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High Tunnel Cultivation: Evaluating the Growth and Productivity of Different Tomato Varieties

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Abstract
Tomato cultivation across various systems, including solar greenhouses and open fields, is vital for ensuring a continuous and diverse supply of fresh produce. This study aimed to evaluate the growth and yield performance of three tomato hybrids—Polfast F1 (V1), Rila F1 (V2), and Naslanda F1 (V3)—under high tunnel conditions in Bragadiru, Romania. Given the increasing importance of controlled environments in optimizing crop production, this research sought to identify the most suitable tomato hybrids for high tunnel cultivation. The experiments were conducted in Bragadiru, Ilfov County, Romania, over two growing cycles from April to July in 2022 and 2023. The data represent average results from both years. Key growth and yield metrics such as plant height, leaf development, fruit set percentage, and overall yield were analyzed. The findings revealed both positive and negative linear correlations between greenhouse conditions and productivity attributes. Naslanda F1 (V3) exhibited the tallest seedlings early in growth (27.3 cm) and the highest leaf count (9.6), while Polfast F1 (V1). At maturity, Rila F1 (V2) attained the greatest height (155.6 cm) and the highest leaf count (24.3), with Polfast F1 (V1) being the shortest (119.7 cm). Rila F1 (V2) also led in fruit set percentages, with 94.57% in the first inflorescence and 87.32% in the fifth, while Naslanda F1 (V3) had the highest fruit mass (0.240 kg) and yield per square meter (19.36 kg/m²). Additionally, Rila F1 produced the most fruits per plant (33.6). Strong correlations were found between plant height and both leaf number (R^2 = 0.794) and fruit mass (R^2 = 0.8938). These results indicate that Naslanda F1 and Rila F1 are particularly well-suited for high tunnel environments, offering substantial potential for enhanced productivity. This study underscores the importance of hybrid selection in maximizing crop yields within protected agriculture systems, thereby contributing to sustainable agricultural practices and food security.

Keywords: Tomato Hybrids, High Tunnel Cultivation, Controlled Environments, Plant Growth Performance, Yield Metrics

Introduction

According to the International Fund for Agricultural Development (IFAD), 70 percent of impoverished people in rural areas rely on agriculture for their livelihoods [1]. For these communities, agriculture is not just a means of income but also a critical source of food. Tomatoes hold a prominent position in global agriculture, ranking as the second most widely produced vegetable worldwide [2, 3]. It is a high-value crop, offer a reliable income stream due to strong market demand and relatively short growing cycle. Tomatoes enhance dietary diversity and provide essential vitamins and minerals, which are crucial for the health and well-being of rural populations. According to data from the Food and Agriculture Organization (FAO), global tomato production hit a record 182,258,016 tons in 2018, cultivated across 4,762,129 hectares with an average yield of 3.83 kg/m² [4]. Additionally, tomatoes contribute to food security by supplying a nutritious and versatile food source [5]. In Romania, 40,734 hectares are currently cultivating 742,899 tons of tomatoes, resulting in an average yield of 1.82 kg/m [6]. This placed Romania in 27th position globally, one of the lowest rankings among the 30 countries analyzed. Tomatoes (*Lycopersicon esculentum* Mill, var. cerasiforme) originate from Central and South America, particularly from Peru and Ecuador [7].

A hybrid model for high tunnel cultivation refers to the integration of various agricultural techniques and practices within high tunnels to optimize crop growth, improve yields, and extend the growing season. High tunnels, also known as hoophouses or polytunnels, are unheated greenhouses that provide a controlled environment for growing crops. High tunnels protect crops from extreme weather and allow control over humidity, temperature, and light, optimizing growth conditions [8]. Using raised beds or containers in high tunnels improves soil drainage and reduces disease pressure. Adding organic matter and customized nutrients boosts plant health and productivity [9]. Choosing the right crop varieties, especially hybrids, is key. Hybrids are favored for traits like disease resistance, higher yields, and adaptation to high tunnel conditions. For tomatoes, specific hybrids can improve fruit set, ripening uniformity, and disease resistance [9]. Efficient irrigation systems like drip or soaker hoses can be used in high tunnels to ensure consistent water supply and minimize waste, which is crucial for high-value crops like tomatoes [10]. Tomatoes (Solanum lycopersicum) are well-suited to high tunnel cultivation due to their need for a warm growing environment and their sensitivity to external weather conditions.

