POTENTIALITY OF VEGETABLE PRODUCTION ON ROOFTOP GARDEN AT DIFFERENT LOCATIONS OF DHAKA CITY

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CERTIFICATE

This is to certify that thesis entitled ***"POTENTIALITY OF VEGETABLE PRODUCTION ON ROOFTOP GARDEN AT DIFFERENT LOCATIONS OF DHAKA CITY"*** *submitted to the* ***Department of Agroforestry and Environmental Science,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in AGROFORESTRY AND ENVIRONMENTAL SCIENCE,*** *embodies the result of a piece of bona fide research work carried out by WASHIM HOSSEN, Registration No. 13-05563 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated: June, 2020
Place: Dhaka, Bangladesh

Dr. Md. Forhad Hossain
Professor
Supervisor

DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

The experiment was conducted at the roof of four residential area of Dhaka city which are located at Mohammadpur, Kolabagan, Adabor and Dhanmondi during the period from October, 2018 to August, 2019. The experiment was laid out in Completely Randomized Design (CRD) having single factors with four replications. There were 16 unit plots in the experiment location. The high yielding variety of BARI developed vegetables seed of bottle gourd, okra, pumpkin and the seedlings of cabbage, cauliflower, tomato, chili and eggplant were collected from Bangladesh Agricultural Research Institute (BARI). Plant height, stem diameter, number of leaves per plant, fruit length, fruit breadth, fruit weight of different vegetables in rooftop garden were significantly affected due to different locations in Dhaka city. Among the locations, per hectare production of cabbage was highest in Mohammadpur (34.50 ton/ha), highest amount of cauliflower production (40.70 ton/ha) was observed in Adabor. On the other hand, in case of per hectare tomato production, highest amount of yield was recorded in Mohammadpur (95.17 ton/ha). Similarly, per hectare chilli production was highest in Kolabagan (6.80 ton/ha). Highest amount of eggplant production was found in Mohammadpur (13.82 ton/ha). In case of okra, highest fruit weight per hectare (13.89 ton) was observed in Mohammadpur. Similarly, in case of bottle gourd, the highest fruit weight per hectare (61.85 ton) was observed from Dhanmondi. Besides this, the highest amount of pumpkin production (24.61 ton/ha) was also found in Dhanmondi. From the study, it is revealed that different locations have the potentiality to influence the yield of vegetables in the Dhaka city context as well as to increase total production per unit area of rooftop garden.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
cm	Centi-meter
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
DAT	Days After Transplanting
et al.	And others
FAO	Food and Agriculture Organization
gm	Gram
ha	Hectare
CRSP	Collaborative Research Support Program
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
m^2	Meter Squares
MP	Muriate of Potash
%	Per cent
CRD	Completely Randomized Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Bangladesh is recognized as one of the vulnerable countries as a victim of adverse impact of climate change. Urban ecology is the direct victim of the diminishing greens contributing to some extent towards global warming. Rooftop garden can provide city-dwellers with a source of fresh produced, improved diet and important household budgetary savings. Koc *et al*. (1999); Mann (2001) and Bellows and Hamm (2003) stated that rooftop garden can supplement the diets of the community as it supplies with fresh produce and provide a tangible benefits tie to food production. The cultivation of food on buildings is a key component to making cities multi-functional, and contributing to their sustainability and habitability (Samangooei *et al*., 2016). Islam (2004) viewed that urban agriculture (UA) contributes to food security by increasing the supply of food. Rapid urbanization and urban growth is placing enormous demand on urban food supply systems. Moreover, many cities in the world are suffering from problems like rapid decrease in green space and increase in heat island effects. Rooftop farming is recommended as a potential solution to these problems (Smit *et al*., 1996).

Dhaka is one of the world's most populated cities with current population of 20.628 million within a small area of 300 square kilo meter (BBS, 2018). Moreover the population is increasing day by day. However, to maintain a pleasant living environment, the balance between green and concrete built-up areas cannot be overlooked (Kabir, 2018). With rapid and unplanned urbanization, incidence of urban poverty and food insecurity has been also increasing alarmingly in Dhaka (Choguill, 1995).

Cultivation on the rooftop of the buildings in urban areas is usually done by using rooftop garden, hydroponics, organic, geoponics or container gardens (Asad and Roy, 2014). Rooftop vegetable production offers many environmental and social benefits to high populated urban cities (Hui, 2011). By utilizing rooftops for vegetable cultivation, it is possible to obtain social, economic and environmental sustainability for the buildings in urban cities.

Rooftop vegetable production can reduce the temperature of roofs and the surrounding air that contribute to overall cooling a local climate (Ries, 2014) and can help to lessen urban heat island effect (Hui, 2011). Rooftop farming can also absorb carbon emissions and noise (Dubbeling, 2014). Rain water is captured and absorbed by the plants and overflowing effect on infrastructure is reduced (Ries, 2014).

The practice of producing vegetables on rooftop garden has been gaining momentum in recent years as a method to facilitate agricultural sustainability in urban areas. The production of vegetables on rooftops should not be thought of as a replacement for large-scale vegetable production in rural areas (Gaglione and Bass, 2010), but rather as an enhancement to the urban food movement by providing another source of local, fresh, foods (Tomalty and Komorowski, 2010). Many urban areas are now producing over 20% of their vegetable needs from within city boundaries (MacRae *et al.*, 2010), but due to limited growing spaces, land for crop production is often the most limiting factor to urban food production systems. Urban farms can produce significantly more produce on a per acre basis than that typically produced in rural areas, due to the intensive, focused small-scale farming techniques utilized for limited spaces (Walters and Midden, 2018).

Rooftop gardens offer an alternative growing space to provide fresh vegetable products to urban markets. Vegetable crops grown on rooftops provide numerous ecological and economic benefits in addition to being a source of locally produced fresh food for city inhabitants (Elstein *et al*., 2008), including storm water management, energy conservation, mitigation of the urban heat island effect, increased longevity of roofing membranes, and providing a more aesthetically pleasing environment in which to work and live (Getter and Rowe, 2006). Despite these possible setbacks from incorporating rooftop garden technology into urban agriculture, the utilization of all available plant growing spaces in and near cities will most likely be required for future generations to sustain food security in urban areas.

In consideration with the above situations, the present research work has been undertaken to study the potentiality of vegetable production on rooftop garden at different locations of Dhaka city with the following objectives:

- To estimate the production of different vegetable on rooftop garden in compare to the field yield
- To find out morphological features of various vegetables produced on different locations of Dhaka city; and
- To compare yield performance of selected vegetables with reference yield

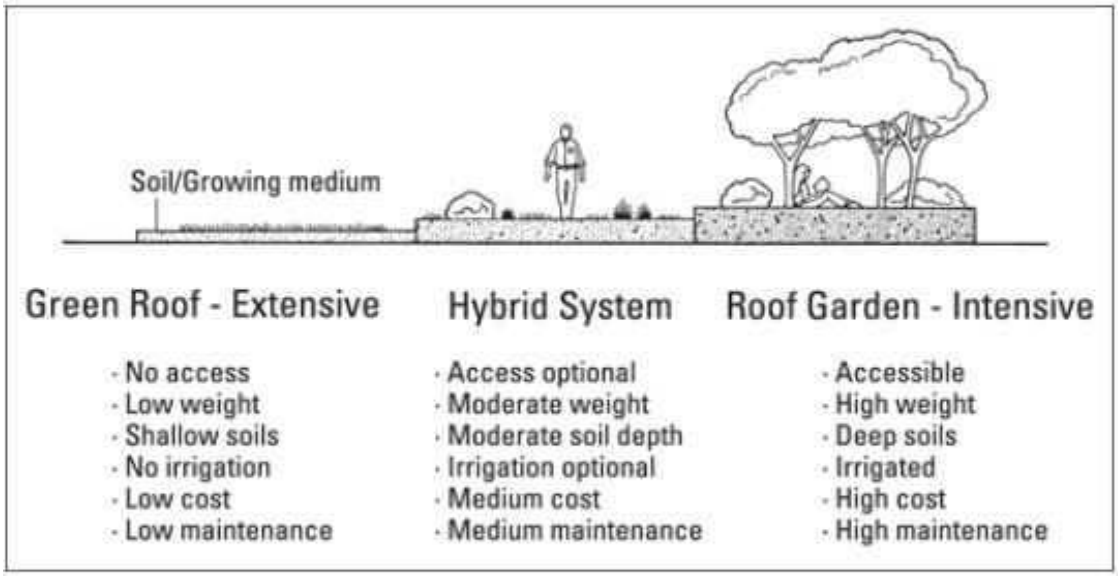
CHAPTER II

REVIEW OF LITERATURE

Food production and consumption in urban areas has become a global concern due to increasing numbers of people living in and moving to urbanized living spaces, which threaten food security (Samangooei *et al*., 2016). Currently, many cities across the world are encouraging the widespread implementation of urban agriculture though policy reform. Some research works regarding roof top gardening were done in home and aboard. But a little work has been done on the potentiality of vegetable production on rooftop garden at different locations of a city. However, available information portioning to this study was reviewed in the following sub headings.

2.1 Rooftop gardening

Rooftop gardens are man-made green spaces on the topmost levels of industrial, commercial, and residential structures. They may additionally be designed to develop produce, supply play space, provide colour and shelter, or honestly be there as a living, green area. Two most important divisions of garden types exist: extensive and intensive. Extensive gardens require minimal upkeep and behave as another form of roofing material. They are no longer intended for heavy foot site visitors nor do they want to meet any extra safety standards. The different extreme consists of intensive gardens created with the intent of lively human use. These gardens require landscaping and ordinary upkeep. In some cases, the roof shape should be bolstered via the addition of decking or extra bracing to accommodate the combined weight of soil, plants, and precipitation. Furthermore, intensive gardens may additionally need to comply with protection rules related to decks and public areas on raised structures. These regulations may additionally require some variety of fencing or barrier to be set up with the intent of preventing humans from slipping over the area of the roofline (Haque, 2020).



Different types of roof gardening (Haque, 2020)

2.2 Rooftop vegetable production in worldwide

There are several examples of rooftop gardens throughout the world that are used to effectively produce a local and sustainable food source. Several cities, including Montreal, Toronto and New York (Specht *et al*., 2014; Thomaier *et al*., 2014), are well-known for their large-scale vegetable production activities on rooftop gardens that provide local sourcing of food. Rooftop farms all over the world are now growing a wide range of vegetables each year on numerous types of buildings for local market sales. Local sustainable food movements are underway in many other cities with a focus of growing vegetables on rooftop gardens, including Beijing, Chicago, Seattle, St. Petersburg, Paris, Vancouver, and Vienna to name a few. In Bologna, Italy, rooftop vegetable gardens could supply about 77% of the inhabitants' requirements for fresh produce (Orsini *et al*., 2014).

In Singapore, inorganic hydroponics is considered the more appropriate farming option, compared with conventional soil culture, in the government housing buildings as it has higher yield, lower labour requirement and needs only lightweight systems, which can be easily assembled over an existing roof (Astee and Kishnani, 2010).

The practice of producing vegetables on rooftop has been increasing in recent years to facilitate agricultural sustainability in urban areas. Rooftop agriculture allows urban areas to become more sustainable in their resource exploitation, and to help the development of food security for local residents. Rooftop gardens are becoming an important part of the recent regeneration of urban agriculture, and provide alternative spaces to grow vegetable products for urban markets (Ouellette *et al*., 2013). Many urban areas are now producing over 20% of their vegetable needs from within city boundaries. Urban agriculture is widely utilized in developing countries, although some cities in developed countries worldwide strive to source at least a portion of their food requirements locally (MacRae *et al*., 2010). The contributions of urban agricultural activities to local food supplies is now significant in several cities, including Bologna (Italy), Chicago (USA), Cleveland (USA), Hong Kong (China), Montreal (Canada), New York (USA), Portland (USA), Seattle (USA), Shanghai (China), Taipei (Taiwan), Tokyo (Japan), Toronto (Canada), and Vancouver (Canada) to name a few (MacRae *et al*., 2010).

Typically the degree of urban growth or sprawl is attempted by quantifying the amount of paved surface or built-up area in a given region obtained from the superimposing multi-temporal geospatial data (Koomen and Stillwell, 2007; Barnes *et al*., 2001; Galster *et al*., 2001). Characterizing the pattern of urban sprawl would then rest on noting the extent of built-up areas and its associated measures that depict sprawl based on the notion of built-up or paved area (Maryama and Thappa, 2010). In Kashmir, a key aspect in the expansion of built-up area is its engulfing of surrounding open spaces within the landscape. It is revealed that the built-up area of the City has increased by 173 percent from 1911 to 1971 at the decadal rate of 28 percent. However, this rate steepened from 1971 to 2010 at the decadal rate of 33.25 percent (Nengroo *et al*., 2017).

