	17.8 b	12.1 ab
N_3	9.1 a	2.9 a	65.6 a	19.5 a	12.5 a
$LSD_{(0.05)}$	0.27	0.12	1.24	0.49	0.47
F-test	*	**	**	**	**
CV%	3.07	4.37	2.06	2.93	4.15

** = Significant at 1% probability,* = Significant at 5% probability, N_0 = Control,N_1 = 150 kgurea ha^{-1}, N_2 = 250 kgurea ha^{-1} and N_3 = 350 kgurea ha^{-1}

Table 7. Effect of spacing on length of stem, diameter of stem, fresh weight of stem, diameter of head and thickness of head of cabbage

Treatments	**Length of stem plant^{-1} (cm)**	**Diameter of stem plant^{-1} (cm)**	**Fresh weight of stem plant^{-1} (g)**	**Diameter of head (cm)**	**Thickness of head (cm)**
S_1	9.0 a	2.7 b	60.1 b	15.6 c	11.1 c
S_2	8.9 a	2.7 b	60.9 b	16.3 b	11.5 b
S_3	8.8 a	2.9 a	63.4 a	19.2 a	12.3 a
$LSD_{(0.05)}$	0.23	0.10	1.07	0.42	0.41
F-test	ns	*	**	**	**
CV%	3.07	4.37	2.06	2.93	4.15

ns = Non significant, ** = Significant at 1% probability, * = Significant at 5% probability, S_1 = 50 cm × 30 cm, S_2 = 50 cm × 40 cm and S_3 = 50 cm × 50 cm

Table 8. Combined effect of nitrogen and spacing on length of stem, diameter of stem, fresh weight of stem, diameter of head and thickness of head of cabbage

Treatment combinations	**Length of stem plant^{-1} (cm)**	**Diameter of stem plant^{-1} (cm)**	**Fresh weight of stem plant^{-1} (g)**	**Diameter of head (cm)**	**Thickness of head (cm)**
N_0S_1	8.8bcde	2.4 f	53.4 f	14.3 j	9.8 f
N_0S_2	9.2 ab	2.4 f	53.7 f	14.4 j	9.9 f
N_0S_3	8.6 de	2.5 ef	54.6 f	16.3 fg	10.2f
N_1S_1	8.9abcd	2.7 de	60.9 e	14.7 ij	11.3 e
N_1S_2	8.7cde	2.7 cd	63.2 cd	15.4 hi	12.1 cde
N_1S_3	8.3 e	2.7 cd	63.7cd	17.3 de	12.4 bc
N_2S_1	9.1abc	3.0 ab	61.7 de	15.8 gh	11.5 de
N_2S_2	8.6cde	2.9bc	63.2 cd	16.7 ef	11.8 cde
N_2S_3	9.1 abc	3.1 a	65.9 b	20.9 b	13.0 ab
N_3S_1	9.1 abc	2.9bc	64.2 bc	17.6 d	11.7 cde
N_3S_2	8.9abcd	2.9bcd	63.3 cd	18.6 c	12.3 bcd
N_3S_3	9.4 a	3.1 a	69.3a	22.2 a	13.6 a
$LSD_{(0.05)}$	0.46	0.21	2.15	0.84	0.82
F-test	*	ns	*	**	**
CV%	3.07	4.37	2.06	2.93	4.15

** = Significant at 1% probability,*= Significant at 5% probability,N_0 = Control, N_1 = 150 kgurea ha^{-1}, N_2 = 250 kgurea ha^{-1}, N_3 = 350 kgurea ha^{-1}, S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm

4.14 Fresh weight of head per plant

Fresh weight of head per plant showed statistically significant differences due to the different doses of nitrogen in cabbage (Table 9). The highest fresh weight of head per plant (2.1kg) was recorded from N_2 and the lowest (1.2kg) was found from control. Optimum doses of nitrogen ensured proper growth of plant and consequently the highest fresh weight of head per plant. The trend of the present result was agreed to that of Ghanti*et al.* (1982), Gupta (1987), Parmar*et al.* (1999), Mahesh-Kumar (2002), Pramanik (2007) and Singh *et al.*

(2007) reported higher yields in cabbage with increased nitrogen rates. This was attributed to the fact that higher nitrogen levels favored the growth of plants with larger leaf area and it was more usefully utilized in head formation.

