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Effect of Different Pruning Systems on Yield and Quality of Tomato Grown Under Greenhouse

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ABSTRACT

An experiment was conducted to assess the effect of different pruning systems on the yield and quality of tomatoes grown under greenhouse at the National Centre for Organic Agriculture, Yusipang for the growing period of March to November 2019. The experiment was conducted with a randomized complete block design with a single factor at three different levels viz. single leader system (T1), double leader system (T2), and unpruned plants (T3) which were treated as the control for the experiment. All the leaves and axillary shoots below the first flower cluster were pruned off. For treatment T1, only the main stem was encouraged to grow. As for the treatment T2, the sucker growing just below the cluster was also encouraged to grow along with the main stem. This sucker served as the second leader. No pruning of leaves or axillary shoots was carried out in the control plot (T3) at all times. The plants that were pruned started fruiting and maturing earlier than that of unpruned plants. It was also observed that the vegetative and reproductive growth of plants was lengthened by pruning. Although the plants pruned into a single leader system yielded higher than the double leader and the unpruned plants, no statistically significant differences were observed amongst the means of the total yield. The difference in the individual fruit weight, length and diameter amongst the treatments were also found to be statistically not significant. The findings from this research suggest that although pruning gives a higher yield than control there is no significant difference in the yield of tomatoes grown in greenhouse till the 6th harvest. Pruning the plants to a single leader system proved to improve the fruit quality substantially for tomatoes grown in the greenhouse.

Keywords: *Tomato Pruning; Yield; Fruit Quality*

1. Introduction

Tomato (*Solanum lycopersicon*) cultivars are annuals belonging to the Solanaceae family and are also sometimes grown as biennials. Tomatoes are among the most important and popularly grown vegetables in terms of economic, nutritional, and culinary values. The flowering habit of tomatoes ranges from highly indeterminate to highly determinate. Owing to its ability to self-pollinate, the crop is suitable for cultivation in greenhouse.

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In Bhutan, tomatoes are grown both under greenhouses and in open fields. Although the total cultivated land under tomato production has gradually increased over the years, the productivity is still considerably low in the country. The Agriculture Statistics 2017 (RSD, 2018a) reports 383 tons of tomatoes produced from 320 acres. This translates to a yield of 1.19 tons from an acre of land which is substantially low. Surprisingly, there is a stark decrease in both the cultivated area as well as production according to RSD (2020). The report highlights a total production of only 232.66 tons from an area of 148.05 acres. This production from within the country was unable to meet the consumer demand, so 2978.46 tons worth Nu.70.14 million of tomatoes was imported from India (RSD, 2018b), and a slightly lesser quantity worth Nu. 62.27 million were imported in 2019 (RSD, 2020).

Various confounding factors influenced by management practices and environmental conditions affect the yield. Ali and Moniruzzaman (2017) stated in their paper on the “Effect of Stem Pruning and Staking on Growth and Yield of Tomato” that yield which is also a genotypic expression is mainly governed by environment and other management factors. As is reflected in RSD (2018b) and RSD (2020) the yield of tomatoes varied amongst dzongkhags. The yield variation could have occurred due to different cultural practices and climatic conditions. The farmers usually grow tomatoes with no or minimal intercultural practices such as stem pruning. The yield, quality, and fruit size of tomatoes are influenced by many factors, including fruit pruning (Saglam & Yazgan, 1999), as well as stem pruning and cultivar selection (Maboko & Du Plooy, 2008). Several reports affirm the benefits of pruning on tomato yields under controlled conditions. Nonetheless, pruning needs and effects on yield depend on cultivar and place. Some literature recommends that tomato plants be pruned to one stem by removing all side shoots (Snyder, 2007). On the other hand, some reported an increase in yield when pruned to two stems (Aung, 1999). Borisoy, Borisova, and Belik (1978) recorded an increase in the yield/area by 10% to 15% when pruned to two stems rather than one.

These literatures confirm that the efficacy of the pruning systems differs by place and cultivar. In Bhutan, no such studies were carried out and farmers usually grow tomatoes without any pruning or management practices. Therefore, this experimental trial was conducted to determine the effect of pruning systems on the yield and quality of indeterminate tomatoes (Cosmic cultivar) under protected conditions in the temperate agroecology of Bhutan.

