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# Influence of Training and Tomato Hybrids on Growth, and Quality of Tomato under Shade Net House

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

This study examines the influence of different training systems and tomato hybrids on the growth, yield, and quality of tomatoes (*Solanum Lycopersicon* L.) under shade net house conditions. It was conducted at the Hi-Tech Horticulture Unit, Centre of Excellence for Vegetables, Karnal, during the 2016-17 growing season. The experiment followed a Factorial arrangement of treatments in Randomized Complete Block Design (FRBD) with two training systems (one-stem and two-stem) and four hybrids (STH-39, STH-901, STH-801, and STH-701). Growth results indicated that the one-stem system significantly enhanced plant height (270.08 cm), leaf area (77.06 cm²), and stem

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girth (1.75 cm), while the two-stem system increased the number of leaves (82.80 per plant). Hybrid STH-801 exhibited superior vegetative performance, with the highest plant height (309.03 cm), maximum number of branches (8.17), and largest leaf area (79.22 $cm^2$). In terms of quality parameters, the training systems had no significant effect on traits such as total soluble solids (TSS), pH, pericarp thickness, or shelf life. However, hybrid STH-801 recorded the highest TSS (5.47 °Brix) and longest shelf life (23 days). STH-39 produced the thickest pericarp (1.10 cm) and largest fruit volume (157 cc), contributing to better fruit quality. These findings highlight the importance of hybrid selection and training systems in improving both the growth and quality of tomatoes under protected cultivation.

*Keywords: Tomato hybrids; quality parameters; training systems; plant.*

## 1. INTRODUCTION

Tomato (*Solanum Lycopersicon* L.), a vital member of the Solanaceae family, is one of the most important vegetable crops cultivated worldwide known for its versatility, Tomatoes are consumed both fresh and in processed forms, making them indispensable to the global food industry. Their adaptability to various climates and growing conditions has led to extensive cultivation across regions such as the USA, the former USSR, Italy, China, Turkey, and India (Ram, 2005). While the tomato is originally native to South America, it has spread globally, becoming a staple crop in a multitude of regions. Over the years, thousands of tomato cultivars have been developed to optimize production for specific environments, fruit characteristics, and consumer preferences. Tomatoes are renowned for their high nutritional value. They contain a wealth of vitamins and antioxidants, including lycopene—a powerful antioxidant that has been linked to numerous health benefits—and vitamin C. Which plays a crucial role in immune system support and general well-being. The consumption of tomatoes has been associated with various health advantages, such as the promotion of blood purification, enhanced gastric health, and the prevention of certain types of cancer, particularly oral cancers (Ram, 2005). Due to these nutritional and medicinal properties, tomatoes hold an esteemed place not only in culinary traditions worldwide but also in health-conscious diets.

However, despite its widespread cultivation and high economic value, tomato production is subject to numerous challenges, particularly in tropical and subtropical regions. In countries like India, where the climate can be harsh during summer months, tomato cultivation faces significant hurdles. High temperatures during this period can severely hinder the process of fruit setting and lead to reduced yields (Berry & Uddin, 2003). This phenomenon is particularly detrimental in the Indian plains, where open-field cultivation dominates. While tomato yields may be abundant during the regular growing season, the excessive heat experienced during the summer drastically reduces productivity. Moreover, high temperatures often lead to a decline in fruit quality due to increased susceptibility to pests and diseases, further exacerbating the problem. The challenges of summer tomato production have led to a growing interest in protected cultivation methods, such as shade net houses. These structures provide a controlled environment that reduces the adverse effects of extreme heat by creating a favourable microclimate for tomato plants. Shade nets effectively reduce light penetration and temperature, which helps improve fruit set, yield, and overall quality during the summer season (Tiwari et al., 2002). By providing an alternative to open-field cultivation during the hot months, shade net cultivation offers a solution to the problem of low tomato availability during this period, allowing for the production of high-quality fruits that can command a premium price in the market. Indeterminate tomato hybrids, which exhibit continuous growth and can reach heights of 10 to 15 feet or more, are particularly well-suited for cultivation under protected structures such as shade nets. These hybrids utilize both the vertical and horizontal space within the structure, maximizing the use of the available area. They also have a higher yield potential compared to determinate varieties, making them ideal for commercial production. With proper care and training systems, these hybrids have been shown to produce yields of up to 180 tonnes per hectare in a six-month growing cycle (Russo, 1993). Training systems play a crucial role in optimizing the growth and productivity of indeterminate tomato plants under protected cultivation. Pruning and training plants to one, two, or three stems allow for closer spacing, improved air circulation, and easier management of the plants, including spraying and harvesting (Edmund et al., 1979). Such practices help maintain the health of the plants, reduce the risk of disease, and improve fruit quality. Additionally, proper training systems can enhance the efficiency of space utilization within the shade net house, further increasing productivity. In India, the majority of tomato production takes place in open fields, leading to a glut of tomatoes in the market during the regular growing season. This oversupply results in lower profits for farmers. However, during the summer months, when high temperatures hinder production, there is a shortage of tomatoes in the market, and prices rise. By adopting shade net cultivation, farmers can produce high-quality tomatoes during the off-season, when demand is high, thereby increasing their profitability. The use of indeterminate hybrids in conjunction with appropriate training systems offers a promising approach to maximizing productivity under these conditions.

