IMPACT OF PLANTING TIME AND NITROGEN ON GROWTH AND YIELD OF TOMATO ON ROOFTOP GARDEN

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CERTIFICATE

*This is to certify that thesis entitled, "***IMPACT OF PLANTING TIME AND NITROGEN ON GROWTH AND YIELD OF TOMATO ON ROOFTOP GARDEN***"submitted to the Faculty of Agriculture, Sher-e-BanglaAgricultural University, Dhaka, in partial fulfillment of the requirements for the degreeof* ***MASTER OF SCIENCE (M.S.) inAGROFORESTRY AND ENVIRONMENTAL SCIENCE****, embodies the result of a piece of bona-fide research work carried out by* ***ISRAT JAHAN PINGKI****, Registration no.* ***14-05890****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 duringthe course of this investigation has duly been acknowledged.

Date:

Place: Dhaka, Bangladesh

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Prof. Dr. Md. Forhad Hossain

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The Author
June, 2021

Dedicated To

My beloved

Brother

IMPACT OF PLANTING TIME AND NITROGEN ON GROWTH AND YIELD OF TOMATO ON ROOFTOP GARDEN

ABSTRACT

The field experiment was conducted at the experimental plot of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from September, 2019 to March, 2020 in Rabi season to find out the impact of different planting time and nitrogen levels on growth and yield of tomato on rooftop garden.BARI tomato-14, also known as ‘Sharabonti’ was used as planting material in this study. The experiment consisted of two factors: Factor A: Planting time (3 dates) as i) P_1 – 1st October, 2019, ii) P_2 – 15th October, 2019 and iii) P_3 – 1st November, 2019. and Factor B: Nitrogen management (4 levels) as i) N_0 - 0 kg ha^{-1} (control), ii) N_1 – 70 kg ha^{-1}, iii) N_2 – 120 kg ha^{-1} and iv) N_3 – 170 kg ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (Factorial) with three (3) replications. Different date of planting, varying level of nitrogen fertilizer and the interaction effect showed significant difference on growth and yield parameters of tomato.Transplanting tomato seedlings at 15th October (P_2) showed the most significant effect on the growth and yield of tomato. Application of 120 kg N ha^{-1}(N_2) had the maximum effect on the growth and yield of tomato. In case of interaction, the highest result was obtained from P_2N_2 (15th October planting with 120 kg N ha^{-1} application) treatment combination. Application of 120 kg N ha^{-1} on tomato plants which were planted at 15th October seemed to be more suitable for getting higher amount and quality fruit yield of tomato on rooftop garden.

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LIST OF ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
eds.	Editors
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
SAU	Sher-e-Bangla Agricultural University
viz.	Namely
%	Percentage
@	At the rate of
AEZ	Agro-Ecological Zone
Agra.	Agricultural
Agric.	Agriculture
Annu.	Annual
Appl.	Applied
Biol.	Biology
Chem.	Chemistry
cm	Centi-meter
CV	Coefficient of Variance
Dev.	Development
Ecol.	Ecology
Environ.	Environmental
et al.	et alia (and others)
Exptl.	Experimental
g	Gram (s)
i.e.	that is
J.	Journal
kg	Kilogram (s)
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
mg	Milligram
Nutr.	Nutrition
Physiol.	Physiological
Progress.	Progressive
Res.	Research
Sci.	Science
Soc.	Society
SRDI	Soil Resource Development Institute
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Programme
Viz	videlicet (L.), Namely

CHAPTER 1

INTRODUCTION

Since independence, the economy of Bangladesh is mostly dependent on its agriculture. But with the recent changes in its economy, urbanization and industrialization have taken over agriculture and as a result, the country's net available cultivable land is being decreased day by day. In Dhaka, one of the world's fastest growing mega cities, open and cultivable land has been converting to built-up area indiscriminately and thus agricultural land has been decreased at an alarming rate (Islam and Ahmed, 2011). Implementing rooftop farming can be a possible solution to reduce the food supply problems, make urban living more self-sufficient and make fresh vegetables more accessible to urban individuals. It is estimated that 10,000 ha space of Dhaka city can be brought under rooftop farming and the residents of the city can taste fresh vegetables as well as over 10% of the demand can be fulfilled through rooftop farming (Wardard, 2014). A survey showed that most of the roofs of Dhaka city are suitable for gardening and do not require major improvement work, sometimes only need some modifications (Islam, 2004).

Today in this urban planet, 54% of the world's population are living in urban areas and the share is expected to increase to 66% by 2050 (United Nations, 2014). Rapid urbanization and urban growth are placing massive demand on urban food supply systems. Moreover, many cities in the world are facing problems like rapid decrease in green space and increase in heat island effects. Urban agriculture or farming is promoted as a potential solution to these problems (Smit*et al*., 2001). Farming on the rooftop of the buildings in urban areas is usually done by using green roof, hydroponics, organic, aeroponics or container gardens (Asad and Roy, 2014).Urban agriculture is the practice of cultivating, processing, and distributing food in or around a village, town, or city. Rooftop garden is a part of urban agriculture. Besides the decorative benefit, roof plantings may provide food, temperature control, hydrological benefits, architectural enhancement, habitats or corridors for wildlife,recreational opportunities, and in large scale it may even have ecological benefits (Stewart and Oke, 2009). Roof top gardening is suitable for vegetables cultivation in our country.

The Solanaceous group of vegetables (tomato, eggplant, chili and bell peppers) generally takes up large amounts of nutrients that have specialized functions and should be supplied to plant at the right time with suitable quantity. Tomato (*Lycopersiconesculentum*Mill.), a member of the family Solanaceae is one of the most important and quality vegetables grown in Bangladesh. It is the "No. 1 processing vegetable" because of its demand not only in processing sector but also as a vegetable and protective food. It ranks third next to potato and sweet potato in terms of world vegetable production (FAO, 2015) and top the list of canned vegetable (Chaudhury, 1979). But in Bangladesh, it ranks second which is next to potato (BBS, 2016). Tomato contains lycopene pigment which is a vital anti-oxidant that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013).Recent statistics showed that tomato was grown in 17.790 hectares of land and the total production was approximately 202.000 metric tons in Bangladesh during the year 2014–2015. Thus, the Average yield of tomato was 18.35 $t \cdot ha^{-1}$ (BBS, 2015). While it was 69.41 $t \cdot ha^{-1}$ in USA, 65.45 $t \cdot ha^{-1}$ in Japan, 48.13 $t \cdot ha^{-1}$ in China, 23.79 $t \cdot ha^{-1}$in Thailand, 21.27 $t \cdot ha^{-1}$ in India and 19.67 $t \cdot ha^{-1}$in Pakistan (FAO, 2014).

In Bangladesh, usually early November is the planting time seems to be the best (Hossain *et al.*, 2013) and late planting results lower yield and enhanced disease infection in tomato.For fruit settings, favourable temperature is around 21°C. Night temperature is more important for tomato fruit setting than that of the day. In Bangladesh, congenial atmosphere remains for tomato production during low temperature winter season that is early November is the best time for tomato planting in our country (Hossain *et al.*, 1986). High temperatures reduce fruit set, fruit production and yield in tomato (Patel *et al*, 2012).

Tomato requires large quantity of readily available nitrogen nutrient (Gupta and Shukla, 1977). To get one-ton fresh fruit production, plant need to absorb on average 2.50–3.00 kg N, 0.20–0.30 kg P and 3.00–3.50 kg K (Hedge, 1997).It has the largest effect on yield and quality of tomato (Xin*et al.*, 1997). Adequate nitrogen increases fruit quality, fruit size, keeping quality, colour, taste and acidity is also increased by excess nitrogen (Sharma and Thakur, 2002).

Green roofs are constructed with less than 20% organic matter combined with coarse, heat-expanded materials, such as slate or shale. This provides for high permeability and low cation exchange capacity (Emilsson*et al.*, 2007). Substrate organic matter breaks down over time (Hathaway *et al.,* 2008). This breakdown of organic matter can result in nutrient leaching which often decreases as the roof ages (Berndtsson, 2010). In order to maintain rooftop productivity, these lost nutrients must replace. In this situation, nitrogen (N) in tomato production should be judicious. Application of N-fertilizer to the soil produces high tomato fruit yield and improves fruit quality (Adams and Israelachvili, 1978) whereas excessive application leads to luxuriant development of vegetative parts of the plant at the expense of reproductive growth (Tisdale *et al*., 2003).

Objectives:

In Bangladesh, there is limited information on the impact of planting time and nitrogen on growth and yield of tomato on rooftop garden. Considering the above-mentioned facts this experiment was conducted to fulfil the following objectives:

1. To find out the effect of planting time on the growth and yield of tomato on rooftop garden,

2. To study the effect of nitrogen on growth and yield of tomato on rooftop garden and

3. To identify the suitable transplanting time and doses of nitrogen fertilizer for better tomato production on rooftop garden.

CHAPTER 2

REVIEW OF LITERATURE

However, the linkages between these and the overlaps should not be overlooked. This literature review draws together a wide range of dimensions in a lattice, to provide a conceptual framework for the research. Literatures related of rooftop gardens and effects of time of planting and doses of nitrogenous fertilizer on the production of tomato which were collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented in this chapter under the following headings-

2.1 Urban agriculture in cities

Urban agriculture is the practice of cultivating, processing, and distributing food in or around a village, town, or city. Urban agriculture can also involve animal husbandry, aquaculture, agroforestry, urban beekeeping and horticulture. Urban agriculture is an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolis, which grows and raises, processes and distributes a diversity of food and non-food products, reusing largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area (Mougeot, 2001).

Hodgon*et al.* (2011) reported that urban agriculture is much more than private gardens and community gardens, and many communities are beginning to see the promise of other forms of urban agriculture.

Moustier (2007) provided an extensive summary of the importance of urban agriculture in 14 African and Asian cities. Among the results they found that 90% of all vegetables consumed in Dar es Salaam and 60% of vegetables consumed in Dakar originated from urban agriculture.

McDonough (2005) engaged with the overall construction of urban landscapes, inclusive of rooftop gardens, the various types, techniques and loading capacities associated to them. This proved useful when realizing the numerous constraints attached to rooftop gardens. Furthermore, the researcher observed that the introduction of sustainable techniques can help reduce problems arising from global warming and opportunity costs when constructing buildings in different habitats and climates.

Thompson and Sorvig (2000) offered understandings of the need for a more holistic and sustainable landscape construction process. This alludes to the role of landscape and urban planning especially with regards to how sustainable landscape construction can be envisioned in a vertical form such as rooftop gardens.

2.2 The benefit of green roof

Orsini*et al.* (2014) carried out a study for addressing the quantification of the potential of rooftop vegetable production in the city of Bologna (Italy) as related to its citizen's needs. The potential benefits to urban biodiversity and ecosystem service provision were estimated. RTGs could provide more than 12,000 t year^{-1} vegetables to Bologna, satisfying 77% of the inhabitants' requirements.

Fioretti*et al.* (2010) has discovered that thermal reduction ratio (TRR) is positively related to the coverage ratio (CR) of plants and the total leaf thickness (TLT) of plants on the rooftop. The area of shadow increases with CR and reduce the transmission of solar radiation. Higher TLT will provide greater thermal resistance and increase the thermal reduction effect.

Wong *et al.* (2009) conducted a study on the thermal performance of extensive rooftop greenery systems in Singapore. The study concluded that the green roof tends to experience lower surface temperature than the original exposed roof surface. In areas well covered by vegetation, over 60% of heat gain was stopped by the implementation of green roof system.

Islam (2004) in his article titled "Roof gardening as a strategy of urban agriculture for food security': the case of Dhaka city, Bangladesh" reported that urban agriculture in the cities of developing countries are growing rapidly which also means the number of low-income consumers is increasing. Because of food insecurity in these cities is increasing. Urban agriculture (UA) contributes to food security by increasing the supply of food and by enhancing the quality of perishable foods reaching urban consumers.

Niachou*et al.* (2001) discovered that indoor temperature values in the building with green roof are lower during the day. They measured the roof temperatures in non-insulated building with and without green roof.

2.3 Nature and its effects on human behaviour

Razzaghmaneshand Beecham(2014) stated that when people deplete and degrade the natural environment, most particularly their meaningful and satisfying experience of it, they diminish their potential for emotional and intellectual capacity. He also suggested that as children get older they lose touch with nature. This is a result of various socially conditioned processes. For example, they value television, computers and video games above trees, insects and birds.

Thomas (2003) stated that the mere presence of natural areas, trees and established landscapes can influence human psyche. People who drive, live and work in tree-lined streets are less prone to violent behaviour. Furthermore, colour therapy specialists stated that in the colour spectrum, green is the neutral colour, perceived as an analeptic for exhaustion and stress.

2.4 Urban ecology and sustainable development through rooftop

Rashid and Ahmed (2009) experimented the thermal performance of rooftop garden in a six storied building established in 2003. They found that the temperature of that building is 3°C lower than other surrounding buildings and this green application can reduce the indoor air temperature 6.8°C from outdoor during the hottest summer period.

Shaw *et al.* (2004) addressed that people generally want wildlife in urban areas and suburban areas, even if they are unsure about some of the potential conflicts. They mentioned that having nature around human in urban environments is an indication that nature still prospers in the places where human dwell. It is a sign that human’s habitat still retains some of its ecological integrity.

Wheeler and Beatley (2004) offered additional analysis of urban ecology addressing it through an eco–city dimension and considering the role of nature and greening of the city. The Eco city vision linked ecological sustainability with social justice and the pursuit of sustainable livelihoods.

Bennett (2003) reported that RTGs (Roof Top Garden), while being aesthetically appealing, can contribute to biodiversity in the urban environment, achieve more sustainable conditions, including those necessary for the production of food and improve the overall quality of urban life.

2.5 Effect of planting date on the growth and yield of tomato

Saroj (2018) conducted a pot culture experiment with the intention of investigating the impact of different sowing dates and concentrations and combinations of NAA and GA_3 on growth and yield contributing attributes of summer tomato. Different concentrations of NAA and GA_3 viz. T_0 = Control, T_1 = foliar application of 20 ppm NAA at vegetative stage, T_2 = 20 ppm GA_3 at vegetative stage, T_3 = 20 ppm NAA + 20 ppm GA_3 at vegetative stage, T_4 = 20 ppm NAA at flower cluster initiation stage, T_5 = 20 ppm GA3 at flower cluster initiation stage, T6 = 20 ppm NAA + 20 ppm GA_3 at flower cluster initiation stage, and different sowing dates *viz.* D_1 = Sowing seeds on 1^{st} June and D_2 = Sowing seeds on 1^{st} July, were used in the study. The growth and yield contributing characters were significantly influenced by the application of NAA and GA_3 and sowing dates. In case of combined effect of sowing date and plant growth regulator, the tallest plant (89.37cm) was found in D_2T_2 and the maximum number of flowers plant^{-1} (39.00), fruits plant^{-1} (35.66) and the highest fruit yield plant^{-1} (663.33g) were found in D_2T_6, whereas the minimum for all these characters were found in D_1T_1 and D_2T_2. Sowing seeds in 1^{st} July and application of 20 ppm NAA along with 20 ppm GA_3 can be effective in enhancing growth and yield of BARI Tomato-10.