2. Materials and Method

This experimental research was conducted from March to October 2019 at the National Centre for Organic Agriculture (NCOA), Yusipang. The trial was conducted in a 20 x 5m^2 greenhouse. Cosmic hybrid, which is an indeterminate variety was used as the test material. The trial was laid out in a Randomized Complete Blocking Design (RCBD) with three replications and three treatments. The three treatments comprised different pruning systems: single leader system (one stem), double leader system (two stems), and unpruned (with multiple leaders). Each replication block measured 16.5 m in length and 1.2m in width comprising randomly distributed treatment plots of sizes 6.6 m^2. A spacing of 50 cm between each plot was kept while maintaining a spacing of 40 cm between two blocks. The plant to plant and row to row spacing was maintained at 50 cm; each treatment plot accommodated 24 plants.

Seeds were sown on 7th March 2019 under a polytunnel. The seedlings were transplanted after 47 days of sowing on 23rd April. After a month of transplanting all the plants were trained on strings tied down vertically from an overhead horizontal trellis placed at a height of 2m. Undesirable lateral branches and axillary shoots were pruned off depending on the treatments. For treatment 1, all the leaves and axillary shoots below the first flower cluster were pruned off as a result of which a single vine-like leader with no side shoots developed. As for treatment 2, all the leaves and suckers on the main stem were removed up to the first flower cluster except for the sucker growing just below the cluster. This sucker was encouraged to grow as the second leader. No pruning of leaves or axillary shoots was carried out in the control plot at all times. Irrigation and other intercultural operations were carried out as and when required. During the whole period of the trial, suckers were clipped off in treatment 1 and treatment 2 whenever required.

The first harvest was carried out on 26th July, 99 days after transplanting. Ten plants were randomly selected from each treatment plot and marked for data collection at each harvest. During each harvest, the individual fruit weight, fruit diameter, and fruit length were measured from 10 randomly selected fruits from the tagged plants. The total yield of each tagged plant and the treatment plot was also recorded during each harvest. Data were recorded from the first harvest to the sixth harvest. The harvest period spanned for approximately 3 months.

Although more than six harvests have been carried out, data was collected for six harvests only. This was due to the lack of adequate samples from control plots after the sixth harvest. Yield and yield parameters like fruit weight, length, and diameter were treated as dependent variables while the three treatments were treated as independent variables. The significance in difference between group means was evaluated using ANOVA while LSD *post hoc* test was conducted for multiple means comparison. Data were analyzed using Statistical Package for Social Sciences (SPSS). Data representation and graphs were carried out using Microsoft Excel.

3. Results and Discussion

3.1 Yield

3.1.1 Yield trend

There are considerable differences between yields of different treatments during all harvests except the third harvest where the differences appear negligible (Figure 1). From the total of six harvests that were assessed, plants pruned into single leader system yielded more than the other two systems for four harvests (Figure 1). During the fourth and sixth harvest, the unpruned plants with multiple leaders (control) yielded higher than the other two treatments. From Figure 1, it can be inferred that it is either the single leader system or the unpruned plants that yielded higher. The plants pruned to double leader system yielded slightly higher than unpruned multiple leader plants for three harvests while yielding lower for the other three harvests.

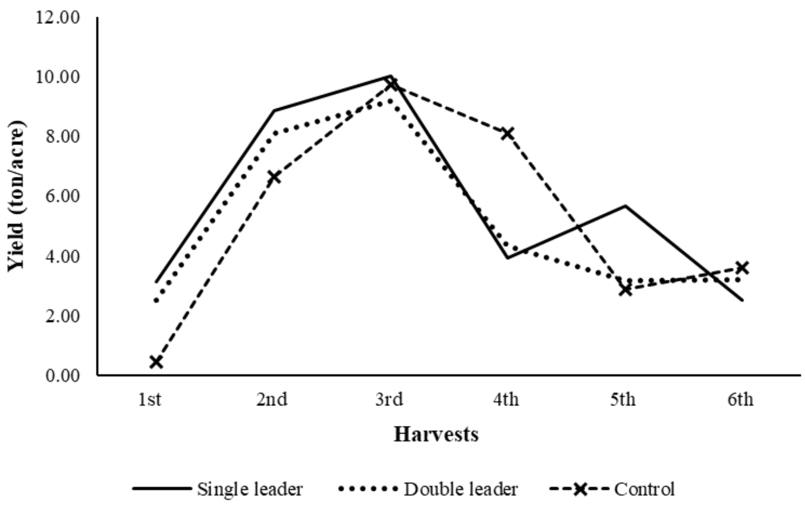

Figure 1. Yield /harvest from each treatment

The yield from pruned plants (single leader and double leader) was significantly higher than the yield from unpruned plants during the first and second harvests although there was no significant difference between the yields of single leader and double leader system plants (Table 1). A similar preliminary study conducted in 2018, published in *Sanam Drupdrey*

