EVALUATION OF VEGETABLES PRODUCTION ON ROOFTOP GARDEN: A RESEARCH ON URBAN AGRICULTURE

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BY

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ABSTRACT

Urban agriculture is the practice of cultivating, processing, and distributing food in or around a village, town, or city. Roof top garden is suitable for vegetables cultivation in our country. Tomato is an important vegetable of robi season and okra and chili are important vegetables of summer season. This experiment was conducted at roof of third floor of Biotechnology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2015 to July 2016. The experiment was laid out in Completely Randomized Design (CRD) having single factors with three replications. The treatment of this experiment were $T_{1=}$ Straw mulch, $T_{2=}$ Wood ash and $T_{3=}$Control. The seedlings of BARI tomato-3 and BARI morich – 1, seeds of BARI derosh -1 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Plant height, stem diameter, number of leaves per plant of tomato, okra and chili are superior in mulching than control. The total yield of tomato, okra and chili were also varied significantly due to the application of different mulching. The highest yield of tomato fruit (29.18 t/ha) was obtained from T_2 (wood ash), while T_3 (control) gave the lowest (21.24 t/ha) yield. The highest fruit yield of okra was recorded (13.48 t/ha) of T_2 (wood ash) and the lowest yield of okra was recorded (8.583 t/ha) of T_3 (control) which was statistically similar with T_1 treatment. The maximum fruit yield of chili was recorded (2.8oo t/ha) of T_2 (wood ash) and the minimum yield was (1.900 t/ha) of T_3 (control) treatment. The results clearly showed that the fruit yield per hectare was increased with the using of mulch materials at rooftop garden. It is apparent that growth and yield of tomato, okra and chili may be increased by using wood ash and straw as mulching materials which create favorable climatic condition in soil environment.

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BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
DAT	=	Day after transplanting
et al.	=	and others *(at elli)*
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^H	=	Hydrogen ion conc.
CRD	=	Completely Randomized Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

CHAPTER I

INTRODUCTION

Dhaka is one of the fastest growing megacities and most densely populated cities in the world and experienced a higher rate of urban growth in recent decades. The Greater Dhaka has a population of over 18 million as of 2016, while the city itself has a population estimated at about 8.5 million. The density of 23,234 people per square kilometer within a total area of 300 square kilometers (Wikipedia). Due to unrestrained urban growth, it will be the fourth largest urban agglomeration of the world with a population of 160.4 million by 2015, up from the 2013 estimate of 156.5 million (World Population Prospects, 2016). The city is considered the largest in all of Bangladesh and the overall metropolitan area is the 9th largest city in the entire world. So, the city is facing incredible problems associated with unplanned development, high level of poverty, social vulnerability, inadequate infrastructure, lack of social services, poor quality of physical and social environment, and inefficient urban management (UN, 1999). In urbanization process, it is found that about 20 percent vegetation cover that was present in 1989 has gradually decreased to 15.5 percent and 7.3 percent in the year 2002 and 2010, respectively. Vegetation was found in the Dhaka metropolitan area is only 1.87 percent (BBS, 2011). For the residents of Dhaka, there is limited access to fresh, healthy, culturally appropriate and affordable food. While nearly almost half of the people of Dhaka are food insecure. Overall, a much higher percentage are unable to obtain fresh and nutritious produce (Food Security in Bangladesh, 2005). High price of food and inability of most families/ households to buy or provide adequate amount of nutritious food make them vulnerable to hunger. Urban agriculture promotion and its sustainability seem to be a remedy to such situations, whole augmenting income and employment opportunities in the cities (Barua and Ikbal, 2012).

Urban agriculture is the practice of cultivating, processing, and distributing food in or around a village, town, or city. Urban agriculture can also involve animal husbandry, aquaculture, agroforestry, urban beekeeping and horticulture. These activities occur in peri-urban areas as well urban areas (FAO 2013). Rooftop garden is a part of urban agriculture. A rooftop garden is a garden on the roof of a building. Besides the decorative benefit, roof plantings may provide food, temperature control, hydrological benefits, architectural enhancement, habitats or corridors for wildlife, recreational opportunities, and in large scale it may even have ecological benefits (Sajjaduzzaman *et al.*, 2005). In Bangladesh ornamental plant, fruit trees, flowering plants and vegetables are mostly growth on rooftops. Temperatures around the building can be lowered in the summer. It can be further insulated from the cold in the winter. The roof life can be extended by protecting it from various weather. This trend will continue as the need to reduce carbon emissions increases.

It's found in a research that 60% space of total Dhaka city occupied with bare roof with no other extensive usage. However, these benefits are difficult to realize because the lands which have traditionally been used for agriculture within our urban areas are in high demand and vulnerable to development. As a result, rooftop agriculture, in containers or on flat roofs has become an attractive possibility (Wikipedia).

Roof top gardening is suitable for vegetables cultivation in our country. Vegetables play an important role in balance diet of human beings. Vegetables are rich sources of vitamins and minerals and also a good source of carbohydrates. Vegetables of Bangladesh are grouped into summer, winter and year round on the basis of growing season. Total production of vegetables meets up to 45-50% of the requirement of the country. Tomato, okra and chili are important high value crops among vegetables in Bangladesh. These are common and economically important vegetables in Bangladesh (BBS, 2008). Due to practice of vegetable production on rooftop garden food production will be increased which meet the demand of urban people and also reduce the meal costs of transport as well as increase the fresher and healthy food production. However, the practically of green roof agriculture has not been extensively tested. This is a new research work that ever performed at this university. In this research work the suitability of various crops on rooftop conditions is evaluated.

Considering the above factors, the present experiment was undertaken to study the following objectives:

1. To study the morphological characteristics of different vegetables in rooftop gardens and
2. To find out the effect of mulch materials on growth and yield of vegetables.

CHAPTER II

REVIEW OF LITERATURE

The aim of this chapter is to describe the review of the past research conducted in line of the major focus of the study. The literature review chapter consists of four sections. The first section illustrates the urban agriculture, its role and importance, rooftop garden in terms of intensive and extensive green roof in the second section, use of mulch materials as a technique of vegetables production in the third section and role of light intensity, soil moisture and soil temperature on vegetables production in the fourth section. Literatures related of rooftop gardens and vegetable which were collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented in this chapter under the following headings-

2.1 Urban Agriculture, its role and importance

Urban agriculture is the practice of cultivating, processing, and distributing food in or around a village, town, or city. Urban agriculture can also involve animal husbandry, aquaculture, agroforestry, urban beekeeping and horticulture. These activities occur in peri-urban areas as well urban areas. The current global urban population is expected to double by 2050, with 90 percent of urban growth taking place in developing countries (Wikipedia). This rapid urbanization process goes hand in hand with increasing food insecurity and malnutrition in cities, especially on the side of the simultaneously increasing population living in poverty. Local governments have to develop new strategies to ensure water, energy and food security for their citizens.

Urban agriculture is an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolis, which grows and raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area (Mougeot, 2001).

Hodgon *et a*l. (2011) reported that urban agriculture is much more than private gardens and community gardens, and many communities are beginning to see the promise of other forms of urban agriculture. This paper is to provide funders with an overview of urban agriculture and its various forms, dimensions, and benefits; its connections to the broader community-based food system.

Tabassum and Sharmin (2010) observed that less green space creates urban heat island effect due to more reflection of solar radiation and outdoor temperature of denser built up area in Dhaka is 1˚C-1.5˚C higher than the immediate urban zones with less green coverage and also can be higher at a range of 0.5-1˚C than the average meteorological record. This research also showed that indoor temperature of residential buildings in less green covered neighborhoods rise at a range of 1˚C-2˚C thus creates thermal discomfort among occupants.

Moustier (2007) provides an extensive summary of the importance of urban agriculture in 14 African and Asian cities. Among the results they found that 90 % of all vegetables consumed in Dar es Salaam (Jacobi et al. 2000) and 60 % of vegetables consumed in Dakar originate from urban agriculture.

Islam (2001) has published an article named "Roof gardening as a strategy of urban agriculture for food security': the case of Dhaka city, Bangladesh." He has reported that urban agriculture in the cities of developing countries are growing rapidly which also means the number of low-income consumers is increasing. Because of food insecurity in these cities is increasing. Urban agriculture (UA) contributes to food security by increasing the supply of food and by enhancing the quality of perishable foods reaching urban consumers.

2.2 Rooftop garden in terms of intensive and extensive green roof

A rooftop garden is a garden on the roof of a building. Besides the decorative benefit, roof plantings may provide food, temperature control, hydrological benefits, architectural enhancement, habitats or corridors for wildlife, recreational opportunities, and in large scale it may even have ecological benefits. The practice of cultivating food on the rooftop of buildings is sometimes referred to as rooftop farming. Rooftop farming is usually done using green roof, hydroponics, aeroponics or air-dyponics systems of container gardens. A lot of various plants can grow in a rooftop garden depending on the weather conditions in that particular region. Rooftop gardening is very fun and can provide a yearly income through the vegetables and fruits growing in it. Rooftop gardens are a tremendously easy, cathartic, accessible way to grow plants and vegetables and they come with a number of benefits.

In Bangladesh ornamental plant, fruit trees, flowering plants vegetables are mostly used. More or less all of the area in city people can establish roof garden on their roof. Green roofs can help in the absorption of carbon dioxide and help reduce air pollution area's aesthetics will be enhanced and property value could be increased .Economically there are no additional land costs. Temperatures around the building can be lowered in the summer   A can be further insulated from the cold in the winter The roof life can be extended by protecting it from various weather conditions Heating and cooling bills will be reduced The rooftop garden space can be used for food production .

