EFFECT OF SPACING AND PLANTING TIME ON GROWTH AND YIELD OF GARLIC

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This is to certify that the thesis entitled, "*EFFECT OF SPACING AND PLANTING TIME GROWTH AND YIELD OF GARLIC (Allium sativum L)*" submitted to the Dept. of Horticulture and postharvest Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE in HORTICULTURE* embodies the result of a piece of *bona fide* research work carried out by *SOHANI SHARMIN* bearing registration number 03-01162 under my supervision and guidance. No part of the thesis has been submitted elsewhere for any other degree or diploma.

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

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Dedicated to
My
Beloved Parents who laid the
Foundation of my success

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The Author

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ABSTRACT

A field experiment was carried out at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from November, 2007 to May, 2008 to study the effect of spacing and planting time on the growth and yield of garlic. The trial consisted of four planting time viz. Pt_1:1 November, Pt_2:15 November, Pt_3:30 November and Pt_4:15 December and three plant spacings viz. S_1:10cm x 10cm, S_2:10cm x 20cm and $S_3$10cm x 30cm. The maximum fresh weight of bulb (11.85 g) and number of cloves $bulb^{-1}$ (22.00) were recorded from S_3 treatment while S_1 treatment gave the minimum but yield (3.95 t/ha) is maximum in S_1 treatment. The maximum fresh weight of bulb (9.680 g); number of cloves $bulb^{-1}$ (24.02) and yield (4.523 t/ha) were recorded from Pt_1 treatment while Pt_4 treatment gave the minimum. For combined application the maximum fresh weight of bulb and number of cloves $bulb^{-1}$ were recorded from S_3Pt_1 treatment combination while S_1Pt_4 treatment combination gave the minimum but maximum yield (5.97 t/ha) was obtained from S_1Pt_1 treatment combination while S_3Pt_3 gave the minimum (2.05 t/ha). In economic analysis, the maximum benefit cost ratio (2.34) was recorded from S_1Pt_1. From the above results, S_1Pt_1 treatment combination were best for growth and yield of garlic.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro Ecological Zone
cv	Cultivar
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCR	Benefit Cost Ratio
CGR	Crop Growth Rate
cm	Centimeter
^{0}C	Degree Celsius
DAP	Days after Planting
DM	Dry Matter
DW	Dry Weight
et al.	And others
FAO	Food and Agriculture Organization
FW	Fresh Weight
g	Gram
hr	Hour
Kg	Kilogram
LAI	Leaf Area Index
DMRT	Duncan's Multiple Range Test
MoP	Muriate of Potash
NAR	Net Accumulation Rate
NS	Non significant
RH	Relative humidity
SAU	Sher-e-Bangla Agricultural University
Sq. m	Square meter
SRDI	Soil Resources and Development Institute
t/ha	Tonnes per hectare
TSP	Triple Superphosphate
%	Per cent

CHAPTER I

INTRODUCTION

Garlic (*Allium sativum* L.) is an aromatic, herbaceous, annual spice and one of the most important bulb crops belonging to the family Alliaceae. It is the second most widely used Allium after onion with the characteristics of pungent smell (Bose and Some, 1990). It originated in Central Asia, especially Mediterranean region from where it extended to North-Eastwards to the Pamir Alii and Tien Shen regions of China (Thompson and Kelly, 1957). The World production of Garlic is about 9280 thousand metric tonnes. China leads the world production of garlic (5964 thousand metric tonnes) and also in the area (467 thousand hectare). The major garlic producing countries of the world are China, South Korea, Spain, India, USA, Russia, Egypt, Thailand and Turkey (FAO, 2006).

Garlic has a worldwide recognition as a valuable spice for foods and a popular remedy for various physiological disorders such as chronic infection of stomach and intestine, dysentry, typhoid, cholera and disease of lung (Chopra et al., 1958). Aqueous extract of garlic cloves has a hypocholesterolaemic action which reduces the cholesterol level in human blood (Augusti, 1977).

Garlic ranks second in the world production among the Alliums after onion (Purseglove, 1975). The average yield of garlic in Bangladesh is only 3.60 t/ha (BBS, 2007) which is very low compared to many countries of the world. In Bangladesh about 4, 43,000 metric tonnes of garlic was produced from 123 thousands hectares of land in 2006-07 (BBS, 2007). The requirement of garlic in Bangladesh is about 8,50,000 metric tonnes (Rahim and Fordham, 1988). The demand of garlic consumption is increasing day by day with ever increasing population of Bangladesh. It is not possible to increase the area of crop due to the limitation of land. The only way to solve the problem is to increase per hectare yield and this can be done in many

ways, among which the important ones are the use of high yielding varieties, proper planting time, proper spacing, proper cultural management practices and suitable size of cloves, as planting materials (Baten *et al.*, 1991; Bhuiyan, 1999).

Planting time plays an important role on the growth and yield of garlic. Garlic is known to be thermo and photo sensitive crop (Jones and Mann, 1963) and its vegetative growth and bulb formation is greatly influenced by growing environment (Jones and Mann, 1963; Rahim and Fordham, 1988). In Bangladesh, the growth period of garlic is centered in the cool season. As a result, only early planted crops can utilize full advantages of the cool period. But late planted crops fail to receive the advantages due to rise in temperature. But the farmers of Bangladesh cannot always adopt early planting due to climatic limitations and cropping pattern. Normally they plant garlic in the month of December after harvesting of transplanted aman paddy. For this reason, the plant is exposed to increasing high temperature before initiation of cloves and during the period of growth and development. So, the yield becomes low and sometimes a percentage of plants fail to initiate bulb at all.

Yield is a function of inter and intra plant competition. Competition associated with different spacing alters plant morphology in various ways. Researchers have shown that weaker plants become barren when spacing was lowest to a greater extent. These plants utilized water and nutrients but contributed for lower yield. As such there is a considerable scope for increasing yield by adjusting an optimum plant spacing (Rahman and Talukdar, 1986). Optimum plant spacing should be maintained to exploit maximum natural resources, such as nutrients, sunlight, soil moisture etc. and to ensure satisfactory yield. High density is undesirable because it encourages inter plants competition for resources. Resource, on the other hand, will simply be misuse under sparse plant spacing. By adjusting proper plant density farmers can easily recover the losses of late planting as it provides shade or somewhat cool condition particularly in the closer planting. In some cases the closer planting can keep the

temperature low up to 2-3^0 C, which ensures somewhat cool environment before bulb initiation (Rahim and Fordham, 1988). Beside this, closer planting ensures more plants per unit area, leading to higher yield per unit area. Closer plant spacing may result higher cost of production. So, proper plant spacing for garlic needs to be estimated.

Considering the above facts, the present study was undertaken with the following objectives:

1. to find out the appropriate planting time of garlic,
2. to investigate the suitable spacing for garlic and
3. to know the combined effect of planting time and spacing on growth and yield of garlic.

CHAPTER II

REVIEW OF LITERATURE

2.1 EFFECT OF SPACING ON GROWTH AND YIELD OF GARLIC

Mueller *et al.* (1998) carried out field trials in Santa Catarina, Brazil, in 1987-89, seed bulbils of garlic cv. Roxo Perola de Cacador with an average weight of 1.5, 2.25 or 3.4 g in 1987 and 1.6, 2.6 or 3.6 g in 1988 were planted 7-10 cm apart with 20, 25 or 30 cm between rows and grown according to recommended procedures for the region. Increasing weight of seed bulbils or reducing the spacing increased yield of total and marketable bulbs, whilst average weight of marketable bulbs and yield of larger bulbs were increased by increases in row spacing and/or by increases in seed bulbil size. Economic returns were highest following planting of bulbils of 3.4-3.6 g in rows 25 cm apart.

Xu-Kun *et al.* (1999) carried out an experiment on the influence of seed cloves and density on garlic yield. The effect of planting bulb size and sowing density on the yield of garlic was investigated. From the mathematical relationship describing this, it was shown that yield was more affected by plant density than by the size of the planting material.

Ingle *et al.* (2000) conducted a field experiment during the rabi season of 1992-93 at Akola. It was revealed that the height of plants, number of leaves, yield contributing characters as well as yield/ha were significantly influenced by planting methods, spacing and cultivars. Dibbling of cloves of garlic cv. G-1 in flat beds at 10X15 cm spacing gave maximum bulb yield and better quality bulbs under Akola conditions.

Naruka (2000) carried out an experiment on the effect of different row spacing on the growth of garlic (*Allium sativum* L.). Garlic cultivars were sown at row spacings of 10

x 7.5 (narrow) and 15 x 7.5 cm (wide) in a field experiment in Rajasthan, India, in October 1998 and 1999. The observations were recorded at maximum growth (105 days after sowing). Higher plant height (50.65 cm), leaf chlorophyll content (1.02 mg/g) and leaf fresh weight (24.92 g/plant) were observed at wide spacing compared to narrow spacing. The number of leaves per plant and maturity period was not affected by row spacing treatments.

Das *et al.* (2001) carried out an experiment on the effect of plant density and mineral nutrition on the yield of garlic (*Allium sativum* L.) cv. Madrasi. In Orissa, India from 1995 to 1997 three spacing (8x8, 10x8, 10x10 and 15x10 cm) and four N: P: K rates (50:50:50, 75:75:75, 100:100:100 and 125:125:125 kg/ha) were used. Among the spacing treatments, 8x8 (at 900 plants/plot) produced the highest yield (165.28 q/ha), followed by 10x8 cm. Among the fertilizer treatments, N: P: K at 100:100:100 kg/ha produced the highest bulb yield (153.78 q/ha), followed by 125:125:125 kg/ha. Combination of 10x8 spacing and 100:100:100 kg N: P: K/ha resulted in the maximum yield of 170.27 q/ha.

Naruka (2001) conducted a field experiment in Jobner, Rajasthan, India, during the rabi seasons of 1998-99 and 1999-2000 to study the effects of row spacing (10 and 15 cm) and nitrogen fertilizer (50, 100, 150, and 200 kg/ha) on the growth, yield, and chemical composition of bulb of garlic cultivars Yamuna Safed, Jajavar Local, and Mathani Local. The growth parameters, yield components (plant height, number of leaves, leaf fresh weight, maturity period, neck thickness, bulb diameter, bulb fresh weight, clove weight, and harvest index, yield, and composition (chlorophyll content) increased significantly with increasing level of nitrogen and row spacing; these were highest with 200 kg N/ha and a row spacing of 15 cm. The total soluble solid content was higher under closer row spacing (10 cm). Jajavar Local was significantly superior over the other two cultivars for all these characters. The interaction studies showed that Jajavar Local grown with 200 kg N/ha and a row spacing of 15 cm gave the

highest bulb yield (128 q/ha), net return (Rs 77236/ha), and benefit cost ratio (3.06:1.00).

Bhati *et al.* (2002) conducted an experiment on the effects of nitrogen rates (50, 100 and 200 kg/ha) and spacing (20 x 10 and 20 x 20 cm) on the yield and quality of garlic in Meerut, Uttar Pradesh, India during the rabi season of 1996-97. The number of cloves, diameter of cloves and bulb, weight of bulb and average yield increased with increasing rates of N and were higher under 20 x 10 cm spacing. The number of A, B and C grade garlic also increased with increasing rates of N and were higher under 20 x 20 cm spacing.

Naruka and Singh (2002) reported garlic cultivars Yamuna Safed, Jajavar Local and Mathani Local were planted at 10 x 7.5 or 15 x 7.5 cm in a field experiment conducted in Jobner, Rajasthan, India during the rabi season of 1998-99. Yamuna Safed planted at 15 x 7.5 cm recorded the highest mean leaf (26.93 g) and bulb fresh weight (32.93 g), bulb diameter (3.94 cm) and number of cloves per bulb (35), whereas Jajavar Local planted at 10 x 7.5 cm recorded the highest mean bulb yield (117 q/ha) and harvest index (69.52%).

Naruka (2002) conducted a field experiment in Jobner, Rajasthan, India, during the rabi season of 1998 and 1999 to study the effect of N (50, 100, 150, and 200 kg/ha) and row spacing (10 x 7.5 and 15 x 7.5 cm) on the composition of garlic bulbs. The interaction between N rate and row spacing significantly affected the components of garlic bulbs, with the combination of 200 kg N/ha and a row spacing of 15 x 7.5 cm giving the highest moisture (63.46%), protein (22.20%), nitrogen (22.08%), potassium (0.77%), sulfur (1.45%), ascorbic acid (13.28 mg/100 g pulp), and volatile oil (0.65%) contents.

Naruka *et al.* (2002) conducted an experiment on the interactive effect of nitrogen, row spacing and cultivars on composition of garlic bulb at the Department of Horticulture, S.K.N. College of Agriculture, Jobner (Jaipur) during the years 1998-99 and 1999- 2000. It was observed that interaction effect of nitrogen, row spacing and cultivars was found significant for nitrogen, sulphur, protein, volatile oil and moisture content of bulb. Maximum values for nitrogen, phosphorous, potassium, sulphur, ascorbic acid, protein, volatile oil and moisture content of bulb were observed when 200 kg nitrogen ha-1 (N4) was applied in conjunction with row spacing 15 x 7.5 cm (S2) and cultivar "Jajavar local" (V3). While the minimum values for these parameters were observed under N_1 S_1 V_1 (50 kg nitrogen ha-1 + 10 x 7.5 cm row spacing + cultivar "Yamuna safed") treatment combination during both the years. Maximum values for T.S.S. were observed under N1S1V2 treatment combination

Hossain *et al.* (2003) conducted field experiments to determine the effect of different seed sizes (large (95.1 g/100 cloves), medium (66.5 g/100 cloves) and small (46.3 g/100 cloves)) and 4 spacings (25 x 20 cm, 20 x 20 cm, 20 x 15 cm and 20 x 10 cm) on growth parameters of garlic cv. Pabna in Bangladesh, during November 2000-April 2001. Large sized cloves had the highest root length, plant height, number of leaves per plant, stem length and total dry matter. Plant spacing of 25 x 20 cm had the highest root length, leaf number per plant and leaf dry matter, while the spacing of 20 x 20 cm gave highest root dry matter and plant height. The highest pseudostem length was obtained from plant spacing of 20 x 10 cm. Further studies are proposed to establish optimum clove sizes and plant densities that could be recommended to farmers.

Lipinski *et al.* (2003) carried out an experiment on the Garlic Nieve INTA plant density and nitrogen fertigation. The effects of planting density (20, 30 and 40 plants/m2) and nitrogen fertilizers (0, 75, 150, 225 and 300 kg/ha) on the yield and quality of garlic cv. Nieve INTA were determined in a field experiment conducted in

Argentina. Planting density of 40 plants/m2 and application of 225 kg N/ha resulted in the highest yield (13 t/ha).

Portela and Dalmasso (2003) conducted an experiment on the planting density and seed-clove weight evaluation on garlic (*Allium sativum* L.) monoclonal cultivars in the East Oasis of Mendoza, Argentina. The effect of planting density and seed clove weight on the productivity of garlic monoclonal cultivars (Peso and Desvio) was investigated in Argentina. The treatments comprised high and middle planting densities (20 and 15 plants/lineal meter), and clove sizes of 8-9 and 4-5 g. Higher total yield was obtained with higher planting density and heavier cloves. None of the treatments appeared to be responsible for the defects in bulb shape.

Castellanos *et al.* (2004) carried out an experiment on the garlic productivity and profitability as affected by seed clove size, planting density and planting method. Depending on clove size and plant stand, planting represents a considerable proportion of the total production costs in garlic cultivation. The objectives of this study were to analyse the influence of seed clove size, planting density and planting method on yield, bulb size and on the profitability of garlic for the fresh market, planted under fertigation. For the plant density study, yields varied from 23.5 to 29.9 t ha-1 for the first year and from 32.1 to 39.7 t ha-1 for the second season. For the seed clove size study, yields varied from 18.7 to 27.3 t ha-1 for the first year and from 16.3 to 32.2 t ha-1 for the second season. Yields and leaf area index (LAI) were directly related to planting density and clove size. The highest yields were attained with maximum studied densities in both seasons. However highest profitability was attained with planting densities of 420 000 plants/ha for the first year, as calculated from the regression equation and 300 000 plants/ha for the second year as there was no statistical difference ($P>0.05$) with the 2 subsequent population treatments and the former has lower costs than the others. The biggest diameters of bulb were always attained with the lowest population densities. In regard to seed size, the highest yield

was achieved with 7.5 g/clove for the first season and 13 g/clove for the second season, which also resulted in biggest bulb diameters and therefore in more valuable commercial classes. In accordance with the regression analysis, highest profits were obtained with clove sizes 3.6-6.5 g/clove, which yielded from 24 to 27 t ha-1 for the first season and from 7 to 10 g/clove for the second season, for yields from 29 to 31 t ha-1. In general, the largest-sized seeds produced lower profits than medium-sized seeds, even though yields were significantly higher. The best planting method for garlic, as evaluated in terms of yield, quality and profitability, was associated with good plant distribution in the field and planting the seed with the apex upwards, characteristics obtained in the hand-planted treatment.

Nosraty (2004) carried out an experiment on the effects of planting method, plant density and seed clove size on yield of Hamedan garlic. The effect of planting density, seed clove size and planting methods on the yield of Hamedan garlic was investigated during 1998-99. The effects of plant density and seed size on yield were significant, while cultivation method did not significantly affect crop yield. The density of 740 000 plants/ha, seed cloves with weights in the range 5-7 g and planting in 2 rows were the best treatments for obtaining the highest yield.