Tomato hybrids are important because they offer improved traits like higher yield, disease resistance, and better adaptability, which boost productivity and quality for growers. Tomato hybrids like 'Polfast F1', 'Rila F1', and 'Naslanda F1' perform well in high tunnels, offering early maturity, high yields, and disease resistance [11]. Their uniformity and enhanced performance make them valuable in both commercial and home gardening early maturity [12]. Proper temperature and humidity control in high tunnels is essential for tomato growth. Use ventilation, shade cloths, and thermal screens to manage these conditions effectively [13]. The increased demand for early-season F1 tomato hybrids, cultivated in protected environments, has led to a preference for imported seeds specially designed for controlled-temperature greenhouses and advanced technologies [14, 15, 16] established those high temperatures negatively impact tomato fruit development, with temperatures above 35°C potentially causing diminished fruit quality and difficulties in pollination and fruit setting. Also, the temperature and eatering is very important [17]. [18], identified tomato cultivars that exhibit a degree of tolerance to elevated temperatures, specifically those exceeding 30°C.

Measuring growth and yield attributes of hybrid tomatoes, such as plant height, fruit set percentage, and overall yield, is crucial for evaluating the suitability of high tunnels for vegetable production. These metrics provide insights into how well different tomato varieties perform in controlled environments, allowing growers to select hybrids that maximize productivity and quality. This data helps optimize high tunnel conditions, improving crop performance and resource efficiency. Accurate assessment of these attributes aids in refining management practices and supports more sustainable, profitable high tunnel systems [9]. The analysis of both the productive performance of varieties and their qualitative characteristics (such as fruit size, shape, color, and taste) is crucial for choosing the right assortment and ensuring production efficiency. [19], suggest that assessing how different varieties resist pest and disease attacks under controlled conditions is very important, as varieties with higher resistance can reduce the need for pesticide use and improve the overall health of the plants. [20], emphasize the importance of tomato variety adaptability for achieving optimal performance.

Material and Methods

The research was conducted in the town of Bragadiru, Ilfov County, Romania, during two growing cycles from April to July in 2022 and 2023. The data presented represent the average results from both years of cultivation. Bragadiru is situated in the vegetable-growing suitability zone I, subzone I, and is characterized by a continental climate with cold winters and warm summers, with thermal contrasts between day and night and between summer and winter. The average annual temperature is 11.5°C, with variations from an average of 23°C in summer to 1.5°C in winter. Annual atmospheric precipitation averages between 500 and 600 mm. In July, the average precipitation is about 60-80 mm, while in January it is 30-40 mm. The relative humidity of the air ranges between 55% and 65%.

Biological Material. The study used three indeterminate tomato hybrids, specifically intended for cultivation in protected environments.

Polfast F1 is an extra-early tomato hybrid with semi-determinate growth. The fruits are flattened-spherical in shape and very resistant to transportation. The color of the fruits is an attractive, uniform red. The average weight of each fruit is 150-160 grams.

Rila F1, the plant is resistant to tomato mosaic virus, verticillium wilt, fusarium wilt, and nematodes. The fruits weigh between 180-200 grams, are round, smooth, firm, and do not have a green cap. The plant requires staking, and the yield can reach 10-12 tons per hectare.

Naslanda F1, the fruits are very large, with a weight of approximately 280-300 grams. This hybrid has high tolerance to alternaria, septoria leaf spot, and anthracnose. It is suitable for both fresh consumption and preservation for winter.

Fig 1: Fructele hibridului Naslanda F1

Experimental Variants: The experiment was conducted in a greenhouse using the Polfast F1, Rila F1, and Naslanda F1 hybrids as follows in Table 1.