Kamrujjaman (2015), wrote a Book name “Green Banking” regarding the Rooftop Gardening. The book contains 7 chapters describing the thermal benefits of roof gardens and the overall techniques and farming procedures of vegetables, fruits, flowers/ornamental plants and multipurpose use of Roof garden.

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

Sharmin (2013) has conducted a case study on Green roof, an innovative approach to achieve environmental sustainability and thermal comfort in Dhaka. She found that green areas (like parks, gardens, vegetation, play fields) in cities and urban lands are being replaced with impervious surfaces resulting from pressure of urbanization which is creating extensive and varied urban environmental degradations. She was focuses on this paper about the potential of extensive over deep intensive green roof in safeguarding the urban built environment and improving environmental sustainability and the local thermal comfort level in dense urban areas of Dhaka city.

Mostafa *et al* (2013) found in his study of present status of rooftop gardening in Sylhet City Corporation of Bangladesh that each gardener was interested in rising of rooftop garden because they think that home gardens could help them to income and save money 29.8% respondents were involved in gardening for economic purpose, 54.9% respondents for environmental amelioration, 95.3% was in favor of mental satisfaction, aesthetic value (82.5%) and leisure time activity (87.8%).

Rashid and Ahmed (2010) experimented the thermal performance of rooftop garden in a six storied building established in 2003. She found that the temperature of this building is 3°C lower than other surrounding buildings and this Green application can reduce the indoor air temperature 6.8°C from outdoor during the hottest summer Period.

Lundholm and oberndorfer (2007) demonstrated that easily measured plant traits (height, individual leaf area, specific leaf area, and leaf dry matter content) can be used to select species to optimize green roof performance across multiple key services.

Kamron (2006) has published an article named ‘Adoption of roof gardening at Mirpur-10 area under Dhaka city’. She has reported that the selected characteristics of the respondents, family size, roof gardening experience, use of information sources, attitude towards roof gardening and knowledge of roof gardening had positive significance of relationship with their adoption of roof gardening. Other characteristics namely: age, family education and family income did not show any significant relationship with the respondent's adoption of roof gardening.

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

Islam (2001) reported that urban population in the cities of developing countries are growing rapidly which also means the number of low-income consumers is increasing. Because of this, food insecurity in these cities is increasing. Urban agriculture (UA) contributes to food security by increasing the supply of food and by enhancing the quality of perishable foods reaching urban consumers. In this study he was try to identify the potential for and barriers to UA with reference to rooftop gardening (RTG) and to explore strategies to promote food security in Dhaka.

Shuvo (2000) proposed for a conceptual framework based on an obligatory on-site adaptation to 'long-term greening' and discussed how this framework should enable a sustainable mainstreaming of the violated constructions ensuring fiscal benefits for RAJUK, building owner and the 'green industry' alike.

Krupka (1992) wrote a book named "Roof gardening: use of plants and vegetation on buildings." This book consists of 20 chapters covering the history and importance of growing plants on buildings from the architectural and town planning aspects, developments in techniques of roof gardening in the last decade, the ecological value of growing plants on buildings, habitat restrictions of vegetation on buildings, planning factors, prevention of damage to buildings, preparation and protection of the habitat and different forms of greening. Chapters 10 to 15 cover the choice of plants for intensive and extensive' greening' of roofs, walls and noise reduction screens. Chapter 16 to 17 deal with the qualitative requirement of seeds, plants and 4 ins-tant vegetation', and planting and vegetation stands in relation to decline criteria. Forms of damage, care and maintenance, and performance of roof and vegetation are covered in the last 3 chapters. The comprehensive coverage of the theoretical and practical aspects of growing vegetation on buildings, the clear diagrams and the extensive list of suitable plants make this book a valuable source of information. It is to be hoped that an English translation will be made so that the information will be made so that the information will be more accessible to a wider readership.

2.3 Use of mulch materials as a technique of vegetables production

Mulches have various effects on the plant growth and yield. Many researchers noted that plants were greatly influenced by mulching.

Parmar *et al.* (2013) carried out a study on watermelon (*Citrulluslanatus thumb*) cv. Kiran at Fruit Research Station, Lalbaugh, Department of Horticulture, College of Agriculture, JAU., to study the effect of different mulching material on growth, yield and quality of water melon cv. Kiran. All the plant growth, yield and quality characters were superior with silver on black polyethylene mulch while, plants without mulch (control) resulted poor growth and yield. With economic point of view, silver on black mulch resulted in the highest net return and found to be more economical with highest benefit cost ratio.

Ashrafuzzaman *et al.* (2011) investigated a field study to evaluate the effect of colored plastic mulch on growth and yield of chili from October 2005 to April 2006. The plastic mulches were transparent, blue, and black and bare soil was the control. Different mulches generated higher soil temperature and soil moisture under mulch over the control. Transparent and blue plastic mulches encouraged weed population which were suppressed under black plastic. Plant height, number of primary branches, stem base diameter, number of leaves and yield were better for the plants on plastic. At the mature green stage, fruits had the highest vitamin-C content on the black plastic

Zande (2006) was reported that the effects of hay, compost, plastic and paper mulches on soil temperature, soil moisture and yield of paste tomato were evaluated on five farms in Virginia. He found that organic mulches reduced afternoon soil temperature and maintained higher soil moisture levels than other treatments.

2.4 Role of light intensity, soil moisture and soil temperature on vegetables production

Hanada (2015) suggested that mulching with fresh leaves gave better yields than contlol in summer in the subtropics, since mulching produced a marked increase in soil temperature.

Rashid and Ahmed (2009) showed that green roof reduces the ceiling surface temperature by a maximum of 3.0°C and on average 1.7°C, in comparison to bare roof. The average indoor air temperature is reduced by 2.4°C with roof during sunshine hours. The amount of solar heat energy entering into the indoors through green roof in comparison with the bare roof is decreased by more than 3 times. Daily average indoor air temperature is 33.0°C with bare roof. This is reduced by 3.0°C with green roof, thereby reducing the average indoor air temperature to 30.0°C.

Hudua *et a*l. (2008) were carried out an experiment to investigate the effect of organic mulch (wheat straw), plastic mulches (black, transparent and yellow polyethylene) and bare soil (as a control) on soil temperature, germination ratio, plant growth, weed percent, water use efficiency and cucumber yield under drip irrigation system. The results showed that soil temperature increased by using mulches. The yield increased by 67, 109, 129, and 124 % with straw, black, transparent and yellow mulch respectively compared with the control. Mulching treatments led to saving in irrigation water for all mulching types compared with the control treatment. The water use efficiency was 6.22, 7.76, 8.51, 8.34, and 2.32 kg/m^3 under straw, black, transparent, yellow and bare soil treatments respectively.

Carter and Butler (2008) evaluated how storm water retention, building energy and temperature, and rooftop habitat are influenced by the use of green roofs using test plots in Georgia and Massachusetts. Green roofs were shown to recreate part of the predevelopment hydrology through increasing interception, storm water storage, evaporation, and transpiration on the rooftop and worked extremely well for small storm events. Temperature reductions were found on the green rooftop as compared to an asphalt surface

Ramakrishna *et al.* (2006) were conducted an On-farm trials in northern Vietnam to study the impact of mulch treatments and explore economically feasible and eco-friendly mulching options. The effect of three mulching materials (polythene, rice straw and chemical) on weed infestation, soil temperature, soil moisture and pod yield were studied. Straw mulch were effective in suppressing the weed infestation. Groundnut plants in straw mulched plots were generally tall, vigorous and reached early flowering. Use of straw as mulch provides an attractive and an environment friendly option in Vietnam, as it is one of the largest rice growing countries with the least use of rice straw. Besides, it recycles plant nutrients effectively

Kuo *et al*. (1978) stated that high light intensity affects the internal temperature of the reproductive organ of tomato. High temperature is known to limit fruit-set of tomato due to simultaneously and/or sequentially impaired series of reproductive processes i.e. Pollen production and development, ovule development, pollination, germination of pollen grains, pollen tube growth, fertilization and fruit initiation.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods that were used in carrying out the experiment.

3.1 Location of the experiment field

The experiment was conducted at the roof of third floor of Biotechnology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2015 to July 2016. The location of the experimental site was at 23°75′ N latitude and 90°34′ E longitudes with an elevation of 8.45 meter from sea level.

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 27.17 ºC and 15.6 ºC respectively during the experimental period. Rabi season is characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate Division) and have been presented in Appendix I.

3.3 Soil

The soil of the experimental site was collected from outside of Dhaka city which was sandy clay. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute

(SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and presented in appendix II.

