INFLUENCE OF PLANTS PER HILL AND HARVESTING TIME ON GROWTH, YIELD AND ECONOMIC BENEFIT OF ONION

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*This is to certify that thesis entitled, "**INFLUENCE OF PLANTS PER HILL AND HARVESTING TIME ON GROWTH, YIELD AND ECONOMIC BENEFIT OF ONION"** 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 **MD. HABIBUR RAHMAN MOLLA, REG NO. 16-07529** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

…………………………….

Dated: December,2017
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Dedicated To

My Beloved Parents

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INFLUENCE OF PLANTS PER HILL AND HARVESTING TIME ON GROWTH, YIELD AND ECONOMIC BENEFIT OF ONION

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ABSTRACT

The experiment was conducted at the horticultural research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November, 2016 to April, 2017 .Three levels of number of plants per hill *viz*. P_1 = One plant per hill, P_2 = Two plants per hill and P_3 = Three plants per hill and three levels of harvesting time *viz*. H_1 = 100 DAT, H_2 = 110 DAT and H_3 = 120 DAT were considered for the present study. The experiment was laid out in Randomized Complete Block Design with three replications. Number of plants per hill had significant effect on growth, yield and yield contributing parameters of onion. Harvesting time of onion had no significant effect on growth and yield contributing parameters except fresh weight per bulb, % dry weight of bulb and bulb yield. Combination of number of plants per hill and harvesting time, the highest fresh weight per bulb(43.52 g/bulb) from P_1H_1 and the highest yield (1.37 kg/plot) and highest yield (24.40 t/ha) were recorded from the treatment combination of P_2H_2 where the lowest fresh weight per bulb (29.07 g/bulb) from P_3H_3 where the lowest yield (0.58 kg/plot) and lowest yield (14.37 t/ha) were recorded from the treatment combination of P_1H_1. The highest BCR (3.51) was obtained from the P_2H_2 where as the lowest BCR (2.08) were from P_1H_1 . It can be concluded that , two plants per hill and 110 days after harvesting provided the best result for growth, yield and economic benefit of Onion.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) rightly called as "queen of kitchen" is one of the oldest and an important spice crop grown in Bangladesh as well as in the world. Onion is an important herbaceous bulb and spice crop in the world which belongs to the family Alliaceae. Onion is mainly used as spices but it is also used as condiments for flavoring food and also as delicious vegetables and salad crop. It increases the taste and flavor of the dish, when used in gravies, soups, stew, stuffing, dried fish and meat. Onion contains high medicinal properties having adequate vitamin B and C, iron and calcium (Vohora *et al*., 1974).

Central Asia is the primary center of its origin and the Mediterranean is the second center for large type onion (McCullum, 1976). Now, it's growing all over the world. The leading onion growing countries of the world are the China, Netherlands, Korea, Israel, Japan, Turkey, Syria, Iran, Egypt, USA, Lebanon, Austria and India (FAO, 2012). In Bangladesh it is commercially cultivated in the greater districts of Dhaka, Mymensingh, Rajshahi, Rangpur, Rajbari, Khustia, Khulna, Barisal and Pabna (BBS, 2015). Among the spice crops grown in Bangladesh, onion ranks top in respect of production and second in respect of area (BBS, 2012).

Onion bulb provides vitamin C 19.7%, fiber 10.8%, molybdenum 10.6%, manganese 10.5%, vitamin B 69.5%, potassium 6.6%, and tryptophan 6.2%. Onions are very low in calories (just 40 cal per 100 g) and fats but rich in soluble dietary fiber. The total production of onion in Bangladesh is about 170 thousand metric tons under the total cultivated area 4,19,122 acres (BBS, 2015). On an average, the total annual requirement of onion in Bangladesh is about 16,50,000 metric tons but production is 10,52,000 metric tons (Anonymous, 2012).

Onion is one of the most widely used vegetable due to its flavoring and seasoning the food, both at mature and immature bulb stage. Besides, it is being used in the manufacture of soups, ketchups, salad and pickles. To a lesser extent, it is used by processing industry for dehydration in the form of onion flakes and powder, which are in great demand in the world market.

Total production of onion can be increased by increasing per hectare yield as in other onion producing countries of the world. But during the last few years it has been found that the area and total production of onion in Bangladesh remained almost same. However, low yield in Bangladesh may be attributed to a number of means viz. unavailability of quality seeds, improper cultural management, number of seedlings per hill, balanced fertilizer, harvesting time, storage method, disease infestation etc.

In Bangladesh the farmers generally allow to grow single plant per hill. The number of plants per hill can increase the production of onion like a number of vegetables such as tomato, sweet potato and carrot (Islam. 1990; Azam, 1989, Tarafder, 1999). To enhance onion production, improved and modern agronomic practices should be applied properly (Islam *et al*., 2007). In case of carrot, planting of more than one plants/hill has been shown that two, three or four plants per hill produced significantly higher yield than one plant per hill (Tarafder, 1999). But the effects of planting more than one plant per hill at different spacings of onion have not been investigated in Bangladesh.

Harvesting of bulb crops at appropriate stage of maturity is a very important factor in yield, quality and storage life. The quality of bulb at harvest and its post harvest storage are expected to be influenced by the stage of the maturity. The time of harvest differs with the varieties, which may be increased or decreased (Varma and Naskar, 1990). The crop intended for storage should be harvested well-matured (Thompson and Kelly, 1957).

Onions are left on the ground to cure in the field for 1- 4 weeks before the foliage is removed (topping). The length of field curing depends on how long it takes for the neck of the onion bulb to dry, which is a reflection of weather conditions and plant maturity. Curing is a drying process carried out to remove excess moisture from the outer skins, roots and neck tissue of harvested onion bulbs. It improves the keeping quality of onion bulbs and reduces the chance of infection by disease-causing organisms in storage (Thompson *et al*. 1972). Onion appearance greatly affects their commercial value. The three main factors that determine the visual quality of bulbs are skin colour, skin staining, and skin retention. Duration of harvest directly affects these factors which also influence the marketing system of onion and selling demand (Wright and Gra, 1997)

The present study was undertaken to study the effect of growth, yield and economic benefit of onion as influenced by number of plants per hill and harvesting time. Considering the above fact the present research will be undertaken with the following objectives:-

1. To observe number of plants per hill for higher growth, yield and economic benefit of onion
2. To identify the optimum harvesting time for better growth, yield and economic benefits of onion
3. To find out the suitable combination of numbers of plants per hill and harvesting time on growth, yield and economic benefit of onion

CHAPTER II

REVIEW OF LITERATURE

Onion is an important spice crop in Bangladesh. The production of onion bulb is influenced by many factors. Number of seedlings per hill and harvesting time are important factors for successful onion production. A limited number of research works on number of seedlings and harvesting time have been conducted in different parts of the worlds but their findings have little relevance to the agro-ecological situation of Bangladesh. The present study has been undertaken to investigate the effect of growth, yield and economic benefit of onion (*Allium cepa* L.) as influenced by number of plants per hill and harvesting time. The relevant literatures available have been reviewed in this chapter.

2.1 Effect of plants per hill

Optimum number of plants/hill is one of the most important and uncontroversial factors for maximizing the yield of crop. The results of many researchers relating to number of plants/hill of underground crops including onion are reviewed. Like other underground crops more than one plant/ hill can increase the yield of onion. The available information relating to plants/hill of onion are reviewed below.

Halder (2001) conducted an experiment on the effect of plant spacing, number of plants per hill and mulching on the growth and yield of Carrot under Bangladesh (BAU) condition. She found that two or three plants per hill produced significantly higher yield than one plant per hill.

Tarafder (1999) studied the effect of plant spacing and number of plants per hill on the growth and yield of Carrot under Bangladesh (BAU) condition. He found that two, three or four plants per hill produced significantly higher yield than one plant per hill.

Herison *et al.* (1993) conducted an experiment at three Onion cultivars sweet Sandwich, Vega and Yula were sown in the green house in 200-cell plastic trays and thinned to one, two or three seedlings/cell. Seedlings were transplanted in to the field 12 weeks after sowing, without separating individual plants from multi plant cells. Two and three plants/cell yielded a higher percentage of bulbs 76 mm in diameter, however one plant/cell yielded more bulbs of 102 mm in diameter.

Frost and Kretechman (1988) worked on a trial with two varieties “Heing 2653” and “Heing 722” of Bomato grown at fore plant populations (21,530; 28,700; 43,050 and 57,400 plants/ha) in both single and twin rows, found that as population pressure increased, number of ripe fruits/plant, ripe fruit size and clusters/plant decreased.

In determining the effect of optimum number of Tomato plants per hill, Rosell *et al.* (1987) observed that the total yield was maximum (28.6 t/ha) with three plants per hill (37,500 plants per hill) with a spacing of 140 cm and 60 cm, respectively between and within the row.

Rahman (2008) conducted an field experiment was carried out at the Sher-e-Bangla Agricultural University Farm, Dhaka, to study the effect of nitrogen and number of plants per hill on growth and yield of Onion (*Allium cepa* L.). He found that three plants per hill with 180 kg N/ha can be used to obtain higher growth as well as higher yield.

Siddique and Rabbani (1987) studied the effects of length of cuttings, part of vine inserted into the soil at planting and number of vines planted per hill on the yield of Sweet potato. They observed that the number of tuberous roots per hill and yield were increased when two vine cuttings were planted per hill.

Saladaga and Rodolfo (1987) stated that generally no significant differences in agronomic characters and yield components of sweet potato were observed using either the traditional method or the recommended practice planting. Varying the number of cuttings per hill significantly influenced only the fresh vine weight of Kaimay BNAS-51 and Summer Big Yellow sweet potato verities. Plants that developed from one cutting per hill produced heavier herbage than other treatments. Root yield was likewise not markedly affected by the number of cuttings per hill although the varieties significantly differed in this parameter. Among the varieties Kaimay obtained the highest value in yield and nearly all yield components.

Dragland (1986) carried out an experiment in Norway seeding of the carrot cv. Nantes Duke sown in may were thinned out to give densities of 45, 70 or 90 plants/m^2 in beds of 2, 3, 4 or 5 rows between path ways (wheel tracks) 150 cm apart, Centre to centre and 28 cm wide. At the first harvest on lst September the highest saleable yield (29 t/ha) was achieved with a density of 70 plants/m^2 distributed in 4 rows. At harvest on 10 October, a density of 90 plants/m^2 in 4 or 5 rows gave the highest yield (42 t/ha).

Hiron (1983) found that, the yield of bulbs greater than 40 mm diameter reaches a maximum of 45-55 ton/ha. When modules containing five to six seedlings are transplanted at ten modules per m^2.In these conditions 60-70% of the bulbs are greater than 60 mm in diameter. Using more seedlings per module, or planting modules at a higher density, reduced mean bulb size.

Vik (1974) carried out an experiment in Norway and showed that satisfactory bulb crops were produced when groups of three to seven seedlings were raised in small pots and transplanted as a cluster. During bulbing the plants pushed each other apart and the resulting bulbs were not misshapen.

Mandal *et al.* (1973) conducted an experiment at Trivandrum in India used non branched (H-165) and branched (H-97) types of Tapioca *(Manihot esculenta)* to study the effect of plant density, fertile level and shoot number on tuber yield and quality of tapioca hybrids and found that two plants per hill gave a better yield than that of one plant per hill. They recommended spacing of 75 cmx75 cm, with two plants per hill and 90 cmx90 cm with one plant per hill for types H-165 and h-97, respectively.