Table 1: Experimental Variants

Varianta experimentală	Hibridul
V 1	Polfast F1
V 2	Rila F1
V 3	Naslanda F1

Cultivation Method and Treatments: Seedling production and establishment of the tomato crop. Seeds were sown on March 20, 2022, and March 27, 2023, in Kekila peat substrate, at a depth of 1 cm and with a spacing of 1 cm between seeds. After covering with a loose layer of substrate and watering, the seed trays were covered with plastic film to maintain the necessary humidity for germination. Once the seedlings had developed their first cotyledon leaves and their first true leaves, they were transplanted into 7 cm pots using a mix of 70% peat and 30% biofertilizer. The seedlings were watered and kept under optimal conditions until planting, which took place at 55 days of age. Seedling maintenance included regular watering to keep the substrate moist, daily ventilation of the greenhouse, and three phytosanitary treatments. The first treatment was applied after sowing with Merpan 80 WDG 0.15%, the second after transplanting with Previcur Energy 0.1%, and the third with Topsin 500 SC 0.14% and Dithane M 45 0.2% Planting distances were 80 cm between rows and 35 cm between plants, resulting in a density of 35,714 plants per hectare.

Agronomic practices and Data collection: After planting, essential technological operations were carried out: staking, weekly pruning, drip irrigation, phase fertilization every 15 days, ventilation, phytosanitary treatments, fruit setting, and leaf removal. Gape filling was carried out 7 days after planting. Fertilization was done with diluted chicken manure extract and Cropmax, applied together with the phytosanitary treatments. During the course of the experiment, observations and measurements were made regarding:

- Seedling Characteristics at Planting: Evaluating the condition and size of seedlings at the time of plantin;
- Tomato Plant Height: Measuring the height of the tomato plants.
- Number of Leaves Per Plant: counting the total number of leaves formed on each plant.
- Number of Flowers in Inflorescence: counting the number of flowers present in each inflorescence.
- Number of Fruits in Inflorescence: counting the number of fruits set in each inflorescence.
- Percentage of Fruit Set: measuring the proportion of flowers that developed into fruits.
- Fruit Yield per Square Meter and per Plant: calculating the total fruit production per square meter and per plant.

Results and Discussions

At early growing stage, a detailed analysis of the tomato seedlings revealed significant variations among the different varieties in view to plant total height. Naslanda F1 (V3) appeared with highest length, with an average height of 27.3 cm, while Rila F1 (V2) followed closely at 26.8 cm, While Polfast F1 (V1) had the shortest stature, with 23.9 cm high on average. In terms of leaf count, Naslanda F1 (V3) also led with an average of 9.6 leaves per plant. Rila F1 (V2) had a slightly lower average of 9.4 leaves, and Polfast F1 (V1) had the lowest number of leaves, with an average of 8.2 leaves. In view to seedling diameter, Polfast F1 (V1) had the highest average diameter of 0.8 cm, followed by Naslanda F1 (V3) with an average diameter of 0.6 cm. Rila F1 (V2) had the smallest diameter, averaging 0.5 cm. These observations indicate that Naslanda F1 (V3) has a more robust structure in terms of height and number of leaves, whereas Polfast F1 (V1) demonstrates a thicker stem diameter, highlighting distinct growth characteristics among the varieties.

Table 2: Characteristics of tomato seedlings at the time of planting

Variant	The height seedling (cm)	The number of leaves (no.)	Seedling diameter at the base (cm)
V 1- Polfast F1	23.9 c	8.2 c	0.7 a
V 2 -Rila F1	26.8 b	9.4 b	0.5 ab
V 3 - Naslanda F1	27.3 a	9.6 a	0.6 ab