Fresh weight of head per plant varied significantly due to different spacing (Table 10). The highest fresh weight of head per plant (1.8kg) was recorded from widest spacing 50 cm × 50 cm (S_3) and the lowest (1.5kg) was observed from closest spacing 50 cm × 30 cm (S_1). Fresh weight of head per plant was increased with the increase in spacing. This might be due to the availability of sufficient amount of light and nutrients. The trends of these present results agreed with that of Mahesh-Kumar (2002), Kumar and Rawat (2002), Manna*net al*., 2001 and Pramanik, 2007.

Significant variation was recorded due to the combined effect of nitrogen and spacings in terms of fresh weight of head per plant in cabbage (Table 11). The highest fresh weight of head per plant (2.3kg) was observed from N_2S_3 and the lowest (1.1 kg) was found in N_0S_1 treatment combination. The trend of the present results was agreed to that of Kumar and Rawat (2002) and Aquino *et al*., 2005 where they reported that nitrogen and pacing affected the quality and yield of cabbage.

4.15 Dry matter percent of head per plant

Dry matter percent of head per plant showed statistically significant differences due to the different doses of nitrogen in cabbage (Table 9). The highest total dry matter percent of head per plant (7.3) was recorded from N_3but it was statistically similar to N_2 (7.1) and the lowest (4.9) was found from control (N_0).The trend of the present results was agreed to that of Manna*net al*. 1999.

Dry matter percent of head per plant varied significantly due to different spacing (Table 10). The highest dry matter percent of head per plant (7.4) was recorded from widest spacing 50 cm ×50 cm (S_3) and the lowest (5.8) from the closest spacing 50 cm × 30 cm (S_1).

Significant variation was recorded due to combined effect of nitrogen and spacings in terms of dry matter percent of head per plant in cabbage (Table 11). The highest dry matter percent of head per plant (9.0) was observed from N_3S_3 which was similar (8.7) to N_3S_3 and the lowest (4.7) was found in N_0S_1.

4.16 Gross yield of cabbage per hectare

Gross yield of cabbage showed statistically significant differences due to the different doses of nitrogen in cabbage (Table 9). The maximum gross yield (145.7tha^{-1}) was recorded from N_2 and the lowest (96.8 tha^{-1}) were found in control (N_0). Ghanti*et al.*(1982), Gupta (1987) and Parmar*et al.* (1999) reported higher yields in cabbage with increased nitrogen rates. This was attributed to the fact that higher nitrogen levels favored the growth of plants with larger leaf area and it was more usefully utilized in head formation, head diameter and gross mass of heads.

Gross yield of cabbage varied significantly due to different spacings (Table 10). The maximum gross yield (146.7 tha^{-1}) was recorded from closest spacing (S_1) and the lowest (109.1 tha^{-1}) from S_3. This result revealed that gross yield was increased with the decreasing of spacing. This is due to the number of plants that lead to give the maximum yield. The trends of these present results agreed with that of Ghanti*et al.* (1982), Islam *et al.* (1989), Mannan*et al.*, 2001, Amreesh 2002, Mahesh-Kumar (2002), Fujiwara 2000 and Pramanik (2007).

Significant variation was recorded due to combined effect of nitrogen and spacings in terms of gross yield of cabbage per hectare (Table 11). The maximum gross yield (168.8 tha^{-1}) was observed from N_2S_1 and the lowest (81.0tha^{-1}) was found in N_0S_3. The trend of the present result was agreed to that of Hill (1990) and Aquino *et al*., 2005.