Dristy (2015) carried out the experiment to investigate the response of tomato with plant growth regulators and transplanting date. In this study, BARI tomato 14 variety was used as a planting material. The treatments consisted of three different times of transplanting; viz. T_1 = First transplanting date (10 December 2014), T_2 = Second transplanting (20 December 2014), T_3 = Third transplanting (30 December 2014), and four different plant growth regulators, viz. Control = no plant growth regulators, Salicylic acid (SA) = 0.3 mM, Gibberellic acid (GA) = 20 ppm and the combination of hormone (salicylic acid 0.3 mM + gibberellic acid 20 ppm). The First transplanting date significantly influence both morphological and yield contributing characters and yield of tomato. The higher values of plant height, cluster $plant^{-1}$, fruit length, fruit breadth, fruit number, individual fruit weight, yield $plant^{-1}$ was found in first transplanting. The highest yield (494 $gm \cdot plant^{-1}$) was obtained from the first transplanting date along with salicylic acid and gibberellic acid and the lowest yield (196 $gm \cdot plant^{-1}$) was in third transplanting date along with control.

Habib (2015) conducted an experiment to find out the role of exogenous foliar application of salicylic acid (SA) on the changes of morphology and fruit yield of tomato at different time of transplanting. In this experiment, variety BARI tomato 15 was used as a planting material and the treatments consisted of three different times of transplanting: T_1 = First transplanting time, (10 December 2014), T_2 = Second transplanting time, (20 December 2014), T_3 = Third transplanting time, (30 December 2014); and four different doses of SA *viz*. C = 0 mM SA, SA_1 = 0.1 mM SA, SA_2 = 0.2 mM SA and SA_3 = 0.3 mM SA. The transplanting time (T_1) significantly changed morphological characters such as plant height, number of leaves per plant, number of branches per plant; and yield contributing characters like number of flower clusters per plant, number of flowers per plant, number of fruits per plant fruit length, fruit breadth, yield per plant compared to third transplanting time (T_3). The maximum yield per plant (331.22 g) was obtained from the first transplanting time (T_1) suggesting that early transplanting time improves fruit yield through promoting the morphological features of tomato.

Ali *et al.* (2014) conducted a field trial to study the performance of tomato as influenced by organic manure and sowing date on the growth and yield of tomato. Treatments consist of control, cow dung, goat manure and poultry manure and sowing date of 8th January 2013, 22nd January 2013, 5th February 2013 and 19th February 2013 dry season. Results obtained indicated that growth and yield of tomato was the lowest in control treatments which showed that the organic manure and sowing date used in the study especially poultry manure and sowing date of 5th February 2013 promoted the yield of tomato. Poultry manure and sowing date 5th February 2013 enhanced tomato vine length, number of leaves plant^{-1}, number of branches plant^{-1}, number of flowers plant^{-1}, number of fruits plant^{-1}, fruit weight plant^{-1}, fruit yield plot^{-1} and fruit yield hectare^{-1} compared to control treatments. There was no significant effect with respect to leaf area plant^{-1}, number of fruits plant^{-1}and fruit weight plant^{-1}.

Zhao *et al.* (2014) carried out an experiment to extend the growing season and protect high-value horticultural crops. High tunnels have been used for many years worldwide and their popularity has increased in Mississippi. A planting date study of 'Roma' tomato (*Solanumlycopersicum*), 'Legend' tomato, 'Ichiban' eggplant (*Solanummelongena* L.), 'Sweet Banana' pepper (*Capsicum annuum*L.), 'Benary's Giant' zinnia (*Zinnia elegans* L.), and 'Potomac Red' snapdragon (*Antirrhinum majus* L.) was conducted in 2010 in three high tunnels in Starkville, Mississippi. Each vegetable and cut flower cultivar were treated as an independent study. There were two planting dates for all the cultivars: 12 March 2010 and 2 April 2010. Only for zinnias, yield (272 stem/plot) of first planting date was higher than planting date two (106 stem/plot). A significant block effect was observed with 'Legend' tomato and 'Ichiban' eggplant where one high tunnel had significantly higher yield than the other two high tunnels. Harvesting of tomato, eggplant, and pepper from high tunnels was a month earlier than the field-grown crops. High tunnels can extend the growing season to provide produce to the market at earlier harvest dates in Starkville, Mississippi.

Hossain *et al*. (2013) conducted an experiment to observe the effect of sowing dates on yield of tomato genotypes. Three sowing dates viz. October 1, October 15 and October 30 were considered as factor A and tomato variety viz., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-9 and BARI Hybrid Tomato-4 considered as factor B. Early flowering (52.40 days) as well as early fruit harvesting (119.13 days) was occurred in October 1 sowing, whereas sowing on October 30 resulted in delayed flowering (71.73 days) and fruit harvesting (140.67 days), respectively. Number of fruits per plant was also the highest (27.40) in October 1 sowing and the lowest (13.73) was in October 30 sowing. Seed sowing of October 1 was found to be better in respect of yield (74.75 t ha^{-1}) compared to October 15 (58.55 t ha^{-1}) and October 30 (24.60 t ha^{-1}) sowing. Among the variety, BARI Tomato-2 produced the highest (68.12 t ha^{-1}) marketable yield followed by BARI

Tomato-9 (56.16 t ha^{-1}) and BARI Tomato-3 while BARI Tomato-4 gave the lowest (36.91 t ha^{-1}) marketable yield.

Ahammad*et al.* (2009) conducted an experiment to observe the effect of planting date and variety on the yield of late planting tomato. The potentiality of fruiting in the late season were evaluated for BARI tomato 4, BARI tomato 5, BARI tomato 6 and BARI tomato 12 by planting on December 01, December 16, January 01, January 16 and February 01. A combination of December 01 planting with BARI Tomato 5 variety performed better in respect of yield (57.07 t ha^{-1}). The variety BARI Tomato 5 also showed potential fruiting capability during late winter season and February 01 planting produced 11 t ha^{-1} of potential yield. All the four varieties showed potential fruiting capability during late winter season and February 01 planting produced 4–6 tons of potential yield during late season.

Al-Kawsar (2008) conducted the experiment to observe the performance of five tomato varieties at different planting dates. There were five tomato varieties, viz., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-9 and BARI hybrid Tomato-4 and two planting dates viz., November 01 and November 15. Planting dates had no significant influence on growth and yield of tomato. However, growth and yield were the best in November 15 planting. The highest yield of tomato (87.42 t ha^{-1}) was obtained from November 15 planting and the lowest yield (59.20 t ha^{-1}) from November 01 planting. Combined effect of varieties and planting dates had significant influence on growth and yield of tomato. BARI hybrid Tomato-4 gave the highest yield (91.15 t ha^{-1}) on November 15 planting and BARI Tomato-9 gave the lowest yield (41.47 t ha^{-1}) on November 15 planting. It was concluded that, BARI hybrid Tomato-4 planted on November 15 would be beneficial for the farmer due to its higher yield (91.15 t ha^{-1}).

Hoque (2006) conducted an experiment to study the production of quality tomato seeds as affected by time of planting and stage of harvesting. The experiment consisted of four different time of planting (October 26, November 11, November 27 and December 13) and four different stages of harvesting (fully-mature with green skin, fully-mature with uniform yellow skin, fully-mature with yellowish red skin and fully-mature with uniform red skin). Results revealed that number of seeds, weight of seeds, seed yield and germination of seeds were the maximum in case of October 26 planting and from the fully-mature fruit with uniform red skin. However, total yield of tomato seed (169.45 kg ha^{-1}) and germination percentage (86.50%) were the highest in fully-mature fruits with uniform red skin, which was statistically different from all other treatments. The combined effects of October 26 planting and fully-mature fruits with uniform red skin produced the highest yield of tomato seeds (307.47 kg ha^{-1}) and the maximum germination percentage of seeds (90.00%).

Hossain *et al.* (2004) conducted an experiment to study the effect of different planting date and variety on the extension of picking period of tomato. The experiment consisted of four tomato varieties (BARI Tomato-4, BARI Tomato-5, BARI Tomato-7 and BARI Tomato-8) and three planting dates (October 25, December 25, and February 24). Planting dates and varieties had significant influence on growth, yield contributing parameters and yield of tomato. Yield and yield contributing characters were the best in October 25 planting. The highest yield of tomato (86.40 $t \cdot ha^{-1}$) was obtained from October 25 planting, compared with the lowest yield (16.8 $t \cdot ha^{-1}$) from February 24 planting. Variety BARI Tomato-7 gave the highest yield (100.13 $t \cdot ha^{-1}$) in October 25 planting. All the parameters showed decreasing response with delay in planting.

Benedictos*et al.* (2000) conducted a field study each year for 3 years (from 1984 to 1986) to investigate whether tomato cultivar or transplant age would reduce flower drop or increase fruit set and thereby increase yield. Seeds of tomato cultivars Ace 55 VF. Primo Early, Koral and Pacesetter 502 were sown in an unheated glasshouse on 6 March, 21 March and 5 April. Transplants at different growth stages were transferred to the field simultaneously on 10 May. Fruit setting rate was measured for 2 successive inflorescences per plant and at 2 periods (before and during the onset of high summer temperatures). Before the onset of high temperatures, Koral had the highest fruit setting rate (88.58%), followed by Pacesetter 502 (84.73%), Ace 55 VF (71.47%) and Primo Early (68.14%). Young (5-week-old) transplants had the highest fruit setting rate (81.69%), followed by medium-aged (7-week-old) transplants (76.94%) and old (9-week-old) transplants (76.04%). During the onset of high temperatures, fruit setting rate was the highest for 1986 (91.7%), followed by 1985 (83,6%) and 1984 (42.7%), but there were no significant differences in yield and number of fruits harvested among the different cultivars and transplant ages. Overall, fruit setting rate before the onset of high temperatures was higher than that during the onset (82.9% and 72.7%, respectively). Cultivar and transplant age had no significant effects on mean yield per plant. In conclusion, sowing date of tomatoes did not have any effect on the reduction of flower drop.

Nessa*et al.* (2000) conducted an experiment to study the comparative performance of ten genotypes of tomato in late planting and reported that the genotype BAU/TM 0058 was the best in late planting. It was closely followed by BAU/TM 0041. They also state that, fruit number and fruit weight should be considered as important criteria for higher yield.

Islam (2000) conducted a field experiment with four different dates of planting (16 October, 15 November, 15 December and 14 January) and four tomato varieties (BINA Tomato-2, BARI Tomato-3, BARI Tomato-4 and BARI Tomato-5) to extend the picking period of tomato through selection of variety and adjustment of date of planting. Planting date and variety significantly influenced the growth, yield components, yield and fruit picking period of tomato. The development of yield components and yield appeared to be the best in October 16 planting. The highest yield of tomato (53.85 $t \cdot ha^{-1}$) was achieved from October 16 planting compared with the lowest yield (20.21 $t \cdot ha^{-1}$) from January 14 planting. The variety BARI Tomato-3 produced the highest yield (50.63 $t \cdot ha^{-1}$) and BINA Tomato-2 gave the lowest yield (34.80 $t \cdot ha^{-1}$). However, BARI Tomato-4 gave the highest yield (55.90 $t \cdot ha^{-1}$) in October 16 planting. Likewise, BARI Tomato-3 gave the highest yield (66.84 $t \cdot ha^{-1}$) in November 15 planting followed by December 15 (51.25 $t \cdot ha^{-1}$) and January 14 plantings (30.21 $t \cdot ha^{-1}$).

Srivastava *et al.* (2000) conducted an experiment with 2 methods of crop raising (direct sowing of seeds in field and transplanting of nursery grown seedlings) and 3 sowing dates (1, 16 and 31 October) on growth and yield of tomato cv. Pant T-3. They stated that the direct field-sown crop resulted in comparatively dwarf plants, significant earliness in fruit maturity and higher early yield as well as cost:benefit ratio when compared with the transplanted crop. Early sowing on 1 October although produced shorter plants, lesser mean number of fruits per plant, yet it proved to be the most economical because of significantly higher early yield. The interaction indicated that direct field sowing of tomato seeds on 1 October in raised beds at 75 cm × 20 cm spacing was more remunerative than the commonly practiced transplanting system.

2.6 Effect of nitrogen on on growth and yield of tomato

Kamruzzaman (2016) conducted a field experiment to study the effect of nitrogen and zinc on growth and yield of tomato. The treatments of the experiment consisted of four levels of nitrogen, viz. N_0: Control, N_1: 100 kg $N \cdot ha^{-1}$, N_2: 120 kg $N \cdot ha^{-1}$, N_3: 140 kg $N \cdot ha^{-1}$ and three levels of zinc, viz. Zn_0: Control, Zn_1: 1 kg $Zn \cdot ha^{-1}$, Zn_2: 2 kg $Zn \cdot ha^{-1}$. The tallest plant (80.88 cm), maximum number of leaves per plant (73.22), maximum number of flower clusters per plant (10.93), maximum number of fruits per cluster (6.48), the highest Vitamin C content (13.94 mg per 100 g), the highest fruit yield per hectare (66.15 ton) were recorded from N_2 treatment (120 kg $N \cdot ha^{-1}$).

Biswas *et al.* (2015) conducted an experiment was to study the growth and yield response of tomato. Experiments consisted of four nitrogen levels viz. Control: No nitrogen, N_1: 100 $kg \cdot ha^{-1}$, N_2: 150$kg \cdot ha^{-1}$ and N_3: 200 $kg \cdot ha^{-1}$. The tallest plant (91.4 cm) was found from N_2. The maximum number of $leaves \cdot plant^{-1}$ (97.8), number of $branches \cdot plant^{-1}$ (10.7), number of $flowers \cdot cluster^{-1}$ (6.4), number of $fruits \cdot cluster^{-1}$ (5.1), number of $clusters \cdot plant^{-1}$ (15.3), fruit diameter (15.6 cm), individual fruit weight (73.1 g), yield (22.2 $kg \cdot plot^{-1}$ and 61.4 $t \cdot ha^{-1}$) and Total Soluble Solid (TSS) (5.5%) were found from N_2 while the minimum from N_0. It was observed that yield, growth parameters and yield contributing attributes are positively correlated with nitrogen levels except control; 150 $kg \cdot ha^{-1}$ nitrogen was found the best compared to other nitrogen level used in this experiment for growth and yield of BARI tomato - 9.

Karim (2015) conducted a field experiment was to study the effect of nitrogen on the growth and yield of BARI Tomato-2 and BARI Tomato-14. There were five nitrogen levels, viz., 0, 80, 100, 120 and 140 kg $N \cdot ha^{-1}$ on two varieties of tomato (BARI Tomato-2 and BARI Tomato-14). Variable nitrogen doses showed significant influence on the growth and yield contributing characters of tomato. The plant height, number of clusters per plant, flower per plant, fruit per plant, weight of fruit per plant and yield of tomato were the maximum when 120 kg $N \cdot ha^{-1}$ was applied.

Sultana (2013) conducted a field experiment to observe the effect of nitrogen and gibberellic acid on growth and yield of tomato. The tomato variety BARI Tomato-14 was used for the experiment. The experiment included four levels of nitrogen i.e. N_0: 0 kg, N_1: 200 kg, N_2: 225 kg and N_3: 250 kg N·ha⁻¹ and three levels of GA_3 i.e. G_0: 0, G_1: 50 and G_2: 70 ppm, respectively. Application of nitrogen influenced independently the growth and yield of tomato. In case of different nitrogen levels, the highest yield of tomato (47.02 t·ha⁻¹) was recorded from N_2 (225 kg N·ha⁻¹) and lowest (35.26 t·ha⁻¹) was from N_0.