3.4 Plant materials collection

The seeds of BARI derosh -1 and the seedlins of BARI tomato-3 and BARI morich-1 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.5 Treatments of the experiment:

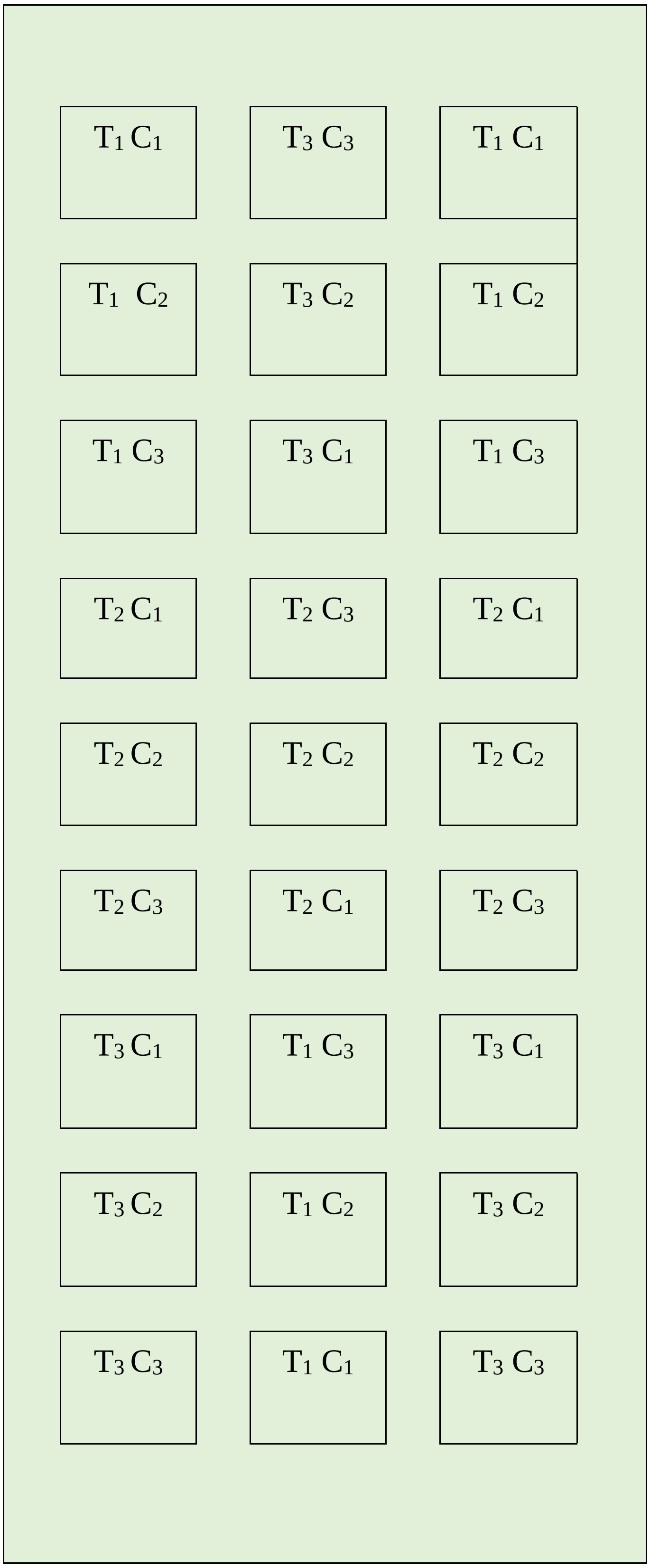
T_1= Straw mulch

T_2= Wood ash

T_3= Control

3.6 Design and layout of the experiment

The experiment was laid out in Completely Randomized Design (CRD) having single factors with three replications. An area of 9 m x 4 m was divided into three equal blocks. Each block was consists of 9 plots where 2 treatments were allotted two block. There were 27 unit plots in the experiment. The size of each plot was 1 m x 1 m, which accommodated 4 plants at a spacing 0.3 m x 0.3 m. The distance between two blocks and two plots were kept 0. 5 m and 0.25 m respectively.



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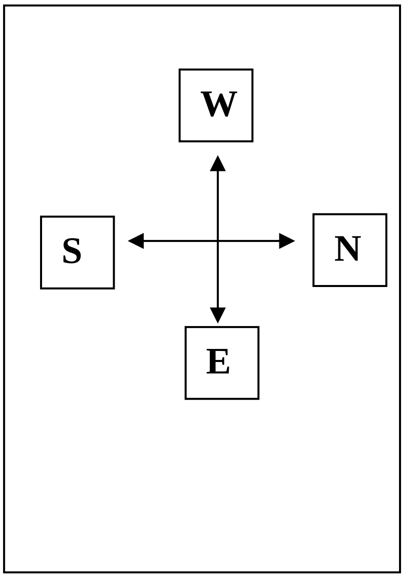

Treatments:
Factor: Mulching

T_1= Straw mulch

T_2= Wood ash

T_3= Control

Experiment layout:

Plot to plot distance = 0.5 m
Block to block distance =0.5m
Plot size = 1×1 m^2
Replication = 3

Crops :
C_1= tomato
C_2= okra
C_3= chili

Fig .1. Layout of the experimental field

3.7. Land preparation

Before starting the experiment there a concrete structure called block using brick and sand were prepared measuring 9 m × 5 m on the roof top of the third floor of Biotechnology Department. Then polythene and newspaper are spreaded on each block. After that each block was filth with soil. The supplied sandy loam soil was prepared and good tilth for ensured for commercial crop production on December 2015. The land were spaded and larger clods were broken into smaller pieces. After spading all the stubbles and uprooted weeds were removed and then the land was made ready.

3.8 Manure and fertilizers and its method of application

Urea, Triple Super phosphate (TSP), Muriate of Potash (MP) and borax were used as source of nitrogen, phosphorus, potassium and boron respectively. Well decomposed cow dung was also applied to the field before final ploughing. The doses and application method of fertilizers were given below:

Table 1. Manures and fertilizers application method on tomato field

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	25 DAT	50 DAT	75 DAT
Cow dung	5 ton	100	- -	- -	- -
Urea	220 kg	50	25	25	- -
TSP	150 kg	100	- -	- -	- -
MoP	180 kg	50	25	25	- -

Table 2. Manures and fertilizers application method on okra field

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	15 DAS	30 DAS	45 DAS
Cow dung	15 ton	100	- -	- -	- -
Urea	150 kg	50	16.67	16.67	16.67
TSP	100 kg	100	- -	- -	- -
MoP	150 kg	100	- -	- -	- -

Table 3. Manures and fertilizers application method on chilli field

Name of Fertilizer	Doses/ha	Application (%)			
		Basal	25 DAT	50 DAT	75 DAT
Cow dung	10 ton	100	- -	- -	- -
Urea	200 kg	50	16.67	16.67	16.67
TSP	100 kg	100	- -	- -	- -
MoP	80 kg	100	- -	- -	- -

3.9 Transplanting of tomato and chili seedlings

For tomato

Collecting healthy and uniform 45 days old tomato seedlings were transplanted in the experimental plots in 23th December, 2015 maintaining a spacing of 30 cm x 30 cm between the plants and rows respectively. This allowed an accommodation of 9 plants in each replication. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

For chili

Healthy and uniform 30 days old chili seedlings were transplanted in the experimental plots in 31th march, 2016 maintaining a spacing of 30 cm x 30 cm between the plants and rows respectively. This allowed an accommodation of 9 plants in each replication. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.10 Sowing of okra seeds

Okra seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth. The soaked seeds were then spreaded 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 15 February 2016. 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.

3.11 Application of mulching materials

Two types of mulching material; viz., wood ash and rice straw mulch were used. The fresh rice straw was chopped into small pieces (5 cm) and sun dried for three days before placing and wood ash was also well dried. The thickness of wood ash and rice straw mulch materials were maintained at 5 cm approximately. It helped in soil moisture conservation.

3.12 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 field. Thereafter irrigation was provided as per when needed.

3.13 Harvesting

Tomato Fruits were harvested at 5-day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 15 march, 2015 and was continued up to 10 April 2015.

Derosh fruit were harvested at every three days interval after first picking**.** Harvesting was started from 25 April, 2016 and was continued up to 10 July 2016. Fruit were harvested through hand picking at tender and marketable stage. Chili Fruits were harvested at 6 to 7 days intervals during early ripe stage when they attained marketable size. Harvesting was started from 1st may, 2016 and was continued up to 30th of July 2016.

3.14 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 following parameters were recorded from the sample plants during the course of experiment.

3.14.1 Plant height

Plant height was measured from sample plants in centimeter from the ground level to the tip of the longest stem of five plants and mean value was calculated. Plant height was measured with a meter scale from three selected plants at 20, 40, and 60 days after transplanting of seedling.

3.14.2 Number of leaves per plant

The number of leaves per plant was measured with a meter scale from three selected plants at 20, 40, and 60 days after transplanting of seedling. The average of primary branches from three plants were computed and expressed in average number of leaves per plant.

3.14.3 Stem diameter

Average stem diameter of selected plant were taken from each plot at 20, 40 and 60 (DAT) with the slide calipers.

3.14.4 Length of fruit

The length of fruit was measured with a meter scale from the neck to the bottom of fruits from each plot and there average was taken and expressed in cm.

3.14.5 Breath of fruit

Breath of fruit was measured at the middle portion of fruit from each plot with a digital calipers and average was taken and expressed in cm.

3.14.6 Individual fruit weight

The weight of individual fruit was measured with a digital weighing machine from each selected plots and average was taken and expressed in gm.

3.14.7 Yield of fruits per plant

An electric balance was used to measure the weight of fruits per plant. The total fruit yield of each plant measured separately during the harvest period and was expressed in gm.

3.14.8 Yield of fruits per plot

An electric balance was used to measure the weight of fruits per plot. The total fruit yield of each unit plot measured separately during the harvest period and was expressed in kilogram (kg).

3.14.9 Yield of fruits per hectare

Yield of fruits per hectare was measured by the following formula:

$$\text{Fruit yield (ton/ha)} = \frac{\text{Fruit yield per plot (kg)} \times 10000}{\text{Area of plot in square meter} \times 1000}$$

3.15 Light measurement

Light was measured by Lux meter on each vegetable crop rows. It was done to determine the availability of light and expressed as lux. Light intensities were measured above the canopy of vegetable crops at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm using Lux meter at three times per month.

3.16 Soil moisture measurement

Soil moisture was measured by Soil Moisture Meter on each vegetable crop rows. It was expressed as percentage (%). Soil moisture was measured at 10 cm depth of soil adjacent to main root of vegetable crop rows at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm in 3 times per month.

3.17 Soil temperature measurement

Soil temperature was measured by Soil Temperature Meter on each vegetable crop rows. It was expressed as degree centigrade li(˚C). Soil temperature was measured at 10 cm deep soil adjacent to main root of vegetable crop rows at 9.00- 10.00 am, 1.00- 2.00 pm and 4.00- 5.00 pm in 3 times per month.