Fig 2: Seedling Development and Tomato Crop Growth in the Greenhouse Environment

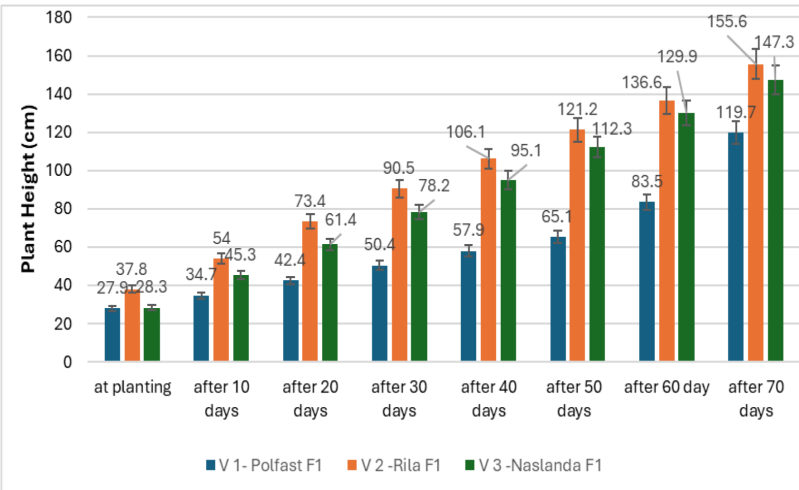

Fig 3: Dynamics of tomato plant height growth

At maturity, significant variations in the height of the tomato plants were also observed among the different varieties. Variant 2 exhibited the tallest growth, reaching an average height of 155.6 cm. This was followed by Variant 3, which measured 147.3 cm. In contrast, Variant 1 demonstrated the shortest stature, with an average height of only 119.7 cm. This reduced height in Variant 1 can be attributed to the semi-determinate growth habit of the Polfast F1 hybrid, as illustrated in Fig 3.

The number of leaves formed on the tomato plants varied significantly across the different variants (Fig 4). Variants 2 and 3 exhibited the highest leaf counts, with Variant 2 reaching an average of 24.3 leaves per plant and Variant 3 slightly surpassing this with 26.6 leaves per plant. In contrast, Variant 1 had the lowest leaf count, averaging only 17.6 leaves per plant. The dynamics of the average number of leaves over the vegetation period further highlight these differences (refer to Figure 2.5). For Variants 1 and 2, leaf growth was consistent and uniform throughout the entire vegetation period. However, in Variant 3, there was a noticeable deceleration in leaf growth towards the latter part of the vegetation period.

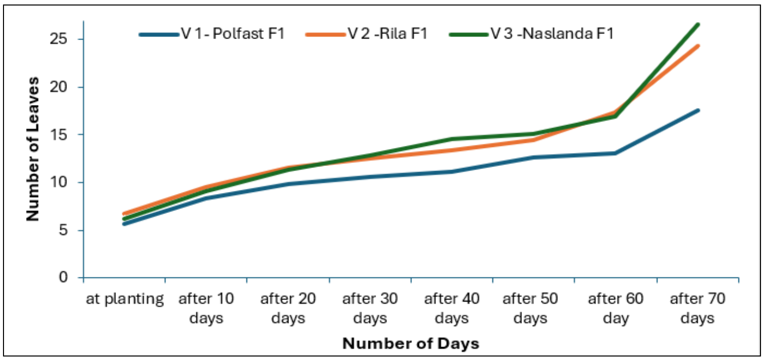

Fig 4: The number of leaves formed per plant

The fruit set percentage for variant V1 was observed to be lower than the general average of 83.08%. Specifically, the fruit set percentage for V1 was approximately 77.65%, indicating a relatively low fruit set rate compared to other variants. This performance is approximately 5.43% below the general average, suggesting that variant V1 has a lower efficiency in converting flowers into fruits compared to its counterparts. On the other hand, variant V2 exhibited a significantly higher fruit set percentage, surpassing the general average. The fruit set percentage for V2 was 94.57%, which is approximately 5.13% above the average. This superior performance indicates that variant V2 is more effective in converting flowers into fruits, potentially due to advantageous genetic or environmental factors.

Variant V3 demonstrated a fruit set percentage very close to the general average. The percentage for V3 was 83.40%, which is 0.30% above the average of 83.08%. This slight increase suggests that while variant V3 performs similarly to the average, it does not show significant improvement over other variants in terms of fruit set efficiency.