Reghin *et al.* (2004) carried out an experiment on the yield response of garlic to different plant densities and weights of seed cloves. The effects of seed clove weight (3.0-3.5 or 2.0-2.9 g) and plant density (33.3, 50.0, 66.6 or 100 plants/m2) on the yield of garlic cv. Roxo Perola de Cacador were studied in Ponta Grossa, Parana, Brazil, during 2002. For densities of 33.3 and 66.6 plants/m2, seed cloves were planted in single rows with spacing of 0.30 m between rows and 0.10 and 0.05 m, respectively, between plants. For densities of 50 and 100 plants/m2, seed cloves were planted in double rows with spacing of 0.30 m between rows and 0.10 and 0.05 m, respectively, between plants. Seed clove weight had no significant effects on bulb yield. However, bulb secondary growth was optimum when seed cloves weighing 2.0-

2.9 g were used. The increase in plant density reduced bulb size and secondary growth, but increased the bulb yield. Increasing the plant density from 33.3 to 100 plants/m2 increased the bulb yield from 1.28 to 2.94 kg/m2 for seed cloves weighing 3.0-3.5 g, and from 1.21 to 2.90 kg/m2 for seed cloves weighing 2.0-2.9 g. Seed cloves weighing 3.0-3.5 g resulted in varying bulb sizes. High-quality bulbs (>47 but <55 mm) were obtained with seed cloves weighing 3.0-3.5 g and a plant density of 40 plants/m2.

Hossain *et al.* (2005) carried out an experiment on the effect of planting density and nitrogen levels on the growth and yield of garlic. An experiment was conducted in Peshawar, Pakistan, during 2003-2004 to study the effects of planting density (40, 60 and 80 plants/2 m2) and 4 levels of N (0, 60, 120 and 180 kg ha-1 as urea) on the growth and yield of garlic (cv. Peshawar local). The lower planting density of 40 plants/2 m2 significantly increased the number of leaves per plant (7.83), bulb weight (60.44 g), bulb diameter (5.52 cm) and number of cloves per bulb (39.4). The greatest leaf length (59.43 cm) and total yield (6.66 t ha-1) were obtained at a planting density of 80 plants/2 m2. Among the N levels, the highest number of leaves per plant (8.29), leaf length (61.06 cm), average bulb weight and diameter (60.78 g and 5.58 cm), number of cloves per bulb (40.1) and total yield (5.87 t ha-1) were recorded for 120 kg N ha-1. The interaction between planting density and N level was significant only for total yield, and the highest yield (7.12 t ha-1) was obtained at a planting density of 80 plants/2 m2 with 120 kg N ha-1.

Ibrahim *et al.* (2005) conducted an experiment on the growth and productivity of sugar beet, onion and garlic grown alone and associations under different inter and intraspacing. Studies were conducted in Toshky (Upper Egypt) during the seasons of 2002-03 and 2003-04 to investigate the growth and productivity of sugarbeet, onion and garlic grown alone or under intercropping systems. Eight intercropping systems comprising 2 ridging distances (60 and 70 cm) and plant spacing at 25 and 35 cm

between sugarbeet plants intercropped with onion and garlic were set up. Sole crops were established at the same inter- and intracrop spacings. Sugarbeet intercropped with garlic and onion did not show better yields than pure stand sugarbeet under the same spacing treatments. The highest intercrop yield was obtained when sugarbeet plants were arranged in ridges at 60 cm apart, and with a 25 cm between sugarbeet and onion. The lowest yield was obtained when ridge spacing was 70 cm, and intrarow spacing was 35 cm between sugarbeet and garlic. Total soluble solids, sucrose percentage and purity decreased with decreasing tuber weight, but these parameters increased with increasing inter- and intrarow spacing. A gradual decrease in onion and garlic yields was observed with increasing inter- and intraspacing. Intercropped onion on ridges 60-cm apart and spaced at 25 cm outyielded all other intercropping treatments. Pure stands showed higher yields under the same spacing treatments. The highest land equivalent ratio (LER) was obtained under 60x25 cm. LER obtained from sugarbeet-onion intercropping was higher than that obtained from sugarbeet-garlic intercropping. The relative crowing coefficient showed the same trend as LER.

Jahangir *et.al.* (2005) conducted an experiment on the response of plant spacing and different levels of Nitrogen and Potassium fertilizer on growth, yield and oil content of garlic. The effects of plant spacing (5, 7.5 and 10 cm), and N (60, 80 and 100 kg/ha) and K (45, 60 and 75 kg/ha) application, on the growth, yield and oil content of garlic were studied in during 2002-03 in Dhaka, Bangladesh. The plant spacing of 5 cm recorded the highest yield (4.6 t/ha bulb). In the fertilizer treatment, the highest bulb weight (21.6 g) and garlic yield (4.9 t/ha) were recorded with 100 kg N+75 kg K/ha. The highest percentage of garlic oil (0.17%) was obtained from the application of 60 kg N+60 kg K< sub>2</ sub>O/ha. With N-K application, the physical-chemical properties of garlic oil such as refractive index, acid value, density and optical rotation remained more or less the same throughout the experiment.

Karaye and Yakubu (2006) conducted an experiment on the influence of intra-row spacing and mulching on weed growth and bulb yield of garlic (*Allium sativum* .) in Sokoto, Nigeria.Two field experiments were conducted during 2000/2001 and 2001/2002 dry seasons under irrigation at Kwalkwalawa Research Fadama Farm of Usmanu Danfodiyo University, Sokoto to investigate the response of weed growth and bulb yield of garlic to intra-row spacing and mulching. The treatments consisted of three intra-row spacings (10, 15, and 20 cm) and four mulching rate (0, 5, 7 and 9 t/ha). These were laid out in split plot design and replicated three times. Intra-row spacing was assigned to main plots and mulching was allotted to sub plots. Gross and net plot sizes were 3x1.5 m and 2.5x1 m, respectively. Results indicated that the number of leaves/plant, weed growth and cured bulb yield responded significantly to intra-row spacing and mulching, except in 2000/2001 trial, when the effect of mulching on cured bulb yield was not significant. Based on the results obtained, it could be concluded that for optimum bulb yield in garlic, the intra-row spacing of 10 cm and 9 t/ha mulching rate should be adopted

Miko and Manga (2006) conducted an experiment on the effect of inter- and intra-row spacings on yield and yield components of garlic (*Allium sativum* L.) in the Sudan Savanna zone of Nigeria. Two experiments were conducted during the 2001-2002 and 2003-2004 dry seasons at the Irrigation Research Station of the Institute for Agricultural Research, Kadawa (11 degrees 39'N and 08 degrees 02'E) situated in the Sudan Savanna ecological zone of Nigeria to test the effect of inter- and intra-row spacing on the yield and yield components of garlic. The treatments were composed of three inter-row spacings (5, 10 and 15 cm) factorially combined with four intra row spacings (5, 10, 15 and 20 cm). Results have shown that inter- and intra-row spacings significantly affected bulb diameter, number of cloves per bulb, clove weight, and fresh and cured bulb weight both for the individual bulb and the projected yield per hectare in all the years. The 10 and 15 cm inter-row spacings produced statistically similar but significantly higher bulb diameter, number of cloves/bulb, fresh and cured

bulb weights, as well as fresh and cured bulb yields than 5 cm inter-row spacing in all seasons. However, the 10 cm intra-row spacing produced comparable bulb diameter, number of cloves/bulb, fresh and cured bulb weights and bulb yield to either 15 or 20 cm, respectively. Interaction effect between inter- and intra-row spacings was significant only for bulb diameter and fresh bulb yield in 2001-2002 only.

2.1 EFFECT OF PLANTING TIME ON GROWTH AND YIELD OF GARLIC

Burba and Borgo (1994) carried out 2-year trials with white and colored garlic types, the bulbs were stored either at ambient temperature or at a lower temperature (15°C). The optimum planting time occurred when the index of visual dormancy break in cloves reached 75%. Another batch of colored garlic bulbs, with or without stalks, was stored in similar conditions and the cloves were planted out on 20 Apr., 5 May or 16 May. Bulbs stored without stalks at 15°C tended to break dormancy earlier than those stored in ambient temperature and this, in combination with early planting, resulted in the highest yield. And the higher yield (5.72-6.01 t/ha) of good quality bulbs were obtained from 11 November planting. The yield was decreased appreciably with later planting.

Anwar *et al.* (1996) carried out an experiment and reported that the planting dates influenced the plant height, number of leaves, neck diameter, bulb diameter, fresh and dry weight of leaf, bulb and roots and bulb yield of garlic. The dry weight of leaves, bulbs and roots were higher when planted earlier. The highest yield was obtained from November 17 planting and 16 January planting gave the lowest yield.

Ara *et al.* (1998) stated that the planting time significantly influences the bulb diameter and yield of garlic under Bangladesh conditions. The largest bulb diameter (2.98 cm) and the highest yield (4.54 t/ha) of garlic were found from the planting date of 29 November. But the average bulb diameter (2.32 cm) and yield (2.18 t/ha) were obtained from December 29 planting.

Sonkamble *et al.* (1999) conducted an experiment on the effect of different dates of planting on growth and yield of garlic. A field experiment was conducted at the Department of Horticulture, Marathwada Agricultural University, Parbhani during 1997-98 in rabi season on garlic planted on 7 dates between 1 September and 30 October. Sprouting, plant height, number of leaves/plant and stem thickness were greatest from planting on 20 October.

Alam (2000) conducted an experiment on the effect of planting time and clove size on the growth and yield of garlic at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh during October, 1999 to April, 2000. It was noted that the highest yield was obtained from 10 October planting compared to 10 November and 10 December planting. The yield contributing characters were also found maximum in earlier planting which was decreased with delayed planting.

Azad (2002) carried out an experiment on the effect of planting time and clove size on the growth and yield of four garlic germplasm at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh during the period from October 2001 to April, 2002. He reported that the maximum plant height, number of green leaves, fresh and dry weight of leaves, bulb roots per plant, bulb diameter, number of cloves per bulb and yield (5.45).

Faruq (2000) carried out an experiment on the effect of date of planting and clove size on the growth and yield of garlic at the Horticulture Farm, Bangladesh Agricultural University, Mymensingh during October, 1999 to April, 2000. It was found that the highest yield was obtained from 30 October planting (5.66 t/ha) and the lowest yield was obtained from 14 December planting (3.33 t/ha)

Pinto *et al.* (2000) conducted an experiment on the Production components and yield loss of garlic cultivars planted at different times in a field naturally infested with

Sclerotium cepivorum. Four annual experiments with garlic (Allium sativum) were established in fields in MG, Brazil, naturally infested with Sclerotium cepivorum, causal agent of garlic white rot, to investigate the effect of time of planting on yield. Initial stands were unaffected by time of planting. Final stands and yields were highest when garlic was planted approximately 1 month earlier (28 January-15 February) when soils were warmer than at the traditional time of planting (15 March-15 April). When garlic was planted at the traditional time, final stands and yields were reduced 56-92% primarily from the attack of S. cepivorum. A 100% loss in yield occurred in some crops planted in cool soils in late March. With an early planting (15 January), final stands were similar to the plantings of 28 January and 15 February, but yields were reduced by half because of a much lower mean weight of the harvested bulbs. In a late planting (15 May), the final stand was 75% lower with correspondingly lower yield than that obtained with the early plantings. The largest bulbs (21.6 g) were obtained from the planting on 28 February; however, the yields from this planting were reduced by half from the planting 2 weeks earlier because of the 50% reduction in final stand. Early planting of garlic is recommended as an important management strategy to avoid white rot in areas with soils infested with sclerotia of S. cepivorum.

Sonkamble *et al.* (2000) conducted an experiment on the effect of different dates of planting on morphological characters of bulb and yield of garlic. Field experiment was conducted at Department of Horticulture, Marathwada Agricultural University, Parbhani, India, during 1997-98, to find out the effect of planting date on morphological characters of bulbs and yield of garlic. Planting corms on 20 October was best with regard to morphological characters of bulbs and yield.

Talukder *et al.* (2000) conducted an experiment on the effects of planting time and different levels of nitrogen on the growth and yield of garlic at the Horiculture Farm of the Bangladesh Agricultural University, Mymensingh, Bangladesh from October

1997 to April 1998. The experiment consisted of two planting dates viz. 31 October and 30 November and four rates of nitrogen viz. 0, 75, 125 and 175 kg/ha. Results from the experiment indicated that the growth and yield of garlic were affected by different dates of planting and rates of nitrogen. Early planting favored better growth and yield. The different rates of nitrogen also showed wide variations with respect to growth and yield of garlic. The highest yield (4.62 t/ha) was produced at the highest rate of nitrogen (175 kg/ha). The combined effect of planting time and different rates of nitrogen showed that early planting (31 October) and highest dose of nitrogen yielded the highest.

Talukder *et al.* (2002) conducted an experiment on the effect of planting time and different levels of potassium on the growth and yield of garlic at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh, from October 1997 to April 1998. The experiment consisted of two planting dates viz., 31 October and 30 November and four levels of potassium viz., 0, 50, 100 and 200 kg K20 ha-1. The growth and yield of garlic were influenced by the different dates of planting time and different levels of potassium. Early planting favored better growth and yield. Different doses of potassium also showed wide variations in respect of growth and yield of garlic. The highest yield (4.36 t ha-1) was obtained at the highest level of potassium (200 kg K20 ha-1). Combined effect of planting time and different levels of potassium showed that the early planting (October 31) and highest level of potassium yielded the best.

Gupta *et al.* (2003) conducted an experiment on the effects of planting date (20 September, 5 October, 20 October and 5 November) and clove size (less than 10 mm, 10-15 mm, and more than 15 mm) on the performance of garlic cv. Yamuna Safed-3 in Karnal, Haryana, India, during the rabi seasons of 1999/2000 and 2000/01. Planting on 5 October and 20 September resulted in the greatest bulb diameter (3.26 3.23 cm), bulb size index (8.76 and 8.68 cm2), clove diameter (0.97 and 0.98), clove size index

(1.86 and 1.84), weight of 20 bulbs (269.17 and 268.39 g), gross yield (166.20 and 1661.57 quintal/ha), and marketable yield (154.17 and 151.85 quintal/ha). Bolting (12.39%) and splitting (13.50%) of bulbs were lowest with planting on 5 November. Planting on 20 September recorded the greatest weight of 50 cloves (68.11 g). Clove size greater than 15 mm gave the greatest bulb diameter (3.15 cm), bulb size index (8.78 cm2), clove diameter (0.96 cm), clove size index (1.79 cm2), weight of 50 cloves (73.21 g), gross yield (162.50 quintal/ha), and marketable yield (151.39 quintal/ha). Cloves less than 10 mm in size resulted in the highest total TSS [total soluble solids] (40.80%) and dry matter (42.62%) contents, and number of cloves per bulb (16.38), and in the lowest bolting (21.92%) and splitting (2.13%). The lowest physiological weight loss after storage (9.88%) was recorded for planting of 15-mm cloves on 5 October, whereas the lowest total loss was recorded for planting of cloves 10-15 mm in size on 5 October (13.75%) and 20 October (15.04%). Thus, planting of cloves 10-15 mm or > 15 mm in size on 5 or 20 October was optimum. [1 quintal=100 kg].

Rahman *et al.* (2004) conducted an experiment on the effects of planting date and gibberellic acid (GA3) on the growth and yield of a local cultivar of garlic during the growing period from November 2001 to April, 2002. The experiment was consisted of four planting dates (November 07, 22 and December 07, 22, 2001) and different concentrations of GA3 (0, 100 and 200 ppm). The objective of the work was to find out the appropriate planting time and effective concentration of GA3 on the growth and yield of garlic. Early planting favorably influenced plant height, number of leaves per plant, dry weights of leaves, bulbs and roots, total dry matter (TDM), leaf area index (LAI), crop growth rate (CGR), bulb diameter, individual bulb weight as well as yield. With the delay in planting time starting from November 07, the yield was chronologically reduced in later plantings. The highest bulb yield (2.67 t ha- 1) was recorded from November 07 planting and the minimum (0.92 t ha-1) from December 22. There was deleterious effect of GA3 concentrations used in this experiment.

Control plants produced higher yield than the plants treated with different concentrations of GA3. The interaction effect of planting dates and GA3 concentrations indicated that early plantings grown without GA3 showed better performance than the late plantings grown with or without GA3.

Singh *et al.* (2004) conducted an experiment on the interaction effect of nitrogen, planting time and spacing on the performance of garlic, *Allium sativum* Linn. cv. Yamuna Safed (G-1 A trial was conducted in Uttar Pradesh, India, during 2002-03 on garlic to find out the optimum rate of nitrogen, planting time and plant spacing to get the highest production of garlic. Treatments comprised: 3 N rates (0, 80 and 160 kg/ha; N< sub>0</ sub>, N< sub>1</ sub> and N< sub>2</ sub>, respectively), 3 planting dates (10 September, 10 October and 10 November; T< sub>1</ sub>, T< sub>2</ sub> and T< sub>3</ sub>, respectively) and 3 row spacings (10x10, 15x15 and 20x20 cm; S< sub>1</ sub>, S< sub>2</ sub> and S< sub>3</ sub>, respectively). The interactions of different levels of nitrogen, planting time and spacing significantly influenced the plant height and yield of garlic. Combined effects of early planting time with the highest nitrogen rate (T< sub>1</ sub>N< sub>2</ sub>) produced a high growth and yield. Early planting with lower spacing resulted in a high yield, while a large number of cloves and fresh weight per bulb were recorded with early planting and the widest spacing (T< sub>1</ sub>S< sub>3</ sub>). The largest bulb diameter was recorded with the widest spacing and highest nitrogen rate (S< sub>3</ sub>N< sub>2</ sub>). The highest level of nitrogen and widest spacing (S< sub>3</ sub>N< sub>2</ sub>) proved less effective on the growth and yield of garlic.).

Nam-SangSik *et al.* (2005) conducted an experiment on the effect of planting dates and planting density using large bulbils for seed clove production of garlic 'Namdo' in Southern regions. An experiment was conducted to study the effects of planting dates and planting densities using the large bulbils for seed clove production of garlic cv.

