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Effect of different rootstocks and scion ages on the productivity of screenhouse grown tomato (*Solanum lycopersicum*)

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ABSTRACT

This study aimed to assess the impact of utilizing diverse rootstocks grafted with scions of varying ages on the growth, yield, and fruit quality of tomatoes. Employing a Completely Randomized Design (CRD), the experiment featured three replications per treatment in a two-factor design. Results revealed that a 30-day-old scion exhibited a highly significant difference in tomato height gain at 15 and 30 days after transplanting (DAT) and statistically mirrored the performance of a 21-day-old scion at 60 DAT. A 25-day-old scion grafted onto wild eggplant demonstrated the greatest height gain among grafts but did not surpass the height of non-grafted tomatoes. Notably, the 30-day-old scion significantly influenced tomato height at 15 and 30 DAT. The 25-day-old scion of wild eggplant exhibited the highest height gain but failed to surpass the non-grafted tomatoes. A 21-day-old scion of eggplant yielded the highest plant and 240 sqm-based tomato yields. Interaction analysis revealed that a 30-day-old scion of eggplant produced the highest yield. Additionally, the 25-day-old scion of wild eggplant resulted in the largest fruit diameter, while the 21-day-old scion of black nightshade displayed the highest sugar content. Different scion and rootstock combinations yielded varying percentages of fruit color. Optimal profitability was achieved with a 30-day-old scion of eggplant, offering the highest net income, while the highest return on investment (ROI) was achieved with a 21-day-old scion of wild eggplant. Findings emphasize the importance of carefully selecting scion age and rootstock combinations to optimize tomato growth, yield, and quality, ultimately enhancing profitability in tomato cultivation.

Contribution/ Originality: This study investigates the productivity of tomatoes grown in screenhouses, specifically exploring the impact of different rootstock and scion ages. The research adopts a methodology using a Completely Randomized Design (CRD) with three replications for each treatment in a two-factor experiment.

1. INTRODUCTION

The cultivation of tomatoes (*Solanum lycopersicum L.*) is a crucial aspect of global agriculture, providing a versatile and widely consumed vegetable that plays a vital role in various cuisines worldwide. In addition to being a main ingredient in many recipes, tomatoes are also the raw material for a wide variety of processed goods, such as juices, pastes, ketchup, and sauces. Their importance in both culinary and economic contexts has spurred extensive research efforts aimed at improving tomato production and quality. In the Philippines, tomatoes, locally known as

"Kamatis," belong to the solanaceous family and are considered one of the edible berries. Typically reaching heights of one to three meters, tomato plants have delicate stems and require support. The cultivation of various tomato varieties in greenhouses has facilitated year-round production. Recent statistics indicate that tomato production in the Philippines, particularly from October to December 2020, totaled 26 thousand metric tons, reflecting a 7.6% decrease compared to the previous year. Notably, Northern Mindanao played a significant role, contributing 57.1% to this quarter's output, followed by the Ilocos Region (9.1%) and the Zamboanga Peninsula (7.5%). However, Cagayan Valley ranked eighth, producing 0.53 thousand metric tons [1]. Tomato producers often encounter production challenges related to soil-borne and foliar diseases, including early blight, late blight, leaf molds, bacterial wilt, and viruses such as tomato leaf curl virus. Inadequate water supply in the soil and atmosphere also significantly impacts tomato yield, size, and quality, with the dry season presenting a common problem in region 2 for tomato production. Environmental stressors, particularly temperature fluctuations, pose additional challenges for tomato cultivation in tropical regions. To mitigate these challenges and improve tomato production, the implementation of agricultural infrastructure, such as screenhouses, has gained importance. Despite requiring initial investment, screenhouses offer numerous advantages, including replicating plant populations seen in open field areas, reducing production risks, enhancing pest control, enabling year-round production, and providing stability and security. Screenhouses, characterized by their insect screening material coverings, offer environmental control and protection from extreme weather conditions and pests, making them particularly suitable for hot and tropical climates.

Grafting, a technique that involves joining a scion plant with desired fruit properties onto a rootstock plant with disease resistance, stress tolerance, or robust root system characteristics, has gained prominence in vegetable cultivation worldwide. Initially used in Japan in the late 1920s to combat soil-borne diseases in cucurbits, grafting is now employed in the Solanaceae and Cucurbitaceae families as well. Grafting has a number of benefits, including better drought tolerance, improved water utilization, resilience to severe temperatures, improved nutrient absorption, increased yield in less productive soils, and higher flower and seed output.