## 2. MATERIALS AND METHODS

The investigation was carried out at Hi-Tech Horticulture unit, at the Department of Horticulture, Centre of Excellence for Vegetables Indo-Israel Project, Karnal during the year 2016-17. Karnal is situated in Northern Transitional Tract of Haryana state at 29.5424°N latitude and 76.9701° E longitude at an altitude of 213 m above mean sea level. Karnal is considered to be tropical region. The experiment followed a Factorial arrangement of treatments in Randomized Complete Block Design (FRBD) with two training systems (one-stem and two-stem) and four hybrids (STH-39, STH-901, STH-801, and STH-701).and a total of eight treatments. The study involved two key factors: tomato hybrids and training systems. Four tomato hybrids were evaluated in this experiment, designated as G1: STH-39, G2: STH-901, G3: STH-801, and G4: STH-701. Each hybrid was subjected to two different training systems: T1, where plants were trained using a single stem method, and T2, where plants were trained using a double stem approach. These combinations of hybrids and training systems were assessed to determine their influence on growth, yield, and fruit quality under shade net house conditions. The data collected in respect of various parameters on growth, yield and quality attributes were analysed statistically as described by Gomez and Gomez (1984). The critical difference (CD) values were calculated at 5% (p=0.05) probability level where F test was found significant.

## 3. RESULTS AND DISCUSSION

The present study evaluated the influence of different training systems and hybrids on various growth and quality parameters, including plant height, number of primary branches, number of leaves, internodal length, stem girth, leaf length, leaf width, and leaf area, Pericarp thickness ph, TSS, Locules per fruit, Shelf life (days) and Number of seeds per fruit. The results of the experiment are summarized below in Tables (1 & 2) and Figs. (1 & 2).

**Growth parameters:** The training system had a notable impact on the vegetative characteristics of hybrid tomato plants. Plants grown under a single stem training system exhibited significantly greater plant height (270.08 cm), a higher number of branches (7.78 per plant), increased internodal length (6.75 cm), longer leaves (15.10 cm), and a larger leaf area (77.06 cm²). This improvement in vegetative traits can be attributed to the optimal nutrient distribution achieved by removing other branches. Similar findings were reported by Mangal et al. (1981) for tomatoes in a plastic house and by Ramirez (1977) in tomato plants. In contrast, plants grown under a double stem training system had a significantly higher number of leaves (82.80 per plant), likely due to the additional stem allowing for more biomass accumulation. However, plants with a single stem exhibited the thickest stem girth (1.75 cm), which could be a result of improved photosynthate distribution, leading to a thicker stem. This phenomenon was also observed by Mangal et al. (1981).

Hybrid tomato plants grown under shade house conditions displayed significant variations in their vegetative traits. The STH-801 hybrid recorded the greatest plant height (309.03 cm), the highest number of branches (8.17 per plant), and the largest leaves (79.22 cm²). It also produced more leaves (85.67 per plant), while the STH-39 hybrid developed the thickest stem (1.78 cm). Additionally, the STH-901 hybrid showed the longest internodal length (6.96 cm) and had the largest leaf size (5.82 cm width and 15.40 cm length). These variations in vegetative characteristics among hybrids were noted by Hazarika and Phookan (2005). The increased plant height, branch number, leaf number, internodal length, stem girth, leaf width, leaf

