EFFECT OF SOWING TIME AND MULCHES ON GROWTH AND YIELD OF GARLIC (*Allium sativum*)

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EFFECT OF SOWING TIME AND MULCHES ON GROWTH AND YIELD OF GARLIC (*Allium sativum)*

BY

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CERTIFICATE

This is to certify that the thesis entitled ***"Effect of sowing time and mulches on growth and yield of garlic"*** *submitted to the Department of Horticulture, 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* ***ALPONA AREPHIN****, Registration No. 11-04373 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2017

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Dedicated To
My Beloved Parents

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The Author

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BY

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ABSTRACT

A field experiment was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period of November 2015 to March 2016. The experiment comprised of three levels of sowing time *viz*., S_1 = 20 October, S_2 = 10 November, and S_3 = 30 November and four levels of mulches *viz*., M_0 = Control (Without mulch), M_1 = Black polythene, M_2 = Water hyacinth, M_3 =Rice straw. There were twelve treatment combinations and the experiment was laid out in Randomized Complete Block Design with three replications. All the studied parameters significantly influenced by sowing time, mulching and their combination. The maximum fresh weight of bulb per plant (16.08 g) was obtained from the S_2 treatment. The minimum fresh weight bulb (14.08 g) was obtained from the S_3 treatment. Significantly higher fresh weight of bulb (17.69 g) was obtained from the M_1 treatment while the lowest yield (11.14 g) was obtained from M_0 treatment. Incase of combined effect the highest fresh weight of bulb (19.57 g) and bulb yield (5.28 t/ha) were recorded from the treatment combination of S_2M_1 while the lowest yield (2.12 t/ha) was obtained from S_1M_0 treatment. In terms of economic return, the highest net return (1,67,909 tk/ha) and benefit cost ratio (1.74) were obtained from S_2M_1 treatment combination. So, S_2M_1 treatment combination is best for commercial garlic production.

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
µg	=	Microgram

CHAPTER I

INTRODUCTION

Garlic (*Allium sativum* L) is the most widely used cultivated Allium species belonging to the family Alliaceae. It is consumed both fresh as well as in dried form as an important ingredient for flavouring various vegetarian and non-vegetarian dishes. Garlic is the second most widely used cultivated bulb crops after onion. It is being used as a spice and vegetable both by poor as well as rich in one or the other form. It is a rich source of carbohydrates (29%), proteins (6.3%), minerals (0.3%) and essential oils (0.1-0.4 %) and also contains fat, vitamin C and sulphur (Memane *et al*., 2008). Ascorbic acid content is very high in green garlic. In addition to this garlic has several medicinal values. It has antibacterial (Arora and Kaur 1999), and antiprotozol properties (Reuter *et al*., 1996). It is beneficial to cardiovascular and immune system and has antioxidant and anticancer properties (Harris *et al*., 2001).

In Bangladesh and other Asian and Middle- East countries, it is being used in several food preparations, notably in chutneys, pickles, curry powders, curried vegetables, meat preparations, tomato ketchup and the like (Bose and Some, 1990). China leads in the world production of garlic (4986 thousand m. tone) and also in area (372 thousand hectares). But the highest national yield is recorded from Armenia (40 t/ha), and the major garlic producing countries are china, South Korea, India, Spain, Egypt, United States, Thailand, Turkey and Mexico. The average yield of garlic in this country is only 2.89 t/ha (FAO, 2014). The total production of garlic is 38,000 metric tons (BBS, 2016), but the requirement is 85,000 metric tons (Rahim, 1992). Garlic is known to be thermo-and photosensitive (Rahim and Fordham, 1988) and its vegetative growth and bulb development are greatly influenced by growing environment (Rahim, 1992).

There are many reports in support that growth and yield of garlic can be increased by judicious application of mulching (Mia, 1996) and optimum sowing time (Rahim, 1988).Due to thermo and photosensitive nature of garlic (Rahim, 1988), the crop is commonly planted with the onset of winter and harvested at the early summer. Bulbing of garlic is controlled by the day length and temperature to which the dormant cloves and growing plants are exposed before bulbing begins. Delay of a few weeks in the normal planting date (Mid October) lead to severe losses in yield (Rahim, 1988).

It is well known that among yield influencing factors under normal conditions, date of planting is a main factor which greatly influences the growth, yield and quality of garlic crop (Kilgori *et al*., 2007). The time of sowing is an important factor in the cultivation of garlic. Higher bulb yields were obtained with earlier planting of garlic during the last week of September and first week of October (Rahim *et al*., 1984).

Tillage practices play a notable role in conserving soil moisture at different depths of the soil profile. For successful garlic production, frequent irrigation is also needed but in the places where garlic is cultivated irrigation facilities are not easily available moreover irrigation increases the cost of production. Mulch reduces water loss resulting in more conservation of soil moisture (Prihar, 1986). As garlic is grown during the rabi season, farmers have to depend either on natural precipitation or on irrigation water. Therefore, judicious mulching may be an effective role to improve garlic production as well as storage (Mondal *et al*., 2007). So artificial mulching by using water hyacinth straw sotty leaves etc was thought to be helpful in this situation.

Therefore, this study was initiated with the general objective of selecting optimum sowing time and suitable mulch materials to be applied in the study area.

Objectives

1. To identify optimum sowing time for better growth and yield of garlic
2. To find out the suitable mulch materials for better growth and yield of garlic
3. To find out the suitable combination of sowing time and mulch materials for ensuring the higher growth and yield of garlic

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh and in many countries of the world garlic is an important and most valuable spice crop. The crop received much attention to the researcher of different countries including Bangladesh. But a few investigations have been taken on the effect of sowing time and mulching practice on garlic production. There is a little or no combined research work to the effect of sowing time and mulching practice on growth and yield of garlic in Bangladesh. The literature and research results related to the present study are reviewed in this chapter.

2.1 Effect of sowing time

Sowing of garlic crop on 30th September significantly increased the growth attributes like plant height (33.90, 53.81 and 71.85 cm), leaves per plant (5.70, 8.40 and 10.67) at 30, 60 and 90 days after sowing respectively in comparison to other dates of sowing. Early sowing of garlic on 30th September significantly increased the bulb yield (14.21 tonnes/ha) in comparison to later date of sowing. Planting of garlic crop in early November gives maximum bulb yield (27200 kg/ha) when compared to planting of late October and late November (19001 and 16800 kg/ha respectively) (Pratibha singh *et al.,* 2010).

Mosleh Ud-Deen (2008) studied the effect of mother bulb size and planting time on growth, bulb and seed yield of onion and revealed that the October 30th planting produced the longest plants in onion (62.29 cm) and highest number of leaves per plant (16.72) when compared to other dates of plantings.

Adekpe *et al.* (2008) reported that out of three dates of planting and three intra row spacings in garlic, plant height, total dry matter, leaf number were significantly higher with the early November planting and all the growth parameters assessed that they did not differ with intra- row spacing

The plant height, plant girth, number of leaves, leaf area per plant, and leaf area index were recorded to be maximum in early date of sowing i.e. on November 15th when compared to late sowings of December 1st and December 15th except the crop growth rate which was more in late planting of December 15th. The yield recorded maximum in garlic with early planting date of November 15th (5.40 t/ha) decreased in late planting dates (Chattopadhyay *et al.*, 2006).

Balraj singh *et al.* (2005) studied the effect of dates of planting, size of bulb and spacing on growth and seed yield of onion and reported that the 1st October planting produced highest plant height (104.97 cm) when compared to other planting dates.

Shahidur Rahman *et al.* (2004) recorded the highest plant height (41.74 cm), number of leaves per plant (6.62), fresh weight and dry weight of leaves (4.26 g and 1.76 g respectively), fresh weight and dry weight of whole plant (both leaves and roots) (5.45 g and 2.03 g respectively) and leaf area index per plant (0.82) when cloves were planted on November 7th while it was decreased in late plantings but the crop growth rate was recorded higher on 22nd November (1.81) and it was decreased in early and late plantings. Bulb yield decreased gradually in garlic with the lateness of planting. The highest yield (2.67 t/ha) was obtained from November 7th planting while the lowest yield (0.92 t/ha) was from December 22nd planting.

Bhuiya *et al*. (2003) conducted an experiment to study the effect of planting time, mulch and irrigation on growth and yield of garlic. There were five planting time *viz*. October 25, November 9, November 25, December 8 and December 23 and 10 days interval irrigation, 20 days interval irrigation and control (no irrigation) were used as the experimental treatments. With the delay in planting time from Oct. 25 yield was chronologically reduced in later plantings. The highest bulb yield (3.9 t ha^{-1}) was recorded when planting was done on October 25 which was statistically

identical to November 9 planting (3.5 t ha^{-1}). The lowest yield was obtained from December 23 (2.3 t ha^{-1}) planting.

Rahim *et al.* (2003) reported highest plant height, maximum number of leaves and fresh weight of leaf per plant (44.90 cm, 10.54 and 4.98 g respectively) when cloves were planted on 30th October. While November 30th planting produced lowest plant height, number of leaves and fresh weight of leaf per plant (33.45 cm, 7.74 and 3.89 g respectively). October 30th planting gave the highest yield/ha (8.56 t) in garlic while decreased in November 30th planting.

Bhuiya *et al.* (2003) studied the effect of the growth and yield of garlic and revealed that highest plant height (52.63 cm) was recorded from November 9th plantation. The lowest plant height (46.69 cm) was recorded from December 23rd planting, while the maximum number of leaves was counted from November 25th (8.97), but December 23rd planting produced the lowest (8.06) and weight of leaves were highest in October 25th planting (11.68 g). In garlic early planting of October 25th gave maximum yield of bulb (391.22 g/plot 3.92 t/ha) when compared to late plantings.

Panda and Mohanty (2002) studied the response of onion to time of planting and revealed that planting on 16th November registered the tallest plant (50.52 cm) and maximum leaves per plant (14.85) when compared to other dates of plantings.

Mohanty (2001) studied the effect of planting time on the performance of onion cultivars and revealed that planting on 16th November exhibited significantly taller plants (50.52 cm) with more number of leaves per plant (14.85) when compared to other dates of plantings (1st November and 1st December) which were on par and decreased significantly in 16th December and 31st December. Maximum plant height (87.67 cm) and number of leaves (8.10) were recorded in garlic when sown on 1st November. While minimum plant height (51.00 cm) and number of leaves (6.48) were noted in the plants sown on 15th December.

Observations total yield in garlic were maximum with planting date of 1st November followed by planting date of 15th December (Muhammad Jamroz *et al.*, 2001).

Sonkamble *et al.* (1999) studied the effect of different dates of planting on growth and yield of garlic and revealed that planting on 20th October recorded significantly maximum plant height, number of leaves per plant and stem girth. Planting of garlic crop on 20th October produced significantly highest yield per hectare (63.44). The lowest yield of 40.93 q/ha was recorded with the sowing on 1st September.

Mohamed Ali and El-Sayed (1999) studied the response of two garlic varieties *(Allium sativum* L.) to different planting dates in arid tropics of northern Sudan and revealed that the early planting on 22nd October gave the highest bulb yields of large bulbs averaged over the two seasons 8452, 6717, 5963 and 5202 kg/ha for the 22nd October, 7th November, 22nd November and 7th December respectively.