4.17 Marketable yield of cabbage per hectare

Marketable yield of cabbage showed statistically significant differences due to the different doses of nitrogen in cabbage (Table 9). The maximum marketable yield (107.3tha^{-1}) was recorded from N_2 and the lowest (62.1 tha^{-1}) were found in control (N_0). Optimum doses of nitrogen ensured proper growth of plant, lesser number of loose leaves and consequently the highest fresh weight of head per plant. The trend of the present result was agreed to that of Batsei*et al*. (1979), Ghanti*et al.* (1982), Lawandee*et al*. (1986), Gupta (1987), Hossain (1998) Parmar*et al.* (1999) and Pramanik (2007) reported higher yields in cabbage with increased nitrogen rates. This was attributed to the fact that higher nitrogen levels favored the growth of plants with larger leaf area and it was more usefully utilized in head formation, head diameter and number of marketable heads.

Marketable yield of cabbage varied significantly due to different spacings (Table 10). The maximum marketable yield (105.6 tha^{-1}) was recorded from closest spacing (S_1) and the lowest (74.3 tha^{-1}) from S_3. This result revealed that gross yield was decreased with the increasing of spacing.The trends of these present results agreed with that of Mannan*et al* 2001, Amreesh 2002, Kumar and Rawat (2002), Mahesh-Kumar (2002), Fujiwara 2003, Esmail, 2004, Ghanti*et al.*(1982), Islam *et al*. (1989) and Pramanik (2007).

Significant variation was recorded due to combined effect of nitrogen and spacings in terms of marketable yield of cabbage per hectare (Table 11). The maximum marketable yield (128.9tha^{-1}) was observed from N_2S_1 and the lowest (53.3tha^{-1}) was found in N_0S_3. The trend of the present results was agreed to that ofHill (1990), Mallik (1996), Parmar*et al*., 1999, Kumar and Rawat (2002) and Aquino *et al*., 2005, where they reported that nitrogen and pacing affected the quality and yield of cabbage.

Table 9. Effect of nitrogen on fresh weight of head, dry matter content of 100 g head, gross yield and marketable yield of cabbage

Treatments	Fresh weight of head plant^{-1} (kg)	Dry matter content of 100 g head plant^{-1} (g)	Gross yield (tha^{-1})	Marketable yield (tha^{-1})
N_0	1.2 d	4.9 c	96.8d	62.1 d
N_1	1.6 c	6.1 b	114.3c	81.7 c
N_2	2.1 a	7.1 a	145.7a	107.3a
N_3	1.9 b	7.3 a	138.4b	96.6 b
$LSD_{(0.05)}$	0.03	0.38	1.35	0.67
F-test	**	**	**	**
CV%	3.34	6.16	2.19	2.75

** = Significant at 1% probability,N_0 = Control,N_1 = 150 kgurea ha^{-1}, N_2 = 250 kgurea ha^{-1} and N_3 = 350 kgurea ha^{-1}

Table 10. Effect of spacing on fresh weight of head, dry matter content of 100 g head, gross yield and marketable yield of cabbage

Treatments	Fresh weight of head plant^{-1} (kg)	Dry matter content of 100 g head plant^{-1} (g)	Gross yield (tha^{-1})	Marketable yield (tha^{-1})
S_1	1.5 c	5.8 b	146.7 a	105.6 a
S_2	1.7 b	5.9b	115.6b	80.8 b
S_3	1.8 a	7.4 a	109.1c	74.3c
$LSD_{(0.05)}$	0.03	0.33	1.17	0.58
F-test	**	**	**	**
CV%	3.34	6.16	2.19	2.75

** = Significant at 1% probability,S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm

Table 11. Combined effect of nitrogen and spacing on fresh weight of head, dry matter content of 100 g head, gross yield and marketable yield of cabbage