Nawaz *et al.* (2012) conducted an experiment on interactive effects of nitrogen (N), phosphorus (P) and zinc (Zn) on growth and yield of tomato. Four levels of nitrogen (0, 100, 150 and 200 kg·ha⁻¹), four levels of phosphorus (0, 60, 80 and 100 kg/ ha) and three levels of zinc (0, 5 and 10 ppm) were applied. The results pertaining to various growth and yield parameters showed that early flowering was observed when plots received phosphorus at 100 kg·ha⁻¹ and zinc at 10 ppm without nitrogen. In contrast, flowering was significantly delayed when plots received nitrogen alone at 200 kg·ha⁻¹. Maximum number of fruits per plant (41.67) was observed when plots received nitrogen at 150 kg·ha⁻¹, phosphorus at 100 kg·ha⁻¹ and zinc at 10 ppm. Total yield (28.43 t·ha⁻¹) was increased 100% as compared to control (13.44 t·ha⁻¹) when plots received nitrogen at 150 kg·ha⁻¹, phosphorus at 100 kg·ha⁻¹ and zinc at 10 ppm.

Nodi (2012) conducted a field experiment was to study the effect of different levels of pruning and nitrogen on the growth and yield of tomato cv. BARI Tomato-14. There were three nitrogen levels, viz., 0, 115, 161 kg N·ha⁻¹ and three pruning levels, viz., no pruning, single pruning and double pruning. Different nitrogen levels showed significant influence on the growth and yield contributing characters of tomato. The plant height, number of clusters per plant, flower per plant, fruit cluster per plant, fruit per plant, fruit diameter, length of individual fruit, weight of fruit per plant and yield (48.4 t·ha⁻¹) were the maximum when 161 kg N·ha⁻¹ was applied.

Oyinlola and Jinadu (2012) conducted a greenhouse experiment to determine the effect of five rates of N fertilizer (0, 30, 60, 90, 120 kg N ha⁻¹) grown in 3 different textural classes (sand, loam and clay) of soil on growth, yield and nutrient composition of tomato. Effects of N on all the parameters determined were significant except plant height at 2 and 4 Weeks after Planting (WAP). The highest plant height at harvest (12 WAP), mean fruit weight, fruit yield and dry matter yield were obtained at 90 kg N ha^{-1}. Tissue nutrient (NPK) concentrations increased as the rate of N increased. Loam soil produced the highest value of all the parameters determined except tissue N concentration. Tomato growth and yield were significantly influenced by soil texture and N applications; loam soil at 90 kg N ha^{-1} proved superior to other treatments.

Biswas (2011) carried out a field experiment to study effect of nitrogen fertilizer on morphology, growth and yield of tomato with four varieties, viz., BARI Tomato-4, BARI Tomato-5, BARI Tomato-7, BARI Tomato-9 of tomato and four levels of nitrogen viz. 0, 100, 150 and 200 kg N·ha^{-1}. Different level of nitrogen had significant influence on yield of tomato imposing 150 kg N·ha^{-1} (N_2) resulted in the highest yield (61.42 t·ha^{-1}) of tomato over control (41.00 t·ha^{-1}).

Kirimi*et al.* (2011) investigated the effects of nitrogen levels and spacing on tomato fruit yield and quality in two seasons. The nitrogen was applied at the rates of 0, 40, 80 and 120 kg N·ha^{-1} in two equal splits. Spacing was 40 cm × 30 cm, 40 cm × 40 cm, 50 cm × 30 cm and 50 cm × 40 cm. Nitrogen @ 80 kg·ha^{-1} and spacing of 40cm × 30 cm had the highest mean fruit numbers in season 2. Nitrogen @ 80 kg·ha^{-1} and spacing of 50 cm ×30 cm had the highest fruit yield in season 1. The study was significant to farmers producing tomatoes under greenhouse, to maximize on profits by scaling down nitrogen fertilizer use to attain high yields and quality of marketable tomato fruits using appropriate spacing.

Fandi*et al.* (2010) concluded that high concentration of N, P and K in the nutrient solution gave higher total yield and tomato fruit weight than the control nutrient solution in tuff culture grown tomato. The control nutrient solution gave the least total soluble solids, titratable acidity content and the highest pH of tomato juice.

Ferreira *et al.* (2010) evaluated nitrogen fertilization efficiency of the tomato crop with organic fertilization. They conducted two experiments at two times: spring/summer and autumn/spring. In both times, the applied N doses, in the form of nitro-calcium, were 0.0, 93.3, 187.0, 374.0 and 748.0 kg·ha^{-1} and the doses of organic fertilization, in the form of cattle manure compost, were 0 t·ha^{-1} and 8 t·ha^{-1} of dry matter. The weight and the number of marketed tomatoes plant^{-1} increased with the increase of N level in the soil. The percentage of commercially discarded fruits was larger in the spring/summer than in the autumn/spring. The nitrogen fertilization efficiency in tomato crop was higher in the autumn/spring than in the spring/summer. In the spring/summer, the efficiency was higher without the addition of organic matter to the soil, whereas in the autumn/spring the opposite took place.

Islam (2010) conducted the experiment to evaluate the effect of nitrogen (N) and phosphorous (P) on the growth and yield of BARI tomato-2 (Ratan). The treatments used were: four levels of nitrogen as N_0: 0 kg N·ha^{-1}, N_{100}: 100 kg N·ha^{-1}, N_{150}: 150 kg N·ha^{-1} and N_{200}: 200 kg N·ha^{-1} and four levels of phosphorous as P_0: 0 kg P_2O_5·ha^{-1}, P_{50}: 50 kg P_2O_5·ha^{-1}, P_{100}: 100 kg P_2O_5·ha^{-1} and P_{150}: 150 kg P_2O_5·ha^{-1}. Plant height at 60 days after transplanting, number of branches per plant, number of flowers per plant, number of fruits per plant and fruit weight per plant increased significantly with increasing N level up to 150 kg·ha^{-1}, whereas fruit yield increased significantly up to 200 kg N·ha^{-1}.

Ren*et al.* (2010) carried out greenhouse field experiments on tomato over four double cropping seasons to understand the effects of manipulating root zone N management (RN) on fruit yields, N savings and N losses under conventional furrow irrigation. About 72% of the chemical N fertilizer used in conventional treatment (CN) inputs could be saved using the RN treatment without loss of yield. The cumulative fruit yields were significantly higher in the RN treatment than in the CN treatment. Average seasonal N from irrigation water (118 kg N ha^{-1}), about 59% of shoot N uptake, was the main nitrogen source in treatments with organic manure application (MN) and without organic manure or nitrogen fertilizer (NN). N losses in the RN treatment were lowered by 54% compared with the CN treatment. Lower N losses were found in the MN and NN treatments due to excessive inputs of organic manure and fruit yields were consequently substantially affected in the NN treatment. The critical threshold of N_{min} supply level in the root zone (0–30 cm) should be around 150 kg N ha^{-1} for sustainable production. April to May in the winter–spring season and September to October in the autumn–winter season are the critical periods for root zone N manipulation during crop growth. However, control of organic manure inputs is another key factor to further reduce surplus N in the future.

Alam (2009) conducted the experiment to evaluate the effect of nitrogen (N) and phosphorous (P) on the growth and yield component of BARI tomato-2 (Ratan) which is one of the high yielding varieties of indeterminate type. The treatments used were: four levels of nitrogen as N_0: 0 kg $N \cdot ha^{-1}$, N_{100}: 100 kg $N \cdot ha^{-1}$, N_{150}: 150 kg $N \cdot ha^{-1}$ and N_{200}: 200 kg $N \cdot ha^{-1}$ and four levels of phosphorous as P_0: 0 kg $P_2O_5 \cdot ha^{-1}$, P_{50}: 50 kg $P_2O_5 \cdot ha^{-1}$, P_{100}: 100 kg $P_2O_5 \cdot ha^{-1}$ and P_{150}: 150 kg $P_2O_5 \cdot ha^{-1}$. Plant height at 60 days after transplanting, number of branches per plant, number of flowers per plant, number of fruits of plant and fruit weight per plant increased significantly with increasing N level up to 150 kg $N \cdot ha^{-1}$, whereas fruit yield increased significantly up to 200 kg $N \cdot ha^{-1}$.

Kikuchi (2009) observed that growth and nitrogen content were different among nine tomato cultivars grown under three nitrogen levels (50, 100, 150 mg $N \cdot L^{-1}$). The efficiency of applied nitrogen to growth was the highest in Odoriko', and the lowest in 'June Pink'. It was suggested that the difference in tomato growth was influenced not only by the difference of nitrogen uptake but also the difference of nitrogen efficiency ratio (dry weight per nitrogen content). A positive correlation between the tomato growth and the content of assimilated nitrogen was observed. Therefore, it was suggested that the ability of nitrogen assimilation was different among the cultivars, and that the difference in ability of nitrogen assimilation influenced the difference in the nitrogen efficiency ratio and growth. They compared 'Odoriko' and 'June Pink' for nitrate (NO^{3-}) reduction, which is the most important step in nitrogen assimilation. It was shown that there were differences of nitrate reductase (NR) activity and rate of nitrate assimilation between the two cultivars.

Balemi (2008) investigated the response of tomato cultivars varying in growth habit to different rates of Nitrogen (N) and Phosphorus (P) fertilizers. Results of 2003–2004 cropping season showed that the application of 110 kg N + 120 kg $P_2O_5 \cdot ha^{-1}$ or 80 kg N + 90 kg $P_2O_5 \cdot ha^{-1}$ resulted in significantly higher total as well as marketable fruit yield of the tomato cultivars. However, the application of the highest fertilizer rate (110 kg N + 120 kg $P_2O_5 \cdot ha^{-1}$) resulted in superior fruit yields whilst the other two rates did not significantly differ from each other in affecting fruit yields. Results of both cropping seasons confirmed significantly higher % marketable fruit yield due to the application of either 110 kg N + 120 kg $P_2O_5 \cdot ha^{-1}$ or 80 kg N + 90 kg $P_2O_5 \cdot ha^{-1}$.

Hasan (2008) carried out a field experiment to study the effect of mulching and nitrogenous fertilizer on the growth and yield of tomato. The tomato variety used in the experiment was BARI Tomato-2. The experiment consisted of three different types of mulches (M_0 = No mulch, M_1 = Black polythene and M_2 = White polythene) and four levels of nitrogen (viz. N_0 = 0, N_1 = 230, N_2 = 240 and N_3 = 250 kg N·ha^{-1}), with their combinations were used as treatments in the study. In case of nitrogen, N_2 (240 kg N·ha^{-1}) resulted the highest yield per hectare of tomato (59.73 t·ha^{-1}) and control produced the lowest (28.13 t·ha^{-1}).

Khondakar (2008) conducted the study to find out the effect of nitrogen on the growth and yield of tomato varieties. The experiment consisted of two factors viz., Factor A: Four level of nitrogen (N_0: Control, N_1: 200 kg N·ha^{-1}, N_2: 230 kg N·ha^{-1} and N_3: 260 kg N·ha^{-1}) and Factor B: Three tomato varieties (V_1: BARI Tomato 1, V_2: BARI Tomato 2 and V_3: BARI Tomato 3). In case of nitrogen, highest number of fruits per plant (36.70). maximum diameter of fruit (3.47 cm) and the highest yield (83.0 t·ha^{-1}) was observed from N_2 and the lowest value was observed from N_0. For the interaction effect of nitrogen and varieties, the highest number of fruits per plant (41.87). the maximum diameter of fruit (3.59 cm) and the highest yield (88.00 t·ha^{-1}) was recorded from N_2V_2 and the lowest value was recorded from N_0V_1. The highest benefit cost ratio (2.44) was recorded from N_2V_2 and lowest (1.87) was obtained from N_0V_1. From economic point of view, it was apparent from the above results that the combination of 230 kg N·ha^{-1} and BARI Tomato 2 was more profitable than rest of the treatment combination.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted to study the impact of different planting time and nitrogen levels on growth and yield of tomato on rooftop garden. The details of the materials and methods of this research work were described in this chapter as well as on experimental materials, site, climate and weather, experimental design, layout, materials used for experiment, raising of seedling, treatments, land preparation, manuring and fertilizing, transplantation of seedlings, intercultural operations, harvesting, collection of data and statistical analysis which are given below:

3.1 Experimental period

This research work was carried out within September, 2019 to March, 2020.

3.2 Location of the experimental field

The experiment was conducted at winter season on rooftop of Biotechnology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from September, 2019 to March, 2020. The location of the experimental site was at $23^0 46^/$N latitude and $90^0 22^/$E longitudes with an elevation of 8.24 meter from sea level (Anon., 1989). Experimental location presented in Appendix I.

3.3 Climate of the experimental area

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris*et al.*, 1979). During the experimental period the maximum temperature (36.8^0C), highest relative humidity (87%) and highest rainfall (273 mm) was recorded for the month of September, 2019 whereas, the minimum temperature (14.6^0C), minimum relative humidity (64%) and no rainfall was recorded for the month of January, 2020. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.4 Soil of the experimental field

Soil of the study site was silty clay loam in texture belonging to Tejgaon series (FAO, 1988). The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28 (Haider, 1991). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. The experimental area having available irrigation and drainage system and situated above flood level. The soil having a texture of sandy loam organic matter 1.15% and composed of 26% sand, 43% silt and 31% clay. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix III.

3.5 Plant materials collection

In this research work, the seeds of BARI tomato-14, also known as 'Sharabonti' was used as planting material. This is a high yielding indeterminate type variety. The seeds were collected from Olericulture division of Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5.1 BARI TOMATO 14 (SHARABONTI)

Developed by	Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
Method of development/origin	AVRDC and developed by selection method
Year of release	2007
Main characteristics	Fruit large, round with fruit attractive red flesh color, average fruit weight $plant^{-1}$ 90-95 g, fruit $plant^{-1}$ 30-35, prolonged harvesting period (40-60 days), storage quality high, life time 110-120 days.
Planting season and time	September to October, Medium to late variety
Days to maturity	Days to maturity 30-35 (anthesis to ripening)
Harvesting time	Fruit harvest up to 45-65 days
Yield	90-95 t ha^{-1}
Resistance/tolerance	Tolerant to bacterial wilt

Source: BARI, 2008

3.6 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Planting time (3 dates) as

i. P_1 – 1st October, 2019,

ii. P_2 – 15th October, 2019 and

iii. P_3 – 1st November, 2019.

Factor B: Nitrogen management (4 levels) as

i. N_0– 0 kg ha^{-1} (control),

ii. N_1 – 70 kg ha^{-1},

iii. N_2 – 120 kg ha^{-1} and

iv. N_3 – 170 kg ha^{-1}.

There were total 12 (3 × 4) combination as a whole *viz.*, P_1N_0, P_1N_1, P_1N_2, P_1N_3, P_2N_0, P_2N_1, P_2N_2, P_2N_3, P_3N_0, P_3N_1, P_3N_2 and P_3N_3.

3.7 Experimental design

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with four replications.