2.3 Rooftop vegetable in Bangladesh

Potential area on rooftops is an utmost essential for enhancing or organizing the backyard in the cities. Presently the rooftops of the residential constructions are being used for a variety of functions such as gardening, drying and washing clothes, playground for children, wonderful guest, passing pleasure time etc. In the study, consequences printed that the easiest percentages of the respondents are being used for gardening (87%), drying cloths (25.8%) and others (11.5%) irrespective of all areas in Dhaka city (Uddin *et al*., 2016). Islam (2004) suggested that the rooftops of the residential constructions was once used for drying (88%) and washing (45%) clothes, as playground for youngsters (97%), for enjoyable friends (20%), for cool air in the course of the summer time (64%), to sunbathe in the wintry weather (33%). On most of the roofs, some shape of pleasure backyard exists (78%), every so often there are fruit gardens (12%), and, much less often, vegetable backyard as nicely (8%) (Haque, 2020).

A study conducted by Safayet *et al*. (2017) stated that the food production value from the rooftop farming of the practitioner of Mirpur area is estimated to be between Tk. 473,846.79 and Tk. 4738,467.936 i.e. US$ 6020 and US$ 60202.

Sajjaduzzaman (2005) reported that the purpose concerning financial gain from roof gardening is a very minor concern (4% only) in Dhaka Metropolitan city of Bangladesh. On the other hand, Rashid *et al*. (2010) described the economic and social benefit of rooftop gardening including fresh food supply for urban residents, converts the hard surface into a soft green surface, energy saving, etc.

Approximately, 25 vegetables are grown in the rooftop gardening in Bangladesh. It is estimated that in Dhaka city Eggplant (61%), Indian spinach (47.8%) and Chilli (45.3%) and Gourds (25%) are produced in rooftop farming. It is also calculated that in Chattogram city Eggplant (48%), Indian spinach (35.7%), Gourds (35.6%), Lady's finger (31%), Tomato (23.7%), Red amaranth (23%), Bean (18%), Cabbage and Cauliflower (7%) are grown (Uddin *et al*., 2016). Agricultural Extension Division provides training and necessary logistics to the individuals for roof gardening and horticultural development. Roof Garden Association (RGA) in Bangladesh is conducting "Rooftop garden Movement" which focuses on technical and financial aspects of roof gardening (Uddin *et al*., 2016). Hope that the day is not far when every city including Dhaka will have a layer of greenery.

2.4 Urban sustainability and rooftop farming

A sustainable city is the city which meets the needs of the present without sacrificing the ability of future generations to meet their own needs (The Science Museum, 2004). The international community is already started to address the issue of urban sustainability. Urban sustainability is the idea that a city can be organized without excessive dependence on the surrounding countryside and be able to power itself with renewable sources of energy. The purpose is to create the least possible ecological footprint and to produce the minimum quantity of pollution possible, to efficient use of land, compost used materials, recycle it or convert waste-to-energy and to make the city's complete contribution to climate change minimal. Urban sustainability can be achieved through the sustainability of social, economic and environmental issues. Along with other initiatives and activities, urban rooftop farming, therefore, has an important role in contributing towards the future sustainability of cities. Hui (2011) and others have listed out social, economic and environmental sustainability to be achieved by urban in local food production and sale, increase in food security and property value, improvement of roof durability, reduction in building cooling load and energy costs, increase availability of biofuels etc. Environmental sustainability can be achieved through reduction in carbon emission food transportation, reduction of wastes by generating less packaging, recycling of organic wastes by composting, mitigation of urban heat island, increase in biodiversity, improvement of air quality urban storm water management, capacity of sound insulation and noise absorption etc. (Hui, 2011).

Rooftop gardens are a constructed vegetated roof system that can provide numerous environmental benefits to the surrounding ecosystem. They aid in storm water management, increase the longevity of roofs, create habitats that support biodiversity in urban settings, provide building insulation that reduce cooling and heating costs, and in addition, can create green spaces for human enjoyment (Velazquez, 2005).

Probably the greatest single environmental benefit provided by rooftop gardens is the reduction in total amounts of storm water runoff as rooftop gardens can reduce runoff as much as 60 to 100%, depending on the type of rooftop garden system (VanWoert *et al*., 2005). However, besides the numerous associated environmental benefits, rooftop gardens can also provide social and learning experiences for local residents.

Rooftop gardens can be a resource to enrich urban education and experiences. Many children have no connection to farming or interactions with outdoor spaces when growing up in an urban environment. They do not gain experiences or have an awareness to visualize how food is produced, such as picking tomatoes from a plant or watching lettuce grow. This emphasizes the role that a rooftop garden on a school or community centre could play. For example, the East Campus of the Ogden International School of Chicago was built in 2011 primarily as an elementary school, but also functions as a community space for the neighbourhood and has a functional rooftop garden used for educational purposes. Thus, although rooftop gardens are primarily installed for their environmental benefits, they can also have educational value for the surrounding communities (Walters and Midden, 2018).

Food production can also be an associated benefit of rooftop gardens. Although rooftop agriculture is gaining momentum and rapidly developing to become an important part of urban agriculture, the overall implementation of growing food on rooftop gardens is limited by many different factors including lack of suitable space on rooftops for growing vegetable crops and building regulations (e.g., weight loads) that prevent food production on roofs (Hui, 2011). Many large rooftops on abandoned apartment buildings, school buildings, industrial buildings, shopping malls, or gymnasiums, can be potential sites for urban farms. As more humans populate urban areas, additional areas to produce food, such as rooftops will be required to supply food for this growing populace (Walters and Midden, 2018).

2.5 Vegetable production on rooftop gardens

Since many vegetables prefer deeper soil depths, intensive rooftop gardens that provide greater rooting depths have been considered best to maximize their productivity. Many intensive rooftop garden mediums provide high organic matter and nutrient content, which allow for a significant amount of root development and above-ground productivity. Yields of deep rooting vegetables such as tomato (*Solanum lycopersicum*) grown in an intensive rooftop garden were shown to be comparable to those from in-ground conventional agriculture systems (Whittinghill *et al*., 2013). Additionally, other research has also indicated that tomato can effectively be grown in an extensive rooftop garden when adequate fertility and moisture is provided (Ouellette *et al*., 2013). Besides tomato, the production of bean (*Phaseolus* *vulgaris*), cucumber (*Cucumis sativus*), pepper (*Capsicum annuum*), basil (*Ocimum basilicum*), and chive (*Allium schoenoprasum*) is possible in an extensive rooftop garden with irrigation and minimal fertilizer inputs (Whittinghill *et al*., 2013). Thus, the use of extensive systems should be more than adequate for shallow-rooted vegetables that include important salad greens crops such as lettuce (*Lactuca sativa*) and kale (*Brassica oleraceae* var. *acephala*).

Vegetable production is a definite possibility in urban areas on retrofitted rooftop gardens using minimal growing substrate depths with intensive seasonal maintenance (Whittinghill *et al*., 2013). Rooftop vegetable crop agriculture can be productive on shallow extensive rooftop gardens using standard rooftop garden substrates, but maximum productivity in these systems will require high nutrient and irrigation inputs. Although there are several challenges to effectively managing rooftop garden vegetable production systems, they provide a unique opportunity to effectively grow food in spaces that are typically unused (Getter and Rowe, 2011).

2.6 Rooftop garden management considerations for vegetable crops

For centuries, urban dwellers have cultivated many vegetables, such as lettuce, pepper, cucumber and tomato in rooftop gardens, but there are still several challenges that need to be overcome to maximize vegetable productivity in rooftop garden settings. Although there are many challenges, these can directly relate to benefits for the surrounding human populace and ecosystems. Many of these challenges and suggestions for improvement are outlined in Table 2, which include biodiversity habitat, growing substrate, irrigation efficiency, maintenance activities, nutrient management, pest control, plant materials (vegetable crop and variety selection), pollination systems, and water management (Walters and Midden, 2018).

Table 1. Current challenges for vegetables grown in extensive rooftop garden culture and possible suggestions for improvement

Challenges	Suggestions for improvement
Biodiversity/ Habitat	Create microhabitats to improve wildlife diversity. Improve plant diversity through creation of various microclimates.
Growing substrate	Alternative growing mixes with high moisture and nutrient holding capacities. Limited amounts of heavy organic materials, like compost.
Irrigation efficiency	Moisture monitoring for specific crop requirements. Water scheduling and adjustment due to rainfall. Match water use requirements to crop needs.
Maintenance activities	Monitor crops every few days to determine work activities to complete. Harvest crop products as needed to maximize productivity.
Nutrient management	Strategic fertilizer management plan to provide adequate nutrients. Decrease nutrient pollutants thorough capture and re-circulation.
Pest control	Minimize transfer or importation of pests to rooftop garden. Weed, insect and disease outbreaks can be minimized by early detection. Utilization of natural materials to prevent pollutants in water runoff.
Plant materials	Dwarf or determinate vegetable varieties to minimize growth. Utilization of plugs or transplants to enhance plant establishment. Secure larger plants in some manner from wind damage.
Pollination systems	Position urban environments to align with developed ecosystems. Ecosystem health dependent on pollinators built into urban environment.
Water management	Medium constrains to increased water retention. Use light-weight organic mulch materials to improve moisture retention and lower soil temperatures.

Source: (Walters and Midden, 2018)

2.7 Growing substrate

Rooftop garden mediums may not contain optimal fertility levels required to maximize vegetable plant growth and productivity, and the success of rooftop vegetable production often depends on fertility management systems to create optimal growing conditions (Bisgrove, 2010). Due to weight limits often associated with extensive rooftop gardens, soil and organic materials can be too heavy to install as a growing medium. The FLL guidelines stipulate ranges for organic matter in rooftop garden mediums. Soil-less alternative growing mixes that are composed predominately of a light-weight material are often used, such as light-weight aggregate or shale (75% to 90%) mixed with a low percentage of organic materials. Thus, extensive rooftop garden substrates tend to be highly mineral-based with small amounts of added organic matter, often less than 10% (Oberndorfer *et al*., 2007). The light-weight material is coarse, inert, and does not provide any nutrients for plant growth. Moreover, the addition of organic materials can provide some nutrients for plant growth, as well as increased nutrient and moisture retention, but will become depleted after a few growing seasons, unless replenished in some manner (Snodgrass and McIntyre, 2010). Although soil-less, light-weight growing mixes are most commonly used for extensive rooftop gardens, soil-based systems that are often used for intensive rooftop garden cultivation are more environmentally and socially beneficial for urban areas than are soil-less based systems (Samangooei *et al*., 2016).

The composition of a rooftop garden medium directly affects runoff and roof weight load capacities. Mediums with slower infiltration rates will cause greater weight loads to develop on roofs compared to those that have faster infiltration rates as they will have quicker water drainage and runoff. The ideal medium for rooftop garden installations would have unique properties that are typically not found in most mediums, such as being light-weight, with easy installation and high insulation properties, have good aeration and high moisture retention capabilities, do not leach large amounts of soluble solids, and have adequate cation-exchange capacity and fertility for plant growth (Elstein *et al*., 2008). Therefore, there is still work to be done in the development of medium materials best suited for extensive rooftop garden vegetable crop culture.

2.8. Plant materials (vegetable crop and variety selection)

Due to the shallow growing medium in extensive rooftop gardens, vegetable crops were thought to be a poor fit for this type of production system. Herbaceous plants (such as vegetables) often require either deeper mediums or greater inputs (e.g., water or nutrients) than the more traditional extensive rooftop garden plants (such as Sedums) (Dvorak and Volder, 2010; Getter and Rowe, 2009; Getter and Rowe, 2006). Besides the additional input requirements, many vegetables, such as tomatoes and peppers, have roots that grow deep into the soil to provide plant support. In comparison, the shallow-rooted and drought tolerant Sedum spp. were thought to be the best choice for extensive rooftop gardens due to their small size, low-growing habit and low water use which related to minimal maintenance activities. Thus, most agree that crops most suitable for extensive rooftop garden culture are those more shallow-rooted vegetables that also tend to be low growing in habit to reduce the effects of wind damage. Although many vegetables are available to grow in this system, lettuce, chicory (*Cichorium intybus*) and endive (*Cichorium endivia*) are crops that can effectively be produced on rooftop gardens with adequate moisture inputs (Cho *et al*., 2010). Salad green vegetable crops typically generate high yields in rooftop garden culture, compared to many other vegetables, as production can be spread out over the growing season to provide consistent harvests, which makes these vegetables a viable option on rooftops (MacRae *et al*., 2010). Additionally, row covers may be used for these crops to further extend production beyond the typical growing season by moderating temperatures.

Vegetable and herb production in an extensive rooftop garden is feasible and can be productive with proper management (Whittinghill *et al*., 2013). Since rooftop gardens can be very hot during the summer months, it can be difficult to provide optimum growing conditions in this environment to sustain maximum growth and productivity of many vegetable and herb crops. This can directly relate to reduced plant survival rates in rooftop garden mediums during dry or hot periods (Snodgrass and Snodgrass 2006). Since many vegetable plants can tolerate shallow medium depths (Velazquez, 2005), high temperatures tend to be more of a problem in a rooftop garden environment than when vegetable plants are grown in soil at ground level, especially if there is no irrigation system to provide water for the resulting high evapotranspiration rates.