3.18 Statistical analysis

The recorded data on different parameters were statistically analyzed by using MSTAT software to find out the significance of variation resulting from the experimental treatments. The mean values for all the treatments were accomplished by DMRT test. The significance of difference between pair of means was tested at 5% and 1% level of probability.

(a) (b) (c)

Plate 1: Structure of the rooftop garden

(a) (b) (c)

Plate 2: Filled the structure of the rooftop garden with soil

Plate 3: Transplanting of seedling

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to evaluate of vegetable production in rooftop gardening: a research on urban agriculture. Data on different levels of yield and yield contributing characters were recorded to find out the optimum levels. The results have been presented, discussed and possible interpretations are given under the following headings:

4.1 Growth and yield performance of Tomato

4.1.1 Plant height (cm)

Plant height is one of the important parameter, which is positively correlated with the yield of tomato. A highly significant variation was observed due to the application of various mulching. The tallest plant (62.28 cm) was produced by T_2 (wood ash), which was statistically similar with T_1 (rice straw) treatment (Figure 2). The shortest height of plant (50.90 cm) was produced by T_3 (control). Gunadi and Suwanti (1988) reported that mulching helped to increase plant height. Similar opinion was also put forwarded by Buitellar (1989). The increased plant height in mulched plants was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches. Changes in the plant height have been observed by using different mulches. Wood ash mulch increased the plant height than other mulches (Shinde *et al.*, 1999).

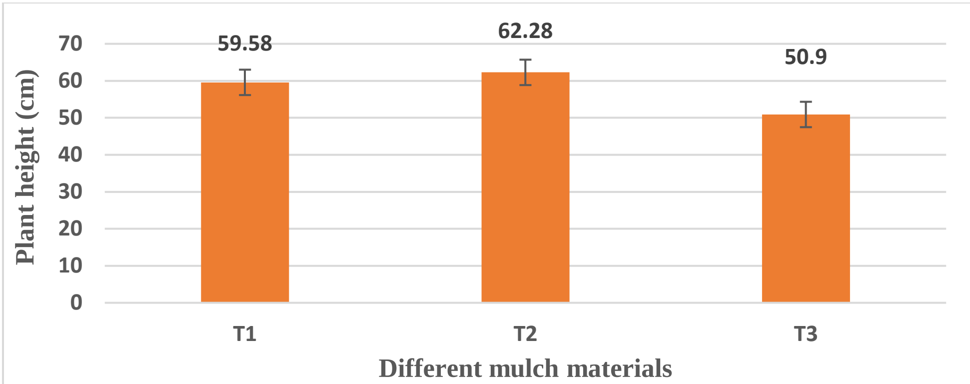

Figure 2. Effect of mulching on the plant height of tomato (LSD $_{(0.05)}$ = 6.32)

4.1.2 Number of leaves per plant

In case of number of leaves per plant, significant difference was observed due to the application of different levels of mulching treatment. The maximum (49.44) number of leaves per tomato plant was recorded from T_2 (wood ash), which was statistically similar with T_1 (rice straw) treatment. While the treatment T_3 (control) gave the minimum (39.89) number of leaves per plan (Figure 3). The microclimatic condition improved by the mulches might have provided a suitable condition for producing higher number of leaves in the plants. Number of leaves was better for the chili on mulches than control reported by Ashrafuzzaman *et al.* (2011)

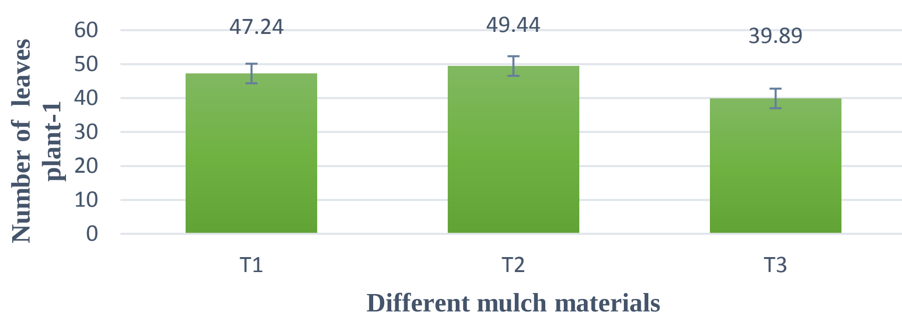

Figure 3. Effect of mulching on the number of leaves plant^{-1} of tomato (LSD $_{(0.05)}$ = 6.21)

4.1.3 Stem diameter

The present study revealed that there has a significant effect of mulching on stem diameter of tomato. The highest stem diameter (10.11 mm) were recorded from the T_2 (wood ash) and the lowest (7.55 mm) stem diameter were recorded from the T_3 (control). The stem diameter was increased possibly due to the readily available mulching which might have encouraged more vegetative growth and development. Wood ash mulch showed superior performance in stem diameter than control (Figure 4). Stem diameter was increased in mulched plants was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches. Parmar *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield**.** Baten, *et al.* (1995) also obtained similar finding in garlic with indigenous mulch. This result clearly showed the stem diameter was gradually increased with the using mulch materials.

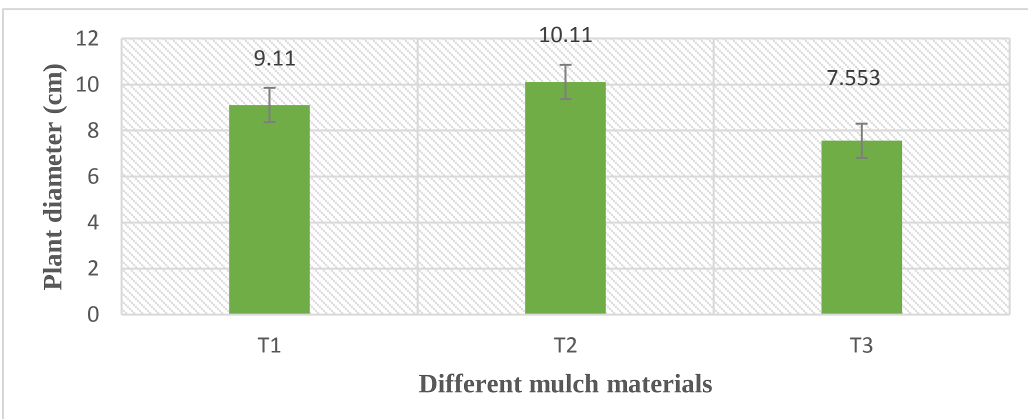

Figure 4. Effect of mulching on the plant diameter of tomato (LSD $_{(0.05)}$ = 1.54)

4.1.4 Length of fruit

Length of tomato fruit had significant variation due to the application of different mulching. The highest length of fruit 5.66 cm was recorded from T_2 (wood ash), which was statistically similar with T_1 (rice straw) and the lowest length of fruit 4.33

cm was recorded from T_3 (control) which was statistically similar with T_1 (rice straw) treatment (Figure 5). Parmar *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield.

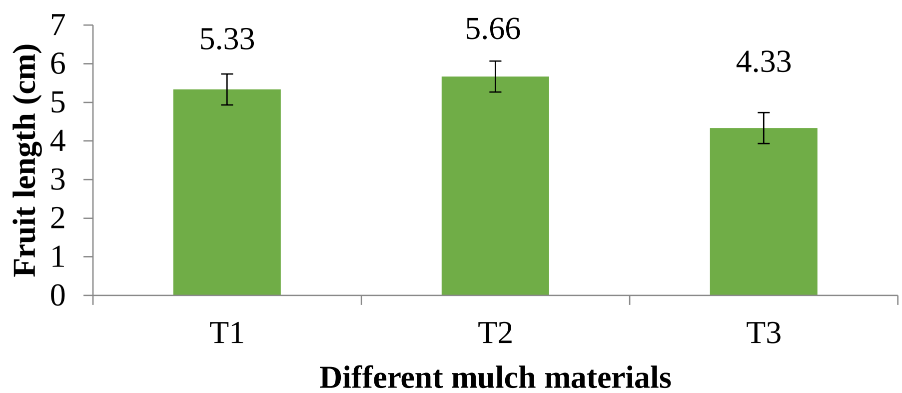

Figure 5. Effect of mulching on the fruit length of tomato (LSD $_{(0.05)}$ = 1.15)

4.1.5 Fruit breadth

Fruit breadth was significantly different due to the application of different mulching. The highest (65.00 mm) diameter of fruit was recorded from T_2 (wood ash), while T_3 gave the lowest (48.00mm) diameter of fruit (Figure 6). This results revealed that the fruit breadth increase with mulching application. Kumar, *et al.* (1995) observed that mulching significantly increased the fruit breadth compared with control.