3.8 Experimental layout

The experiment plot was prepared properly using bricks, sand, cement etc. An area of 60.00 m^2 was divided into 4 blocks. The whole experimental area was divided into three equal blocks, each representing a replication. The size of each unit plot was 10.00 m × 1.50 m. The space was kept 1.00 m between the blocks and 0.50 m between the plots were kept. The distance between row to row and plant to plant was 60 cm and 40 cm, respectively.

3.9 Raising of seedling

The soil was well prepared and converted into loose friable condition in obtaining good tilth. All weeds, stubbles and dead roots were removed. Tomato seedlings were raised in three seedbeds of 2.00 m × 1.00 m size. The seeds were sown in the seedbeds on 6th September, 2019; 21st September, 2019 and 7th October, 2019. Five grams of seeds were sown in each seedbed. Within 3 to 5 days emergence of the seedlings took place. Then covered with light soil and shading was provided by bamboo mat (chatai) to protect young seedlings from scorching sunshine and rainfall. Light watering, weeding and mulching were done as and when necessary to provide seedlings with a good condition for growth.

3.10 Plot preparation

Sandy loam soil, well dried cowdung and proper amount of fertilizer were mixed as per plot recommendation and then plot was filled with that. Furadan 5G (an insecticide) @ 15 kg ha^{-1} was also applied during final soil preparation to control cut worm and other soil insects. Then plots were placed into rooftop and arranged through experimental design. The plots were ready for transplanting seedling.

3.11 Manures and fertilizers

Fertilizer	Quantity	Application method
Cow dung	15.00 t ha^{-1}	Final plot preparation
Urea	As per treatment	15, 25 and 35 DAT
TSP	200 kg ha^{-1}	Final plot preparation
MoP	175 kg ha^{-1}	Final plot preparation
Zinc Sulphate	10 kg ha^{-1}	Final plot preparation

Source: Rashid (2012).

According to Rashid (2012), the entire amount of cowdung, Urea as a source of nitrogen, TSP as a source of phosphorus, MoP as a source of potassium and zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) as a source of zinc. Cowdung, TSP, MoP and zinc sulphate were applied as basal dose during final land preparation. Urea was applied as per treatment in three equal splits at 15, 25 and 35 days after transplanting as ring method.

3.12 Transplanting of seedlings

Healthy and uniform 25 days old seedlings were uprooted separately from the seedbed and ten seedlings were transplanted in each experimental plot at the afternoon of 1st October, 2019 maintaining experimental design. Similarly, 2nd transplanting was done 15 days interval (15th October, 2019) after first sowing and 3rd transplanting was done 15 days interval (1st November, 2019) after second transplanting. In order to minimize damage of the root system, the seedbed was watered before uprooting the seedlings. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedling from the sun and removed after seedlings were established. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.13 Intercultural operations

3.13.1 Shading

A transparent polythene shade was provided to protect the plants from excess rainfall and sunlight. It was made with the help of polythene sheet and bamboo sticks. The shade was maintained up to 40 days after transplanting.

3.13.2 Weeding and mulching

Weeding was accomplished by hand and when necessary with the help of khurpi (a type of spatula) to keep the crop free from weeds, for better soil aeration and to break the crust. Mulching was also done to help in soil moisture conservation.

3.13.3 Gap filling

A few gap fillings was done by healthy seedlings of the same stock where planted seedlings failed to survive. When the seedlings were well established, the soil around the base of each seedling was pulverized.

3.13.4 Irrigation

Irrigation was provided immediately after transplanting and it was continued until the seedlings were established in the plot. High frequency of irrigation was demanded because it was a rooftop experiment. Usual irrigation schedule for field grown tomato was not followed. Irrigation was provided each alternate day in general but sometimes the plants demanded everyday irrigation.

3.13.5 Stalking

After the well establishment of the plants, staking was done to each plant by means of bamboo sticks to keep them upright because tomato is a herbaceous plant with higher fruit weight.

3.13.6 Plant protection

3.13.6.1 Insect pests

Aphid (a leaf sucking insect) infested the crop at vegetative and early reproductive stages, which was controlled by Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks. White fly infested the crop at early reproductive stage, which was controlled by means of spraying with Admire 200 SL @ 0.5 ml L^{-1} of water at 7 days interval for 2 weeks. Melathion 57 EC was applied @ 2 ml L^{-1} of water against the insect pests like leaf hopper, fruit borer and others. The insecticide application was made fortnightly after transplanting and stopped before second week of first harvest.

3.13.6.2 Disease

During foggy weather precautionary measure against disease attack of tomato was taken by spraying Diathane M-45 fortnightly @ 2 g L^{-1} of water, at the early vegetative stage. Ridomil gold was also applied @ 2 g L^{-1} of water against blight disease of tomato.

3.13.7 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they developed slightly red color. Harvesting of tomato (1st October, 2019 transplanting) was started from 24th November, 2019 and was continued up to 7th January, 2020 and harvesting of tomato (15th October, 2019 transplanting) was started from 6th December, 2019 and was continued up to 28th January, 2020. Harvesting of tomato (1st November, 2019 transplanting) was started from 19th December, 2019 and was continued up to 5th February, 2020.

3.14 Data collection

The following data were recorded

i. Plant height (cm) at 30, 55 and 80 days after transplanting (DAT),

ii. Number of leaves plant^{-1} at 30, 55 and 80 days after transplanting (DAT),

iii. Leaf area index (LAI),

iv. Chlorophyll content of leaf (mg g^{-1} FW),

v. Number of flower cluster plant^{-1},

vi. Number of fruit cluster plant^{-1},

vii. Number of flower cluster^{-1},

viii. Number of fruit cluster^{-1},

ix. Number of fruit plant^{-1},

x. Fruit length (cm),

xi. Fruit breath (cm),

xii. Individual fruit weight (g) and

xiii. Yield plant^{-1} (kg).

3.15 Detailed procedures of data collection

3.15.1 Plant height

Plant height was measured from the sample plants in centimetre from the ground level to the tip of the longest stem and means value was calculated. Plant height was recorded 30, 55 and 80 days after transplanting (DAT) to observe the growth rate.

3.15.2 Number of leaves plant^{-1}

Number of leaves was counted from the ground level to the tip of the longest stem and mean value was calculated. Number of leaves was recorded from 30, 55 and 80 days after transplanting (DAT) to observe the growth rate of the plants.

3.15.3 Leaf area index (LAI)

Leaf area index (LAI) is a ratio of total surface area of leaves to a unit area of lands. Green leaf area (LA) was measured by an automatic leaf area meter (Model: LI-3100, Li-COR, Lincoln, NE, USA) just after removal of leaves to avoid rolling and shrinkage and then transformed into leaf area index (LAI) according to Yoshida (1981).

3.15.4 Chlorophyll content of leaf

Chlorophyll content of leaves was measured at 50 days after transplanting (DAT). Mature leaf (fourth leaves from top) were measured all time. Three mature plant of each plot were measured by using portable Chlorophyll Meter (SPAD-502, Minolta, Japan) and then calculated an average SPAD value for each plot at each sampling time. The chlorophyll meter Soil Plant Analysis Development (SPAD-502) is a simple and portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves (Kariya*et al.,* 1982; Torres-netto*et al.,* 2005). It provides instantaneous and non-destructive readings on plants based on the quantification of the intensity of absorbed light by the tissue sample using a red LED (wavelength peak is ~650 nm) as a source. An infrared LED, with a central wavelength emission of approximately 940 nm, acts simultaneously with the red LED to compensate for the leaf thickness (Minolta camera Co. Ltd., 1989).

3.15.5 Number of flower cluster plant^{-1}

The number of flower clusters was counted from the sample plants periodically and the average number of flower clusters produced per plant was calculated.

3.15.6 Number of fruit cluster plant^{-1}

The number of fruit clusters was counted from the sample plants periodically and the average number of fruit clusters produced per plant was calculated.

3.15.7 Number of flower cluster^{-1}

The number of flowers per cluster was calculated as follows:

$$\text{Number of flower cluster}^{-1} = \frac{\text{Total number of flowers in sample plant}}{\text{Total number of flowers clusters in sample plants}}$$

3.15.8 Number of fruit cluster^{-1}

The number of fruits per cluster was calculated as follows:

$$\text{Number of fruit cluster}^{-1} = \frac{\text{Total number of fruits in sample plant}}{\text{Total number of fruits clusters in sample plants}}$$

3.15.9 Number of fruit plant^{-1}

Total number of fruits was counted from selected plants and their average was taken as the number of fruits per plant at harvest.

3.15.10 Fruit length

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the length of fruit by slide calipers. The length of fruit was calculated by making the average of five fruits from each of the six plants.

3.15.11 Fruit breadth

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the breadth of fruit by slide calipers. The diameter of fruit was calculated by making the average of five fruits from each of the six plants.

3.15.12 Individual fruit weight

Among the total number of fruits harvested during the period from first to final harvest, the fruits, except the first and last harvest, were considered for determine the individual fruit weight in gram. The weight was calculated from total weight of fruits was divided by total number of fruits of every harvest and finally making the average was made from four times harvesting data.

3.15.13 Yield plant^{-1}

Yield of tomato per plant was recorded as the whole fruit per plant and wasexpressed in kilogram (kg).

3.16 Light measurement

Light was measured by Lux meter on each vegetable crop rows. It was done to determine the availability of light and expressed as lux. Light intensities were measured above the canopy of tomato crops at 8.30-10.30 am and 3.30-4.30 pm using Lux meter at three times per month.

3.17 Soil moisture measurement

Soil moisture was measured by Soil Moisture Meter on each vegetable crop rows. It was expressed as percentage (%). Soil moisture was measured at 10 cm depth of soil adjacent to main root of vegetable crop rows at 8.30-10.30 am, 12.30-1.30 pm and 3.30- 4.30 pm in 3 times per month.

3.18 Soil temperature measurement

Soil temperature was measured by Soil Temperature Meter on each vegetable crop rows. It was expressed as degree centigrade (˚C). Soil temperature was measured at 10 cm deep soil adjacent to main root of vegetable crop rows at 8.30-10.30 am, 12.30-1.30 pm and 3.30-4.30 pm in 3 times per month.

3.19 Statistical Analysis

The data obtained for different characters were statistically analysed to observe the significant difference among different treatments. The analysis of variance (ANOVA) of all the recorded parameters were performed using MSTAT-C software. The difference of the means value was separated by least significance difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to find out the impact of different planting time and nitrogen levels on growth and yield of tomato on rooftop garden. The results obtained from the study have been presented, discussed and compared in this chapter through table(s) and figures. The analysis of variance of data in respect of all the parameters has been shown in Appendix IV to IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings. The analytical results have been presented in Table 1 through Table 13 and Figure 1 through Figure 6.

4.1 Plant height (cm)

4.1.1 Effect of planting time

In this study, the effect of planting time of tomato in relation to delay of transplanting reduced the plant height (Figure 1). The main effect of planting time indicated that the plant height gradually increased when recorded at different growth period; observed at 30, 55 and 80 days after transplanting (DAT) (Appendix IV). In this experiment, it was observed that the tallest plant (67.92, 99.67 and 111.08 cm at 30, 55 and 80 DAT, respectively) was observed in 1st transplanting (1st October) whereas, the shortest plant (60.09, 91.92 and 103.33 cm at 30, 55 and 80 DAT, respectively) was observed in 3rd transplanting (1st November) which was followed by 15th October (63.62, 94.93 and 106.00 cm at 30, 55 and 80 DAT, respectively). In this study late planting of tomato showed a great reduction in plant height as compared to early transplanting. Many previous authors stated that different days of transplanting changed the height of the plant (Chen and Kuc, 1999). The present result agreed with the reports of Hoque and Rahman (1988).

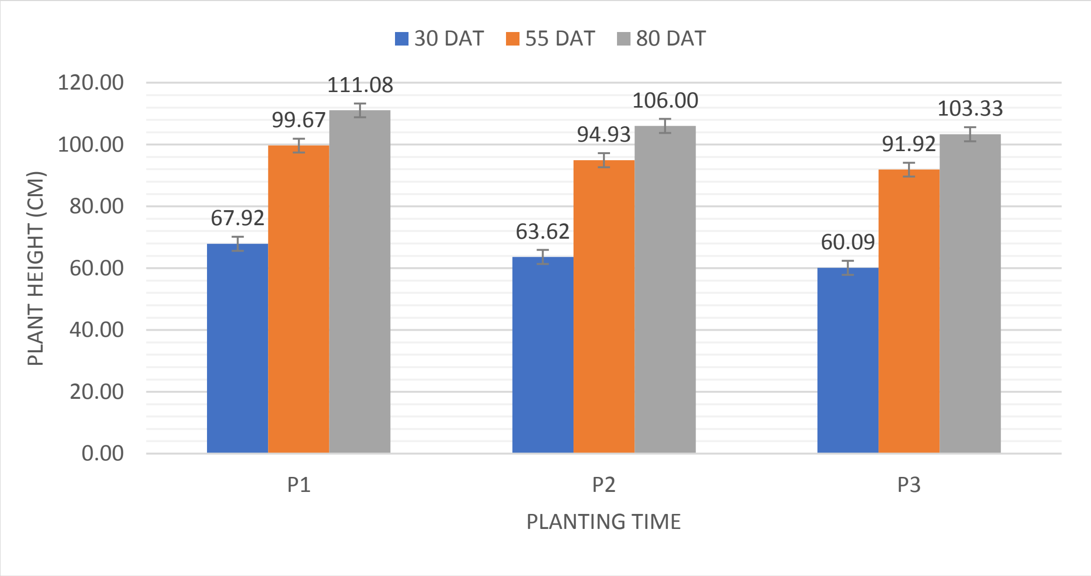

Figure 1. Effect of different planting time on plant height (cm) at different days after transplanting of BARI Tomato 14(LSD value = 1.67, 2.78 and 2.58 at 30, 55 and 80 DAT, respectively)

Note: P_1 – 1st October, P_2 – 15th October and P_3 – 1st November.

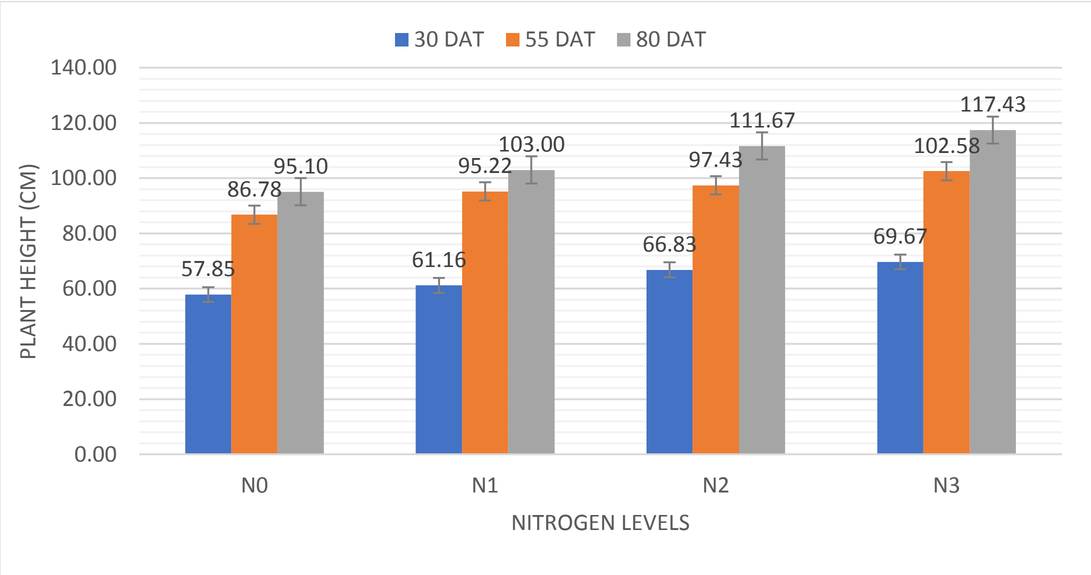

Figure 2. Effect of different nitrogen levels on plant height (cm) at different days after transplanting of BARI Tomato 14(LSD value = 1.67, 2.78 and 2.58 at 30, 55 and 80 DAT, respectively)

Note: N_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1} and N_3 – 170 kg N ha^{-1}.