Another management concern is vegetable crop size at maturity. The most suitable vegetable varieties for extensive rooftop gardens are those that are dwarf or determinate in growth habit, as they will minimize growth while providing significant yields. Moreover, most staking and/or trellising operations for plants are not really an option; and, any support system that is used must be secured to the roof in some way to avoid damaging the roof membrane and to remain intact during strong winds. Since larger-sized vegetable plants must be secured to the roof in some manner to prevent wind damage, smaller-sized varieties would be less likely to suffer from wind damage. Wind exposure can destroy plantings of taller growing vegetable crops, like tomato and pepper, unless some type of windbreak is used to minimize damaging winds.

Light-weight mediums with limited organic matter also limits the success of seeding operations in an extensive rooftop garden environment (Snodgrass and McIntyre 2010; Snodgrass and Snodgrass 2006). Smaller seed can often fall into deep gaps in the substrate material, resulting in no germination from either no moisture reaching the seed or being at an increased depth from which they cannot emerge. Therefore, vegetable transplant plugs can be used to enhance establishment and plant survival rates, although this requires either an added greenhouse production facility or additional costs to purchase vegetable plants. The added costs for vegetable transplants will often be a good investment considering inadequate stands that can result from directly seeding into extensive mediums on a rooftop garden.

CHAPTER III

MATERIALS AND METHODS

This chapter arranges the materials and methods including a brief description of the experimental site, climate, soil, planting materials, treatment of the experiment, experimental design, land preparation, intercultural operations, harvesting, data collection etc. and analytical methods used for the experiment. The details of research procedure are described here.

3.1 Location of the experiment field

The experiment was conducted at the roof of four residential area of Dhaka city which are Mohammadpur, Kolabagan, Adabor and Dhanmondi during the period from October, 2018 to August, 2019.

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during the rest of the year (Rabi season). The total rainfall of the experimental site was 83.6 mm during the study period. The average monthly maximum and minimum temperature were 28 ºC and 17 ºC, respectively during the experimental period. Rabi season is characterized by plenty of sunshine.

3.3 Soil

The Soil of the experimental field belongs to the Tejgaon series of AEZ No. 28, Madhupur Tract and has been classified as Shallow Red Brown Terrace Soils in Bangladesh soil classification system. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed from some important physical and chemical parameters. Some initial physical and chemical characteristics of the soil are presented in Appendix II and III.

3.4 Plant materials collection

For Rabi and Kharif-I season, the high yielding variety of BARI invented vegetables seed of bottle gourd, okra, pumpkin and the seedlings of cabbage, cauliflower, tomato, chili and eggplant were collected from Bangladesh Agricultural Research Institute (BARI).

3.5 Treatment of the experiment

Every location of the experiment was counted as a treatment. Because every location had different from environmental characteristics.

T_1= Mohammadpur

T_2= Adabor

T_3= Kolabagan

T_4= Dhanmondi

3.6 Design of the experiment

The experiment was laid out in Completely Randomized Design (CRD) having single factors with four replications. In the study area, four block per roof was constructed very carefully. Each block was consists of 4 plots. The area of each block was 6.5m×1m. There were 16 unit plots in each experiment location. The size of each plot was 1 m x 1 m, which accommodated 4 plants at a spacing of 0.3 m x 0.3 m.

3.7 Land preparation

Before starting the experiment a concrete structure called block using brick and sand were prepared in every study area. Then polythene and newspaper are spread on each block. After that each block was filth with soil. The supplied soil in each area was prepared and good tilth for ensure for commercial crop production on September,

2018. The soils were spaded and larger clods were broken into smaller pieces. After spading all the stubbles and uprooted weeds were removed and then the plot was made ready.

3.8 Manure and fertilizers and its method of application

The recommended doses of urea, Triple Super phosphate (TSP), Muriate of Potash (MP) and borax were used as source of nitrogen, phosphorus, potassium and boron respectively for all crops. Well decomposed cow dung was also applied to the each plot before transplantation.

3.9 Transplanting of seedlings

For Tomato

Collecting healthy and uniform 45 days old tomato seedlings were transplanted in the experimental plots in 23rd October, 2018 maintaining a spacing of 30 cm x 30 cm between the plants and rows, respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

For Eggplant

Healthy and uniform 30 days old eggplant seedlings were transplanted in the experimental plots in 23rd October, 2018 maintaining a spacing of 30 cm x 30 cm between the plants and rows respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

For Cabbage and Cauliflower

13-15 days healthy and uniform seedlings were transplanted in the experimental plot in 23rd October, 2018 maintaining a spacing of 30 cm x 30 cm between the plants and rows respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

Seed Sowing of Okra, Bottle Gourd and Pumpkin

All this selected kharif-I seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth. The soaked seeds were then spread over polythene sheet for 2 hours to dry out the surface water. This treatment was given to help quick germination of seeds. The seeds were sown in the rows of the raised bed on 20th April 2019. Row to row and plant to plant distance were maintained 30 cm and 30 cm, respectively. Two to three seeds were sown in each pit. Then the seeds were covered with fine soil by hand.

Transplanting of seedlings-

For Chili

Healthy and uniform 30 days old chili seedlings were transplanted in the experimental plots in 20th April 2019 maintaining a spacing of 30 cm x 30 cm between the plants and rows respectively. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling**.**

3.10 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants, which are as follows:

a) Gap filling

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

b) Weeding

Weeding were accomplished as and whenever necessary to keep the crop free from weeds for better soil aeration and to break the crust.

c) Staking and Pruning

When the plants were well established, staking was given to each plant by bamboo sticks to keep them erect. Within a few days of staking, as the plants grew up, the plants were given a uniform moderate pruning.

d) Irrigation

Light irrigation was provided immediately after transplanting the seedlings and it was continued till the seedlings established in the rooftop garden. Thereafter irrigation was provided as per when needed.

3.11 Harvesting

Harvesting was started from 15th march, 2019 and was continued up to 10 April 2019 for Rabi season crops. Fruit were harvested through hand picking at tender and marketable stage. Kharif-I crops harvesting was started from June, 2019- July, 2019.

3.12 Data collection

Three plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the different parameters were recorded from the sample plants during the course of experiment.

3.12.1 Cabbage

To evaluate the growth and yield performance of cabbage various data were collected under some sub-headings. Those are given bellow:

Plant height: Plant height of cabbage was measured from three randomly selected plants at fully matured head stage of cabbage.

Number of leaves: Data were collected on the number of leaves of cabbage per plant from three randomly selected plants at fully matured head stage of cabbage.

Leaf length: Data were collected on the length of fully grown leaves of cabbage from three randomly selected plants at fully matured head stage of cabbage.

Leaf breadth: Data were collected on the breadth of fully grown leaves of cabbage from three randomly selected plants at fully matured head stage of cabbage.

Stem diameter: Data were collected on the diameter of cabbage stem from three randomly selected plants at fully matured head stage of cabbage.

Curd diameter: Data were collected on the diameter of curd of cabbage from three randomly selected plants which was harvested at fully matured head stage of cabbage.

Fruit weight: Data were collected on the weight of curd of cabbage from three randomly selected plants which was harvested at fully matured head stage of cabbage. Beside this, curd weight of cabbage per plot was collected which was also harvested at fully matured head stage of cabbage. Then fruit weight of cabbage per hectare was calculated and recorded.

3.12.2 Cauliflower

To evaluate the growth and yield performance of cauliflower various data were collected under some sub-headings. Those are given bellow:

Plant height: Plant height of cauliflower was measured from three randomly selected plants at fully matured bud stage of cauliflower.

Number of leaves: Data were collected on the number of leaves of cauliflower per plant from three randomly selected plants at fully matured bud stage of cauliflower.

Leaf length: Data were collected on the length of fully grown leaves of cauliflower from three randomly selected plants at fully matured bud stage of cauliflower.

Leaf breadth: Data were collected on the breadth of fully grown leaves of cauliflower from three randomly selected plants at fully matured bud stage of cauliflower.

Stem diameter: Data were collected on the diameter of cauliflower stem from three randomly selected plants at fully matured bud stage of cauliflower.

Curd diameter: Data were collected on the diameter of curd of cauliflower from three randomly selected plants which was harvested at fully matured bud stage of cauliflower.

Fruit weight: Data were collected on the weight of curd of cauliflower from three randomly selected plants which was harvested at fully matured bud stage of cauliflower. Beside this, curd weight of cauliflower per plot was collected which was also harvested at fully matured bud stage of cauliflower. Then fruit weight of cauliflower per hectare was calculated and recorded.

3.12.3 Tomato

To evaluate the growth and yield performance of tomato various data were collected under some sub-headings. Those are given bellow:

Plant height: Plant height of tomato was measured from three randomly selected plants at fully matured stage.

Number of leaves: Data were collected on the number of leaves of tomato per plant from three randomly selected plants at fully matured stage.

Leaf length: Data were collected on the length of fully grown leaves of tomato per plant from three randomly selected plants at fully matured stage.

Leaf breadth: Data were collected on the breadth of fully grown leaves of tomato per plant from three randomly selected plants at fully matured stage.

Number of branches: Data were collected on the number of branches of tomato per plant from three randomly selected plants at fully matured stage.

Number of fruit per plant: Data were collected on the number of fruit of tomato per plant from three randomly selected plants at fully matured stage.

Fruit diameter: Data were collected on the diameter of tomato fruit from three randomly selected plants at fully matured stage.

Fruit weight: Data were collected on the weight of tomato fruit per plant from three randomly selected plants at fully matured stage. Beside this, tomato fruit weight per plot was collected which was also harvested at fully matured stage. Then fruit weight of tomato per hectare was calculated and recorded.

3.12.4 Eggplant

To evaluate the growth and yield performance of eggplant various data were collected under some sub-headings. Those are given bellow:

Plant height: Plant height of eggplant was measured from three randomly selected plants at fully matured stage.

Number of leaves: Data were collected on the number of leaves of eggplant per plant from three randomly selected plants at fully matured stage.

Number of branches: Data were collected on the number of branches of eggplant per plant from three randomly selected plants at fully matured stage.

Number of fruit per plant: Data were collected on the number of fruit per plant from three randomly selected plants at fully matured stage.

Fruit weight: Data were collected on the weight of eggplant fruit per plant from three randomly selected plants at fully matured stage. Beside this, fruit weight of eggplant per plot was collected which was also harvested at fully matured stage. Then fruit weight of eggplant per hectare was calculated and recorded.

3.12.5 Chilli

To evaluate the growth and yield performance of chilli various data were collected under some sub-headings. Those are given bellow:

Plant height: Plant height of chilli was measured from three randomly selected plants at fully matured stage.

Number of leaves: Data were collected on the number of leaves of chilli per plant from three randomly selected plants at fully matured stage.

Leaf length: Data were collected on the length of fully grown leaves of chilli per plant from three randomly selected plants at fully matured stage.

Leaf breadth: Data were collected on the breadth of fully grown leaves of chilli per plant from three randomly selected plants at fully matured stage.

Number of branches: Data were collected on the number of branches of chilli per plant from three randomly selected plants at fully matured stage.

Stem diameter: Data were collected on the diameter of stem of chilli plant from three randomly selected plants at fully matured stage.

Fruit weight: Data were collected on the weight of chilli fruit per plant from three randomly selected plants at fully matured stage. Beside this, fruit weight of chilli per plot was collected which was also harvested at fully matured stage. Then fruit weight of chilli per hectare was calculated and recorded.

3.12.6 Okra

To evaluate the growth and yield performance of okra various data were collected under some sub-headings. Those are given bellow:

Plant height: Plant height of okra was measured from three randomly selected plants at fully matured stage.

Number of leaves: Data were collected on the number of leaves of okra per plant from three randomly selected plants at fully matured stage.

Leaf length: Data were collected on the length of fully grown leaves of okra per plant from three randomly selected plants at fully matured stage.

Stem diameter: Data were collected on the diameter of stem of okra per plant from three randomly selected plants at fully matured stage.

Fruit length: Data were collected on the length of okra fruit per plant from three randomly selected plants at fully matured stage.

Fruit weight: Data were collected on the weight of okra fruit per plant from three randomly selected plants at fully matured stage. Beside this, fruit weight of okra per plot was collected which was also harvested at fully matured stage. Then fruit weight of okra per hectare was calculated and recorded.

3.12.7 Bottle Gourd

To evaluate the growth and yield performance of bottle gourd various data were collected under the sub-heading are given bellow:

Fruit weight: Data were collected on the weight of bottle gourd fruit per plant from three randomly selected plants at fully matured stage. Beside this, fruit weight of bottle gourd per plot was collected which was also harvested at fully matured stage. Then fruit weight of bottle gourd per hectare was calculated and recorded.

3.12.8 Pumpkin

To evaluate the growth and yield performance of pumpkin various data were collected under the sub-heading are given bellow:

Fruit weight: Data were collected on the weight of pumpkin per plant from three randomly selected plants at fully matured stage. Beside this, fruit weight of pumpkin per plot was collected which was also harvested at fully matured stage. Then fruit weight of pumpkin per hectare was calculated and recorded.