Namdo in Southern regions of Korea. The bulbils, 0.5-0.7 g, were planted in 15 and 25 September, and in 6, 15 and 27 October. Planting densities were 18x10, 15x10, 12x10, and 9x10 cm. Vegetative growth of garlic in the field was significant among the planting dates. In the distribution of bulb diameter, those planted in mid- and late-October produced higher percentage of small bulbs, 45.7-47.4%. Bulb weight and yield of garlic decreased at later planting dates. The number of seed cloves weighing more than 2.5 g was obtained in September planting, i.e. 203-199 cloves/m2. The number of seed cloves weighing more than 2.5 g was highest at 9x10 cm planting. For large bulbil cultivation, the recommended suitable planting date is in mid- or late-September with a density of 9x10 cm.

Poldma *et al.* (2005) conducted an experiment on the influence of planting time on the development, yield and quality of garlic (*Allium sativum* L.) in Estonia. This research studied the influence of different planting times in autumn and spring on growth, yield and bulb quality of garlic. Experiments were carried out with local winter garlic clone in Tartu, southern part of Estonia in 2000-02. Six planting times with an interval of 10 days were used in autumn (from September to November) and 2 planting variants in spring. The average diurnal temperature remained below 0 degrees C from the 15th of November in Estonia. The planting times in autumn were calculated as 50, 40, 30, 20, 10 and 1 day before the above mentioned date. Seed cloves planted in spring were previously cold treated at 4.0+or-1 degrees C before planting for 30 and 50 days in 2001, and 15 and 30 days in 2002. The winter damage of cloves, plant growth characteristics (number of leaves, plant height and diameter of plant stem), yield and quality were measured. The yield of garlic bulbs varied between 0.43 and 1.46 kg m-1. Results of the research showed that the highest yield of garlic was obtained when planting was done 1-1.5 months before diurnal temperature remained constantly below 0 degrees C. Late planting times in autumn had the highest winter damage. Garlic planted in spring had lower yield and 16% of bulbs produced only one round

clove. None of the experimental factors had an impact on the plant height and diameter of plant stem.

Sirohi (2005) conducted an experiment on the effect of time of planting and spacing on yield of garlic (*Allium sativum* L.). A study was conducted during 2001-02 to determine the effect of planting date (1 October, 11 October, 21 October and 31 October) and spacing (15x10 and 15x15 cm) on the yield of garlic (Allium sativum) under the climatic conditions of Muzaffarnagar, Uttar Pradesh, India. Among the treatments, planting on 11 October with closer spacing (15x10 cm) produced the maximum fresh weight per bulb (56.8 g), while the minimum fresh weight per bulb (43.3 g) was recorded when planting was done on 31 October at the wider spacing (15x15 cm). Bulb diameter, number of cloves per bulb and bulb yield were highest (5.5 cm, 37.2 and 100.1 q/ha, respectively) upon planting on 11 October at the closer spacing.

Chattopadhyay *et al.* (2006) conducted an experiment on the Dynamics of growth and yield of garlic (*Allium sativum* L.) in variable planting time and applied nutrients. A field experiment was conducted during rabi 1999 and 2000, at Mophanpur, Nadia, West Bengal, India, to assess the performance of garlic under three sowing dates and eight nutrient levels. Vegetative growth parameters were significantly influenced with the earliest date of planting (15 November) along with NPK at 60:60:120 kg/ha in combination with either mustard cake or neem cake (5 t/ha) or FYM (30 t/ha). A reduction in nutrient levels and delay in planting beyond 15 November increased the shoot/bulb ratio. The migration coefficient gradually decreased with delay in planting beyond 15 November. The weight of individual clove was reduced by nearly 60% with delayed planting on 25 December. Bulb yield was maximum with first planting date along with application of NPK at the highest level in combination with mustard cake at 5 t/ha.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The experiment was carried out at Horticulture Farm in Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during the rabi season (November, 2007 to May, 2008). It was located in 23.74^0 N latitude and 90.35^0 E longitudes. The altitude of the location was 8.2m from the sea level (Bangladesh Meteorological Department, Agargaon, Dhaka-1207).

3.2 Climate

The experimental area was situated in the sub-tropical climatic zone, which was characterized by heavy rainfall during the months of April to September and scanty rainfall during the rest period of the year. Details of weather data during the growing period of garlic from November, 2007 to May, 2008 in respect of temperature (^{O}C), rainfall (cm) and relative humidity (%) for the study period were collected from Bangladesh Meteorological Department, Agargoan, Dhaka-1207 (Appendix I).

3.3 Soil

The experimental site was located in the Modhupur Tract (AEZ-28) and it was medium high land with adequate irrigation facilities. The soil was having a texture of sandy loam with pH 5.6. Physical and chemical properties of soil in the experimental field were tested by SRDI Laboratory (Appendix II).

3.4 Plant material

A local cultivar of garlic was used in this experiment. Bulbs were collected from Meherpur district of Bangladesh. Uniform sizes of cloves were selected for planting.

The average weight and diameter of cloves were 0.9g-1.13g and 0.6cm-0.7cm, respectively.

3.5 Design of the experiment

The experiment was conducted by Randomized Complete Block Design (RCBD) with three replications. Two factors were used in the experiment viz. four planting time and three of spacing.

Factor A. Three different spacing (Coded as S)

S_1: 10 x 10 cm,

S_2: 10 x 20 cm and

S_3: 10 x 30 cm.

Factor B. Four planting time (Coded as Pt)

Pt_1: 1 November, 2007,

Pt_2: 15 November, 2007,

Pt_3: 30 November, 2007 and

Pt_4: 15 December, 2007.

Therefore the treatment combinations were 12 and these were S_3Pt_1, S_3Pt_2, S_3Pt_3, S_2Pt_4, S_1Pt_2, S_2Pt_3, S_1Pt_1, S_3Pt_4, S_2Pt_1, S_1Pt_3, S_2Pt_2 and S_1Pt_4.

3.6 Layout of the experiment

The experimental area was first divided into three blocks. Each block was divided into 12 plots for the treatment combinations. Therefore the total number of plots was 36. Thereafter 12 treatment combinations were assigned randomly to each block as per design of the experiment. The size of the unit plot was 5m × 1m. A distance of 50cm between the plots and 1m between the blocks were kept. Thus the total area of the experiment was 324 m^2.

3.7 Land preparation

The experimental field was first opened on 15 October, 2007 by a tractor to destroy soil born pathogens and soil inhabitant insects. It was then thoroughly prepared by ploughing and cross ploughing followed by laddering to bring a good tilth. The clods were broken and the soil was leveled until the desired tilth was achieved for planting of cloves. During the land preparation, weeds and stubbles of the previous crops were collected and removed from the field. The basal dose of manure and fertilizers were applied at the final ploughing. According to design and layout the plots were prepared.

3.8 Application of manure and fertilizers

Manure and fertilizers were applied according to Fertilizer Recommendation Guide in 2005 (published by BARC). The recommended doses were N 90 kg/ha, P_2O_5 45 kg/ha, K_2O 120 kg/ha, S 30 kg/ha, Zinc sulphate 3 kg/ha and Cowdung 3 t/ha

Half of N and K_2O and full of P_2O_5, Zinc sulphate and Cowdung were applied at the final land preparation. Remaining N and K_2O were applied as top dressing followed by irrigation.

3.9 Planting of cloves

The cloves were planted according to treatments. The depth of planting was maintained around 2.5 cm from the surface of the soil.

3.10 Intercultural operations

3.10.1. Gap filling

The experimental area was kept under careful observation. The unsprouted cloves and damaged plants were replaced by healthy seedling taken from border plant within two weeks after planting.

3.10.2. Weeding and mulching

Three times weeding were done during crop period, viz. 29 October, 14 November and 29 November to keep the plot free from weeds. The soil was mulched by breaking the crust for easy aeration and to conserve soil moisture after each irrigation. The experimental field was kept under careful observation.

3.10.3. Irrigation

Few times irrigation was done during crop period, viz. 1 November, 15 November, 30 November and 15 December and many times for proper growth and development. Irrigation was provided in each plot uniformly by watering – can after N & K_2O fertilizers application. Care was taken to avoid flowing of water from one plot to another.

3.10.4. Plant protection

Leaf blotch disease was noticed in the experimental plot. Curative measure was taken by spraying Bavistin 50WP at an interval of 10 days @ 50 g in 10 liters of water.

3.11 Harvesting

The crops were harvested at different times when the plants reached maturity showing the sign of normal drying out of most of the leaves and by natural dropping at the neck the tops. The first, second, third and fourth time planted crops were harvested at 16 March, 2008; 1 April, 2008; 16 April, 2008 and 1 May, 2008 respectively. Ten consecutive plants were harvested row-wise at random and they were lifted with the help of a 'Nirani'. Data were recorded periodically during the growing season. Care was taken so that no bulb was injured during lifting.

3.12 Collection of data:

3.12.1. Plant height (cm)

Ten plants were randomly selected from each plot and height was taken with the help of transparent plastic scale precisely. Plant height were measured in centimeter (cm) at 30, 45, 60, 75 and 90 days after planting (DAP) from the point of attachment of the leaves to the ground level up to the tip of the longest leaf and mean value was calculated.

3.12.2. Number of leaves plant^{-1}

Number of leaves from ten randomly selected plants was counted at 30, 45, 60, 75 and 90 DAP. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of ten plants was considered as number of leaves in one plant.

136 (02) 21/01/10

3.12.3. Neck diameter of leaves (cm)

Neck diameter of leaves of ten randomly selected plants was measured at 30, 45, 60, 75 and 90 DAP in centimeter with the help of slide calipers.

3.12.4. Fresh weight of leaves plant^{-1} (g)

Leaves of ten randomly selected plants at the maximum growth stage were detached by a sharp knife from pseudostem attachment and average fresh weight of leaves was taken by an electric balance and mean weight was recorded in gram.

3.12.5. Fresh weight of roots plant^{-1} (g)

Fresh weight of roots of ten sample plant was taken and their average was calculated in gram after harvesting.

3.12.6. Fresh weight of bulb (g)

After removing the root and top portion keeping only 2.5 cm with neck, the bulb weight of 10 selected plants were taken and their average was calculated.

3.12.7. Dry weight of leaves plant^{-1} (g)

After harvest, leaves of ten selected plants from each plot were weighed then putting envelop and kept in an oven at 70^{0}C for drying, after sun drying. It took 72 hours to reach the constant weight and the average dry weight of leaves per plant was calculated in gram (g).

3.12.8. Dry weight of bulb (g)

Dry weight of bulb was taken from the sample plants when it was dried at 70^{0}C for 72 hours in an oven just after sun drying for two days and average was calculated and was expressed in gram (g).

3.12.9. Dry weight of roots (g)

After harvest roots of ten selected bulbs from each plot were weighed and sun dried, then it was kept in an oven at 70^{0}C for drying. It took 72 hours to reach the constant weight and the average dry weight of roots per plant was calculated in gram (g).

3.12.10. Diameter of bulb (cm)

After final harvest, the diameter at the middle part of the bulb was taken from the ten plants and their average was calculated.

3.12.11. Number of cloves bulb^{-1}

After final harvest, the number of cloves of ten bulbs was counted thoroughly. The mean number of bulbs was calculated.

3.12.12. Bulb yield (t/ha)

Yield of bulb per plot was converted into yield per hectare and expressed in tons.

3.13 Statistical analysis

The collected data on different yield and yield components of the experiment were statistically analyzed wherever necessary following factorial experiment in randomized complete block design (RCBD). The means for all treatments were calculated and the analyses of variances for all the characters under consideration were performed by "F" variance test using MSTAT computer package program. The significance of difference between pair of means were performed by Duncan's Multiple Range Test (DMRT) test taking the probability level 5% as the maximum unit of significance.

3.14 Economic analysis

The cost of production was analyzed in order to find out the profitability of the treatment combinations. All the non-material and material input costs and interest on running capital were considered for computing the cost of production. The interests were calculated @ 13% per year for 6 months. The cost and return analysis was done in details according to the procedures followed by Alam *et al.* (2000). Benefit cost ratio was calculated using the following formula:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross Return (Tk/ha)}}{\text{Total Cost of Production (Tk/ha)}}$$

CHAPTER IV

RESULT AND DISCUSSION

4.1 Plant height at different days after planting

Significant variation was found in plant height among different spacing at different days after planting (DAP) (Figure 1). The tallest plant at 30 (25.15 cm), 45 (28.86 cm), 60 (35.23 cm), 75 (39.13 cm) and 90 (45.32 cm) DAP were found in the widest spacing (S_3:10 x 30 cm) and the shortest plant at 30 (19.42 cm), 45 (23.15 cm), 60 (28.57 cm), 75 (32.42 cm) and 90 (36.75 cm) DAP were recorded from the closest plant spacing (S_1: 10 x 10 cm) and it was gradually increased as the plant population decreased. The average height of plant increased as the plant density decreased from 100 to 60 plants/m^2 area. The reduced vegetative growth in the plant density was probably due to increased competition among the plants for food, light, water and space. Higher plant height in garlic planted at wider spacing have been reported by Hossain *et al.* (2003), Ingle *et al.* (2000), Naruka (2001) and Naruka (2000).

There was significant difference among different planting dates in respect of plant height at different DAP (Figure 2). The tallest plant at 30 (26.76 cm), 45 (30.77 cm), 60 (37.26 cm), 75 (40.71 cm) and 90 (47.03 cm) DAP were obtained from early planting (Pt_1) and the shortest at 30 (17.10 cm), 45 (21.14 cm), 60 (26.73 cm), 75 (30.81 cm) and 90 (32.78 cm) DAP were found at late planting (Pt_4). This might be due to the reason that the crops planted on 1 November availed relatively favorable environment, longer cool period and shorter day length which possibly enhanced growth, resulting in maximum plant height. The tallest plant produced by early planted crop was also reported by Sonkamble *et al.* (1999), Singh *et al.* (2004), Rahman *et al.* (2004), Poldma *et al.* (2005) and Azad (2002).

At different DAP the combined effect of spacing and planting time showed significant difference in respect of plant height (Table 1). The tallest plant at 30 (30.20 cm), 45 (34.20 cm), 60 (41.40 cm), 75 (45.30 cm) and 90 (52.07 cm) DAP were obtained from the treatment combination of S_3Pt_1 (10 cm×30 cm spacing and 1 November planting) which was statistically similar to that of S_2Pt_1 and S_2Pt_2. The shortest plant at 30 (15.20 cm), 45 (19.17 cm), 60 (23.73 cm), 75 (28.03 cm) and 90 (30.27 cm) DAP were obtained from the treatment combination of S_1Pt_4 (10 cm×10 cm spacing and 15 December planting) which was statistically similar to that of S_2Pt_4. The trend of plant height in respect of spacing and planting time showed that the particular planting time obtained the highest plant height in wider plant spacing. Similar trend of results were found by Singh *et al.* (2004) and Ingle *et al.* (2000).

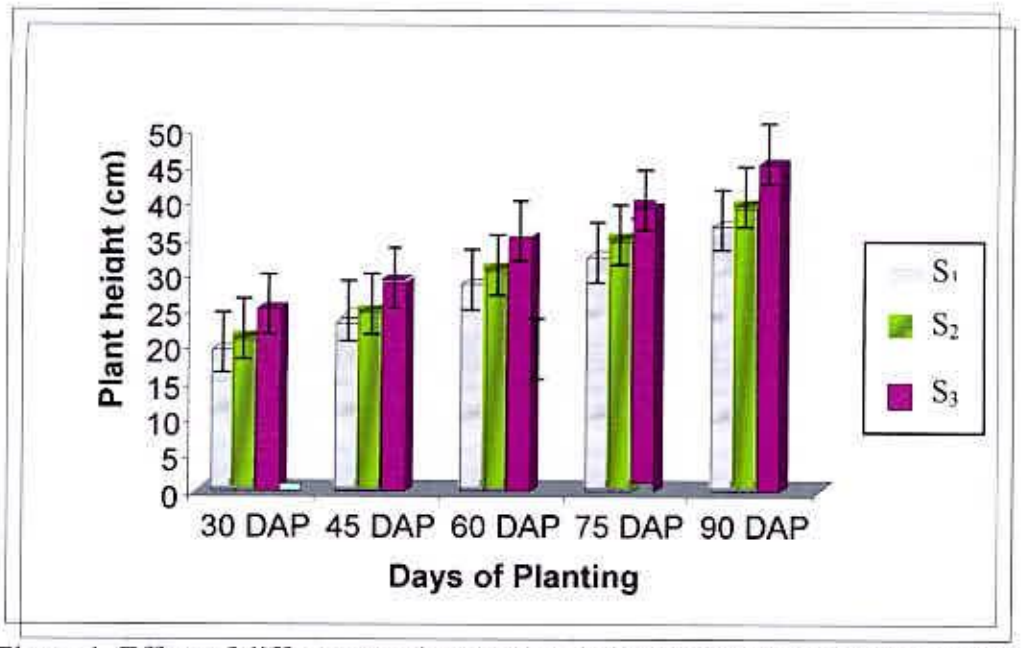


Figure 1. Effect of different spacing on plant height at different days after planting in garlic

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.