Humayun-Khan *et al.*, (1997) Conducted on experiment on garlic cultivars (Swat Local, Tarnab Peshawar and Italian) were planted on 3 different dates 22nd September, and 7th and 22nd October, at Mingora, Swat, Pakistan. For all planting dates, the highest yields were produced by cv. Italian. For all cultivars, the yields were highest for the early planting followed by the 2nd and 3rd planting dates.

Bomme *et al.* (1996) in Germany reported in garlic crop that the most suitable cultivars for field cultivation were Stamm, Burgenland, Thuringer, Mako and Ungarischer. Cloves should be planted from middle of September to middle of October at a depth of 7-8 cm and a density of 5, 00,000 cloves/ha (row spacing of 25 cm and a planting distance of 8 cm). Bulbs should be harvested the following year, producing a yield of 160-240 dt/ha (dry ton per hectare) fresh bulbs (80-120dt/ha superficially dried bulbs) with an allicin content of 0.32-1.01%.

Optimum planting dates were 20th September and 5th October in garlic crop which

recorded higher number of leaves per plant when compared to 5th November, 20th March and 5th April planting (Orlowski and Rekowska, 1993).

Planting on 20th September resulted in significantly more growth and highest yield (99.21 q/ha) followed by planting on 10th October (82.08 q/ha) and 1st September (78.69 q/ha). Yield reduction was quite high from planting on 30th October and thereafter (Kargirwar and Kulwal, 1991).

Lee *et al.* (1989) reported that the garlic cultivar Daeseo and Namdo when planted on 10th, 20th, and 30th September produced higher number of leaves per plant when compared to 10th and 20th October plantings.

Bhathal and Thakur (1986) observed different planting dates with three different cultivars (56-4, G-11 and G-15) and recorded highest mean yield (133.1 q/ha) from October 15 th planting which declined to 100.6 q/ha when planted on 16th November.

Das *et al.* (1985) studied the effect of time of planting on growth and yield of multiple clove garlic and revealed that sowing on 11th November recorded maximum plant height (53.93 cm) and number of leaves per plant (6.75). The values have decreased in these parameters in late sowings. Among six different dates of planting at an interval of 10 days starting from 1st November to 22nd December, 11th November planting was found to the most effective and gave highest yield of 57.25 q/ha.

Among different clove sizes *viz*., large, medium and small mother bulbs planted on three dates from 31st October to 10th December, recorded the highest bulb yield of 15 tones per hectare with, large mother bulbs planted on 31st October (Rahim *et al.,* 1984).

Among the three garlic cultivars *viz*., Jureia, Amaranate and Dourados, theDourados gave higher yield ranging from 5.2-8.4 tonnes per hectare followed

By Jureia (5.3-7.6 t/ha) and Amaranate (3.02-4.3 t/ha) when planted at monthly intervals from late November to late May. They also observed the best planting time with regard to yield for Jureia, Amaranate and Dourados cultivars as late February to late April, late January to late March and late January to late April respectively (Souza and Casali, 1982).

Hari Om and Srivastva (1974) observed maximum number of leaves per plant when planted on 6th September compared to planting of 20th September and 3rd, 17th October and 4th November. September 6th to October 3rd as optimum than other sowing dates for getting higher bulb yield in garlic

2.2 Effect of mulching

Kabir *et al*. (2016) conducted an experiment to study the effect of tillage and mulches on the growth and yield of garlic. The experiment consisted of four mulches (control, rice straw, water hyacinth and Curcuma amada leaf). The results revealed that different mulches had remarkable contributions on the growth and yield of garlic. The highest values of growth parameters as well as bulb yield were obtained from rice straw mulch identical with that of water hyacinth mulch. It was also noticed that both the tillage conditions as well as mulches showed profound effects on the yield and yield contributing parameters. Moreover, the highest net return (196647Tk. /ha) and the highest BCR of 2.90 was obtained from zero tillage with rice straw.

Mahdieh *et al*. (2012) conducted an experiment using three kinds of mulches (Transparent and black PE and rice straw) and found that plastic mulch increased minimum temperature of soil, accelerated plant height, early growth, early yield, and bring satisfactory weed control without any application of herbicides. Results also showed that garlic total yield, bulb ash percent, TSS, vitamin C and flavonoids content were affected by mulching. Although mulching could improved some quality indices in garlic but no effect on forcing was observed. Due to two

years experiment and interaction between year and mulches the usage of rice straw in rainy and cool season and plastic mulch in low rain fall and warm season recommended increasing garlic quality

Tillage practices play a notable role in conserving soil moisture at different depths of the soil profile (Mondal *et al*., 2007). As garlic is grown during the rabi season, farmers have to depend either on natural precipitation or on irrigation water. Therefore, judicious mulching may be an effective role to improve garlic production as well as storage.

Mulches serve as protective covering, reduce moisture loss from the soil by preventing evaporation from the sunshine and desiccating winds, regulate soil temperature cooler in summer and warmer in winter. The temperature regulating effect encourages the root growth and weight. It was observed that different mulching materials highly influenced the plant height and bulb diameter (Iroc *et al*., 1991) as well as yield of garlic (Rekowska and Skupien, 2007).

Mulching helps in significant increase in N, P and K uptake over unmulched (Hossain *et al*., 2007). Therefore, a better understanding of the uses of mulching in garlic production is very importantin order to develop management strategies, which optimize moisture and increasing returns to the producers by increasing Garlic yield and quality.

Karaye and Yakubu (2006) Results of different kinds of mulching indicated increased plant growth, yields, and improved bulb size of the garlic. Many of these effects were attributed to the capacity of the mulch to conserve soil moisture (Wolde, 2014), regulate soil temperature control weeds and diseases and reduce loss of nutrients (Gebrehaweria, 2007).

Jamil *et al*. (2005) observed the effects of different type of mulches (plastic, straw and sawdust, excluding, control) and their duration (one month and whole season) on the growth and yield of garlic were observed in a field experiment. Straw and

plastic mulches increased the bulb yield and yield components, irrespective of their duration. Straw mulch is recommended for the garlic production based on better overall performance than the others and also for being cheaper and organic in nature.

Bhuiya *et al*., (2003) conducted an experiment to study the effect of mulch and irrigation on growth and yield of garlic. There were seven types of mulch and irrigation treatments *viz*. Straw, water hyacinth, black polyethylene, transparent polyethylene, 10 days interval irrigation, 20 days interval irrigation and control (no mulch and no irrigation) were used as the experimental treatments. Water hyacinth mulching yielded (4.27 t ha^{-1}) best which was statistically identical with straw mulch (3.97 t ha^{-1}). The lowest yield was obtained from white polyethylene mulch and control.

Umar *et al*., (2000) mulching is a cropping practice that entails placing organic or inorganic or synthetic materials on soil close to plants to provide a more favorable environment for growth and development. Organic or inorganic mulches can be used for weed control. Mulch controls weeds by smothering seedlings, prevent day light which helps foster germination from reaching weed seeds and prevents airborne seeds from taking hold on the soil surface (Umar *et al*., 2000).

While working on garlic mulching in Bangladesh Agricultural University, Mymensingh, Hassan (1999) reported that water hyacinth mulch gave the tallest plant and highest number of leaves per plant at 75 DAP. The author also added that fresh weight of leaf, bulbs and roots, dry weight of leaf, bulbs and roots and

bulb diameter were increased. Different mulches had marked influence on the yield contributing characters of garlic were also reported by (Bhuiyan, 1999).

The effect of mulch and five levels of irrigation on soil evaporation, transpiration, evapotranspiration and yield of onion were studied in a glasshouse pot

experiment by Abu-Awad (1999) and described that increasing irrigation level significantly increased evapotranspiration and/or transpiration. With mulch treatments, evapotranspiration was significantly reduced, while transpiration was significantly increased compared with open soil surface treatments. In covered soil surface treatments, onion yields were significantly higher than in open surface treatments.

Abdallah (1998) conduced an experiment on onion seedbed solarization in field naturally infested with weeds. Seedbed plots were covered early with 50 micrometer thick transparent polythene mulch for 6 weeks. Seedbed solarization gave the lowest number and weight of weeds m'^{2} and significantly increased the production of healthy onion seedlings per unit area compared to the control.

In Indonesia, straw has been proved to be the best mulch for garlic compared to transparent plastic, black plastic and cabbage residues as it yielded the largest bulbs and the highest number of cloves/bulb (Uddin, 1997).

In Polland, plastic film mulching has been proved to be effective in garlic production. Black plastic film mulch has a positive effect on yield and quality of garlic as stated by Rekowaka (1997) and adding that the highest marketable yield was obtained compared with unmulched control. The black plastic mulch also produced the largest and heaviest bulb.

Mia (1996) conducted an experiment to observe the performance of different mulches in Bangladesh Agricultural University, Mymensingh. He noticed that mulches showed better performance in most of the yield contributing characters, such as plant height, number of leaves per plant, pseudostem diameter and dry matters of root and shoot of onion.

Hossain (1996) carried out an experiment in Bangladesh Agricultural University, Mymensingh. Plant height, leaf number, pseudostem and bulb diameter, dry

matter content of foliage, bulb weight and bulb yield were found significantly higher for mulched plants.

Plastic mulching increased the soil temperature (Chen and Chen, 1996).

Baten *et al.* (1995) conducted an experiment in Bangladesh Agricultural University, Mymensingh to evaluate the effectiveness of different mulches on the growth and yield of garlic and narrated that plants treated with any of the mulches significantly increased plant height, number of leaves per plant, length of leaf, length of pseudostem, number of roots per plant, bulb and neck diameters compared with the control. Bulb length, bulbs diameter, clove length, clove diameter, 100 clove weight and yield were also significantly higher in mulched plants. Mulches provided weed control and among the treatments, water hyacinth gave the best results in terms of garlic yield.

Mulching has been reported to conserve moisture (Duranti and Cuocolo, 1989) by protecting the plant from excess transpiration and direct evaporation from soil thus reducing the irrigation requirements (Gajri *et al*., 1994).

Adetunji (1994) conducted a trial to optimize water use and soil condition during dry season in semi-arid region, onion was mulched with polythene film and reported that mulching significantly enhanced vegetative growth

Mulching with straw reduced the maximum soil temperature (Alam *et al.,* 1993).

Iroc *et al.* (1991) reported that different mulching materials influenced the average height and the average bulb diameter of garlic seedlings. Garlic mulched with rice husk and cogon produced the biggest bulb diameter while the other treatments resulted in reduced bulb diameters. The plants mulched with grab grass and cogon significantly developed the smallest bulb.

In an experiment conducted by Suh *et al.* (1991) with transparent polythene film and black polythene film mulches onion crops and found that the mean soil water

content was 2.1-2.8% higher in the mulched plots than the control. They also stated that soil moisture conservation was an important aspect for crop-growth and yield.

Roy *et al.* (1990) by using water hyacinth, straw and sawdust as mulch on potato, opined that mulches increased leaf area index (LAI) and crop growth rate (CGR).

Sumi *et al.* (1986) stated that mulching gave a maximum yield of garlic (10.30 t/ha) with an average bulb size of 31.22 g while the lowest was 6.06 t/ha with an average bulb size of 19.01 g respectively for the unmulched control.

The rapid growth made under plastic film mulches or tunnels tends to accelerate secondary growth of garlic and this causes undesirable rough bulb to develop as discussed by Moon and Lee (1985).

