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Effect of Different Roofing Materials on Growth and Yield of Tomato

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Abstract

High temperature, humidity, rainfall, and light intensity are limiting factors for tomato production. Types of roofing materials used for production can extend the growing season. In this study, effects of different types of roofing materials on yield and growth parameters of tomatoes were assessed. Growth parameters were recorded every 15 days after transplantation. Yield and its components were determined at harvest time. Differences on yield and growth parameters were compared using the Kruskal-Wallis test at $p < .05$. Plastic roofing produced better yield and quality fruit compared to other roofing materials during the experiment. However, the study needs to be extended to three seasons at different agro-ecological zones.

Keywords: humidity, roofing materials, temperature, tomato, yield

Introduction

Tomato (*Lycopersicon esculentumn* L.) belongs to the family Solanaceae and is a widely eaten vegetable in the world. It can be eaten fresh or in processed forms (Isah *et al.*, 2014). It is the most consumed non-starchy vegetable and is a source of dietary lycopene, a powerful source of antioxidants (Freeman and Reimers, 2010). It can give 45% of vitamin C and 20% of vitamin A. Tomato also contributes vitamin B, potassium, iron, and calcium to the diet (Anastacia *et al.,* 2011). It ranks second to potato in the world Food and Agriculture Organization ([FAO], 2015). Globally, the current production of tomatoes is approximately 130 million tons. China, the EU, India, the US, and Turkey are the top five largest producers and accounts for 70% of the total production.

Tropical and subtropical climates significantly reduce tomato yield due to unfavorable conditions such as high temperature, flooding, strong winds, and more pests and diseases (Palada *et al.,* 2003). Protected agriculture (PA) is a strategy that employs greenhouses, rain shelters, and net houses to produce crops profitably. PA differs based on the type of protective material used, the size and complexity of the structure, and the degree to which the environment is manipulated or controlled (Martin, 2015).

As per the Ministry of Agriculture and Forest [MOAF] (2017), the total production of to-

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matoes was 899 MT in 2014, 627 MT in 2015, 455 MT in 2016, and 383 MT in 2017, showing a rapid reduction in the total production in Bhutan. There was a reduction in production from about 38% in 2014 to 16.3% in 2017.

Overhead plastic roofing and net roofing are increasingly viewed as more sustainable than greenhouses because they require much lower initial capital investment. Temperature is generally lower compared to that of in greenhouse. However, yields and productivity are higher from greenhouses than that from open fields (Martin, 2015). Plants cultivated under other roofing materials keep the leaves drier, which reduces leaf diseases and pest infestation (Sideman, 2016). Other roofing materials also extend the growing season. Therefore, a field experiment was conducted to assess the growth and yield of tomatoes under different roofing materials.

Materials and Method

Study area

The field experiment was carried at the agricultural farm of the College of Natural Resources, Lobesa, under Punakha Dzongkhag, from July to October 2019. The area falls under the dry subtropical zone at an elevation of 1450 m asl. The area experiences hot and humid summer with heavy rainfall during the monsoon months of June, July, and August, while winter is moderate (Chophel and Dorji, 2014). The study site has an average annual rainfall of 890 mm with a maximum temperature of 36 ^{0}C and average humidity of 75% (National Center for Hydrology and Meteorology [NCHM], 2017). Plastic, agro-green, thatch straw, bamboo poles, watering can, spades, weeding hoes, data loggers (HOBO 1-800-LOGGERS), digital caliper, measuring tape, weighing balance, and refractometer were used.

The experiment was laid out in Randomized Complete Block Design (RCBD) with 12 experimental plots. Each experimental unit measured 4 m x 1 m with a 0.8 m space between each unit and 0.5 m between the replications. The plant to plant distance was maintained at 60 cm and 40 cm between row to row with 12 plants per plot. The total area comprised 83.2 m^2. The four treatments comprised of open field (T1), overhead white plastic (T2), agro-net roofing with 75% shading (T3), and thatch straw (T4). Each treatment was replicated thrice, and each experimental plot measured 4 m^2.

Seed and nursery preparations

Tomato seeds were sown on 31 June 2019 inside a shed house at the College agriculture farm. A packet of tomato seeds (10 g) of Ratan variety was broadcasted on a raised bed. The growing media was prepared from leaf mold and sand at a ratio of 2:1.

Field preparation

Field preparation including clearing of areas, bed preparation, and weeding was done manually. Compost (125 g/hill) was applied during transplanting, and a total of 18,000 g of compost was applied per plot.

Transplanting

Once the seedlings attained 10-12 cm height or 3-4 true leaf stage, seedlings were transplanted in a well-prepared seedbed. Transplanting of seedlings was done on 31 July 2019.