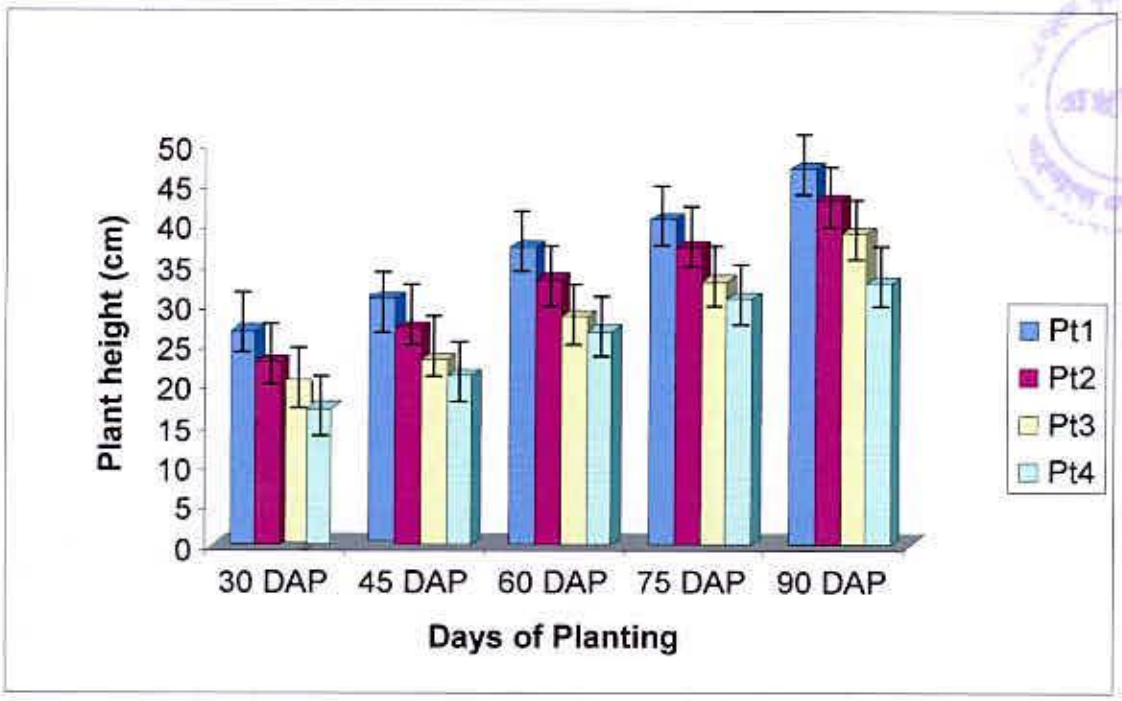


Figure 2. Effect of planting time on plant height at different days after planting in garlic

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 1. Combined effect of different spacing and planting time on plant height at different days after planting in garlic

Treatment	Plant height (cm)				
	30 DAP	**45 DAP**	**60 DAP**	**75 DAP**	**90 DAP**
S_1Pt_1	24.17bc	28.10bc	34.12bc	37.03bc	43.07bc
S_1Pt_2	24.03bc	27.10bc	33.07bcd	36.73bcd	42.30bcd
S_1Pt_3	22.03bcd	26.10bcd	32.03bcde	36.13bcd	42.17bcd
S_1Pt_4	15.20e	19.17e	23.73f	28.03e	30.27e
S_2Pt_1	26.20ab	30.03ab	36.17ab	20.03ab	38.07ab
S_2Pt_2	26.03ab	30.00ab	36.25ab	40.10ab	46.73ab
S_2Pt_3	18.17de	20.23de	25.30ef	29.53de	35.20de
S_2Pt_4	16.07e	30.17de	26.17def	30.23cde	30.00e
S_3Pt_1	30.20a	34.20a	41.40a	45.30a	52.07a
S_3Pt_2	24.03bc	25.10bcde	31.13bcde	35.40bcd	39.23cd
S_3Pt_3	20.30cde	24.10bcde	30.30bcdef	34.17bcde	38.07cd
S_3Pt_4	19.17cde	22.27cde	27.30cdef	32.03Cde	38.30cd
LSD	4.895	5.382	6.390	6.354	6.389
Level of significance	*	*	*	*	*
Cv (%)	13.26	12.44	12.01	10.60	9.33

Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability.
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

4.2 Number of leaves per plant at different days after planting

There was significant difference in the number of leaves per plant due to different spacing at different DAP (Figure 3). Garlic planted at the widest spacing (S_3 treatment) resulted in the highest number of leaves per plant at 30 (4.30), 45 (5.25), 60 (5.12), 75 (5.93) and 90 (6.38) DAP and it was gradually decreased and the lowest in S_1 treatment at 30 (3.28), 45 (4.00), 60 (4.76), 75 (5.28) and 90 (5.78) DAP. The highest number of leaves in reduced plant density was probably due to less competition among the plants for food and space in the lowest density planting. Increased number of leaves in garlic at wider spacing was also reported by Hossain *et al.* (2005), Hossain *et al.* (2003), Ingle *et al.* (2000) and Naruka (2001).

Number of leaves per plant was significantly influenced by different planting dates at different DAP (Figure 4). Early planting produced higher number of leaves per plant. There was gradual increased in the number of leaves per plant with the progress of time. Early planting (1 November i.e, Pt_1 treatment) produced maximum number of leaves per plant at 30 (4.70), 45 (5.50), 60 (6.04), 75 (6.57) and 90 (7.13) DAP and the minimum at 30 (2.83), 45 (3.70), 60 (4.13), 75 (4.73) and 90 (5.20) DAP were found in case of 15 December planting (Pt_4). This is possibly due to the fact that plants attained higher vegetative growth with greater number of leaves per plant in case of early planting. Azad (2002), Poldma *et al.* (2005) and Rahman *et al* (2004) found the same pattern of higher number of leaves per plant due to early planting.

The combined effect of different dates of planting and spacing was statistically significant in respect of number of leaves per plant at different DAP (Table 2). The maximum number of leaves at 30 (5.50), 45 (6.20), 60 (6.60), 75 (7.10) and 90 (7.60) DAP were observed in the treatment combination of S_3Pt_1 while the lowest number of leaves at 30 (2.60), 45 (3.20), 60 (4.00), 75 (4.50) and 90 (5.00) DAP were obtained in the treatment combination of S_1Pt_4.

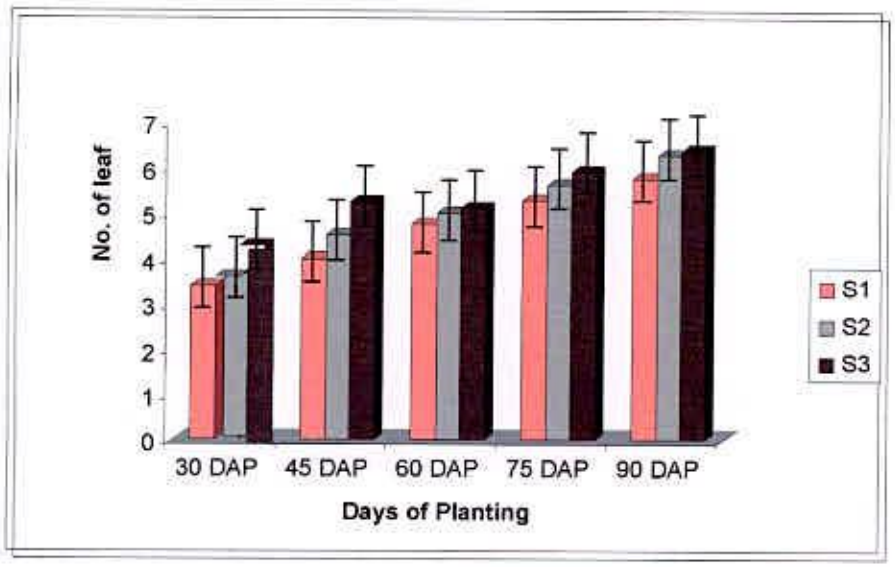


Figure 3. Effect of different spacing on number of leaf plant^{-1} at different days after planting in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.

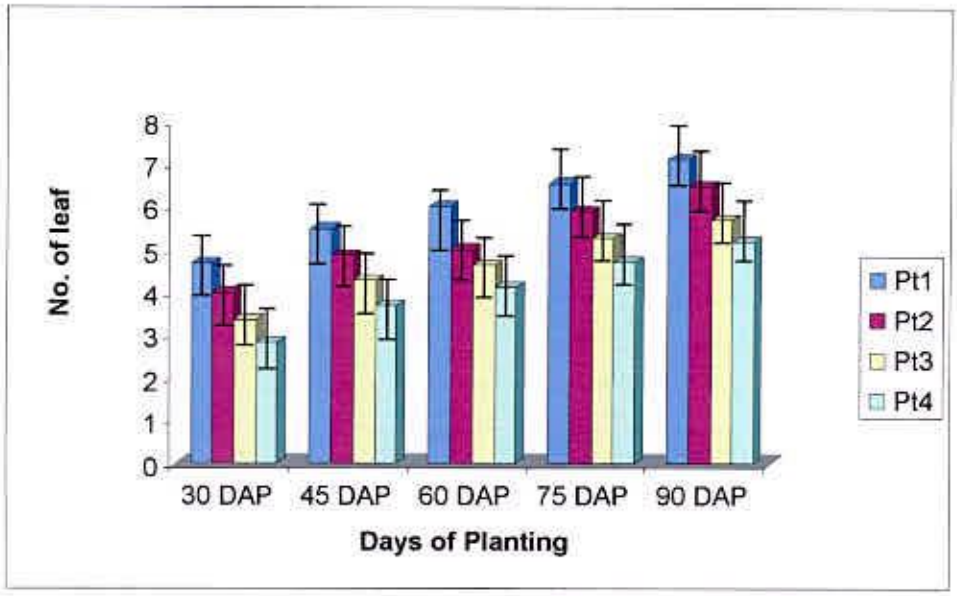


Figure 4. Effect of planting time on number of leaf plant^{-1} at different days after planting in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 2. Combined effect of different spacing and planting time on number of leaf per plant at different days after planting in garlic

Treatment	Number of leaf plant^{-1} at				
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
S_1Pt_1	4.00d	4.90bc	4.67cde	5.40cd	6.00cd
S_1Pt_2	3.20ef	4.40cd	4.20de	5.00de	5.50de
S_1Pt_3	2.70fg	3.50def	4.20de	4.70de	5.10e
S_1Pt_4	2.60g	3.20f	4.00e	4.50e	5.00e
S_2Pt_1	4.00cd	5.00bc	5.10cd	6.00bc	6.60bc
S_2Pt_2	4.50bc	5.50ab	5.00cd	6.20bc	6.80bc
S_2Pt_3	3.00efg	3.70def	4.50de	5.00de	5.20e
S_2Pt_4	3.10efg	4.30cd	4.80cde	5.40cd	6.00cd
S_3Pt_1	5.50a	6.20a	6.60a	7.10a	7.60a
S_3Pt_2	4.60b	5.40b	6.00ab	6.50ab	7.00ab
S_3Pt_3	4.00d	4.90bc	5.53bc	6.10bc	6.80bc
S_3Pt_4	3.50de	4.20cde	5.00cd	5.50cd	6.10cd
LSD	o.4878	0.7342	0.8551	0.7342	0.7322
Level of significance	*	*	*	*	*
Cv (%)	7.75	9.41	10.17	7.71	7.05

Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability.
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

4.3 Neck diameter

Significant variation was observed among different spacing in garlic at different DAP (Figure 5). The maximum neck diameter at 30 (0.39 cm), 45 (0.44 cm), 60 (0.50 cm), 75 (0.63 cm) and 90 (0.83 cm) DAP) were recorded at the widest spacing (S_3 treatment) and minimum at 30 (0.19 cm), 45 (0.23 cm), 60 (0.29 cm), 75 (0.42 cm) and 90 (0.61 cm) DAP were observed at the closest spacing (S_1 treatment). It was revealed that the neck diameter increased with the increase of plant spacing. The highest neck diameter in reduced plant density was probably due to less competition among the plants for food and space in the lowest density planting. Similar results were reported by Miko *et al.* (2006) and Hossain *et al.* (2005).

The influence of planting date on neck diameter was found to be significant at different DAP (Figure 6). The maximum neck diameter at 30 (0.36 cm), 45 (0.42 cm), 60 (0.48 cm), 75 (0.62 cm) and 90 (0.82 cm) DAP were recorded at early planting (Pt_1 treatment) and the minimum at 30 (0.22 cm), 45 (0.27 cm), 60 (0.32 cm), 75 (0.45 cm) and 90 (0.65 cm) DAP were found at later planting (Pt_4 treatment). It was revealed that the neck diameter decreased with the increase of planting time This is possibly due to the fact that plants attained higher vegetative growth in case of early planting Similar results were reported by Rahman *et al.* (2004), Azad (2002) and Anwar *et al.* (1996).

There was significant variation due to combined effect of different spacing and planting time on neck diameter at different DAP in garlic (Table 3). The maximum neck diameter at 30 (0.49 cm), 45 (0.54 cm), 60 (0.60 cm), 75 (0.75 cm) and 90 (0.95 cm) DAP were recorded in the treatment combination of S_3Pt_1 and the minimum at 30 (0.14 cm), 45 (0.18 cm), 60 (0.24 cm), 75 (0.36 cm) and 90 (0.56 cm) DAP were observed in the treatment combination of S_1Pt_4.

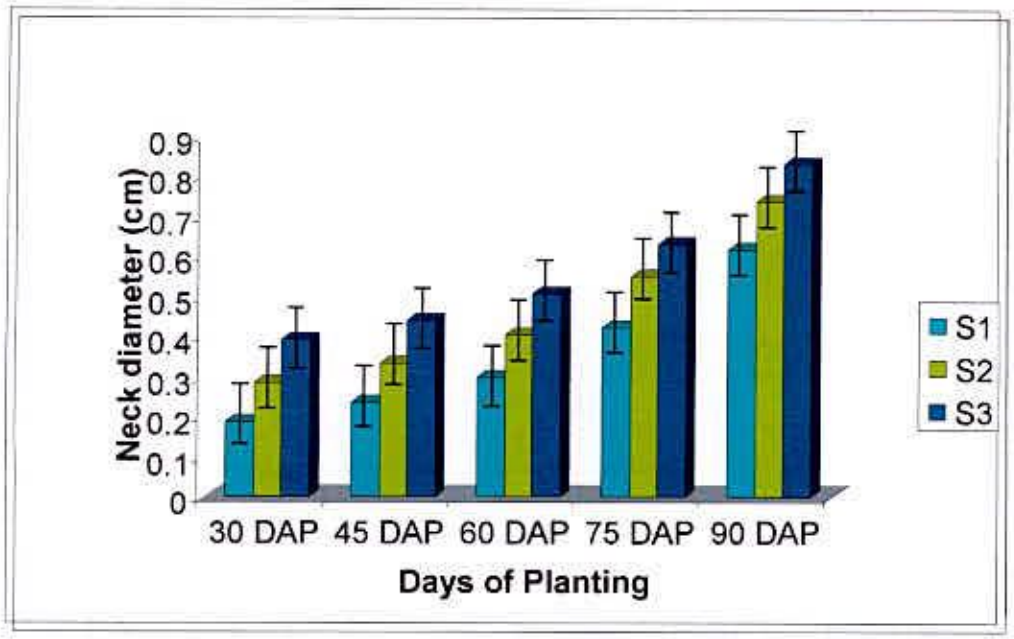


Figure 5. Effect of different spacing on neck diameter at different days after planting in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.

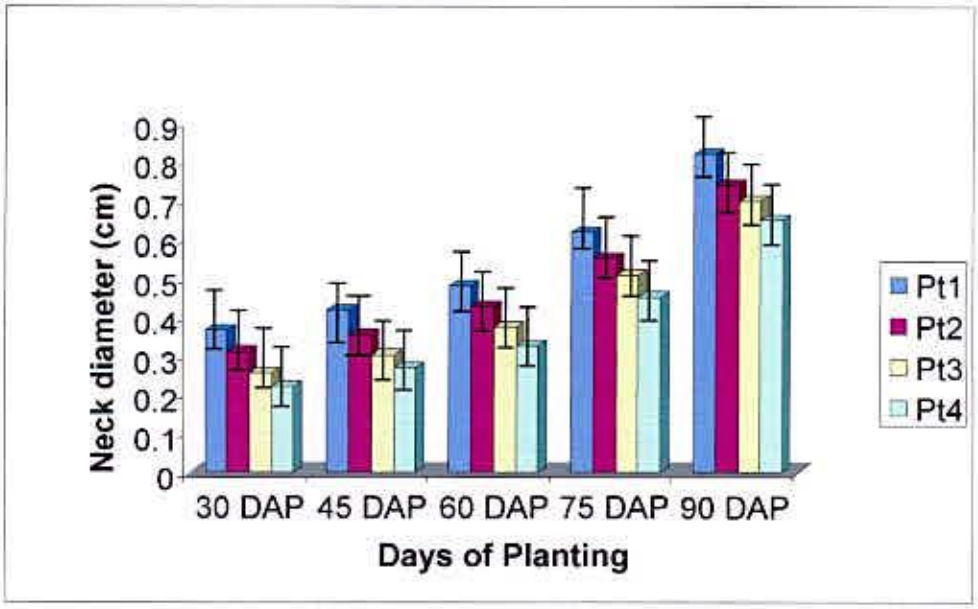


Figure 6. Effect of planting time on neck diameter at different days after planting in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 3. Combined effect of different spacing and planting time on neck diameter at different days after planting in garlic

Treatment	Neck diameter at				
	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
S_1Pt_1	0.35c	0.40c	0.48bc	0.60bc	0.80ab
S_1Pt_2	0.30cd	0.36cd	0.40cde	0.52cde	0.72bcd
S_1Pt_3	0.23ef	0.27ef	0.34efg	0.48def	0.68bcd
S_1Pt_4	0.14h	0.18h	0.24h	0.36g	0.56d
S_2Pt_1	0.31cd	0.36cd	0.43cd	0.58bcd	0.75bc
S_2Pt_2	0.43b	0.47b	o.55ab	0.65b	0.85ab
S_2Pt_3	0.16gh	0.21gh	0.27gh	0.41fg	0.60cd
S_2Pt_4	0.26de	0.30e	0.38def	0.52cde	0.70bcd
S_3Pt_1	0.49a	0.54a	0.60a	0.75a	0.95a
S_3Pt_2	0.35c	0.41c	0.48bc	0.62bc	0.82ab
S_3Pt_3	0.26de	0.31de	0.37def	0.49def	0.69bcd
S_3Pt_4	0.20fg	0.24fg	0.31fgh	0.43efg	0.62cd
LSD	0.053	0.053	0.075	0.092	0.15
Level of significance	*	*	*	*	*
Cv (%)	12.94	9.64	10.71	10.87	11.89

Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

4.4 Length of leaf

Length of leaf was significantly influenced by different plant spacing (Figure 7). The maximum length of leaf (48.58 cm) was obtained at the widest spacing (S_3 treatment) and the minimum (35.97 cm) was found at the highest density (S_1 treatment). As the wider spaced plants get more nutrition and space compared to closer spaced plants, their vegetative growth increased, as a result, length of leaf was also increased. Similar results were also observed by Hossain *et al.* (2005).