Steven (2001) conducted an experiment on Short-day onions (*Allium cepa* L.) grown under humid, subtropical conditions at two locations for bulb size and yield at five harvest dates (H_1 to H_5) ranging from 94 to 132 days after transplanting (DAT) for „Granex 33" and from 115 to 153 DAT for „Texas Grano 1015Y". Maximum yields were attained by H_4 for both cultivars and were attributed to increased bulb size rather than differences in plant (bulb) population. Non-dried, large bulbs (>7.6 cm diameter) from each harvest were trimmed and stored at 1 or 10°C and 80% relative humidity (RH) for 2 weeks plus 2 weeks at 20°C and 80% RH to simulate commercial storage and handling. Initial respiration rates of bulbs of both cultivars decreased >60% between H_1 and H_4. Bulbs also retained higher fresh weight during storage as harvest was delayed. Storage for 2 weeks at 1°C suppressed sprouting of immature (H_1) „Texas Grano 1015Y" bulbs, but not of „Granex 33" bulbs from one location. Storage at 10 °C did not suppress sprouting of either cultivar. Decay became more prevalent with delayed harvest, but „Granex 33" was more resistant to decay than was „Texas Grano 1015Y", which developed up to 40% decay after 2 weeks at 20 °C. Harvest at 115 and 132 DAT resulted in acceptable yields for „Granex 33" and „Texas Grano 1015", respectively, and satisfactory postharvest quality of non-dried bulbs following 2 weeks of storage at 1°C and 80% RH plus 2 weeks at 20°C.

Sultana (2015) conducted an experiment to investigate the effect of age of seedlings and number of plants per hill on the growth and yield of onion. Four levels of age of seedling *viz*. T_1 = 30, T_2 = 40, T_3 = 50 and T_4 = 60 days old seedling, respectively and three levels of plants per hill *viz*. P_1 = one, P_2 = two and P_3 = three plants/hill were considered for the study. The highest yield of onion (8.45 t/ha) was produced by P_2 treatment and the lowest yield (6.92 t/ha) was at P_1

treatment. The combined effect of age of seedling and number of plants/hill demonstrated a significant variation in fresh weight of bulb (ranging from 68.25 g to 48.82 g) and yield (ranging from 5.52 to 9.40 t/ha). The highest yield was (9.40 t/ha) found at T_3P_2 treatment. The treatment T*3*P*2* increased the total yield and gave the highest gross return (Tk. 4,23,000/ha) and net (Tk. 2,66,984/ha) returns with the highest profit (BCR value of 2.71) compared with the rest of the treatment combinations.

3.2 Effect of harvesting time

Quality of onion are known to be affected by several factors such as mineral nutrition, irrigation schedule or rainfall (Chung, 1989), cultivar differences, harvesting time and the use of growth regulators (Hussien, 1996). Harvest maturity affects postharvest life (Tucker and Drew, 1982) and carbohydrate content (Nilsson, 1980) of onion bulbs. Smittle and Maw (1988) harvested and dried two mild onion cultivars („Granex 33", „Sweet Georgia") at typical harvest maturity. Postharvest losses for bulbs from the first harvest were minimal during 1 month of storage at 22 to 25 °C. However, the percentage of marketable bulbs after storage decreased when bulbs were harvested later. Wall and Corgan (1994) obtained similar results with dried, short-day onions; as harvest was delayed, the incidence of decay increased during 20 d of storage under ambient conditions.

Kopsell and Randle (1997) found that short-day onions, when dried for 7 d under cover at 20 to 25°C, sprouted after 2 months of storage at 5°C, whereas more pungent, long-day cultivars remained dormant during storage for up to 8 months. Note that “drying” is the most accurate term for onions, since moisture is removed from the neck and outer scales of the bulb, serving as protective barriers during subsequent handling and storage. “Curing” is appropriate for crops such as potatoes (*Solanum tuberosum* L.) that undergo suberization in response to mechanical injuries.

Sebsebe *et al*. (2010) carried out experiments to evaluate the effects of four levels of N application, three harvest stages and two curing levels on yield, bulb quality and shelf life of local shallot cultivar. Optimization of nitrogen (N) fertilization levels, harvesting stages and curing treatments among the management practices were used for onion bulbs. Results of the study showed that increasing in the N application rate up to 100 kg N ha^{-1} and delay of harvesting up to 100% top fall, bulb yield of shallot increased considerably. A yield increase of 149, 68 and 72% at the 50, 75 and 100% top fall at harvest on fertilized relative to unfertilized plots. However, there was associated increment in percent bulb rotting and sprouting, loss in bulb diameter, bulb weight loss and unmarketability with increased N application. Harvesting at 75% top fall showed better dry matter content of bulbs, reduced percent rot, sprouting and weight loss and improved marketability of bulbs. Interaction effects of N rates and harvest stage were observed in percent bulb rotting where the highest incidence was in 150 kg N ha^{-1} and 50% top fall harvest treatments and the least in unfertilized plot harvested at 100% top fall. The result of this study has shown N application in the range of 50 - 100 kg N ha^{-1}, harvesting at 75% top fall and curing bulbs before foliage removal is a good compromise for yield and post harvest quality and shelf life of shallot bulbs under ambient storage conditions.

Brewster (1996) found that cultivar stage of bulb development, premature defoliation, skin integrity and conditions during maturation, harvesting and curing are also among factors contributing to quality of bulbs during storage.

Brewster (1996) also opined that onions are harvested at maturity level and neck fall is an indication of maturity. Onions for dry bulbs are ready for harvest when the bulbs are mature and 50 - 80% of the tops fall over. If they have to be stored, harvesting has to be done after the tops have broken down but before the foliage has completely dried. During curing, the thin outer layers of the bulb are dried to form one or more complete dry skins, which act as a barrier to water loss and microbial infection.

Currah and Proctor (1990) and Brewster (1994) found that the use of plant nutrients and time of harvesting are known to affect quality and storability of onion and increase yield of onions, many researchers found that high levels of nitrogenous fertilizer resulted in reduced onion storage life. Shallot is considered to have similar nutritional requirements and its storage life could be affected like other Alliums.

Choudhury (1996) stated that the timing of harvesting should be decided based on the considerations that relatively early harvesting favors better skin retention while later harvesting maximizes yields. Therefore, time of harvest is a compromise between maximum yield and maximum storage life and skin quality.

Gubb and Tavish (2002) observed that the rate of weight loss increased with late harvest and resulted lower yield of onion. The fact that during curing, the thin outer layers of the bulb are dried to form one or more complete dry skins, which act as a barrier to water loss. Curing also dries the neck of the bulbs and makes them tightly closed.

Currah and Rabinowitch (2002) found that fleshy harvested onions contain 80 - 90% water according to cultivar and water removal from the outer skins during curing causes a rapid loss of up to 5% of total weight and resulted reduced fresh yield. As bulbs are cured the metabolic activities will be kept to the minimum since bulbs are at their dormancy that keeps respiration rates low.

Wright *et al*. (2001) carried out a field study over two growing seasons to investigate the effects of physiological maturity of onions (*Allium cepa* L.) at harvest and different topping methods on bulb colour, skin retention, and the incidence of storage rots. Onion plants were lifted at five different stages of maturity from 0 to 4 weeks after 50% leaf collapse (top-down). The timing of foliage removal had no effect on mean skin colour score, but onions that were topped before curing had slightly more bulb skins than onions topped after curing. Timing of onion lifting to optimize bulb quality appears to be a trade-off between skin retention and colour. These results confirm that traditional method of harvesting onions where onions are lifted at 60-80% top-down, the bulbs are field-cured, and the foliage is removed after curing, is the simplest method and best compromise to ensure postharvest onion yield, quality, successful storage and marketing.

Leong and Abu (1986) carried out a study on peat for two seasons to determine the best time of harvesting shallot (onion) and its effect on subsequent yield. Randomized complete block design was used with treatments replicated four times. The best time to harvest shallot on peat was at 70 DAP which coincided with 95% lodging and browning of the shallot leaves. The study also found that the maturation periods of the bulbs at the time of harvest affected subsequent yield. Locally produced planting material performed unfavorably compared with imported shallot. The number of bulbs and percentage of white tip were not affected by bulbs of different maturation periods.

Vitnor *et al*. (2017) carried out an investigation on effect of last irrigation and curing on yield and post-harvest losses of Rabi onion. After field and shade curing, the onion bulbs were kept three months upto September under ambient conditions to assess the post-harvest losses. Treatments were evaluated on the basis of storage life of onion. As regards to field curing treatments, field curing of onion bulbs for four days curing in field condition produced significantly higher fresh onion and minimum percent weight loss over no curing.

Chapter III

MATERIALS AND METHODS

The present research work was conducted at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2016 to April, 2017. Brief descriptions of soil, climate, materials and methods that are used in carrying out the experiment have been presented in this chapter.

3.1 Experimental site

The experiment was carried out at Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh. It is located at 90°22′ E longitude and 23°4l′ N latitude at an altitude of 8.6 meters above the sea level. The land belongs to Agro-ecological zone of Modhupur Tract, AEZ-28. The experimental site is presented in Appendix I.

3.2 Climatic condition

The experimental area is under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during kharif season (April-September). Details of weather data in respect of temperature (^{0}C), rainfall (mm) and relative humidity (%) for the study period was collected from Bangladesh Meteorological Department, Agargoan, Dhaka-1207 (Appendix II).

3.3 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix III.

3.4 Planting Material used for the Experiment

Seeds of one onion cultivar namely "Hybrid KSP-106" were used for the experiment. The seeds were collected from Kalash Seeds Pvt. Ltd.

3.5 Treatment of the Experiment

The experiment consists of two factors which were effects of plants per hill and harvesting time. Details of factors and their combined effects are given bellow:

Factor A: Plants per hill– 3 levels

1) P_1= One plant per hill
2) P_2= Two plants per hill
3) P_3= Three plants per hill

Factor B: Harvesting time – 3 levels

1) H_1 = 100 DAT
2) H_2= 110 DAT
3) H_3 = 120 DAT

Therefore the treatment combinations were given below:

P_1H_1, P_1H_2, P_1H_3, P_2H_1, P_2H_2, P_2H_3, P_3H_1, P_3H_2, P_3H_3

3.6 Design of the experiments

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Two factors were considered *viz*. plants per hill and harvesting time for the present study.