Leaf area, leaf number of sweet potato cv. Jewel were significantly higher for mulched than for unmulched plants as concluded by Hochmuth and Howell (1983) adding that the highest marketable yield (18. 6 t/ha) was obtained from mulched raised beds where flat unmulched beds gave the lowest yield treatments.

A three years study on mulching in Chinese cabbage by Oh *et al.* (1984) revealed that minimum, mean and maximum soil temperature at 5, 10 and 15 cm depth were always highest under clear polythene followed by black polythene mulch. Soil temperatures under rice straw and in unmulched plots were very similar.

From a seasonal study of mulches, Manrique and Mayer (1984) observed that plastic mulches raised soil temperature during the winter giving significantly higher yield. In summer, plastic mulches increased day soil temperature to above 30°C giving an unfavourable environment for plant growth and tuber formation in potato. But favourable soil temperature in both winter and summer was maintained by straw mulch.

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials and methods which were used in the field to conduct the experiment during the period from November 2015 to March 2016. It comprises a short description of experimental site, soil and climate, variety, growing of the crops, experimental design and treatments and collection of data presented under the following headings:

3.1 Experimental site

The study was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. Geographically the experimental area is located at 23°41′N latitude and 90°22′E longitudes at the elevation of 8.6 m above the sea level. The map showing the experimental site under study in Appendix I.

3.2 Climate and weather

The climate of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.3 Characteristics of soil

Soil of the experimental field was silty loam in texture. The soil of the experimental area belongs to the Modhupur Tract under the AEZ No. 28. Soil sample of the experimental plot was collected from a depth of 0-30 cm before conducting the experiment and analyzed in the Soil Resources Development

Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix III.

3.4 Plating mater

The research work was conducted with the bulb of garlic cultivar ‘pabna’. Local cultivar planting materials (clove) were collected from local market of Pabna district.

3.5 Land preparation

The selected experimental plot was first opened in the month of October, 2016 by a tractor with disc plough. It was then thoroughly prepared by ploughing and cross ploughing with power tiller followed by laddering. The comers of the plots were trimmed by spade. The clods were broken into friable soil and the surface was leveled until the desired tilth was obtained. All the weeds, their rhizomes and stubbles were collected and removed from the plots. Irrigation and drainage channels were prepared around the plots.

3.6 Manures and fertilizers

The following doses of manure and fertilizers were applied to the plots for bulb production (BARI, 2015)

Manure /fertilizer	Doses/ha
Cowdung	5 t/ha
Urea	271 kg/ha
TSP	267 kg/ha
MOP	333 kg/ha
Gypsum	110 kg/ha

Entire amount of cow dung, urea, TSP, MP were applied in the unit plot during final land preparation of 7 days before clove sowing and thoroughly mixed with soil.

3.7 Treatments of the experiment

The experiment consisted of 2 factors as follows:

Factor A: Sowing time - Three levels

1. S_1 = 20 October
2. S_2 = 10 November
3. S_3 = 30 November

Factor B: Mulching - Four levels

1. M_0 = Control (No mulch)
2. M_1 = Black polythene
3. M_2 = Water hyacinth
4. M_3 = Rice straw

3.8 Design of the experiment

The factorial experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. The treatment combinations were accommodated in individual unit plot among the total plots.

3.9 Layout of the experiment

The entire experimental plot was divided into three blocks, each of which then divided into 36 unit plots. The size of the unit plot was 1 m × 0.9 m. Two adjacent unit plots and blocks were separated by 0.4 m and 0.5 m, respectively. The treatments were distributed randomly among the unit plots of each block so as to all of treatments were placed once in each block. Total field size = 5m × 16m. Layout of the experiment field is shown in Appendix IV.

3.10 Clove sowing

The clove for planting was selected from large bulb of garlic. The garlic cloves were separated from each mother bulb for sowing in the field and were planted in each unit plot as per treatment maintaining a spacing of 20 cm × l5 cm. The cloves were dibbed at about 4 cm depth of soil.

3.11 Mulching

Mulching with water hyacinth, straw and black polythene was done after 10 days of planting when emergence of seedlings was completed. Black polythene sheet with small holes which maintained proper spacing were spreaded over the plot so that the seedlings could emerge easily through the holes. Then the cloves were planted in the soil of each hole at required depth with a pointed stick.

3.12 Intercultural operations

3.12.1 Gap filling

The experimental area was kept under careful observation. The unsprouted cloves were replaced by healthy seedlings taken from border plants within two weeks after plantation. The damaged plants were also replaced by healthy border plants planted on the same time.

3.12.2 Weeding

Weeding was done regularly in the control plots to keep them free from weeds. Though mulches are used others plots so only weeding is done on control plot. Hand weeding is done.

3.12.3 Plant protection

Rovral at the rate of 20 g in 10 litres of water was applied at an interval of 15 days after planting up to one month before harvesting to control purple leaf blotch disease of garlic.

3.13 Harvesting

The harvest of the crop was done following sowing date after attaining full maturity, showing the sign of drying out of most of the leaves and softening of the neck of the bulb.

3.14 Collection of data

Data were collected on the following parameters

- Plant height (cm)
- Number of leaves per plant
- Fresh weight of leaf
  Fresh weight of root
- Fresh weight of bulb
- Leaf dry weight
- Root dry weigh
  Bulb dry weight
- Bulb diameter
- Number of cloves per bulb
- Yield per plant
- Yield per plot (kg)
- Yield per ha (t)

3.15 Procedure of recording data

Ten plants were selected randomly from each unit plot for the collection of data during different growing stages of plants. Data were collected at 30, 60 and 90 days after sowing (DAS) and at harvest.

3.15.1 Plant height (cm)

Plant height was measured from the ground level to the tip of the longest leaf at different days after planting.

3.15.2 Number of leaves per plant

Total number of leaves was counted of each plant at different days after sowing. Data was also collected in respect of following characteristics at harvest and means were calculated.

3.15.3 Fresh weight of leaves per plant (g)

The leaves of ten selected plants from each plot were collected including pseudostem. Weight of leaves was taken by a specify the mulching with made in country triple beam balance and mean was calculated.

3.15.4 Fresh weight of roots per plant (g)

Fresh weights of roots of ten randomly selected plants were separated from the bulbs and their average weight was calculated.

3.15.5 Fresh weight of bulb (g)

After removing the roots and top portion, weight of bulbs of ten selected plants were taken and their average was calculated.

3.15.6 Dry weight of leaves per plant (g)

Leaves of ten selected plants were weighed and dried in air for 72 hours. Air dried leaves were kept in an oven at 70°C for 72 hours. Finally, mean dry weight was calculated.

3.15.7 Dry weight of roots per plant (g)

Dry weight of roots per plant was recorded after oven dry of the roots.

3.15.8 Bulb diameter (cm)

The individual bulb diameter was taken with slide calipers and their mean was calculated.

3.15.9 Number of cloves per bulb

The cloves were counted from 10 bulbs and their average was taken as the number of cloves per bulb.

3.15.10 Dry weight of bulb (g)

Dry weight of bulbs was taken and means were calculated.

3.15.11 Yield per plot (kg)

Bulb yield / plot was calculated after harvesting all bulbs of the plot.

3.15.12 Yield (ton/ha)

Bulb yield per plot was converted into yield per hectare and was expressed in metric ton.

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analyses of variance were calculated. The significance of the difference among the treatments means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

3.17 Economic analysis

The cost of production was analyzed in order to find out the most economic combination of different level of planting time and mulching practice. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 12% in simple rate. The market price of garlic was considered for estimating the cost and return.

The benefit cost ratio (BCR) was calculated as follows:

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

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study regarding the effect of sowing time and mulching on growth and yield of garlic have been presented and possible interpretations have been made with Figure and Table in this chapter which is given below:

4.1 Plant height (cm)

Plant height of garlic was significantly influenced by different sowing time at different growth stages (Fig. 1 and Appendix V). Plant height was recorded from 30 DAS to harvest at an interval of 30 days and at harvest. The effect of sowing time on the plant height was fund to be significantly influenced at different days after sowing (Table .1). The maximum plant height (48.58 cm) was recorded at 90 DAS from the S_2 (10 November sowing) treatment. The minimum plant height (44.46cm) was found from the S_1 (20 October sowing) treatment on the same DAS (Fig 1). This might be due to the fact that the crops sowing on the 10 November availed relatively favourable environment, longer cool period and shorter day length which possibly enhance growth, resulting in maximum plant height. Similar results was also observed by Das *et al.* (1985), Rahim *et al.* (2003) and Mosleh Ud-Deen (2008). In all treatments it was observed that the plant height increase gradually with the advancement of time reaching a pick at 90 DAS and then it began to decrease due to senescence and drying up the tip of leaves.

Different mulching practices showed significant variation on plant height of garlic at different growth stages (Fig. 2 and Appendix V). It was found that the highest plant height (50.0 cm) at 90 DAS was obtained from M_1 (Black polythene) treatment where as the lowest plant height (41.78 cm) was found from M_0 treatment at the same DAS. The result obtained from the present study was similar with the findings of Iroc *et a*l., 1991, Mia (1996) and Mahdieh *et al*., (2012). In the

present study black polythene mulch maintain higher moisture content in soil and make uniform temperature than unmulched soil, which ultimately helped in realising plant nutrient rapidly and promoted higher plant growth.

