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RESEARCH ARTICLE

Performance of grafted tomato using rootstocks of different eggplant cultivars

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Abstract

This study examined grafting as an agronomic strategy to enhance the productivity of hybrid tomatoes cultivated in open-field conditions, with a particular focus on improving fruit size, weight and overall yield. The experiment employed a randomized complete block design (RCBD) with three replicates to ensure robust and statistically valid results. Five treatments were evaluated: (T1) non-grafted tomato, (T2) tomato grafted onto wild eggplant (red), (T3) wild eggplant (green), (T4) open pollinated variety (OPV) eggplant and (T5) hybrid eggplant. Key performance indicators measured included the number of fruits per plant, average fruit size and total yield per treatment. Results showed that plants grafted onto wild green, OPV and Hybrid eggplant rootstocks consistently produced a higher number of fruits compared to the non-grafted control. In terms of fruit size, both wild green and wild red eggplant rootstocks yielded larger fruits, indicating their strong potential for enhancing marketable quality. Furthermore, the highest total yields were obtained from tomatoes grafted onto wild green and hybrid eggplant rootstocks, suggesting their suitability for maximizing production efficiency. These findings highlight that the selection of appropriate rootstocks, particularly wild green and hybrid eggplant, can significantly improve hybrid tomato performance. Beyond productivity gains, grafting offers added benefits such as improved plant vigor, enhanced tolerance to soil borne diseases and greater resilience to environmental stresses. As such, this technique represents a practical and sustainable approach for commercialtomato growers seeking to increase yield and profitability while supporting long-term agricultural sustainability.

Keywords: crop management; fruit yield; grafting; hybrid tomato; rootstock; sustainable agriculture

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular vegetable crops grown worldwide, both in an open field and in greenhouses. In fact, it is planted to about 4.4 million hectares around the world. In the Philippines, around 17000 hectares are grown to tomato with Pangasinan and Bukidnon as the top producing areas. It is one of the leading vegetable crops in the country both in terms of hectarage and volume of production (1).

The demand for the crop is year-round, owing to the versatility of its usage in both fresh and processed food preparation. Their taste, health benefits and popularity make them appealing to both growers and consumers. These can be eaten fresh in salads, sauces and sandwiches. It is also used to flavor soups, meat and fish dishes. It can be made into candies, dried fruit and wine. Various products can also be derived from processed stuff which includes purees, juice, catsup and canned whole and diced.

Tomato is the largest source of dietary lycopene, a powerful antioxidant that, unlike nutrients in most fresh fruits and vegetables, has even greater bioavailability after cooking and processing. Tomatoes also contain other protective properties, including antithrombotic and anti-inflammatory functions. Research has additionally found a relationship between tomato consumption and a lower risk of certain cancers as well as other conditions such as cardiovascular disease, osteoporosis, ultraviolet light-induced skin damage and cognitive dysfunction (2).

Tomato can be grown year-round; production is concentrated during the cool months (from October to early February), which is the regular growing season. This result in the market glut from January to May and limited supply during the off-season (June to December). Tomato generally requires a favorable temperature (18-24 °C) for optimum fruit set (1). Tomato production during the off-season in most Southeast Asian countries is constrained by biotic and abiotic factors including flooding, heavy rainfall, high temperature and a high incidence of soil-borne diseases such as bacterial wilt and nematodes (3). Due to low yields and limited supply, market prices of tomato during the wet season are usually high. Currently, more than 40 million grafted tomato seedlings are estimated to be used annually in North American greenhouses (5). In tomato, increased yields have shown that a vigorous root system in non-infested soils can lead to enhanced crop productivity (4). Grafting offers innovative cultural practices that can be used to manage soil-borne disease pressure, achieve greater fruit yields and increase nutrient uptake efficiency (5).

For almost 10 years, AVRDC-The World Vegetable Center developed grafting technology for the tomato to increase yield and production. Studies conducted over several years in Taiwan have shown that grafting tomato onto eggplant (*Solanum melongena*) rootstocks increased tomato tolerance to flooding and bacterial wilt, resulting in higher yield and economic returns than non-grafted plants. Grafting eggplant onto wild *Solanum* rootstock showed significant yield increases as compared to self-grafted controls (6). In greenhouse production, eggplant grafted onto tomato rootstock exhibited improved yields as a result of increased fruit size and fruit number compared to non-grafted controls and plants grafted onto eggplant rootstocks (7).

The profitability of grafted tomato technology to enhance off-season production in Central Luzon is no longer a question. However, the technology should be tried in other tomato growing areas and by more farmers in commercial scale in order for the growers and consumers realize similar benefits from the technology and likewise define the limits of the adaptability of the technology (8). The objective of the study sought to evaluate the potential of grafting as a major component in an integrated approach to increase crop productivity of hybrid tomato cultivar under open field condition. Specifically, it aimed to determine which scion-rootstock combination produces quality fruits in terms of size and weight and identify the treatments produces high yields. This study is based on the principles of plant physiology, grafting compatibility and crop management strategies, providing a foundation for understanding the impact of grafting on tomato production.