Numerous studies have reported that the interaction between rootstocks and scions can lead to increased root vigor, greater water and mineral intake, and, subsequently, improved yield and fruit quality. The urgent need for sustainable and effective tomato production techniques in the face of evolving environmental challenges, such as changing climate patterns and the rising prevalence of pests and diseases, emphasizes the significance of this study. Moreover, the study aligns with the broader global agenda of enhancing food security and ensuring a consistent supply of nutritious, high-quality produce to meet the demands of a growing population.

The journey through this research unfolds a comprehensive investigation into the effects of various rootstocks and scion ages on the growth, yield, and quality of screenhouse-grown tomatoes. Through rigorous experimentation, meticulous data collection, and robust analysis, this study endeavours to unearth novel strategies and best practices that harness the full potential of screenhouse cultivation for tomato production. Ultimately, the findings of this research hold the promise of contributing to sustainable agriculture and bolstering the resilience of tomato cultivation systems, thus advancing the field of horticulture and addressing the global challenge of ensuring a reliable and consistent supply of this indispensable vegetable.

This study evaluates the effects of scion age and rootstock on tomato growth and yield, providing information about how to maximise tomato output for both profitability and quality.

2. MATERIALS AND METHODS

The study was conducted at the Nursery Farm Screenhouse located at Isabela State University (ISU) Compound Garita, Cabagan Isabela, on November 4, 2021, and February 27, 2022. In this study, we used hybrid tomato seeds from a multinational company with a yield potential of 2–3 kilograms per plant. Hybrid tomato seeds from a multinational company, boasting a yield potential of 2–3 kilograms per plant, were utilized in the study.

With a density of 20,000 plants per hectare, the anticipated yield ranged from 40 to 60 tons per hectare. This particular tomato variety exhibited adaptability and vitality in tropical climates, featuring medium-sized, round, and firm fruits with exceptional disease and heat resistance. The fruits matured 60–65 days post-transplant. For seedling production, a soil mixture of sieved garden soil, carbonized rice hull, and vermicompost in a 1:1:1 ratio was sterilized and placed in seedling trays. Seeds were sown, staggered every 5 days, and the trays were shaded until seedlings emerged. 15 days after sowing, the seedlings were drenched with a calcium nitrate solution. Grafting occurred at 21, 25, and 30 days after sowing using cleft grafting techniques. After 14 days of healing and 7 days of hardening, grafted tomatoes were transplanted into polyethylene bags filled with a soil mixture. Transplanting was done late in the afternoon, and the missing hills were replanted three days later for a uniform plant population. Fertilization involved following recommendations from the tomato seed producer and the Department of Agriculture for basal fertilizer application, with periodic hand weeding to control weeds. The trellises were erected 15 days post-transplantation to provide support for the tomato plants. Watering occurred on alternate days until the early stage of fruiting, after which it was reduced to every three days throughout the harvesting period, mostly in the morning or late afternoon. Insect pests like tomato fruit worms were manually removed and treated with insecticide, while diseases like early blight and stem-end rot were managed with Copper Hydroxide based on recommended guidelines, with spray frequency adjusted as needed. Harvesting- Harvesting of tomato fruits started 62 days after transplanting. All fruits manifesting maturity were harvested for data collection. Harvesting was done at weekly intervals, up to eight harvests. The color quality of harvested tomatoes was classified using the United States standards for grading of fresh tomatoes, namely, stage 1 (matured green), stage 2 (breaker), stage 3 (turning), stage 4 (pink), stage 5 (light red), and stage 6 (red). Grafted tomato seedlings were cultivated following a factorial Completely Randomized Design (CRD) layout, manipulating Scion Ages (21, 25, and 30 days after sowing) and Rootstocks (Eggplant, Wild eggplant, Black nightshade, non-grafted).