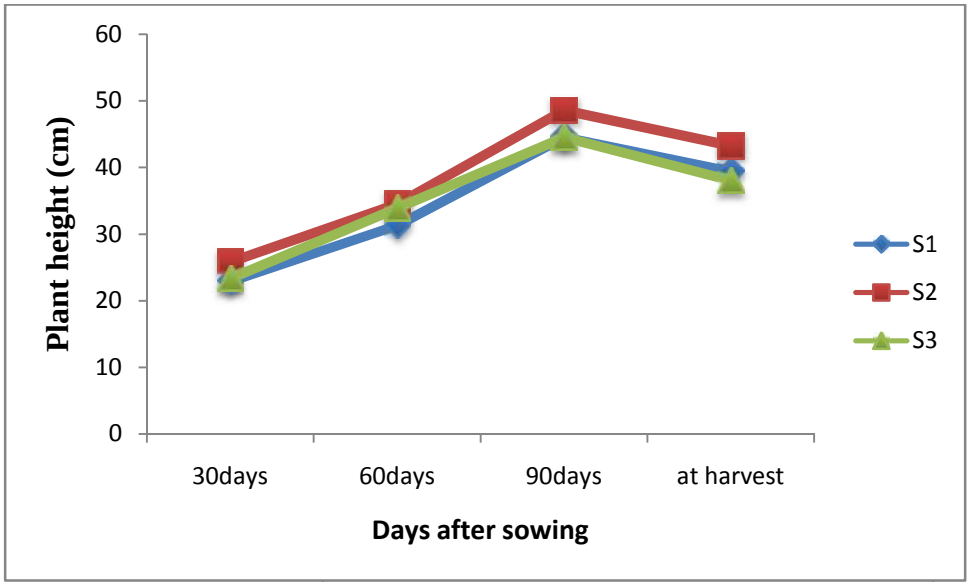

Fig.1. Plant height of garlic influenced by different sowing time

S_1 = 20 October, S_2 = 10 November, S_3 = 30 November

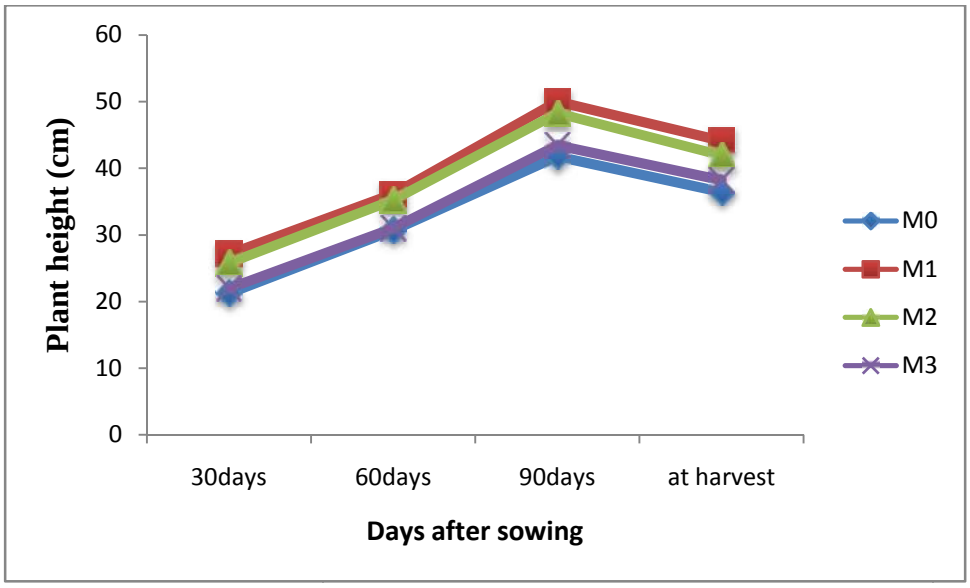

Fig 2. Plant height of garlic influenced by different mulching

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice stra

Combined effect of sowing time and mulching showed significant variation on plant height at different growth stages of garlic (Table 1 and Appendix V). The combined effect of sowing time and mulching was also found to be statistically significant in this respect (Table 1). Plant height per plant increased from 30 DAS to 90 DAS and there after it continued to decrease up to harvest. At 90 DAS the maximum plant height (56.33 cm) was obtained from the treatment combination of S_2M_1 (10 November sowing with black polythene mulch) while the lowest plant height (41.33 cm) was recorded from treatment combination of S_1M_0 (20 October sowing and no mulch) at the same DAS (Table 1). Chattopadhyay *et al.*,(2006) they reported that the plant height, plant growth, number of leaves, leaf area were recorded to be maximum in garlic when 15 November sowing compaired to late sowing.

Table 1. Plant height of garlic influenced by different sowing time and mulching combination

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
S_1M_0	18.33 f	27.67 f	41.33 f	37.67 g
S_1M_1	26.00 bc	33.66 b	48.33 c	42.00 c
S_1M_2	25.00 cd	31.67 d	45.67 d	40.67 de
S_1M_3	22.33 e	32.33 cd	42.00 ef	36.66 ghi
S_2M_0	24.33 d	32.67 bcd	42.00 ef	35.67 i
S_2M_1	30.00 a	41.33 a	56.33 a	50.66 a
S_2M_2	27.33 b	33.67 b	50.33 b	45.66 b
S_2M_3	21.66 e	30.33 e	45.67 d	41.00 cd
S_3M_0	21.00 e	31.67 d	42.00 ef	36.00 hi
S_3M_1	25.33 cd	33.33 bc	45.33 d	39.66 ef
S_3M_2	25.00 cd	40.33 a	48.67 c	39.33 f
S_3M_3	22.00 e	30.33 e	42.67 e	37.00 gh
$LSD_{0.05}$	1.39	1.13	1.19	1.09
CV (%)	5.41	7.67	7.25	9.37

Means in a column followed by the same letter do not differ significantly at 5% level S_1 = 20 October, S_2 =10 November, S_3 = 30 November,
M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

4.2 Number of leave per plant

Significant variation was observed for number of leaves per plant at different growth stages of garlic (Fig 3 Appendix VI). Number of leaves per plant was recorded at 30 DAS to 90 DAS at an interval of 30 days. Significant variation was observed on number of leaves per plant due to the effect of sowing time at different days after sowing (Table 2 appendix VI). Numerically leaf production was increased up to 90 DAS and there after decrease due to senescence. The maximum number of leaves (7.25) per plant was recorded from S_2 (10 November sowing) treatment at 90 DAS and The lowest number leaves (5.97) per plant was obtained from S_3 (30 November) treatment at the same DAS (Table 2 appendix VI). The difference in number of leaves caused by the time of sowing might be due to the variation in the environmental conditions. Incase of optimum time of sowing plant got favourable growing conditions to complete its vegetative growth and realising higher number of leaves per plant. Similar results was also observed by Sonkamble *et al.* (1999), Mohanty (2001), Chattopadhyay *et al.,* (2006) and Mosleh Ud-Deen (2008)

Different mulching practices showed significant variation on number of leaves plant^{-1} at different growth stages (Fig. 4 and Appendix VI). It was observed that the highest number of leaves per plant (7.22) at 90 DAS was obtained from the mulch treatment, M_1 (Black polythene) followed by M_2 (Water hyacinth) where the lowest number of leaves per plant (5.67) was obtained from the mulch treatment, M_0 (Control) at same DAS which was statistically identical with M_3 (Rice straw). Such effects may be attributed to supply of sufficient amount of soil moisture, which equally contributed to the formation of maximum number of leaves per plant. The results obtained from the present study was similar with the findings of Mia (1996) and Baten *et al.* (1995).

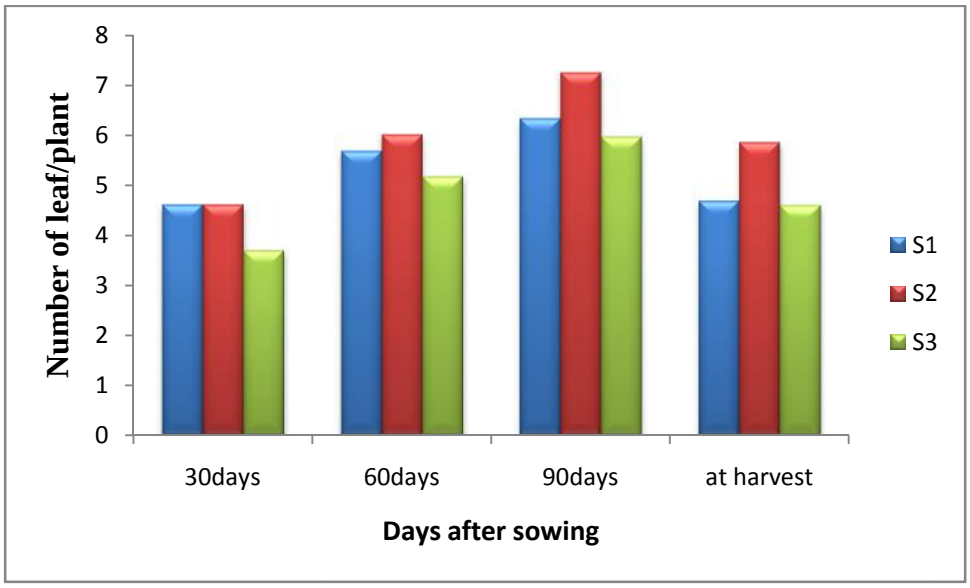

Fig. 3. Number of leaves per plant of garlic influenced by different sowing time

S_1 = 20 October, S_2 = 10 November, S_3 = 30 November

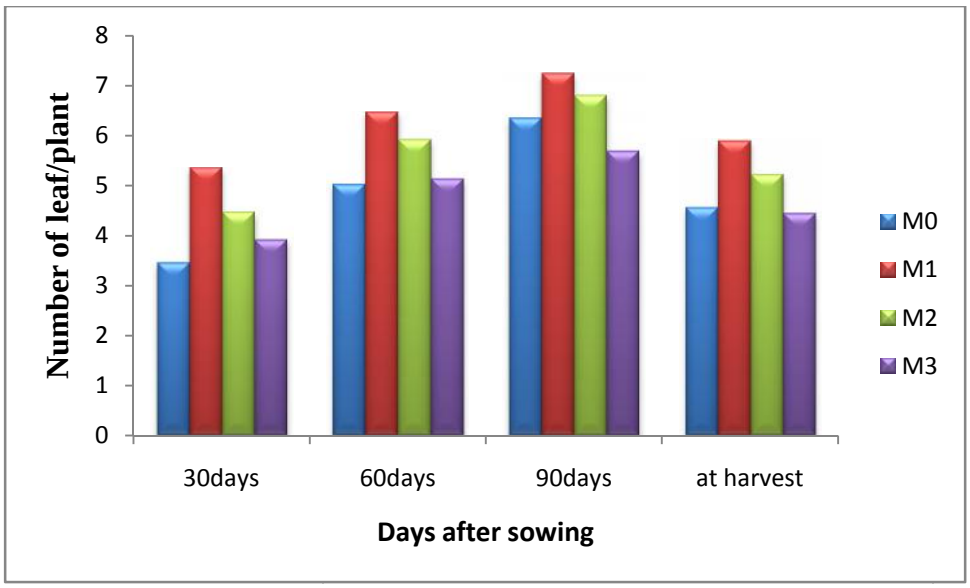

Fig 4. Number of leaves per plant of garlic influenced by different mulching

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

Combined effect of sowing time and mulching showed statistically significant in respect of number of leaves per plant at different growth stages of garlic (Table 2 and Appendix VI). Results exposed that at 90 DAS the highest number of leaves (7.00) per plant was obtained from the treatment combination of S_2M_1 which was statistically identical with S_2M_2 at same DAS. The lowest number of leaves (5.00) per plant at 90 DAS was obtained from the treatment combination of S_3M_0 (30 November sowing with control plot) which was statistically similar with S_1M_0, S_1M_3 and S_3M_3 (Table 2 appendix VI). From the results of the present study it can be concluded that the treatment combination S_2M_1 provided better growing condition perhaps due to supply of adequate plant nutrient available form, resulting in the maximum number of leaves per plant.

Table 2. Number of leaves per plant of garlic influenced by combined effect of Different sowing time and mulching

Treatments combination	Number of leaves per plant			
	30 DAS	60 DAS	90 DAS	At harvest
S_1M_0	4.33 cd	5.00 c	6.00 de	4.33 cd
S_1M_1	5.33 ab	6.33 b	7.00 b	5.33 b
S_1M_2	4.33 cd	6.33 b	6.67 bc	4.67 bcd
S_1M_3	4.33 cd	5.00 c	5.67 e	4.33 cd
S_2M_0	3.00 e	5.00 c	7.00 b	5.00 bc
S_2M_1	6.00 a	7.33 a	8.00 a	7.00 a
S_2M_2	5.00 bc	6.33 b	7.67 a	6.33 a
S_2M_3	4.33 cd	5.33 c	6.33 cd	5.00 bc
S_3M_0	2.67 e	4.67 d	5.00 f	4.00 d
S_3M_1	4.67 bcd	5.67 bc	6.67 bc	5.33 b
S_3M_2	4.00 d	5.00 c	6.00 de	4.67 bcd
S_3M_3	3.00 e	5.00 c	6.00 de	4.33 cd
$LSD_{0.05}$	0.68	0.66	0.58	0.72
CV (%)	8.98	8.16	9.97	10.42

Means in a column followed by the same letter do not differ significantly at 5% level. S_1 = 20 October, S_2 =10 November, S_3 = 30 November

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

4.3 Fresh weight of leaf

Fresh weight of leaf was significantly affected by sowing time of garlic (Table 3 and Appendix VII). It was found that the highest fresh weight of leaf (25.49 g) was obtained from the S_2 (10 November) treatment followed by S_3 (30 November) treatment. The lowest fresh weight of leaf (20.35 g) was obtained from the S_1 (20 October) treatment. Rahim *et al.* (2003) and Shahidur Rahman *et al.* (2004) also found similar results with the present study.