Table 3: Fruit set percentage in the first inflorescence (%)

Varianta	The evolution of the first inflorescence		Fruit Set Percentage (%)	Percentage Relative to Average (%)
	No. of flowers	No. of fruit		
V 1- Polfast F1	5.6	4.4	78.57	94.57
V 2 -Rila F1	7.9	6.9	87.34	105.13
V 3 -Naslanda F1	5.4	4.5	83.33	100.30
Media			83.08	

A varying fruit set percentages has been observed among different hybrid variants. The Polfast hybrid demonstrated a fruit set percentage of 78.41%, which is notably lower than the average fruit set percentage of 83.51% of all the varieties. This performance was approximately 5.10% below the average, indicating a less efficient conversion of flowers into fruits compared to the other variants. The Rila F1 variant exhibited a fruit set percentage of 86.90%, significantly higher than the average of 83.51%. This results in a percentage relative to the average of 103.08%, which suggests that Rila F1 outperforms the average by approximately 3.08%. This high performance highlights its better efficiency in converting flowers into fruits compared to the other hybrids. The Naslanda F1 variant also showed a higher fruit set percentage of 85.27%, which is slightly above the average of 83.51%. With a percentage relative to the average of 102.02%, Naslanda F1's performance is approximately 2.02% above the average. While this indicates a good efficiency in fruit conversion, it is marginally lower than that of Rila F1 (see Table 4).

Table 4: Percentage of fruit set at the second inflorescence (%)

Varianta	The evolution of the second inflorescence		Fruit Set Percentage (%)	Percentage Relative to Average (%)
	No. of flowers	No. of fruit		
V 1- Polfast F1	5.3	4.2	79.25	94.90
V 2 -Rila F1	7.9	6.8	86.08	103.08
V 3 -Naslanda F1	5.4	4.6	85.19	102.02
Media			83.51	

Analysis of the Polfast F1 hybrid revealed that the fruit set percentage for the third inflorescence was notably lower than the average for hybrids. Specifically, while the average fruit set percentage for hybrids was 81.75%, the Polfast F1 hybrid achieved a fruit set percentage of 92.79%. Despite this impressive figure, it represents a performance approximately 7.21% below the hybrid average, indicating a relatively lower efficiency in converting flowers into fruits compared to other variants.

In contrast, the Rila hybrid demonstrated the highest fruit set percentage among all variants, exceeding the average by approximately 4.20%. This superior performance underscores the Rila hybrid's efficiency in converting flowers into fruits, highlighting it as a highly effective and high-quality variant for fruit production.

Furthermore, the Naslanda hybrid recorded a fruit set percentage of 84.21%, which is above the general average of 81.75%. This corresponds to a performance level that is about 3.00% higher than the average, reflecting good efficiency. However, the Naslanda hybrid’s performance is slightly lower than that of the Rila F1 variant (see Table 5).

Analyzing the percentage of fruit set at the fourth inflorescence (Table 6), it is noted that there are significant differences between the variants. Thus, the highest percentage of fruit set is obtained in Variant 2, at 86.08%. Variant 3 achieves a fruit set percentage of 83.64%, while the percentage of fruit set in Variant 1 is the lowest, at 80.00%.

Regarding the fruit set percentage in the fifth inflorescence (as shown in the Table 7, Variant 2 ranks first with 87.32%, followed by Variant 3 with 83.67%. In the case of Variant 1, due to the determinate growth of the Polfast F1 tomato hybrid, the plants produced only four inflorescences.

Table 5: Percentage of fruit set at the third inflorescence (%)

Variant	**Evolution of the third inflorescence**		**Fruit Set Percentage (%)**	**Percentage Relative to Average (%)**
	Number of Flowers	**Number of Fruits**		
V 1- Polfast F1	5,8	4,4	75,86	92,79
V 2 -Rila F1	8,1	6,9	85,19	104,20
V 3 -Naslanda F1	5,7	4,8	84,21	103,00
Average			81,75	

Table 6: Percentage of fruit set at the fourth inflorescence (%)

Variant	**Evolution of the Fourth Inflorescence**		Fruit Set Percentage (%)	Percentage Relative to Average (%)
	Number of Flowers	Number of Fruits		
V 1- Polfast F1	**5.5**	**4.4**	**80.00**	**96.11**
V 2 -Rila F1	**7.9**	**6.8**	**86.08**	**103.41**
V 3 -Naslanda F1	**5.5**	**4.6**	**83.64**	**100.48**
Average			**83.24**	

Table 7: Percentage of fruits attached to the 5th inflorescence (%)