3.7 Layout of the field experiment

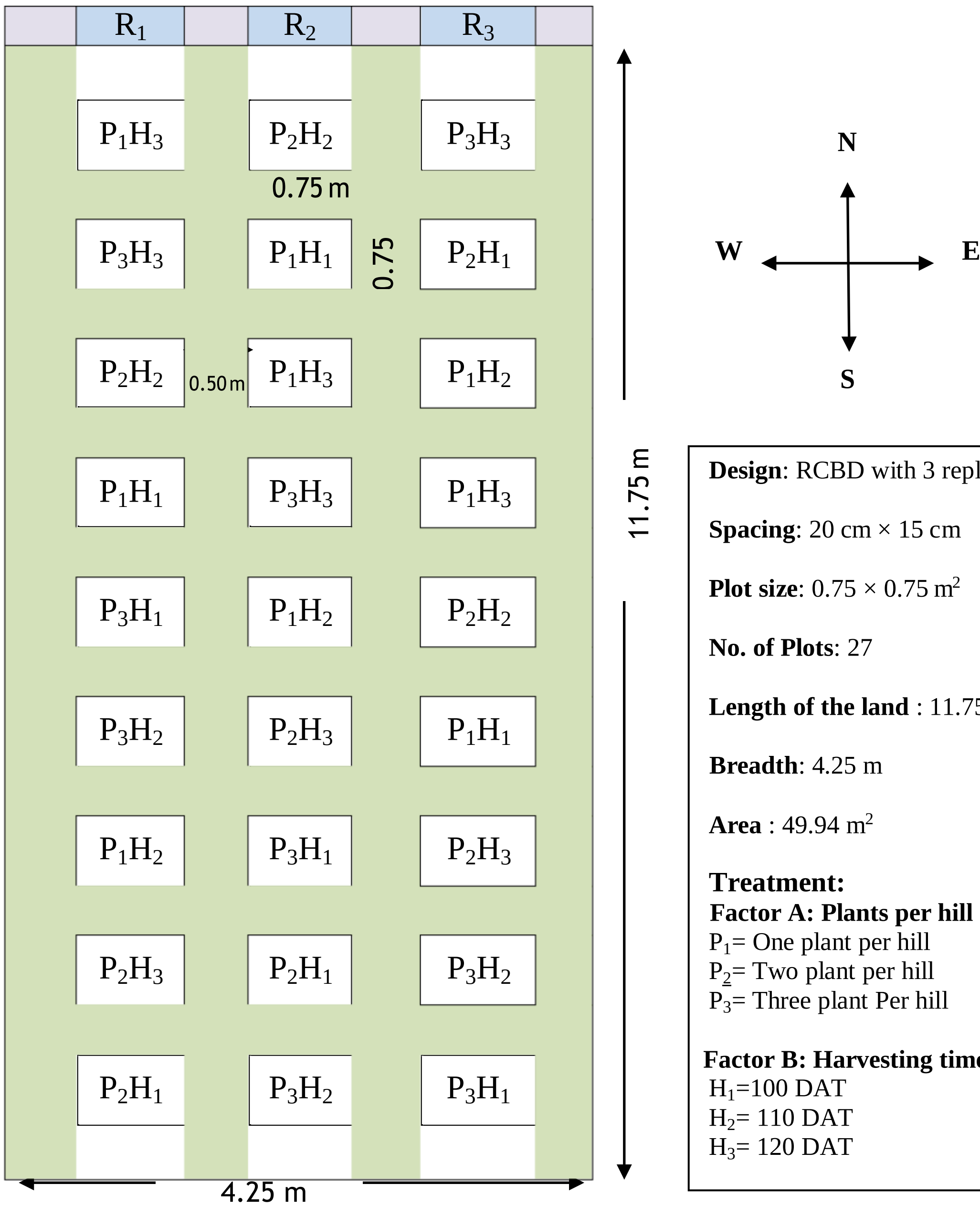
The experimental area was first divided into three blocks. Each block was divided into 9 plots for the treatment combinations. Therefore, the total no. of plots was 27. Thereafter 9 treatment combinations were assigned to each block as per design of the experiment. The size of the unit plot was 0.75 m × 0.75m. A distance of 20 cm between the rows and 15 cm between the plants were kept and each unit plot. The distance maintained between two plots was 0.5 m and between blocks was 0.75 m. The layout of experiment field is presented in Fig. 1.

3.8 Details of the field operations

The particulars of the cultural operations carried out during the experiment are presented below:

3.8.1 Seedbed preparation

The land which was selected for raising seedlings was fine textured and well drained. The land was opened and drying for 10 days. Seedbed was made on 19November, 2016 for raising seedlings and the size of the seedbed was 3 m with a height of about 20 cm. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtained good tilth. Weeds, Stubbles and dead roots were removed from the seedbed. Cowdung was applied to the prepared seedbed at the rate of 10 t/ha. Applying Furadan 3G @ 20 kg/ha was covered by polythene for two days. Onion seeds were soaked overnight (12 hours) in water and allowed to sprout in a piece of moist cloth keeping in the sun shade for one day.



Design: RCBD with 3 replications

Spacing: 20 cm × 15 cm

Plot size: 0.75 × 0.75 m^2

No. of Plots: 27

Length of the land : 11.75 m

Breadth: 4.25 m

Area : 49.94 m^2

Treatment:
Factor A: Plants per hill
P_1= One plant per hill
P_2= Two plant per hill
P_3= Three plant Per hill

Factor B: Harvesting time
H_1=100 DAT
H_2= 110 DAT
H_3= 120 DAT

Fig. 1. Field layout of the experiment plot on onion in the Randomized Block Design

3.8.2 Seed treatment and seed sowing

Seeds were treated by Vitavax-200 @ 5g/1kg seeds to protect some seed borne diseases. The date of the seed sowing was 20 November, 2016. Seeds were sown on in the seedbed to get 30 days old seedlings. Seeds was sown at a depth of 0.6 cm and covered with a fine layer of soil followed by light watering by water can. The young seedlings were exposed to dew by night and mild sunshine in the morning and evening. Shade was given over the seedbed to retain soil moisture and to save the seedlings from direct sun and rain.

3.8.3 Raising of seedlings

Light watering and weeding were done several times. No chemical fertilizers are applied for rising of seedlings. When the seedlings of the seedbeds attained a height of about 10 cm, thinning operation was done. Healthy and 30 days old seedlings were transplanted into the main field on 20 December, 2016.

3.8.4 Land preparation

The experimental area was first opened on 14December, 2016 by a disc plough in direct sunshine to kill soil borne pathogens and soil inhabitant insects. Then the land was prepared by several ploughing and cross ploughing with a power tiller followed by laddering to bring a good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. The weeds, crops residues and stables were removed from the field. The basal dose of manures and fertilizers was applied at the finally ploughing. According to design and layout the plots was prepared. The soil was treated by Sevin 50 WP @ 5 kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm.

3.8.5 Manures and fertilizers

The following doses of nutrients as per treatment were applied to the each plot for bulb production:

Manure and Fertilizer	Rate ha^{-1}
Cowdung	10 ton
Urea	As per treatment
TSP	220 kg
MOP	150 kg
Gypsum	110 kg

(BARI, 2016)

A basal dose of well-decomposed cowdung 10 t/ha was applied just after opening the land. The total amount of TSP, ½ MP and full gypsum were applied at the final land preparation. Total urea and ½ MP were applied in two installments. The first installmentswere applied at 30 days after transplanting, second installments were applied 45 days after transplanting as top dressing. The fertilizer was thoroughly mixed with the soil.

3.8.6 Transplanting of seedlings

Healthy and disease free uniform sized 30 days old seedlings was uprooted from the seedbeds and transplanted to the main field on 20 December, 2016as per treatment after a slight trimming of leaves and roots of healthy seedlings and maintaining a spacing of 20 cm ×15 cm. The seedbed was watered before uprooting the seedlings so as to minimize the damage of roots. The seedlings were watered immediately after transplanting. Some seedlings were also transplanted adjacent to the experimental area to be used for gap fillings.

3.8.7 Intercultural Operations

After transplanting of seedlings, intercultural operations were done whenever required for getting better growth and development of the plants. So the crop was always kept under careful observation.

3.8.7.1 Gap Filling

Required gap filling were done by using healthy plants from the excess plants within one week. Damaged/ dead seedlings were removed.

3.8.7.2 Weeding and mulching

Weeding was done three to four times after transplanting to keep the crop free from weeds and mulching was provided by breaking the crust of the soil for easy aeration and to conserve soil moisture, when needed especially after irrigation.

3.8.7.3 Irrigation and drainage

Irrigation was given by a watering can be and or hose pump when needed. First irrigation was given just after transplanting. During this time, care was taken so that irrigated water could not pass from one plot to another. Mulching was also done after irrigation at appropriate time by breaking the soil crust. During irrigation, the soil was made saturated with water. After rainfall excess water was drained out when necessary.

3.8.7.4 Plant protection

Insect: Preventive measure was taken against soil borne insects. Furadan 3G @ 20 kg/ha was applied for the prevention of cutworm. After pesticide application no insect infestation was found in the field.

Disease: Few days after transplanting some plants were attacked by purple blotch disease caused by Alternariaporri. It is controlled by spraying Ruvral 50 WP @ 2 g/ L of water at 7 days interval.

3.8.8 Harvesting

The crop was harvested as per treatment started on 30March, 2017. Onions were lifted with the help of hand and care was taken so that no bulb was injured during lifting. After harvesting the tops were removed by cutting off the pseudo stem and keeping 2.5 cm with the bulb.

3.8.9 Storage of bulbs

The bulbs of each harvest were dried in shade in the field for one day with tops after harvest and then tops were separated in the following day leaving 2 cm neck. Curing of bulbs was done in a room at ambient temperature (29.6 ±2.60C) for 7 days and then stored in a well-ventilated room.

3.9 Collection of data

Data were collected on the following parameters

- **A. Growth parameters**
  1) Plant height (cm)
  2) Leaf length (cm)
  3) Root length (cm)
- **B. Yield contributing parameters**
  1) Neck (pseudostem) diameter (cm)
  2) Bulb length (cm)
  3) Bulb diameter (cm)
  4) Fresh weight bulb^{-1} (g)
  5) Dry weight of 100 g bulb (g)
- **C. Yield parameters**
  1) Yield plot^{-1} (kg)
  2) Yield ha^{-1} (t)
- **D. Economic analysis**
  1) Cost of production (Tk. ha^{-1})
  2) Gross return (Tk. ha^{-1})
  3) Net return (Tk. ha^{-1})
  4) Benefit Cost Ratio (BCR)

3.10 Procedure of recording data

3.10.1 Plant height (cm)

The height of the randomly selected ten plants was measured of each plot after 20 days of transplanting to at 65 DAT with 15 days interval. The height was measured in centimeter (cm) from the neck of the bulb to the tip of the longest leaf and average height of ten plants was calculated in centimeter.

3.10.2 Leaf length (cm)

Leaf length was measured with a meter scale from base to tip of the longest plant from ten randomly selected plants at different days after transplanting started at20 DAT to at 65 DAT with 15 days interval and finally mean value was calculated.

3.10.3 Root length (cm)

The length of root was measured from each plot of 10 randomly selected plants at the time of harvest. The length was measured in centimeter (cm) and average root length was calculated in centimeter.

3.10.4 Neck diameter (cm)

Neck diameter was measured at the neck of ten randomly selected plants with a slide caliper after harvesting and average mean was calculated and expressed in centimeter.

3.10.5 Bulb length (cm)

After harvesting the length of bulb was measured with a scale from the neck to the bottom of the bulb of ten randomly selected plants from each plot and their average was taken in centimeter.

3.10.6 Bulb Diameter (cm)

After harvesting the diameter of bulb was measured at the middle portion of ten randomly selected plants from each plot and their mean value was taken in centimeter.

3.10.7 Fresh weight bulb^{-1} (g)

To determine the weight of individual bulb from ten randomly selected plants by an electric balance. After removing the top portion of the bulb keeping only 2.5 cm with neck. The bulb weight of plants was taken and means value was calculated.

3.10.8 Dry matter content of bulb (%)

To determine the dry matter content of bulbs, 100 g of bulb was randomly collected from harvested bulb of each plot. The bulbs were sliced with a sharp knife. The fresh sample was dried under sunlight scorching and kept in an oven at 70°C for 72 hours until constant weight. Finally dry weight was taken with an electric balance and dry matter percentage was calculated by the following formula.

$$\text{Dry matter (\%)} = \frac{\text{Dry weight of bulb}}{\text{Fresh weight of bulb}} \times 100$$

3.10.9 Bulb yield per plot (kg)

All bulb was collected from each replication of each treatment combination. Bulb weight per plot was measured by an electric balance and than average was expressed as bulb yield per plot in kilogram.

3.10.10 Bulb yield per hectare (t)

Plot yield of harvested fresh bulb was converted to per hectare yield and it was expressed in ton.

3.11 Statistical analysis

The collected data on various parameters under study were statistically analyzed using MSTAT-C computer package programmed. The means for all the treatments were calculated and analysis of variance for all the characters was performed by the F- variance test (Gomez and Gomez, 1984). Significance of difference between means was evaluated by Least Significance Difference (LSD) and the probability level 5% and 1% for the interpretation of results.

3.12 Economic analysis

Economic analysis was done to find out the cost effectiveness of different treatments like different levels of fertilizer and bending process in cost and return were done in details according to the procedure of Alam*et al*. (1989).

3.12.1 Analysis for total cost of production of onion

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix XII.