Sampling method

The plant samples for data collection and analysis were tagged using a simple random sampling method. Six plants in each plot were tagged; from every treatment, 18 plants (6 plants x 3 replications) were selected, making up to 72 sample plants from 12 plots.

Intercultural operation

Weeding and hoeing were done twice at 30 DAT [Days After Transplanting] and 60 DAT with the frequent clearing of surroundings. Pest management was done using the physical control method, whereas frequent pruning and staking were done for disease management. Irrigation was done twice per week in plastic and thatch straw roofing, depending on the soil moisture content. Irrigation for open field and shade-net were not required because there was frequent rainfall during the cultivation period.

Data collection and analyses

Data on growth parameters were collected four times at an interval of 15 DAT and yield and yield parameters at the time of harvest. Heights of sample plants (tagged) were measured using measuring tape from the base to the tip of the plants. The numbers of branches that developed from the main stem were counted, whereas, for the plant canopy, two opposite branches/leaves covering the widest land surface was measured. A Vernier caliper was used to measure the stem diameter at 2 mm above the ground level.

Data on yield and their components (fruit number, fruit weight, fruit height, fruit diameter, and TSS (Total Soluble Solid content) were measured at the harvest time. The fruit attaining light red stage (stage 5) were harvested from all the sample plants and counted plant-wise every week till the fourth harvest. From the total harvested plant samples, two representative fruits were measured for their length and width. In total, 36 fruits from each replication were used for measuring its length and width. Two representative fruits were measured using the auto weighing balance, and these fruits were used for assessing the TSS. Data were stored in Microsoft Excel 2007 worksheet. Yield, yield parameters and growth parameters were compared using the Kruskal-Wallis test ($p < .05$).

Yield measurement

The following formulae were used to calculate the yield:

Yield/plot = (Average yield of sample plant x total number plants/plot) kg

$$\text{Yield/m}^2 = \frac{\text{Yield/plot}}{\text{Area of the plot}} \ \text{kg/m}^2$$

$$\text{Yield/acre} = \frac{\text{Total yield/plot}}{\text{Area of the plot}} \ \text{x area of acre (kg/acre)}$$

$$\text{Yield/hectare} = \frac{\text{Yield/acre x 2.471}}{1000} \ \text{kg/ha}$$

Results and Discussion

Days to start of flowering and maturity after transplanting

The types of roofing materials significantly affected the number of days taken to initiate flowering ($H_{(1,3)} = 9.531$, $p = .023$) with mean rank of 2.67 in plastic, 4.5 in open field, 7.83 in agro -net and 11 in thatch straw roofing. The pairwise comparisons showed a significant difference ($p = .026$) between plastic (Median = 0) and thatch straw roofing (Median = 3) whereas there was no significant difference between other treatments. The potential reason for the difference could be attributed to the fewer days required to initiate flowering in plastic roofing. This finding is supported by Alemayehu (2017) who also reported that flowering in tomatoes is earlier in plastic roofing than in open fields.

In addition, the effect of treatments on the number of days to maturity was significant ($H_{(1,3)} = 10.458$, $p = .015$) with mean rank of 2 in plastic, 5 in open field, 8 in agro-net and 11 in thatch straw roofing. The pairwise comparisons showed a significant difference ($p = .013$) between the plastic (Median = 0) and thatch straw roofing (Median = 3), but there was no significant difference between other treatments. Plastic roofing had early maturity. This result corresponds well with the report that the flowering of tomato is earlier under plastic roofing material (Kelly *et al.* 2014).

Growth parameters

Plant height, stem diameter, plant canopy, and number of branches were measured for all treatments. There were no significant effects of roofing materials on the plant height, stem diameter, plant canopy and number of branches; $H_{(1,\ 3)} = 2.078$, $p = .556$ at 15 DAT, $H_{(1,\ 3)} = 6.171$, $p = .104$ at 30 DAT, $H_{(1,\ 3)} = .776$, $p = .858$ at 45 DAT and $H_{(1,\ 3)}$

= .671, p = .880 at 60 DAT.