Different mulching practices showed significant variation on fresh weight of leaf (Table 3 and Appendix VII). Results indicated that the maximum fresh weight of leaf (27.94 g) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth) treatment where the lowest fresh weight of leaf (19.82 g) was obtained from the M_0 (Control) treatment which was statistically identical with M_3 (Rice straw) treatment. There results indicated that mulched supplied available moisture condition, suppress well growth condition, increase microbial activity and provide better growing condition than unmulched plant, which helped for getting proper vegetative growth as well as maximum fresh weight of leaves .Similar results was also observed by Hassan (1999) and Bhuiyan, (1999).

Combined effect of sowing time and mulching showed significant variation on fresh weight of leaf (Table 3 and Appendix VII). It was found that the maximum fresh weight of leaf (32.00 g) was obtained from the treatment combination of S_2M_1 followed by S_2M_2. The minimum fresh weight of leaf (16.32 g) was obtained from the treatment combination of S_1M_0 which was nearest to the treatment combination of S_1M_3.

4.4 Fresh weight of root

The fresh weight of root per plant was significantly differed due to different sowing time of garlic (Table 3 and Appendix VII). Results revealed that the

highest fresh weight of root (0.72 g) was obtained from the S_2 (10 November) treatment followed by S_3 (30 November) treatment. The lowest fresh weight of root (0.512 g) was obtained from the S_1 (20 October) treatment. Similar result was also found by Shahidur Rahman *et al.* (2004).

Application of different mulching practices showed significantly influence on the fresh root weight of garlic (Table 3 and Appendix VII). Significantly highest fresh weight of root (0.733 g) was obtained from the M_2 (water hyacinth) treatment which was statistically identical with M_1 (black polythene) where the lowest fresh weight of root (0.482 g) was obtained from the mulch treatment, M_0 (Control). Hassan (1999), Iroc *et al*., (1991) and Rekowska and Skupien, (2007) also found similar results compared to the present study.

Fresh weight of root differed significantly by combined effect of sowing time and mulching (Table 3 and Appendix VII). The highest fresh weight of root (0.910 g) was obtained from the treatment combination of S_2M_1 followed by S_2M_2 (0.806 g) treatment. The lowest fresh weight of root (0.430 g) was obtained from the treatment combination of S_1M_0 which was closely followed S_1M_3, S_2M_0 and S_3M_0 treatment combination respectively.

4.5 Fresh weight of bulb

From the present research work, it was found that the significant variation among the treatments in respect of fresh weight of bulb due to different sowing time (Table 3 Appendix VII) . It was found that the maximum fresh weight of bulb (16.08 g) per plant was obtained from the S_2 (10 November) treatment followed by S_3 (30 November) treatment where the lowest fresh weight of bulb (14.08 g) was obtained from the S_1 (20 October) treatment. It might be due to the fact that long growing period, prevailing cool temperature and short day during growing stage have increasing the vegetative growth which contributed to increase the bulb weight 10 November sowing .High temperature and long day are not good for

proper bulb formation. Therefore early sowing garlic produced smaller bulbs resulting in the lowest fresh weight. The findings obtained from Shahidur Rahman *et al.* (2004), Mosleh Ud-Deen (2008) and Pratibha singh *et al.*, (2010) was similar with the present study.

Application of different mulching treatments showed significant variation in respect of fresh weight of bulb of garlic (Table 3 and Appendix VII). Results signified that the highest fresh weight of bulb (17.69 g) was obtained from M_1 (Black polythene) treatment followed by M_2 (16.28 g) (Water hyacinth) treatment. The lowest fresh weight of bulb (11.14 g) was obtained from the M_0 (Control) treatment. The reason higher fresh weight of bulb per plant due to the sufficient soil moisture content which make availability of soil nutrients and supported proper vegetative growth by producing succulent bulb with more protoplasm in the cell and ultimately increasing bulb fresh weight than unmulched plant. Similar observation was also found by Kabir *et al*. (2016) and Jamil *et al*. (2005).

Combined effect of sowing time and mulching showed significant variation on fresh weight of bulb of garlic (Table 3 and Appendix VII). The highest fresh weight of bulb (19.57 g) was obtained from the treatment combination of S_2M_1 (10 November sowing with Black polythene) followed by S_2M_2. The lowest fresh weight of bulb (10.66 g) was obtained from the treatment combination of S_1M_0 which was statistically similar with S_3M_0.

Table 3. Fresh weight of leaf, root and bulb of garlic influenced by different Sowing time and mulching and their combination

Treatments	Fresh weight (g)		
	Fresh weight of leaf	Fresh weight of root	Fresh weight of bulb
Effect of sowing time			
S_1	20.35 c	0.512 c	14.08 c
S_2	25.49 a	0.720 a	16.08 a
S_3	22.35 b	0.642 b	14.66 b
$LSD_{(0.05)}$	0.46	0.069	0.29
CV (%)	7.45	11.68	8.62
Effect of mulching			
M_0	19.82 c	0.482 c	11.14 d
M_1	27.94 a	0.711 a	17.69 a
M_2	23.23 b	0.733 a	16.28 b
M_3	19.93 c	0.621 b	14.65 c
$LSD_{(0.05)}$	0.54	0.102	0.34
CV (%)	7.45	11.68	8.62
Combined effect of sowing time and mulching			
S_1M_0	16.32 j	0.430 i	10.66 g
S_1M_1	26.03 c	0.613 f	17.38 b
S_1M_2	20.07 gh	0.530 g	16.27 c
S_1M_3	19.00 i	0.503 h	14.33 e
S_2M_0	21.13 ef	0.510 h	11.55 f
S_2M_1	32.00 a	0.910 a	19.57 a
S_2M_2	27.93 b	0.806 b	17.90 b
S_2M_3	20.77 fg	0.653 e	15.30 d
S_3M_0	22.34 d	0.506 h	11.20 fg
S_3M_1	25.81 c	0.610 f	16.13 c
S_3M_2	21.72 de	0.773 c	14.66 e
S_3M_3	19.71 hi	0.706 d	14.32 e
$LSD_{0.05}$	0.93	0.016	0.58
CV (%)	7.45	11.68	8.62

Means in a column followed by the same letter do not differ significantly at 5% level S_1 = 20 October, S_2 =10 November, S_3 = 30 November

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

4.6 Leaf dry weight

Different sowing time showed significant influence on leaf dry weight of garlic (Table 4 and Appendix VIII). It was observed that the highest leaf dry weight (5.28 g) was obtained from the S_2 (10November) treatment where the lowest leaf dry weight (4.32 g) was obtained from the S_1 (20 October) treatment which was statistically identical with S_3 (30 November, 2016). The results obtained from the present study was conformity with the findings of Shahidur Rahman *et al.* (2004) and Rahim *et al. (2003)*

Application of different mulching treatment showed significant variation on leaf dry weight of garlic (Table 4 and Appendix VIII). Results revealed that the highest leaf dry weight (6.47 g) was obtained from the M_1 (Black polythene) treatment followed by M_2 (4.69) (Water hyacinth) treatment where the lowest leaf dry weight (3.72 g) was obtained from the M_0 (Control) treatment. The results obtained from the findings of Shahidur Rahman *et al.* (2004) supported the present study.

Combined effect of sowing time and mulching showed significant variation on leaf dry weight of garlic (Table 4 and Appendix VIII). It was indicated that the highest leaf dry weight (6.71 g) was obtained from the treatment combination of S_2M_1 (10 November sowing time with black polythene mulch) followed by S_2M_2. Where the lowest leaf dry weight (3.33 g) was obtained from the treatment combination of S_1M_0 (20 October sowing with no mulch treatment).

4.7 Root dry weight

Significant variation was observed on root dry weight of garlic affected by different sowing time (Table 4 and Appendix VIII). Results exhibited that the highest root dry weight (0.21 g) was obtained from the S_2 (10 November) treatment where the lowest root dry weight (0.170 g) was obtained from the S_1 (20

October) treatment which was statistically identical with S_3 (30 November) treatment. Shahidur Rahman *et al.* (2004) also found similar results that supported the present study.

Root dry weight of garlic was significantly varied with the application of mulching (Table 4 and Appendix VIII). The highest root dry weight (0.22 g) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth) (0.17 g) treatment and M_3 (Rice straw) (0.17g) treatment where the lowest root dry weight (0.16 g) was obtained from the M_0 (Control) treatment. Similar results was also observed by Hassan (1999)

Combined effect of sowing time and mulching showed significant variation on root dry weight of garlic (Table 4 and Appendix VIII). It was exposed that the highest root dry weight (0.26 g) was obtained from the treatment combination of S_2M_1 followed by S_2M_2 and S_1M_1. The lowest root dry weight (0.13 g) was obtained from the treatment combination of S_1M_0.

4.8 Bulb dry weight

Bulb dry weight of garlic was significantly influenced by different sowing time of garlic (Table 4 and Appendix VIII). It was found that the highest bulb dry weight (4.50 g) was obtained from the S_2 (10 November) treatment followed by S_1 (20 October) treatment where the lowest bulb dry weight (3.61 g) was obtained from the S_3 (30 November) treatment. The result found from the present study was similar with the findings of Adekpe *et al.* (2008).

A significant variation on the bulb dry weight of garlic was found (Table 4 and Appendix VIII). Results indicated that the highest bulb dry weight (4.88 g) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth treatment). The lowest bulb dry weight (2.36 g) was obtained from the

M_0 (Control) treatment. Similar results was also observed by Hassan (1999), Mia (1996) and Hossain (1996).

Combined effect of sowing time and mulching showed significant variation on bulb dry weight of garlic (Table 4 and Appendix VIII). It was shown that the highest bulb dry weight (5.26 g) was obtained from the treatment combination of S_2M_1 (10 November sowing with Black polythene mulch followed by S_1M_1 and S_2M_2. The lowest bulb dry weight (2.07 g) was obtained from the treatment combination of S_3M_0 (30 November sowing with no mulch) which was close to S_1M_0.

4.9 Bulb diameter

Different sowing time showed significant influence on bulb diameter of garlic (Table 5 and Appendix IX). The highest bulb diameter (2.97 cm) was obtained from the S_2 (10 November) treatment followed by S_1 (20 October) treatment and the lowest bulb diameter (2.59 cm) was obtained from the sowing time, S_3 (30 November) treatment. It was probably due to the fact that 10 November sowing crops possibly got favourable condition for better growth than those of other sowig date This findings are in aggrement with the findings of many authors (Rahim *et al* ., (1984).