(MoAF 2020), revealed that the productivity of the plants grown with plastic mulching and pruned to single leader system gave the highest yield.

Table 1. Tomato yield from the three treatments during each harvest

Treatments	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Single Leader	3.15 ± 0.35^{a}	8.86 ± 0.42^{a}	10.02 ± 2.78^{a}	3.93 ± 1.93^{a}	5.66 ± 2.38^{a}	2.52 ± 0.57^{a}
Double Leader	2.52 ± 0.83^{a}	8.08 ± 0.82^{a}	9.17 ± 3.56^{a}	4.33 ± 2.19^{a}	3.15 ± 2.23^{a}	3.19 ± 0.14^{a}
Control	0.44 ± 0.11^{b}	6.64 ± 0.55^{b}	9.73 ± 2.29^{a}	8.09 ± 2.18^{a}	2.88 ± 0.74^{a}	3.62 ± 0.48^{a}
P-value	0.002	0.013	0.938	0.095	0.230	0.056

Values with different letters are significantly different according to LSD test at $P<0.01$. The yield means are in tons per acre.

The pruned plants started bearing fruits earlier than the unpruned plants. Apart from that, it was observed that the fruits in pruned plants started maturing earlier compared to those in unpruned plants. This onset of early fruit-bearing and maturity, according to Preece and Read (2005), can be the probable reason for the yields from the two systems being significantly higher than that of non-pruned plants during the initial harvests. Preece and Read (2005) further supplemented that pruning off excessive vegetative growth increases photosynthetic efficiency which results in earlier fruit maturity. This is in agreement with the findings of Mbonihankuye, Kusolwa, and Msogoya (2012) who observed that the fruits pruned into single-stemmed plants matured earlier than those with more stems. In a similar study carried out in Bangladesh, Ali and Moniruzzaman (2017) also observed that pruned plants matured earlier (79.27 days) than unpruned plants (90.27days).

Apart from delayed fruit maturity, it was also observed that the unpruned plants bore fruits later than the pruned plants. Attributing to this, Goda, Mohamed, Helaly, and El-Zeiny (2014) reported a higher early yield per plot due to the pruning treatments. Davis and Estes (1993) reasoned that fruiting is delayed in unpruned plants due to carbohydrates being partitioned to vegetative growth instead of reproductive growth for a longer period. Further, Mbonihankuye et al. (2012) stated that in addition to efficient carbohydrate partitioning, pruning also accelerates an increase in photosynthetic efficiency which results in earlier fruiting and maturity. On the other hand, yields from unpruned plants were significantly higher than that of single leader plants during the fourth and sixth harvests (Table 1). This is an indication that earlier fruit-bearing and maturity contributed substantially to the initial yields of pruned plants.

The result presented in Table 1 is in accordance with a report by Mondal, Puteh, and Razzaque (2016), which explains that single leader plants resulted in higher yield due to earlier fruit-bearing and maturity owing to increased reproductive efficiency caused by pruning. The study by Mbonihankuye et al. (2012) revealed that pruned and staked tomato plants produce flowers two to three weeks earlier than non-pruned plants, resulting in earlier fruit set and maturity.

Though data on the number of flowers were not collected, it was observed that the number of flowers borne by plants pruned to single stems was comparatively lesser than the plants with two stems and no pruning. This is in agreement with Mbinga (1983) who also found that the more severe the pruning, the lower the number of flowers per plant but the fruits were bigger. This led to the single leader system bearing comparatively lesser numbers but heavier and larger fruits. Single stem plants produced the highest fruit set followed by two stem and non-pruned plants according to Mbonihankuye et al. (2012). This is attributed to the improved fruit formation as a result of a better leaf-fruit ratio and correspondingly lesser competition in pruned plants. Ara, Bashar, Begum, and Kakon (2007) found the same results where they observed that the highest proportion of flowers formed fruits under a single stem system.