3.12.2 Gross income

Gross income was calculated on the basis of sale of mature bulb. The price of bulb was assumed to be Tk. 20/kg basis of current market value of Kawran Bazar, Dhaka at the time of harvesting.

3.12.3 Net return

Net return was calculated by deducting the total production cost from gross income for each treatment combination.

3.12.4 Benefit cost ratio (BCR)

The economic indicator BCR was calculated by the following formula for each treatment combination.

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

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the discussion of the results obtained from the study on the effect of growth, yield and economic benefit of onion (*Allium cepa* L.) as influenced by number of plants per hill and harvesting time. The analyses of variance (ANOVA) of the data on different growth and yield components have been presented in Appendix (IV-VIII). The results have been presented and discussed in the different tables and graphs and possible interpretations are given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Plant height was significantly influenced by the treatment of different plants per hill at different growth stages of the test crops (Fig. 2 and Appendix IV). Results indicated that at 20 DAT (days after transplanting) the tallest plant (31.07 cm) was found from P_1 (One plant per hill) where the smallest plant (22.80 cm) was observed from P_3 (Three plants per hill) treatment. The result on plant height from P_2 (Two plants per hill) at 20 DAT showed intermediate result (23.79 cm) compared to P_1 (One plant per hill) and P_3 (Three plants per hill) treatments. Similar trend was also observed at 35, 50 and 65 DAT among the treatments. Results revealed that the highest plant height at 35 DAT (42.35 cm), at 50 DAT (50.94 cm) and at 65 DAT (62.39 cm) was recorded from the treatment, P_1 (One plant per hill) where the lowest plant height at 35 DAT (30.14 cm), at 50 DAT (39.00 cm) and at 65 DAT (53.68 cm) was recorded from the treatment, P_3 (Three plants per hill). At all growth stages the treatment, P_2 (Two plants per hill) showed intermediate result in respect of plant height compared to P_1 (One plant per hill) and P_3 (Three plants per hill) treatment. Such result from the present study on plant height might be due to cause of nutrient availability and free growing space. Higher number of seedling compete for nutrients to each other, moreover free space for growth characters is declined and resulted shortest plant with P_3 (Three plants per hill). The variation in plant height as influenced by number of plant per hill was perhaps due to proper utilization nutrients, moisture and light. This result is agreed with the findings of Rahman (2004).

Significant influence was not found in terms of plant height of onion at different days after transplanting (DAT) affected by time of harvest (Fig. 3 and Appendix IV). But at 20 DAT, the highest plant height (27.83 cm) was observed from the treatment H_1 (100 DAT) where the lowest (25.25 cm) was from H_3 (120 DAT). At 35, 50 and 65 DAT, the highest plant height was also found from H_1 (100 DAT) and the lowest plant height was also found from H_3 (120 DAT). The highest plant height at 35 DAT (36.34 cm), at 50 DAT (45.32 cm) and at 65 DAT (58.58 cm) was achieved from H_1 (100 DAT) whereas the lowest plant height at 35 DAT (34.54 cm), at 50 DAT (43.63 cm) and at 65 DAT (57.41 cm) was found from H_3 (120 DAT). It was evident that plant growth of onion is limited after certain duration and it goes to its maturity and death is occurred. From this point of view plant height was not significant with harvesting time under equal management of all treatments.

Significant influence was noted on plant height of onion at different days after transplanting (DAT) affected by combined effect of plant per hill and harvesting time (Table 1 and Appendix IV). Results signified that the treatment combination of P_1H_1 gave highest plant height at all growth stages where P_3H_3 showed lowest plant height. At 20 DAT, the highest plant height (32.51 cm) was achieved from the treatment combination of P_1H_1 which was significantly different from all other treatment combinations. But the advancement of crop growing periods, the treatment combination of P_1H_2 and P_1H_3 showed significantly similar result with

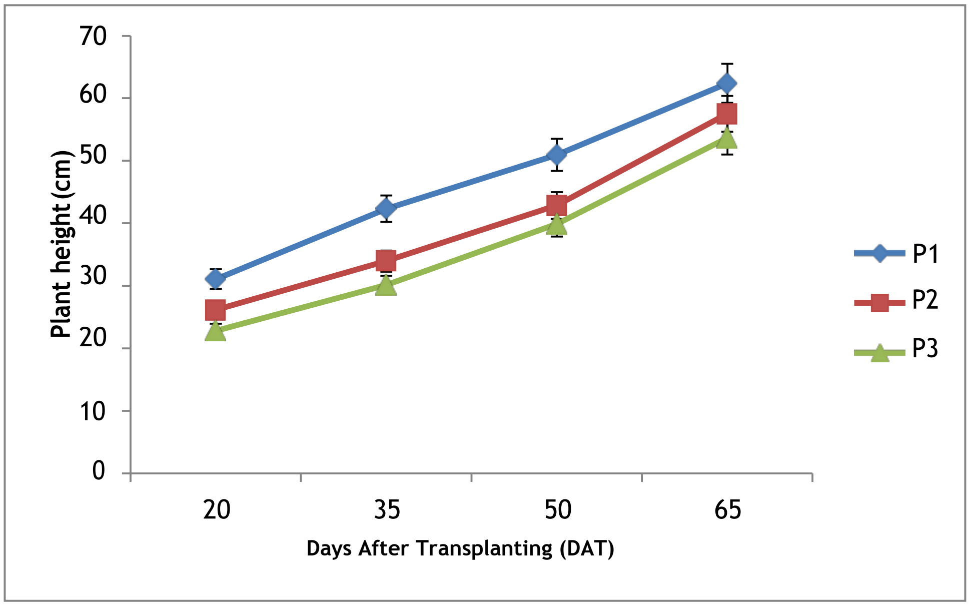


Fig. 2. Effect of plant height as influenced by plants per hill of onion

Where, P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

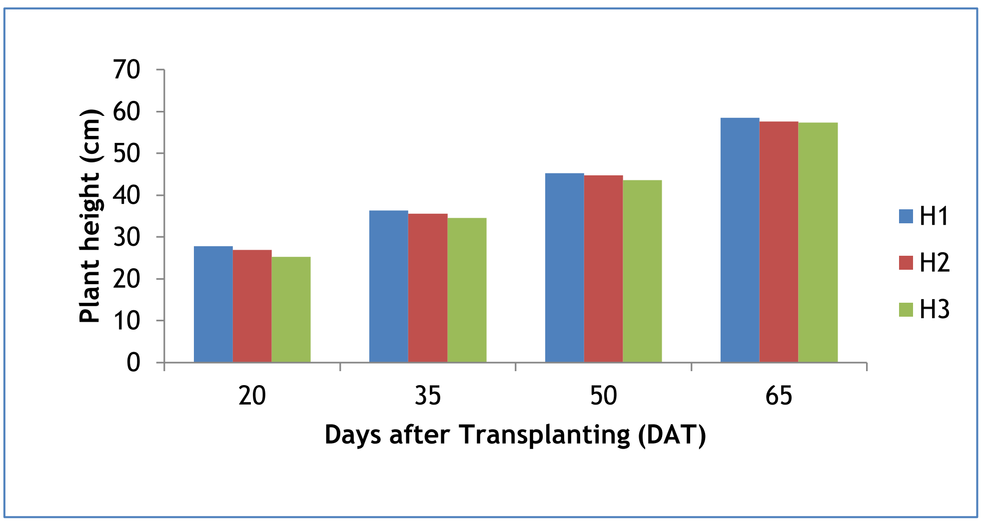


Fig. 3. Effect of plant height as influenced by harvesting time of onion

Where, H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

P_1H_1. The highest plant height at 35 DAT (43.56 cm), 50 DAT (51.99 cm) and 60 DAT (63.25 cm) was recorded from the treatment combination of P_1H_1 which was significantly similar with P_1H_2 and P_1H_3. At 20 DAT, the lowest plant height (20.01 cm) was recorded from the treatment combination of P_3H_3 which was significantly different from others. At 35 and 50 DAT, the lowest plant height (28.70 and 38.37 cm, respectively) was found from the same treatment combination. At 65 DAT, the lowest plant height (52.88 cm) was also found from the treatment combination of P_3H_3 which was statistically similar with P_3H_2.

Table 1: Combined effect of plants per hill and harvesting time on plant height (cm) at different days after transplanting of onion

Treatment	Plant height (cm) at different days after transplanting (DAT)			
	20 DAT	35 DAT	50 DAT	65 DAT
P_1H_1	32.51 a	43.56 a	51.99 a	63.25 a
P_1H_2	30.86 b	41.97 ab	50.54 ab	62.05 ab
P_1H_3	29.83 bc	41.53 ab	50.30 ab	61.87 ab
P_2H_1	26.36 cd	34.20 c	43.17 c	57.53 c
P_2H_2	26.10 cd	34.33 c	43.18 c	57.57 c
P_2H_3	25.92 cd	33.40 cd	42.23 cd	57.48 c
P_3H_1	24.63 d	31.27 de	40.80 e	54.97 d
P_3H_2	23.77 d	30.44 e	40.52 e	53.20 de
P_3H_3	20.01 e	28.70 f	38.37 f	52.88 e
$LSD_{0.05}$	2.512	2.376	1.052	1.867
CV(%)	6.81	6.98	8.07	5.79

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

Note: P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

4.1.2 Leaf length (cm)

Variation on leaf length differed significantly due to different treatments of number of plants per hill at different growth stages of crops duration (Fig. 4 and Appendix V). Results revealed that at 20 DAT, the maximum leaf length (26.90 cm) was found from P_1 (One plant per hill) where the minimum leaf length (21.30 cm) was observed from P_3 (Three plants per hill) treatment. The treatment P_2 (Two plants per hill) at 20 DAT showed intermediate result (23.79 cm) compared to P_1 (One plant per hill) and P_3 (Three plants per hill) treatments. Similarly, the maximum leaf length at 35 DAT (39.39 cm), 50 DAT (47.92 cm) and 65 DAT (58.39 cm) was recorded from the treatment, P_1 (One plant per hill) where the minimum leaf length at 35 DAT (26.06 cm), 50 DAT (34.90 cm) and 65 DAT (43.79 cm) was recorded from the treatment, P_3 (Three plants per hill). At all growth stages the treatment, P_2 (Two plants per hill) showed intermediate result in respect of leaf length compared to P_1 (One plant per hill) and P_3 (Three plants per hill) treatments. Higher number of plants per hill showed lower leaf length might be due to cause of dry matter accumulation was lower because nutrient supply management was same during growing period.

Significant influence was not found in terms of leaf length of onion at different days after transplanting (DAT) influenced on harvesting time (Fig. 5 and Appendix V). But it was found that at 20 DAT, the maximum leaf length (24.73 cm) was observed from the treatment H_1 (100 DAT) where the lowest (23.47 cm) was found from H_3 (120 DAT). Similarly, the maximum leaf length at 35 DAT (32.99 cm), 50 DAT (41.88 cm) and 65 DAT (51.81 cm) was achieved from H_1 (100 DAT) whereas the minimum leaf length at 35 DAT (31.45 cm), 50 DAT (40.30 cm) and 65 DAT (49.50 cm) was achieved from H_3 (120 DAT).