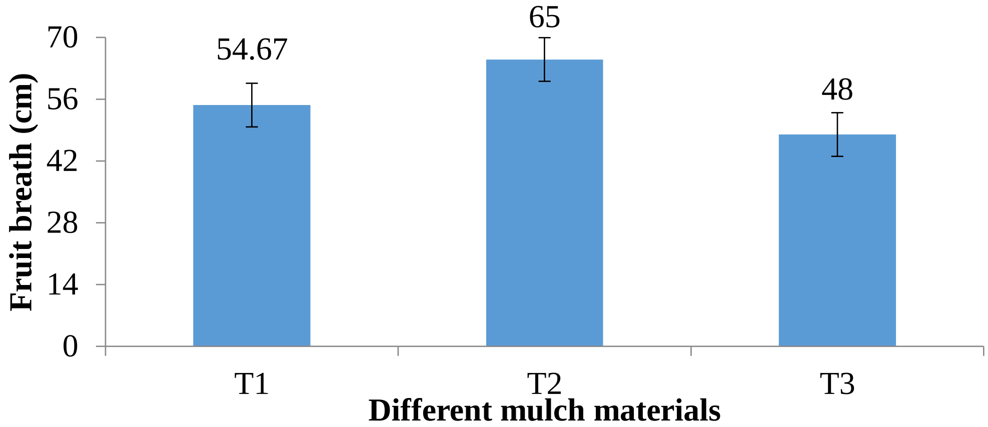

Figure 6. Effect of mulching on the fruit breath of tomato (LSD $_{(0.05)}$ = 3.12)

4.1.6 Individual fruit weight

Weight of individual fruit of tomato varied significantly due to the application of different mulching. The highest weight of individual fruit (87.00g) was found from T_2 (wood ash) which was statistically similar with T_1 (rice straw). The lowest fruit weight of tomato (65.00 g) was observed from T_3 (control). Wood ash mulch showed superior performance in fruit weight than control (Figure 7). Significant variation was recorded for the interaction effect of mulching for weight of individual fruit. Bhangu and Singh (1993) observed that mulched produced the largest fruit (66.69 g) compare with control.

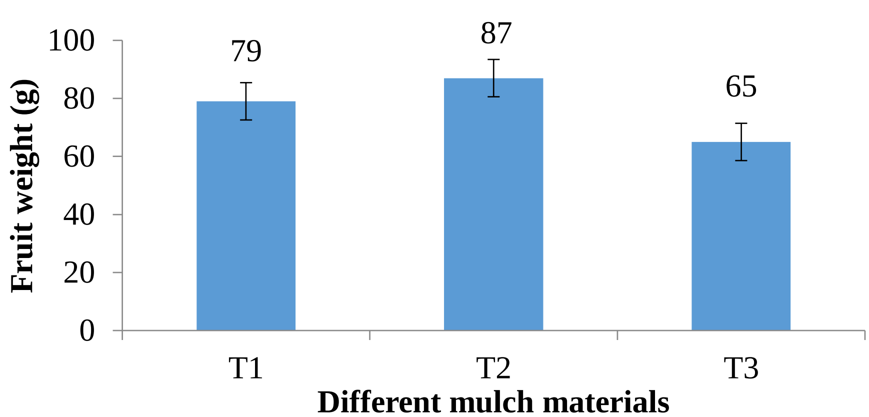

Figure 7. Effect of mulching on the fruit weight of tomato (LSD $_{(0.05)}$ = 8.71)

4.1.7 Yield of tomato per hectare

The total yield of tomato varied significantly due to the application of different mulching. The results clearly showed that the fruit yield per hectare was increased with the using of mulching. The highest yield of fruit (29.18 t/ha) was obtained from T_2 (wood ash), while T_3 gave the lowest yield of tomato (21.24 t/ha). Wood ash mulch has positive effect in fruit weight than control (Figure 8). Parmar *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield.

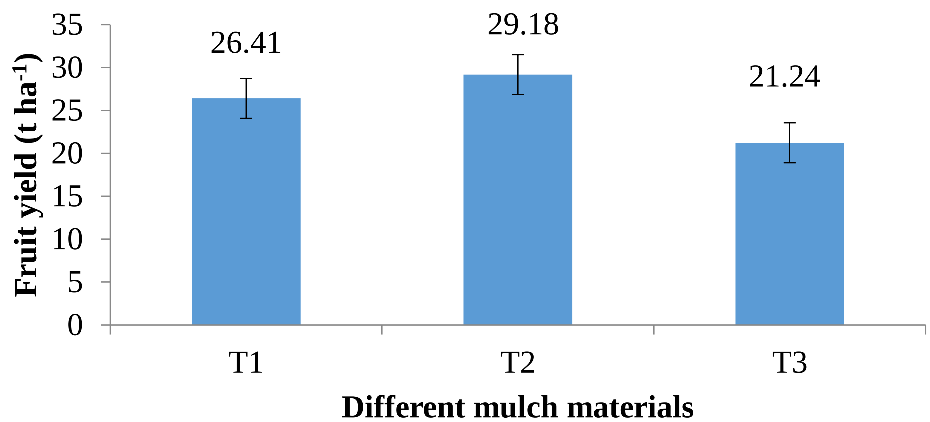

Figure 8. Effect of mulching on the fruit yield of tomato (LSD $_{(0.05)}$ = 2.75)

4.1.8 Light Availability on tomato Crop

Light availability on the tomato plant in mulching and control crop plots was measured at 20 days interval over the growing season (Table 1). Light intensity from T_1, T_2 and T_3 treatment were recorded 29.99, 30.24 and 29.26 (Klux). No significant difference of light intensity was found on the tomato plot.

4.1.9 Soil moisture in tomato field

The soil moisture (%) availability over the time (days after measurement) in tomato field was recorded (Table 1). The significant variation of soil moisture was observed due to the application of different mulching. The soil moisture was reduced in control and increased in the mulch materials. The highest soil moisture was recorded 27.94% at T_2 (wood ash) and the lowest soil moisture was recorded 15.01 % at T_3 (control).

4.1.10 Soil Temperature in tomato field

Effect of soil temperature (^{0}C) was recorded from various treatment in tomato plot and was found significant variation ((Table 1). The highest soil temperature (22.32 ^{0} C) was recorded from T_3 (control) treatment where soil moisture was found lower (15.01 %). However the lowest soil temperature was recorded from T_2 treatment (18.80 ^{0} C). It was noticed that lower soil temperature helped to increased higher soil moisture which helped to increase tomato yield.

Table 1. Availability of light intensity, soil moisture and soil temperature on tomato field

Treatments	Light intensity	Soil moisture	Soil temperature
T_1	29.99 a	23.25 a	20.50 b
T_2	30.24 a	23.97 a	18.22 c
T_3	29.26 a	15.01 b	22.32 a
CV (%)	3.56	1.92	4.27

4.2 Growth and yield performance of okra

4.2.1 Plant height (cm)

Mulches have significant effect on plant height. Okra plant height was also significantly affected due to the application of different mulching treatment. The tallest plant (71.95 cm) was recorded T_2 (wood ash), which was statistically similar with T_1 (rice straw) treatment. On the other hand, the shortest plant (64.33cm) was produced by T_3 (control) which was statistically similar with T_1 (rice straw) treatment. Apparently sufficient soil moisture was conserved under wood ash mulch that might have improved the plant growth as well as fruit weight. Wood ash mulch showed superior performance in plant height than control (Figure 9). Gunadi and Suwanti (1988) reported that mulching helped to increase plant height. Similar opinion was also put forwarded by Buitellar (1989). The increased plant height in mulched plants was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches. Changes in the plant height have been observed by using different mulches and plastic mulch increased the plant height than other mulches (Shinde *et al.*, 1999).

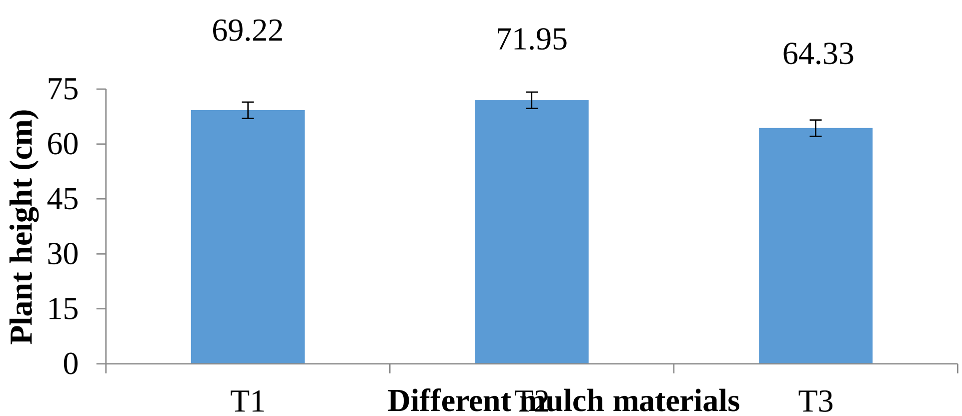

Figure 9. Effect of mulching on the plant height of okra (LSD $_{(0.05)}$ = 6.49)

4.2.1 Number of leaves per plant

Mulches has the positive effect on generating and retaining higher number of leaves per plant. The highest number of leaves was counted in wood ash mulch and followed by straw mulch. Control always showed the least number of leaves. The maximum 41.78 number of leaves per okra plant was recorded from T_2 (wood ash), which was statistically similar with T_1 (rice straw) treatment. While the treatment T_3 gave the minimum 36.11 number of leaves okra per plant which was statistically similar with T_1 treatment (Figure 10). He found that high temperature and low light intensity accelerated the number of leaves per plant. Number of leaves was better for the chili on organic mulch than control reported by. M. Ashrafuzzaman, *et al.* (2011).