Fruit numbers per plant

The effect of treatments on the number of fruits per plant was significant; $H_{(1,3)} = 9.359$, $p = .025$ with a mean rank of 9.67 for plastic roofing, 9.33 for open field, 5 for agro-net, and 2 for thatch straw roofing. The pairwise comparisons showed a significant difference (p = .039) between the thatch straw (Median = 0) and plastic roofing (Median = 3) whereas, there is no significant difference between other treatments. The highest mean rank of fruits per plant in plastic roofing could be due to a favourable environment during the flowering stage and occurrence of less pests and diseases. Palada *et al.* (2003) reported that plants in the plastic house generally give more fruits than in the open field. Conversely, the lowest mean rank of fruits per plant in thatch straw could be due to inadequate sunlight, where most of the plant nutrients are consumed for vegetative growth. As stated by Rajasekar *et al.* (2013), the other reason could be due to early catch-up of the plant by late blight disease before the plants complete full production cycle.

Fruit height and fruit diameter

There was a statistically significant difference between the treatments for the fruit height ($H_{(1,3)} = 8.967$, $p = .030$) with a mean rank of 10.33 in plastic roofing, 8.17 in the open field, 5.50 in agro-net, and 2 in thatch straw roofing. The pairwise comparisons showed a significant difference (p = .027) between plastic (Median = 3) and thatch straw roofing (Median = 0), whereas there was no significant difference between other treatments. According to Hochmuth (n.d.), plastic house controls environmental factors and favors the uniform growth of plants.

Similarly, different roofing materials significantly affect fruit diameter ($H_{(1,3)} = 8.273$, $p = .041$ with a mean rank of 10 in plastic roofing, 8.17 in the open field, 5.83 in agro-net roofing, and 2 in thatch straw roofing. The pairwise comparisons showed a significant difference (p = .039) between plastic (Median = 3) and thatch straw roofing (Median = 0), whereas there is no significant difference between other treatments. The lowest mean rank recorded in thatch straw roofing could be due to poor vegetative growth and inadequate sunlight as observed during the trial period. The Cooperative Extension Services (2010) suggested that fruit width directly relates to low photosynthesis rate and poor vegetative growth.

Individual fruit weight and total soluble solids (TSS)

There was no significant effect of treatments on the fruit weight ($H_{(1,3)} = 7.667$, $p = .053$) and TSS content of the fruits ($H_{(1,3)} = 3.205$, $p = .361$. TSS content in fruits depends on the number of fruits per plant. Gautier *et al.* (2001) stated that fewer fruits per plant reduce inter-fruit competition and more assimilates are diverted to fewer fruits.

Yield

Kruskal Wallis test showed a significant difference in the yield in tomatoes between treatments ($H_{(1,3)} = 8.556$, $p = .036$) with mean rank of 10.33 in plastic roofing, 7.67 in the open field, 6 in agro-net, and 2 in thatch straw roofing. The pairwise comparison showed a significant difference between plastic (median = 3) and thatch roof (median = 0) with p = 0.026, whereas there was no significant difference between other treatments. Agro-net and thatch straw roofing have a declining mean rank in yield. The result agrees with the study conducted by Nangare *et al.* (2015) where the shading effect (75%) reduces yield. Thatch straw roofing had the least yield. This could be due to the blockage of sunlight and rainfall by the straw.

Tomatoes in plastic-covered structures produced significantly higher yields and better quality fruits than in open field conditions (Alemayehu, 2017). Shao *et al.* (2015) supported that plastic roofing provides the best results by increasing the yield of tomatoes by

11.87 % compared to the open field.

Incidences of pest and diseases

High temperature and incessant rainfall during crop establishment encouraged incidences of some pests and diseases. Some of the pests recorded were caterpillars and tomato fruit borers, which belonged to the Noctuidae family. Pest incidences were more in open fields. Caterpillars were found feeding on the foliage of tomato plants. This could be due to direct exposure of plants to sun and rainfall, which provide favorable conditions for the growth of pests and diseases. In addition, fruit cracking was also observed in the open field. Except under plastic roofing, diseases such as late blight and fusarium wilt had infected plants in all other treatments due to prolonged humidity. In plastic roofing, plants were protected from the impact of rain droplets, which otherwise create suitable microclimates for the growth and development of diseases such as late blight (Alemayehu, 2017). The pest *Helicoverpa armigera* attacks tomatoes grown in open field (Nangare *et al*., 2015).

Conclusion

Yield and quality of fruits were better in plastic roofing. Tomatoes grown under the plastic roofing flowered and reached maturity early compared to other treatments. However, the effect of treatments on the growth and development of tomato plant was non-significant. Conversely, tomato fruits harvested from the open field were infested with pests and had fruit cracking. Thatch straw roofing was not suitable for tomato production due to poor penetration of sunlight. Thus, plastic roofing was the most suitable treatment for growing tomatoes due to its relatively higher yield potential from July to October. However, the result from the single study would be inadequate to draw a conclusion. Therefore, further research with repetition for three seasons spread over different agro-ecological zones can validate the current findings.

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