3.13 Statistical analysis

Data were statistically analysed by MSTAT-C software and least significant difference (LSD) range tests was used to determine the levels of significant differences among different treatments.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the growth and yield of different Rabi and Kharif-1 vegetables as influenced by different locations have been presented and discussed in this chapter. The analysis of variance (ANOVA) of data on different growth and yield parameters are presented in the Appendices V-IX. The results of the study have been presented and discusses with the help of table and graphs and possible interpretations given under the following sub-headings.

4.1 Effect of locations on Rabi season vegetables in rooftop garden

4.1.1 Growth and yield performance of cabbage

4.1.1.1 Effect of locations on morphological characteristics of cabbage

Plant height

Plant height is one of the important parameter, which is positively correlated with the yield of cabbage. In case of plant height of cabbage, significant variation was observed in different experiment locations. However, the highest plant height (42.95 cm) was observed in Dhanmondhi which was statistically similar with Adabor (41.12 cm), followed by Mohammadpur (38.77 cm). The lowest plant height of cabbage (36.24 cm) was observed in kolabagan (Figure 1).

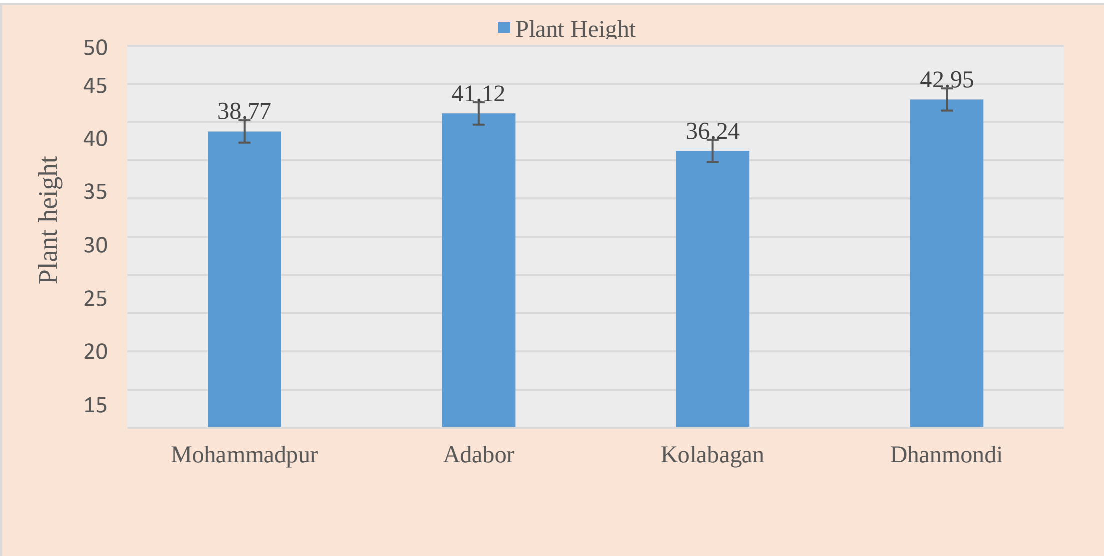


Figure 1. Plant height of cabbage at different locations in Dhaka city

Number of leaves per plant

In case of the number of leaves per plant, significant effect was observed in different location due to soil and climatic condition of the location. The highest number of leaves of Cabbage (13.67) was found in Adabor which was statistically similar to Kolabagan (36.24) and Mohammadpur (12.38). But in Dhanmondi the lowest number of leaves (11.87) was observed for cabbage (Table 2).

Leaf length

The highest leaf length was observed in Dhanmondi which was 27.10 cm. But the lowest leaf length (22.23 cm) was observed from Adabor which was statistically similar with Kolabagan (23.31 cm), which was followed by Mohammadpur (24.22 cm). So in that case, significant variation was found in leaf length of cabbage in different experiment location (Table 2).

Leaf breadth

A significant variation was observed in different experimental location in case of leaf breadth of cabbage. The highest leaf breadth (14.65 cm) was observed in Mohammadpur, which was statistically similar with Adabor (13.96 cm). On the other hand, the lowest leaf breadth (12.77 cm) was recorded from Kolabagan which was followed by Dhanmondi (13.76 cm) (Table 2).

Stem Diameter

In case of stem diameter of cabbage, significant variation was observed in different experimental locations of the research. The highest stem (2.20 cm) diameter was observed from Kolabagan which was statistically different from all other treatments. On the other hand, the lowest stem diameter (1.91 cm) was observed in Dhanmondi, which was followed by Mohammadpur (2.00 cm) (Table 2).

Table 2. Morphological characteristics of cabbage at different locations in Dhaka city

Treatment	Number of Leaf	Leaf Length (cm)	Leaf Breadth (cm)	Stem Diameter (cm)
Mohammadpur	12.38 ab	24.22 b	14.65 a	2.00 bc
Adabor	13.67 a	22.23 c	13.96 a	2.06 b
Kolabagan	12.99 ab	23.31 bc	12.77 b	2.20 a
Dhanmondi	11.87 b	27.10 a	13.76 ab	1.91 c
LSD $_{(0.05)}$	**1.34**	**1.54**	**1.19**	**0.14**
CV (%)	**7.00**	**4.21**	**5.71**	**4.55**

4.1.1.2 Effect of locations on yield contributing characteristics of cabbage

Curd diameter

Different treatment show significant variation on curd diameter of cabbage. The highest number of curd diameter (15.08 cm) observed from Mohammadpur which was followed by Kolabagan (14.51 cm). On the other hand, the lowest (13.10 cm) was observed from Dhanmondi, which was followed by Adabor (13.68 cm) (Table 3).

Fruit weight

Significant variation was observed in case of single fruit weight of cabbage in different experimental locations. The highest fruit weight (0.91 kg) was found from Mohammadpur, which was statistically similar with the weight of single cabbage in Adabor (0.88 kg). Whereas the lowest fruit weight (0.79 kg) was observed from Dhanmondi, followed by Kolabagan (0.84 kg) (Table 3).

Fruit weight/plot

The highest fruit weight per plot (3.45 kg) was observed from Mohammadpur which was statistically different from all other treatments. The lowest fruit weight per plot (3.22 kg) was observed from Kolabagan (Table 3).

Fruit weight/ hectare

The highest fruit weight per hectare of cabbage was observed from Mohammadpur which was 34.50 ton/ha. The lowest fruit weight per hectare (32.21 ton/ha) was observed from Kolabagan. But in reference field condition, the highest yield was 40-45 ton per hectare. But in roof top garden the highest yield was found 34.50 ton/ha. So, the production of cabbage on roof top garden was profitable for city dweller for their daily nutrient requirement (Table 3).

From this above findings it was revealed that, the production of cabbage was high at Mohammadpur area but it was lower than the referenced yield of cabbage. Less use of inorganic fertilizer to produce cabbage at rooftop garden could be the major issue for the lower production of cabbage than the referenced yield.

Table 3. Yield contributing characteristics of cabbage at different locations of Dhaka city

Treatment	Curd Diameter (cm)	Fruit Weight (kg)	Fruit Wt./Plot (kg)	Fruit Wt./Ha (ton)	Reference Yield (ton/ha)
Mohammadpur	15.08 a	0.91 a	3.45 a	34.50 a	
Adabor	13.68 bc	0.88 a	3.37 b	33.74 b	
Kolabagan	14.51 ab	0.84 ab	3.22 d	32.21 d	40-45
Dhanmondi	13.10 c	0.79 b	3.82 c	32.84 c	
LSD $_{(0.05)}$	**1.01**	**0.08**	**0.60**	**0.07**	**-**
CV (%)	**6.78**	**6.86**	**3.65**	**3.12**	**-**

4.1.2 Growth and yield performance of cauliflower in rooftop garden

4.1.2.1 Effect of locations on morphological characteristics of cauliflower

Plant height

The plant height of cauliflower was significantly influenced by different treatments. The highest plant height (52.33 cm) was observed in Dhanmondi which was statistically different from all other treatments. On the other hand, the lowest plant height (46.93 cm) was observed in Mohammadpur (Figure 2).

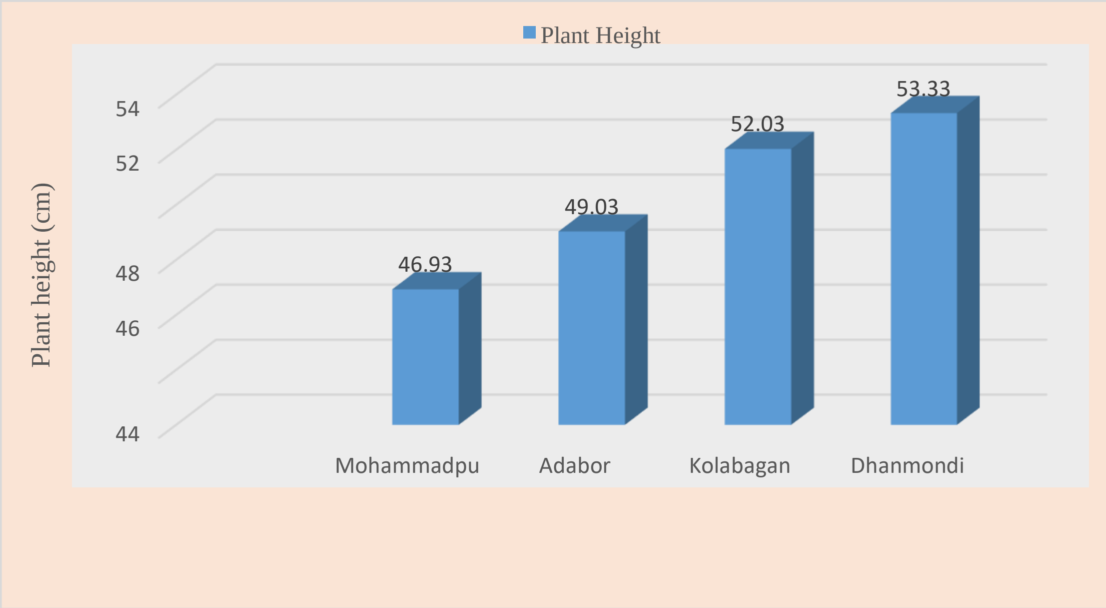


Figure 2. Plant height of cauliflower at different locations in Dhaka city

Number of leaves per plant

Different experimental locations had significantly influenced the number of leaves of cauliflower. The highest number of leaves (22.90) obtained from Kolabagan, which was statistically different from all other treatments. The lowest number of leaves (19.41) was observed from Dhanmondi which was statistically different from Adabor (21.55) and Kolabagan (22.90) (Table 4).

Leaf length

Different treatment had significant effect of the leaf length of cauliflower. The tallest leaf (40.28 cm) was observed from Adabor which was statistically different from all other treatments. The shortest leaf was observed from Mohammadpur (37.02 cm) (Table 4).

Leaf breadth

The study revealed that there was highly significant effect of different treatment on leaf breadth of cauliflower. Average maximum leaf breadth (14.49 cm) was observed from Mohammadpur which was statistically different from all other treatments. Whereas, the average lowest leaf length (12.64 cm) was observed from Kolabagan (Table 4).

Stem Diameter

Different locations had a significant effect on the stem diameter of cauliflower. The highest stem diameter (3.25 cm) was observed from Kolabagan, which was statistically different from all other experimental locations. Whereas, the lowest number of stem diameter (2.87 cm) was observed from Dhanmondi, which was also statistically different from all other locations (Table 4).

Table 4. Morphological characteristics of cauliflower at different locations in Dhaka city

Treatment	Number of leaf	Leaf Length (cm)	Leaf Breadth (cm)	Stem Diameter (cm)
Mohammadpur	20.89 c	37.02 d	14.49 a	2.68 d
Adabor	21.55 b	40.28 a	13.42 c	3.04 b
Kolabagan	22.90 a	38.88 c	12.64 d	3.25 a
Dhanmondi	19.41 d	39.62 b	13.99 b	2.87 c
LSD $_{(0.05)}$	**0.58**	**0.51**	**0.30**	**0.12**
CV (%)	**10.83**	**10.87**	**4.66**	**8.12**

4.1.2.2 Effect of locations on yield contributing characteristics of cauliflower

Curd Diameter

Fruit diameter was highly significant due to applying different treatment in cauliflower. The highest curd diameter (15.06 cm) was observed from Dhanmondi which was statistically different from all other treatments. On the other hand, the lowest curd diameter (13.34 cm) was observed from Kolabagan, which was also statistically different from all other treatments (Table 5).

Fruit Weight

Fruit weight was not varied significantly for the application of different treatment. The highest fruit weight (0.84 kg) was observed from Kolabagan and the lowest fruit weight (0.72 kg) was observed from Dhanmondi which was statistically similar with Adabor (0.74) and Mohammadpur (0.75) (Table 5).

Fruit weight per plot

In different locations, a significant variation was observed in fruit weight of cauliflower per plot. The highest fruit weight per plot (4.07 kg) of cauliflower was observed from Adabor which was statistically different from all other treatments. The lowest fruit weight (3.65 kg) was observed from Mohammadpur which was also statistically different from all the treatments (Table 5).

Fruit weight per hectare

The highest amount of yield (40.70 ton/ha) was observed from Adabor which was identical for reference yield of cauliflower in field condition (37-45 ton/ha). The lowest amount of yield (36.53 ton/ha) was obtained from Mohammadpur which was statistically similar different from other treatments (Table 5).