The concept of rootstock-scion interactions serves as a key theoretical underpinning, emphasizing the physiological and biochemical exchanges between the grafted components. Rootstocks influence nutrient uptake, water absorption and disease resistance, while scions contribute to fruit development and quality. The compatibility between the rootstock and scion is crucial for graft success, affecting plant vigor, stress tolerance and overall productivity (9).

The stress tolerance mechanisms play a vital role in explaining how grafting enhances plant resilience against abiotic and biotic stressors. Rootstocks with superior stress resistance can improve water-use efficiency, salinity tolerance and disease resistance, thereby mitigating adverse environmental conditions. The yield improvement models provide insights into how grafting influences crop performance (10). By selecting appropriate rootstocks, growers can optimize plant growth, increase fruit yield and enhance overall production efficiency. These models highlight the physiological advantages of grafted plants, including enhanced nutrient uptake, improved photosynthetic activity and better adaptation to environmental challenges.

The grafting technology using locally selected eggplant rootstocks has been shown to improve tomato performance by enhancing yield, disease resistance and overall plant vigor (11). Several studies have identified potential rootstocks from bacterial wilt screening trials, with some showing strong compatibility and resilience when grafted with commercial tomato cultivars (12, 13). Earlier research also demonstrated that grafting can positively influence the growth and fruit quality of both tomato and eggplant crops (14). Statistical data from national agricultural reports provide baseline information for crop production trends in the Philippines, which can support the evaluation of grafting outcomes (15).

Efficient regeneration techniques from protoplasts of eggplant rootstock cultivars and wild relatives offer promising avenues for breeding and genetic improvement (16). Bacterial wilt, a major constraint to tomato production, has been the focus of over a century of research, emphasizing the importance of resistant rootstocks (17). Additional considerations, such as the nutritional value of tomato products, practical grafting recommendations for disease resistance and the influence of fumigation and grafting on root disease control, further highlight the multifaceted benefits of grafting technologies in sustainable tomato production (18-20). By integrating these theoretical perspectives, this study aims to analyze the effectiveness of grafting as a strategy for enhancing tomato production, improving stress tolerance and maximizing yield potential.

Materials and Methods

Seed procurement

The parental stock materials consisting of tomato hybrid seeds, open-pollinated variety (OPV) eggplant seeds and hybrid eggplant seeds were secured from an authorized distributor in the locality, while two varieties of wild eggplant seeds (red and green) were obtained from Saguday, Quirino, Philippines.

Seedling production

The two wild varieties of eggplant seeds (treatments 2 and 3) were sown five days earlier and the two cultured varieties (treatment 4 and 5) were sown ten days earlier than that of the scion (treatment 1-hybrid tomato), to an individual 6-cm diameter seedling pot with a well prepared and sterilized mixture of equal parts of organic fertilizer, carbonized rice hull and fine sand. The hybrid tomato seeds were sown in a 4 cm in diameter seedling tray. Seedlings were grown in a nursery covered with transparent plastic and partial shade to protect from direct sunlight and to suppress if in case, the direct impact of heavy rainfall. Five days after emergence of the scion, it was sprayed with fungicide to prevent the possible damping-off attack.

Production of grafted seedlings

Fig. 1 shows the selection of 32-day-old hybrid rootstocks, which were grafted first because of their larger stem diameters that provided a sturdier base for the scion. The three other rootstock varieties were subsequently prepared, ensuring that each rootstock and scion had matching stem diameters for optimal fit. Fig. 2 shows the cutting of the stems of both rootstock and scion at an approximately 30° angle using a sterilized razor blade. This oblique cut increased the contact surface area, enhancing the likelihood of a successful vascular connection. Fig. 3 shows the use of a 20 mm latex tube to unite the rootstock and scion, ensuring the cuts were parallel and that the cambial layers were properly aligned. This precise alignment is critical for the transport of nutrients and water between the grafted parts. Fig. 4 shows the latex tube being gently pressed over the junction to maintain firm contact, displacing trapped air and serving as a sealant against water, air and pathogen intrusion. After assembly, the newly grafted seedlings were placed in total shade inside a spacious nipa hut to reduce transpiration stress and facilitate healing.

Fig. 1. Selected rootstock with 10 mm diameter.

Fig. 2. Selected scion matched with the rootstock.

Fig. 3. Grafting union of the rootstock and scion.

Fig. 4. Newly grafted tomato plant and scion.