Treatment combinations	**Fresh weight of head plant^{-1} (kg)**	**Dry matter content of 100 g head plant^{-1} (g)**	**Gross yield (tha^{-1})**	**Marketable yield (tha^{-1})**
N_0S_1	1.1 i	4.7 c	120.5 f	75.5 h
N_0S_2	1.2 h	4.8 c	88.9 i	57.5 j
N_0S_3	1.3 g	5.3 c	81.0 j	53.3 k
N_1S_1	1.4 f	6.2 b	134.7 d	95.5 d
N_1S_2	1.6 e	5.3 c	106.0 g	76.2 gh
N_1S_3	1.8 d	6.7 b	102.1 h	73.3 i
N_2S_1	1.9 c	6.1 b	168.8 a	128.9 a
N_2S_2	2.1 b	6.4 b	137.3 c	99.5 c
N_2S_3	2.3 a	8.7 a	131.1 e	93.3 e
N_3S_1	1.8d	6.3 b	162.8 b	122.2 b
N_3S_2	1.9 c	6.7b	130.1 e	90.2 f
N_3S_3	1.9 c	9.0 a	122.3 f	77.3 g
$LSD_{(0.05)}$	0.05	0.67	2.35	1.16
F-test	**	**	**	**
CV%	3.34	6.16	2.19	2.75

** = Significant at 1% probability,N_0 = Control, N_1 = 150 kgurea ha^{-1}, N_2 = 250 kgurea ha^{-1}, N_3 = 350 kgurea ha^{-1}, S_1 = 50 cm×30 cm, S_2 = 50 cm×40 cm and S_3 = 50 cm×50 cm

4.18 Economic analysis

Economic analysis was done with a view to observing the comparative cost and benefit under different treatment combinations. For this purpose, the input cost for land preparation, seed cost, manures and fertilizers, intercultural operation and manpower required for all the operations from sowing to harvesting were recorded against each treatment, which were then enumerated into cost per hectare. The details economic analysis has been presented in Appendix-X.

Variation in cost of production was noticed due to the cost of fertilizer (Table 12). The total cost of cultivation ranged between 125032 and 138154 Tk.ha^{-1}.The cultivation cost increased with increasing doses of fertilizer. The highest cost of production was involved when used 350 kg urea ha^{-1} (Tk138154ha^{-1}). The lowest cost of production was in control (Tk125032ha^{-1}). The highest gross return was obtained from the treatment combination of 250 kg urea ha^{-1}with closest spacing 50 cm×30 cm (Tk644500ha^{-1}) while the lowest gross return was found from the treatment combination of N_0S_3(266500ha^{-1}). However, the highest net profit was obtained from the treatment combination of 250 kg urea ha^{-1} with closest spacing 50 cm×30 cm (Tk510098ha^{-1}). The maximum benefit-cost ratio was recorded in the treatment combination of 250 kg urea ha^{-1} with closest spacing 50 cm×30 cm(4.7) while the lowest benefit-cost ratio was recorded in the treatment combination of N_0S_3 (2.1).

Table 12.Economic analysis in cabbage production as influenced by nitrogen and spacing

Treatment combinations	Marketable yield(tha^{-1})	Total cost of production (Tk.ha^{-1})[a]	Gross return (Tk.ha^{-1})[b]	Net profit (Tk.ha^{-1})	Benefit cost ratio
N_0S_1	75.5	125032	377500	252468	3.0
N_0S_2	57.5	125032	287500	162468	2.2
N_0S_3	53.3	125032	266500	141468	2.1
N_1S_1	95.5	130653	477500	346847	3.6
N_1S_2	76.2	130653	381000	250347	2.9
N_1S_3	73.3	130653	366500	235847	2.8
N_2S_1	128.9	134402	644500	510098	4.7
N_2S_2	99.5	134402	497500	363098	3.7
N_2S_3	93.3	134402	466500	332098	3.4
N_3S_1	122.2	138154	611000	472846	4.4
N_3S_2	90.2	138154	451000	312846	3.2
N_3S_3	77.3	138154	386500	248346	2.7

[a] Calculated on the basis of February 2013 market price

[b] Considering Tk. 5 per kg of marketable head of cabbage at harvest

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted at the research farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2012 to February 2013 to study the effect of nitrogen and spacing on growth and yield of cabbage. There were fourdoses of nitrogen and three spacings. Thus there were twelve treatments and the experiment was laid out in RCBD design with three replications. The unit plot size was 3 m × 2 m. The crop was harvested on 10 February 2013.

Experimental result revealed that 250 kg urea ha^{-1}were performed better than other doses of nitrogen and gave maximum yield of marketable head of cabbage. The lowest values of almost all characters were obtained from control.