With the sixth observed harvest, the reproductive period of unpruned plants ended earlier than pruned plants. The sixth harvest was carried out on 18th September, 2019. Two more subsequent harvests that extended till 22nd October, 2019 were carried out in the single and double leader plants after the sixth harvest. It is indicative from the late onset of fruits and earlier cessation of the reproductive phase, that the reproductive period of unpruned plants is shorter by a month than pruned plants. The unlimited vegetative growth in unpruned plants can be a plausible cause for the short reproductive period. When the vegetative growth is excessive, the available assimilates for the reproductive growth is decreased which results in a shortened reproductive life of plants. Mbonihankuye et al. (2012) also reported a similar inference where the increase in available assimilates for fruit set will lead to an increase in the length of both the vegetative and productive periods. Mangal and Jasim (1987) showed that pruning of axillary shoots help in diverting the flow of nutrients towards the apical growing point. This improves plant growth which ultimately enhances the assimilation of materials like carbohydrates and proteins resulting in higher fruit yield and a longer reproductive phase. To supplement further, Hesami, Khorami, and Hosseini (2012) wrote that the lengthened growth of tomato plants may be attributed to the increase in the availability of nutrients, water, and light to plants enabled by pruning.

3.1.2 Total Yield

The overall yield produced by single leader plants is higher than the yields from other two treatments (Table 2).

Table 2. Yield/acre

Treatments	Yield (tons/acre)
Single Leader	35.68±5.17[a]
Double Leader	32.88±3.10[a]
Control	32.25±2.07[a]
P-value	*0.517*

Although a difference in the yield was observed between single leader and the other two treatments, the difference is not found to be statistically significant (Table 2). Similar studies conducted in other places also reported higher yields from pruned plants than from unpruned plants. However, these studies observed plants pruned into two stems yielding higher than plants pruned into single stem unlike the current study where single stemmed plants yielded higher. For instance, from similar research conducted in Dhaka by Sultana, Dilruba, Parveen, Kulsum, and Parvin (2016) a minimum yield (33.97kg/plot) from plants pruned to one stem and the highest yield (36.57 kg/plot) from double leader plants was reported. An experiment carried out in Bangladesh by Ali and Moniruzzaman (2017) also exhibited a higher yield (29.57 tons/ac) from the double leader system followed by triple leader system (27.99 tons/ac) with the lowest yield from single leader system (24 tons /ac). Another study carried out by Ara et al. (2007) in Bangladesh reported the highest yield from two stem pruning (38.35 tons /ac) and the lowest from no pruning (26.14 tons /ac).

Though no significant difference was observed from this study regarding total yield, the noticeable superiority of the single leader plants over the other two treatments is probable due to the subsequent reason. The other two treatments yielded lower than single leader plants due to competition between the stems within plants for water and nutrients, as well as root system limitations to cope with water and nutrient demand (Mourão, Brito, Moura, Ferreira, & Costa, 2017). As is indicative from Table 2, this resulted in single leader plants producing larger fruits and heavier fruits which ultimately increased the overall yield from plants pruned to a single stem. Nganga (1984, as cited in Mbonihankuye et al., 2012) reported a similar finding in his experiment that pruning resulted in a higher flower-fruit ratio in general, and it is suggested that a higher fruit: leaf ratio achieved on fewer leaves through pruning may enhance fruit yield production in a plant Similarly, Mbonihankuye et al. (2012) based on the study by Mnzava

(1984) argue that pruning to a single stem had the effect of increasing fruit set. Thus, a higher yield from the pruned plants during the initial stages eventually increased the overall yield of the single stemmed plants.

3.2 Fruit Quality

To assess fruit quality, parameters like fruit weight, length and diameter were taken into consideration.

3.2.1 Fruit Weight

Regarding fruit characteristics, it can be gathered from Table 3 that single leader plants produced bigger fruits that weighed higher than the ones from double leader and multiple leaders or unpruned (control) plants. However, the differences were not significant between the treatments in terms of individual fruit weight (Table 3). The comparatively higher fruit weight in plants pruned to single stem corroborates with the findings of Ara et al. (2007) who reported the highest fruit weight from plants pruned to one stem.