The bulb diameter of garlic varied significantly due to the application ofdifferent mulching (Table 5 and Appendix IX). The highest bulb diameter (3.17 cm) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth) treatment where the lowest bulb diameter (2.36 cm) was obtained from the mulch treatment, M_0 (Control) treatment. This is probally due to the fact that black polythene maintained higher moister content provide winter protection by increasing soil temperature and keep the soil aerated by reducing soil compaction than unmulched soil which ultimately helped in increasing bulb diameter of garlic.

Similar result was also achieved by Iroc *et al*., 1991, Baten *et al.* (1995) and Hossain (1996).

Bulb diameter of garlic differed significantly by combined effect of sowing time and mulching (Table 5 and Appendix IX). The highest bulb diameter (3.36 cm) was obtained from the treatment combination of S_2M_1 (10 November sowing with Black polythene mulch) which was statistically similar with S_1M_1. The lowest bulb diameter (2.21 cm) was obtained from the treatment combination of S_3M_0 (30 November with no mulch) which was statistically identical with S_1M_0.

4.10 Number of cloves per bulb

Number of cloves per bulb varied significantly due to different sowing time (Table 5 and Appendix IX). Results demonstrated that the highest number of cloves bulb^{-1} (22.08) was recorded from the S_2 (10 November) treatment where the lowest number of cloves bulb^{-1} (17.83) was obtained from the S_1 (20 October) treatment which was statistically identical to S_3 (30 November) treatment. Uddin, (1997) was also found similar results with the present investigation.

Table 4. Dry weight of leaf, root and bulb garlic influenced by different sowing Time and mulching combination

Treatments	Dry weight (g)		
	Leaf	Root	Bulb
Effect of sowing time			
S_1	4.32 b	0.17 b	3.96b
S_2	5.28 a	0.21 a	4.50 a
S_3	4.34 b	0.17 b	3.61 c
$LSD_{0.05}$	0.07	0.028	0.029
CV (%)	11.43	10.58	7.54
Effect of mulching			
M_0	3.72 d	0.16 c	2.36 d
M_1	6.47 a	0.22 a	4.88 a
M_2	4.69 b	0.18 b	4.54 b
M_3	3.98 c	0.17b	4.31 c
$LSD_{0.05}$	0.08	0.011	0.034
CV (%)	11.43	10.58	7.54
Combined effect of sowing time and mulching			
S_1M_0	3.33 h	0.13 h	2.13 i
S_1M_1	5.83 c	0.20 b	4. b
S_1M_2	4.17 ef	0.18 de	4.463 d
S_1M_3	4.06 f	0.16 fg	4.273 e
S_2M_0	4.23 e	0.18 e	2.87 h
S_2M_1	6.71 a	0.26 a	5.26 a
S_2M_2	6.16 b	0.20b	4.99b
S_2M_3	3.73 g	0.19 cd	4.87 c
S_3M_0	3.78 g	0.17ef	2.07 j
S_3M_1	5.56 d	0.19 bc	4.41 d
S_3M_2	3.77 g	0.15 g	4.16 f
S_3M_3	4.13 ef	0.17 ef	3.79 g
$LSD_{0.05}$	0.14	0.011	0.058
CV (%)	11.43	10.58	7.54

Means in a column followed by the same letter do not differ significantly at 5% level S_1 = 20 October S_2 =10 November S_3 = 30 November

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

Application of mulching practices showed significant variation on number of cloves per bulb of garlic (Table 5 and Appendix IX). The highest number of cloves per bulb (22.22) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth) treatment and M_3 (Rice straw) where the lowest number of cloves per bulb (16.55) was obtained from the M_0 (Control)treatment. Baten *et al.* (1995) also made similar observation with the present study.

Number of cloves bulb^{-1} differed significantly by combined effect of sowing time and mulching (Table 5 and Appendix IX). It was found that the highest number of cloves per bulb (25.33) was recorded from the treatment combination of S_2M_1 (10 November sowing with Black polythene mulch) followed by S_2M_2 where the lowest number of cloves per bulb (15.33) was obtained from the treatment combination of S_1M_0 (20 October sowing with no mulch) which was statistically identical with S_3M_0 and S_3M_3 and statistically similar with S_1M_2.

4.11 Fresh weight of bulb/ plant

Different sowing time showed significant influence on fresh weight of bulb per plant of garlic (Table 5 and Appendix IX). Results exposed that the highest yield per plant (21.90 g) was obtained from the S_2 (10November) treatment followed by S_1 (20 October) treatment where the lowest yield per plant (17.67 g) was obtained from the time S_3 (30 November) treatment.

Different mulching practices showed significant variation on yield per plant of garlic (Table 5 and Appendix IX). It was observed that the highest yield per plant (22.20 g) was obtained from the M_1 (Black polythene) followed by M_2 (Water hyacinth) treatment where the lowest yield per plant (17.11 g) was obtained from the M_0 (Control) treatment which was statistically identical to M_3 (Rice straw) treatment.

Combined effect of sowing time and mulching showed significant variation on yield per plant of garlic (Table 5 and Appendix IX). Results revealed that the

highest yield per plant (27.93 g) was obtained from the treatment combination of S_2M_1 (10 November sowing with Black polythene mulch) followed by S_2M_2. The lowest yield per plant (16.33 g) was obtained from the treatment combination of S_3M_0 (30 November with no mulch) which was statistically similar with S_1M_3 and S_2M_0.

4.12 **Yield / plot**

Different sowing time showed significant influence on yield per plot of garlic (Table 5 and Appendix IX). Results indicated that the highest yield per plot (0.842 kg) was obtained from the S_2 (10 November) treatment followed by S_1 (20 October) treatment where the lowest yield per plot (0.419 kg) was obtained from the S_3 (30 November) treatment.

Different mulching practices showed significant variation on yield/ plot of garlic (Table 5 and Appendix IX). It was indicated that the highest yield per plot (0.526 kg) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth) treatment. The lowest yield $plot^{-1}$ (0.334 kg) was obtained from the M_0 (Control) treatment

Yield per plot of garlic differed significantly by combined effect of sowing time and mulching (Table 5 and Appendix IX). It was found that the highest yield per plot (0.587 kg) was obtained from the treatment combination of S_2M_1 (10 November sowing with Black polythene mulch) followed by S_1M_1 and S_2M_2. The lowest yield per plot (0.320 kg) was obtained from the treatment combination of S_3M_0 (30 November sowing with no mulch) which was statistically similar with S_1M_0.

4.13 Yield / **ha**

Yield per ha of garlic was significantly influenced by different sowing time at different growth stages (Table 5 and Appendix IX). It was observed that the highest yield per ha (4.35 t) was recorded from the S_2 (10 November) treatment followed by S_1 (20 October) where the lowest yield per ha (3.80 t) was obtained from S_3 (30 November) treatment. The plant of 10 November sowing better growth due to larger period of growth under favourable climate condition, the better growth of crop contributed to increase the bulb size and number of clove which ultimately gave the higher yield of bulbs. Yield decreased incase of late sowing. The result obtained from the present study was conformity with the findings of Bhuiya *et al.* (2003), Rahim *et al.* (2003) and Mosleh Ud-Deen (2008).

Different mulching practices showed significant variation on yield per ha of garlic at different growth stages (Table 5 and Appendix IX). Results indicated that the highest yield per ha (4.77 t) was obtained from the M_1 (Black polythene) treatment followed by M_2 (Water hyacinth) treatment. The lowest yield per ha (3.00 t) was obtained from the M_0 (Control) treatment. The results also achieved by Kabir *et al*. (2016), Mahdieh *et al*. (2012), Jamil *et al*. (2005) and Wolde (2014) was similar with the present study.

Yield/ ha of garlic differed significantly by combined effect of sowing time and mulching (Table 5 and Appendix IX). The results exhibited that the highest yield / ha (5.28 t) was obtained from the treatment combination of S_2M_1 (10 November sowing with Black polythene mulch followed by S_2M_2. Again, the lowest yield per ha (2.88 t) was obtained from the treatment combination of S_3M_0 (30 November sowing with no mulch) which was statistically similar with S_1M_0.

Table 5. Yield attributes and yields of garlic influenced by different sowing Time and mulching combination

Treatments	Yield attributes and yield				
	Bulb diameter (cm)	Number of cloves per bulb	Fresh weight of bulb /plant (g)	Yield / plot (kg)	Yield / ha (t)
Effect of sowing time					
S_1	2.71 b	17.83 b	19.00 b	0.449 b	3.95 b
S_2	2.97 a	22.08 a	21.90 a	0.482 a	4.35 a
S_3	2.59 c	18.00 b	17.67 c	0.419 c	3.80 c
$LSD_{0.05}$	0.09	0.68	0.73	0.028	0.08
CV (%)	9.27	9.56	12.87	12.87	11.74
Effect of mulching					
M_0	2.36 d	16.55 c	17.11 c	0.334 d	3.00 d
M_1	3.17 a	22.22 a	22.20 a	0.526 a	4.77 a
M_2	2.93 b	19.33 b	20.88 b	0.488 b	4.42 b
M_3	2.55 c	19.11 b	17.89 c	0.439 c	3.95 c
$LSD_{0.05}$	0.10	0.78	0.84	0.010	0.09
CV (%)	9.27	9.56	12.87	12.87	11.74
Combined effect of sowing time and mulching					
S_1M_0	2.22 g	15.33 h	18.00 de	0.336 fg	3.03 gh
S_1M_1	3.23 ab	21.00 cd	19.00 cd	0.521 b	4.69 c
S_1M_2	2.77 de	16.67 gh	18.00 de	0.488 c	4.39 d
S_1M_3	2.51 f	19.00 ef	16.67 ef	0.430 e	3.87 f
S_2M_0	2.65 ef	18.00 fg	17.00 ef	0.346 f	3.12 g
S_2M_1	3.36 a	25.33 a	27.93 a	0.587 a	5.28 a
S_2M_2	3.05 bc	23.00 b	25.33 b	0.537 b	4.90 b
S_2M_3	2.94 cd	22.00 bc	18.00 de	0.459 d	4.13 e
S_3M_0	2.21 g	16.33 h	16.33 f	0.320 g	2.88 h
S_3M_1	2.97 c	20.33 de	19.67 c	0.472 cd	4.35 d
S_3M_2	2.96 c	18.33 f	19.33 cd	0.440 e	3.96 f
S_3M_3	2.21 g	16.33 h	19.00 cd	0.429 e	3.86 f
$LSD_{0.05}$	0.18	1.36	1.46	0.018	0.16
CV (%)	9.27	9.56	12.87	12.87	11.74

Means in a column followed by the same letter do not differ significantly at 5% level S_1 = 20 October S_2 = November S_3 = 30 November

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

4.14 Performance on economic return

4.14.1 Cost of production

Different treatment combination showed major differences in terms of cost of production of garlic (Table 6 and Appendix X). The highest cost of production (228,091 Tk/ha) was obtained from S_1M_1, S_2M_1 and S_3M_1 where the second highest cost of production of garlic (222,541 Tk/ha) was obtained from S_1M_3, S_2M_3 and S_3M_3. The lowest cost of production (194,791 Tk/ha) was recorded from S_1M_0, S_2M_0 and S_3M_0.