**Table 1. Influence of training and tomato hybrids on growth of tomato under shade net house**

| Treatments | Plant height (cm) | Number of primary Branches per plant before pruning | Number of leaves per Plant | Internodal length (cm) | Stem girth (cm) | Leaf length (cm) | Leaf width (cm) | Leaf area ($cm^2$) |
|---|---|---|---|---|---|---|---|---|
| | | | | **Factor A (Training)** | | | | |
| **$T_1$ (One stem)** | 270.08 | 7.78 | 54.33 | 6.75 | 1.75 | 15.10 | 5.67 | 77.06 |
| **$T_2$ (Two stem)** | 260.41 | 7.68 | 82.50 | 6.51 | 1.63 | 14.64 | 5.59 | 73.40 |
| **SEm (±)** | 2.45 | 0.09 | 1.73 | 0.07 | 0.022 | 0.11 | 0.09 | 0.43 |
| **CD (P=0.05)** | 7.42 | NS | 5.25 | 0.22 | 0.067 | 0.34 | NS | **1.33** |
| | | | | **Factor B (Hybrids)** | | | | |
| **$G_1$ (STH-39)** | 160.03 | 7.17 | 38.17 | 6.03 | 1.78 | 14.76 | 5.48 | 70.13 |
| **$G_2$ (STH-901)** | 295.78 | 7.67 | 72.33 | 6.96 | 1.62 | 15.40 | 5.82 | 77.95 |
| **$G_3$ (STH-801)** | 390.03 | 8.17 | 85.67 | 6.92 | 1.70 | 14.42 | 5.56 | 79.22 |
| **$G_4$ (STH-701)** | 306.12 | 7.93 | 77.50 | 6.62 | 1.63 | 14.89 | 5.67 | 73.61 |
| **SEm (±)** | 3.46 | 0.12 | 2.45 | 0.10 | 0.02 | 0.16 | 0.61 | 0.62 |
| **CD (P=0.05)** | 10.50 | 0.36 | 7.43 | 0.30 | 0.07 | 0.47 | NS | 1.18 |
| | | | | **Interaction (Training x Hybrids)** | | | | |
| **$T_1G_1$** | 161.07 | 7.07 | 29.00 | 6.04 | 1.83 | 15.29 | 5.49 | 71.81 |
| **$T_1G_2$** | 300.93 | 7.73 | 52.00 | 7.12 | 1.69 | 15.49 | 5.81 | 78.44 |
| **$T_1G_3$** | 310.40 | 8.20 | 76.67 | 7.01 | 1.75 | 14.47 | 5.64 | 81.53 |
| **$T_1G_4$** | 307.90 | 8.13 | 59.67 | 6.84 | 1.71 | 15.15 | 5.77 | 76.45 |
| **$T_2G_1$** | 159.00 | 7.27 | 47.33 | 6.03 | 1.69 | 14.24 | 5.47 | 68.44 |
| **$T_2G_2$** | 270.63 | 7.60 | 92.67 | 6.80 | 1.62 | 15.32 | 5.84 | 77.47 |
| **$T_2G_3$** | 307.65 | 8.13 | 95.67 | 6.84 | 1.70 | 14.37 | 5.48 | 76.92 |
| **$T_2G_4$** | 304.33 | 7.73 | 95.33 | 6.39 | 1.68 | 14.64 | 5.87 | 70.77 |
| **SEm (±)** | 4.89 | 0.17 | 3.46 | 0.14 | 0.03 | 0.22 | 0.121 | 0.88 |
| **CD (P=0.05)** | 14.85 | NS | 10.51 | NS | NS | NS | NS | NS |