Plant spacing played a vital role on the growth and yield of cabbage. Maximum values for head yield were found from closest spacing50 cm×30 cm and the lowest values from widest spacing50 cm × 50 cm.

Combination of different doses of nitrogen and spacing exhibited significant variation for all the parameters studied. Yield traits expressed maximum values due to 250 kg urea $ha^{-1}$and closest spacing 50cm×30cm.

The cultivation cost increased with increasing the doses of nitrogen. The maximum benefit-cost ratio (4.7) was recorded in the treatment combination of 250 kg urea $ha^{-1}$with spacing 50 cm × 30 cmand it was lowest in the treatment combination of 0 kg urea ha^{-1} with spacing 50 cm× 50 cm (2.1).

Findings of the experiment indicated that the yield of cabbage head was greatly involved by nitrogen and spacing. Higher doses of nitrogen increases the number of loose leaves per head that increased the gross yield of cabbage but ultimately decreased the marketable yield of cabbage. Yield was increased due to optimum doses of nitrogen and closest spacing that ensure highest number of plant per plot.

The result obtained from the investigation exhibited a great influence of nitrogen and spacing for the production of cabbage. So, it can be concluded that, treatment combination of 250 kg urea ha^{-1} with spacing 50 cm×30 cmis suitable for cabbage production. It needs further trial to authenticate the results of the experiment.

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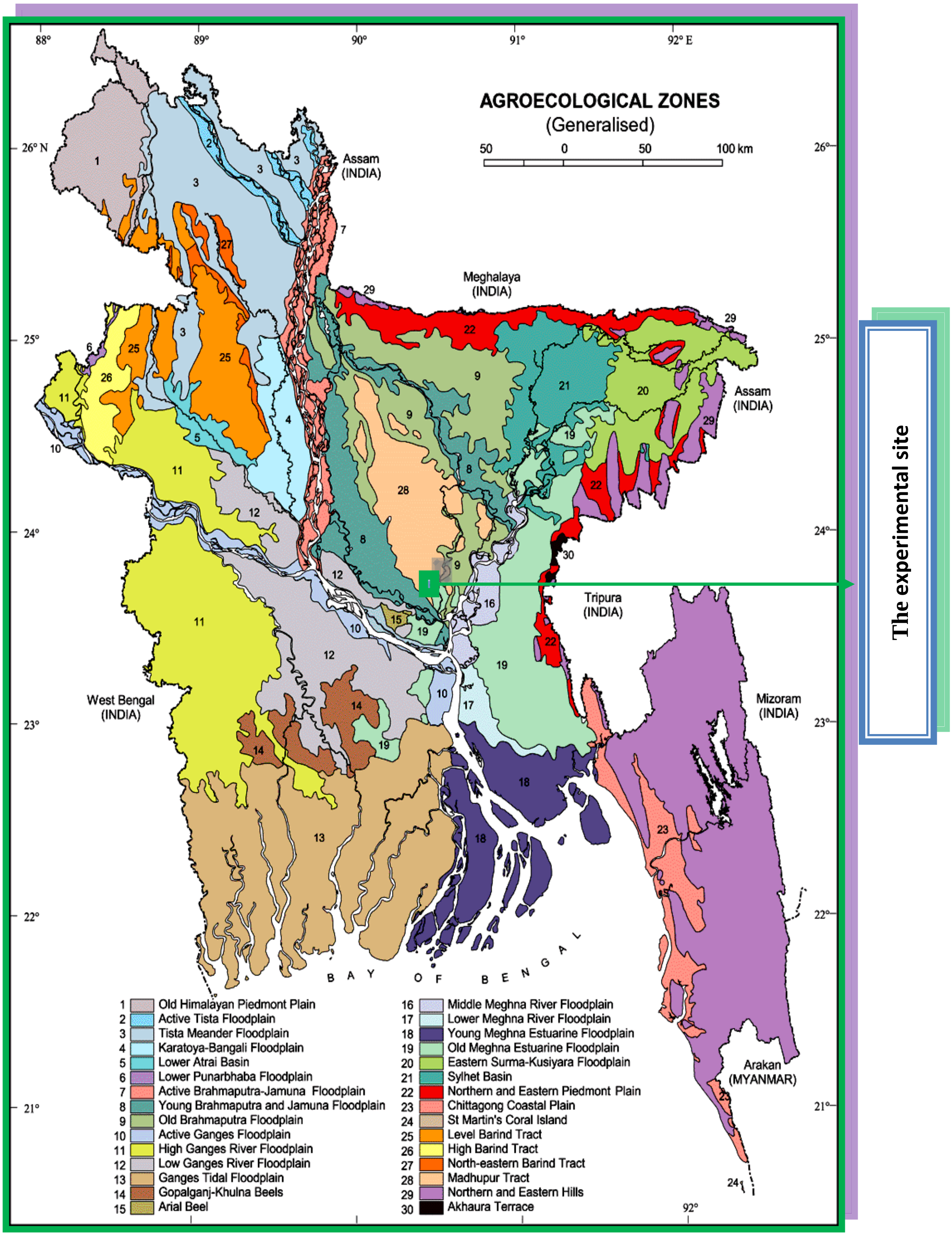
Appendices