From this above findings it was revealed that, the cauliflower production was highest at Adabor area and it was more or less similar with the referenced yield of cauliflower. Use of organic fertilizer to produce cauliflower at rooftop garden could be the major issue for the more or less similar production of cauliflower than the referenced yield.

Table 5. Yield contributing characteristics of cauliflower at different locations in Dhaka city

Treatment	Curd Diameter (cm)	Fruit Weight (kg)	Fruit Wt./Plot (kg)	Fruit Wt./Ha (ton)	Reference Yield (ton/ha)
Mohammadpur	14.74 b	0.75 b	3.65 d	36.53 d	37-45
Adabor	14.02 c	0.74 b	4.07 a	40.70 a	
Kolabagan	13.34 d	0.84 a	4.01 b	40.06 b	
Dhanmondi	15.06 a	0.72 b	3.77 c	37.67 c	
LSD $_{(0.05)}$	**0.21**	**0.08**	**0.33**	**0.58**	
CV (%)	**7.99**	**7.18**	**7.18**	**7.18**	

4.1.3 Growth and yield performance of tomato in rooftop garden

4.1.3.1 Effect of locations on morphological characteristics

Plant height

Different experimental locations had a significant effect on plant height of tomato. The tallest plant (175.00 cm) was observed in Mohammadpur which was statistically different from other treatments. The shortest plant (169.10 cm) of tomato was observed in Kolabagan. Buitellar (1989) reported that the increased plant height of plants was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches (Figure 3).

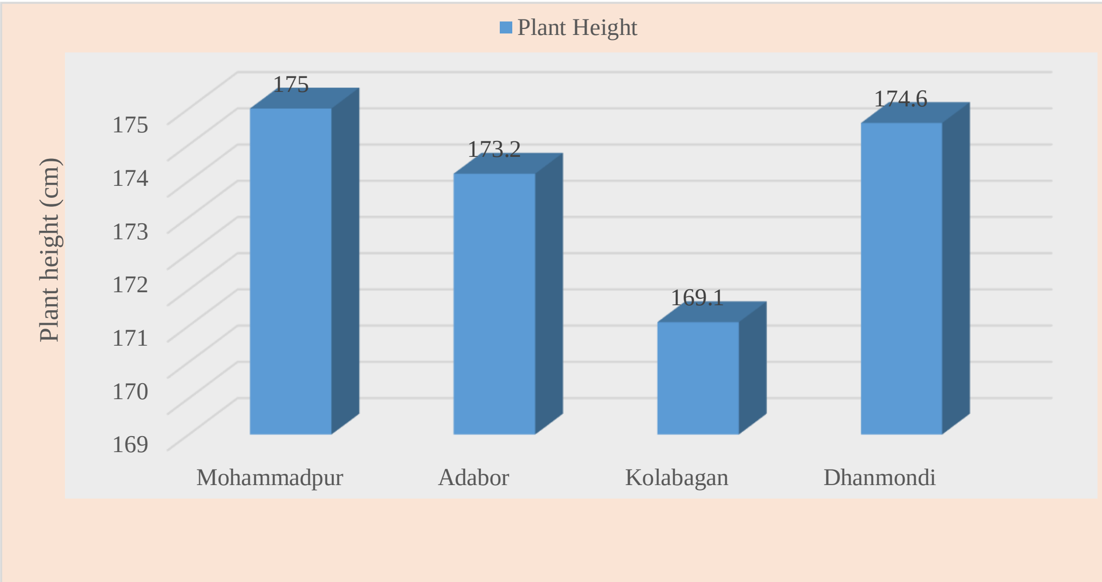


Figure 3. Plant height of tomato at different locations in Dhaka city

Number of leaves per plant

In case of number of leaves per plant, there was significant difference was observed. The maximum number of leaves (476.40) was observed in Kolabagan which was statistically different other treatments. On the other hand, the lowest number of leaves (425.90) was observed from Adabor which was statistically different with other locations. Ashrafuzzaman *et al.,* (2011) reported that the microclimatic condition improved by the mulches might have provided a suitable condition for producing higher number of leaves in the plants (Table 6).

Leaf Length

Different treatment had significant effect of the leaf length of cauliflower. The highest leaf length was observed from Dhanmondi which was 13.72 cm. This result was statistically different from other treatments. The shortest leaf length was observed from Mohammadpur (12.76 cm) (Table 6).

Leaf breadth

Leaf breadth was significantly influenced by different treatment. The highest leaf breadth (4.71 cm) was observed from Mohammadpur which was statistically different from other treatments. The lowest leaf breadth was observed from Dhanmondi which was 3.94 cm (Table 6).

Number of branch per plant

Different treatment had significantly influenced on the number of branch of tomato plants. The highest number of branch (43.00) was observed from Mohammadpur. The lowest number of plants (33.18) was found from Adabor which was also statistically different from other treatments (Table 6).

Table 6. Various morphological characteristics of tomato at different locations in Dhaka city

Treatment	Number of leaf	Leaf Length (cm)	Leaf Breadth (cm)	Number of Branch
Mohammadpur	443.00 c	12.76 d	4.71 a	43.00 a
Adabor	425.90 d	13.06 c	4.23 b	33.18 d
Kolabagan	476.40 a	13.43 b	4.62 a	41.23 c
Dhanmondi	460.80 b	13.72 a	3.94 c	42.32 b
LSD $_{(0.05)}$	**1.15**	**0.53**	**0.11**	**0.07**
CV (%)	**7.84**	**7.44**	**9.73**	**5.11**

4.1.3.2 Effect of locations on yield contributing characteristics of tomato

Number of fruit per plant

Number of tomato fruit per plant was significantly influenced by different locations. The highest number of fruit (69.64) was observed from Mahammudpur whereas the second highest was observed from Adabor (67.44). The lowest number of fruit (62.77) was obtained from Dhanmondi (Table 7).

Fruit diameter

In case of fruit diameter, different treatment had significant variation on tomato. The highest fruit diameter (8.69 cm) was observed from Mohammadpur which was statistically similar from Adabor (8.62 cm). On the other hand, the lowest fruit diameter (8.35 cm) was observed from Dhanmondi (Table 7).

Fruit weight per plant

The highest fruit weight (4.90 kg) per plant was observed from Dhanmondi, which was statistically similar with Adabor (4.23 kg) whereas the lowest fruit weight was observed from Kolabagan (3.87 kg) (Table 7).

Fruit weight per plot

The highest fruit weight per plot (9.52 kg) was obtained from Mohammadpur which was statistically different from other treatments. The lowest number of fruit per plot (7.63 kg) was observed from Adabor (Table 7).

Fruit weight per hectare

In case of fruit weight per hectare, the reference yield was 95-100 ton per hectare. The highest fruit weight per hectare (95.17 ton) was gained from Mohammadpur. The lowest fruit weight (76.25) per hectare was observed from Adabor (Table 7).

From this above findings it was revealed that, the production of tomato was vary from locations to locations and it was highest at Mohammadpur area and more or less similar with referenced yield of tomato. Use of organic fertilizer and intensive care to produce tomato at rooftop garden could be the major issue for more or less similar production of tomato compared to the referenced yield.

Table 7. Yield contributing characteristics of tomato at different locations in Dhaka city

Treatment	Number of Fruit	Fruit Diameter (cm)	Fruit Waight/ plant (kg)	Fruit Wt./Plot (kg)	Fruit Wt./Ha (ton)	Reference Yield (ton/ha)
Mohammadpur	69.64 a	8.69 a	4.68 b	9.52 a	95.17 a	
Adabor	67.44 b	8.62 a	4.23 c	7.63 d	76.25 d	
Kolabagan	64.03 c	8.46 b	3.87 d	9.30 b	93.03 b	95-100
Dhanmondi	62.77 d	8.35 c	4.90 a	7.84 c	78.31 c	
LSD $_{(0.05)}$	**0.38**	**0.11**	**0.20**	**0.62**	**NS**	
CV (%)	**5.96**	**5.21**	**2.95**	**12.95**	**12.95**	

4.1.4 Growth and yield performance of eggplant in rooftop garden

4.1.4.1 Effect of locations on morphological characteristics of eggplant

Plant height

Different treatment had positive effect on plant height of eggplant. The highest plant height (92.63 cm) was observed from Adabor which was statistically different from all other treatments. The lowest plant height (81.05 cm) was observed from Mohammadpur which was also statistically different from others (Figure 4).

Figure 4. Plant height of eggplant at different locations in Dhaka city

Number of leaves

A significant variation was observed in number of leaves in different study area. The highest number of leaves (186.40) was found in Adabor which was statistically similar with Mohammadpur (183.20). On the other hand, the lowest number of leaves per plant (167.70) was observed in Dhanmondi which was followed by Kolabagan (177.50) (Table 8).

Number of branch per plant

The highest number of branch (7.46) was obtained from Kolabagan which was statistically different from all other treatments. Whereas, the lowest number of branch (6.89) was observed in Mohammadpur, which was statistically similar with Adabor (186.40). So it said that, different location of the experimental site created a significant variation in the number of branch of eggplant (Table 8).

Table 8. Morphological characteristics of eggplant at different locations in Dhaka city

Treatment	Number of leaves	Number of branch
Mohammadpur	183.20 a	6.89 c
Adabor	186.40 a	7.02 c
Kolabagan	177.50 b	7.46 a
Dhanmondi	167.70 c	7.28 b
LSD $_{(0.05)}$	**4.02**	**0.16**
CV (%)	**11.49**	**11.47**

4.1.4.2 Effect of locations on yield contributing characteristics of eggplant

Number of fruit per plant

In case of number of fruit per plant, location of experiments played a significant role in the production of the number of fruit. The highest number of fruit (34.05) was observed in Adabor which was statistically different from others. On the other hand, the lowest number of fruit (31.05) was observed in Mohammadpur (Table 9).

Fruit weight per plant

Fruit weight per plant was significantly influenced by different treatment of the experiment. The highest fruit weight per plant (3.66 kg) was observed from Dhanmondi which was statistically different from all other locations. Whereas, the lowest number of fruit weight per plant (3.46 kg) was observed in Kolabangan which was followed by Adabor (3.52 kg) (Table 9).

Fruit weight per plot

The highest fruit weight per plot (13.81 kg) was found in Mohammadpur. The lowest number of fruit per plot (11.99 kg) was observed in Adabor .The fruit weight per plot in Kolabagan and Dhanmondi is (12.33 kg) and (12.99 kg) respectively (Table 9).

Fruit weight per hectare

Average of highest fruit weight per hectare (13.82 ton) was observed in Mohammadpur. The second highest yield (13.00 ton) was obtained from Dhanmondi. The lowest yield per hectare (12.00 ton) was observed from Adabor which was statistically similar with Kolabagan (12.35 ton). This yield performance of eggplant was identical to the production of eggplant in reference field (15-25 ton). So, roof top production of eggplant was effective for city dwellers for their daily need (Table 9).

From this finding it was revealed that, the production of eggplant was highest at Mohammadpur area compare to other locations but it was much lower than the referenced yield of eggplant. Less use of inorganic fertilizer to produce eggplant at rooftop garden could be a reason for the lower production of eggplant than the referenced yield.

Table 9. Yield contributing characteristics of eggplant at different locations in Dhaka city

Treatment	Number of Fruit	Fruit Weight/plant (kg)	Fruit Wt./Plot (kg)	Fruit Wt./Ha (ton)	Reference Yield (ton/ha)
Mohammadpur	31.05 d	3.66 a	13.81 a	13.82 a	
Adabor	34.05 a	3.52 bc	11.99 d	12.00 c	
Kolabagan	33.03 b	3.46 c	12.33 c	12.35 c	15-25
Dhanmondi	31.95 c	3.58 b	12.99 b	13.00 b	
LSD $_{(0.05)}$	**0.59**	**0.07**	**0.15**	**4.77**	
CV (%)	**11.21**	**11.33**	**7.76**	**7.77**	

4.2 Effect of locations on Kharif-I season vegetables in rooftop garden

4.2.1 Growth and yield performance of Chilli in rooftop garden

4.2.1.1 Effect of locations on morphological characteristics of Chilli

Plant height

Different treatment showed significant variation in plant height of chili. The tallest plant (126.60 cm) was observed from Kolabagan which was statistically different from Kolabagan (126.6 cm) and Mohammadpur (123.4 cm). The shortest plant height (113.10 cm) observed from Dhanmondi (Figure 5).