4.1.2 Effect of nitrogen levels

Plant height of tomato was significantly increased by different levels of nitrogen (Figure 2). In case of different nitrogen application significant difference was observed at 30, 55 and 80 DAT (Appendix IV). At 30, 55 and 80 DAT, the tallest plant (69.67, 102.58 and 117.43 cm, respectively) was obtained from N_3 (170 kg N ha^{-1}) treatment whereas, shortest plant (57.85, 86.78 and 95.10 cm, respectively) was recorded from N_0 (0 kg N ha^{-1}) treatment. This might be due to higher availability of N and their uptake that progressively enhanced the vegetative growth of the plant. Kuksal*et al.* (1977) also reported that nitrogen application at higher rate increased plant height. These are an agreement with those of Ali *et al.* (1990), Mondal and Gaffer (1983), Gaffer and Razzaque (1983), who have reported that different levels of nitrogen significantly increased plant height. Melton and Dufault (1991) found that plant height of tomato was increased as the highest level of nitrogen application. Chung *et al.* (1992) reported that plant height increased with increasing nitrogen rate. Singh and Sharma (1999) and Sandoval *et al.* (1999) stated that, plant height, number of leaves increased with N levels. Similar options were put forward by Sharma *et al.* (1999) and Hossain (2007).

4.1.3 Interaction effect of different planting time and nitrogen levels

The result of the present study showed that interaction effect between planting time with different levels of nitrogen showed a significant effect on incensement of plant height (Table 1 and Appendix IV). At 30, 55 and 89 DAT, the tallest plant (76.00, 108.70 and 125.00 cm, respectively) was found in P_1N_3 (1^{st} October with 170 kg N ha^{-1}) treatment. On the other hand, the shortest plant (54.23, 82.33 and 90.00 cm at 30, 55 and 89 DAT, respectively) was observed in P_3N_0 (1^{st} November with 0 kg N ha^{-1}) treatment. These results revealed that 1^{st} transplanting of seedling and higher dose of nitrogen were influential nutrients for increasing the plant height.

Table 1. Interaction effects of different planting time and nitrogen on plant height (cm) at different days after transplanting of BARI Tomato 14

Treatment combination	Plant height (cm) at		
	30 DAT	55 DAT	80 DAT
P_1N_0	60.00 f	88.67 g	100.30 g
P_1N_1	66.67 d	99.00 c	104.30 e
P_1N_2	69.00 b	102.30 b	114.70 b
P_1N_3	76.00 a	108.70 a	125.00 a
P_2N_0	59.33 f	89.33 g	95.00 h
P_2N_1	59.83 f	94.00 ef	102.70 ef
P_2N_2	67.00 cd	94.67 ef	112.30 c
P_2N_3	68.33 bc	101.70 b	114.00 bc
P_3N_0	54.23 h	82.33 h	90.00 i
P_3N_1	56.97 g	92.67 f	102.00 fg
P_3N_2	64.50 e	95.33 de	108.00 d
P_3N_3	64.67 e	97.33 cd	113.30 bc
LSD $_{(0.05)}$	**1.56**	**2.11**	**2.04**
CV (%)	**4.86**	**7.49**	**3.92**

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

P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

4.2 Number of leaves plant^{-1}

4.2.1 Effect of planting time

The number of leaves plant^{-1} is a fundamental morphological character for plant growth and development as leaf number is the main photosynthetic organ. To investigate the effect of different planting time of tomato on change in the number of leaves plant^{-1} up to 80 DAT were counted. Different planting time showed a significant influenced on the formation of leaves plant^{-1} (Figure 3 and Appendix V). At 30 DAT, the maximum number of leaves plant^{-1} (63.09) was recorded from P3 (1st November) which was statistically identical to P2 (62.59) and the minimum (52.67) was recorded from P1 (1stOctober). At 55 DAT, the maximum number of leaves plant^{-1} (77.18) was recorded from P3 (1st November) and the minimum (65.85) was recorded from P1 (1st October). At 80 DAT, the maximum number of leaves plant^{-1} (84.18) was recorded from P3 (1st November) whereas, the minimum (76.93) was recorded from P1 (1st October) which was statistically identical to P2 (78.53). These results indicate that the highest number of leaves plant^{-1} found from late transplanting whereas the lowest number of leaves plant^{-1} was produced from early transplanting. Adil*et al.* (2013) support this experiment.

4.2.2 Effect of nitrogen levels

Number of leaves plant^{-1} of tomato varied significantly due to the application of different level of nitrogen at 30, 55 and 80 DAT (Figure 4 and Appendix V). At 30, 55 and 80 DAT, the maximum number of leaves plant^{-1} (65.78, 79.23 and 90.02 cm, respectively) was recorded from N_3 (170 kg N ha^{-1}) treatment whereas, the minimum number of leaves plant^{-1} (53.00, 64.12 and 71.29 cm, respectively) was recorded from N_0 (0 kg N ha^{-1}) treatment. Singh and Sharma (1999) stated that, number of leaves increased with N levels. Melton and Dafult (1991) reported similar result.

4.2.3 Interaction effect of different planting time and nitrogen levels

The interaction between different planting time and nitrogen levels was found significant on the number of leaves plant^{-1} (Table 2 and Appendix V). At 30 DAT, the maximum number of leaves plant^{-1} (68.67) was found in P_3N_3 (1st November with 170 kg N ha^{-1}) treatment combination whereas, the minimum (40.67) was found in P_1N_0 (1st October with 0 kg N ha^{-1}) treatment combination. At 55 and 80 DAT, the maximum number of leaves plant^{-1} (84.18 and 92.15, respectively) was found in P_3N_3 (1st November with 170 kg N ha^{-1}) treatment combination whereas, the minimum (60.80 and 68.11, respectively) was found in P_1N_0 (1st October with 0 kg N ha^{-1}) treatment combination which was statistically similar with P_2N_0 (62.23) at 55 DAT and statistically identical to P_2N_0 (67.60) at 80 DAT.

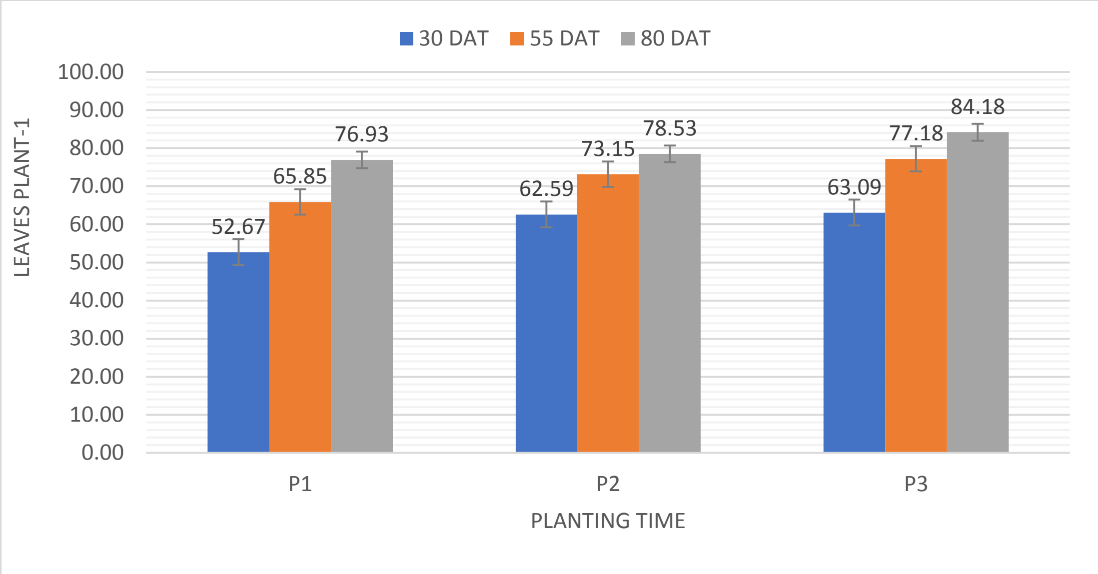

Figure 3. Effect of different planting time on number of leaves plant^{-1} at different days after transplanting of BARI Tomato 14(LSD value = 2.81, 2.34 and 2.91 at 30, 55 and 80 DAT, respectively)

Note: P_1 – 1st October, P_2 – 15th October and P_3 – 1st November.

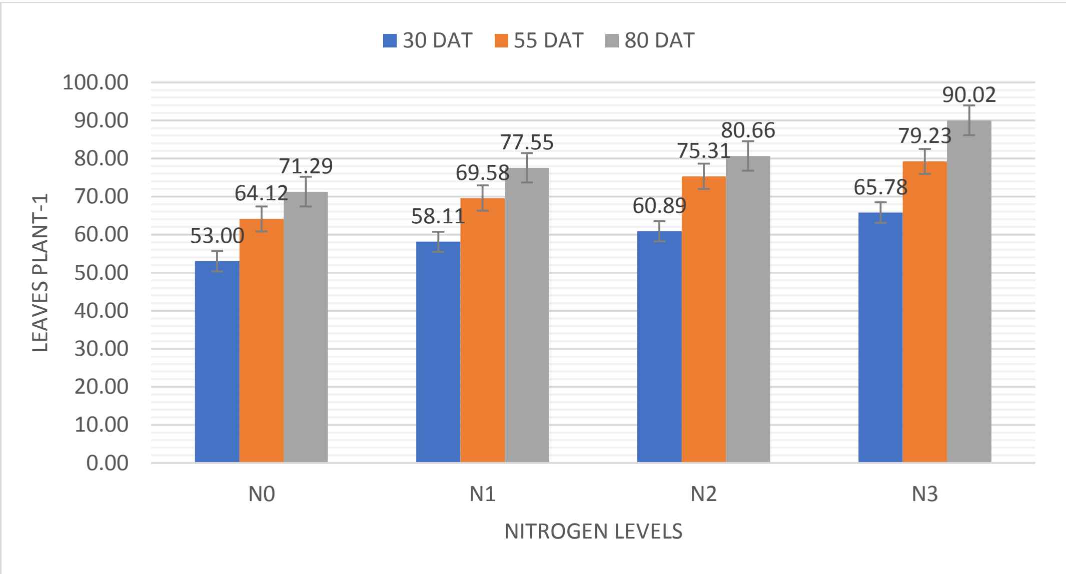

Figure 4. Effect of different nitrogen levels on number of leaves plant^{-1} at different days after transplanting of BARI Tomato **14** (LSD value = 2.81, 2.34 and 2.91 at 30, 55 and 80 DAT, respectively)

Note: N_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1} and N_3 – 170 kg N ha^{-1}.

Table 2. Interaction effects of different planting time and nitrogen on number of leaves plant^{-1} at different days after transplanting of BARI Tomato 14

Treatment combination	Number of leaves plant^{-1} at		
	30 DAT	**55 DAT**	**80 DAT**
P_1N_0	40.67 h	60.80 i	68.11 h
P_1N_1	51.33 g	63.62 h	74.75 g
P_1N_2	55.00 f	66.65 g	76.61 fg
P_1N_3	63.67 bc	72.33 de	88.75 b
P_2N_0	60.67 d	62.23 hi	67.60 h
P_2N_1	61.00 d	71.05 ef	77.25 ef
P_2N_2	63.67 bc	78.14 c	79.61 de
P_2N_3	65.00 b	81.17 b	89.15 b
P_3N_0	57.67 e	69.32 f	78.15 ef
P_3N_1	62.00 cd	74.08 d	80.65 d
P_3N_2	64.00 bc	81.15 b	85.75 c
P_3N_3	68.67 a	84.18 a	92.15 a
LSD $_{(0.05)}$	**2.63**	**1.88**	**2.39**
CV (%)	**5.93**	**9.28**	**8.52**

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

P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

Table 3. Effects of different planting time on chlorophyll content (mg g^{-1} FW) of BARI Tomato 14

Planting time	Chlorophyll content (mg g^{-1} FW)
P_1	1.61
P_2	1.58
P_3	1.54
LSD $_{(0.05)}$	**NS**
CV (%)	**6.37**

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

Note: P_1 – 1st October, P_2 – 15th October and P_3 – 1st November.

4.4 Chlorophyll content (mg g^{-1} FW)

4.4.1 Effect of planting time

Chlorophyll content of tomato leaves were non-significantly affected by the planting time (Table 3 and Appendix VI). Numerically, the maximum chlorophyll content (SPAD value) (1.61 mg g^{-1} FW) was recorded from 1st transplanting (1st October) and the minimum (1.54 mg g^{-1} FW) was recorded from 3rd transplanting (1st November).

Table 4. Effects of different nitrogen levels on leaf chlorophyll content (mg g^{-1} FW) of BARI Tomato 14

Nitrogen levels	Chlorophyll content (mg g^{-1} FW)
N_0	1.48 c
N_1	1.54 bc
N_2	1.66 a
N_3	1.62 ab
LSD $_{(0.05)}$	**0.11**
CV (%)	**6.37**

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

Note: N_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1} and N_3 – 170 kg N ha^{-1}.

4.4.2 Effect of nitrogen levels

Chlorophyll content of tomato leaves were significantly affected by the different nitrogen levels (Table 4 and Appendix VI). Chlorophyll content (SPAD value) increased with the advancement of plant age irrespective of nitrogen and thereafter decreased due to yellowing of leaves. The maximum chlorophyll content (SPAD value) (1.66 mg g^{-1} FW) was recorded from 120 kg N ha^{-1} (N_2) which was statistically similar to N_3 (1.62 mg g^{-1} FW) and the minimum (1.48 mg g^{-1} FW) was recorded from 0 kg N ha^{-1} (N_0) which was statistically similar to N_1 (1.54 mg g^{-1} FW). Use of different nitrogen levels varied the chlorophyll content of tomato. Similar trends of result observed by many other researcher (Bavec and Bavec, 2001; Güler*et al.*,2006). Scholberg (2000) conducted an experiment and agreed with the results.

4.4.3 Interaction effect of different planting time and nitrogen levels

Chlorophyll content of tomato leaves were significantly affected by the different planting time with nitrogen levels (Table 5 and Appendix VI). The maximum chlorophyll content (SPAD value) (1.73 mg g^{-1} FW) was recorded from 1st October planting of tomato with the application of 120 kg N ha^{-1} (P_1N_2). On the other hand, the minimum (1.45 mg g^{-1} FW) was recorded from 1st November with 0 kg N ha^{-1} (P_3N_0) which was statistically similar to P_2N_0 (1.49 mg g^{-1} FW), P_1N_0 (1.51 mg g^{-1} FW), P_3N_1 (1.51 mg g^{-1} FW), P_2N_1 (1.55 mg g^{-1} FW) and P_1N_1 (1.56 mg g^{-1} FW).

