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RESEARCH ARTICLE

ROOFTOP GARDENING A SOURCE OF ENVIRONMENT CONSERVATION AND CROP PRODUCTION WITH CHANGING CLIMATE FOR DHAKA CITY

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ABSTRACT

The cities of the world are facing serious problems due to environmental hazards. The Department of Agricultural Extension has been implementing a pilot project on expansion of roof gardening in the Dhaka city since 2018 to reduce the increasing temperature, air pollution and for food production. However, no study has been conducted to find out the suitable technologies for producing fresh, safe and nutritious foods in the roof garden and to investigate the role of this roof garden on environment conservation for the Dhaka city dwellers with changing climate. Therefore, a research based roof garden model was developed at Sher-e-Bangla Agricultural University with the financial help of NATP-2 project. The experimental results showed that roof garden reduced upper surface temperature of roof more than 9°C and lower surface temperature of roof by 1.74°C and believe to reduce the electricity consumption for cooling the room of the top floor of the building during summer season. The oxygen and carbon dioxide percent were higher and lower, respectively in the garden than the bare roof. Therefore, the results suggest that urban crop production and environmental balance can be achieved to a certain extent by increasing the intensity of roof gardening in the Dhaka city.

KEYWORDS

Model roof garden, crop production, temperature, oxygen, carbon dioxide.

1. BACKGROUND

Green spaces in urban areas have been decreasing due to rapid urbanization and densification in cities. In the urban area, the atmospheric temperature is high compared to the surrounding rural areas creating an urban heat island (UHI) effect (Arabi et al., 2015; Sharma et al., 2016; Wong et al., 2011). In addition, the environmental pollution in cities is gradually increasing due to thermal properties of the building materials, restricted green areas that limit evapo-transpiration, excess emission of greenhouse gases (GHG), increasing influx of people to city, addition of volatile organic compounds with changing climate. The concrete structures including building roofs occupy almost 60% space along with reduction of vegetation increase urban temperature in Dhaka city (Ahmed et al., 2013). Therefore, these phenomena are known for producing environmental problems that threaten quality of life.

The green roof is gaining importance as an alternative to providing green spaces in urban areas. Many researchers have reported that roof garden improves air quality, reduces urban temperature, increases building value and biodiversity, and uses a space of crop production in the city (Gupta and Mehtha, 2017; Sonne, 2006). Dense blocks and high land prices make it more difficult to establish green space in an urban area; a green roof is considered, as it could be installed on top of pre-existing infrastructure (Bae, 2012). Getter and Rowe reported that green roofs are environmentally beneficial, providing varied services such as carbon sequestration, habitat restoration and urban heat island effect mitigation (Getter and Rowe, 2006). However, to my knowledge no study has conducted to study the effects of roof gardening in an urban area, Dhaka city with changing environment.

It was reported that urban agriculture is gaining attention as rooftop farming which provides a solution to food security and adaptation to climate change (Gupta and Mehtha, 2017). Rooftop gardens makes a bridge between city dwellers and the nature thus increase urban resilience with changing environment. Different types of urban agriculture-vertical farming, community gardening and rooftop gardening have been implementing throughout the world including Bangladesh. A technically feasible, socially acceptable, and environment friendly rooftop garden model is needed and up-scaled gradually in the Dhaka city through maintaining linkage among research institutes, extension services recommended (Uddin et al., 2016).

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Recently, government organization of Bangladesh Departmental of Agricultural Extension (DAE) has started a pilot project name as "Urban Agricultural Production Support Project" especially for roof gardening in the Dhaka City. Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) have been encouraging the city dwellers about roof gardening practices by adopting different policies including rebating holding tax. Therefore, a research-based roof garden model was developed with a furnished training room at the corner of the existing roof garden in 2018 by the support of CRG sub-project under NATP-2 Project to increase the intensity of roof gardening as a component of urban agriculture in the Dhaka city with the changing climate.

2. METHODOLOGY

A research-based rooftop garden model was developed at Sher-e-Bangla Agricultural University (SAU) with the mission of improving the environment, ensuring food security and nutrition, experimenting with new gardening techniques for spreading the urban agriculture in the Dhaka city (Picture 1). The necessary gardening equipments including, measuring tape, scissor, khurpi, container, spade, water cane, sprayer etc. and gardening materials including soil, vermicompost, cowdung, inorganic fertilizers, pesticides, plant growth regulators, seeds, seedling, fruit and medicinal plants etc. and plant growing structures including pot, concrete bed, wooden bed, half drums etc. were used to develop this research based roof garden model.