Each treatment was replicated three times, with ten sample plants per replication. Data were collected for various parameters, including height gain at 15, 30, and 60 days after transplanting, yield parameters, computed yield, fruit quality (size and sugar content), and fruit color percentage. Cost and return analysis were performed to assess the economic aspects, calculating gross sales, net income, and return on investment (ROI). Statistical analysis was conducted using Sirichai 6.0 software, and differences among treatment means were compared using the Duncan Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

3.1. Gain in Height (cm)

As shown in Table 1, T11 (25-day-old non-grafted tomato), T10 (21-day-old non-grafted tomato), and T12 (30-day-old non-grafted tomato) obtained the highest gain in height at 15 DAT, 30 DAT, and 60 DAT. Moreover, T5 obtained the highest gain in height among the grafts at 15 DAT, 30 DAT, 60 DAT, and 90 DAT. The data suggest that grafting a tomato does not surpass the gain in height of a non-grafted tomato, but the gap in accumulated gain in height becomes smaller as the tomato grows older.

This observation is the same as the result of the study of Aribawa and Kariada [2] where he found out that the grafted tomato plants in the early stage had slower growth than the non-grafted tomato, but when it reached the reproductive stage, the increase was almost equal. The slow growth of grafted tomatoes in the early stages may be because the plant is still adjusting to the rootstock and its environment.

The same discovery was made by Saeri, et al. [3] in their study, which found that the initial growth of grafted tomato plants is slower than that of the non-grafted control tomato plants, but the grafted tomato plants grew faster than the control plants during the experiment. When plants are grafted, the scion and the rootstock are separated before the grafting, and the tissues in the stem vessels and around the cutting fuse when the scion and rootstock are joined. When grafted plants are compared to non-grafted plants, grafting hinders or disturbs the initial growth of the graft. Gaps in the fusing area may interfere with water, nutrients, growth regulators, and photosynthates. As a result, the early nutrient absorption process in non-grafted plants is smoother than in grafted tomato plants [3].

Table 1. Mean gain in height (cm) of tomato at 15, 30, and 60 DAT.

Treatments	Gain in height (cm)		
	15 DAT	30 DAT	60 DAT
T1	15.53^{cd}	64.18^{bc}	131.17^{bc}
T2	15.23^{cd}	59.40^{cd}	127.80^{bc}
T3	12.00^{cde}	48.23^{de}	117.60^{c}
T4	16.40^{bcd}	63.97^{bc}	144.27^{ab}
T5	16.73^{bc}	68.27^{bc}	145.47^{ab}
T6	15.22^{cd}	58.37^{cd}	118.87^{c}
T7	8.78^{e}	39.55^{ef}	84.31^{d}
T8	11.07^{de}	45.87^{e}	83.03^{d}
T9	7.99^{e}	29.03^{f}	50.88^{e}
T10	21.35^{b}	82.65^{a}	153.75^{a}
T11	26.85^{a}	85.25^{a}	156.55^{a}
T12	21.15^{b}	73.25^{ab}	143.45^{ab}
ANOVA	**	**	**

Note: DAT- days after transplanting; cm- centimetres; superscript lowercase letters (a, b, ...) indicate statistical groupings, where values with the same letter do not differ significantly. Conversely, values with different letters (e.g., 'a' and 'b') are statistically significant, ** means highly significant.

3.2. Yield and Yield Parameters

The interaction effect of different rootstocks and scion ages on mean yield per sample plant is illustrated in Table 2, column 2. Among the treatments, T3 had the highest fruit yield, reaching 393.12 grams, followed by T4, T5, and T1, with mean yields of 388.23 grams, 375.85 grams, and 363.90 grams, respectively. Statistical analysis using DMRT indicated a highly significant difference among the tested treatments. Treatments T1, T3, T4, and T5 were statistically similar, with mean yields of 323.58 grams and 301.85 grams for T2 and T6, respectively. In contrast, these treatments were significantly different from the lowest four treatments, namely T7, T8, T11, and T12, which had mean yields of only 72.84 grams, 90.80 grams, 116.58 grams, and 98.15 grams, respectively.

These findings align with the Saeri, et al. [3] study, which also observed increased tomato yields when grafted onto eggplant and S. torvum rootstocks compared to non-grafted plants. However, they diverge from Ahmad, et al. [4] research, which reported statistically similar fruit yields between eggplant and black nightshade rootstocks, though eggplant rootstock still yielded the highest.

Table 2. Interaction effect of the different rootstocks and scion ages on the mean yield (g) per plant and computed yield (kg) per 240sqm.).