In a similar study conducted in Bangladesh by Ali and Moniruzzaman (2017), an observation that corroborates this result was made. They reported a maximum individual fruit weight (108.40g) from one stemmed plant (combined with staking) whereas the minimum fruit weight of 69.13g was observed in unpruned plants (with staking).

Hence, it can be inferred from these observations that pruning takes a vital part in enhancing the fruit size and weight. It is unmistakable that pruning a plant into a single stem reduces the number of potential fruiting branches, thus leading to a reduced number of fruits on a plant. This reduction in the number of fruits in single leader plants conceivably reduced the competition between fruits for assimilates which resulted in comparatively heavier fruits. Hence, it can be understood that the significantly heavier fruits compensated for the lesser number of fruits per plant in single leader plants. An observation made by Veliath and Ferguson (1972) validates this statement where it was observed that an increase in the total number of flowers and fruits has been shown to increase the competition for photosynthates which ultimately led to a decrease in fruit size and weight. The improved reproductive efficiency due to reduced competition and increased assimilates translocation to the sink (fruit) resulted in larger and good quality fruits in pruned plants than in unpruned plants (Mondal et al., 2016).

Apart from increased fruit size, as a response to the reduced fruit loads, fruit quality is also improved (Hesami et al., 2012). Muhammad and Singh (2007) also elucidated that unpruned plants produced smaller sized fruits that are of inferior quality because of the continuous partition of carbohydrates between vegetative and reproductive growth. Thus, results from research conducted in various places prove that proper balance between vegetative and reproductive growth which is an outcome of pruning could improve fruit quantity and quality (Arzani, Bahadori, & Piri, 2009).

3.2.2 Fruit Length

There are no apparent significant differences in the fruit length between all the treatments (Table 3), though plants pruned to single leader yielded a comparatively higher length of fruits than the two other treatments.

3.2.3 Fruit Diameter

In terms of individual fruit diameter, plants pruned to a single stem produced fruits of comparatively higher diameter followed by plants pruned to double and multiple leaders. The differences were found to be non-significant between the treatments, however.

Table 3. Fruit quality characteristics

Treatments	Fruit weight	Fruit length	Fruit Diameter
Single Leader	83.21 ± 19.85^{a}	57.25 ± 5.56^{a}	49.77 ± 4.64^{a}
Double Leader	74.51 ± 15.46^{a}	55.82 ± 4.34^{a}	47.80 ± 3.97^{a}
Control	69.45 ± 21.69^{a}	54.20 ± 6.40^{a}	46.29 ± 5.23^{a}
P- value	*0.104*	*0.260*	*0.088*

As per the Agricultural and Processed Food Products Export Development Authority (APEDA)(APEDA, 2017), India, tomatoes from all three treatments fall under the small category (fruit weight = <100g) for the international market. In the case of size, single leader and double leader plants produced tomatoes that fall under the size code 4 (Diameter: 47-56mm) while those from multiple leader plots fall under size code 3 (Diameter:40-46mm). According to these standards, all three treatments produced fruits that fulfilled the international market standards.

In addition, it was observed that unpruned plants were severely susceptible to blight. Similarly, according to Kanyomeka and Shivute (2005), tomato plants that were not pruned were attacked by early blight disease while the pruned ones were not affected at all. This can be attributed to the dense vegetative growth preventing efficient air movement and light penetration around the plants, thus making it favourable for the fungus to thrive and spread profusely. In conjunction with the observations made, a paper on Pruning and Staking Tomatoes by Chen and Lal (1999) states that Pruning (removal of side shoots and lower shoots) allows for efficient air circulation, thereby reducing the incidence of blight.

4. Conclusion

Although the pruned plants produced higher yields compared to unpruned, the difference is not statistically significant till the 6th harvest. Thus, till the 6th harvest, there is no significant effect of pruning on the yield of tomatoes as per this study. However, pruned plants produced comparatively bigger and heavier fruits, thus improving quality in terms of size and weight. In addition to enhancing the fruit quality, the results indicate that pruning enables earlier fruit set and maturity, and lengthens both the vegetative and reproductive growths of tomato plants.

Overall, this study indicates that pruning contributes to a slight increase in the yield compared to non-pruning, and it significantly enhances fruit quality and extends the harvest period.

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