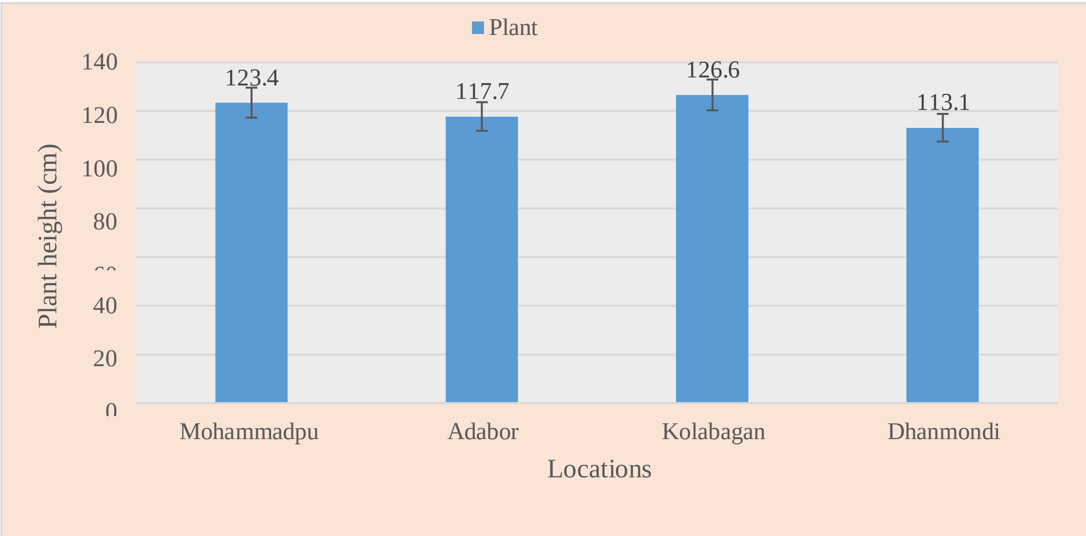


Figure 5. Plant height of chilli at different locations in Dhaka city

Number of leaves

Different treatment had positive significance on generating and retaining higher number of leaves per plant. The maximum number of leaves (308.20) was obtained from Adabor whereas the lowest number of plant leaves (275.90) from Mohammadpur (Table 10).

Leaf length and leaf breadth

There was significant variation found in leaf length and leaf breadth of chili due to application of various treatments. The highest leaf length (13.50 cm) was obtained from Dhanmondi. The lowest leaf length (12.57 cm) was observed in Mohammadpur. For leaf breadth, the highest leaf breadth (3.54 cm) observed from Kolabagan which was statistically similar with Mohammadpur (3.53 cm) and Adabor (3.48). The lowest leaf breadth (3.09 cm) was observed in Dhanmondi (Table 10).

Number of branch

Different treatment had significant variation for the branching number of chili. The highest number of branch (30.61) was observed from Mohammadpur which was statistically different from all other treatments. The lowest number of branch was found in Dhanmondi which was 26.59 (Table 10).

Stem diameter

The present study was showed that different treatment had no significant effect on stem diameter of chili. Average highest stem diameter (1.19 cm) was observed from Adabor whereas the lowest stem diameter (1.08 cm) was observed in Kolabagan (Table 10).

Table 10. Morphological characteristics of chilli at different locations in Dhaka city

Treatment	Number of Leaf	Leaf Length (cm)	Leaf Breadth (cm)	Number of Branch	Stem Diameter (cm)
Mohammadpur	275.90 d	12.57 d	3.53 a	30.61 a	1.12 a
Adabor	308.20 a	13.18 b	3.48 a	29.30 b	1.19 a
Kolabagan	290.30 b	12.85 c	3.54 a	28.01 c	1.08 a
Dhanmondi	282.60 c	13.50 a	3.09 b	26.59 d	1.18 a
LSD $_{(0.05)}$	**2.76**	**0.21**	**0.08**	**0.45**	**0.15**
CV (%)	**6.63**	**10.05**	**10.68**	**11.03**	**7.23**

4.2.1.2 Effect of locations on yield contributing characteristics of chilli

Fruit weight per plant

Fruit weight per plant was varied from different location. There was a significant variation was found in fruit weight per plant of chili due to various treatment. The highest fruit weight per plant (0.79 kg) was obtained from Kolabagan. The lowest fruit weight per plant (0.39 kg) was observed from Dhanmondi (Table 11).

Fruit weight per plot

The highest fruit weight per plot (0.68 kg) was obtained from Kolabagan which was followed by Mohammadpur (0.64 kg). On the other hand, the lowest amount of fruit weight per plot (0.54 kg) gathered from Dhanmondi (Table 11).

Fruit weight per hectare

The reference yield of chili was 8-12 ton hectare whereas in the roof top garden the highest fruit weight per hectare (6.80 ton/ha) was observed from Kolabagan which was statistically different from other treatments. Whereas, the lowest yield per hectare was observed from Dhanmondi (5.39 ton) (Table 11).

From this above findings it was revealed that, the production of chilli was different in different locations in Dhaka city and it was highest at Kolabagan area but the yield was much lower than the referenced yield of chilli. Less use of inorganic fertilizer to produce chilli at rooftop garden could be a major issue for the lower production of chilli than the referenced yield.

Table 11. Yield contributing characteristics of chilli at different locations in Dhaka city

Treatment	Fruit Weight/plant (kg)	Fruit Weight/plot (kg)	Fruit Wt./Ha (ton)	Reference Yield (ton/ha)
Mohammadpur	0.63 b	0.64 ab	6.43 b	
Adabor	0.48 c	0.60 b	5.96 c	
Kolabagan	0.79 a	0.68 a	6.80 a	8-12
Dhanmondi	0.39 d	0.54 c	5.39 d	
LSD $_{(0.05)}$	**0.05**	**0.05**	**0.24**	
CV (%)	**6.63**	**12.81**	**12.62**	

4.2.2 Growth and yield performance of okra

4.2.2.1 Effect of location on morphological characteristics of okra

Plant height

The maximum plant highest of okra (102.00 cm) was observed from Adabor which was statistically different from Dhanmondi (98.13 cm) and Mohammadpur (95.37 cm). The average lowest height of plat was obtained from Kolabagan which was (88.38 cm) (Figure 6).

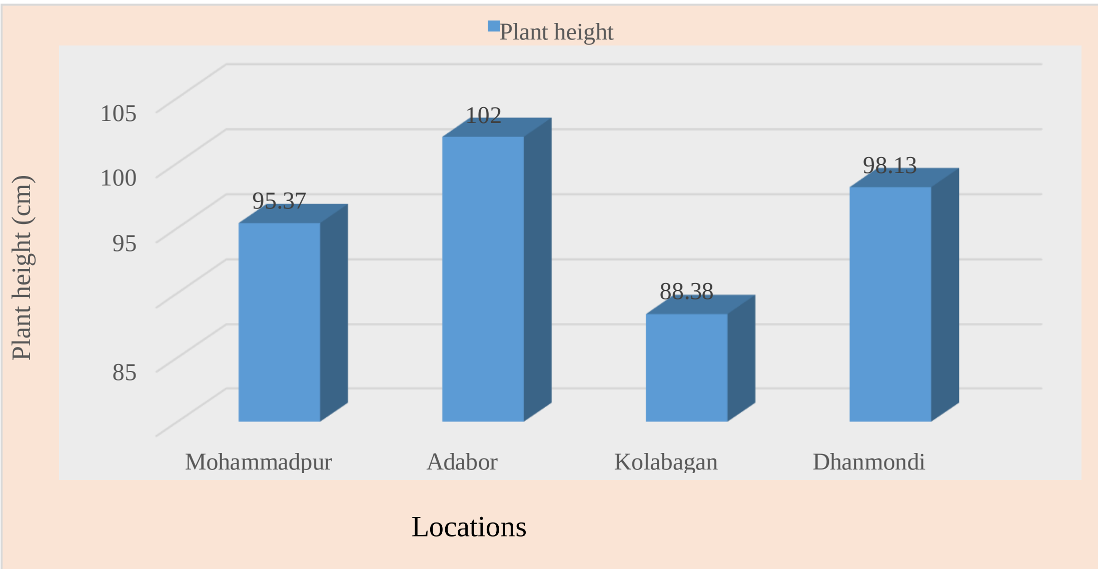


Figure 6. Plant height of okra at different locations in Dhaka city

Number of leaves per plant

Number of leaves of okra is an important character for production of okra. The average of highest number of leaves of okra (77.38) was observed from Kolabagan. The average of lowest number of leaves (62.63) was found from Dhanmondi (Table 12).

Leaf length

The highest leaf length of okra (15.63 cm) was observed from Dhanmondi which was statistically similar from Kolabagan and Mohammadpur. The lowest leaf length (13.50 cm) was observed from Adabor (Table 12).

Stem diameter

The highest stem diameter (1.16 cm) was observed from Adabor which was similar from all other locations. The lowest number of stem diameter was observed from Dhanmondi which was 1.03 cm (Table 12).

Table 12. Morphological characteristics of okra at different locations in Dhaka city

Treatment	Number of leaf	Leaf length (cm)	Stem diameter (cm)
Mohammadpur	68.88 b	15.53 a	1.15 a
Adabor	69.75 b	13.50 b	1.16 a
Kolabagan	77.38 a	15.27 a	1.10 a
Dhanmondi	62.63 c	15.63 a	1.03 a
LSD $_{(0.05)}$	**2.97**	**2.60**	**0.24**
CV (%)	**2.83**	**11.49**	**14.59**

4.2.2.2 Effect of locations on yield contributing characteristics of okra

Fruit length

Data showed that there was a significant variation was observed from fruit length of okra due to different treatment. The highest fruit length was observed from Kolabagan

(18.33 cm) which was statistically different from all other locations. The shortest number of fruit length (15.25 cm) was observed from Adabor (Figure 7).

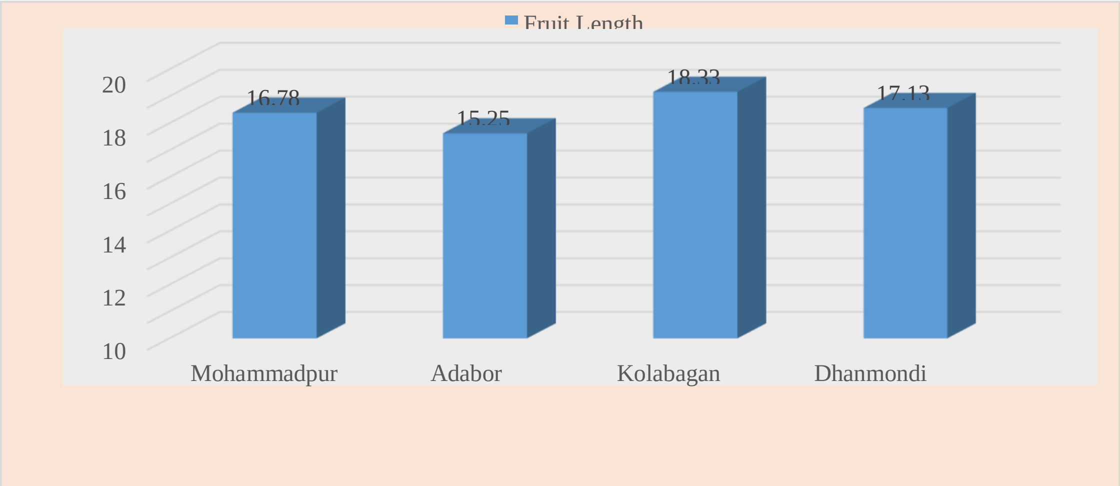


Figure 7. Fruit length of okra at different locations in Dhaka city

Fruit weight per plant

The maximum fruit weight (1.42 kg) was observed from Mohammadpur. But the lowest number of fruit weight (1.11 kg) was obtained from Adabor which was also different from all other treatments (Table 13).

Fruit weight per plot

In that case, the highest fruit weight (13.89 kg) was obtained from Mohammadpur which was similar from Kolabagan and Dhanmondi. The lowest fruit weight per plot (10.84 kg) was observed from Adabor (Table 13).

Fruit weight per hectare

The highest fruit weight per hectare (14.25 ton) was observed from Mohammadpur. The second highest production of okra was observed from Dhanmondi (13.72 ton). The lowest fruit per hectare was obtained from Kolabagan which was 11.12 ton/hectare. The reference yield of okra per hectare was 15-18 ton per hectare. So, in this case, okra production was identical for roof garden in the city like Dhaka (Table 13).

Table 13. Yield contributing characteristics of okra at different locations in Dhaka city

Treatment	Fruit Weight (kg)/ Plant	Fruit Wt./Plot (kg)	Fruit Wt./Ha (ton)	Reference yield (ton/ha)
Mohammadpur	1.42 a	13.89 a	14.25 a	
Adabor	1.11 b	10.84 c	12.37 c	15-18
Kolabagan	1.23 ab	12.91 b	11.12 d	
Dhanmondi	1.38 a	13.52 a	13.72 b	
LSD $_{(0.05)}$	**0.22**	**0.41**	**0.39**	
CV (%)	**11.52**	**2.12**	**2.01**	

From this above findings it was revealed that, the production of okra was vary from locations to locations and it was high at Mohammadpur area but the productions was lower than the referenced yield of okra. Less use of inorganic fertilizer and different growing conditions could be the major issue for the lower production of okra than the referenced yield.

4.2.3 Yield performance of bottle gourd at different locations

Fruit weight per plant

Data revealed that fruit weight of bottle gourd had a significant variation for applying various level of treatment. The highest fruit weight per plant of bottle gourd (25.37 kg) was observed from Dhanmondi. The lowest fruit weight (9.25 kg) was observed from Adabor (Table 14)

Fruit weight per plot

The highest fruit weight per plot (63.43 kg) was obtained from Dhanmondi which was statistically different from all other treatments. The lowest fruit weight per plot (22.37 kg) was obtained from Adabor (Table 14).