Treatments	Mean yield (g)	Computed yield (kg)
T1	363.9^{a}	655.01^{a}
T2	323.58^{ab}	582.45^{ab}
T3	393.12^{a}	707.61^{a}
T4	388.23^{a}	698.82^{a}
T5	375.85^{a}	676.52^{a}
T6	301.59^{ab}	542.86^{ab}
T7	72.84^{d}	131.11^{d}
T8	90.8^{d}	163.44^{d}
T9	237.19^{bc}	426.94^{bc}
T10	155.94^{cd}	280.7^{cd}
T11	116.58^{d}	209.85^{d}
T12	98.15^{d}	176.66^{d}

Note: Kg: kilogram; superscript lowercase letters (a, b, ...) indicate statistical groupings, where values with the same letter do not differ significantly.
Conversely, values with different letters (e.g., 'a' and 'b') are statistically significant.

3.3. Computed Yield (kg/240 sq.m)

In Table 2, column 3, the interaction effect of different rootstocks and scion ages is evident. Among the treatments, T3 yielded the highest with 707.61 kg/240sqm, followed by T4 (698.82 kg/240 sqm.), T5 (676.52 kg/240sqm.), T1 (655.01 kg/240 sqm.), T2 (582.45 kg/240sqm.), and T6 (542.86 kg/240 sqm.). Conversely, the lowest computed yields were observed in T7 and T8, yielding only 131.11 kg/240 sqm. and 163.44 kgs/240 sqm., respectively. Statistical analysis revealed that T1, T3, T4, and T5 are statistically similar in computed yield to T2 and T6, which both yielded approximately 583.45 kg/240sqm. and 542.86 kg/240sqm., respectively. However, these six treatments differ significantly from the four lowest-yielding treatments (T7, T8, T11, and T12), which produced only 131.11 kg/240sqm., 163.44 kg/240sqm., 209.85 kg/240sqm., and 176.66 kg/240sqm., respectively.

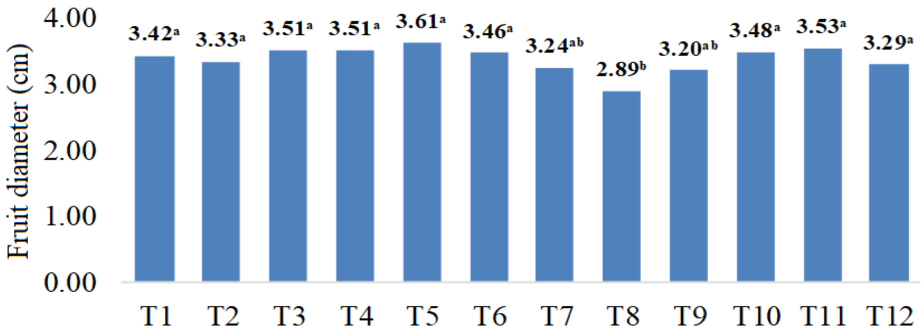

Figure 1. Interaction effect of the different rootstocks and scion ages on the computed yield (kg/240sqm.) of tomato.

Note: Lowercase letters (a, b, ...) indicate statistical groupings, where values with the same letter do not differ significantly. Conversely, values with different letters (e.g., 'a' and 'b') are statistically significant.

3.4. Mean Fruit Diameter (cm)

Figure 1 illustrates how different rootstocks and scion ages affect the fruit diameter. Analysis of variance revealed that the interaction effect of different rootstocks and scion ages on the fruit diameter of tomatoes is significant. T5, T11, T3, T4, T10, T6, T1, T2, and T12 obtained significantly bigger fruit compared with black nightshade rootstock (T7, T8, and T9). However, among the nine (9) treatments that obtained the biggest fruit diameter, grafted tomatoes did not statistically outsize the non-grafted tomatoes. Whereas, based on PNS, T3, T4, T5, and T11 are the treatments that fall on small types of round tomatoes, while the other treatments produce smaller fruits.

Table 3. Mean sugar content (°Brix) of tomato at six different stages of fruit maturity.