4.14.2 Gross return

In case of gross return, different treatment combination showed considerable gross return (Table 6). The highest gross return (396000 Tk/ha) was obtained from S_2M_1 where the second highest gross return (367500 Tk/ha) was obtained from S_2M_2. The lowest gross return (216000 Tk/ha) was recorded from S_3M_0 followed by S_1M_0 (227250 Tk/ha).

4.14.3 Net return

Different treatment combinations showed large differences in terms of net return (Appendix X and Table 6). The highest net return (167,909 Tk/ha) was obtained from S_2M_1 followed by S_2M_2 (152,729 Tk/ha). The lowest net return (21,209 Tk/ha) was recorded from S_3M_0 which was close to S_1M_0 (32,459 Tk/ha).

4.14.4 Benefit cost ratio (BCR)

Different treatment combination showed imperative differences on benefit cost ratio regarding garlic production (Appendix X and Table 6). Results indicated that the highest benefit cost ratio (1.74) was obtained from S_2M_1 followed by S_2M_2 (1.71) where the lowest benefit cost ratio (1.11) was recorded from S_3M_0. The results also obtained from S_1M_1, S_1M_2, S_3M_1 and S_3M_2also gave promising results in terms of BCR but lower than the highest results.

Table 6. Cost and return of garlic cultivation as influenced by combination of different Sowing time and mulching

Treatment	Cost of production (Tk/ha)	Yield of garlic (t/ha)	Gross return (Tk/ha)	Net return (Tk/ha)	Benefit cost ratio
S_1M_0	194,791	3.03	227250	32,459	1.17
S_1M_1	228,091	4.69	351750	123,659	1.54
S_1M_2	214,771	4.39	329250	114,479	1.53
S_1M_3	222,541	3.87	290250	67,709	1.30
S_2M_0	194,791	3.12	234000	39,209	1.20
S_2M_1	228,091	5.28	396000	167,909	1.74
S_2M_2	214,771	4.9	367500	152,729	1.71
S_2M_3	222,541	4.13	309750	87,209	1.39
S_3M_0	194,791	2.88	216000	21,209	1.11
S_3M_1	228,091	4.35	326250	98,159	1.43
S_3M_2	214,771	3.96	297000	82,229	1.38
S_3M_3	222,541	3.86	289500	66,959	1.30

Means in a column followed by the same letter do not differ significantly at 5% level S_1 = 20 October, S_2 = November, S_3 = 30 November,
M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw

Sale of marketable seed @ Tk . 60,000/ton

Net return =Gross return –Total cost of production

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

3,96,000/2,28,091=1.74

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was carried out at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the period from November 2015 to March 2016 to study the effect of sowing time and mulching on growth and yield of garlic. The experiment comprised of three levels of sowing time *viz*., S_1 = 20 October S_2 = 10 November S_3 = 30 November and four levels of mulching *viz*., M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw. Thus there were twelve treatment combinations and the experiment was laid out in randomized complete block design with three replications.

All the growth parameters like plant height, number of leaves, fresh weight of leaf, fresh weight of root, fresh weight of bulb, leaf dry weight, root dry weight, bulb dry weight, bulb diameter, number of cloves / bulb, yield / plant (g), yield / plot (kg), and yield / ha (t) varied significantly due to sowing time and mulching.

In case of studied parameters regarding sowing time; the highest plant height (25.83, 34.50, 48.58, 43.25 cm) and number of leaves per plant (4.60, 6.00, 7.25 and 5.83) at 30, 60, 90 DAS and at harvest respectively were obtained from the sowing time, S_2 (10 (November). The highest fresh weight of leaf (25.49 g), fresh weight of root (0.72 g), fresh weight of bulb (16.08 g), leaf dry weight (5.28 g), root dry weight (0.210 g), bulb dry weight (4.50 g), bulb diameter (2.97 cm), number of cloves $bulb^{-1}$ (22.08), yield per plant (21.90 g), yield per plot (0.842 kg) and yield per ha (4.35 t) were also obtained from the sowing time, S_2 (10 November). Again, the lowest plant height (22.91, 31.33, 44.46, and 38.00 cm at 30, 60, 90 DAS and at harvest respectively) was obtained from the sowing time, S_1 (20 October) and this sowing time also showed lowest fresh weight of leaf (20.35 g), fresh weight of root (0.512 g), fresh weight of bulb (14.08 g), leaf dry weight

(4.32 g), root dry weight (0.171 g) and number of cloves bulb^{-1} (17.83). But the lowest number of leaves per plant (3.67, 5.16, 5.97 and 4.58 at 30, 60, 90 DAS and at harvest respectively) was obtained from the sowing time, S_3 (30 November). The lowest bulb dry weight (3.61 g), bulb diameter (2.59 cm), yield per plant (17.67 g), yield per plot (0.419 kg) and yield per ha (3.80 t) were also obtained from the sowing time, S_3 (30 November).

Considering mulching treatments, the highest plant height (27.11, 36.11, 50.00 and 44.11 cm) and number of leaves per plant (5.33, 6.44, 7.22 and 5.89) at 30, 60, 90 DAS and at harvest respectively were obtained from the mulch treatment, M_1 (Black polythene). The highest fresh weight of leaf (27.94 g), fresh weight of root (0.711 g), fresh weight of bulb (17.69 g), leaf dry weight (6.47 g), root dry weight (0.222 g), bulb dry weight (4.88 g), bulb diameter (3.17 cm), number of cloves bulb^{-1} (22.22), yield per plant (22.20 g), yield per plot (0.526 kg) and yield per ha (4.77 t) were also obtained from the mulch treatment, M_1 (Black polythene). Whereas the lowest plant height (21.22, 30.67, 41.78 and 39.35 cm at 30, 60, 90 DAS and at harvest respectively), number of leaves per plant (3.44, 5.00, 5.67 and 4.44 at 30, 60, 90 DAS and at harvest respectively), fresh weight of leaf (19.82 g), fresh weight of root (0.482 g), fresh weight of bulb (11.14 g), leaf dry weight (3.72 g), root dry weight (0.162 g), bulb dry weight (2.36 g), bulb diameter (2.36 cm), number of cloves per bulb (16.55), yield per plant (17.11 g), yield per plot(0.334 kg) and yield per ha (3.00 t) were obtained from the control treatment, M_0 (Control).

In terms of combined effect of sowing time and mulching treatment; The highest plant height (30.00, 41.33, 56.33 and 50.66 cm) and number of leaves per plant (30.00, 41.33, 56.33 and 50.66) at 30, 60, 90 DAS and at harvest respectively were obtained from the treatment combination of S_2M_1. This treatment combination (S_2M_1) also showed highest fresh weight of leaf (32.00 g), fresh weight of root

(0.910 g), fresh weight of bulb (19.57 g) leaf dry weight (6.71 g), root dry weight (0.263 g), bulb dry weight (5.26 g), bulb diameter (3.36 cm), number of cloves bulb^{-1} (25.33), yield plant^{-1} (27.93 g), yield plot^{-1} (0.587 kg) and yield ha^{-1} (5.28 t). The lowest plant height (18.33, 27.67, 41.33 and 37.67 cm at 30, 60, 90 DAS and at harvest respectively), fresh weight of leaf (16.32 g), fresh weight of root (0.430 g), fresh weight of bulb (10.66 g), leaf dry weight (3.33 g), root dry weight (0.137 g) and number of cloves bulb^{-1} (15.33) were obtained from the treatment combination of S_1M_0. But the lowest number of leaves per plant (18.33, 27.67, 41.33 and 37.67 at 30, 60, 90 DAS and at harvest respectively), bulb dry weight (2.08 g), bulb diameter (2.21 cm), yield per plant (16.33 g), yield per plot (0.320 kg) and yield per ha (2.88 t) were obtained from the treatment combination of S_3M_0.

Considering economic performance, the highest cost of production (228,091 Tk/ha) was obtained from S_1M_1, S_2M_1 and S_3M_1 where the lowest cost of production of (194,791 Tk/ha) was recorded from S_1M_0, S_2M_0 and S_3M_0. The highest gross return (396000 Tk/ha), net return (167,909 Tk/ha) and BCR (1.74) were obtained from S_2M_1 where the lowest gross return (216000 Tk/ha), net return (21,209 Tk/ha) and BCR (1.11) was recorded from S_3M_0.

The result of the experiment revealed that

1. The sowing time S_2 (10 November) showed best vegetative growth and yield of garlic.
2. Black polythene (M_1) as mulch materials gave best results for both vegetative growth and yield of garlic.
3. Based on the findings of the experiment, it can be concluded that for getting maximum production of garlic the clove should be sowing 10 November with application of black polythene mulch as an alternative to irrigation

4. In terms of economic performance, combination of the sowing time S_2 (10 November) and black polythene (M_1) as mulch materials gave best results regarding gross return, net return and benefit cost ration (BCR).

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

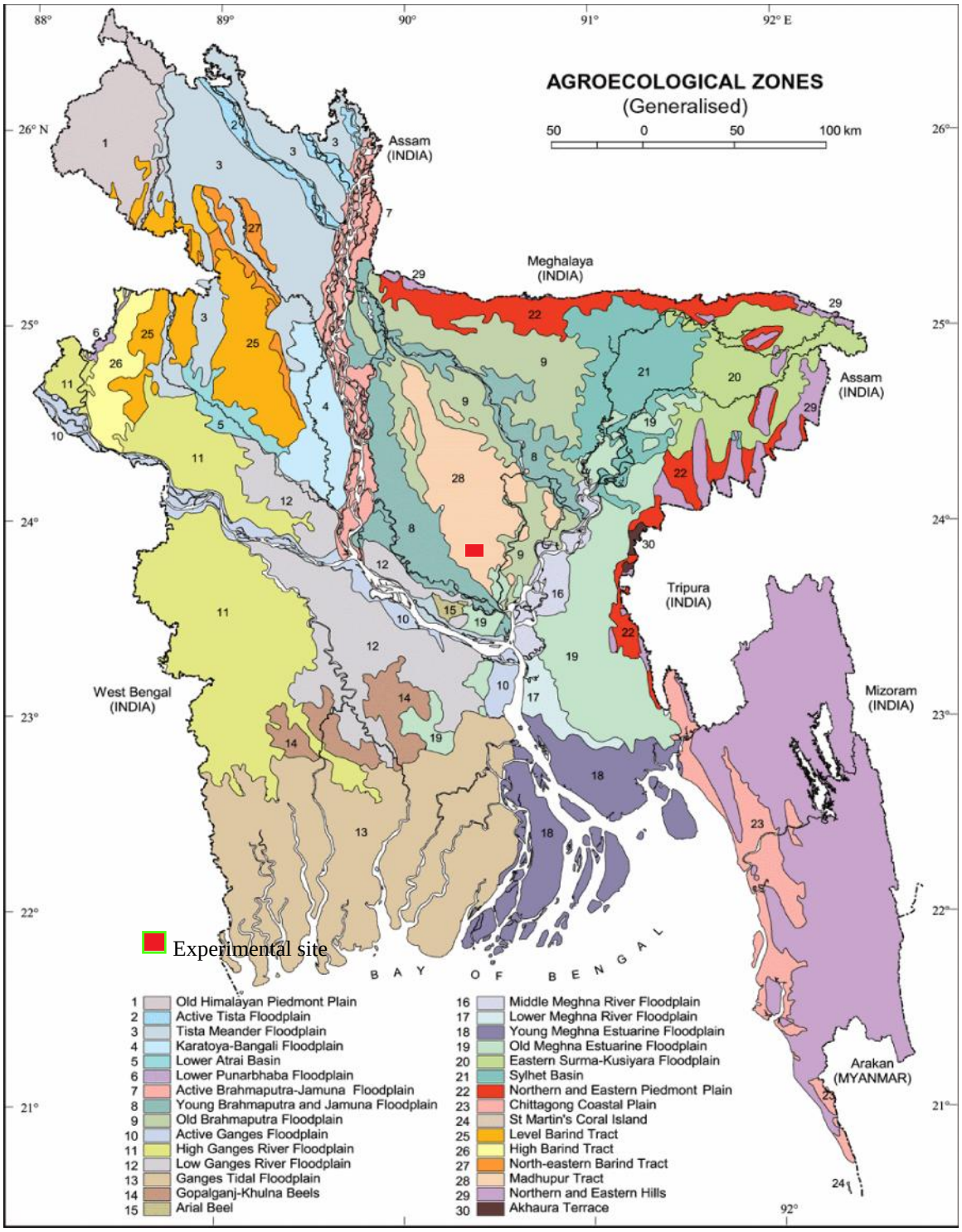


Fig. 9. Experimental site

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from March to June, 2017

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
2016	November	28.60	8.52	18.56	56.75	14.40
2016	December	25.50	6.70	16.10	54.80	0.0
2017	January	23.80	11.70	17.75	46.20	0.0
2017	February	22.75	14.26	18.51	37.90	0.0
2017	March	35.20	21.00	28.10	52.44	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