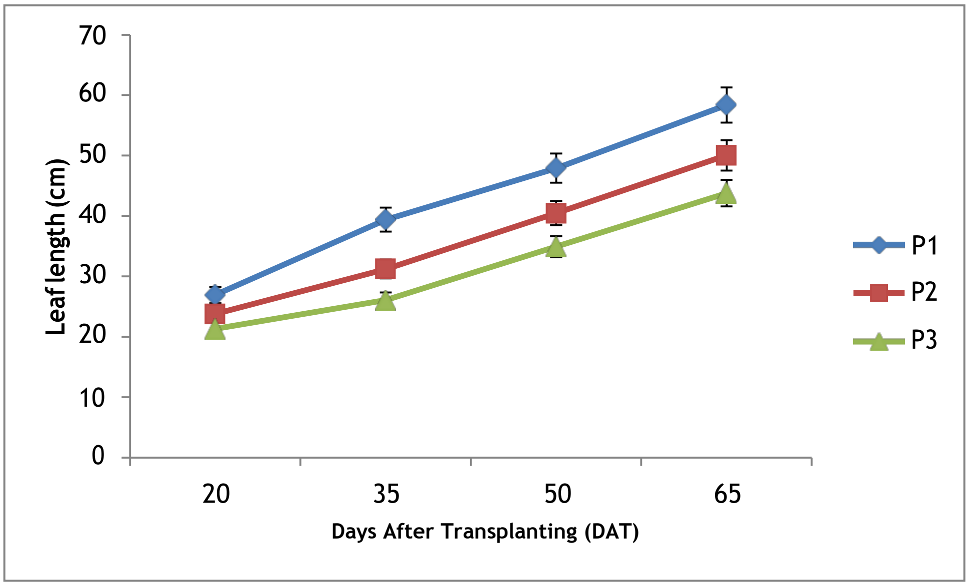


Fig. 4. Effect of leaf length as influenced by plants per hill of onion

Where, P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

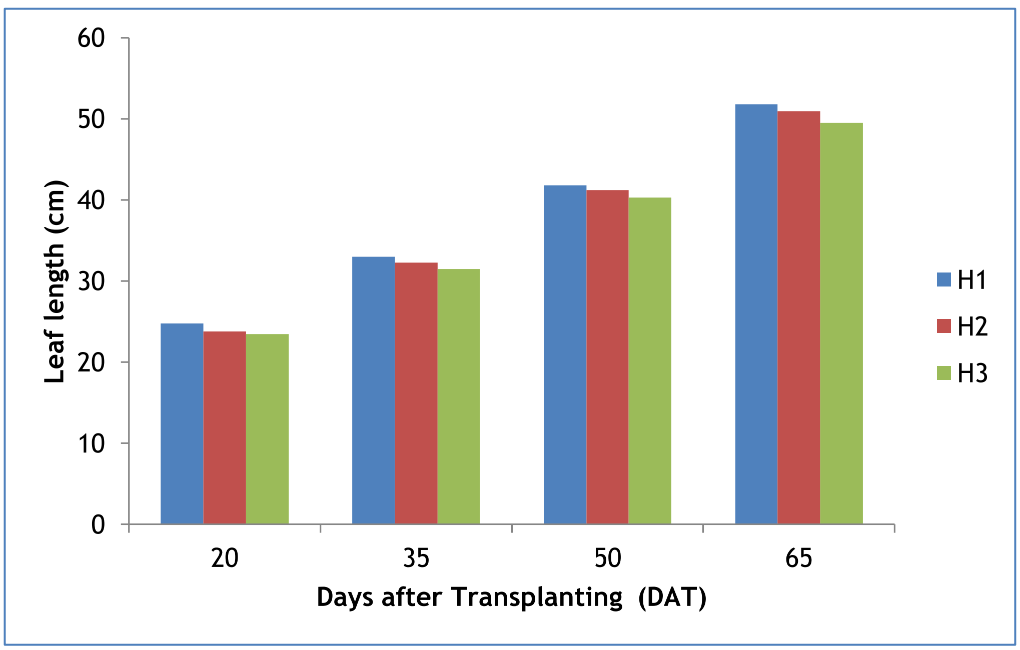


Fig. 5. Effect of leaf length as influenced by harvesting time of onion

Where, H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

Considerable influence was observed on leaf length of onion at different days after transplanting (DAT) persuaded by combined effect of plant per hill and harvesting time (Table 2 and Appendix V). Results signified that the treatment combination of P_1H_1 gave maximum leaf length where P_3H_3 showed minimum leaf length at all growth stages.At 20 DAT, the maximum leaf length (27.76 cm) was achieved from the treatment combination of P_1H_1 which was significantly different from all other treatment combinations whereas the minimum leaf length (20.63 cm) was recorded from the treatment combination of P_3H_3 which was statistically similar with P_3H_2. Similarly, the maximum leaf length at 35 DAT (40.19 cm), 50 DAT (48.43 cm) and 60 DAT (59.68 cm) was recorded from the treatment combination of P_1H_1 which was significantly similar with P_1H_2 and P_1H_3. The minimum leaf length at 35 DAT (24.90 cm), 50 DAT (33.60 cm) and 60 DAT (42.52 cm) was recorded from the treatment combination of P_3H_3 which was significantly similar with P_3H_2 at 35 DAT.

Table 2: Combined effect of plants per hill and harvesting time on leaf length (cm) at different days after transplanting of onion

Treatment	Leaf length (cm) at different days after transplanting (DAT)			
	20 DAT	35 DAT	50 DAT	65 DAT
P_1H_1	27.76 a	40.19 a	48.43 a	59.68 a
P_1H_2	26.55 b	39.08 ab	47.93 ab	57.88 ab
P_1H_3	26.38 b	38.90 ab	47.41 ab	57.62 ab
P_2H_1	24.52 c	31.76 c	41.36 c	51.22 c
P_2H_2	23.44 cd	31.35 c	40.16 cd	50.57 cd
P_2H_3	23.40 cd	30.55 cd	39.88 d	48.37 e
P_3H_1	21.92 e	27.02 e	35.64 e	44.54 f
P_3H_2	21.35 ef	26.27 ef	35.46 e	44.30 f
P_3H_3	20.63 f	24.90 f	33.60 f	42.52 g
$LSD_{0.05}$	1.588	1.614	1.512	1.627
CV(%)	3.91	6.28	4.77	5.40

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

Note: P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

4.1.3 Root length (cm)

At harvest root length of onion was found significant with the treatment of number of plants per hill (Fig. 6 and Appendix VI). It was noted that the highest root length (10.10 cm) was recorded from P_1 (One plant per hill) treatment which was significantly different from others whereas the lowest root length (6.94 cm) was recorded from P_3 (Three plants per hill) treatment. The treatment, P_2 (Two plants per hill) showed medium level of root length compared to the treatment of P_1 (One plant per hill) and P_3 (Three plants per hill). The highest root length from this treatment might be due to cause of higher nutrient availability to plants because of lower plant number per hill where same fertilizer doses were used for all the treatment.

Variation on root length of onion was not found significant among the treatments influenced by harvesting time (Fig. 7 and Appendix VI). But it was observed that the highest root length (9.08 cm) was achieved from H_3 (120 DAT) treatment whereas the lowest root length (8.13 cm) was achieved from H_1 (100 DAT) treatment.

The recorded data on root length was significant due to the combined of number of plants per hill and harvesting time (Table 3 and Appendix VI). Results revealed that the highest root length (10.43 cm) was obtained from the treatment combination of P_1H_3 which was statistically identical with P_1H_2. The lowest root length (6.63 cm) was obtained from treatment combination of P_3H_1 which was statistically identical with P_3H_2.

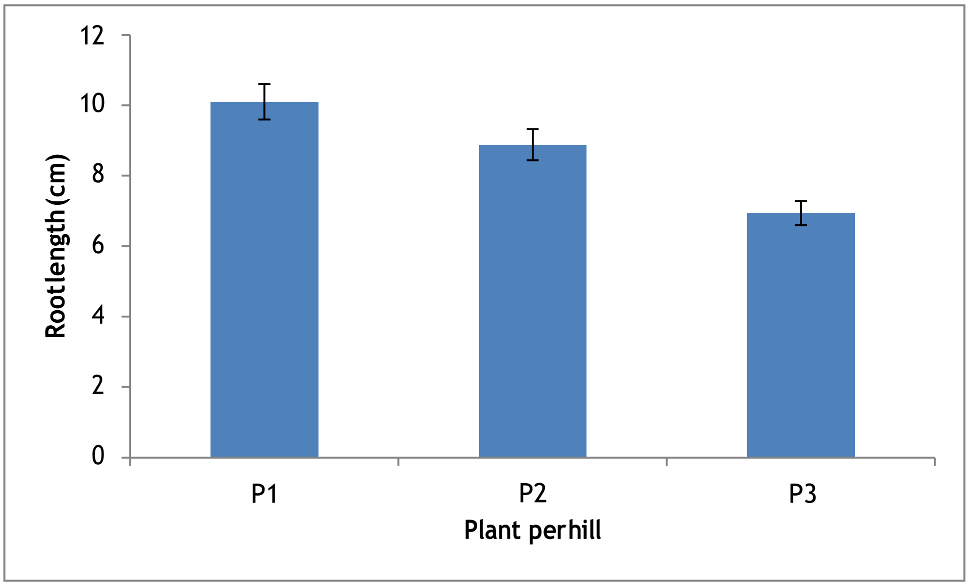


Fig. 6. Effect of root length as influenced by plants per hill of onion

Where, P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

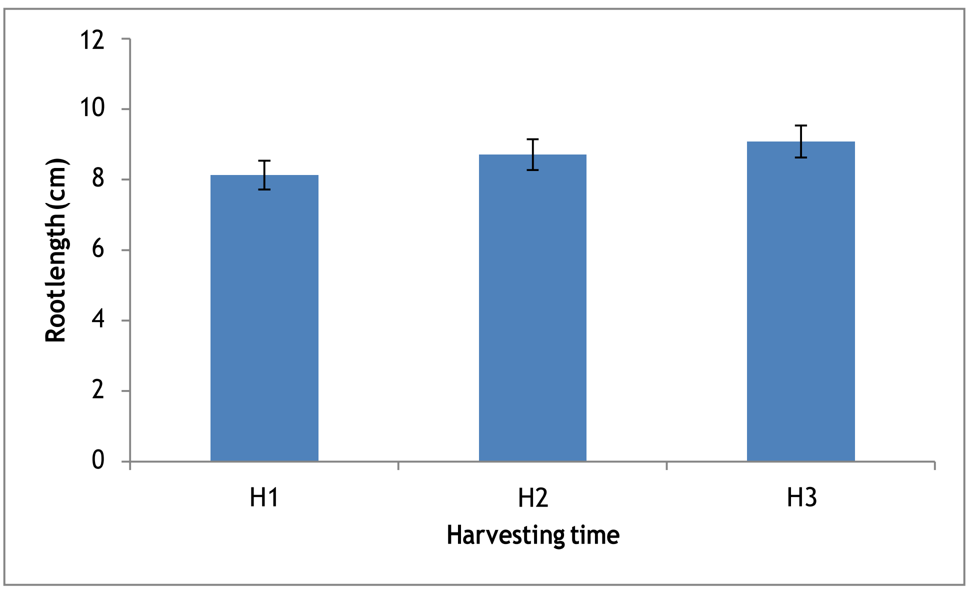


Fig. 7. Effect of root length as influenced by harvesting time of onion

Where, H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

Table 3. Combined effect of plants per hill and harvesting time on root length (cm) of onion

Treatment	Root length (cm)
P_1H_1	9.60 b
P_1H_2	10.27 a
P_1H_3	10.43 a
P_2H_1	8.16 d
P_2H_2	9.17 bc
P_2H_3	9.30 bc
P_3H_1	6.63 f
P_3H_2	6.69 f
P_3H_3	7.51 e
$LSD_{0.05}$	0.385
CV(%)	5.40

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

Note: P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

4.2 Yield contributing parameters

4.2.1 Neck diameter (cm)

Significant influence was noted on neck diameter of onion affected by number of plants per hill (Table 4 and Appendix VII). It was eminent that the highest neck diameter (1.29 cm) was recorded from P_1 (One plant per hill) treatment which was significantly different from others whereas the lowest neck diameter (0.99 cm) was recorded from P_3 (Three plants per hill) treatment which was statistically identical with P_2 (Two plants per hill). It had be showed that the increase in nec diameter of plant was reported when one seedling was transplanted per hill. Similar result was obtained of Herison *et al*. (1993).