APPENDICES

Appendix I. Map showing the experimental site



Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2011 to February 2012

Time	** Air temperature (^{0}C)			**Relative humidity (%)	*Rainfall (mm)
	Maximum	Minimum	Mean		
October, 2012	29.18	18.26	23.72	81	39
November, 2012	28.79	18.54	23.76	82.53	83.1
December, 2012	25.32	14.40	19.86	84.06	0.00
January, 2013	21.77	10.17	15.97	83.65	Trace
February, 2013	26.77	15.49	21.13	75.21	27.10

*Monthly total, ** Monthly average, Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka, Bangladesh

Appendix III. Analytical data of soil sample of the experimental plot

A. Morphological Characteristics

Morphological features	Characteristics
Location	Horticulture Garden, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land Type	Medium high land
Soil Series	Tejgaon
Topography	Fairly leveled
Flood Level	Above flood level
Drainage	Well drained

B. Mechanical analysis

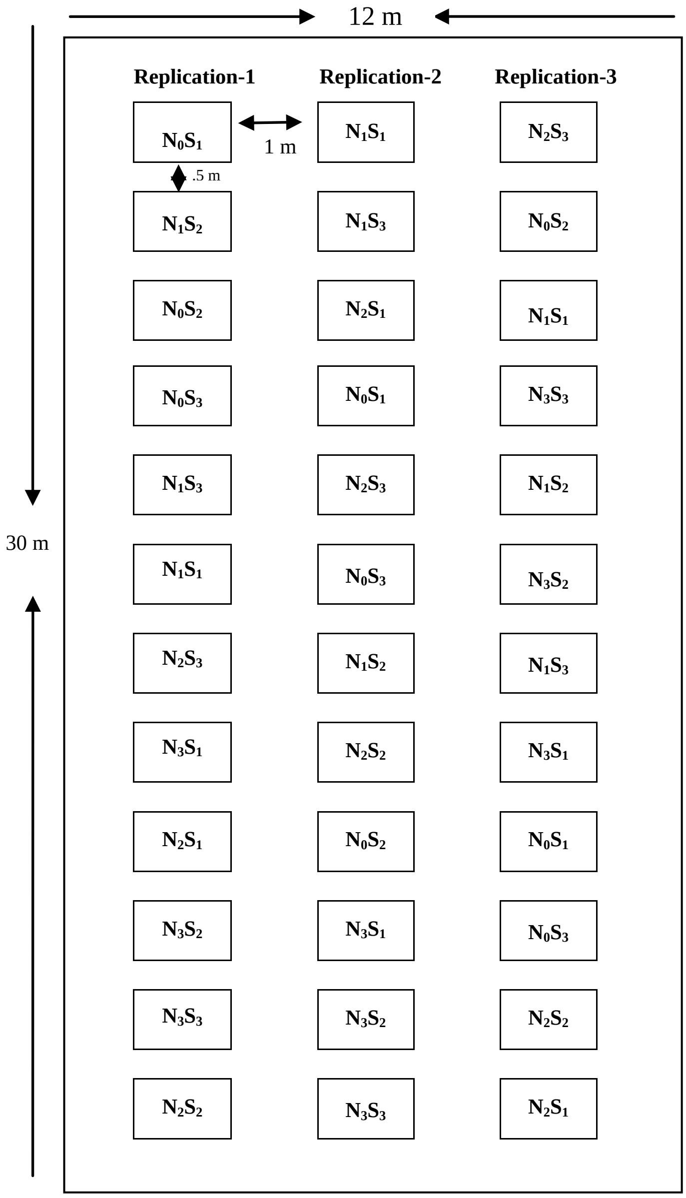
Constituents	Percent
Sand	27
Silt	43
Clay	30