Treatments	Fruit maturity					
	Stage 1 (Green)	Stage 2 (Breaker)	Stage 3 (Turning)	Stage 4 (Pink)	Stage 5 (Light red)	Stage 6 (Red)
T1	3.25	3.51^{de}	3.39^{ef}	4.26^{b}	4.09^{c}	4.47^{cdef}
T2	3.38	4.11^{b}	3.76^{cde}	4.41^{b}	4.10^{c}	4.23^{cdef}
T3	3.53	4.07^{b}	4.39^{ab}	4.03^{bc}	4.14^{c}	4.64^{abcd}
T4	3.51	3.57^{cde}	4.02^{bcd}	3.19^{e}	4.84^{b}	4.72^{abcd}
T5	3.53	3.83^{bcd}	3.21^{f}	4.00^{bc}	4.39^{c}	4.48^{cdef}
T6	3.43	3.55^{cde}	3.82^{cde}	3.50^{de}	4.16^{c}	3.89^{f}
T7	3.58	4.80^{a}	4.57^{a}	4.57^{a}	6.03^{a}	5.41^{a}
T8	3.49	4.70^{a}	4.20^{abc}	4.03^{bc}	4.83^{b}	5.33^{ab}
T9	3.57	3.93^{bc}	4.03^{bc}	4.31^{b}	4.94^{b}	4.86^{abc}
T10	3.23	3.11^{f}	3.23^{f}	3.16^{e}	3.32^{d}	3.96^{ef}
T11	3.44	3.25^{ef}	3.57^{def}	4.06^{bc}	4.30^{c}	4.29^{cdef}
T12	3.44	3.95^{bc}	3.37^{ef}	3.67^{cd}	4.14^{c}	3.99^{def}
ANOVA	ns	**	**	**	**	**

Note: Means not sharing letters in common differ significantly by Duncan's multiple range test (DMRT).
** = Highly significant; Superscript lowercase letters (a, b, ...) indicate statistical groupings, where values with the same letter do not differ significantly. Conversely, values with different letters (e.g., 'a' and 'b') are statistically significant.

This observation is in contrast with the study of Krumbein, et al. [5] who found out that grafting tomatoes often results in a significant increase in fruit weight and consequently in fruit diameter and size compared with non-grafted or self-grafted plants.

3.5. Sugar Content of Tomatoes

The interaction effect of the different rootstocks and scion ages on the sweetness of fresh tomatoes at different stages of fruit maturity is shown in Table 3. Analysis of variance revealed no significant difference among the treatments at stage 1. Meaning different rootstock and scion ages did not produce significantly sweeter tomato fruits.

At stage 2 (breaker), T7 and T8 had the highest sugar content, with mean readings of 4.80 oBrix and 4.70 oBrix, respectively. T2 and T3 followed closely with statistically similar mean Brix readings of 4.11 oBrix and 4.07 oBrix, while T10 had the lowest at 3.10 oBrix. T7 recorded the highest mean Brix reading at stage 3 (turning), 4.57 oBrix, with T3 and T8 following closely behind with 4.39 oBrix and 4.20 oBrix, respectively. Conversely, T10 and T5 had the lowest readings at 3.23 oBrix and 3.21 oBrix respectively. Moving to stage 4 (pink), T7 had the highest Brix reading at 5.07 oBrix, followed closely by statistically similar treatments T2 (4.41 oBrix), T9 (4.31 oBrix), and T1 (4.26 oBrix). T4 and T10 had the lowest readings at 3.19 oBrix and 3.15 oBrix, respectively. At stage 5, T7 recorded the highest mean Brix reading of 6.03 oBrix, followed by the statistically equal treatments T9, T4, and T8. Meanwhile, T10 had the lowest mean Brix reading at 3.32 oBrix. Lastly, at stage 6, T7 had the highest mean Brix reading at 5.41 oBrix, followed by T8 (5.33 oBrix) and T9 (4.86 oBrix), while T6 had the lowest at 3.89 oBrix.

Analysis of variance indicated that different rootstocks and scion ages significantly influenced tomato sweetness at stages 2, 3, 4, 5, and 6 of fruit maturity. Specifically, T7 produced the sweetest fruit among all treatments, consistent with findings by Ahmad, et al. [4] where the Brix reading for sandal cultivars grafted onto mocow (black nightshade) was significantly different from sandal cultivars grafted onto brinjal (eggplant) rootstock and non-grafted sandal. Moreover, in the Milenkovic, et al. [6] study, sugar reductions due to grafting ranged from minor (2.3%) in cv. Beef F1 to substantial (30.3%) in cv. Optima F1. Fruit maturity at harvest influences fruit sugar concentration, which suggests that changes in dry matter content may be a factor in reduced sugar concentration in grafted plants. Alternatively, the use of water-efficient rootstocks might increase fruit water content, even when sufficient assimilates are available, potentially leading to reduced fruit sugar concentration.