Neck diameter on onion was not varied significantly due to harvesting time (Table 4 and Appendix VII). But it was observed that the highest neck diameter (1.22 cm) was achieved from H_1 (100 DAT) treatment whereas the lowest neck diameter (1.10 cm) was achieved from H_3 (120 DAT) treatment.

Significant variation was remarked on neck diameter influenced by combined of number of plants per hill and harvesting time (Table 4 and Appendix VII). Results exposed that the highest neck diameter (1.39 cm) was obtained from the treatment combination of P_1H_1 which was statistically similar with P_1H_2 and P_1H_3. The lowest neck diameter (0.92 cm) was obtained from treatment combination of P_3H_1 which was statistically similar with the treatment combination of P_2H_2, P_3H_1 and P_3H_2.

4.2.2 Bulb length (cm)

Number of plants per hill had significant influence on bulb length on onion (Table 4 and Appendix VII). It was found that the highest bulb length (4.71 cm) was recorded from P_1 (One plant per hill) treatment which was significantly different from others whereas the lowest bulb length (2.87 cm) was recorded from P_3 (Three plants per hill) treatment. The treatment, P_2 (Two plants per hill) showed intermediate result on bulb length compared to the treatment of P_1 (One plant per hill) and P_3 (Three plants per hill). This result is in agreement with the results of Hiron (1983); he noted that the onion bulb size is decreased with the increasing plant population. Rahman (2008) also reported that the bulb length of onion per plant was the highest (2.32 cm) when one plant was grown per hill and the three plants per hill showed the lowest (2.19 cm) length of bulb of onion.

There was no significant variation on bulb length influenced by harvesting time (Table 4 and Appendix VII). But it was observed that the highest bulb length (3.97 cm) was achieved from H_2 (110 DAT) treatment whereas the lowest bulb length (3.81 cm) was achieved from H_3 (120 DAT).

Bulb length was significantly influenced by combined of number of plants per hill and harvesting time (Table 4 and Appendix VII). Results showed that the highest bulb length (4.99 cm) was obtained from the treatment combination of P_1H_2 which was statistically similar with P_1H_1 and P_1H_3. The lowest bulb length (2.70 cm) was obtained from treatment combination of P_3H_3 which was significantly different from all other treatment combinations.

4.2.3 Bulb diameter (cm)

Significant variation was observed on bulb diameter on onion influenced by number of plants per hill (Table 4 and Appendix VII). The highest bulb diameter (4.69 cm) was recorded from P_1 (One plant per hill) treatment followed by the treatment, P_2 (Two plants per hill) whereas the lowest bulb diameter (3.21 cm) was recorded from P_3 (Three plants per hill) treatment. The decreased diameter of bulb in case of more than one plant/hill was due to more competition for nutrients, air and water. These results are in conformity with the results of Herison *et al.* (1993), they obtained larger diameter bulbs when one seedling was transplanted per hill. Similar result was obtained by Rahman (2004). He reported that the diameter of onion bulb per plant was the maximum (4.22 cm) when one plant was grown per hill and the minimum diameter was obtained when three plants were grown per hill.

Bulb diameter was not significantly varied due to harvesting time (Table 4 and Appendix VII). But it was recorded that the highest bulb diameter (4.05 cm) was achieved from H_1 (100 DAT) treatment whereas the lowest bulb diameter (3.76 cm) was achieved from H_3 (120 DAT) treatment.

Remarkable variation was observed on bulb diameter influenced by combined of number of plants per hill and harvesting time (Table 4 and Appendix VII). It was remarked that the highest bulb diameter (4.76 cm) was obtained from the treatment combination of P_1H_3 and P_1H_2. The lowest bulb diameter (3.12 cm) was obtained from treatment the combination of P_3H_3 which was statistically similar with the treatment combination of P_3H_2.

4.2.4 Fresh weight bulb^{-1} (g)

Significant influence was noted on fresh weight bulb^{-1} of onion affected by number of plants per hill (Table 4 and Appendix VII). The results examined that the highest fresh weight bulb^{-1} (41.64 g) was recorded from P_1 (One plant per hill) treatment followed by the treatment P_2 (Two plants per hill) whereas the lowest fresh weight bulb^{-1} (30.83 g) was recorded from P_3 (Three plants per hill) treatment. The decreasing trend of fresh weight per bulb with the increase of number of plants per hill, facing inter plant competition for light, nutrient, moisture and air. This result is also conformity to Vik (1994). He found that bulb weight was decreased when 3-7 seedlings were raised in small plots.

Variation on fresh weight bulb^{-1} was noted significant influenced by harvesting time (Table 4 and Appendix VII). Results signified that the highest fresh weight bulb^{-1} (38.29 g) was achieved from H_1 (100 DAT) treatment whereas the lowest fresh weight bulb^{-1} (35.58 g) was achieved from H_3 (120 DAT) treatment which was statistically identical with H_2 (110 DAT) treatment.

The recorded data on fresh weight bulb^{-1} was significant with combined of number of plants per hill and harvesting time (Table 4 and Appendix VII). It was verified that the highest fresh weight bulb^{-1} (43.52 g) was obtained from the treatment combination of P_1H_1 which was statistically similar with P_1H_2. Similarly, the treatment combinations, P_1H_3 and P_2H_1 also showed comparatively higher fresh weight bulb^{-1} but significantly different from P_1H_1. The lowest fresh weight bulb^{-1} (29.07 g) was obtained from the treatment combination of P_3H_3 which was statistically similar with P_3H_2.

4.2.5 Dry matter content of bulb (%)

Considerable influence was observed on dry matter content of weight bulb of onion persuaded by number of plants per hill (Table 4 and Appendix VII). The results showed that the highest dry matter content of weight bulb (18.04%) was recorded from P_1 (One plant per hill) treatment followed by the treatment P_2 (Two plants per hill) whereas the lowest dry matter content of weight bulb (14.58%) was recorded from P_3 (Three plants per hill) treatment. This result are similar with Rahman (2004).

Significant variation was remarked on dry matter content of weight bulb of onion influenced by harvesting time (Table 4 and Appendix VII). Results signified that the highest dry matter content of weight bulb (16.46%) was achieved from H_2 (110 DAT) which was statistically identical with H_3 (120 DAT) treatment whereas the lowest dry matter content of weight bulb (15.76%) was achieved from H_1 (100 DAT) treatment. Bulb yield increased with the progress of growth and maturing of the bulb. This may be explained with a progressive increase of day- length and sunlight intensity during the crop cycle (Ierna, 2009).

Remarkable variation was observed on dry matter content of weight bulb influenced by combined of number of plants per hill and harvesting time (Table 4 and Appendix VII). It was verified that the highest dry matter content of weight bulb (18.46%) was obtained from the treatment combination of P_1H_2 which was statistically identical with P_1H_3 and statistically similar with P_1H_1. Similarly, the treatment combinations, P_2H_2 and P_2H_3 also showed comparatively higher dry matter content of weight bulb but significantly different from P_1H_3. The lowest dry matter content of weight bulb (14.27%) was obtained from the treatment combination of P_3H_1 which was statistically similar with P_3H_2.

Table 4. Combined effect of plants per hill and harvesting time on yield contributing parameters of onion

Treatment	Yield contributing parameters				
	Neck diameter (cm)	Bulb length (cm)	Bulb diameter (cm)	Fresh weight $bulb^{-1}$ (g)	Dry weight of bulb (%)
Effect of plants per hill					
P_1	4.71 a	4.69 a	1.29 a	41.64 a	10.10 a
P_2	4.06 b	3.82 b	1.15 b	37.87 b	8.88 b
P_3	2.87 c	3.21 c	0.99 b	30.83 c	6.94 c
$LSD_{0.05}$	0.414	0.256	0.183	2.067	1.271
CV(%)	7.96	9.31	5.78	4.54	9.25
Effect of harvesting time					
H_1	3.86	4.05	1.22	38.29 a	8.13
H_2	3.97	3.91	1.11	36.48 b	8.71
H_3	3.81	3.76	1.11	35.58 c	9.08
$LSD_{0.05}$	0.328^{NS}	0.373^{NS}	0.179^{NS}	0.587	1.183^{NS}
CV(%)	3.91	6.28	4.77	3.91	5.40
Combined effect of plant per hill and harvesting time					
P_1H_1	1.39 a	4.52 ab	4.76 a	43.52 a	17.53 ab
P_1H_2	1.23 ab	4.99 a	4.58 ab	41.23 ab	18.46 a
P_1H_3	1.25 ab	4.63 ab	4.73 a	40.17 bc	18.14 a
P_2H_1	1.23 b	4.13 c	4.13 b	38.53 bc	15.47 bc
P_2H_2	1.07 cd	4.32 bc	3.94 bc	37.60 c	15.67 b
P_2H_3	1.15 bc	3.73 de	3.40 d	37.49 c	15.86 b
P_3H_1	1.03 cd	2.93 d	3.30 d	32.83 d	14.27 d
P_3H_2	1.02 cd	2.97 d	3.20 de	30.60 de	14.40 cd
P_3H_3	0.92 d	2.70 f	3.12 e	29.07 e	15.06 b-d
$LSD_{0.05}$	0.145	0.284	0.316	2.891	1.097
CV(%)	4.77	3.91	6.28	3.91	6.28

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

Note: P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

4.3 Yield parameters

4.3.1 Yield per plot (kg)

Significant variation was observed on yield plot^{-1} of onion influenced by number of plants per hill (Table 5 and Appendix VIII). Results indicated that the highest yield plot^{-1} (1.28 kg) was recorded from P_2 (Two plants per hill) which was statistically identical with P_3 (Three plants per hill) treatment whereas the lowest yield plot^{-1} (0.76 kg) was recorded from P_1 (One plant per hill) treatment. This might be due to the fact increase in yield from more than one plants/hill to the increase in number of plants/unit area. Similar result was reported by Mondal and Brewster (1989).

Yield per plot was significantly varied due to harvesting time (Table 5 and Appendix VIII). It was examined that the highest yield plot^{-1} (1.21 kg) was achieved from H_2 (110 DAT) treatment whereas the lowest yield plot^{-1} (0.99 kg) was achieved from H_1 (100 DAT) treatment which was statistically identical with H_3 (120 DAT). Similar result was also observed by Choudhury (1996) found that time of harvest is a compromise between maximum yield and maximum storage life and skin quality.

Remarkable variation was observed on yield plot^{-1} influenced by combined of number of plants per hill and harvesting time (Table 5 and Appendix VIII). It was remarked that the highest yield plot^{-1} (1.37 kg) was obtained from the treatment combination of P_2H_2 which was statistically similar with P_2H_3. The treatment combinations, P_1H_3 and P_3H_2 also showed comparatively higher yield plot^{-1} but significantly different from P_2H_2. The lowest yield plot^{-1} (0.58 kg) was obtained from the treatment combination of P_1H_1 which was significantly different from all other treatment combinations. This findings are agreement with Mondol and Breuste (1989). They found that high plant density gave higher yield.

4.3.2 Yield per hectare (t)

Significant variation was found on yield per hectare of onion influenced by number of plants per hill (Table 5 and Appendix VIII). Results showed that the highest yield hectare (22.92 t) was recorded from P_2 (Two plants per hill) followed by the treatment P_3 (Three plants per hill) whereas the lowest yield hectare (15.43 t) was recorded from P_1 (One plant per hill) treatment. This result is in agreement with the results of Halder (2001), he found that two or three plants/hill produced significantly higher yield than one plant. The results of plant/hill are in agreement with the findings of Tarafder (1999). He found that two or three or four plants/hill produced significantly higher yield than one plant/hill of carrot. Similar trend was obtained by Mandal et al. (1973), they found that two plants per hill gave better yield than that of one plant/hill.