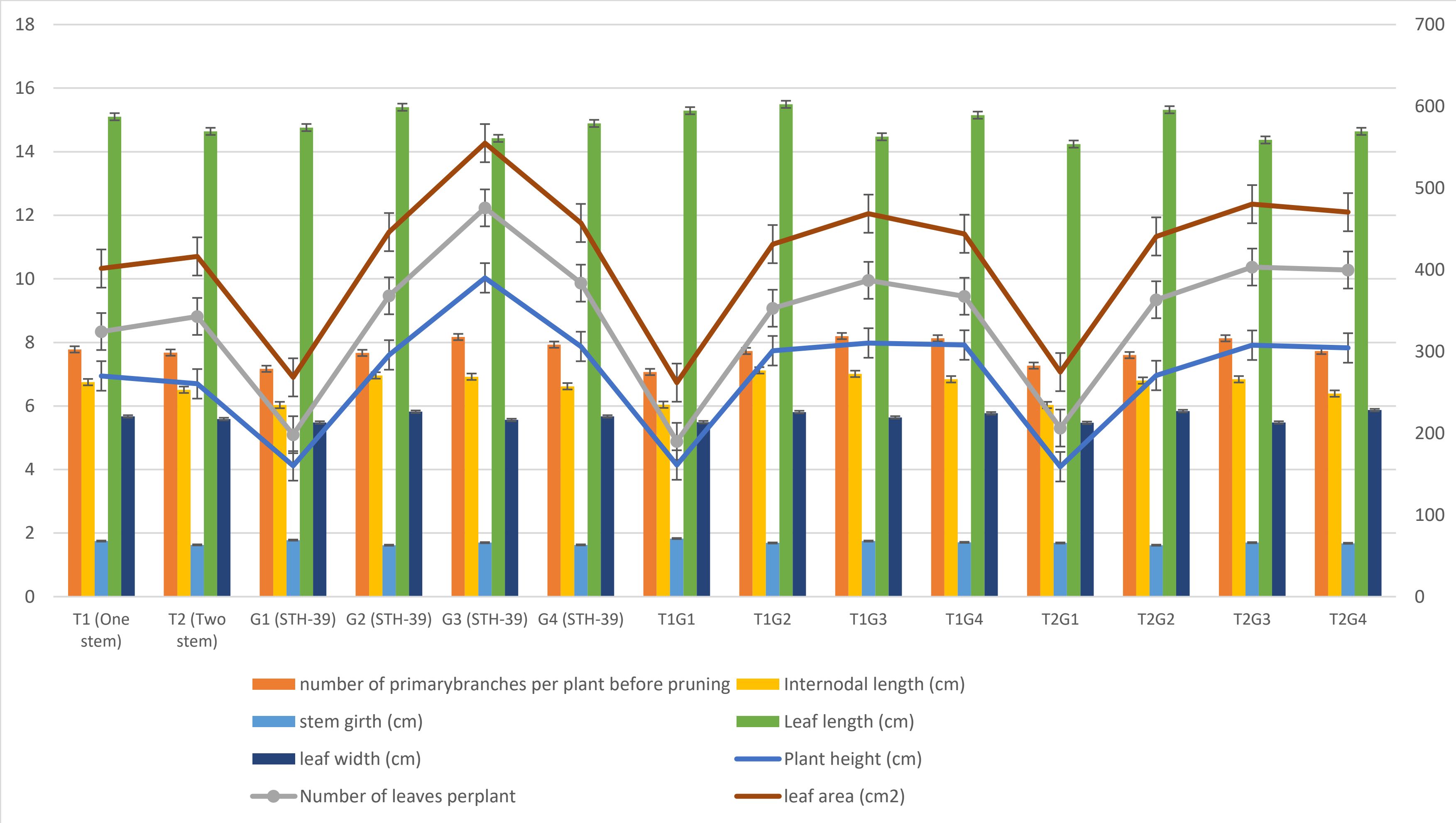


**Fig. 1. Influence of training and tomato hybrids on growth of tomato under shade net house**

**Table 2. Influence of training and tomato hybrids on quality of tomato under shade net house**

| Treatments | Pericarp thickness (cm) | pH | TSS (°B) | Locules per Fruit | Shelf life (days) | Number of seeds per Fruit |
|---|---|---|---|---|---|---|
| | | | **Factor A (Training)** | | | |
| **$T_1$ (One stem)** | 0.89 | 5.30 | 5.28 | 2.40 | 22.16 | 115.00 |
| **$T_2$ (Two stem)** | 0.85 | 5.28 | 5.27 | 2.55 | 22.17 | 114.00 |
| **SEm (±)** | 0.06 | 0.01 | 0.02 | 0.07 | 0.17 | 1.10 |
| **CD (P=0.05)** | NS | NS | NS | NS | NS | NS |
| | | | **Factor B (Hybrids)** | | | |
| **$G_1$ (STH-39)** | 1.10 | 4.20 | 5.18 | 2.53 | 23.00 | 53.50 |
| **$G_2$ (STH-901)** | 0.80 | 5.60 | 5.27 | 2.50 | 22.00 | 139.00 |
| **$G_3$ (STH-801)** | 1.00 | 6.20 | 5.47 | 2.50 | 23.00 | 141.50 |
| **$G_4$ (STH-701)** | 0.80 | 5.20 | 5.19 | 2.37 | 21.00 | 123.50 |
| **SEm (±)** | 0.08 | 0.02 | 0.03 | 0.09 | 0.24 | 1.55 |
| **CD (P=0.05)** | 0.24 | 0.06 | 0.10 | NS | 0.72 | 4.71 |
| | | | **Interaction (Training x Hybrids)** | | | |
| **$T_1G_1$** | 1.10 | 4.10 | 5.18 | 2.60 | 23.67 | 54.00 |
| **$T_1G_2$** | 0.60 | 5.63 | 5.19 | 2.50 | 21.33 | 138.00 |
| **$T_1G_3$** | 1.00 | 6.30 | 5.58 | 2.40 | 22.33 | 143.00 |
| **$T_1G_4$** | 0.80 | 5.17 | 5.17 | 2.10 | 21.33 | 124.00 |
| **$T_2G_1$** | 1.10 | 4.20 | 5.18 | 2.50 | 23.00 | 53.00 |
| **$T_2G_2$** | 0.90 | 5.57 | 5.35 | 2.50 | 22.00 | 140.00 |
| **$T_2G_3$** | 0.90 | 6.17 | 5.36 | 2.60 | 22.67 | 140.00 |
| **$T_2G_4$** | 0.80 | 5.17 | 5.21 | 2.60 | 21.00 | 123.00 |
| **SEm (±)** | 0.11 | 0.03 | 0.04 | 0.14 | 0.34 | 2.20 |
| **CD (P=0.05)** | NS | NS | NS | NS | NS | NS |