Significant variation in respect of length of leaf per plant was recorded in different planting time (Figure. 8). The maximum length of leaf (53.22 cm) was obtained from early planting (Pt_1 treatment) and the minimum (32.98 cm) was obtained from late planting (Pt_4 treatment). It was revealed that the length of leaf decreased with the increase of planting time This is possibly due to the fact that plants attained higher vegetative growth in case of early planting This result was also agreed by a scientist Rahman *et al.* (2004).

Combined effect between different spacing and planting time in respect of length of leaf was also found significant (Table 4). The treatment combination of S_3Pt_1 produced the highest (62.43 cm) length of leaf and the lowest (17.27 cm) was found from the treatment combination of S_1Pt_4.

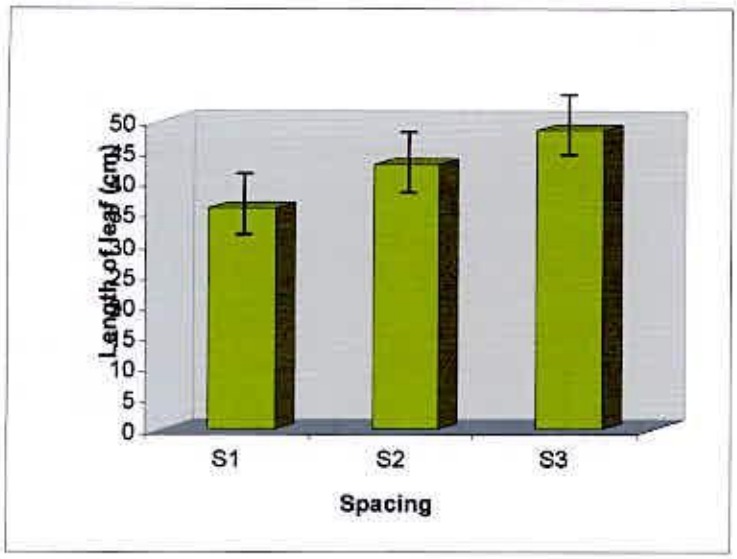


Figure 7. Effect of different spacing on length of leaf in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.

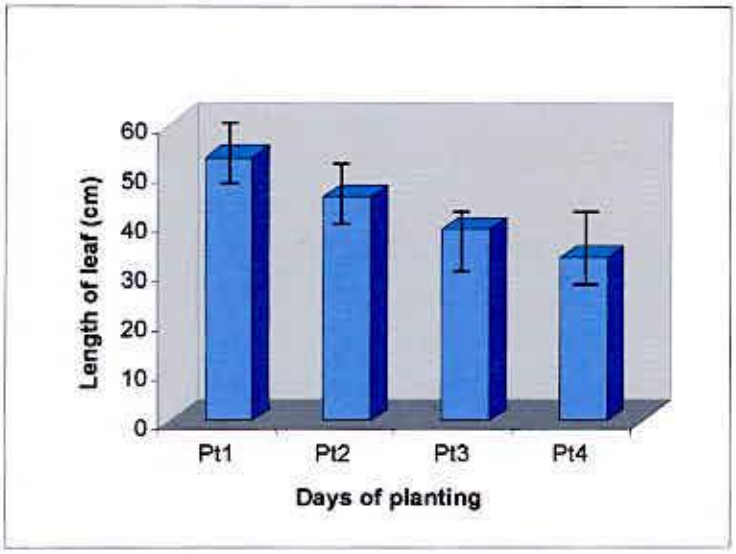


Figure 8. Effect of planting time on length of leaf in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

4.5 Fresh weight of leaves

Treatment means in terms of fresh weight of leaves per plant was recorded at the time of harvest and it varied significantly at different spacing (Figure 9). The Widest spacing (S_3 treatment) gave the maximum fresh weight (20.17 g) of leaves and the lowest was found (11.29 g) from the closest (S_1 treatment) plant spacing. It was also observed that the fresh weight of leaves per plant increased as the plant density decrease. The increased fresh weight of leaves in wider spacing probably due to the less competition of nutrition and greater utilization of light and space. Naruka (2002) found the same pattern of higher fresh weight of leaves per plant due to wider spacing.

A significant variation in respect of fresh weight of leaves per plant was found due to the effect of planting dates (Figure 10). The highest fresh weight of leaves (22.31 g) was found in plants raised from early planting (Pt_1 treatment)and the lowest (8.72 g) was found in case of Pt_4 treatment. Higher fresh weight of leaves in early planted garlic was possibly due to long time of photosynthesis and higher number of leaves which led to more deposition of reserve materials during the vegetative growth of plant. Anwar *et al.* (1996) also reported that fresh weight of leaves was higher in case of early planted crop.

The combined effect of different planting date and spacing was also found significant and have been presented in Table 5. The treatment combination of 1 November and the widest spacing (10×30 cm) i.e, S_3Pt_1 produced the highest fresh weight of leaves (28.54 g) and 15 December and closest spacing (10×10 cm) i.e, S_1Pt_4 gave the lowest (6.53 g) fresh weight of leaves per plant.

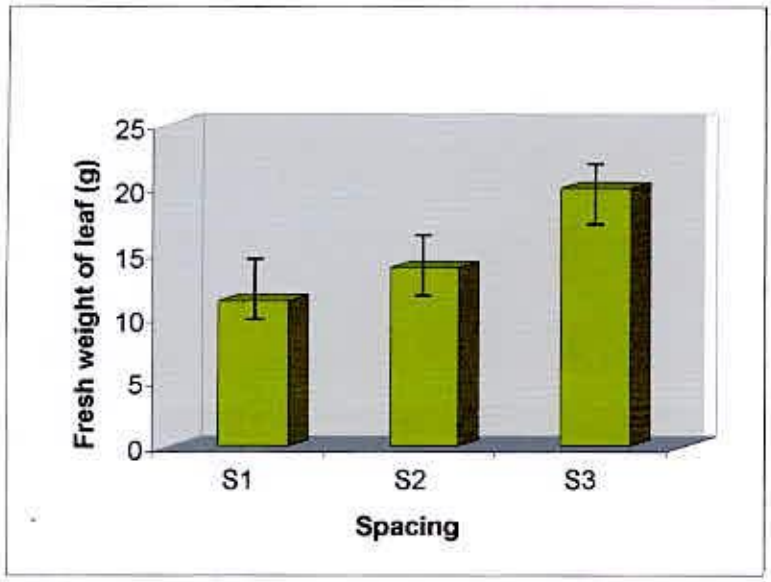


Figure 9. Effect of different spacing on fresh weight of leaf per plant in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.

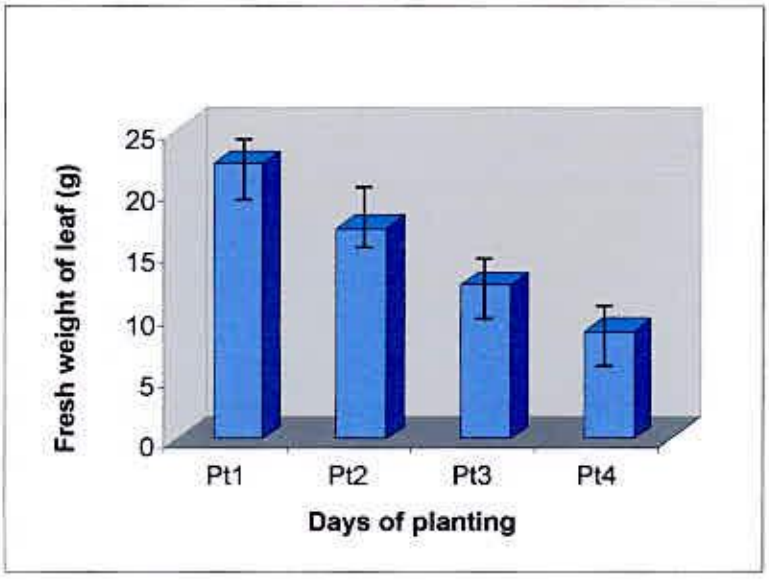


Figure 10. Effect of planting time on fresh weight of leaf per plant in garlic.

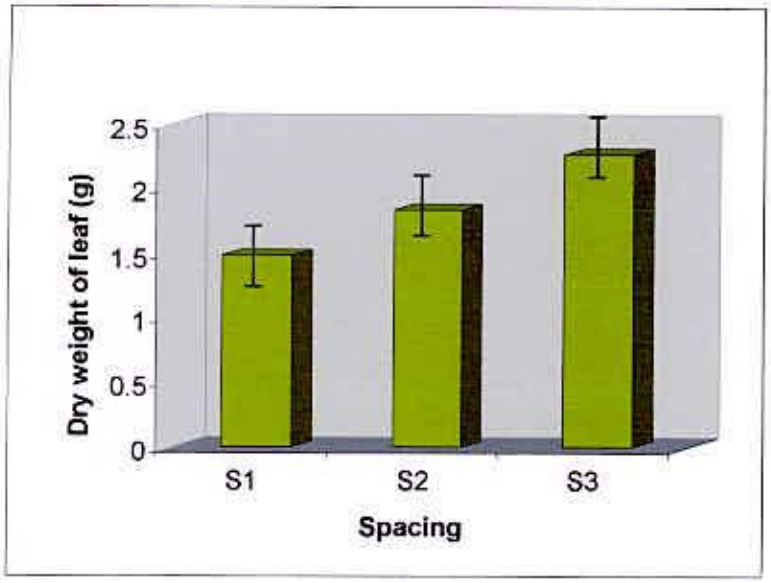
Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

4.6 Dry weight of leaves per plant

Dry weight of leaves per plant was also showed highly significant difference among the different spacing (Figure 11). It was observed that wider spacing (S_3 treatment) produced the highest dry weight (2.28 g) of leaves per plant, while the closest spacing (S_1treatment) gave the lowest (1.49 g) in this regard. The result showed that dry weight of leaves per plant increased as the spacing increase. The increased dry weight of leaves in wider spacing probably due to the less competition of nutrition and greater utilization of light and space. Hossain *et al.* (2003) also reported that dry weight of leaves was higher in case of wider spacing.

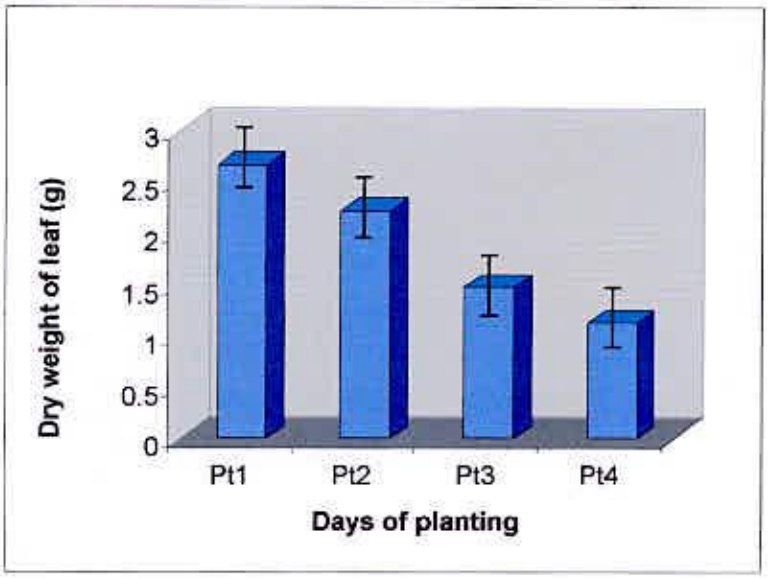
Significant variation was found among four different planting dates in respect of dry weight of leaves per plant and the results have been presented in Figure. 12. The highest dry weight of foliage (2.66 g) was obtained from early planting (Pt_1 treatment). The late planting (Pt_4 treatment) produced the lowest dry weight of leaves (1.13 g) though it was found statistically identical to the treatment of Pt_3. The dry weight of leaves per plant was higher when planted earlier. This was possibly due to more number of leaves and higher photosynthesis. This agrees with the result of Anwar *et al.* (1996) who reported that dry weight of leaves were higher when planted earlier.

The results of combined effect of planting date and spacing in respect of dry weight of leaves per plant were statistically significant (Table 6). The treatment combination of 1 November planting and wider spacing (10×30 cm) i.e, S_3Pt_1 produced the highest dry weight (3.33 g). On the other hand, 15 December planting and closest spacing (10×10 cm) i.e, S_1Pt_4 gave the lowest (1.05 g) dry weight of leaves per plant.



11. Effect of different spacing on dry weight of leaf per plant in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



12. Effect of planting time on dry weight of leaf per plant in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 4. Combined effect of different spacing and planting time on length of leaf, fresh weight of leaf per plant and dry weight of leaf per plant in garlic

Treatment	Length of leaf (cm)	Fresh weight of leaf per plant (g)	Dry weight of leaf per plant (g)
S_1Pt_1	36.00fg	16.94cd	1.65c
S_1Pt_2	34.50g	12.11efg	1.20def
S_1Pt_3	28.43h	7.54gh	1.15ef
S_1Pt_4	17.27i	6.53h	1.05f
S_2Pt_1	52.50b	15.53de	2.10b
S_2Pt_2	32.53gh	23.11b	3.00a
S_2Pt_3	40.43ef	9.11fgh	1.20def
S_2Pt_4	43.40de	11.43efg	1.60cd
S_3Pt_1	62.43a	28.54a	3.33a
S_3Pt_2	51.40bc	21.39bc	2.50b
S_3Pt_3	46.43cd	17.00d	2.16b
S_3Pt_4	37.07fg	12.52def	1.55cde
LSD	5.066	4.394	0.3898
Level of significance	*	*	*
Cv (%)	7.03	17.13	12.29

Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability.
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

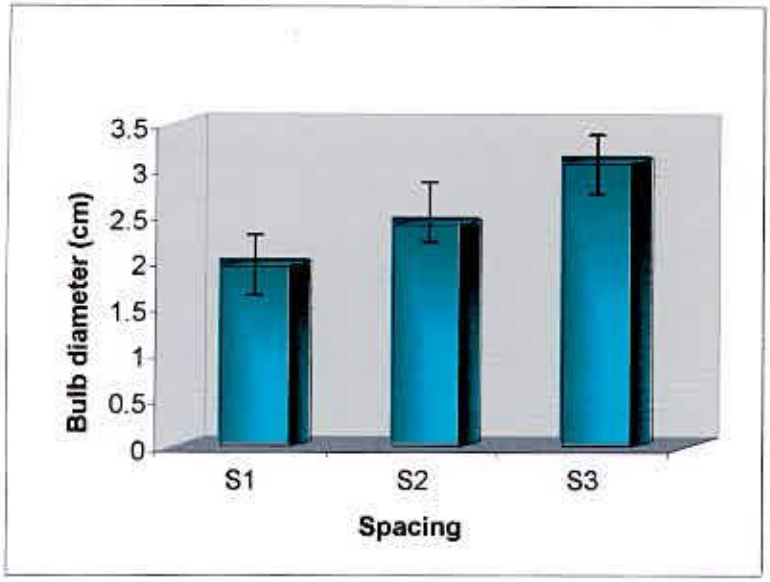
Plate 1: Photograph showing the general view of the experimental site at different spacing and planting time

4.7 Bulb diameter

Main effect of different spacing was observed statistically significant in respect of bulb diameter (Figure. 13). The size of bulb was also influenced markedly by plant density. The biggest bulb (3.087 cm) was obtained from the widest plant spacing (S_3 treatment) and smallest (1.96 cm) was from the closest spacing (S_1 treatment). It was revealed that as the spacing increase the diameter of bulb was increased gradually. Increased bulb size in garlic with wider spacing has also been noted by a number of authors (Miko *et al.*, 2006; Hossain *et al.*, 2005; Bhati *et al.*, 2002; Naruka, 2002; Naruka, 2001). The reason for which the diameter increases in wider spacing might be due to the utilization of more light, nutrition and accumulation of more photosynthesis.

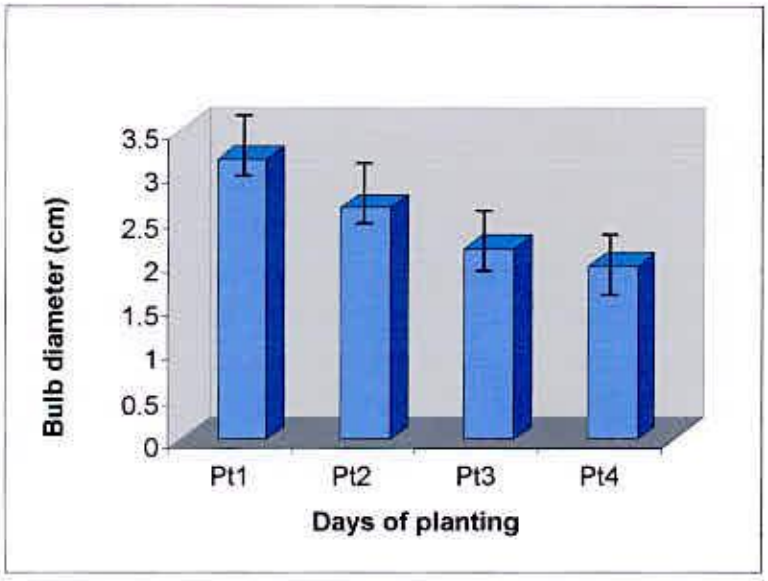
Bulb diameter was significantly influenced by planting date (Figure. 14). The maximum diameter of bulb (3.17 cm) was obtained from early planting (Pt_1 treatment) and the minimum (1.96 cm) from late planting (Pt_4 treatment). It is probably due to the fact that plants of early planted crop attained higher vegetative growth which possibly led to the development of larger bulb. These findings are in agreement with the findings of many authors (Nam-SangSik *et al.*, 2005; Sirohi, 2005; Rahman *et al.*, 2004; Gupta *et al.*, 2003; Azad, 2002; Ara *et al.*, 1998; Anwar *et al.*, 1996). They stated that bulb diameter was maximum with the earliest planting.