Yield per hectare was significantly varied due to harvesting time (Table 5 and Appendix VIII). It was examined that the highest yield per hectare (22.46 t) was achieved from H_2 (110 DAT) treatment followed by the treatment H_3 (120 DAT) whereas the lowest yield per hectare (16.69 t) was achieved from H_1 (100 DAT). Choudhury (1996) found that time of harvest is a compromise between maximum yield and maximum storage life and skin quality. Similar result was also observed by Sebsebe *et al*. (2010), Kopsell and Randle (1997) and Choudhury (1996).

Remarkable variation was observed on yield per hectare influenced by combined of number of plants per hill and harvesting time (Table 5 and Appendix VIII). It was verified that the highest yield per hectare (24.40 t) was obtained from the treatment combination of P_2H_2 which was significantly different from all other treatment combinations. The second highest yield per hectare (23.00 t) was achieved from the treatment combination of P_2H_3. The lowest yield hectare (14.37 t) was obtained from the treatment combination of P_1H_1 which was also significantly different from all other treatment combinations followed by P_1H_2 and P_1H_3.

Table 5. Effect of plants per hill and harvesting time on yield parameters of onion

Treatment	Yield parameters	
	Yield plot^{-1} (kg)	Yield ha^{-1} (t)
Effect of plants per hill		
P_1	0.76 b	15.43 c
P_2	1.28 a	22.92 a
P_3	1.21 a	21.78 b
$LSD_{0.05}$	0.2189	0.7158
CV(%)	3.91	6.28
Effect of harvesting time		
H_1	0.99 b	16.69 c
H_2	1.21 a	22.46 a
H_3	1.05 b	18.99 b
$LSD_{0.05}$	0.109	0.7158
CV(%)	3.91	6.28
Combined effect of plant per hill and harvesting time		
P_1H_1	0.58 e	14.37 h
P_1H_2	0.99 cd	16.87 g
P_1H_3	1.26 b	16.83 g
P_2H_1	0.70 d	19.43 f
P_2H_2	1.37 a	24.40 a
P_2H_3	1.27 ab	23.00 b
P_3H_1	1.11 c	20.50 de
P_3H_2	1.25 b	22.47 bc
P_3H_3	1.21 bc	21.53 cd
$LSD_{0.05}$	0.109	1.240
CV(%)	8.17	9.33

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

Note: P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

4.4 Economic analysis

All the material and non-material input cost like land preparation, onion seed cost organic manure, fertilizers, irrigation and manpower required for all the operation, interest on fixed capital of land (Leased land by loan basis) and miscellaneous cost were considered for calculating the total cost of production from planting seeds to harvesting of onion bulb were calculated for unit plot and converted into cost per hectare (Table 6 and Appendix IX). Price of onion bulb was considered at market rate. The economic analysis is presented under the following headlines:

4.4.1 Gross income

The combination of different levels of plants per hill and harvesting time showed different gross return among the treatment combinations (Table 6). Gross income was calculated on the basis of sale of mature bulb. The highest gross return (610000 Tk) obtained from P_2H_2 treatment combination and lowest gross return (359250 Tk) obtained from P_1H_1 treatment combination.

4.4.2 Net return

The combination of different levels of plants per hill and harvesting time showed different net return among the treatment combinations (Table 6). The highest net return (436027 Tk) obtained from P_2H_2 treatment combination and lowest net return (186407 Tk) was obtained from P_1H_1 treatment combination.

4.4.3 Benefit cost ratio (BCR)

Different BCR among the different treatment combinations of plants per hill and harvesting time was obtained (Table 6). The highest Benefit cost ratio (BCR); 3.51 was obtained from P_2H_2 treatment combination and lowest Benefit cost ratio (2.08) was obtained from P_1H_1 treatment combination. From economic point of view, it was apparent from the above results, the combination of P_2H_2 (Two plants per hill with harvesting at 110 DAT) was more profitable than rest of the treatment combinations.

Table 6. Cost and return analysis of onion bulb considering different plants per hill abd harvesting time

Treatment	Bulb yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total cost of production (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
P_1H_1	14.37	359250	172843	186407	2.08
P_1H_2	16.87	421750	173973	247777	2.42
P_1H_3	16.83	420750	175103	245647	2.40
P_2H_1	19.43	485750	172843	312907	2.81
P_2H_2	24.40	610000	173973	436027	3.51
P_2H_3	23.00	575000	175103	399897	3.28
P_3H_1	20.50	512500	172843	339657	2.97
P_3H_2	22.47	561750	173973	387777	3.23
P_3H_3	21.53	538250	175103	363147	3.07

Note: P_1= One plant per hill, P_2= Two plants per hill, P_3= Three plants per hill

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

Price of onion = 25 Tk/ kg

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the horticultural research farm of Sher –e-Bangla Agricultural University, Dhaka, during the period from November, 2016 to April, 2017 to study the effect of growth, yield and economic benefit of onion (*Allium cepa* L.) as influenced by number of plants per hill and harvesting time. The experiment consisted of two factors; (i)three levels of number of plants hill^{-1}*viz*. P_1 = One plant hill^{-1}, P_2 = Two plants hill^{-1} and P_3 = Three plants hill^{-1} and (ii) three levels of harvesting time*viz*. H_1 = 100 DAT, H_2 = 110 DAT and H_3 = 120 DAT. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The size of the unit plot was .75 m × .75 m. The distance maintained between two plots was 0.5 m and between blocks was 0.75 m.

Number of plants hill^{-1} had significant effect on growth, yield and yield contributing parameters of onion. Results revealed that in terms of growth parameters, the tallest plant (62.39 cm), maximum leaf length (58.39 cm) and highest root length (10.10 cm) were found from P_1 (One plant hill^{-1}) treatment. The lowest plant height (53.68 cm), minimum leaf length (43.79 cm) and lowest root length (6.94 cm) were found from P_1 (One plant hill^{-1}) treatment. Considering yield contributing parameters, the highestneck diameter (1.29 cm), highest bulb length (4.71 cm), highest bulb diameter (4.69 cm), highest fresh weight bulb^{-1} (41.64 g) and highest dry weight bulb^{-1} (18.04%) were obtained from P_1 (One plant hill^{-1}) treatment.The lowest neck diameter (0.99 cm), lowest bulb length (2.87 cm), lowest bulb diameter (3.21 cm), lowest fresh weight bulb^{-1} (30.83 g) and lowest dry weight bulb^{-1} (14.58%) were obtained from P_3 (Three plants hill^{-1}) treatment.Regarding, yield parameters, the highestyield plot^{-1} (1.28kg) and highest yield ha^{-1} (22.92t) were recorded from P_2 (Two plants hill^{-1}) treatment where the lowest yield plot^{-1} (0.76 kg) and lowest yield ha^{-1} (15.43 t) were recorded from P_1 (One plant hill^{-1}) treatment.

Under the present study, harvesting time of onion had no significant effect on growth and yield contributing parameters (plant height, leaf length, root length, neck diameter, bulb length and bulb diameter) except fresh weight bulb^{-1} and % dry weight of bulb. Yield of onion was also affected significantly by harvesting time. Results indicated that the highest fresh weight bulb^{-1} (38.29 g) was recorded from H_1 (100 DAT) treatment and the highest % dry weight of bulb (16.46%) was recorded from H_3 (120 DAT) treatment but the highest yield plot^{-1} (1.21 kg) and highest yield ha^{-1} (22.46 t) were achieved from H_2 (110 DAT) treatment. Similarly, the lowest fresh weight bulb^{-1} (35.58 g) was recorded from H_3 (120 DAT) treatment and the lowest % dry weight of bulb (15.76%) was recorded from H_1 (100 DAT) treatment but the lowest yield plot^{-1} (1.21 kg) and lowest yield ha^{-1} (22.46 t) were achieved from H_1 (100 DAT) treatment.

Combined effect of number of plants hill^{-1} and harvesting time showed significant variation on growth, yield and yield contributing parameters of onion.In terms of growth parameters, the tallest plant (63.25 cm) and maximum leaf length (59.68 cm) were achieved from the treatment combination of P_1H_1 but the highest root length (10.43 cm) was found from the treatment combination of P_1H_3. The lowest plant height (52.88 cm) and minimum leaf length (42.52 cm) were recorded from the treatment combination of P_3H_3 but the lowest root length (6.63 cm) was found from P_3H_1. Considering yield contributing parameters, the highest neck diameter (1.39 cm), highest bulb diameter (4.76 cm) and highest fresh weight bulb^{-1} (43.52 g) were achieved from the treatment combination of P_1H_1 but the highest bulb length (4.99 cm) and highest dry weight bulb^{-1} (18.46%) were obtained from the treatment combination of P_1H_2. The lowest neck diameter (0.92 cm), lowest bulb length (2.70cm), lowest bulb diameter (3.12 cm) and lowest fresh weight bulb^{-1} (29.07 g) were obtained from the treatment combination of P_3H_3 but lowest dry weight bulb^{-1} (14.27%) was obtained from the treatment combination of P_3H_1.Regarding, yield parameters, the highest yield plot^{-1} (1.37 kg) and highest yield ha^{-1} (24.40 t) were recorded from the treatment combination of P_2H_2 where the lowest yield plot^{-1} (0.58 kg) and lowest yield ha^{-1} (14.37 t) were recorded from the treatment combination of P_1H_1.

Considering economic analysis, it was found that the highest gross return (392000Tk) and the highest net return (436027 Tk) were obtained from the treatment combination of P_2H_2. The highest Benefit cost ratio (BCR); 3.51 was also obtained from P_2H_2 (Two plants hill^{-1} with harvesting at 110 DAT) treatment combination.

Again, the lowest gross return (359250 Tk), lowest net return (186407Tk) and lowest Benefit cost ratio (2.08) were obtained from P_1H_1 (One plant hill^{-1} with harvesting at 100 DAT) treatment combination.

Based on the experimental results, it may be concluded that

1. The effect of number of plants hill^{-1}had positive effect on growth, yield and yield attributes of onion.
2. The treatment combination of P_2 (Two plants hill^{-1}) with H_2 (harvesting at 110 DAT) seemed to be more suitable for getting higher yield in onion.
3. From economic point of view the treatment combination of P_2H_2(Two plants hill^{-1} with harvesting at 110 DAT) was more suitable under the present study.

Recommendations

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. Such study may be conducted in different agro-ecological zones (AEZ) and seasons of Bangladesh for exploitation of regional adaptability and other performances
2. Some other levels of plants hill^{-1} and harvesting time may be included in future program for more confirmation of the results.