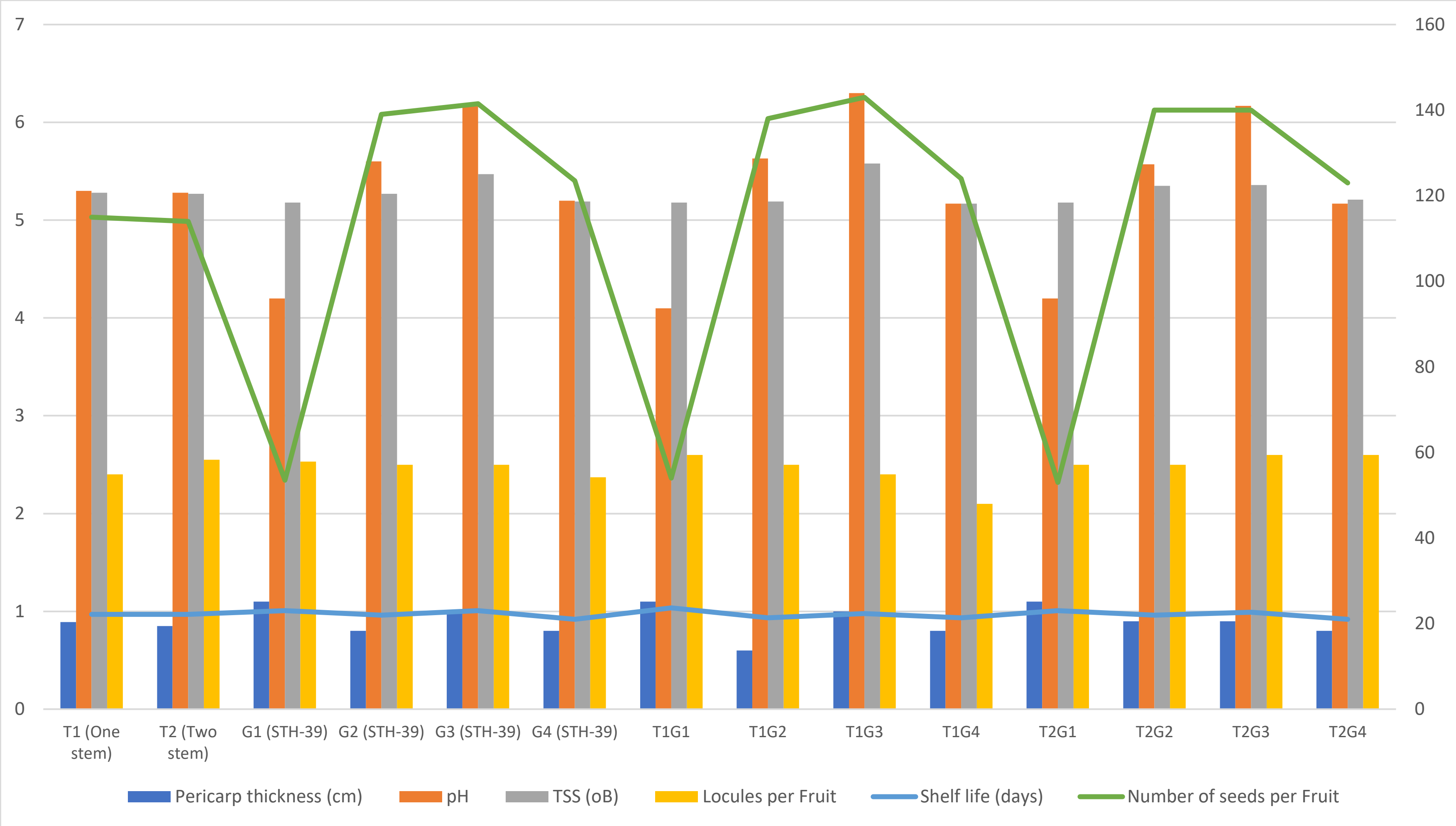


**Fig. 2. Influence of training and tomato hybrids on quality of tomato under shade net house**

length, and leaf area are likely due to the favourable microclimate provided by the shade house, which enhances growth by increasing metabolic processes such as photosynthesis and respiration, as well as improving plant acclimatization. These results are consistent with the findings of Papadopoulos and Ormrod (1991), Hazarika and Phookan (2005) in tomato plants grown under plastic rain shelters, and Choudhury and Bhuyan (1992), who observed enhanced growth parameters in tomato plants during early stages under shade house conditions. The interaction between hybrid tomato plants grown in shade houses and the training system showed no significant effect on vegetative parameters, except for plant height, where the STH-801 hybrid was significantly taller under both the single and double stem training systems (310.40 cm and 307.67 cm, respectively).

**Quality parameters:** The training system showed no significant effect on Total Soluble Solids (TSS), which ranged from 5.27 to 5.28, pH (5.28-5.30), shelf life (22.16-22.17 days), or pericarp thickness (0.85-0.89 cm). These findings align with those of Sandhu et al. (1999) for tomatoes. However, there were significant differences among the hybrids, which could be attributed to the genetic characteristics of each hybrid.

Tomato genotypes varied significantly when compared based on chemical or quality parameters. The STH-801 hybrid exhibited higher TSS (5.47 °Brix), a lower pH (6.20), longer shelf life (23 days), and greater pericarp thickness (1.00 cm). The extended shelf life is directly related to the increased pericarp thickness, while the other chemical parameters are primarily genetically controlled. Similar results have been reported by Rai et al. (1995) for capsicum under shade house conditions, by Hazarika and Phookan (2005) for tomatoes grown in polyhouses, and by Thangam and Thamburaj (2008) for tomatoes grown in shade houses.

The interaction between the training system and tomato genotypes was found to be non-significant for all treatment combinations. However, the STH-801 hybrid grown with a single stem training system recorded a higher TSS (5.58 °Brix) and pH (6.30). Meanwhile, STH-39 exhibited a thicker pericarp (1.10 cm) and longer shelf life (23.67 days) compared to other treatment combinations. The increased shelf life is attributed to the thicker pericarp and the single stem system, which produced fewer fruits per plant but allowed greater accumulation of photosynthates in the fruits. Similar observations were made by Sandhu et al. (1999) in tomatoes.

## 4. CONCLUSION

This study demonstrates that the selection of appropriate training systems and hybrid varieties plays a crucial role in optimizing the growth, yield, and quality of tomatoes under shade net house conditions. The double-stem training system significantly improved yield-related parameters, including the number of clusters per plant and overall yield per square meter, whereas the single-stem system enhanced vegetative traits such as plant height, leaf area, and stem girth. Among the hybrids, STH-801 exhibited superior performance in both growth and quality parameters, including the highest total soluble solids (TSS) and extended shelf life. These findings highlight the potential of integrating well-suited hybrids and training methods to maximize tomato production under controlled environments, particularly in regions with challenging climatic conditions.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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