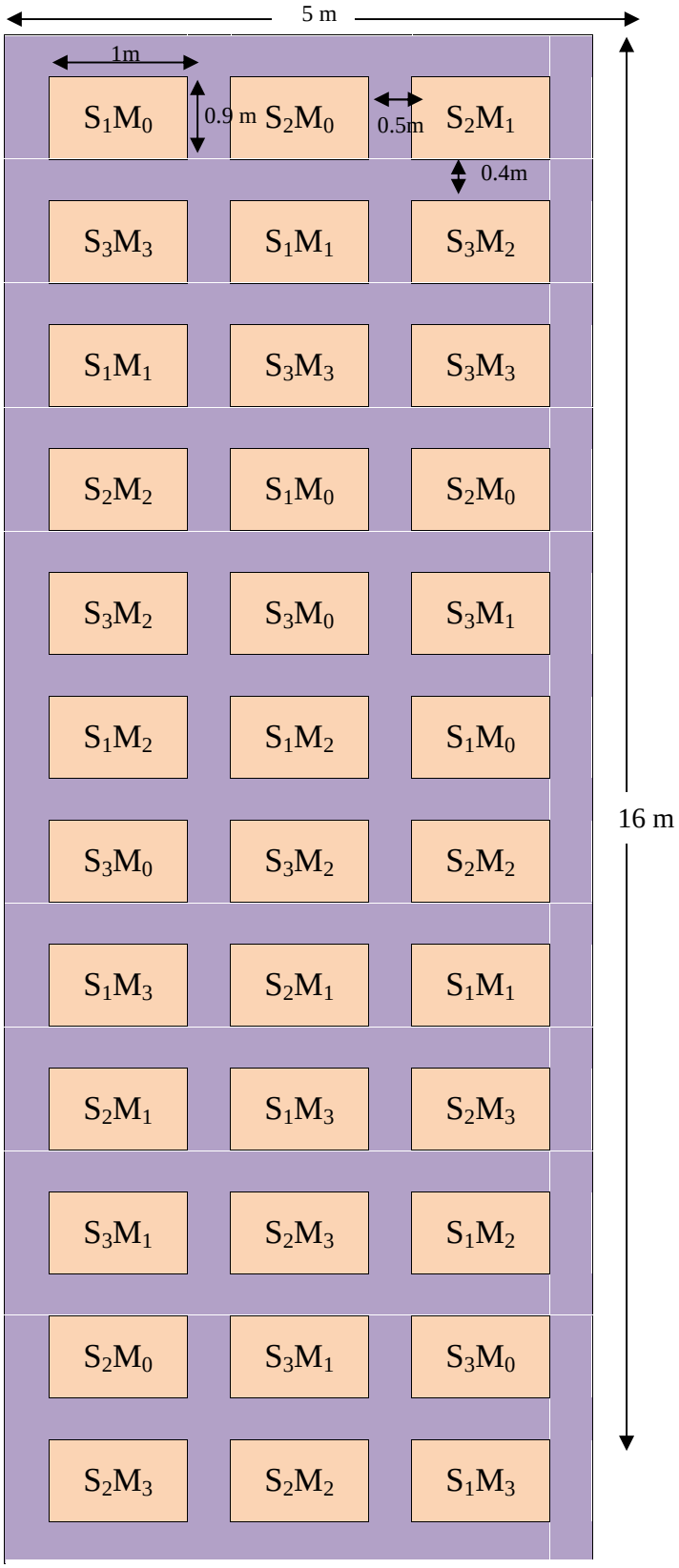
Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (µ gm/gm)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV. Layout of the experiment field



Plot Size: 1 m×0.9 m

Spacing: 20 cm×15 cm

Spacing between plot: 0.4 m

Spacing between block: 0.5 m

Fig. 10. Layout of the experiment field

Appendix V. Analysis of variance of data on plant height at different after sowing

Source of variation	Degrees of freedom	Mean square of plant height			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	5.533	66.809	0.353	0.486
Factor A	2	57.377**	88.242**	7.767**	13.380**
Factor B	3	16.576**	95.986**	12.098**	17.015**
AB	6	31.049*	67.771*	4.026*	12.704*
Error	22	11.566	21.538	1.152	4.713

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

Appendix VI. Analysis of variance of data on number of leaves/plant at different days after mulching

Source of variation	Degrees of freedom	Mean square of number of leave/ plant			
		30 DAS	60 DAS	90 DAS	At harvest
Replication	2	3.021	0.787	8.902	20.701
Factor A	2	26.481*	44.896**	87.875**	94.121**
Factor B	3	29.095*	49.280**	85.623**	104.005**
A ×B	6	22.282*	19.005*	55.516*	78.951*
Error	22	7.458	6.046	17.932	31.059

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

Appendix VII. Analysis of variance of data on fresh weight of leaf, root and bulb of garlic

Source of variation	Degrees of freedom (df)	Mean square of fresh weight (g)		
		Fresh weight of leaf (g)	Fresh weight of root (g)	Fresh weight of bulb (g)
Replication	2	249.51	0.041	0.021
Factor A	2	1406.03**	1.262*	6.195**
Factor B	3	5201.43**	4.093**	9.876**
A ×B	6	411.14*	1.406*	3.697*
Error	22	132.67	0.643	1.005

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

Appendix VIII. Analysis of variance of data on dry weight of leaf, root and bulb of garlic

Source of variation	Degrees of freedom (df)	Mean square of		
		Leaf dry weight (g)	Root dry weight (g)	Bulb dry weight (g)
Replication	2	2.108	5.472	2.290
Factor A	2	64.250**	101.372**	29.637**
Factor B	3	75.811**	125.430**	24.808**
A ×B	6	35.811*	61.426*	19.771*
Error	22	23.237	21.988	7.142

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

Appendix IX. Analysis of variance of data on yield of garlic

Source of variation	Degrees of freedom	Mean square of yield				
		Bulb diameter	Number of cloves bulb^{-1}	Yield plant^{-1}	Yield plot^{-1}	Yield ha^{-1}
Replication	2	9.991	443.5	4.382	0.011	0.103
Factor A	2	97.014**	2409.3**	63.332**	0.614*	4.361**
Factor B	3	12.570**	45510.2**	51.010**	1.022**	7.529**
A ×B	6	44.302*	6428.8**	49.268**	0.436*	2.366*
Error	22	15.549	535.4	3.018	0.016	0.307

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

Appendix X. Cost of production ha $^{-1}$

A. Input cost

Treatment combination	Labour cost	Ploughing cost	Seed cost	Mulching cost	Manure and fertilizers				Insecticide/ pesticides	Sub-total (A)
					Cowdung	Urea	TSP	MP		
S_1M_0	32,000	18,000	60,000	0	12500	4336	6,675	5328	8,000	146,839
S_1M_1	32,000	18,000	60,000	30000	12500	4336	6,675	5328	8,000	176,839
S_1M_2	32,000	18,000	60,000	18000	12500	4336	6,675	5328	8,000	164,839
S_1M_3	32,000	18,000	60,000	25000	12500	4336	6,675	5328	8,000	171,839
S_2M_0	32,000	18,000	60,000	0	12500	4336	6,675	5328	8,000	146,839
S_2M_1	32,000	18,000	60,000	30,000	12500	4336	6,675	5328	8,000	176,839
S_2M_2	32,000	18,000	60,000	18,000	12500	4336	6,675	5328	8,000	164,839
S_2M_3	32,000	18,000	60,000	25,000	12500	4336	6,675	5328	8,000	171,839
S_3M_0	32,000	18,000	60,000	0	12500	4336	6,675	5328	8,000	146,839
S_3M_1	32,000	18,000	60,000	30,000	12500	4336	6,675	5328	8,000	176,839
S_3M_2	32,000	18,000	60,000	18,000	12500	4336	6,675	5328	8,000	164,839
S_3M_3	32,000	18,000	60,000	25,000	12500	4336	6,675	5328	8,000	171,839

Appendix X . Cost of production ha $^{-1}$ (cont'd)

B. Overhead cost (Tk./ha) (Total cost of production, Gross return, Net return and BCR)

Treatment combination	Cost of lease of land (Tk.14% of value of land cost/year)	Miscellaneous cost (Tk. 5% of the input cost	Interest on running capital for 6 months (Tk. 12% of cost/year)	Sub-total (Tk.) (B)	Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)] (Tk/ha)	Gross return (Tk/ha)	Net return (Tk/ha)	Benefit cost ratio (BCR)
S_1M_0	30,000	7,342	10,610	47,952	194,791	227250	32,459	1.17
S_1M_1	30,000	8,842	12,410	51,252	228,091	351750	123,659	1.54
S_1M_2	30,000	8,242	11,690	49,932	214,771	329250	114,479	1.53
S_1M_3	30,000	8,592	12,110	50,702	222,541	290250	67,709	1.30
S_2M_0	30,000	7,342	10,610	47,952	194,791	234000	39,209	1.20
S_2M_1	30,000	8,842	12,410	51,252	228,091	396000	167,909	1.74
S_2M_2	30,000	8,242	11,690	49,932	214,771	367500	152,729	1.71
S_2M_3	30,000	8,592	12,110	50,702	222,541	309750	87,209	1.39
S_3M_0	30,000	7,342	10,610	47,952	194,791	216000	21,209	1.11
S_3M_1	30,000	8,842	12,410	51,252	228,091	326250	98,159	1.43
S_3M_2	30,000	8,242	11,690	49,932	214,771	297000	82,229	1.38
S_3M_3	30,000	8,592	12,110	50,702	222,541	289500	66,959	1.30

S_1 = 20 October, S_2 = 10 November, S_3 = 30 November

M_0 = Control, M_1 = Black polythene, M_2 = Water hyacinth, M_3 = Rice straw