Variant	**Evolution of the Fifth Inflorescence**		Fruit Set Percentage (%)	Percentage Relative to Average (%)
	Number of Flowers	Number of Fruits		
V 1- Polfast F1	-	-	-	-
V 2 -Rila F1	**7.1**	**6.2**	**87.32**	**102.13**
V 3 -Naslanda F1	**4.9**	**4.1**	**83.67**	**97.87**
Average			**85.50**	

Fig 5: Appearance of tomato crops with Polfast, Rila and Naslanda hybrids

The Naslanda F1 hybrid exhibited the highest average fruit mass, reaching 0.240 kg per fruit, nearly twice that of the Polfast F1 hybrid, which averaged 0.128 kg per fruit. The Rila F1 hybrid showed an intermediate fruit mass, averaging 0.150 kg per fruit. These variations in fruit mass suggest potential genetic differences among the hybrids or differences in their adaptation to the growing conditions. Detailed comparisons of the fruit characteristics are illustrated in Figures 6 and 7.

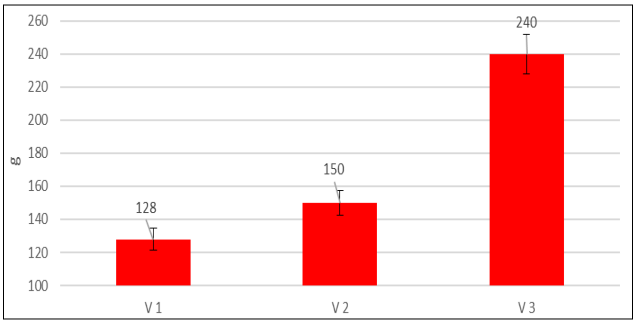

Fig 6: Average Fruit Mass

Fig 7: Appearance of tomato fruits

The evaluation of fruit production across different varieties revealed notable differences in both the number of fruits per plant and yield per square meter. Among the varieties tested, Rila F1 exhibited the highest average number of fruits per plant, producing an impressive 33.6 fruits. This is nearly double the production of Polfast F1, which averaged 17.4 fruits per plant. Naslanda F1 fell in between, with an average of 22.6 fruits per plant. This variation is significant for growers focused on maximizing total fruit production, as a higher fruit count per plant can substantially increase overall yield.

In terms of yield per square meter, which is a critical measure of space utilization efficiency, Naslanda F1 achieved the highest yield at 19.36 kg/m². Rila F1 followed with a yield of 17.99 kg/m². Polfast F1 demonstrated the lowest efficiency with a yield of 7.95 kg/m². This data is particularly valuable for growers with limited space, as it highlights which varieties can provide the highest yield per unit area.

Overall, Rila F1 and Naslanda F1 are advantageous for different production goals: Rila F1 for its high fruit count per plant and Naslanda F1 for its superior yield per square meter. These findings are crucial for optimizing both total production and space utilization in diverse growing environments (see Table 8).

Table 8: Fruit production

Variant	Total number of fruits per plant	Production	
		Per plant (kg)	Per m² (kg)
V 1- Polfast F1	17.4	2.23	7.95
V 2 -Rila F1	33.6	5.04	17.99
V 3 -Naslanda F1	22.6	5.42	19.36

There is a directly proportional correlation between the height of tomato plants and the average number of leaves, indicating that an increase in height correlates with an increase in the number of leaves ($R^2 = 0.794$)., Fig 8.

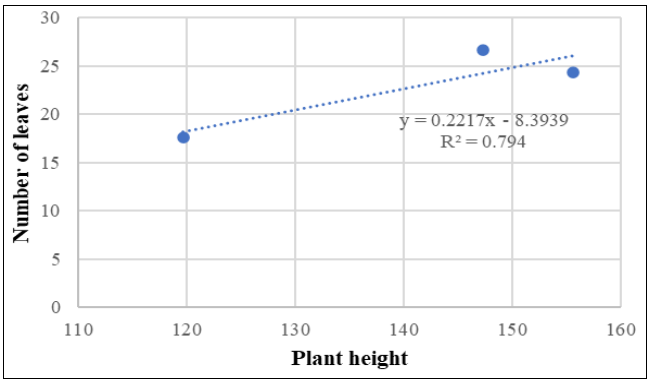

Fig 8: Relationship between plant height and number of leaves per plant

The correlation between plant height and fruit mass per plant indicates a direct relationship between plant height and the average fruit mass per plant. This means that plant height influences the number of tomatoes produced. The R^2 value of 0.8938 suggests a strong correlation, indicating that approximately 89.38% of the variation in fruit mass per plant can be explained by changes in plant height., Fig 9.