Table 5. Interaction effects of different planting time and nitrogen on chlorophyll content (mg g^{-1} FW) of BARI Tomato 14

Treatment combination	Chlorophyll content (mg g^{-1} FW)
P_1N_0	1.51 d-f
P_1N_1	1.56 cd
P_1N_2	1.73 a
P_1N_3	1.65 b
P_2N_0	1.49 ef
P_2N_1	1.55 c-e
P_2N_2	1.64 b
P_2N_3	1.63 b
P_3N_0	1.45 f
P_3N_1	1.51 d-f
P_3N_2	1.60 bc
P_3N_3	1.59 bc
$LSD_{(0.05)}$	**0.06**
CV (%)	**6.37**

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

Note: P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

4.5 Number of flower cluster plant^{-1}

4.5.1 Effect of planting time

In this experiment, there was a significant difference in number of flower clusters plant^{-1} at different planting time on rooftop (Table 6 and Appendix VII). The highest number of flower cluster plant^{-1} (14.26) was found from P_2 (15th October) whereas, the lowest number of cluster (12.03) was recorded from P_1 (1st October). These results indicate that higher temperature reduces the formation of number of flower clusters plant^{-1}. Therefore, it is suggesting that medium temperature stress significantly affect the both vegetative and reproductive development in tomato.

4.5.2 Effect of nitrogen levels

Number of flower cluster plant^{-1} progressively increased with increasing level of N up to a certain level (Table 7 and Appendix VII). The highest number of flower cluster plant^{-1} (15.38) was found from N_2 (120 kg N ha^{-1}) whereas, the lowest number of cluster (10.99) was recorded from N_0 (0 kg N ha^{-1}). Midan*et al.* (1985) reported similar type result. Singh and Sharma (1999) stated that, number of flower cluster, fruit weight and yield increased with increasing N level.

4.5.3 Interaction effect of different planting time and nitrogen levels

The combined effect of different planting time and nitrogen rate had significant variation in number of flower cluster plant^{-1} of Tomato (Table 8 and Appendix VII). The highest number of flower cluster plant^{-1} (16.27) was found from P_2N_2 (15th October with 120 kg N ha^{-1}) treatment combination. On the other hand, the lowest number of flower cluster plant^{-1} (9.00) was recorded from P_1N_0 (1st October with 0 kg N ha^{-1}) treatment combination.

Table 6. Effects of different planting time on number of flower cluster plant^{-1}, number of fruit cluster plant^{-1}, number of flower cluster $^{-1}$, number of fruitcluster $^{-1}$ and number of fruit plant^{-1} of BARI Tomato 14

Planting time	No. of flower cluster plant^{-1}	No. of fruit cluster plant^{-1}	No. of flower cluster $^{-1}$	No. of fruit cluster $^{-1}$	No. of fruit plant $^{-1}$
P_1	12.03 c	8.53 c	5.75 c	2.05 c	18.79 c
P_2	14.26 a	10.76 a	6.65 a	2.95 a	32.91 a
P_3	13.45 b	9.95 b	6.39 b	2.69 b	28.12 b
$LSD_{(0.05)}$	**0.49**	**0.73**	**0.23**	**0.25**	**4.51**
CV (%)	**5.74**	**4.92**	**6.83**	**8.39**	**5.27**

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

Note: P_1 – 1st October, P_2 – 15th October and P_3 – 1st November.

4.6 Number of fruit cluster plant^{-1}

4.6.1 Effect of planting time

The different time of planting showed significant variation in the number of fruitcluster plant^{-1} (Appendix VII). The maximum number of fruit cluster plant^{-1} (10.76) was produced by 15th October (P_2) planting whereas, 1st October (P_1) planting produced the minimum number of fruit cluster plant^{-1} (8.53) (Table 6). The number of fruit cluster plant^{-1} decreased gradually as the temperature increased later. Similar result was reported by Hossain (2001).

4.6.2 Effect of nitrogen levels

The effect of different levels of nitrogen in respect of fruit clusters plant^{-1} was significant (Appendix VII). The maximum number of fruit clusters per plant (11.88) was found from 120 kg N ha^{-1} (N_2) treatment. On the other hand, the minimum (7.49) was found from no nitrogen or the control treatment (Table 7). Midan*et al.* (1985) reported similar type result.

4.6.3 Interaction effect of different planting time and nitrogen levels

The combined effect of different planting time and nitrogen rate had significant variation in number of fruit cluster plant^{-1} of Tomato (Table 8 and Appendix VII). The highest number of fruit cluster plant^{-1} (12.77) was found from P_2N_2 (15th October with 120 kg N ha^{-1}) treatment combination which was statistically identical to P_3N_2 (12.33) whereas, the lowest value (5.50) was recorded from P_1N_0 (1st October with 0 kg N ha^{-1}) treatment combination.

4.7 Number of flower cluster $^{-1}$

4.7.1 Effect of planting time

Planting time had significant effect on number of flower cluster^{-1} of tomato (Table 6 and Appendix VII). The highest number of flower cluster^{-1} observed from the 2nd transplanting (15th October) was (6.65) and the lowest number of flower cluster^{-1} observed from 1st transplanting (1st October) was (5.75). From this result it was found that the early transplanted tomato seedlings produce the minimum number of flower cluster^{-1} than the late transplanting. The number of flower cluster^{-1} increased gradually as the temperature decreased later. Similar result was reported by Hossain (2001).

4.7.2 Effect of nitrogen levels

A significant variation in the number of flower cluster^{-1} was observed due to effect of different levels of nitrogen (Table 7 and Appendix VII). The highest number of flower cluster^{-1} (7.34) was produced at 120 kg N ha^{-1} (N_2) treatment whereas, the lowest (5.28) was produced at 0 kg N ha^{-1} (N_0) treatment. The results show that the number of flower cluster^{-1} was gradually increased with increasing up to certain levels of nitrogen. Garrison *et al.* (1967) reported that increasing levels of nitrogen increased flower formation of several clusters of processing tomato.

4.7.3 Interaction effect of different planting time and nitrogen levels

Combined effect of different planting time and levels of nitrogen on number of flower cluster^{-1} were found to be significant (Appendix VII). The height number of flower cluster^{-1} (7.98) was observed in the treatment combination of 15th October with 120 kg N ha^{-1} (P_2N_2). On the other hand, the lowest number of flower cluster^{-1} (4.75) from the treatment combination of 1st October with 0 kg N ha^{-1} (P_1N_0) (Table 8).

Table 7. Effects of different nitrogen levels on number of flower cluster plant^{-1}, number of fruit cluster plant^{-1}, number of flower cluster $^{-1}$, number of fruitcluster $^{-1}$ and number of fruit plant^{-1} of BARI Tomato 14

Nitrogen levels	No. of flower cluster plant^{-1}	No. of fruit cluster plant^{-1}	No. of flower cluster $^{-1}$	No. of fruit cluster $^{-1}$	No. of fruit plant $^{-1}$
N_0	10.99 d	7.49 d	5.28 d	1.58 d	12.45 d
N_1	12.71 c	9.21 c	5.64 c	1.94 c	17.97 c
N_2	15.38 a	11.88 a	7.34 a	3.64 a	43.73 a
N_3	13.91 b	10.41 b	6.78 b	3.08 b	32.28 b
LSD $_{(0.05)}$	**0.49**	**0.73**	**0.23**	**0.25**	**4.51**
CV (%)	**5.74**	**4.92**	**6.83**	**8.39**	**5.27**

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

N_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1} and N_3 – 170 kg N ha^{-1}.

4.8 Number of fruit cluster $^{-1}$

4.8.1 Effect of planting time

Planting time had significant effect on number of fruit cluster^{-1} of tomato (Table 6 and Appendix VII). The maximum number of fruit cluster^{-1} observed from the 2nd transplanting (15th October) was (2.95) and the minimum number of fruit cluster^{-1} observed from 1st transplanting (1st October) was (2.05). From this result it was found that the early transplanted tomato seedlings produce the minimum number of flower cluster^{-1} than the late transplanting. The number of fruit cluster^{-1} increased gradually as the temperature decreased later. Similar result was reported by Hossain (2001).

4.8.2 Effect of nitrogen levels

A significant variation in the number of fruit cluster^{-1} was observed due to effect of different levels of nitrogen (Table 7 and Appendix VII). The maximum number of fruit cluster^{-1} (3.64) was produced at 120 kg N ha^{-1} (N_2) treatment whereas, the minimum (1.58) was produced at 0 kg N ha^{-1} (N_0) treatment. The results show that the number of fruit cluster^{-1} was gradually increased with increasing up to certain levels of nitrogen. Garrison *et al.* (1967) reported that increasing levels of nitrogen increased flower formation of several clusters of processing tomato.

4.8.3 Interaction effect of different planting time and nitrogen levels

Combined effect of different planting time and levels of nitrogen on number of fruit cluster^{-1} were found to be significant (Appendix VII). The maximum number of fruit cluster^{-1} (4.28) was observed in the treatment combination of 15th October with 120 kg N ha^{-1} (P_2N_2). On the other hand, the minimum number of fruit cluster^{-1} (1.05) from the treatment combination of 1st October with 0 kg N ha^{-1} (P_1N_0) (Table 8).

4.9 Number of fruit plant $^{-1}$

4.9.1 Effect of planting time

Significant effect of planting time was found on the number of fruit plant^{-1} of tomota (Table 6 and Appendix VII). The highest number (32.91) of fruit plant^{-1} was obtained P_2 (15th October) treatment. On the other hand, the lowest number (18.79) of fruit plant^{-1} was obtained from the P_1 (1st October) treatment. So, from this result we can say that the early transplanting of tomato seedlings gives more fruit than the late transplanting due to high temperature (BARI, 1989). For this reason, it can be easily said that environmental condition regulates the number of fruit plant^{-1}. Generally, earlier planting should have produced maximum number of fruit plant^{-1}. Similar results were reported by Hossain (2001). Hossain *et al*. (2013) reported that the number of fruit plant^{-1} was also the highest (27.40) in 10 October sowing and the lowest (13.73) was in 30 October sowing.

4.9.2 Effect of nitrogen levels

The effect of different levels of nitrogen on the number of fruit plant^{-1} was significant (Table 7 and Appendix VII). Number of fruit plant^{-1} gradually increased with increasing levels of nitrogen up to 120 kg N ha^{-1} than decreasing. The highest number of fruit plant^{-1} (43.73) was obtained with the application of 120 kg N ha^{-1} (N_2), which was statistically different from other treatments. The lowest number of fruit plant^{-1} (12.45) was produced by control (0 kg N ha^{-1}) treatment. It was observed that the application of nitrogen up to 120 kg ha^{-1} increased number of fruit plant^{-1}. Further addition of nitrogen decreased the number of fruit plant^{-1}. Sharma (1995) found highest number of fruit plant^{-1} with 120 kg N ha^{-1}. Nassar (1986) also found that high nitrogen levels tended to increase average number of fruit plant^{-1}. Such influence of nitrogen has also been reported by Islam *et al*. (1997). They reported that the highest number of fruit plant^{-1} was produced by the application of 250 kg N ha^{-1}. Midan*et al*. (1985) reported the number of fruit plant^{-1} increased as the nitrogen levels was also increased.

4.9.3 Interaction effect of different planting time and nitrogen levels

The interaction effect of the treatment combinations of different planting time and nitrogen levels on number of fruit plant^{-1} were significant (Table 8 and Appendix VII). The highest fruit per plant (54.66) was found in 15th October planting with 120 kg N ha^{-1} application, which was highly significant with all other treatments. The lowest number of fruit plant^{-1} (5.78) was produced by the 1st October planting with 0 kg N ha^{-1} application.

Table 8. Interaction effects of different planting time and nitrogen on number of flower cluster plant^{-1}, number of fruit cluster plant^{-1}, number of flower cluster $^{-1}$, number of fruit cluster $^{-1}$ and number of fruit plant $^{-1}$ of BARI Tomato 14

Treatment combination	No. of flower cluster plant^{-1}	No. of fruit cluster plant^{-1}	No. of flower cluster $^{-1}$	No. of fruit cluster $^{-1}$	No. of fruit plant $^{-1}$
P_1N_0	9.00 j	5.50 g	4.75 j	1.05 k	5.78 h
P_1N_1	12.17 h	8.67 e	5.15 i	1.45 j	12.57 g
P_1N_2	14.03 d	10.53 bc	6.66 d	2.96 e	31.17 d
P_1N_3	12.93 f	9.43 d	6.42 e	2.72 f	25.65 e
P_2N_0	12.67 fg	9.17 de	5.68 g	1.98 h	18.16 f
P_2N_1	13.63 e	10.13 c	5.88 f	2.18 g	22.08 ef
P_2N_2	16.27 a	12.77 a	7.98 a	4.28 a	54.66 a
P_2N_3	14.47 c	10.97 b	7.05 c	3.35 c	36.75 c
P_3N_0	11.30 i	7.80 f	5.42 h	1.72 i	13.42 g
P_3N_1	12.33 gh	8.83 e	5.88 f	2.18 g	19.25 f
P_3N_2	15.83 b	12.33 a	7.38 b	3.68 b	45.37 b
P_3N_3	14.33 cd	10.83 b	6.88 c	3.18 d	34.44 cd
LSD $_{(0.05)}$	**0.37**	**0.57**	**0.19**	**0.14**	**4.27**
CV (%)	**5.74**	**4.92**	**6.83**	**8.39**	**5.27**

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

P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

4.10 Fruit length (cm)

4.10.1 Effect of planting time

The planting time exhibited no significant variation in the length of fruit (Figure 5 and Appendix VIII). However, the numerically longest fruit length (4.03 cm) wasproduced by 15th October (P_2) planting and 1st October (P_1) planting produced the shortest fruit length (3.75 cm). This result is supported by Hossain (2001).

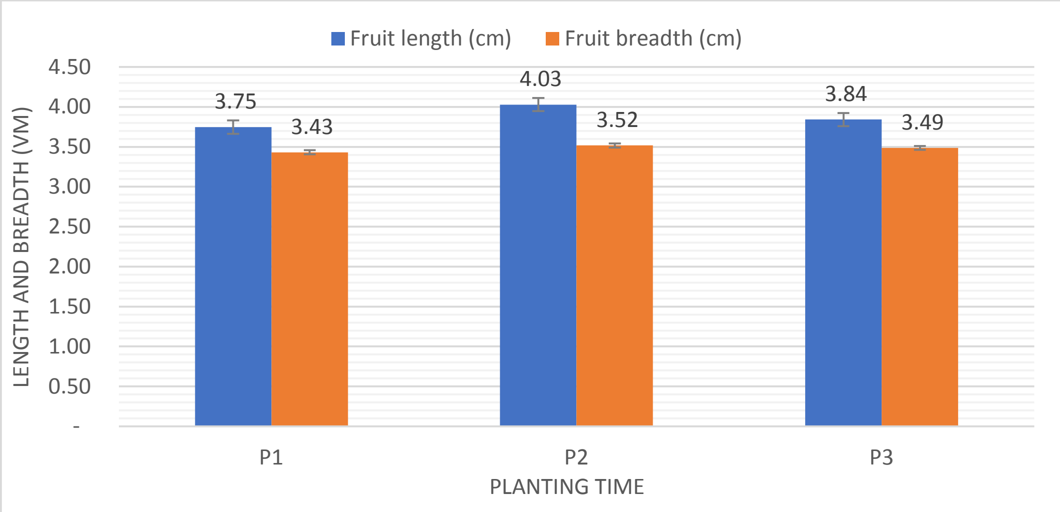

Figure 5. Effect of different planting time on fruit length (cm) and fruit breadth (cm) of BARI Tomato 14(LSD value = Non-Significant and Non-Significant, respectively)

Note: P_1 – 1st October, P_2 – 15th October and P_3 – 1st November.