Table 4. Mean frequency (%) of fruit color at six different stages of fruit maturity.

Treatments	Fruit maturity					
	Stage 1 (Green)	Stage 2 (Breaker)	Stage 3 (Turning)	Stage 4 (Pink)	Stage 5 (Light red)	Stage 6 (Red)
T1	8.28%^{e}	7.28%^{de}	16.79%^{cd}	20.00%^{c}	24.80%^{b}	17.41%^{bc}
T2	10.92%^{de}	6.15%^{de}	16.53%^{cd}	23.83%^{abc}	27.83%^{ab}	21.18%^{ab}
T3	19.11%^{ab}	5.87%^{e}	18.45%^{bc}	26.30%^{a}	25.74%^{b}	17.19%^{bc}
T4	17.37%^{bc}	10.61%^{cde}	16.79%^{cd}	27.87%^{a}	23.70%^{b}	13.66%^{cd}
T5	8.22%^{e}	10.92%^{bcd}	21.00%^{ab}	27.65%^{a}	28.30%^{ab}	5.71%^{e}
T6	15.00%^{bcd}	14.20%^{abc}	17.52%^{c}	27.61%^{a}	20.96%^{b}	4.09%^{e}
T7	12.25%^{cde}	6.88%^{de}	13.79%^{d}	27.30%^{a}	34.71%^{a}	25.04%^{a}
T8	17.19%^{bc}	14.52%^{abc}	15.41%^{cd}	25.04%^{ab}	25.22%^{b}	12.04%^{d}
T9	19.00%^{ab}	8.86%^{de}	15.75%^{cd}	21.42%^{bc}	27.24%^{b}	16.60%^{bcd}
T10	23.25%^{a}	15.48%^{ab}	20.96%^{ab}	26.72%^{a}	21.64%^{b}	3.01%^{e}
T11	17.72%^{bc}	18.51%^{a}	8.19%^{e}	25.00%^{ab}	25.24%^{b}	5.24%^{e}
T12	16.47%^{bc}	8.70d%^{e}	21.77%^{a}	24.00%^{abc}	26.58%^{b}	5.04%^{e}
ANOVA	**	**	**	*	**	**

Note: Means not sharing letters in common differ significantly by Duncan's multiple range test (DMRT).
*, ** = Highly significant; Superscript lowercase letters (a, b, ...) indicate statistical groupings, where values with the same letter do not differ significantly. Conversely, values with different letters (e.g., 'a' and 'b') are statistically significant.

3.6. Percentage (%) of the Six Different Stages of Fruit Maturity

Table 4 displays the interaction effects of various rootstocks and scion ages on fruit maturity stages. Stage 1 percentages ranged from 8.22% to 23.25%, with the highest in T10 (21-day-old non-grafted) and the lowest in T5 (25-day-old scion grafted to wild eggplant). Analysis of variance indicated a significant difference among treatments, particularly with T10 differing significantly from others. Meanwhile, stage 2 percentages varied from 5.87% to 18.51%, with T11 (25-day-old non-grafted) having the highest and T3 (30-day-old scion grafted to eggplant) having the lowest. Significant differences among treatments were noted, with T11 differing significantly from T10, T8, and others. In terms of stage 3, T12 had the highest percentage at 21.77%, then T5, T10, T3, and so forth. ANOVA showed significant differences among treatments, with T12 differing significantly from T5, T10, T3, and others. At stage 4, T4, T5, T6, and T7 had the highest recorded percentages, ranging from 27.30% to 27.87%. Analysis revealed significant differences among treatments, particularly with T4, T5, T6, and T7 differing significantly from others. T7 had the highest proportion of light red color (34.71%), and T5 and T2 came in second and third, respectively (28.30% and 27.83%). Treatments T9, T12, T3, T11, T8, T1, T4, T10, and T6 showed statistically similar light red color percentages. Analysis of variance revealed that different rootstock and scion ages have highly significant effects on the percentage of harvested light red color. This indicates that T7 produced a significant difference in the percentage of light red color compared to T5, T2, and the other treatments.