The variation in bulb diameter due to the combined effect of planting date and different spacing was found to be statistically significant (Table 7). The maximum diameter of bulb (3.96 cm) was found from the treatment combination of November 1 planting and the widest spacing (10×30 cm) i.e, S_3Pt_1 and the minimum (1.441 cm) was found from December 15 planting and the closest spacing (10×10 cm) i.e, S_1Pt_4.



13. Effect of different spacing on bulb diameter in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



14. Effect of planting time on bulb diameter in garlic.

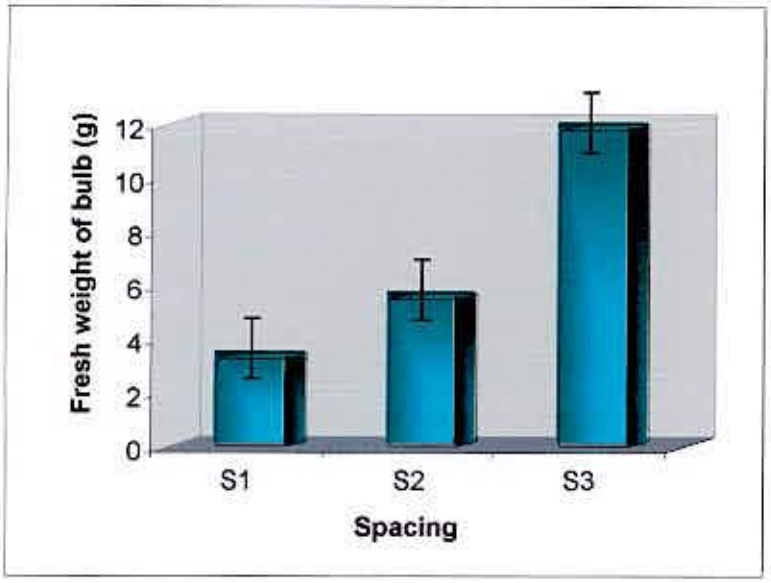
Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

4.8 Fresh weight of bulb

The individual bulb weight taken at the time of harvesting was influenced significantly by different spacing (Figure. 15). The maximum weight of individual bulb (11.85 g) was obtained from the widest spacing (S_3 treatment) and the minimum (3.31 g) was found from the closest spacing. The highest fresh weight of individual bulb in wider spacing was contributed to the increased vegetative growth of plant as resulted from less competition. These findings agreed with the findings of Miko *et al.* (2006), Hossain *et al.* (2005), Bhati *et al.* (2002) and and Naruka (2002) showed that closer plant spacing reduces the individual bulb size and bulb weight.

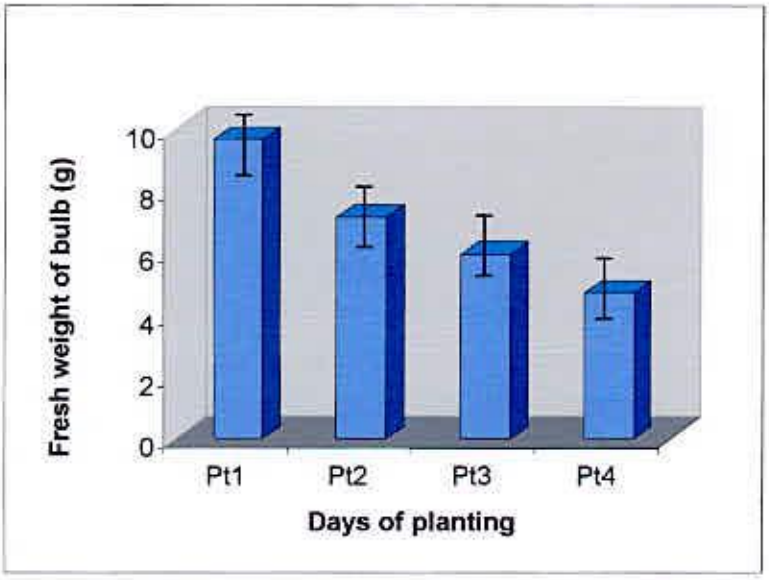
Significant difference in fresh weight of garlic bulb was noticed due to the effect of different dates of planting (Figure. 16). A trend of decrease in fresh weight of bulb per plant was observed as planting was delayed. The maximum (9.68 g) bulb weight was recorded from early planting (Pt_1 treatment) and the late planting (Pt_4 treatment) gave the lowest weight (4.73 g). The long growing period, prevailing cool temperature and short day during early stage might have increased the vegetative growth which contributed a lot to increase the bulb weight in early planting. Therefore early planted garlic produced heavier and larger sized bulbs resulting in the highest weight. Similar results were also reported by many authors like Sirohi (2005), Rahman *et al.* (2004), Singh *et al.* (2004), Gupta *et al.* (2003) and Anwar *et al.* (1996).

Combined effect between different planting dates and different spacing in respect of fresh weight of individual bulb was also found significant (Table. 8). The maximum fresh weight of bulb per plant (17.90 g) was found in the treatment combination of 1 November and 10×30 cm spacing i.e, S_3Pt_1. On the other hand, the minimum weight (2.60 g) was obtained when cloves are planted on 15 December and 10×10 spacing i.e, S_1Pt_4.



15. Effect of different spacing on fresh weight of bulb in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



16. Effect of planting time on fresh weight of bulb in garlic.

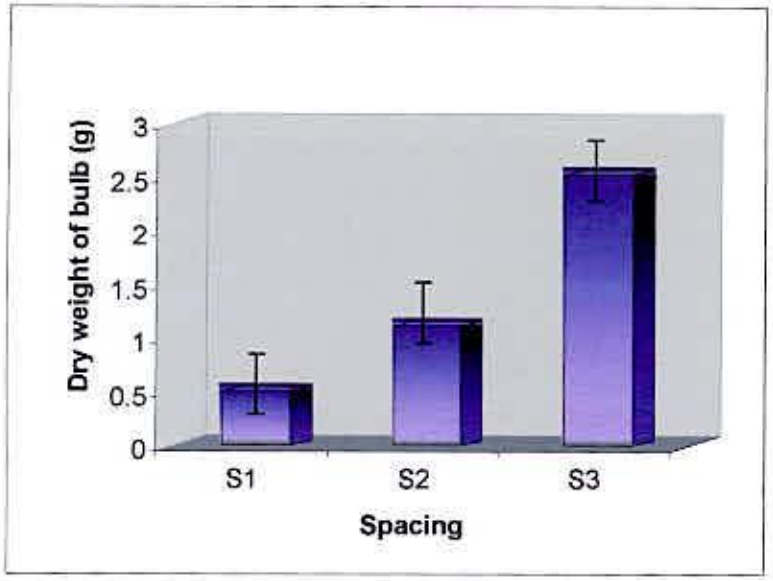
Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

4.9 Dry weight of bulb

Different plant spacing also showed significant variation on dry weight of bulb (Figure. 17). The highest dry weight (2.52 g) was recorded in the widest spacing of (S_3 treatment) and the lowest dry weight (0.50 g) was recorded from the closest spacing of (S_1 treatment). The results revealed that dry weight of individual bulb increased as the spacing increase. This finding also agreed with the findings of Miko *et al.* (2006), Hossain *et al.* (2005), Jahangir *et al.* (2005), Bhati *et al.* (2002) and Naruka (2001).

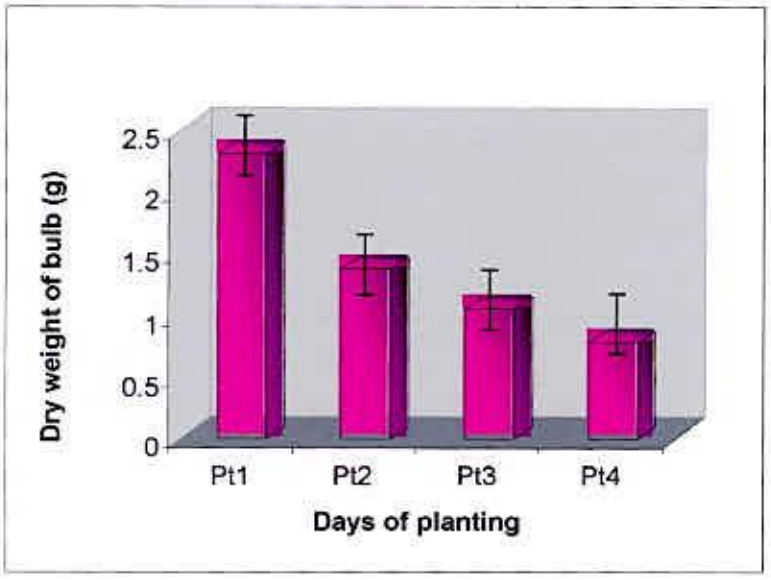
Planting time had remarkable influenced on dry weight of garlic bulb (Figure 18). The dry weight of bulb was found to be the maximum (2.30 g) when planted on 1 November i.e, Pt_1 treatment and the minimum (2.16 g) from Pt_4 treatment. The maximum dry weight of bulb from earlier planting might have the resultant effect of the maximum development of larger bulbs produced by the early planted crop. Nam-SangSik *et al.* (2005), Rahman *et al.* (2004) and Anwar *et al.* (1996) reported that dry weight of bulb per plant was higher when planted earlier.

Significant variation was recorded due to combined effect of different planting time and spacing in respect of dry weight of bulb (Table 5).From the results, it was found that November 1 planting combined with the widest spacing (10×30 cm) produced the highest dry weight of bulb (4.57 g) and 15 December planting with 10×10 cm spacing i.e, S_1Pt_4 gave the lowest (0.41 g).



17. Effect of different spacing on dry weight of bulb in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



18. Effect of planting time on dry weight of bulb in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 5. Combined effect of different spacing and planting time on bulb diameter, fresh weight of bulb and dry weight of bulb in garlic

Treatment	Bulb diameter (cm)	Fresh weight of bulb (g)	Dry weight of bulb (g)
S_1Pt_1	2.81bcd	9.90c	1.89c
S_1Pt_2	2.56cde	7.50d	1.19e
S_1Pt_3	1.64fg	4.10fg	0.70g
S_1Pt_4	1.44g	2.60h	0.41h
S_2Pt_1	2.74bcd	5.90e	1.21e
S_2Pt_2	3.01bc	12.11b	2.44b
S_2Pt_3	1.84fg	3.00h	0.46h
S_2Pt_4	2.10ef	5.10ef	0.87f
S_3Pt_1	3.96a	17.90a	4.57a
S_3Pt_2	3.12b	7.00d	1.68d
S_3Pt_3	2.45de	4.13fg	0.67g
S_3Pt_4	2.12ef	3.52gh	0.49h
LSD	0.487	0.980	0.1693
Level of significance	*	*	*
Cv (%)	11.61	8.40	7.33

Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability.
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

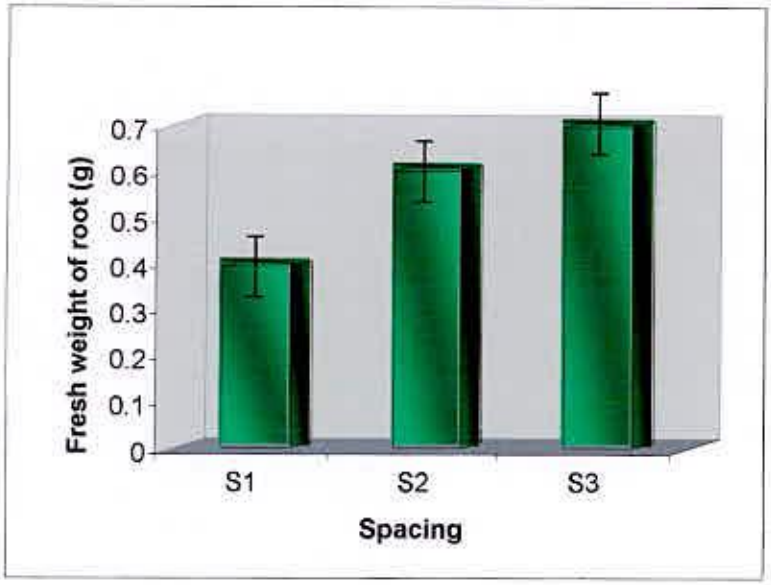
Plate 2. General view of cloves of garlic after harvest.

4.10 Fresh weight of roots

A significant variation was found due to plant spacing on fresh weight roots per plant (Figure. 20). It was revealed that the plants grown in the widest spacing (S_3 treatment) produced the maximum fresh weight (0.69 g) of roots per plant. On the other hand, the minimum fresh weight (0.39 g) was recorded from closest spacing (S_1 treatment). As the wider spaced plants get more nutrition and space compared to closer spaced plants, their vegetative growth and root growth also increased, as a result, fresh weight root per plant is also increased. Hossain *et al.* (2003) gets the maximum length and the maximum number of roots per plant at 10×30 cm spacing.

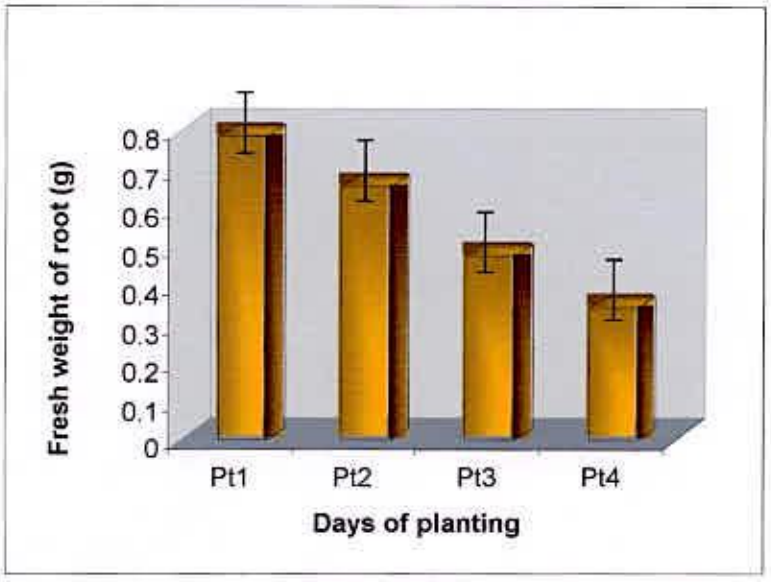
The production of fresh weight of roots was found to be significantly influenced by planting time (Figure. 19). Plants grown from early planting (Pt_1 treatment) showed the highest weight (0.78 g). The lowest (0.34 g) weight was obtained from Pt_4 treatment. The results revealed that gradual decrease in fresh weight of roots occurred with the delay in planting which was also reported by Rahman *et al.* (2004) and Anwar *et al.* (1996).

Due to combined effect of different planting time and spacing showed significant effect on the fresh weight of roots per plant (Table. 6). The treatment combination of 1 November planting and 10×30 cm spacing i.e, S_3Pt_1 produced the maximum (0.95 g) fresh weight of roots per plant, while the lowest (0.20 g) was recorded from the combined result of 15 December planting and 10×30 spacing i.e, S_1Pt_4.



19. Effect of different spacing on fresh weight of root in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



20. Effect of planting time on fresh weight of root in garlic.

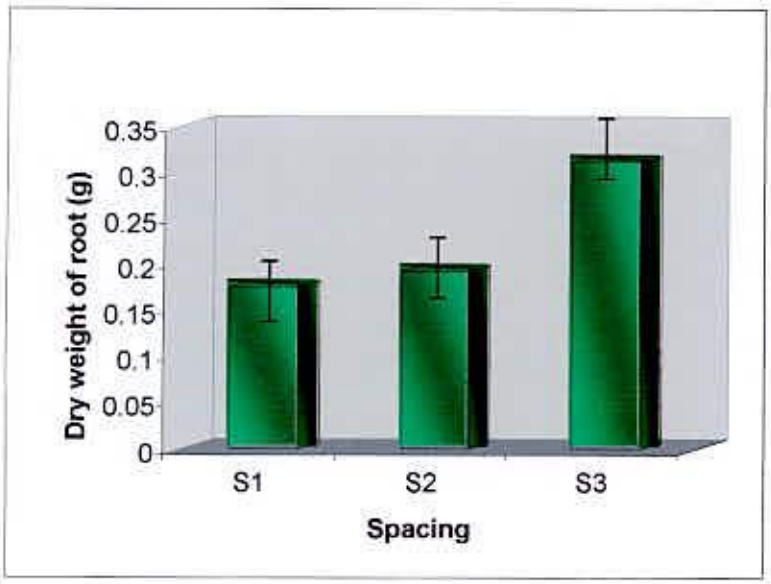
Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

4.11 Dry weight of roots per plant

Figure 21 showed significant variations among the different spacing in respect of dry weight of roots. The widest spacing (S_3 treatment) produced the highest dry weight of roots (0.31 g) per plant but the closest spacing (S_1 treatment) gave the lowest weight (0.17 g) of roots.