Picture 1: Established research-based rooftop garden model

Suitable design and methodologies were followed to establish a research-based rooftop garden on the roof of the academic building of SAU. The description of the target building: age, height, access, barriers, roof quality, and neighboring buildings were analyzed to make this garden. The roof loading capacity and safety; access of sunlight, wind, water and electricity; roof enclosure and peripheral surveillance were also analyzed during the preparation of rooftop garden. The area and design of the garden was almost 3000 square feet. The 50% garden area has allotted for as model part which includes vegetable, flowers, fruits, spices medicinal plants and the remaining 50% area for conducting different experiments to pursue MS and PhD degree in this department.

Pavement casting was done on the existing roof to prevent the leaching of water into the garden roof. The drainage lines were made in the garden to release excess water of the garden with the original building drainage system. The garden structure was framed with MS bar, GI and nylon net to protect the plants. Garden paths were decorated with roof tiles. In the research area, the different sizes of permanent beds as concrete bed, and wooden bed, plastic containers, earthen pots, were placed in the garden. Different types of vertical gardening, plastic bed and half drum were set up in the rest part of the garden. The irrigation facilities such as drip irrigation system, water tank, hose pipe etc. were set to apply water in the garden as required.

The soil or planting medium was light weight to conform roof load capacity. The medium for this garden were mixed with three (3) parts loamy soil and two (2) part organic manures which include decomposed cowdung, vermicompost, cocomix, bone meal, oil cake for supplying adequate moisture, nutrients, water to plants. The planting media was also treated with, furadan, metalaxyl mancozeb fungicide and karate syngenta insecticides to kill soil nematode, fungi and insects, respectively. In addition, inorganic fertilizers triple super phosphate (TSP), diamonium phosphate (DAP), muriate of potash (MP), gypsum, zinc, boron, and magnesium were added into the soil according to crop types.

In an intensive rooftop garden, the growth media were varied in depth from 20 - 50 cm according to type of plants. The less than 20 cm soil depth were used in bamboo structured bed and bottle for leafy vegetables and leafy condiments such as spinach, red amaranth, Indian spinach, leafy coriander, respectively whereas thick soil layers more than 20 cm were used for fruit vegetables plants like tomatoes, eggplants, cucumbers, melons, cucurbits, squash etc. The plants were arranged according to their morphological architecture as well as height of the plant so that every plant can get required amount of sunlight for enhancing the growth and productivity of the crops in the garden.

The different garden crops were selected in view of the three pillars of sustainability: ecological, economic/high value and social for being *kharif-1, kharif-2* and *rabi* season. The varietal selection is an important strategy to develop a comprehensive model of rooftop garden. The dwarf, short duration, high yielding, good quality and tolerant to water deficiency & heat stress crop varieties have considered for sustainable establishment of roof garden in Dhaka city. In addition, special attention was taken to keep the tallest fruit plants including guava, mango, banana, lime, dragon, carambola, sofeda, jamrul, orange etc at the northern side of the garden whereas smaller size plants like numerous vegetable such as spinach, lettuce, indian spinach, swamp cabbage, cabbage, cauliflower, brinjal, onion, garlic, turmeric, coriander etc at the southern side of the garden to ensure the supply of maximum sunlight during *rabi* season.

The cucurbits like cucumber and gourds and cowpea were planted as a vine crops for *rabi* season. Tomato, broccoli, cabbage, chili, brinjal, capsicum seedlings were transplanted from seed bed to wooden bed and pot/container. The lettuce, leafy coriander, mint, onion, garlic, spinach, mustard, seasonal ornamental flowers were grown in wooden bed, wooden vertical bottle garden, wooden vertical pipe garden, earthen pot etc. Some plants were kept in the shade space to get better yield because they could not tolerate high light intensity, example strawberry, betel leaf etc. Different types of seasonal flowers, fruits and medicinal plants have been grown in the garden.

The necessary intercultural operations and management practices were done as the requirement of plant types. The water was applied in the garden from water reservoir by a pipe and with a small water jar shower. Urea and muriate of potash was used as source of nitrogen and potash in the growing plants through topdressing. Plant bio-regulators, gibberellic acid (GA), salicylic acid (SA), humic acid were applied on the growing crops for improving their yield and tolerance in response changing of environment. Integrated pest management techniques were practiced to safe the plants from insects and diseases. The plant debris and dead part of the garden was deposited in the compost bin.

2.1 The data of the following environmental parameters were recorded with suitable equipments on June 2018.

1. *Roof upper and lower surface temperature in garden area and outside garden area:* The infrared thermometer, P-JING Model GM 400 was used to measure roof upper surface temperature in garden area and without garden area, and recorded in ˚C on June 2018.
2. *Atmospheric temperature, oxygen (O_2), carbon dioxide (CO_2) and humidity of in the roof garden and outside garden area:* Atmospheric oxygen (O_2), carbon dioxide (CO_2) and humidity of inside the roof garden at SAU and outside/ public bare roof were measured with *Lutron* Air Quality Meter Model AQ-9901SD, Taiwan on June 2018.