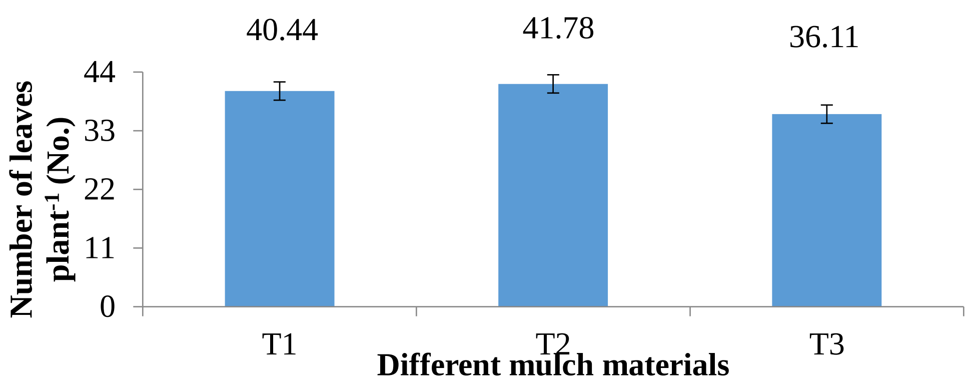

Figure 10. Effect of mulching on the number of leaves plant^{-1} of okra (LSD $_{(0.05)}$ = 4.19)

4.2.3 Stem diameter

The present study revealed that there was a highly significant effect of mulching on stem diameter of okra. Average highest stem diameter 10.39 mm was obtained from T_2 (wood ash) which was statistically similar with T_1 (rice straw) treatment and lowest stem diameter 8.223 mm from T_3 (control) which was statistically similar with T_1 (rice straw) treatment (Table 2). Favorable weather condition and moisture of the soil are the important parameters affecting on stem diameter of plant. Parmar *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield. Baten, *et al.* (1995) also obtained similar finding in garlic with indigenous mulch. This result clearly showed the stem diameter was gradually increased with the increasing mulching.

Table 2. Effect of mulching on the stem diameter of okra

Treatment	**Stem diameter**
	Okra
T_1	9.890 ab
T_2	10.39 a
T_3	8.223 b
CV (%)	9.23

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, $T_{1=}$ Straw mulch; $T_{2=}$ Wood ash; $T_{3=}$ Control

4.2.4 Length of fruit

Length of fruit had significant variation due to the application of different mulching. The maximum (15.67 cm) length of fruit were recorded from T_2 (wood ash) which was statistically similar with T_1 (rice straw) treatment. The T_3 (control) treatment gave the minimum (4.33 cm) length of fruit. Which was statistically similar with T_1 (rice straw) treatment (Figure 11). Parmar, *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield.

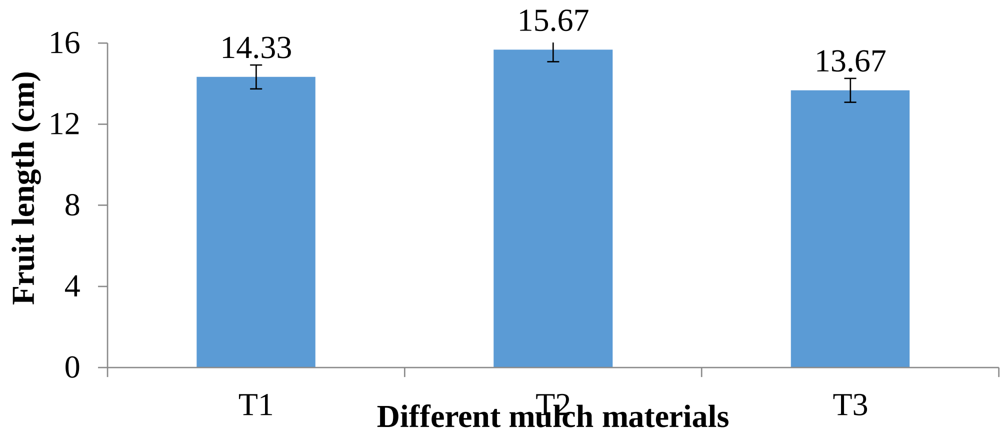

Figure 11. Effect of mulching on the fruit length of okra (LSD $_{(0.05)}$ = 1.63)

4.2.5 Fruit breadth (mm)

Fruit breath of okra was influenced by the mulching treatment. Statistically significant variation was found on fruit breadth due to different mulching materials. Fruit breath of okra was significantly different due to the application of different mulching. The highest (28.67 mm) breadth of fruit was recorded from T_2 (wood ash), while T_3 gave the minimum (18.00 mm) breadth of fruit (Table 3). This results revealed that the fruit breadth increase with mulching application. The surface mulch can change the quantity of light and spectral balance reaching plants, with resulting effects on plant growth. Plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield (Parmar *et al.* 2013). Baten, *et al.* (1995) also found that mulch had positive effect of increasing fruit breath compare with control.

Table 3. Effect of mulching on the fruit breath of okra

Treatment	Fruit breath
	Okra
T_1	21.00 b
T_2	28.67 a
T_3	18.00 c
CV (%)	5.33

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, $T_{1=}$ Straw mulch; $T_{2=}$ Wood ash; $T_{3=}$ Control

4.2.6 Individual fruit weight

Weight of individual fruit of okra was varied significantly for the application of different mulching. The highest weight of individual okra fruit (31.67 g) was found T_2 (wood ash). The lowest weight (25.33 g) was found T_3 (control) treatment (Table 4). Significant variation was recorded for the interaction effect of mulching for weight of individual fruit. Bhangu and Singh (1993) observed that mulched produced the largest fruit (66.69 g) compare with control.

Table 4. Effect of mulching on the fruit weight and fruit yield of okra

Treatments	Fruit weight (g)	Fruit yield (t ha^{-1})
T_1	29.00 b	10.80 b
T_2	31.67 a	13.48 a
T_3	25.33 c	8.583 b

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, $T_{1=}$ Straw mulch; $T_{2=}$ Wood ash; $T_{3=}$ Control

4.2.7 Total yield okra per hectare

Mulching produced more yield than control. It means that mulch had positive influence on yield of crops. The highest fruit yield of okra was recorded (13.48 t/ha)) of T_2 (wood ash). The lowest yield of okra was recorded (8.583 t/ha) of T_3 (control) which was statistically similar with T_1 (rice straw) treatment (Table 4). The results clearly showed that the fruit yield per hectare was increased with the using of mulching. Sreeck, *et al.* (1995) reported that soil temperature and yield were generally higher under mulch condition. Parmar *et al.* (2013) also found that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield.

4.2.8 Light Availability on okra Crop

Light availability on the okra plant in mulching and control crop plots was measured at 20 days interval over the growing season (Table 5). Significant variation of light intensity was recorded when okra cultivation on different mulching. The highest light intensity was observed (34.76 k.lux) from T_2 (wood ash) treatment which was statistically similar with T_1 (rice straw) treatment. The lowest light intensity was recorded (34.51 k.lux) from T_3 (control) treatment which was also statistically similar with T_1 (rice straw) treatment.

4.2.9 Soil moisture in okra field

The soil moisture (%) availability over the time (days after measurement) in tomato field was observed (Table 5). The significant variation of soil moisture was observed due to the application of different mulching. The soil moisture was reduced in control and increased in the mulch materials. The highest moisture recorded 27.94% in T_2 (wood ash) and the lowest moisture was recorded 22.19% in T_3 (control).

4.2.10 Soil Temperature in okra field

The significant variation of soil temperature in tomato field was observed due to the application of different mulching (Table 5). The highest soil temperature was observed (28.50 ^{0} C) from T_3 (control) treatment where soil moisture was found lower (31.43 %). The lowest soil temperature was recorded (25.60 ^{0} C) T_2 (wood ash) where soil moisture was found higher (35.88 %). Soil temperature is an important factor on okra crop production. It was found that mulching decreased the soil temperature and increased soil moisture which helped to increase okra production.

Table 5. Availability of light intensity, soil moisture and soil temperature on okra field

Treatments	Light intensity	Soil moisture	Soil temperature
T_1	34.71 ab	34.02 b	26.93 b
T_2	34.76 a	35.88 a	25.41 c
T_3	34.51 b	31.43 c	28.71 a
CV (%)	0.31	2.55	3.89

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, $T_{1=}$ Straw mulch; $T_{2=}$ Wood ash; $T_{3=}$ Control

4.3 Growth and yield performance of chili

4.3.1 Plant height (cm)

Different mulches showed significant variation on plant height of chilli. The maximum plant height of chili (30.08 cm) was recorded by T_2 (wood ash), which was statistically similar with T_1 (rice straw) treatment. The minimum plant (25.71 cm) was recorded by T_3 (control) which was statistically similar with T_1 (rice straw) treatment. Wood ash mulch showed superior performance in plant height than control (Table 6). Gunadi and Suwanti (1988) reported that mulching helped to increase plant height. Similar opinion was also put forwarded by Buitellar (1989). The increased plant height in mulched plants was possibly due to better availability of soil moisture and optimum soil temperature provided by the mulches. Changes in the plant height have been observed by using different mulches and plastic mulch increased the plant height than other mulches (Shinde *et al.*, 1999).

Table 6. Effect of mulching on the plant height of chili

Treatment	**Plant height**
	Chili
T_1	27.91 ab
T_2	**30.08 a**
T_3	25.71 b
CV (%)	5.13

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, T_1= Straw mulch; T_2= Wood ash; T_3= Control

4.3.2 Number of leaves per plant

Mulches has the positive effect on generating and retaining higher number of leaves per plant. The highest number of leaves was counted in wood ash mulch and followed by straw mulch. Control always showed the least number of leaves. The maximum 64.44 number of leaves per chili plant was recorded from T_2 (wood ash), which was statistically similar with T_1 (rice straw) treatment. While the treatment T_3 gave the minimum 56.33 number of leaves chili per plant which was statistically similar with T_1 treatment (Figure 12). The microclimatic condition improved by the mulches might have provided a suitable condition for producing higher number of leaves in the plants. This is an agreement with Calvert (1957). He found that high temperature and low light intensity accelerated the number of leaves per plant. Number of leaves was better for the chili on organic mulch than control reported by. M. Ashrafuzzaman, *et al.* (2011).