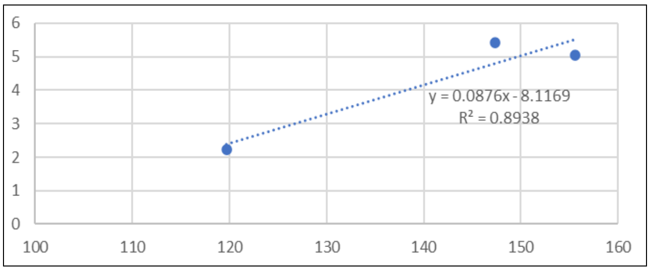

Fig 9: Relationship between plant height and fruit production per plant

Discussion

The analysis of tomato seedlings during the early growth stage reveals notable variations among different hybrid varieties in high tunnel environments with controlled conditions. High tunnels provide an optimal growing environment by modifying temperature, humidity, and other microclimatic factors, which are critical for tomato and other horticultural plants growth and yield [21, 22]. The findings of this study align with previous research that highlights the impact of controlled environments on the growth characteristics of tomatoes, particularly in hybrid varieties [23]. At the early growth stage, Naslanda F1 (V3) displayed the tallest stature, averaging 27.3 cm, followed closely by Rila F1 (V2) at 26.8 cm. Polfast F1 (V1) was shorter at 23.9 cm. This variation in height can be attributed to the genetic makeup of these hybrids and their adaptability to the controlled environment within high tunnels. Previous studies have demonstrated that hybrid varieties can exhibit significant differences in growth patterns under optimal conditions. For example, [24] reported that high tunnel environments promote taller plants due to the enhanced microclimate, which accelerates growth rates and elongation in certain varieties. The increased height of tomato varieties could be due to their higher photosynthetic efficiency and better resource allocation in such environments [25].

The number of leaves is a crucial factor in determining the photosynthetic capacity of the plant, which directly influences growth and yield. The robust leaf production in Naslanda F1 suggests a better potential for higher yield, as supported by previous research that correlates higher leaf count with improved fruit set and yield in tomatoes under controlled conditions [26]. Interestingly, while Polfast F1 showed a shorter stature and fewer leaves, it had the largest stem diameter at 0.8 cm. A thicker stem diameter often indicates better structural support and resilience, particularly in environments with high plant density or under stress conditions. This observation is consistent with findings from [27], who noted that thicker stems in tomato plants often correspond to greater resistance to physical damage and improved nutrient transport efficiency under high tunnel cultivation. In contrast, Rila F1 exhibited the smallest diameter, averaging 0.5 cm, which might suggest a more delicate structure that could be susceptible to mechanical stress but may still perform well in the controlled conditions of a high tunnel.

At maturity, significant height differences persisted among the varieties. Rila F1 (V2) reached the tallest height of 155.6 cm, followed by Naslanda F1 (V3) at 147.3 cm, while Polfast F1 (V1) remained the shortest at 119.7 cm. This reduction in height for Polfast F1 can be attributed to its semi-determinate growth habit, which inherently limits plant height. Such growth habits are often desirable in high tunnel systems where vertical space may be limited, and determinate or semi-determinate varieties can prevent overcrowding and ensure better light penetration and air circulation within the canopy [28].