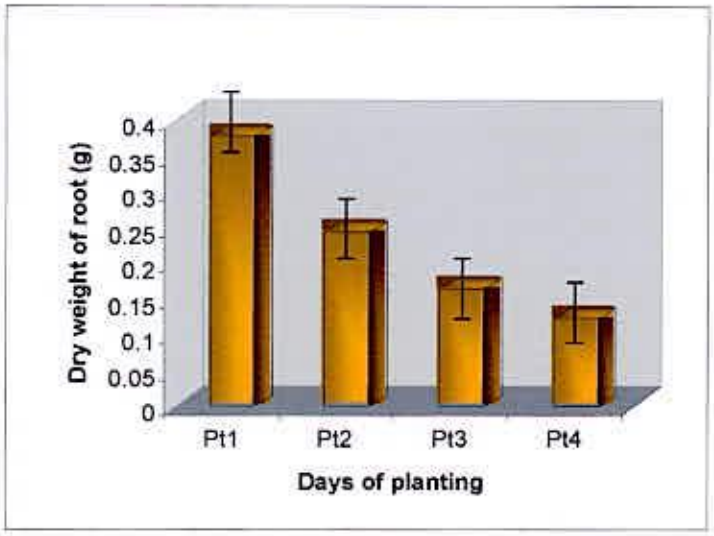
The variation in dry weight of roots per plant was statistically influenced due to different planting time (Figure 22). The highest dry weight of roots per plant (0.37 g) was obtained from early planting (Pt_1 treatment). The lowest dry weight of root (0.12 g) which was statistically similar to 30 November was found in case of Pt_4 treatment. Rahman *et al.* (2004) and Anwar *et al.* (1996) reported that dry weight of roots was higher when planted earlier.

The combined effect of planting time and spacing on the dry weight of roots per plant was found to be statistically significant (Table 6). The maximum dry weight (0.54 g) of roots were found in the combination of 1 November planting i.e, S_3Pt_1 with the widest spacing of 10×30 cm and the minimum dry weight (0.09 g) was recorded from 15 December planting and 10×10 cm spacing i.e, S_1Pt_4 which was statistically similar to the combination of 15 December planting and 10×20 cm spacing.



21. Effect of different spacing on dry weight of root in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



22. Effect of planting time on dry weight of root in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 6. Combined effect of different spacing and planting time on fresh weight of root and dry weight of root in garlic

Treatment	Fresh weight of root (g)	Dry weight of root (g)
S_1Pt_1	0.62cd	0.21ef
S_1Pt_2	0.41e	0.16de
S_1Pt_3	0.40e	0.12cd
S_1Pt_4	0.20g	0.09f
S_2Pt_1	0.70c	0.20cd
S_2Pt_2	0.81b	0.34b
S_2Pt_3	0.31f	0.16de
S_2Pt_4	0.50e	0.12ef
S_3Pt_1	0.95a	0.54a
S_3Pt_2	0.80b	0.36b
S_3Pt_3	0.60d	0.23c
S_3Pt_4	0.45c	0.19cd
LSD	0.092	0.053
Level of significance	*	*
Cv (%)	9.99	12.70

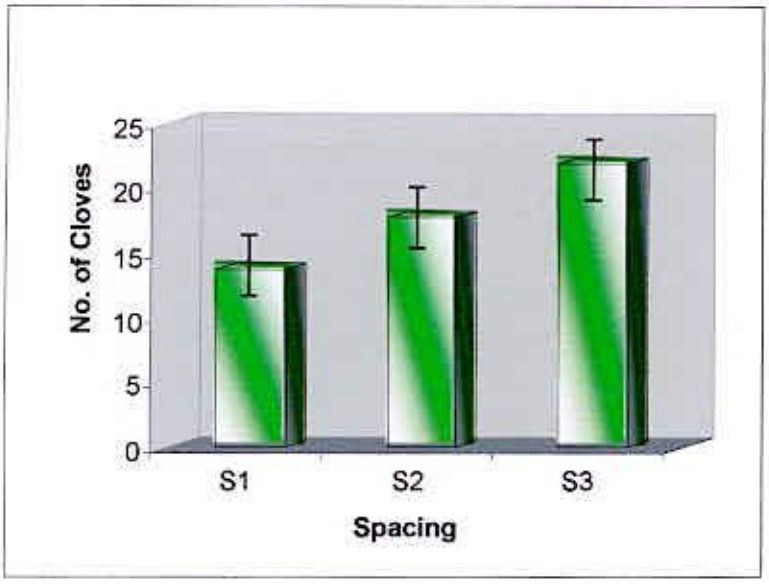
Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability.
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

4.12 Number of cloves per bulb

Different spacing of garlic showed significant variations in number of cloves per bulb (Figure. 23). The maximum number of cloves per bulb (22.00) was found in the widest spacing (S_3 treatment) and the minimum (13.82) was performed by the closest spacing (S_1 treatment). This result is similar to Hossain *et al.* (2005), Bhati *et al.* (2002) and Naruka (2002) who get maximum number of cloves per bulb in lowest planting density.

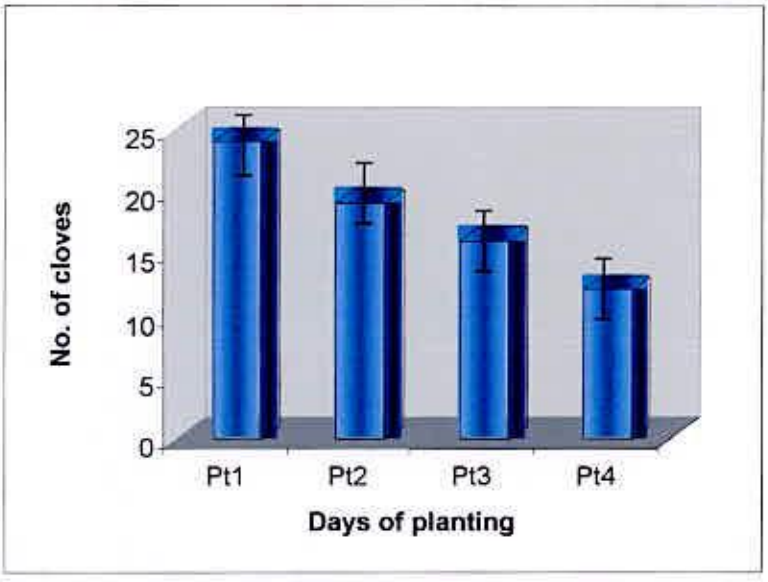
Number of cloves per bulb varied significantly due to different planting time (Figure 24). Early planting (Pt_1 treatment) gave the highest number of cloves per bulb (24.02) and the lowest number (12.21) was found from late planting (Pt_4 treatment). This is possibly due to the fact that early planting resulted in better vegetative growth and led to the differentiation of higher number of cloves. These findings are in agreement with the reports of Sirohi (2005), Singh *et al.* (2004) and Azad (2002) who reported that number of cloves decreased as the planting was delayed.

The combined effect of planting date and spacing was found statistically significant in respect of number of cloves per bulb (Table 7). The highest number of cloves per bulb (28.51) was recorded in the treatment combination of 1 November and 10×30 cm planting i.e, S_3Pt_1 which was statistically similar to S_2Pt_2. whereas, the lowest number of cloves per bulb (1.00) was found in the treatment combination of 15 December and 10×10 cm planting i.e, S_1Pt_4.



23. Effect of different spacing on number of cloves per bulb in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



24. Effect of planting time on number of cloves per bulb in garlic.

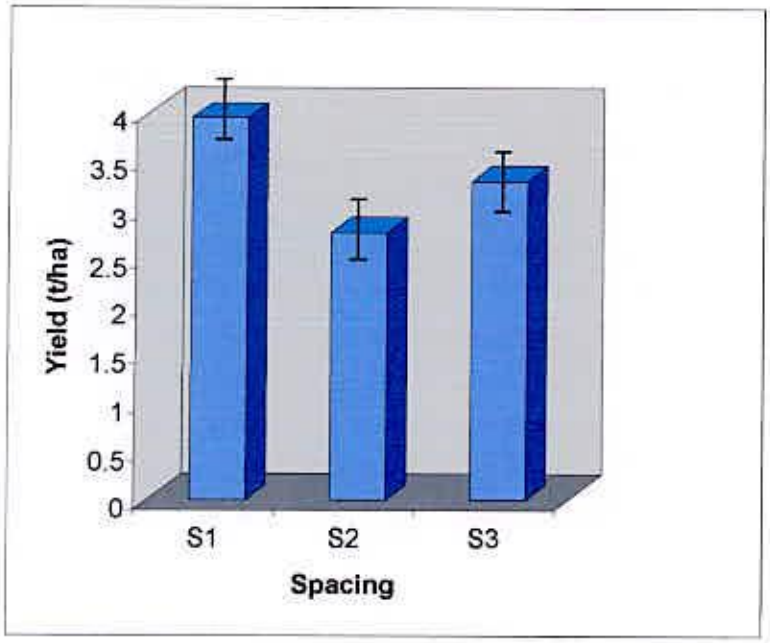
Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

4.13 Yield (t/ha):

Significant variation was found on yield per hectare due to different plant spacing (Figure. 25). Closest plant spacing (10×10 cm i.e, S_1) was produced highest yield (3.95 t/ha). The yield per hectare was decreased upto 2.763 t/ha as the plant spacing decrease upto S_1 treatment. The trend of decreasing yield per hectare was observed as the plant spacing increases per unit area. The highest plant density gave the highest yield also reported by others like Karaye *et al.* (2006), Miko *et al.* (2006), Hossain *et al.* (2005), Ibrahim *et al.* (2005), Jahangir *et al.* (2005), Castellanos *et al.* (2004), Nosraty (2004), Reghin *et al.* (2004), Lipinski *et al.* (2003), Portela *et al.* (2003), Naruka (2002), Das *et al.* (2001), Naruka, 2001; Ingle *et al.* (2000) and Mueller *et al.* (1998).

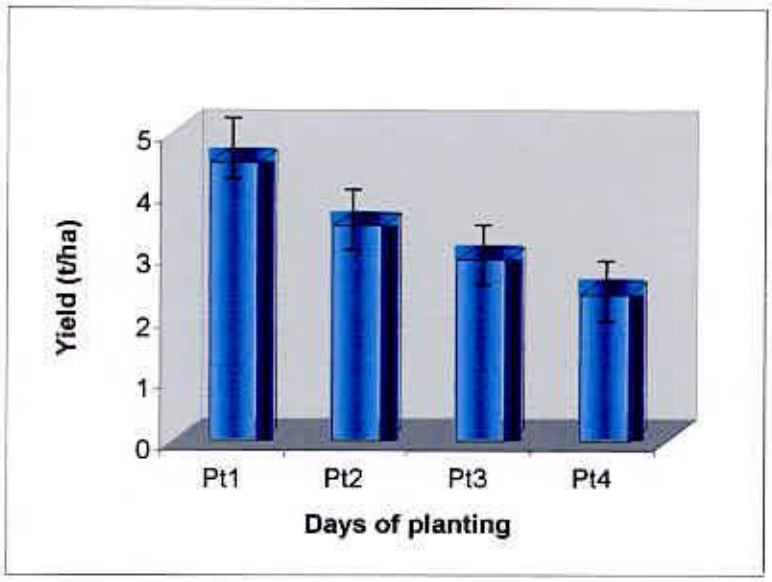
The yield of garlic bulb was significantly influenced by the time of planting (Figure. 26). The early planted crop (Pt_1 treatment) produced the highest yield (4.52 t/ha) and the lowest (2.38 t/ha) was obtained from the late planting (Pt_4 treatment). The plants of 1 November had better growth due to longer period of growth under favourable climatic conditions. The better growth of in case of early planting has contributed a lot to increase the bulb size which ultimately gave the higher yield of bulbs. The yield of garlic bulb decreased with the delayed planting date as have been stated by many authors (Chattopadhyay *et al.*, 2006; Sirohi, 2005; Rahman *et al.*, 2004; Singh *et al.*, 2004; Gupta *et al.*, 2003; Talukder *et al.*, 2002; Alam, 2000; Faruq, 2000; Anwar *et al.*, 1996 and Burba *et al.*, 1994).

The combined effects of planting date and spacing have been presented in Table. 7. The highest yield of bulb (5.97 t/ha) was obtained from the treatment combination of 1 November planting and 10×10 cm spacing i.e, S_1Pt_1 and the lowest (2.05 t/ha) was found from the widest spacing (10×30 cm) and late planted crop (30 November) i.e, S_3Pt_3.



25. Effect of different spacing on yield (t/ha) in garlic.

S_1: 10 x 10 cm, S_2: 10 x 20 cm and S_3: 10 x 30 cm.



26. Effect of planting time on yield (t/ha) in garlic.

Pt_1: 1 November, 2007, Pt_2: 15 November, 2007, Pt_3: 30 November, 2007 and Pt_4: 15 December, 2007.

Table 7. Combined effect of different spacing and planting time on number of cloves per bulb and yield in garlic

Treatment	Number of cloves per bulb	Yeild (t/ha)
S_1Pt_1	13.82ef	5.97a
S_1Pt_2	17.78cde	3.50c
S_1Pt_3	22.00bc	2.95de
S_1Pt_4	1.00g	3.50c
S_2Pt_1	24.18ab	4.10b
S_2Pt_2	24.04ab	4.03b
S_2Pt_3	14.20ef	3.00cde
S_2Pt_4	19.01cd	2.55ef
S_3Pt_1	28.51a	3.30cd
S_3Pt_2	11.50f	2.60e
S_3Pt_3	17.01de	2.05f
S_3Pt_4	19.80bcd	2.50ef
LSD	4.405	0.4878
Level of significance	*	*
Cv (%)	14.56	8.65

Means in the column followed different letter (s) differed significantly by DMRT at 5% level of probability.
Pt_1 = 1 November, Pt_2 = 15 November, Pt_3 = 30 November, Pt_4 = 15 December
S_1 = 10 cm x 10 cm, S_2= 10 cm x 20 cm, S_3= 10 cm x 30 cm

4.14 Economic analysis

Input costs for land preparation, cost of seed, fertilizer and manpower required for all the operations from sowing to harvesting of garlic were recorded for unit plot and converted into cost per hectare. Fixed cost for all the treatment was same. The total cost of production was the total cost of input and fixed cost. The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under the following headings.

4.14.1 Gross return

In the combination of plant spacing and planting time showed various gross return under different treatment combination (Table 8). The highest gross return (Tk. 328350.00/ha) was obtained from the treatment combination of S_1Pt_1 and the second highest gross return (Tk. 225500.00/ha) was obtained in S_2Pt_1. The lowest gross return (Tk. 112750.00/ha) was obtained from the treatment (S_3Pt_3)

4.14.2 Net return

In case of net return different treatment combination showed unlike types of net return. The highest net return (Tk. 188049.00/ha) was obtained from the treatment combination of S_1Pt_1 and the second highest net return (Tk. 93978.00/ha) was obtained from the treatment combination of S_2Pt_1. The lowest net return (Tk. 2299.00/ha) was obtained from the S_3Pt_3 treatment combination (Table 8).

4.14.3 Benefit cost ratio

The combination of plant spacing and planting time for benefit cost ratio was different in all treatment combination (Table 8). The highest benefit cost ratio (2.34) found in the treatment combination of S_1Pt_1 and the second highest benefit cost ratio (1.71) was estimated from the treatment combination of S_2Pt_1. The lowest benefit cost ratio (1.01) was obtained from S_3Pt_3. From economic point of view, it was apparent from the above results that the treatment combination of S_1Pt_1 was more profitable than rest of the treatment combinations.

Table 8. Cost and return of garlic cultivation as influenced by plant spacing and planting time

Treatment Combination	Cost of production (Tk./ha)	Yield of garlic	Gross return (Tk./ha)	Net return (Tk./ha)	Benefit cost ratio
S_1Pt_1	140301	5.970	328350	188049	2.34
S_1Pt_2	136171	3.500	192500	56329	1.41
S_1Pt_3	140301	2.950	162250	21949	1.16
S_1Pt_4	141481	3.500	192500	51019	1.36
S_2Pt_1	131522	4.100	225500	93978	1.71
S_2Pt_2	135652	4.030	221650	85998	1.63
S_2Pt_3	135652	3.000	165000	29348	1.22
S_2Pt_4	136832	2.550	140250	3418	1.02
S_3Pt_1	128690	3.300	181500	52810	1.41
S_3Pt_2	132820	2.600	143000	10180	1.08
S_3Pt_3	110451	2.050	112750	2299	1.01
S_3Pt_4	134000	2.500	137500	3500	1.03

S_1: 10 cm x 10 cm
S_2: 10 cm x 20 cm
S_3: 10 cm x 30 cm

Pt_1: 1 November, 2007
Pt_2: 15 November, 2007
Pt_3: 30 November, 2007
Pt_4: 15 December, 2007

Market price of garlic @ Tk. 55,000/ton; Gross return = Total yield (t/ha) × Tk. 55000
Net return = Gross return - Total cost of production
Benefit Cost Ratio (BCR) = Gross return/Total cost of production

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2007 to May 2008 to study the effect of plant spacing and planting time on growth and yield of garlic. The experiment consisted of three plant spacing viz. S_1:10×10 cm, S_2:10×20 cm and S_3:10×30 cm and four time of planting viz. Pt_1:1 November, Pt_2:15 November, Pt_3:30 November and Pt_4:15 December, respectively. The two-factor experiment consisted of 12 treatment combination was laid out in randomized complete block design (RCBD) with 3 replications. The size of unit plot was 5 m×1 m.. Data on different parameters were statistically analyzed to evaluate the treatment effects.

Significant variations found in plant height due to different spacing and planting time at different DAP. The tallest plant at 30 (25.15 cm), 45 (28.86 cm), 60 (35.23 cm), 75 (39.13 cm) and 90 (45.32 cm) DAP were found in the widest spacing (S_3 treatment) and the shortest plant at 30 (19.42 cm), 45 (23.15 cm), 60 (28.57 cm), 75 (32.42 cm) and 90 (36.75 cm) DAP were recorded from the closest plant spacing (S_1 treatment). The tallest plant at 30 (26.76 cm), 45 (30.77 cm), 60 (37.26 cm), 75 (40.71 cm) and 90 (47.03 cm) DAP were obtained from early planting (Pt_1 treatment) and the shortest at 30 (17.10 cm), 45 (21.14 cm), 60 (26.73 cm), 75 (30.81 cm) and 90 (32.78 cm) DAP were found at late planting (Pt_4 treatment). The tallest plant at 30 (30.20 cm), 45 (34.20 cm), 60 (41.40 cm), 75 (45.30 cm) and 90 (52.07 cm) DAP were obtained from the treatment combination of S_3Pt_1. The shortest plant at 30 (15.20 cm), 45 (19.17 cm), 60 (23.73 cm), 75 (28.03 cm) and 90 (30.27 cm) DAP were obtained from the treatment combination of S_1Pt_4.