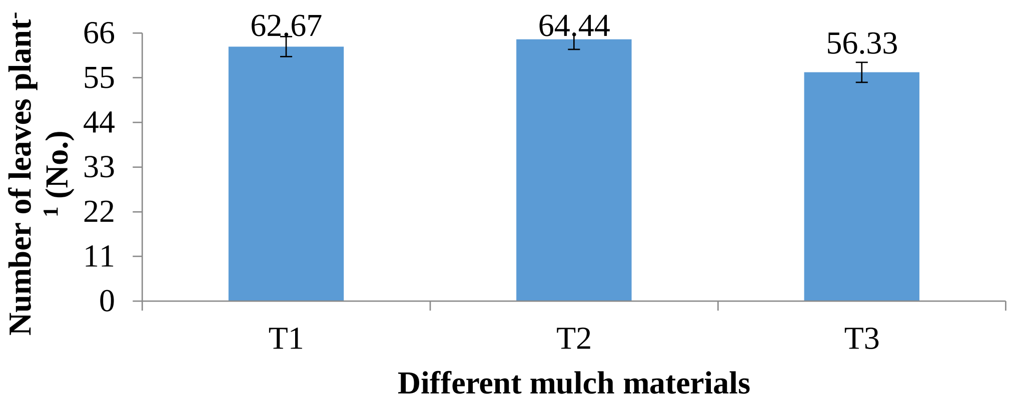

Figure 12. Effect of mulching on the number of leaves plant^{-1} of chili (LSD $_{(0.05)}$ = 4.91)

4.3.3 Stem diameter

The present study revealed that there was a highly significant effect of mulching on stem diameter of chili. Average maximum stem diameter of chili plant 5.557 mm was obtained from T_2 (wood ash) which was statistically similar with T_1 (rice straw) treatment and minimum stem diameter 4.893 mm from T_3 (control) which was statistically similar with T_1 (rice straw) treatment (Table 7). Parmar *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield. Baten, *et al.* (1995) also obtained similar finding in garlic with indigenous mulch. This result clearly showed the stem diameter was gradually increased with the increasing mulching.

Table 7. Effect of mulching on the stem diameter of chili

Treatment	stem diameter
	Chili
T_1	5.233 ab
T_2	5.557 a
T_3	4.893 b
CV (%)	4.82

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, T_1= Straw mulch; T_2= Wood ash; T_3= Control

4.3.4 Length of fruit

Length of fruit had significant variation due to the application of different mulching. The maximum (5.733 cm) length of fruit were recorded from T_2 (wood ash) which was statistically similar with T_1 (rice straw) treatment. The T_3 (control) treatment gave the minimum (4.33 cm) length of fruit. Which was statistically similar with T_1 (rice straw) treatment (Figure 13). Parmar, *et al.* (2013) reported that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield.

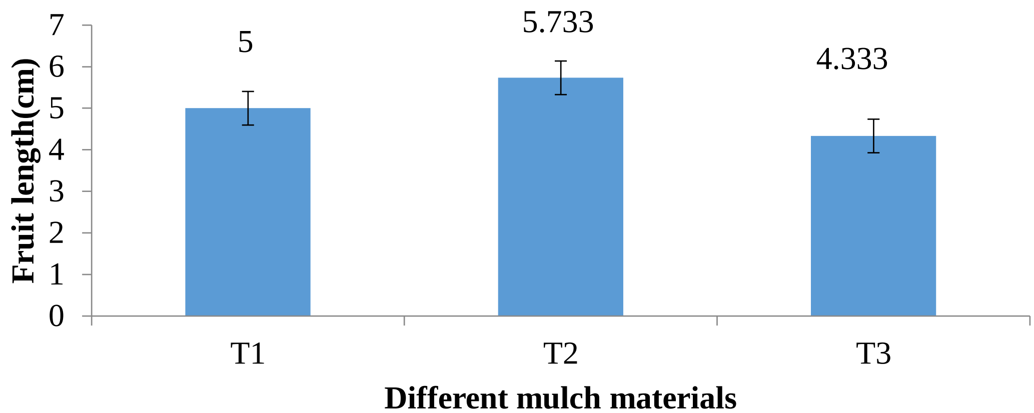

Figure 13. Effect of mulching on the fruit length of chili (LSD $_{(0.05)}$ = 0.64)

4.3.5 Fruit breadth (mm)

Fruit breath was not differed significantly due to the application of different mulching on chili. The highest (14.03 mm) breadth of fruit was recorded from T_2 (wood ash), while T_3 gave the minimum (13.77 m) breadth of fruit but they are statistically identical (Table 8). The surface mulch can change the quantity of light and spectral balance reaching plants, with resulting effects on plant growth. Plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield (Parmar *et al.* 2013). Baten, *et al.* (1995) also found that mulch had positive effect of increasing fruit breadth compare with control.

Table 8. Effect of mulching on the fruit breath of chili

Treatment	Fruit breath
	Chilli
T_1	14.03 a
T_2	14.73 a
T_3	13.77 a
CV (%)	5.13

In a column means having similar letter (s) are statistically similar and those having dissimilar differ significantly at 5% level, Where, $T_{1=}$ Straw mulch; $T_{2=}$ Wood ash; $T_{3=}$ Control

4.3.6 Individual fruit weight

Weight of individual fruit of chili was varied significantly for the application of different mulching. The highest weight of individual chili fruit (7.333 g) was found T_2 (wood ash). The lowest weight (5.33 g) was found T_3 (control) treatment (Table 9). Significant variation was recorded for the interaction effect of mulching for weight of individual fruit. Bhangu and Singh (1993) observed that mulched produced the largest fruit (66.69 g) compare with control

4.3.7 Total yield chilli per hectare

Mulching produced more yield than control. It means that mulch had positive influence on yield of crops. The highest fruit yield were recorded (2.800 t/ha) of T_2 (wood ash) and the lowest yield was recorded (1.900 t/ha) of T_3 (control). The results clearly showed that the fruit yield per hectare was increased with the using of mulching (Table 9). The mulched plot was probably associated with the conservation of moisture and improved microclimate both beneath and above the soil surface. The suitable condition enhanced the plant growth and development and produced increased yield compared to the control. Sreeck, *et al.* (1995) reported that soil temperature and yield were generally higher under mulch condition. Parmar *et al.* (2013) also found that all the plant growth, yield and quality characters were superior with mulch while, plants without mulch (control) resulted poor growth and yield.

Table 9. Effect of mulching on the fruit weight and fruit yield of chili

Treatments	Fruit weight (g)	Fruit yield ($t\ ha^{-1}$)
T_1	6.03 b	2.30 b
T_2	7.33 a	2.80 a
T_3	5.33 b	1.90 c
CV (%)	7.69	8.21

4.3.8 Light Availability on chili Crop

Light availability on the chili plant in mulching and control crop plots was measured at 20 days interval over the growing season (Table 10). Significant variation of light intensity was recorded when okra cultivation on different mulching. The highest light intensity was observed (34.76 klux) from T_2 (wood ash) treatment which was statistically similar with T_1 (rice straw) treatment. The lowest light intensity was recorded (34.51 klux) from T_3 (control) treatment which was also statistically similar with T_1 (rice straw) treatment.

4.3.9 Soil moisture in chili field

The soil moisture (%) availability over the time (days after measurement) in chili field was recorded (Table 10). The significant variation of soil moisture was observed due to the application of different mulching. The soil moisture was reduced in control and increased in the mulch materials. The highest moisture recorded 35.88 % in T_2 (wood ash) and the lowest moisture was recorded 31.43 % in T_3 (control).

4.3.10 Soil Temperature in chili field

Soil temperature (^{0}C) was recorded from various treatment in chili field and significant variation was found ((Table 10). In general, soil temperature was increased in bare soil. The highest soil temperature (28.71 ^{0} C) was recorded from T_3 (control) treatment where soil moisture was found lower (31.41 %). However the lowest soil temperature was recorded from T_2 treatment (25.41 ^{0} C). It was noticed that lower soil temperature helped to increased higher soil moisture which helped to increase chili yield.

Table 10. Availability of light intensity, soil moisture and soil temperature on chilli field

Treatments	Light intensity	Soil moisture	Soil temperature
T_1	34.71 ab	34.02 b	26.93 b
T_2	34.76 a	35.88 a	25.41 c
T_3	34.51 b	31.43 c	28.71 a
CV (%)	0.31	2.55	3.89