Fruit weight per hectare

The reference yield of bottle gourd was 60-65 ton per hectare. In roof top experiments, the highest fruit weight per hectare (61.85 ton) was observed from Dhanmondi. The lowest fruit weight per hectare was observed from Adabor which was 21.53 ton (Table 14).

From this above findings it was revealed that, the production of bottle gourd was highest at Dhanmondi area compare to other locations and it was more or less similar with the referenced yield of bottle gourd.

Table 14. Yield of bottle gourd at different locations in Dhaka city

Treatment	Fruit weight (kg)/ plant	Fruit wt./plot (kg)	Fruit wt./ha (ton)	Reference yield (ton/ha)
Mohammadpur	24.67 b	61.67 b	60.23 b	
Adabor	9.25 d	22.37 d	21.53 d	
Kolabagan	19.37 c	54.68 c	53.78 c	60-65
Dhanmondi	25.37 a	63.43 a	61.85 a	
LSD $_{(0.05)}$	**0.47**	**0.40**	**0.50**	
CV (%)	**1.57**	**0.52**	**0.68**	

4.2.4 Yield performance of Pumpkin in rooftop garden

Fruit weight per plant

In case of pumpkin gourd, there was significant variation found due to different treatment. The highest fruit weight per plant (7.88 kg) was observed in Mohammadpur and Dhanmondi, which was statistically similar with Kolabagan (7.78 kg). The lowest fruit weight per plant (7.50 kg) was obtained from Adabor (Table 15).

Fruit weight per plot

The average of highest fruit weight of pumpkin (23.99 kg) was obtained from Dhanmondi which was statistically similar with Kolabagan (23.98 kg) and

Mohammadpur (23.92 kg). The lowest fruit weight per plot (22.23 kg) was obtained from Adabor (Table 15).

Fruit weight per hectare

The average fruit weight per hectare (24.61 ton) was found from Dhnmondi, which was statistically similar with Mohammadpur (24.58 ton). The lowest fruit weight per hectare was observed from Adabor which was 23.43 ton per hectare. This result also similar from the reference yield which was 20-30 ton/ha (Table 15).

Table 15. Yield of pumpkin at different locations in Dhaka city

Treatment	Fruit/ plant (kg)	Fruit wt./plot (kg)	Fruit wt./ha (ton)	Reference yield (ton/ha)
Mohammadpur	7.88 a	23.92 a	24.58 a	
Adabor	7.50 b	22.23 b	23.43 b	
Kolabagan	7.78 a	23.98 a	24.32 a	20-30
Dhanmondi	7.88 a	23.99 a	24.61 a	
LSD $_{(0.05)}$	**0.67**	**0.08**	**0.10**	
CV (%)	**5.72**	**1.36**	**1.17**	

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The experiment was conducted at the roof of four residential area of Dhaka city which are, Mohammadpur, Kolabagan, Adabor and Dhanmondi during the period from October, 2018 to August, 2019. The experiment was laid out in Completely Randomized Design (CRD) having single factors with four replications. In the study area, four block per roof was constructed very carefully. Each block was consists of 4 plots. The area of each block was 6.5m×1m. There were 16 unit plots in the experiment location. The high yielding variety of BARI invented vegetables seed of bottle gourd, okra, pumpkin and the seedlings of cabbage, cauliflower, tomato, chilli and eggplant were collected from Bangladesh Agricultural Research Institute (BARI). Plant height, stem diameter, number of leaves per plant, fruit length, fruit breadth, fruit weight, total fruit weight were significantly affected due to the application of different treatment on rooftop garden.

Performance of Cabbage

The highest plant height (42.95 cm) was observed in Dhanmondhi which was statistically similar with Adabor (41.12 cm), followed by Mohammadpur (38.77 cm). The lowest plant height of cabbage (36.24 cm) was observed in Kolabagan. The highest number of leaves (13.67) was found in Adabor which was statistically similar to Kolabagan (36.24) and Mohammadpur (12.38). But in Dhanmondi the lowest number of leaves (11.87) was observed for cabbage. The highest leaf length was observed in Dhanmondi which was (27.10 cm). But the lowest leaf length (22.23 cm) was observed from Adabor which was statistically similar with Kolabagan (23.31 cm), which was followed by Mohammadpur (24.22 cm). The highest leaf breadth

(14.65 cm) was observed in Mohammadpur, which was statistically similar with Adabor (13.96 cm). On the other hand, the lowest leaf breadth (12.77 cm) was found from Kolabagan which was followed by Dhanmondi (13.76 cm). The highest stem (2.20 cm) diameter was observed from Kolabagan which was statistically different from all other treatments. On the other hand, the lowest stem diameter (1.91 cm) was observed in Dhanmondi, which was followed by Mohammadpur (2.00 cm). The highest number of curd diameter (15.08 cm) observed from Mohammadpur which was followed by Kolabagan (14.51 cm). On the other hand, the lowest (13.10 cm) was observed from Dhanmondi, which was followed by Adabor (13.68 cm). The highest fruit weight (0.91 kg) was found from Mohammadpur and the lowest fruit weight (0.79 kg) was observed from Dhanmondi. The highest fruit weight per plot (3.45 kg) was observed from Mohammadpur which was statistically different from all other treatments. The lowest fruit weight per plot (3.22 kg) was observed from Kolabagan. The highest fruit weight per hectare of cabbage was observed from Mohammadpur which was 34.50 ton/ha. The lowest fruit weight per hectare (32.21 ton/ha) was observed from Kolabagan.

Performance of Cauliflower

The highest plant height (52.33 cm) was observed in Dhanmondi which was statistically different from all other treatments. On the other hand, the lowest plant height (46.93 cm) was observed in Mohammadpur. The highest number of leaves (22.90) obtained from Kolabagan, which was statistically different from all other treatments. The lowest number of leaves (19.41) was observed from Dhanmondi which was statistically different from Adabor (21.55) and Kolabagan (22.90). The tallest leaf (40.28 cm) was observed from Adabor which was statistically different from all other treatments. The shortest leaf was observed from Mohammadpur (37.02

cm). Average maximum leaf breadth (14.49 cm) was observed from Mohammadpur which was statistically different from all other treatments. Whereas, the average lowest leaf length (12.64 cm) was observed from Kolabagan. The highest stem diameter (3.25 cm) was observed from Kolabagan. Whereas, the lowest number of stem diameter (2.87 cm) was observed from Dhanmondi. The highest curd diameter (15.06 cm) was observed from Dhanmondi. On the other hand, the lowest curd diameter (13.34 cm) was observed from Kolabagan. The highest fruit weight (0.84 kg) was observed from Kolabagan and the lowest fruit weight (0.72 kg) was observed from Dhanmondi which was statistically similar with Adabor (0.74) and Mohammadpur (0.75). The highest fruit weight per plot (4.07 kg) of cauliflower was observed from Adabor. The lowest fruit weight (3.65 kg) was observed from Mohammadpur. The highest amount of yield (40.70 ton/ha) was observed from Adabor which was identical for reference yield of cauliflower in field condition (37-45 ton/ha). The lowest number of yield (36.53 ton/ha) was obtained from Mohammadpur.

Performance of Tomato

The tallest plant (175.00 cm) was observed in Mohammadpur. The shortest plant (169.10 cm) of tomato was observed in Kolabagan. The maximum number of leaves (476.40) was observed in Kolabagan. On the other hand, the lowest number of leaves (425.90) was observed from Adabor. The highest leaf length was observed from Dhanmondi which was 13.72 cm. The shortest leaf length was observed from Mohammadpur (12.76 cm). The highest leaf breadth (4.71 cm) was observed from Mohammadpur. The lowest leaf breadth was observed from Dhanmondi which was 3.94 cm. The highest number of branches (43.00) was observed from Mohammadpur. The lowest number of branches (33.18) was found from Adabor. The highest number of fruit (69.64) was observed from Mahammudpur. The lowest number of fruit (62.77) was obtained from Dhanmondi. The highest fruit diameter (8.69 cm) was observed from Mohammadpur. On the other hand, the lowest fruit diameter (8.35 cm) was observed from Dhanmondi. The highest fruit weight (4.90 kg) per plant was observed from Dhanmondi, whereas the lowest fruit weight was observed from Kolabagan (3.87 kg). The highest fruit weight per plot (9.52 kg) was obtained from Mohammadpur. The lowest number of fruit per plot (7.63 kg) was observed from Adabor. The highest fruit weight per hectare (95.17 ton) was gained from Mohammadpur. The lowest fruit weight (76.25) per hectare was observed from Adabor.

Performance of Eggplant

The highest plant height (92.63 cm) was observed from Adabor. The lowest plant height (81.05 cm) was observed from Mohammadpur. The highest number of leaves (186.40) was found in Adabor. On the other hand, the lowest number of leaves per plant (167.70) was observed in Dhanmondi. The highest number of branches (7.46) was obtained from Kolabagan. Whereas, the lowest number of branches (6.89) was observed in Mohammadpur. The highest number of fruits (34.05) was observed in Adabor. On the other hand, the lowest number of fruits (31.05) was observed in Mohammadpur. The highest fruit weight per plant (3.66 kg) was observed from Dhanmondi. Whereas, the lowest number of fruit weight per plant (3.46 kg) was observed in Kolabangan. The highest fruit weight per plot (13.81 kg) was found in Mohammadpur. The lowest number of fruit per plot (11.99 kg) was observed in Adabor. Average of highest fruit weight per hectare (13.82 ton) was observed in Mohammadpur. The lowest yield per hectare (12.00 ton) was observed from Adabor.

Performance of Chilli

The tallest plant (126.60 cm) was observed from Kolabagan. The shortest plant height (113.10 cm) observed from Dhanmondi. The maximum number of leaves (308.20) was obtained from Adabor whereas the lowest number of plant leaves (275.90) from Mohammadpur. The highest leaf length (13.50 cm) was obtained from Dhanmondi. The lowest leaf length (12.57 cm) was observed in Mohammadpur. The highest leaf breadth (3.54 cm) observed from Kolabagan. The lowest leaf breadth (3.09 cm) was observed in Dhanmondi. The highest number of branch (30.61) was observed from Mohammadpur. The lowest number of branch was found in Dhanmondi which was (26.59). Average highest stem diameter (1.19 cm) was observed from Adabor whereas the lowest stem diameter (1.08 cm) was observed in Kolabagan. The highest fruit weight per plant (0.79 kg) was obtained from Kolabagan. The lowest fruit weight per plant (0.39 kg) was observed from Dhanmondi. The highest fruit weight per plot (0.68 kg) was obtained from Kolabagan. On the other hand, the lowest amount of fruit weight per plot (0.54 kg) gathered from Dhanmondi. The highest fruit weight per hectare (6.80 ton/ha) was observed from Kolabagan. Whereas, the lowest yield per hectare was observed from Dhanmondi (5.39 ton).

Performance of Okra

The highest fruit length was observed from Kolabagan (18.33 cm). The lowest number of fruit length (15.25 cm) was observed from Adabor. The maximum fruit weight per plant (1.42 kg) was observed from Mohammadpur. But the lowest number of fruit weight per plant (1.11 kg) was obtained from Adabor. The highest fruit weight per hectare (13.89 ton) was observed from Mohammadpur. The lowest fruit per hectare was obtained from Adabor which was 10.84 ton/hectare.

Performance of Bottle Gourd

The highest fruit weight per plant of bottle gourd (25.37 kg) was observed from Dhanmondi. The lowest fruit weight (9.25 kg) was observed from Adabor. The highest fruit weight per plot (63.43 kg) was obtained from Dhanmondi. The lowest fruit weight per plot (22.37 kg) was obtained from Kolabagan. The highest fruit weight per hectare (61.85 ton) was observed from Dhanmondi. The lowest fruit weight per hectare was observed from Adabor which was 21.53 ton.

Performance of Pumpkin

The highest fruit weight per plant (7.88 kg) was observed in Mohammadpur and Dhanmondi. The lowest fruit weight per plant (7.50 kg) was obtained from Adabor. The average of highest fruit weight of pumpkin (23.99 kg) was obtained from Dhanmondi. The lowest fruit weight per plot (22.23 kg) was obtained from adabor. The average fruit weight per hectare (24.61 ton) was found from Dhanmondi. The lowest fruit weight per hectare was observed from Adabor which was 23.43 ton per hectare.

5.2 CONCLUTION

Considering the above result of this experiment the following conclusions can be drawn:

1. Most of the time the highest yield was produced from Mohammadpur and Dhanmondi. Because this two study area had the highest soil moisture and optimum soil temperature which create favourable climatic condition for crop production.
2. The results clearly showed that rooftop garden is suitable for vegetables production.

5.3 RECOMMENDATIONS

Considering the findings of the study the following recommendations can be drawn:

1. To maximize the use of rooftop of urban area this study should need to set up further in different urban region of Bangladesh.
2. To increase the yield of fresh and organic vegetables some study should need as similar as present study.
3. More vegetable crops needed under this type of study for determine their efficacy at different locations of Bangladesh.