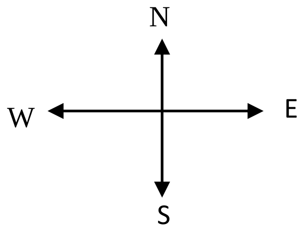
C. Chemical analysis

Soil properties	Amount
Soil pH	5.8
Organic carbon (%)	0.45
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K (%)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Field layout of the two factors experiment in the Randomized complete Block Design





Plot size: 3 m x 2 m
Spacing between plots: 50 cm
Spacing between replication: 1 m

Factor A:
Four levels of nitrogen: denoted as (N)

N_0 : Control (No fertilizer)

N_1 : 150 kg/ha

N_2 : 250 kg/ha

N_3 : 350 kg/ha

Factor B:
Three different spacing: denoted as (S)

S_1 : 50 cm × 30 cm

S_2 : 50 cm × 40 cm

S_3 : 50 cm × 50 cm

Appendix V. Analysis of variance on data with the effect of nitrogen and spacing on plant height (cm) of cabbage at different days after transplanting (DAT)

Source of variation	Degrees of freedom	Mean square Plant height at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.025	0.287	0.448	1.223
Factor A	3	0.322*	18.554**	56.764**	108.861**
Factor B	2	0.725**	2.034**	13.588**	29.456**
AB	6	0.183*	0.292 ns	1.254**	1.450**
Error	22	0.081	0.314	0.295	0.306

Appendix VI. Analysis of variance on data with the effect of nitrogen and spacing on spreading of plant (cm) of cabbage at different days after transplanting (DAT)

Source of variation	**Degrees of freedom**	**Mean square**			
		Spreading of plant (cm) at			
		20 DAT	**40 DAT**	**60 DAT**	**80 DAT**
Replication	2	0.038	0.621	0.334	0.322
Factor A	3	151.076**	99.831**	118.056**	105.657**
Factor B	2	11.459**	49.801**	74.288 **	90.751**
AB	6	1.246**	5.330**	4.018**	9.772 **
Error	22	0.256	0.578	0.333	0.658

Appendix VII. Analysis of variance on data with the effect of nitrogen and spacing on number of loose leaves, weight of loose leaves, fresh weight of plant (kg), number of lateral roots, length of root (cm) and fresh weight of root (g) of cabbage

Source of variation	**Degrees of freedom**	**Mean square of**					
		Number of loose leaves plant^{-1}	**Weight of loose leaves plant^{-1} (g)**	**Fresh weight of plant (kg)**	**Number of lateral roots plant^{-1}**	**Length of root plant^{-1} (cm)**	**Fresh weight of root plant^{-1} (g)**
Replication	2	0.980	878.448	0.040	1.617	0.351	1.100
Factor A	3	49.020**	86899.838 **	2.030**	8.494**	0.255ns	50.438**
Factor B	2	82.323**	190284.722**	0.908**	6.811**	0.258ns	51.268**
AB	6	20.715**	37524.298**	0.058**	0.976**	0.387ns	7.997**
Error	22	0.911	1300.594	0.011	0.000	0.228	1.000

Appendix VIII. Analysis of variance on data with the effect of nitrogen and spacing on length of stem (cm), diameter of stem (cm), fresh weight of stem (g), diameter of head (cm) and thickness of head (cm) of cabbage