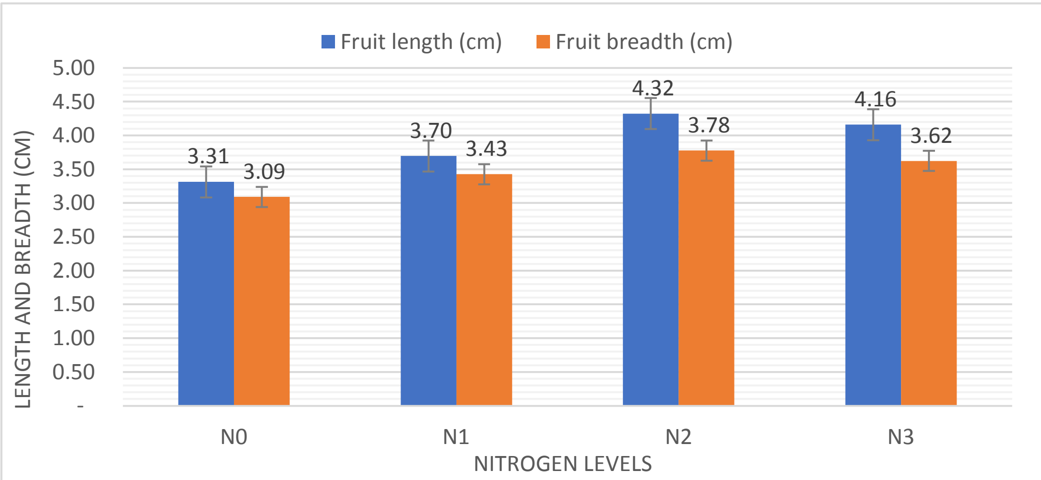

Figure 6. Effect of different nitrogen levels on fruit length (cm) and fruit breadth (cm) of BARI Tomato 14(LSD value = 0.31 and 0.12, respectively)

Note: N_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1} and N_3 – 170 kg N ha^{-1}.

4.10.2 Effect of nitrogen levels

Due to different levels of nitrogen application significant difference was found fruit length of tomato (Figure 6 and Appendix VIII). The longest fruit length (4.32 cm) was obtained from N_2 (120 kg N ha^{-1}) treatment which was statistically identical to N_3 (4.16 cm) treatment. On the other hand, the shortest fruit length (3.31 cm) was found from N_0 (0 kg N ha^{-1}) treatment. Huett (1993) with tomato cv. Flora-Dade on krasnozem soils to examine the effects of N and agreed with the results. Nassar (1986) had similar report which supports the present results. Islam *et al* (1997) reported that the length of individual fruit was increased with increased level of nitrogen.

4.10.3 Interaction effect of different planting time and nitrogen levels

The interaction effect of the treatment combinations of different planting time and nitrogen levels on fruit length were significant (Table 9 and Appendix VII). The longest fruit length (4.55 cm) was obtained from P_2N_2 (15^{th} October planting with 120 kg N ha^{-1} application) treatment whereas, the shortest fruit length (3.14 cm) was found from P_1N_0 (1^{th} October planting with 0 kg N ha^{-1} application) treatment.

4.11 Fruit breadth (cm)

4.11.1 Effect of planting time

The variation in the breadth of fruit three different planting time was exhibited no significant (Figure 5 and Appendix VIII). The numerically largest fruit breadth (3.52 cm) was produced by 15^{th} October (P_2) planting and 1^{st} October (P_1) planting produced the shortest fruit breadth (3.43 cm). Mid October planting produce largest fruit breadth is reported by Hossain (2001). Sharma and Tiwari (1996) was not similar with this result.

4.11.2 Effect of nitrogen levels

The variation in breadth of fruit among the different doses of nitrogen was found to be statistically significant (Figure 6 and Appendix VIII). The largest fruit breadth (3.78 cm) was found from the plant grown with 120 kg N ha^{-1} (N_2) treatment and then decreased gradually with the increasing rate of nitrogen, while the shortest fruit breadth (3.09 cm) was produced from the control (0 kg N ha^{-1}) treatment (N_0). Similar results were found by Islam *et al.* (1997). They reported that the breadth of individual fruit was increased with the increased nitrogen levels. Nassar (1986) also reported similar results.

4.11.3 Interaction effect of different planting time and nitrogen levels

Combined effect of different planting time and levels of nitrogen on breadth of fruit of tomato were found to be significant (Table 9 and Appendix VIII). The largest fruit breadth (3.86 cm) was obtained from P_2N_2 (15th October planting with 120 kg N ha^{-1} application) treatment whereas, the shortest fruit breadth (3.00 cm) was found from P_1N_0 (1th October planting with 0 kg N ha^{-1} application) treatment which was statistically identical to P_3N_0 (3.06 cm) (1th November planting with 0 kg N ha^{-1} application).

Table 9. Interaction effects of different planting time and nitrogen on fruit length (cm) and fruit breadth (cm) of BARI Tomato 14

Treatment combination	Fruit length (cm)	Fruit breadth (cm)
$\mathbf{P_1N_0}$	3.14 h	3.00 f
$\mathbf{P_1N_1}$	3.76 f	3.47 d
$\mathbf{P_1N_2}$	4.10 cd	3.71 b
$\mathbf{P_1N_3}$	3.99 de	3.55 c
$\mathbf{P_2N_0}$	3.41 g	3.21 e
$\mathbf{P_2N_1}$	3.88 ef	3.29 e
$\mathbf{P_2N_2}$	4.55 a	3.86 a
$\mathbf{P_2N_3}$	4.28 bc	3.71 b
$\mathbf{P_3N_0}$	3.39 g	3.06 f
$\mathbf{P_3N_1}$	3.45 g	3.52 d
$\mathbf{P_3N_2}$	4.32 b	3.76 b
$\mathbf{P_3N_3}$	4.21 bc	3.61 c
LSD $_{(0.05)}$	**0.19**	**0.08**
CV (%)	**5.68**	**5.18**

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

P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

4.12 Individual fruit weight (g)

4.12.1 Effect of planting time

Individual fruit weight of tomato is highly influenced by different planting time (Table 10 and Appendix IX). The maximum fruit weight (95.51 g) was obtained from the 2^{nd} transplanting on 15^{th} October (P_2). On the other hand, the minimum fruit weight (90.21 g) was obtained from 1^{st} transplanting on 1^{th} October (P_1). Similar results were also reported by Hossain *et al.* (1986) and BARI (1989).

4.12.2 Effect of nitrogen levels

In case of nitrogen application significant difference was found on individual fruit weight of tomato (Table 11 and Appendix IX). The maximum fruit weight (100.91 g) was obtained from N_2 (120 kg N ha^{-1}) treatment and followed by (95.07 g) N_3 treatment. On the other hand, the minimum weight of fruit (84.05 g) was found from N_0 (0 kg N ha^{-1}) treatment. Khalil *et al.* (2001) conducted an experiment in Peshawar, Pakistan and agreed with the similar results due to nitrogen application. Gupta and Sengar (2000) found that tomato cv. Pusa Gaurav was treated with N and found increased individual fresh weight of tomato.

4.12.3 Interaction effect of different planting time and nitrogen levels

The significant difference was found from the combined effect of different planting time and levels of nitrogen (Table 12 and Appendix IX). The maximum fruit weight (103.29 g) was obtained from P_2N_2 (15^{th} October planting with 120 kg N ha^{-1} application) treatment. On the other hand, the minimum weight of fruit (81.25 g) was found from P_1N_0 (1^{th} October planting with 0 kg N ha^{-1} application) treatment.

4.13 Yield plant^{-1} (kg)

4.13.1 Effect of planting time

Planting time imposed significant difference in respect of yield plant^{-1} of tomato (Table 10 and Appendix IX). The highest (3.22 kg) yield plant^{-1} was recorded from 2^{nd} transplanting on 15^{th} October (P_2) treatment whereas, the lowest (1.77 kg) was recorded in 1^{st} transplanting on 1^{st} October (P_1). The profound influence of time of planting on the yield of tomato has also been reported by Hoque and Rahman (1988) and Hossain *et al.* (1986). Similar results were also reported by Taleb (1994). The result of the present experiment agrees with the findings of Russo (1996).

Table 10. Effects of different planting time on individual fruit weight (g) and yield plant^{-1} (kg) of BARI Tomato 14

Planting time	Individual fruit weight (g)	Yield plant^{-1} (kg)
P_1	90.21 c	1.77 c
P_2	95.51 a	3.22 a
P_3	91.99 b	2.65 b
LSD $_{(0.05)}$	**1.36**	**0.55**
CV (%)	**8.72**	**5.26**

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

P_1 – 1st October, P_2 – 15th October and P_3 – 1st November.

Table 11. Effects of different nitrogen levels on individual fruit weight (g) and yield plant^{-1} (kg) of BARI Tomato 14

Nitrogen levels	Individual fruit weight (g)	Yield plant^{-1} (kg)
N_0	84.05 d	1.06 d
N_1	90.24 c	1.63 c
N_2	100.91 a	4.42 a
N_3	95.07 b	3.08 b
LSD $_{(0.05)}$	**1.36**	**0.55**
CV (%)	**8.72**	**5.26**

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

N_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1} and N_3 – 170 kg N ha^{-1}.

4.13.2 Effect of nitrogen levels

At different levels of nitrogen application significant difference on yield plant^{-1} was found (Table 11 and Appendix IX). Yield plant^{-1} increased with increasing level of N up to 120 kg ha^{-1}. Further addition of N above 120 kg ha^{-1} decreased yield plant^{-1} of tomato. The highest (4.42 kg) yield plant^{-1} was obtained in N_2 (120 kg N ha^{-1}) treatment and the lowest value (1.06 kg) was obtained in N_0 (0 kg N ha^{-1}) treatment. Profound influence of nitrogen level to increase tomato yield has been reported by many author (Doss *et al.,* 1981 and Midan*et al.,* 1985). Similar effects of different nitrogen levels in respect of fruit weight per plant have been reported by Varis and George (1985). Nassar (1986) reported that the maximum yield was achieved at 296 kg N ha^{-1}. Kaniszeski*et al.* (1987) found a significant increase in total yield of tomato fruit in the nitrogen fertilization up to 225 kg N ha^{-1}. Scholberg (2000) conducted an experiment and supported the results. Ceylan*et al.* (2001) conducted a field experiment to assess the effect of ammonium nitrate and urea fertilizers on nitrogen uptake and accumulation in tomato plants under field conditions and supported the similar results.

Table 12. Interaction effects of different planting time and nitrogen on individual fruit weight (g) and yield plant^{-1} (kg) of BARI Tomato 14

Treatment combination	Individual fruit weight (g)	Yield plant^{-1} (kg)
P_1N_0	81.25 j	0.47 i
P_1N_1	86.70 h	1.09 h
P_1N_2	101.23 b	3.16 d
P_1N_3	91.64 f	2.35 e
P_2N_0	86.52 h	1.57 g
P_2N_1	94.37 e	2.08 ef
P_2N_2	103.29 a	5.65 a
P_2N_3	97.84 c	3.60 c
P_3N_0	84.37 i	1.13 h
P_3N_1	89.64 g	1.73 fg
P_3N_2	98.20 c	4.46 b
P_3N_3	95.73 d	3.30 cd
LSD $_{(0.05)}$	**1.24**	**0.37**
CV (%)	**8.72**	**5.26**

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

P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

4.13.3 Interaction effect of different planting time and nitrogen levels

In case of combined effect of different planting time and levels of nitrogen application significant difference was found on yield plant^{-1} of tomato (Table 12 and Appendix

IX). The highest (5.65 kg) yield plant^{-1} was obtained from P_2N_2 (15th October planting with 120 kg N ha^{-1} application) treatment. On the other hand, the lowest (0.47 kg) yield plant^{-1} was found from P_1N_0 (1th October planting with 0 kg N ha^{-1} application) treatment.

Table 13. Availability of light intensity, soil moisture and soil temperature on tomato field

Treatment combination	Light Intensity (klux)	Soil moisture (%)	Soli temperature (˚C)
P_1N_0	30.00 i	28.12 h	35.30 a
P_1N_1	36.67 f	29.00 g	34.30 b
P_1N_2	39.00 c	30.30 e	32.70 d
P_1N_3	36.00 g	38.70 a	29.00 f
P_2N_0	39.33 b	29.33 fg	34.00 b
P_2N_1	39.83 a	30.00 e	32.70 d
P_2N_2	37.00 e	34.67 d	29.30 f
P_2N_3	38.33 d	37.70 b	27.00 h
P_3N_0	34.23 h	29.33 fg	33.00 c
P_3N_1	36.97 e	29.67 f	31.00 e
P_3N_2	34.50 h	35.33 c	28.00 g
P_3N_3	34.67	37.33 b	26.30 i
CV (%)	**4.86**	**7.49**	**3.92**

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

P_1 – 1st October, P_2 – 15th October, P_3 – 1st November, andN_0 – 0 kg N ha^{-1} (control), N_1 – 70 kg N ha^{-1}, N_2 – 120 kg N ha^{-1}, N_3 – 170 kg N ha^{-1}.

4.14 Light availability on tomato crop

Light availability plays a significant role in tomato production. Light availability on the tomato plant on plots was measured at 60 days after transplanting (Table 13). The highest light intensity was observed (39.83 klux) from P_2N_1. On the other hand, the lowest light intensity was recorded (30.00 klux) from P_1N_0 treatment.

4.15 Soil moisture in tomato field

The soil moisture (%) availability over the time (days after measurement) in tomato field was recorded (Table 13). At the initial stage of tomato growing season, soil moisture was higher but gradually decreased with increasing day after measurement. The highest moisture was recorded (38.70 %) P_1N_3 and the lowest moisture was recorded 28.12 % in P_1N_0 treatment.

4.16 Soil temperature in tomato field

Soil temperature (˚C) was recorded from various treatment at 10 days interval in tomato field and significant variation was found ((Table 13). In general, soil temperature was increased in bare soil. The highest soil temperature (35.30˚C) was recorded from P_1N_0 treatment. However, the lowest soil temperature was recorded from P_3N_3 treatment (26.30˚C). It was noticed that lower soil temperature helped to increased higher soil moisture which helped to increase tomato yield.

CHAPTER 5

SUMMARY

The field experiment was conducted at the experimental plot of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from September, 2019 to March, 2020 in Rabi season to find out the impact of different planting time and nitrogen levels on growth and yield of tomato on rooftop garden.BARI tomato-14, also known as 'Sharabonti' was used as planting material in this study. The experiment consisted of two factors: Factor A: Planting time (3 dates) as i) P_1 – 1st October, 2019, ii) P_2 – 15th October, 2019 and iii) P_3 – 1st November, 2019. and Factor B: Nitrogen management (4 levels) as i) N_0 - 0 kg ha^{-1} (control), ii) N_1 – 70 kg ha^{-1}, iii) N_2 – 120 kg ha^{-1} and iv) N_3 – 170 kg ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (Factorial) with three (3) replications. Total 36 unit-plots was made for the experiment with 12 treatments. Each plot was of required size. Data on different growth and yield parameter of tomato were recorded and significant variation was recorded for different treatments.