Figure 2: Showing model and research area of the garden

Figure 3: Showing leafy, flower and fruit vegetables in different growing structure.

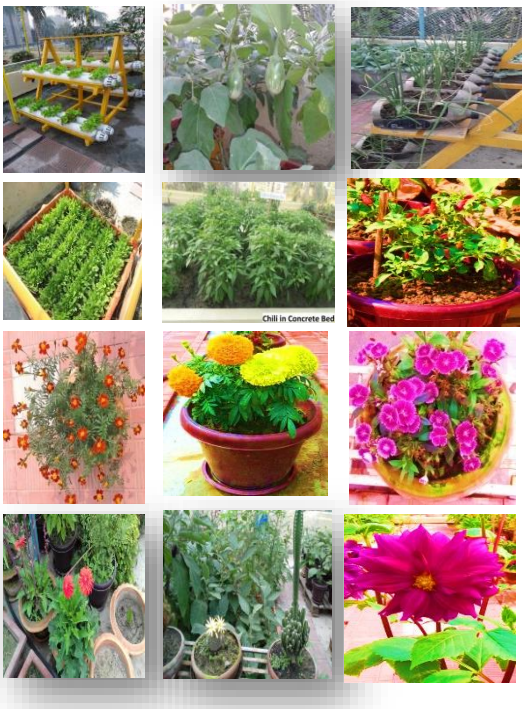

Figure 4: Showing different vegetables and flowers in diverse growing structure.

Figure 5: Showing different fruits plants in diverse growing structure in the roof garden.

3. Results and Discussion

It is well known that rooftops can make significant contributions to urban heat islands during the summer when solar energy that makes contact with roof surfaces. On the other hand, a scientist reported that irrigated roof became cooler than non-irrigated roof and other researcher reported that green roofs were found to be cooler both on the surface and inside than conventional roofs (Sonne, 2006; Simmons, 2008). However, to our knowledge, no study has explained whether rooftop garden reduces urban heat islands generation in Dhaka city during summer season. In this study, we measured atmospheric temperature and roof upper and lower temperature in and outside the garden.

In this study, the significant differences of temperature were found between in and outside the garden namely roof air temperature, roof upper and lower surface temperature. The roof air temperature in rooftop garden (32.97 ˚C) whereas the roof air temperature outside roof garden (36.03 ˚C); roof upper surface temperature in roof garden (39.7˚C) whereas roof upper surface temperature outside roof garden (50.1˚C); and roof lower surface temperature in roof garden (30.1˚C) whereas roof lower surface temperature outside roof garden (31.9˚C) were recorded from this research based roof garden model and outside the garden area, respectively (Figure 1: A,B and C). These experimental results highlighted that roof garden reduced roof surface temperature more than 10˚C along with roof lower surface temperature 1.85 ˚C and suggesting that roof gardens reduces urban heat islands effects as well as electricity consumption for cooling during summer season.

Climate change and air pollution are closely linked and the most important environmental health risk. Climate change increases the concentration of atmospheric ozone and dust by increasing temperatures, sunlight, and humidity which are higher in urban than rural areas due to the concentration of major emissions sources including dense housing, transport vehicles and industry etc. The emission of volatile organic compounds (VOCs) known as hydrocarbons which are generated in the troposphere from the fossil fuel including diesel, petrol, gasoline etc. The carbon dioxide, carbon monoxide, sulphur dioxide, oxides of nitrogen produced from the combustion of the fossil fuel of different sources. The carbon dioxide, carbon monoxide, nitrogen oxides convert into ozone by sunlight and thus increase the atmospheric temperature. In urban areas transport routes and residential areas are often very close to each other and therefore transport is a major contributor to urban air pollution with carbon dioxide, carbon monoxide, nitrogen oxides, ozone etc. Plants are natural filter which can absorb carbon dioxide and other gases to make sound environment. The most detrimental pollutants for human health are particulate (PM_{10}) and ozone (O_3) which alleviated by greenery in urban locations. However, no study has conducted to analyze the contribution of urban greening as roof gardening on mitigation of atmospheric pollutants in Dhaka city. Therefore, we measured atmospheric carbon dioxide, carbon monoxide, oxygen, humidity in and outside the roof garden.