While the percentage of red color ranges from 3.01% to 25.04%, with T7 as the highest and T10 as the lowest. The analysis of variance (Table 5) shows a significant difference among the treatments. Meaning T7 was significantly different from T2, T3, T1, and the other treatments.

Table 5. Analysis of variance (ANOVA) for the mean percentage (%) of fruit color at stage 6 (red).

Source of variation	Degrees of freedom	Sum of square	Mean square	F - computed	F-tabulated	
					5%	1%
Replication	2	10.79	5.39	1.40	3.4	5.61
Treatment	11	1834.05	166.73	43.28	2.25	3.17
Factor A (Scion ages)	2	590.65	295.33	76.66**	3.4	5.61
Factor B (Rootstock)	3	231.56	77.19	20.04**	3.01	4.71
A x B	6	1011.84	168.64	43.78**	2.51	3.67
Error	24	92.46	3.85			
Total	35	1926.51	55.04			

Note: ** Highly significant.

3.7. Cost and Return Analysis

As reflected in Table 6, the highest production cost per 240 sq.m. was recorded in T1, T2, and T3 with a total of P 22,490.00, followed by T4, T5, and T6 with a production cost of P 22,090.00.

Table 6. Gross income (P), the total cost of production (P), net income (P), and ROI derived from tomato production per hectare as affected by different rootstock and scion ages grown in the greenhouse.

Treatment	Gross income	Rank	Total cost of production	Rank	Net income (P/240sqm.)	Rank	ROI (%)	Rank
T1	P 32, 751	4	P 22, 490	1	P 10, 261	4	45.62	4
T2	P 29, 123	5	P 22, 490	1	P 6, 633	5	29.49	5
T3	P 35, 381	1	P 22, 490	1	P 12, 891	1	57.32	2
T4	P 34, 941	2	P 22, 090	2	P 12, 851	2	58.18	1
T5	P 33, 826	3	P 22, 090	2	P 11, 736	3	53.13	3
T6	P 27, 143	6	P 22, 090	2	P 5, 053	6	22.87	6
T7	P 6, 556	12	P 22, 040	3	P – 15, 535	12	-70.32	12
T8	P 8, 172	11	P 22, 040	3	P – 13, 918	11	-63.01	11
T9	P 21, 347	7	P 22, 040	3	P -743	7	- 3.36	7
T10	P 14, 035	8	P 19, 650	4	P – 5, 615	8	- 28.58	8
T11	P 10, 493	9	P 19, 650	4	P – 9, 158	9	- 46.60	9
T12	P 8, 833	10	P 19, 650	4	P – 10, 817	10	- 55.05	10

Note: P- Philippine pesos (e.g., P 32,751), sqm- square meter, %- percent, (-) negative.

T3 obtained the highest yield value per 240 sq.m. with P 35,381. 00, followed by T4 with P 34,941, T5 with P 33,826.00, T1 with P 32,751.00, T2 with P 29,123.00, and T6 with P 27,143.00. Net income was highest at T3 with P 12, 891.00, followed closely by T4 at P 12, 851.00, and T5 at P 11,736.00. T1 obtained a net gain of P 10,261.00, while T2 had P 6, 633.00, T6 had 5, 053.00. However, T7, T8, T9, T10, T11, and T12 obtained negative net income.

4. CONCLUSIONS

This study unveils vital insights into scion age, rootstock selection, and their collective impact on screenhouse tomato growth, yield, and quality. Notably, 30-day-old scions demonstrated significant early growth advantages, while 25-day-old scions grafted to wild eggplant showed superior height gain. Among yield parameters, 21-day-old scions and eggplant rootstock proved optimal, with a remarkable 707.61 kg/240sqm yield achieved by 30-day-old scions on eggplant rootstock. Quality parameters emphasized size and sugar content, with 25-day-old scions on wild eggplant excelling in diameter, and 21-day-old scions on black nightshade displaying high sugar content. Grafting and scion age also influenced fruit coloration. These findings offer practical guidance for screenhouse tomato growers, with potential applications in open field conditions. Furthermore, the study's call for a follow-up investigation in open field conditions underscores its commitment to providing robust and versatile solutions that cater to diverse agricultural.

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