Source of variation	Degrees of freedom	Mean square				
		Length of stem plant^{-1} (cm)	Diameter of stem plant^{-1} (cm)	Fresh weight of stem plant^{-1} (g)	Diameter of head (cm)	Thickness of head (cm)
Replication	2	0.520	0.039	1.114	1.041	0.123
Factor A	3	0.354*	0.607**	239.246**	36.439**	11.692**
Factor B	2	0.057 ns	0.078*	35.790**	43.759**	4.405**
AB	6	0.299*	0.016ns	5.611*	1.988 **	0.397ns
Error	22	0.075	0.015	1.606	0.249	0.235

Appendix IX. Analysis of variance on data with the effect of nitrogen and spacing on fresh weight of head, dry matter content of 100 g head, gross yield and marketable yield of cabbage

Source of variation	Degrees of freedom	Mean square			
		Fresh weight of head plant^{-1} (kg)	Dry matter content of 100 g head plant^{-1} (g)	Gross yield (tha^{-1})	Marketable yield (tha^{-1})
Replication	2	0.040	0.616	128.445	104.482
Factor A	3	1.342**	10.605**	4539.623**	3444.496**
Factor B	2	0.227**	10.365**	4846.116**	3252.289**
AB	6	0.018**	1.326**	9.365 **	95.885**
Error	22	0.000	0.155	1.932	0.467

Appendix-X. Production cost of cabbage per hectare as influenced by nitrogen and spacing (Tk/ha)

A. Input cost

Treatment Combinations	Labour cost	Ploughing cost	Seed Cost	Irrigation cost	Manures and fertilizers				Insecticides/ Pesticides cost	Sub Total cost (A)
					Cowdung	Urea	TSP	MoP		
N_0S_1	15000	10000	3000	5000	2500	0	10000	12000	8000	65500
N_0S_2	15000	10000	3000	5000	2500	0	10000	12000	8000	65500
N_0S_3	15000	10000	3000	5000	2500	0	10000	12000	8000	65500
N_1S_1	15000	10000	3000	5000	2500	4500	10000	12000	8000	70000
N_1S_2	15000	10000	3000	5000	2500	4500	10000	12000	8000	70000
N_1S_3	15000	10000	3000	5000	2500	4500	10000	12000	8000	70000
N_2S_1	15000	10000	3000	5000	2500	7500	10000	12000	8000	73000
N_2S_2	15000	10000	3000	5000	2500	7500	10000	12000	8000	73000
N_2S_3	15000	10000	3000	5000	2500	7500	10000	12000	8000	73000
N_3S_1	15000	10000	3000	5000	2500	10500	10000	12000	8000	76000
N_3S_2	15000	10000	3000	5000	2500	10500	10000	12000	8000	76000
N_3S_3	15000	10000	3000	5000	2500	10500	10000	12000	8000	76000

Labour cost @ Tk. 150/day; Cowdung @ Tk. 500/t; Urea @ Tk. 30/kg; TSP @ Tk. 40/kg; MoP @ Tk. 40/kg

B. Overhead cost (Tk/ha)

Treatment combinations	Cost of lease of land for 6 months (13% of value of land Tk. 8,00000/year)	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 months (Tk. 13% of cost/year)	Sub Total cost (B)
N_0S_1	52000	3275	4257	59532
N_0S_2	52000	3275	4257	59532
N_0S_3	52000	3275	4257	59532
N_1S_1	52000	3762	4891	60653
N_1S_2	52000	3762	4891	60653
N_1S_3	52000	3762	4891	60653
N_2S_1	52000	4088	5314	61402
N_2S_2	52000	4088	5314	61402
N_2S_3	52000	4088	5314	61402
N_3S_1	52000	4415	5739	62154
N_3S_2	52000	4415	5739	62154
N_3S_3	52000	4415	5739	62154

C. Total cost of production

[Input cost (A)+ overhead cost (B)]
125032
125032
125032
130653
130653
130653
134402
134402
134402
138154
138154
138154