Plate 4: Tomato production

Plate 5: Yield of tomato

Plate 6: Treatment of experiment

Plate 7: Vegetative growth of okra plant

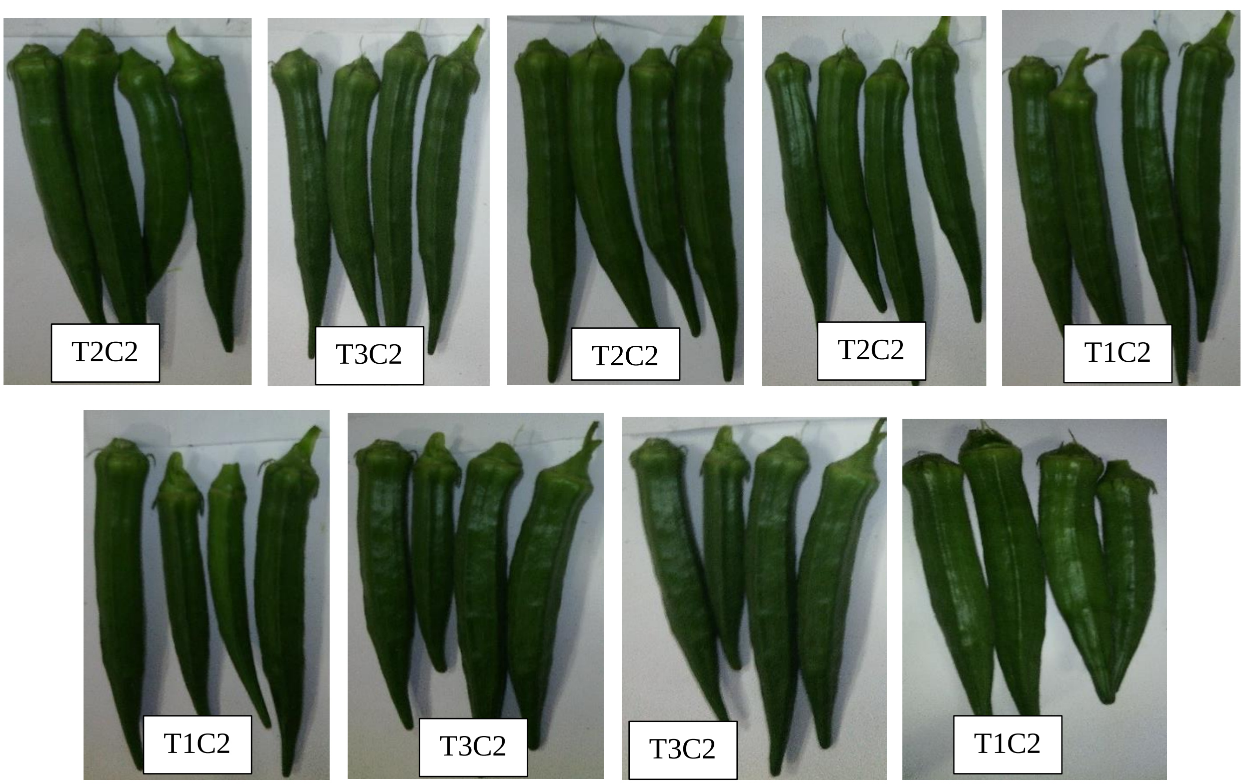

Plate 8: Yield of okra

Plate 9: Treatment of experiment

Plate 10: Vegetative growth of chili plant

Plate11: Yield of chili

Plate 12: Microclimatic instrument

Plate 13: Total view of the rooftop garden

CHAPTER V

SUMMARY AND CONCLUSION

Summary

The experiment was conducted at the roof of Biotechnology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2015 to July 2016. The experiment was laid out in Completely Randomized Design (CRD) having single factors with three replications. An area of 9 m x 4 m was divided into three equal blocks. Each block was consists of 9 plots where 2 treatments were allotted randomly. There were 27 unit plots in the experiment. The size of each plot was 1 m x 1 m, which accommodated 9 plants at a spacing 0.3 m x 0.3 m. The distance between two blocks and two plots were kept 1.0 m and 0.5 m respectively. The treatment of this experiment is $T_{1=}$ Straw mulch, $T_{2=}$ Wood ash $T_{3=}$ Control .The seeds of BARI tomato-3, BARI derosh-1 and BARI MORICH-1 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Plant height, stem diameter, number of leaves per plant, fruit length, fruit breadth, fruit weight, total fruit weight, and microclimatic data such as light intensity, soil temperature, soil moisture were significantly affected due to the application of different mulching treatment on rooftop garden.

Performance of tomato: The vegetative and reproductive characters of tomato were significantly influenced when cultivated on mulching. The tallest plant height (62.28 cm) were produced by T_2 (wood ash), The maximum (49.44) number of leaves per tomato plant was recorded from T_2 (wood ash), The highest plant diameter (10.11 mm) was recorded from the T_2(wood ash) treatment, The highest length (5.66 cm)of fruit was recorded from T_2(wood ash), The highest (65.00 mm) diameter of fruit was recorded from T_2 (wood ash), The highest weight of individual fruit (87.00g) was found from T_2 (wood ash) The maximum yield of fruit (29.18 t/ha) was obtained from T_2 (wood ash). The shortest plant (50.90 cm) was produced by T_3 (control) , the minimum (39.89) number of leaves per plant was found in T_3(control), the lowest stem diameter (7.55mm) was recorded from T_3(control), the lowest length of fruits is(4.333 cm) was recorded from T_3(control), the lowest weight (65.00 g) was observed from T_3(control). T_3 (control) gave the lowest (21.24 t/ha) yield.

Average soil temperature (^{0} C) in tomato field was recorded which significantly different due to the application of various mulching. The highest soil temperature for T_3 (22.32 ^{0}C) which was create negative effect on tomato yield. Average lowest soil temperature for T_2 (18.80^0 C) which influenced tomato yield. The highest moisture recorded 27.94% in T_2 (wood ash) and the lowest moisture was recorded 15.01 % in T_3 (control). It was found that availability of mulching on rooftop garden, vegetables production were increased because mulching helped to conserved moisture and temperature. Light intensity is available on tomato field.

Performance of okra: The tallest plant height (71.95 cm) was produced by T_2 (wood ash), The maximum (41.78) number of leaves per okra plant was recorded from T_2 (wood ash), The highest plant diameter (10.39 mm) was recorded from the T_2(wood ash) treatment, The highest length (15.67 cm) of fruit were recorded from T_2(wood ash) ,The highest (28.67 mm) diameter of fruit was recorded from T_2 (wood ash), The highest weight of individual fruit (31.67g) was found from T_2 (wood ash) The maximum yield of fruit (13.48 t/ha) was obtained from T_2 (wood ash). The shortest plant (64.33 cm) was produced by T_3 (control) , the minimum (36.11) number of leaves per plant was found in T_3(control), the lowest stem diameter (8.22 mm) was recorded from T_3(control), the lowest length of fruits is(, 13.67 cm) was recorded from T_3(control), the lowest weight (25.33 g) was observed from T_3(control). T_3 (control) gave the lowest (8.58 t/ha) yield.

Light intensity is available on okra field. Soil temperature were differed significantly due to the application of different mulching. Average highest soil temperature for T_3 (28.50^0 C) which was create negative effect on okra yield. Average lowest soil temperature for T_2 (25.60 ^{0} C) which increase okra production. The highest moisture recorded 27.94% in T_2 (wood ash) and the lowest moisture was recorded 22.19% in T_3 (control).

Performance of chili: Plant height of chili was significantly influenced by using mulching. The tallest plant height (30.08 cm) was produced by T_2 (wood ash), The maximum (64.44) number of leaves per chili plant was recorded from T_2 (wood ash), The highest plant diameter (5.55 mm) was recorded from the T_2(wood ash) treatment, The highest length (5.733 cm)of fruit was recorded from T_2(wood ash) ,The highest (14.73 mm) diameter of fruit was recorded from T_2 (wood ash), The highest weight of individual fruit (7.33 g) was found from T_2 (wood ash), The maximum yield of (13.48 t/ha) was obtained from T_2 (wood ash). The shortest plant (25.71 cm) were produced by T_3 (control) , the minimum (56.33) number of leaves per plant was found in T_3(control), the lowest stem diameter (4.89 mm) was recorded from T_3(control), the lowest length of fruits is(4.33cm) was recorded from T_3(control), the lowest weight (5.33 g) was observed from T_3(control). T_3 (control) gave the lowest (1.90 t/ha) yield.

Average highest soil temperature for T_3 (28.71 ^{0} C) which create negative effect on chili production. The lowest soil temperature of T_2 (25.41 ^{0} C) was recorded which increase chili yield. The highest moisture recorded 35.88 % in T_2 (wood ash) and the lowest moisture was recorded 31.43 % in T_3 (control). No significant difference of light intensity was found on the chili field

Conclusion

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

1. The yield components and yield of tomato, okra and chili were positively influenced by the use of wood ash and rice straw mulch on rooftop garden. The highest yield was produced from wood ash mulch.
2. Mulch materials help to conserved soil moisture and decreased soil temperature which create favorable climatic condition for crop production.
3. The results clearly showed that rooftop is suitable for vegetables production and the fruit yield per hectare was increased with the using of mulching at the rooftop garden.

The present study revealed that wood ash and straw mulch have potentiality to influence the yield of tomato, okra and chili under Bangladesh context as well as to increase total production per unit area of land. Moreover these two mulches are available with minimum cost in our country. Therefore it can be suggest that growth and yield of tomato, okra and chili may be increased by using wood ash and straw as mulching materials which create favorable climatic condition in soil environment.

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APPENDICES

Appendix I. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

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

Appendix II. Monthly meteorological information during the period from November, 2015 to April, 2016

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2015	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	0
2016	January	25.20	12.80	69	00
	February	27.30	16.90	66	39
	March	31.70	19.20	57	23
	April				

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. Analysis of variance of the data on plant height, leaf no., plant diameter, light intensity, soil moisture and soil temperature of tomato as influenced by different mulch materials

Source of variation	df	Mean square value					
		Plant height	Leaf no.	Plant diameter	Light intensity	Soil moisture	Soil temperature
Treatment	2	106.02*	75.089*	4.992*	0.772*	74.266*	47.862*
Error	6	10.01	9.667	0.592	1.115	0.159	1.000

*Significant at 5% level of significance

NS Non significant

Appendix IV. Analysis of variance of the data on plant height, leaf no., plant diameter light intensity, soil moisture and soil temperature of okra as influenced by different mulch materials

Source of variation	df	Mean square value					
		Plant height	Leaf no.	Plant diameter	Light intensity	Soil moisture	Soil temperature
Treatment	2	44.715*	26.333*	3.852*	0.354*	26.472*	6.551*
Error	6	10.539	4.401	0.768	0.287	0.127	0.155

*Significant at 5% level of significance

^{NS} Non significant

Appendix V. Analysis of variance of the data on plant height, leaf no., plant diameter, light intensity, soil moisture and soil temperature of chili as influenced by different mulch materials

Source of variation	df	Mean square value					
		Plant height	Leaf no.	Plant diameter	Light intensity	Soil moisture	Soil temperature
Treatment	2	14.323*	54.568*	0.330*	0.053*	14.959*	1.938*
Error	6	2.049	6.047	0.063	0.011	0.743	1.107

*Significant at 5% level of significance

^{NS} Non significant