Different date of planting showed significant difference on growth and yield parameters of tomato. The tallest plant (67.92 cm, 99.67 cm and 111.08 cm at 30, 55 and 80 DAT, respectively) was observed in 1st transplanting (1st October) whereas, the shortest plant (60.09 cm, 91.92 cm and 103.33 cm at 30, 55 and 80 DAT, respectively) was observed in 3rd transplanting (1st November). The maximum number of leaves plant^{-1} (63.09, 77.18 and 84.18 at 30 DAT, 55 DAT and 80 DAT, respectively) was recorded from P3 (1st November) whereas the minimum number of leaves plant^{-1} (52.67, 65.85 and 76.93 at 30 DAT, 55 DAT and 80 DAT, respectively) was recorded from P1 (1st October). Numerically, the highest LAI (5.92) and the maximum chlorophyll content (SPAD value) (1.61 mg g^{-1} FW) was recorded from 1st transplanting (1st October) and the lowest LAI (5.73) and the minimum chlorophyll content (SPAD value) (1.54 mg g^{-1} FW) was recorded from 3rd transplanting (1st November) (P_3). The highest number of flower cluster plant^{-1} (14.26), the maximum number of fruit cluster plant^{-1} (10.76), the highest number of flower cluster^{-1} (6.65),

the maximum number of fruit cluster^{-1} (2.95), the highest number of fruits plant^{-1} (32.91), numerically the longest fruit length (4.03 cm), numerically the largest fruit breadth (3.52 cm), the maximum fruit weight (95.51 g) and the highest fruit yield plant^{-1} (3.22 kg) was found from P_2 (15th October) treatment, whereas; the lowest number of flower cluster plant^{-1} (12.03), the minimum number of fruit cluster plant^{-1} (8.53), the lowest number of flower cluster^{-1} (5.75), the minimum number of fruit cluster^{-1} (2.05), the lowest number of fruits plant^{-1} (18.79), the shortest fruit length (3.75 cm), the shortest fruit breadth (3.43 cm), the minimum fruit weight (90.21 g) and the lowest fruit yield plant^{-1} (1.77 kg) was obtained from 1st transplanting on 1st October (P_1).

Varying level of nitrogen fertilizer had significant effect on different growth, yield attributing and yield parameter of tomato. At 30, 55 and 80 DAT, the tallest plant (69.67, 102.58 and 117.43 cm, respectively) was obtained from N_3 (170 kg N ha^{-1}) treatment whereas, the shortest plant (57.85, 86.78 and 95.10 cm, respectively) was recorded from N_0 (0 kg N ha^{-1}) treatment. At 30, 55 and 80 DAT, the maximum number of leaves plant^{-1} (65.78, 79.23 and 90.02 cm, respectively) was recorded from N_3 (170 kg N ha^{-1}) treatment whereas, the minimum number of leaves plant^{-1} (53.00, 64.12 and 71.29 cm, respectively) was recorded from N_0 (0 kg N ha^{-1}) treatment. The maximum LAI (6.08), the maximum chlorophyll content (SPAD value) (1.66 mg g^{-1} FW), the highest number of flower cluster plant^{-1} (15.38), the maximum number of fruit clusters per plant (11.88), the highest number of flower cluster^{-1} (7.34), the maximum number of fruit cluster^{-1} (3.64), the highest number of fruits plant^{-1} (43.73), the longest fruit length (4.32 cm), the largest fruit breadth (3.78 cm), the maximum fruit weight (100.91 g) and the highest yield plant^{-1} (4.42 kg) was obtained with the application of 120 kg N ha^{-1}(N_2); while, the lowest LAI (5.42), the minimum chlorophyll content (SPAD value) (1.48 mg g^{-1} FW), the lowest number of flower cluster plant^{-1} (10.99), the minimum number of fruit clusters per plant (7.49), the lowest number of flower cluster^{-1} (5.28), the minimum number of fruit cluster^{-1} (1.58), the lowest number of fruits plant^{-1} (12.45), the shortest fruit length (3.31 cm), the smallest fruit breadth (3.09 cm), the minimum weight of fruit (84.05 g) and the lowest fruit yield plant^{-1} (1.06 kg) was recorded from 0 kg N ha^{-1} (N_0) treatment.

Interaction of different planting date and varying level of nitrogen fertilizer had significant effect on different growth, yield attributing and yield parameter of tomato. At 30, 55 and 89 DAT, the tallest plant (76.00, 108.70 and 125.00 cm, respectively) was found in P_1N_3 (1st October with 170 kg N ha^{-1}) treatment. On the other hand, the shortest plant (54.23, 82.33 and 90.00 cm at 30, 55 and 89 DAT, respectively) was observed in P_3N_0 (1st November with 0 kg N ha^{-1}) treatment combination. At 30, 55 and 80 DAT, the maximum number of leaves $plant^{-1}$ (68.67, 84.18 and 92.15, respectively) was found in P_3N_3 (1st November with 170 kg N ha^{-1}) treatment combination whereas, the minimum number of leaves $plant^{-1}$ (40.67, 60.80 and 68.11, respectively) was found in P_1N_0 (1st October with 0 kg N ha^{-1}) treatment combination. The highest LAI (6.13) and the maximum chlorophyll content (SPAD value) (1.73 mg g^{-1} FW) was recorded from 1st October with 120 kg N ha^{-1} (P_1N_2) treatment combination. On the other hand, the lowest LAI (5.21) and the minimum chlorophyll content (SPAD value) (1.45 mg g^{-1} FW) was recorded from 1st November with 0 kg N ha^{-1} (P_3N_0).The highest number of flower cluster $plant^{-1}$ (16.27), the highest number of fruit cluster $plant^{-1}$ (12.77), the highest number of fruits per plant (54.66), the longest fruit (4.55 cm), the largest breadth of fruit (3.86 cm), the maximum fruit weight (103.29 g) and the highest fruit yield $plant^{-1}$ (5.65 kg) was obtained from P_2N_2 (15th October planting with 120 kg N ha^{-1} application) treatment combination. On the other hand, the lowest number of flower cluster $plant^{-1}$ (9.00), the lowest number of fruit cluster $plant^{-1}$ (5.50), the lowest number of fruits $plant^{-1}$ (5.78), the shortest length of fruit (3.14 cm), the shortest breadth of fruit (3.00 cm), the minimum weight of fruit (81.25 g) and the lowest yield of fruits $plant^{-1}$ (0.47 kg) was recorded from P_1N_0 (1st October with 0 kg N ha^{-1}) treatment combination.

The highest light intensity was observed (39.83 k lux) from P_2N_1. On the other hand, the lowest light intensity was recorded (30.00 k lux) from P_1N_0 treatment. The highest moisture was recorded (38.70 %) P_1N_3 and the lowest moisture was recorded 28.12 % in P_1N_0 treatment. The highest soil temperature (35.30°C) was recorded from P_1N_0 treatment. However, the lowest soil temperature was recorded from P_3N_3 treatment (26.30°C).

CONCLUSION

a) The effect of different planting date and various level of nitrogenous fertilizer was found to be significant on growth and yield of tomato on rooftop garden.

b) Application of 120 kg N ha^{-1} on tomato plants which were planted at 15^{th} October seemed to be more suitable for getting higher amount and quality fruit yield of tomato on rooftop garden.

RECOMMENDATION

Considering the results of the present experiment, further studies in the following areas are suggested:

- More varieties of tomato may be used with different nitrogen fertilizer dose and planting date for getting variety specific fertilizer and planting recommendation.

- Studies of similar nature could be carried out in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of zonal adaptability.

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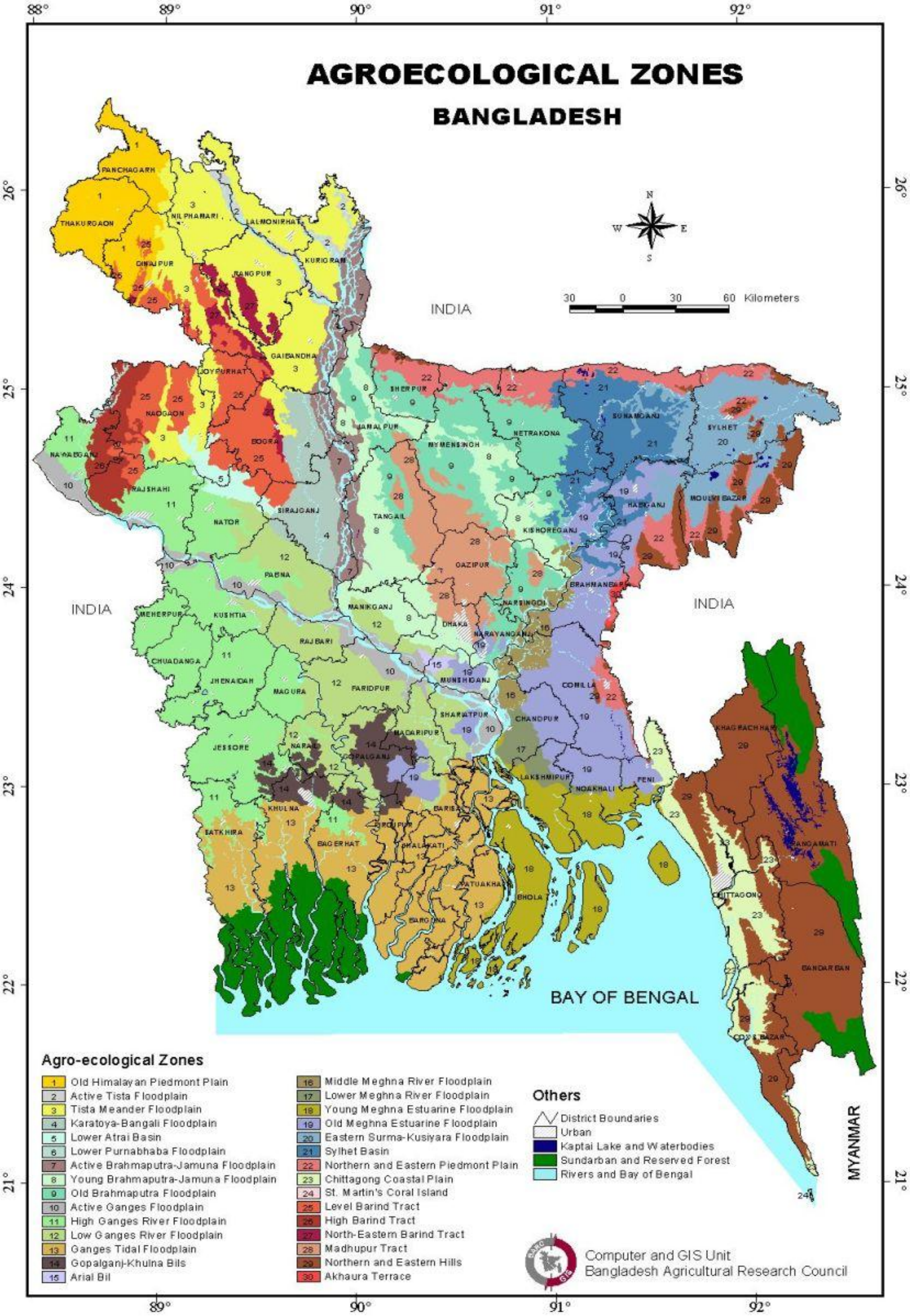
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from September, 2019 to March, 2020

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
September, 2019	35.27	22.37	89	77
November, 2019	31.82	14.04	81	24
December, 2019	23.40	10.50	87	5
January, 2020	20.18	7.04	80	0
February, 2020	18.20	9.70	76	15
March, 2020	25.80	18.52	83	31

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix III. Characteristics of experimental fields soil was analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro rice-Fallow-Aman rice

B. Physical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30

C. Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (meq/100 g soil)	0.10
Available S (ppm)	45

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

Appendix IV. Analysis of variance (mean square) of plant height at different DAT

Source of variation	Degrees of freedom	Plant height		
		30 DAT	55 DAT	80 DAT
Replication	2	5.852	80.983	156.225
Planting time (A)	2	10.897*	49.245*	170.324*
Nitrogen (B)	3	6.051*	49.026*	110.420*
A×B	6	0.549**	3.452**	9.923**
Error	22	1.305	8.520	29.517

* and ** indicate significant at 5% and 1% level of probability, respectively.

Appendix V. Analysis of variance (mean square) of Number of leaves plant^{-1} at different DAT

Source of variation	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAT	55 DAT	80 DAT
Replication	2	0.274	0.239	7.238
Planting time (A)	2	11.356*	13.411*	571.676*
Nitrogen (B)	3	13.758*	16.141**	546.668**
A×B	6	0.104**	0.396*	8.145**
Error	22	0.037	0.283	0.825

* and ** indicate significant at 5% and 1% level of probability, respectively

Appendix VI. Analysis of variance (mean square) of Leaf area index (LAI)and Crop growth rate (CGR)

Source of variation	Degrees of freedom	Leaf area index (LAI)	Crop growth rate (CGR)
Replication	2	0.274	0.239
Planting time (A)	2	11.356*	207.136*
Nitrogen (B)	3	13.758*	16.141**
A×B	6	0.104**	0.001*
Error	22	0.037	0.283

*** and ** indicate significant at 5% and 1% level of probability, respectively**

Appendix VII. Analysis of variance (mean square) of yield components

Source of variation	Degrees of freedom	No. of flower cluster plant^{-1}	No. of fruit cluster plant^{-1}	No. of flower cluster $^{-1}$	No. of fruit cluster $^{-1}$	No. of fruit plant $^{-1}$
Replication	2	156.208	80.330	31.342	28.073	41.200
Planting time (A)	2	62.519*	65.135*	8.090**	46.212*	119.856*
Nitrogen (B)	3	3.558**	11.910*	2.122**	25.339*	26.023*
A×B	6	3.345**	2.393**		2.480*	6.475*
Error	22	20.387	48.889	1.673** 20.423	10.007	13.856

*** and ** indicate significant at 5% and 1% level of probability, respectively**

Appendix VIII. Analysis of variance (mean square) of fruit length and fruit breadth

Source of variation	Degrees of freedom	Fruit length (cm)	Fruit breadth (cm)
Replication	2	2.765	7.313
Planting time (A)	2	0.633*	145.606*
Nitrogen (B)	3	1.753*	12.964**
A×B	6	0.355*	3.995**
Error	22	0.365	0.310

*** and ** indicate significant at 5% and 1% level of probability, respectively**

Appendix IX. Analysis of variance (mean square) of yield

Source of variation	Degrees of freedom	Individual fruit weight (g)	Yield plant^{-1} (kg)
Replication	2	6.516	10.002
Planting time (A)	2	53.933*	20.601**
Nitrogen (B)	3	3.034*	23.761**
A×B	6	6.954**	11.002**
Error	22	0.585	0.002

*** and ** indicate significant at 5% and 1% level of probability, respectively**