The fruit set percentage is a critical indicator of a tomato plant's ability to convert flowers into fruits. The variations in fruit set efficiency among the hybrids reveal differences in their genetic makeup and adaptation to the controlled environment within high tunnels. For instance, the V1 variant showed a fruit set percentage of 77.65%, which is relatively low compared to other variants and the general average. This performance might suggest that V1 may not be the best choice for growers looking for high fruit set efficiency under similar conditions. In contrast, V2 exhibited a fruit set percentage of 94.57%, significantly above the general average, indicating its superior adaptation to the high tunnel environment. These findings align with previous research that highlights the importance of hybrid selection in achieving optimal fruit set. For example, studies by [29], emphasized that high tunnel environments, when combined with the right hybrid selection, could lead to substantial increases in fruit set and overall yield. The V2 and Rila F1 hybrids, which both showed high fruit set percentages, underscore the effectiveness of controlled environments in enhancing tomato productivity. Furthermore, the comparison between V3 and the general average suggests that while V3 performs slightly better than average, it does not offer significant advantages over other hybrids.

One of the most striking findings is the substantial difference in average fruit mass among the hybrids. The Naslanda F1 hybrid, with an average fruit mass of 0.240 kg, outperformed both Rila F1 and Polfast F1, indicating a possible genetic advantage or better adaptation to the specific growing conditions. This finding is consistent with the work of [30], who reported that high tunnels could enhance fruit size and quality due to the controlled environment reducing stress factors such as extreme temperatures and pest pressure. The significant differences in yield per square meter between the hybrids are also noteworthy. Naslanda F1 achieved the highest yield at 19.36 kg/m², which is crucial information for growers with limited space. This superior yield, compared to the lower performance of Polfast F1 at 7.95 kg/m², suggests that Naslanda F1 is a more space-efficient option for high tunnel cultivation. These results are in line with studies by [31], which found that certain hybrids could outperform others in high tunnel environments, particularly when it comes to maximizing yield per unit area. The positive correlation between plant height and fruit mass per plant ($R^2 = 0.8938$) suggests that taller plants tend to produce more fruits. This finding reinforces the idea that plant vigor, as indicated by height, is directly linked to fruit production. Previous research by [32], also supports this, showing that taller plants in controlled environments typically yield higher fruit masses due to more efficient resource allocation.

Present study findings are highly relevant for selecting the optimal growing model for tomatoes, particularly in high tunnel environments. For growers focusing on maximizing fruit count per plant, the Rila F1 hybrid stands out as a superior choice. However, for those prioritizing yield per square meter, Naslanda F1 would be the recommended variety. Additionally, the strong correlation between plant height and fruit mass per plant suggests that selecting for taller, more vigorous plants could further enhance yield. When compared to previous records of tomato growth in high tunnels, these results suggest that hybrid selection plays a more significant role than previously anticipated. Earlier studies, such as those by [33], primarily focused on the impact of environmental control on general tomato yield. However, this study highlights that the choice of hybrid can lead to substantial differences in both yield and fruit quality.

Conclusions

Tomato plant height and the average number of leaves were directly proportional; as plant height increased, so did the number of leaves. Plants with greater vegetative growth had more fruits per inflorescence and a higher fruit set percentage.In the first inflorescence, Variant 2 (Rila F1) had the highest fruit set percentage, followed by Variant 3 (Naslanda F1) and Variant 1 (Polfast F1). This trend continued in subsequent inflorescences. For the second inflorescence, Rila F1 outperformed with a fruit set percentage 3.08% above average, while Naslanda F1 was slightly above average and Polfast F1 below average.

In the third inflorescence, Rila F1 maintained its lead with an 85.19% fruit set percentage, followed by Naslanda F1 at 84.21%. Polfast F1 had the lowest at 75.86%. For the fourth inflorescence, Rila F1 again showed superior performance with an 86.08% fruit set percentage, while Naslanda F1 was near average and Polfast F1 at 80.00%. Overall, Naslanda F1 was the most efficient in terms of production per plant and per square meter, thanks to its high fruit mass and number. Rila F1 also had a high fruit yield per plant, though slightly less efficient per square meter. Polfast F1, despite fewer and smaller fruits, may offer advantages like a shorter maturation time. Present study findings underscore the importance of selecting the right hybrid variety for high tunnel tomato production. By choosing hybrids like Rila F1 or Naslanda F1, growers can optimize both fruit production and space utilization, leading to higher efficiency and profitability in tomato cultivation under controlled environments.

Conflicts of Interest

The authors declare no conflicts of interest.

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