CHAPTER VI

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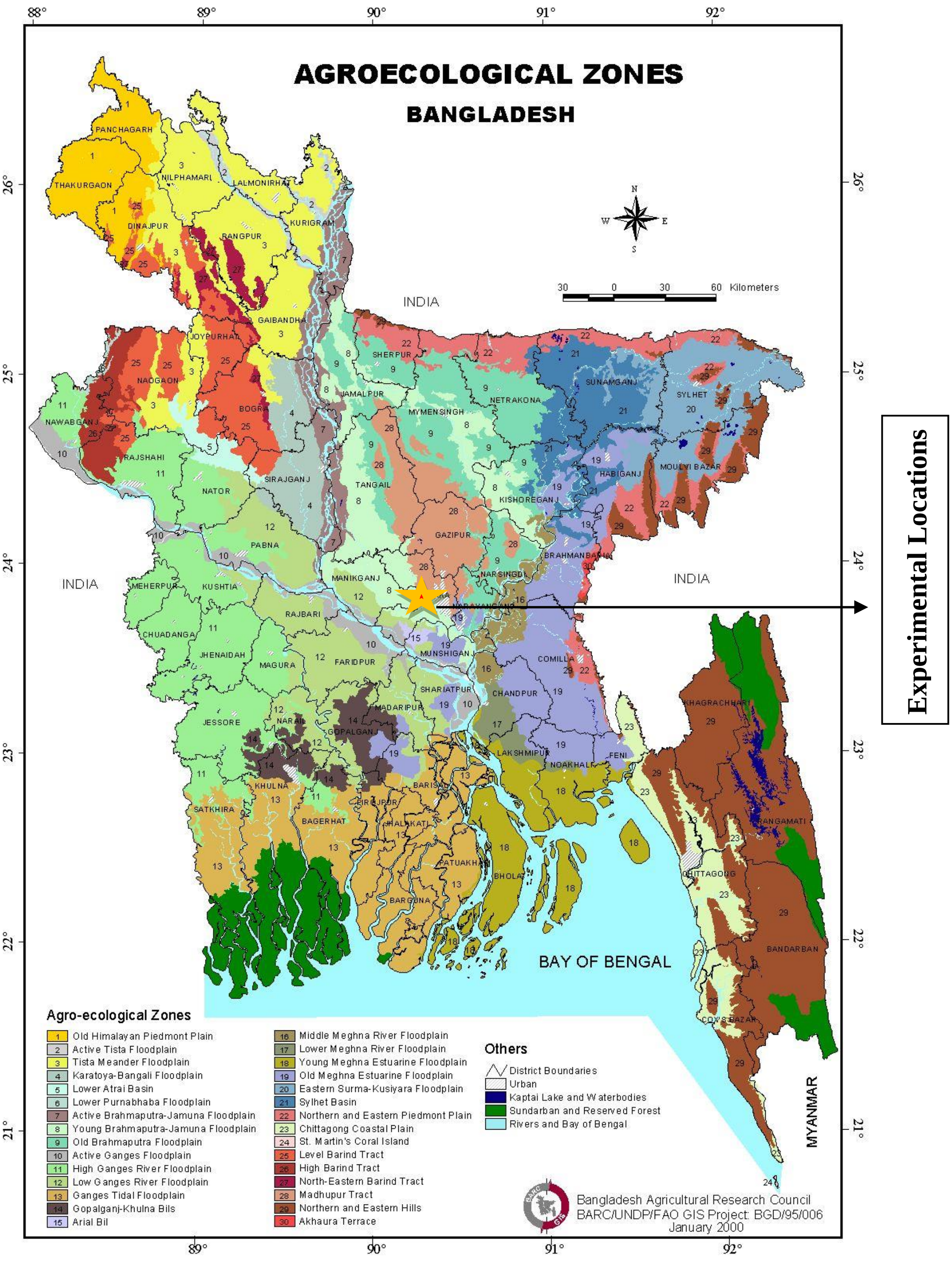
APPENDICES

Appendix I. Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from October 2018 to March 2019.

Month	Temperature (℃)		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
October	31.4	22.6	65	7.0
November	30.2	20.6	67	6.0
December	26.8	17.1	76	33.0
January	23.6	12.6	68	0.0
February	29.2	18.1	61	20.0
March	33.3	22.3	59	3.0

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207.

Appendix II. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

Appendix III: Initial Physical and Chemical Characteristics of the Soil

Characteristics		Value
Mechanical fraction:	% Sand (2.0-0.02 mm)	22.26
	% Silt (0.02-0.002 mm)	56.72
	% Clay (<0.002 mm)	20.75
Textural Class		Silt Loam
pH (1:2.5 Soil-water)		5.9
Organic Matter (%)		1.09
Total N (%)		0.06
Available K (ppm)		15.63
Available P (ppm)		10.99
Available S (ppm)		6.07

Appendix IV: One way ANOVA for cabbage

For plant height					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	101.386	33.795	34.045	0.000
Within	12	11.912	0.993		
Total	15	113.297			
Number of leaves per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	7.298	2.433	3.063	0.0693
Within	12	9.531	0.794		
Total	15	16.829			
Leaf length					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	52.391	17.464	16.826	0.0001
Within	12	12.455	1.038		
Total	15	64.846			

Leaf breadth					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	7.238	2.413	3.899	0.0371
Within	12	7.426	0.619		
Total	15	14.646			
Stem diameter					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.183	0.061	7.078	0.0054
Within	12	0.103	0.009		
Total	15	0.286			
Curd diameter					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	9.219	3.073	6.785	0.0063
Within	12	5.435	0.453		
Total	15	14.653			
Single fruit weight					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.032	0.011	3.132	0.0657
Within	12	0.041	0.003		
Total	15	0.073			
Fruit weight/plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	10.854	3.618	22.676	0.0000
Within	12	1.915	0.160		
Total	15	12.768			
Yield/ha					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**

Between	3	12.125	4.042	2449.565	0.0000
Within	12	0.020	0.002		
Total	15	12.145			

Appendix V: One way ANOVA for cauliflower

For plant height					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	100.712	33.571	219.166	0.0000
Within	12	1.838	0.153		
Total	15	102.550			
Numbers of leaves per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	25.374	8.458	56.264	0.0000
Within	12	1.804	0.150		
Total	15	27.178			
Leaf length					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	23.841	7.947	68.914	0.0000
Within	12	1.384	0.115		
Total	15	25.225			
Leaf breadth					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	7.559	2.520	65.038	0.0000
Within	12	0.465	0.039		
Total	15	8.024			
Stem diameter					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**

Between	3	0.693	0.231	39.617	0.0000
Within	12	0.070	0.006		
Total	15	0.763			
Curd diameter					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	7.120	2.373	118.264	0.0000
Within	12	0.241	0.020		
Total	15	7.360			
Single fruit weight					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.095	0.032	9.951	0.0014
Within	12	0.038	0.003		
Total	15	0.133			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	46.399	15.466	320.492	0.0000
Within	12	0.579	0.048		
Total	15	46.978			
Fruit weight per hectare					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.464	0.155	306.728	0.0000
Within	12	0.006	0.001		
Total	15	0.470			

Appendix VI: One way ANOVA for tomato

For plant height					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	104.680	34.893	518.156	0.0000
Within	12	0.808	0.067		
Total	15	105.488			
Numbers of leaves per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	5741.563	1913.854	70.568	0.0000
Within	12	325.447	27.121		
Total	15	6067.010			
Leaf length					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	2.142	0.714	143.555	0.0000
Within	12	0.060	0.005		
Total	15	2.201			
Leaf breadth					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	1.512	0.504	109.986	0.0000
Within	12	0.055	0.005		
Total	15	1.567			
Number of branch per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	249.558	83.186	36167.354	0.0000
Within	12	0.028	0.002		
Total	15	249.585			
Number of fruit per plant					

Sources of variances	df	SS	MS	F	P
Between	3	118.734	39.578	633.526	0.0000
Within	12	0.750	0.062		
Total	15	119.484			
Fruit diameter					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.284	0.095	18.323	0.0001
Within	12	0.062	0.005		
Total	15	0.346			
Fruit weight per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	2.546	0.849	50.028	0.0000
Within	12	0.204	0.017		
Total	15	2.750			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	1148.919	382.973	2286.983	0.0000
Within	12	2.009	0.167		
Total	15	1150.928			
Fruit weight per hectare					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	11.489	3.830	2335.799	0.0000
Within	12	0.020	0.002		
Total	15	11.509			

Appendix VII: One way ANOVA for chilli

For plant height					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	433.366	144.455	360.127	0.0000
Within	12	4.813	0.401		
Total	15	438.180			
Numbers of leaves per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	2324.898	774.966	231.826	0.0000
Within	12	40.115	3.343		
Total	15				
Leaf length					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	1.918	0.639	34.390	0.0000
Within	12	0.223	0.019		
Total	15	2.141			
Leaf breadth					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.557	0.186	56.710	0.0000
Within	12	0.039	0.003		
Total	15	0.596			
Number of branch per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	35.729	11.910	136.056	0.0000
Within	12	1.050	0.088		
Total	15	36.780			
Stem diameter					

Sources of variances	df	SS	MS	F	P
Between	3	0.033	0.011	1.621	0.2364
Within	12	0.082	0.007		
Total	15	0.115			
Fruit weight per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.380	0.127	88.977	0.0000
Within	12	0.017	0.001		
Total	15	0.397			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	4.465	1.488	57.378	0.0000
Within	12	0.311	0.026		
Total	15	4.777			
Fruit weight per hectare					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.044	0.015	49.252	0.0000
Within	12	0.004	0.000		
Total	15	0.048			

Appendix VIII: One way ANOVA for eggplant

For plant height					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	321.702	107.234	490.363	0.0000
Within	12	2.624	0.219		
Total	15	324.327			
Numbers of leaves per plant					

Sources of variances	df	SS	MS	F	P
Between	3	807.262	269.087	37.851	0.0000
Within	12	85.309	7.109		
Total	15	892.572			
Number of branch per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.776	0.259	23.268	0.0000
Within	12	0.133	0.011		
Total	15	0.910			
Number of fruit per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	20.386	6.795	43.845	0.0000
Within	12	1.860	0.155		
Total	15	22.245			
Fruit weight per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.086	0.029	12.829	0.0005
Within	12	0.027	0.002		
Total	15	0.113			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	7.681	2.56	268.628	0.0000
Within	12	0.114	0.010		
Total	15	7.795			
Fruit weight per hectare					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.077	0.026	263.213	0.0000
Within	12	0.001	0.000		
Total	15	0.078			

Appendix IX: One way ANOVA for okra

For plant height					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	397.077	132.359	170.702	0.0000
Within	12	9.305	0.775		
Total	15	406.382			
Numbers of leaves per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	438.375	146.125	37.701	0.0000
Within	12	46.511	3.876		
Total	15	484.886			
Leaf length					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	11.976	3.992	1.346	0.3059
Within	12	35.597	2.966		
Total	15	47.573			
Stem Diameter					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.064	0.021	0.833	
Within	12	0.309	0.026		
Total	15	0.373			
Fruit length					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	19.270	6.423	4.156	0.0310
Within	12	18.545	1.545		
Total	15	37.815			
Fruit weight per plant					

Sources of variances	df	SS	MS	F	P
Between	3	0.242	0.081	3.681	0.0435
Within	12	0.263	0.022		
Total	15	0.505			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	22.230	7.410	100.513	0.0000
Within	12	0.885	0.074		
Total	15	23.114			
Fruit weight per hectare					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	23.742	7.914	118.774	0.0000
Within	12	0.800	0.067		
Total	15	24.542			

Appendix IX: One way ANOVA for bottle gourd

Fruit weight per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	664.089	221.363	2319.452	0.0000
Within	12	1.145	0.095		
Total	15	665.234			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	4402.870	1467.623	21051.229	0.0000
Within	12	0.837	0.070		
Total	15	4403.706			
Yield					

Sources of variances	df	SS	MS	F	P
Between	3	4272.807	1424.269	12729.935	0.0000
Within	12	1.343	0.112		
Total	15	4274.149			

Appendix IX: One way ANOVA for pumpkin

Fruit weight per plant					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	0.387	0.129	0.656	
Within	12	2.361	0.197		
Total	15	2.748			
Fruit weight per plot					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	9.062	3.021	29.614	0.0000
Within	12	1.224	0.102		
Total	15	10.286			
Yield					
Sources of variances	**df**	**SS**	**MS**	**F**	**P**
Between	3	3.660	1.220	15.125	0.0002
Within	12	0.968	0.081		
Total	15	4.627			

PLATES

Eggplant **Cabbage**

Cauliflower **Chili**

Plate 1. Photographs show vegetables (Eggplant, Cabbage, Cauliflower, Chili) grown on rooftop garden in the study site.

Okra

Pumpkin

Tomato

Bottle gourd

Plate 2. Photographs show vegetables (Okra, Pumpkin, Tomato, Bottle gourd) grown on rooftop garden in the study site.