There was significant difference in the number of leaves per plant due to different spacing and planting time at different DAP. Garlic planted at the widest spacing (S_3 treatment) resulted in the highest number of leaves per plant at 30 (4.30), 45 (5.25), 60 (5.12), 75 (5.93) and 90 (6.38) DAP and the lowest in S_1 treatment 30 (3.28), 45 (4.00), 60 (4.76), 75 (5.28) and 90 (5.78) DAP. Early planting (Pt_1 treatment) produced the maximum number of leaves per plant at 30 (4.70), 45 (5.50), 60 (6.04), 75 (6.57) and 90 (7.13) DAP and the minimum at 30 (2.83), 45 (3.70), 60 (4.13), 75 (4.73) and 90 (5.20) DAP were found in case of late planting (Pt_4 treatment). The maximum number of leaves at 30 (5.50), 45 (6.20), 60 (6.60), 75 (7.10) and 90 (7.60) DAP were observed in the treatment combination of S_3Pt_1 while the lowest number at 30 (2.60), 45 (3.20), 60 (4.00), 75 (4.50) and 90 (5.00) DAP were obtained in the treatment combination of S_1Pt_4

Significant variation was observed among different spacing and planting time in garlic at different DAP. The maximum neck diameter of leaf at 30 (0.39 cm), 45 (0.44 cm), 60 (0.50 cm), 75 (0.63 cm) and 90 (0.83 cm) DAP) were recorded at the widest spacing (S_3 treatment) and the minimum at 30 (0.19 cm), 45 (0.23 cm), 60 (0.2975 cm), 75 (0.42 cm) and 90 (0.61 cm) DAP were observed at the closest spacing (S_1 treatment). The maximum neck diameter of leaf at 30 (0.36 cm), 45 (0.42 cm), 60 (0.48 cm), 75 (0.62 cm) and 90 (0.82 cm) DAP were recorded at early planting (Pt_1 treatment) and the minimum at 30 (0.22 cm), 45 (0.27 cm), 60 (0.32 cm), 75 (0.45 cm) and 90 (0.65 cm) DAP were found at later planting (Pt_4 treatment). The maximum neck diameter of leaf at 30 (0.49 cm), 45 (0.54 cm), 60 (0.60 cm), 75 (0.75 cm) and 90 (0.95 cm) DAP were recorded in the treatment combination of S_3Pt_1 and the minimum at 30 (0.14 cm), 45 (0.18 cm), 60 (0.24 cm), 75 (0.36 cm) and 90 (0.56 cm) DAP were observed in the treatment combination of S_1Pt_4.

Length of leaf was significantly influenced by different plant spacing and planting time. The maximum length of leaf (48.58 cm) was obtained at the lowest density (S_3

treatment) and the minimum (35.97 cm) was found at the highest density (S_1 treatment). The maximum length of leaf (53.22 cm) was obtained from early planting (Pt_1 treatment) and the minimum (32.98 cm) was obtained from late planting (Pt_4 treatment). The treatment combination of S_3Pt_1 produced the highest (62.43 cm) length of leaf and the lowest (17.27 cm) was found from the treatment combination of S_1Pt_4

Treatment means in terms of fresh weight of leaves per plant was recorded at the time of harvest and it varied significantly at different spacing and planting time. The widest spacing (S_3 treatment) gave the maximum fresh weight (20.17 g) of leaves and the lowest was found (11.29 g) from the closely (S_1 treatment) spaced plants. The highest fresh weight of leaves (22.31 g) was found in plants raised from early planting (Pt_1 treatment) and the lowest (8.72 g) was found in case of late planting (Pt_4 treatment). The treatment combination of S_3Pt_1 produced the highest fresh weight of leaves (28.54 g) and S_1Pt_4 gave the lowest (6.53 g) fresh weight of leaves per plant.

Dry weight of leaves per plant was also showed highly significant difference among the different spacing and planting time. It was observed that the widest spacing (S_3 treatment) produced the highest dry weight (2.28 g) of leaves per plant, while the closest spacing (S_1 treatment) gave the lowest (1.49 g) in this regard. The highest dry weight of foliage (2.66 g) was obtained from early planting (Pt_1 treatment). The late planting (Pt_4 treatment) produced the lowest dry weight of leaves (1.13 g). The treatment combination of S_3Pt_1 treatment produced the highest dry weight (3.33 g). On the other hand, S_1Pt_4 gave the lowest (1.05 g) dry weight of leaves.

Main effect of different spacing and planting time were observed statistically significant in respect of bulb diameter. The biggest bulb (3.08 cm) was obtained from the widest spacing (S_3 treatment) and the smallest bulb (1.964 cm) was obtained from the closest plant spacing (S_1 treatment). The maximum diameter of bulb (3.17 cm)

was obtained from early planting (Pt_1 treatment) and the minimum (1.96 cm) from late planting (Pt_4 treatment). The maximum diameter of bulb (3.96 cm) was found from the treatment combination of S_3Pt_1 and the minimum (1.44 cm) was found from S_3Pt_1.

The individual bulb weight taken at the time of harvesting was influenced significantly by different spacing and planting time. The maximum weight of individual bulb (11.85 g) was obtained from the widest spacing (S_3 treatment) and the minimum (3.31 g) from the closest spacing. The bulb weight as recorded was maximum (9.68 g) at early planting (Pt_1 treatment) and the late planting (Pt_4 treatment) gave the minimum weight (4.73 g). The maximum fresh weight of bulb per plant (17.90 g) was found in the treatment combination of S_3Pt_1. On the other hand, the minimum weight (2.60 g) was obtained when cloves are planted on the treatment combination of S_1Pt_4.

Different spacing and planting time also revealed significant variation in dry weight of bulb. The highest dry weight (2.52 g) was recorded in wider spacing (S_3 treatment) and the lowest dry weight (0.50 g) was recorded from the closest spacing (S_1 treatment). The dry weight of bulb was found maximum (2.30 g) when planted on Pt_1 treatment and the minimum from Pt_4 treatment (2.16 g). From the results, it was found that the treatment combination of S_3Pt_1 produced the highest dry weight of bulb (4.57 g) and S_1Pt_4 gave the lowest (0.41 g).

Significant variation in respect of fresh weight roots per plant was recorded in different plant spacing and planting time. The results revealed that the plants grown in the widest spacing (S_3 treatment) produced the maximum fresh weight (0.69 g) of roots per plant. On the other hand, the minimum fresh weight (0.39 g) was recorded from closest spacing (S_1 treatment). Plants grown from early planting (Pt_1 treatment) showed the highest weight (0.78 g) and the lowest (0.34 g) weight was obtained from

late planting (Pt_4 treatment). The treatment combination of S_3Pt_1 produced the maximum (0.95 g) fresh weight of roots per plant, while the lowest (0.20 g) was recorded from the combined result of S_1Pt_4.

Significant variation was found among the different spacing and planting time in respect of dry weight of roots. The widest spacing (S_3 treatment) produced the highest dry weight of roots (0.31 g) per plant but the closest spacing (S_1 treatment) gave the lowest weight (0.17 g) of roots. The highest dry weight of roots per plant (0.37 g) was obtained from early planting (Pt_1 treatment) and the lowest dry weight of root (0.12 g). The maximum dry weight (0.54 g) of roots were found in the combination of S_3Pt_1 and the lowest dry weight (0.09 g) was recorded from treatment combination of S_1Pt_4.

Different spacing and planting time of garlic showed significant variations in number of cloves per bulb. The maximum number of cloves per bulb (22.00) was found in wider spacing (S_3 treatment) and the lowest (13.82) from S_1 treatment. Early planting (Pt_1 treatment) gave the highest number of cloves per bulb (24.02) and the lowest number (12.21) was found from late planting (Pt_4 treatment). The highest number of cloves per bulb (28.51) was recorded in the treatment combination of S_3Pt_1. whereas, the lowest number of cloves per bulb (1.00) was found in the treatment combination of S_1Pt_4.

Significant variation in respect of yield per hectare was found among different plant spacing and planting time. The closest plant spacing (S_1 treatment) was produced highest yield (3.95 t/ha). The yield per hectare was decreased upto 2.76 t/ha as the plant spacing increase upto S_3 treatment. The early planted crop (Pt_1 treatment) produced the highest yield (4.52 t/ha) and the lowest (2.38 t/ha) was obtained from the late planting (Pt_4 treatment). The highest yield of bulb (5.97 t/ha) was obtained from the treatment combination of S_3Pt_1 and the lowest (2.05 t/ha) was found from the widest spacing and late planted crop i.e, S_3Pt_3.

The highest gross return (Tk. 328350/ha), net return (Tk. 188049/ha) and benefit cost ratio (2.34) were obtained from the treatment combination of S_1Pt_1 and the lowest gross return (Tk. 112750/ha), net return (Tk. 2299/ha) and benefit cost ratio (1.01) were obtained from S_3Pt_3 treatment combination. Among the treatment combination of S_3Pt_1 was more effective for growth, but S_1Pt_1 was more effective for yield and profitable than rest of the treatment combination.

Considering the situation of the present experiment, the following suggestion may be drawn:

1. Similar study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Yield and yield contributing characters decreased gradually with the delay of planting. Early planting would be beneficial for planting garlic.
3. Wider plant spacing would be beneficial for future study.

CHAPTER VI
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APPENDICES

Appendix I. Trend of garlic production in Bangladesh (1994-2006)

Year	Area (.000 ha)	Production (.000ton)	Yield (ton/ha)
1994-1995	12.95	40	3.09
1995-1996	12.95	39	3.01
1996-1997	12.95	39	3.01
1997-1998	13.03	40	3.07
1998-1999	13.23	38	2.87
1999-2000	13.39	40	2.99
2000-2001	13.55	39	2.88
2001-2002	14.03	41	2.92
2002-2003	12.40	43	3.47
2003-2004	18.14	73	4.02
2004-2005	63 acre	90	
2005-2006	66 acre	102	

Source: BBS, 2007

Appendix II. Physical and Chemical properties of soil in the experimental field

Physical properties of soil

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

Source: SRDI, Farmgate, Dhaka

Chemical properties of soil

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

Source: SRDI, Farmgate, Dhaka

Appendix III. Monthly Air temperature, Rainfall and Relative humidity of the experimental site during the study (October, 2007 to February, 2008)

Year	Month	Average* air temperature (°C)			Total** Rainfall (mm)	Average* Relative humidity (%)
		Maximum	Minimum	Mean		
2007	October	30.5	24.3	27.4	417	80
	November	29.7	20.1	24.9	5	65
	December	26.9	15.8	21.35	0	68
2008	January	24.6	12.5	18.7	0	66
	February	27.1	16.8	21.95	0	64
	March	31.5	19.6	25.55	160	47

* Monthly Average

** Monthly Total

Source: The Meteorological Department (Weather division & Climate division) of Bangladesh, Agargaon, Dhaka-1207.

Appendix IV. Analysis of variance on plant height and number of leaves per plant of garlic as influenced by plant spacing and planting time

Source of variation	Degrees of freedom	Mean square									
		Plant height (cm) at					Number of leaves per plant at				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Replication	2	96.973	184.697	306.542	453.674	438.988	4.083	4.687	4.631	4.688	4.688
Plant spacing (A)	2	106.883**	105.272**	141.747**	140.334**	232.181**	3.293**	4.710**	0.416**	1.277**	1.240**
Planting time (B)	3	148.285**	163.437**	201.250**	176.651**	336.196**	5.849**	5.400**	5.872**	5.657**	6.496**
Interaction (A×B)	6	0.441	0.697	1.260	2.290	3.461	0.129	0.040	0.187	0.074	0.173
Error	22	8.358	10.102	14.239	14.081	14.236	0.083	0.188	0.255	0.188	0.187

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

Appendix V. Analysis of variance on Neck diameter of leaf in garlic as influenced by plant spacing and planting time

Source of variation	Degrees of freedom	Mean square				
		Neck diameter of leaves per plant (cm)				
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
Replication	2	0.001	0.002	0.002	0.003	0.008
Plant spacing (A)	2	0.123**	0.129**	0.132**	0.132**	0.136**
Planting time (B)	3	0.036**	0.039*	0.041*	0.045**	0.045*
Interaction (A×B)	6	0.001	0.001	0.001	0.002	0.002
Error	22	0.001	0.001	0.002	0.003	0.008

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

Appendix VI. Analysis of variance on Length of leaf (cm), Fresh weight of leaf per plant (g), dry weight of leaf per plant (g), Bulb diameter (cm), Fresh weight of bulb (g) and Dry weight of bulb (g) in garlic as influenced by plant spacing and planting time

Source of variation	Degrees of freedom	Mean square					
		Length of leaf (cm)	Fresh weight of leaf per plant (g)	Dry weight of leaf per plant (g)	Bulb diameter (cm)	Fresh weight of bulb (g)	Dry weight of bulb (g)
Replication	2	10.129	6.929	0.083	0.085	0.332	0.010
Plant spacing (A)	2	480.902**	249.076**	1.886**	3.844**	235.691**	12.803**
Planting time (B)	3	682.239*	309.512*	4.343*	2.619*	39.920**	3.970**
Interaction (A×B)	6	19.135	5.655	0.335	0.181	12.680	1.503
Error	22	8.950	6.735	0.053	0.083	0.335	0.010

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

Appendix VII. Analysis of variance on Fresh weight of bulb (g), Dry weight of bulb (g), Number of cloves per bulb and Yield (t/ha) in garlic as influenced by plant spacing and planting time

Source of variation	Degrees of freedom	Mean square			
		Fresh weight of bulb (g)	Dry weight of bulb (g)	Number of cloves per bulb	Yield (t/ha)
Replication	2	0.003	0.001	6.653	0.083
Plant spacing (A)	2	0.292**	0.067**	200.806**	4.243**
Planting time (B)	3	0.342*	0.112*	223.6607**	7.473*
Interaction (A×B)	6	0.005	0.012	4.475	0.765
Error	22	0.003	0.001	6.768	0.083

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

Appendix VIII. Production cost of garlic/hectare

A. Input cost

Treatment Combination	Labor cost	Ploughing cost	Seed Cost	Manure and fertilizers				Insecticide/ pesticides	Sub Total (A)
				Cowdung	Urea	TSP	MP		
S_3Pt_1	17000.00	12000.00	38,100.00	8400.00	2080.00	4464.00	5600.00	6000.00	95500
S_3Pt_2	20500.00	12000.00	38,100.00	8400.00	2080.00	4464.00	5600.00	6000.00	99000
S_3Pt_3	13000.00	12000.00	28,500.00	8400.00	2080.00	4464.00	5600.00	6000.00	80044
S_2Pt_4	21500.00	12000.00	40500.00	8400.00	2080.00	4464.00	5600.00	6000.00	102400
S_1Pt_2	17000.00	12000.00	44,440.00	8400.00	2080.00	4464.00	5600.00	6000.00	101840
S_2Pt_3	20500.00	12000.00	40500.00	8400.00	2080.00	4464.00	5600.00	6000.00	101400
S_1Pt_1	20500.00	12000.00	44,440.00	8400.00	2080.00	4464.00	5600.00	6000.00	105340
S_3Pt_4	21500.00	12000.00	38100.00	8400.00	2080.00	4464.00	5600.00	6000.00	100000
S_2Pt_1	17000.00	12000.00	40,500.00	8400.00	2080.00	4464.00	5600.00	6000.00	97900
S_1Pt_3	20500.00	12000.00	44,440.00	8400.00	2080.00	4464.00	5600.00	6000.00	105340
S_2Pt_2	20500.00	12000.00	40,500.00	8400.00	2080.00	4464.00	5600.00	6000.00	101400
S_1Pt_4	21500.00	12000.00	44,440.00	8400.00	2080.00	4464.00	5600.00	6000.00	106340

Garlic clove @ Tk. 80/kg; Cowdung @ Tk. 600/ton, Urea @ Tk. 8/kg, TSP @ Tk. 16 /kg, MP @ Tk. 16/kg; Labour cost @ Tk. 100/day

S_1: 10 cm x 10 cm
S_2: 10 cm x 20 cm
S_3: 10 cm x 30 cm

Pt_1: 1 November, 2007
Pt_2: 15 November, 2007
Pt_3: 30 November, 2007
Pt_4: 15 December, 2007

Appendix IX. Contd.

B. Overhead cost (Tk /ha)

Treatment Combination	Cost of lease of land for 6 months	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 13% of cost/year	Sub total (Tk) (B)	Total cost of production (Tk./ha) [Input cost (A)+ overhead cost (B)]
S_3Pt_1	16000	4775	12415	33190	128690
S_3Pt_2	16000	4950	12870	33820	132820
S_3Pt_3	16000	4002	10405	30407	110451
S_2Pt_4	16000	5120	13312	34432	136832
S_1Pt_2	16000	5092	13239	34331	136171
S_2Pt_3	16000	5070	13182	34252	135652
S_1Pt_1	16000	5267	13694	34961	140301
S_3Pt_4	16000	5000	13000	34000	134000
S_2Pt_1	16000	4895	12727	33622	131522
S_1Pt_3	16000	5267	13694	34961	140301
S_2Pt_2	16000	5070	13182	34252	135652
S_1Pt_4	16000	5317	13824	35141	141481

S_1: 10 cm x 10 cm
S_2: 10 cm x 20 cm
S_3: 10 cm x 30 cm

Pt_1: 1 November, 2007
Pt_2: 15 November, 2007
Pt_3: 30 November, 2007
Pt_4: 15 December, 2007