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APPENDICES

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

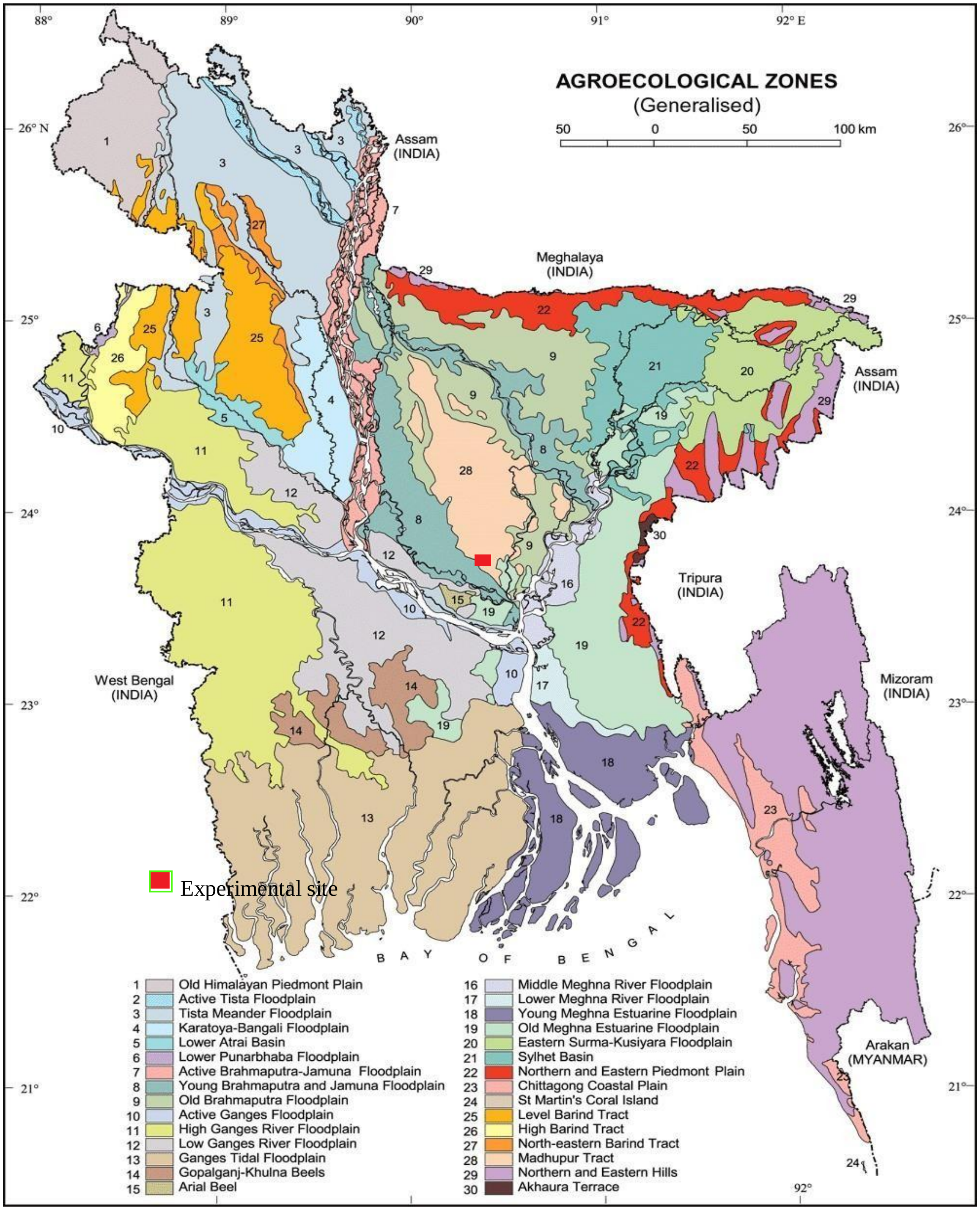


Fig. 8. Experimental site

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from November 2016to April, 2017

Month	Air temperature (0C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
October, 2017	26.5	19.4	81	22
November, 2017	25.8	16.0	78	00
December, 2017	22.4	13.5	74	00
January, 2018	24.5	12.4	68	00
February, 2018	27.1	16.7	67	30

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

Appendix III. Characteristics of experimental soil analyzed at Soil Resource Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV: Plant height (cm) of onion influenced by effect of plants per Hill and harvesting time

Source of variation	Degrees of freedom	Plant height (cm) at different days after transplanting (DAT)			
		20 DAT	35 DAT	50 DAT	65 DAT
Replication	2	0.036	0.341	0.626	0.732
Factor A	2	4.256*	13.061**	15.632*	18.263**
Factor B	2	1.312^{NS}	6.415^{NS}	9.312^{NS}	8.54 ^{NS}
AB	4	3.538*	10.523*	14.124**	11.329*
Error	18	0.366	0.786	1.052	1.514

Appendix V: Leaf length (cm) of onion influenced by plants per hill and harvesting time

Source of variation	Degrees of freedom	Leaf length (cm) at different days after transplanting (DAT)			
		20 DAT	35 DAT	50 DAT	65 DAT
Replication	2	0.261	0.348	0.283	0.663
Factor A	2	2.326*	5.146**	8.661*	10.22*
Factor B	2	1.104^{NS}	2.065^{NS}	5.214^{NS}	5.64^{1NS}
AB	4	1.012**	7.537*	10.383**	11.38*
Error	18	0.362	0.424	1.063	1.024

Appendix VI. Yield contributing parameters of onion influenced by effect of plant hill^{-1} and harvesting time

Source of variation	Degrees of freedom	Root length (cm)
Replication	2	0.106
Factor A	2	4.318*
Factor B	2	2.017^{NS}
AB	4	6.221*
Error	18	0.207

Appendix VII. Yield contributing parameters of onion influenced by effect of plant hill^{-1} and harvesting time

Source of variation	Degrees of freedom	Yield contributing parameters				
		Bulb length (cm)	Bulb diameter (cm)	Neck diameter (cm)	Fresh weight bulb^{-1} (g)	Dry weight of bulb (%)
Replication	2	0.048	0.018	0.011	0.317	0.074
Factor A	2	3.246**	1.385*	1.036*	9.135*	6.526*
Factor B	2	1.085^{NS}	0.312^{NS}	0.405^{NS}	6.514*	4.371**
AB	4	4.117**	2.403*	1.152**	7.328*	5.288*
Error	18	0.076	0.014	0.011	1.123	0.432

Appendix VIII. Yield parameters of onion influenced by different plant hill^{-1} and harvesting time

Source of variation	Degrees of freedom	Yield parameters	
		Yield plot^{-1} (kg)	Yield ha^{-1} (t)
Replication	2	0.026	0.671
Factor A	2	2.139**	7.223*
Factor B	2	1.514**	7.264**
AB	4	2.036*	9.315**
Error	18	0.018	1.028

Appendix IX.Cost of production of onion influenced by seedlings per hill and harvesting time

A. Input cost (Tk. ha^{-1})

Treatments	Cultivation with Labor	Onion seed	Manure and fertilizer					Transplanting cost	Pesticides	Irrigation	Subtotal (A)
			Cowdung	Urea	TSP	MP	Gypsum				
P_1H_1	60000	1000	25000	3840	5500	2400	1320	12000	4000	2500	117560
P_1H_2	60000	2000	25000	3840	5500	2400	1320	12000	4000	2500	118560
P_1H_3	60000	3000	25000	3840	5500	2400	1320	12000	4000	2500	119560
P_2H_1	60000	1000	25000	3840	5500	2400	1320	12000	4000	2500	117560
P_2H_2	60000	2000	25000	3840	5500	2400	1320	12000	4000	2500	118560
P_2H_3	60000	3000	25000	3840	5500	2400	1320	12000	4000	2500	119560
P_3H_1	60000	1000	25000	3840	5500	2400	1320	12000	4000	2500	117560
P_3H_2	60000	2000	25000	3840	5500	2400	1320	12000	4000	2500	118560
P_3H_3	60000	3000	25000	3840	5500	2400	1320	12000	4000	2500	119560

Note: P_1= One plant $hill^{-1}$, P_2= Two plants $hill^{-1}$, P_3= Three plants $hill^{-1}$

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DAT

Seed :250 tk/kg, Cowdung: 2.5tk/kg, Urea: 16tk/kg, TSP: 25tk/kg, MP: 16tk/kg, Gupsum: 12tk/kg

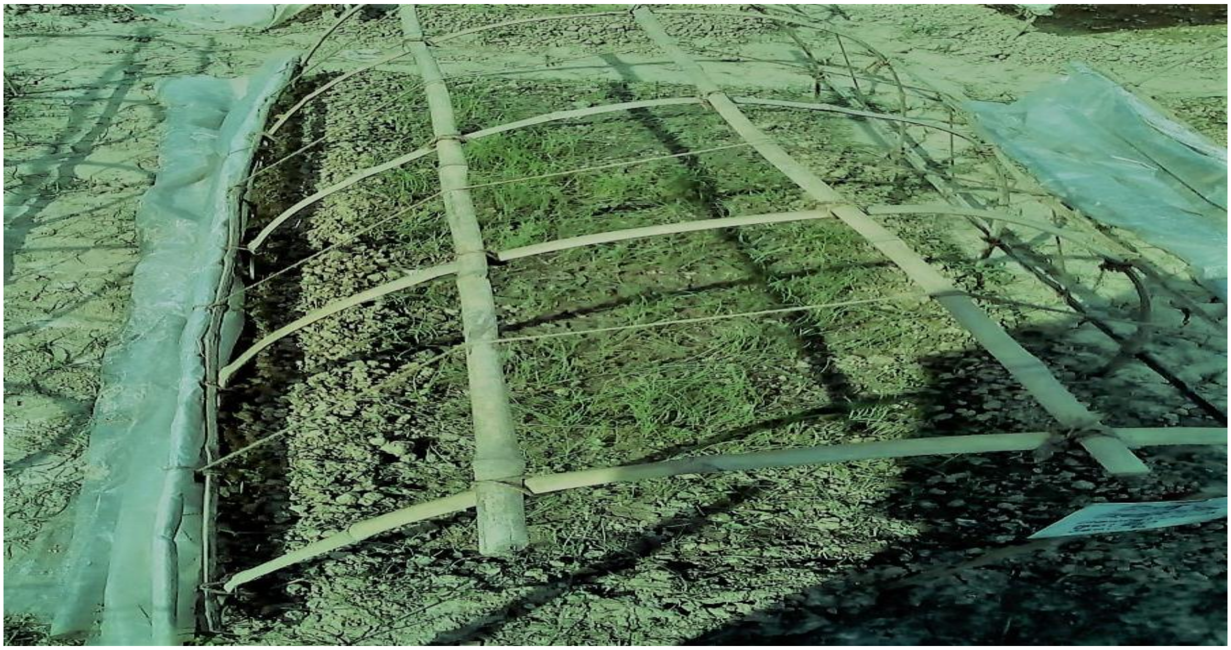
B. Overhead cost (Tk. ha^{-1}), Cost of production (Tk. ha^{-1}), Gross return (Tk. ha^{-1}), Net return (Tk. ha^{-1}) and BCR

Treatments	Overhead cost (Tk. ha^{-1})				Subtotal (A)	Total cost of production (A+B)	Yield ha^{-1} (ton)	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
	Cost of leased land for 6 months (8% of value of land Tk. 10,00,000/-	Miscellaneous cost (Tk. 5% of the input cost)	Interest on running capital for 6 month (8% of cost year-1)	Subtotal (B)						
P_1H_1	40000	5878	9404.8	55282.8	117560	172843	14.37	359250	186407	2.08
P_1H_2	40000	5928	9484.8	55412.8	118560	173973	16.87	421750	247777	2.42
P_1H_3	40000	5978	9564.8	55542.8	119560	175103	16.83	420750	245647	2.40
P_2H_1	40000	5878	9404.8	55282.8	117560	172843	19.43	485750	312907	2.81
P_2H_2	40000	5928	9484.8	55412.8	118560	173973	24.40	610000	436027	3.51
P_2H_3	40000	5978	9564.8	55542.8	119560	175103	23.00	575000	399897	3.28
P_3H_1	40000	5878	9404.8	55282.8	117560	172843	20.50	512500	339657	2.97
P_3H_2	40000	5928	9484.8	55412.8	118560	173973	22.47	561750	387777	3.23
P_3H_3	40000	5978	9564.8	55542.8	119560	175103	21.53	538250	363147	3.07
Selling price of bulb = 25 Tk/kg										

Note: P_1= One plant hill^{-1}, P_2= Two plants hill^{-1}, P_3= Three plants hill^{-1}

H_1 = 100 DAT, H_2= 110 DAT, H_3 = 120 DA

PLATES



Plat 1. A Photograph showing the raising of seedling in the seed bed.

Plant 2. A pictorial view of onion field showing intercultural operation

Plate 3. A photograph showing experimental plot of onion field.

Plate 4. A photograph showing the harvesting of onion.

Plate 5. A photograph showing the harvested onion from different treatment combinations