In this study, O_2 percent is significantly higher in rooftop garden (19.09%) than the bare roof (18.60%) (Figure: 1D) and CO_2 concentration was statistically lower in garden area than outside the garden and we found the CO_2 concentration 352 ppm in garden area which is lower than the CO_2 concentration 496 ppm outside the garden area but the both measurements is above the WHO limits (250 ppm) (Figure 1 E). These results showed that roof garden certainly decreases the CO_2 concentration that mitigate the greenhouse effect and ultimately reduce the temperature. But we did not find any significant difference of carbon mono oxide (CO) concentration between in and outside the garden which were lower than WHO limits 9 ppm. As CO concentration of the atmosphere both in and outside the garden, the humidity percent did not show any significant difference in comparison with in and outside the garden (Figure 1 F). Here, it is notable that the humidity percent was always higher in the garden area than the bare roof which depends on several factors including wind speed, plant density and types, temperature etc.

Previous many reports showed that, the atmospheric temperature of urban area is high compared to the surrounding rural areas creating an

urban heat island (UHI) effect (Arabi et al., 2015; Sharma et al., 2016; Wong et al., 2011). The air pollutants *viz.* hydrocarbon and nitrogen oxides as trapped pollutants which converted into ozone by sunlight and rising carbon dioxide increases temperature is a matter of concern at all levels because higher temperatures and O_3. Some researchers revealed that air pollutants and particulate matters had enough potential to cause severe health effect like respiratory, cardiovascular diseases (Dockery et al., 1993; Koken et al., 2003).

Therefore, now-a-day many developed countries have been considered it as a serious matter of concern and took a systematic monitoring program especially in urban cities. As a mitigation strategy, urban greening as rooftop garden systems improve air quality and decrease the UHI, extend roof life, reduce energy use, increase property value, pleasing work environment, increased biodiversity and source of crop production which are consistent with our experimental findings (Figure 1 A-D) (Hui, 2006; Tomalty and Komorowski, 2010). In addition, reported that urban green roofs/roof gardens have the greatest effect on energy consumption for buildings than bare or dark roof because dark roof surface membranes became brittle or damage rapidly to ultraviolet light and by the expansion and contraction caused by widely fluctuating roof temperatures (Oberndorfer et al., 2007). Therefore, all together it is concluded that massive implementation of rooftop gardening in the city will decrease the urban heat island effect and CO_2 and increase O_2 content of the atmosphere and thereby promotes eco-friendly practices and create new possibilities of food security and safety, nutrition, employment in Dhaka city.

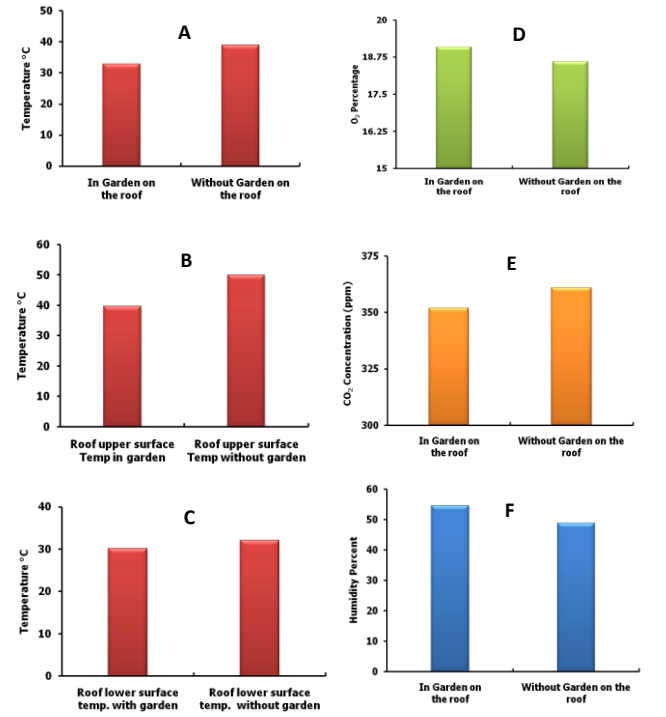

Figure 1: The atmospheric data (A; B; C) Atmospheric, roof upper surface and lower surface temperature was recorded inside and outside of the rooftop garden; (D) atmospheric oxygen (O2) percentage was measured inside and outside of the rooftop; (E) atmospheric carbon dioxide (CO2) content was measured inside and outside of the rooftop garden; (F)) atmospheric humidity was measured inside and outside of the rooftop garden; (All Data were recorded with Lutron Air Quality meter Model AQ-9901SD in June 2018, Summer Season).

4. Conclusion

It is concluded that massive implementation of rooftop gardening in the city will decrease the urban heat island effect and CO 2 concentration and increase O 2 percent of the atmosphere and thereby promotes eco-friendly practices and create new possibilities of safe vegetables and fruits which improve nutrition in the food chain in the form of supplying minerals and vitamins to the city dwellers.

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