Newly grafted seedlings were placed in a cool dry place with high relative humidity and no exposure to light for three days to control rapid evapotranspiration then gradually exposed to light for four days. Grafted seedlings were transferred to a nursery for hardening five days before transplanting. Water was sprinkled to avoid water stress and pesticide was applied to prevent the attack of insect pests and pathogenic microorganisms. The emerging buds below the grafting union were removed before transplanting.

Field layout, design and treatment

The experimental area was divided into three equal blocks. Each block was further subdivided into five equal plots each with a dimension of 3.0 m × 4.0 m. The treatments were randomly assigned through the randomization procedure for single factor RCBD. The treatments were the following:

T1 - control (non-grafted tomato)

T2 - grafted tomato onto wild eggplant (red)

T3 - grafted tomato onto wild eggplant (green)

T4 - grafted tomato onto OPV eggplant

T5 - grafted tomato onto hybrid eggplant

Fertilizer application

The organic fertilizer compost was applied before transplanting at the rate of 10 tons per hectare compost and chicken dung at 3 tons per hectare, following general recommendations. These amendments were incorporated into the soil during the final harrowing. Based on the soil analysis, the soil had a pH of 6.9, 1.55 % organic matter, 12 ppm phosphorus and 136 ppm potassium. According to the fertilizer recommendation of 90-60 kg NP per hectare, the basal application consisted of 5.6 bags per hectare of 16-20-0 and 0.5 bag per ha of 0-18-0, were applied before planting. The second application was made 15 days after transplanting consisting of 2 bags per hectare of urea.

Transplanting and replanting

The grafted seedlings were transplanted two weeks after grafting at a distance of 0.5 m between hills and 0.75 m between ridges. One seedling was planted per hole. The seedlings were covered with fine thin soil and the base was gently pressed for plant anchorage and roots to be in contact with the soil. The newly planted seedlings were irrigated. Missing hills were replanted immediately to maintain the desired plant population.

Plant care and management

Furrow irrigation was carried out at six and nine weeks after transplanting, ensuring adequate moisture during critical growth stages. Emerging weeds were removed promptly through hand weeding to minimize competition. Insect pests were managed by early-morning applications of appropriate insecticides. Hilling-up was performed immediately after side-dressing to cover the applied fertilizer and suppress new weed growth. Each plant was also provided with a stake to prevent lodging; grafted plants, in particular, were carefully trained and tied to the stakes to avoid bending and to prevent rupture at the graft union, which could otherwise allow pathogen entry and lead to infection.

Harvesting

The fruits were harvested at physiological maturity. Harvesting of samples was done per sample plant and per plot, weighed and recorded immediately.

Collection of data

The plant height of ten representative sample plants per treatment was measured at 20, 40, 60 and 80 days after transplanting, with measurements taken from the base of the plant to the tip of the primary stem. The branches of the sample plants were counted at the last priming and the total number of branches was divided by ten to determine the average number of branches per plant. Ten representative plants per treatment were also used to record the number of fruits, which were properly labelled, counted and recorded every priming; all fruits from the first to the last priming were summed and divided by ten to obtain the average number of fruits per plant. Fruits were weighed at every priming and after the final priming, the total fruit weight was recorded, summed and divided by the number of samples to obtain the average fruit weight per plant. The computed fruit yield was then determined based on the average yield per plant multiplied by the plant population per 1000 m^2, expressed in kilograms.

$$\text{Yield (kg) in } 1000\ m^2 = \text{yield/plant} \times 2666 \text{ plants}$$

Data analysis

All the data gathered were recorded and analyzed using analysis of variance (ANOVA) for a RCBD with five treatments and three replicates. Duncan's multiple range test (DMRT) was employed for mean comparison. The analysis included verification of ANOVA assumptions, such as normality and homogeneity of variance. Additional details, including the statistical confidence level, software used and procedures for assumption checking, were documented to ensure the validity and reliability of results.

Results and Discussion

Plant height

Table 1 presents the plant height measurements at 20, 40, 60 and 80 days after transplanting (DAT), as influenced by different rootstocks. At 20 days after transplanting, plant height varied significantly among treatments ($p < 0.01$). The non-grafted tomato (T1) was the tallest, with a mean height of 41.67 cm. This was followed by tomatoes grafted onto a hybrid eggplant rootstock (T5) at 29.16 cm, wild green eggplant rootstock (T3) at 25.36 cm, wild red eggplant rootstock (T2) at 22.30 cm and OPV eggplant rootstock (T4) at 24.80 cm.

Table 1. Plant height of tomato at 20, 40, 60 and 80 days after transplanting as affected by different rootstocks

Treatment	20 Days (cm)	40 Days (cm)	60 Days (cm)	80 Days (cm)
T1 - non-grafted	41.67^a	91.36^a	108.60	110.30^b
T2 - wild Red	22.30^b	59.96^b	91.00	106.10^b
T3 - wild Green	25.36^b	61.33^b	103.56	119.70^a
T4 - OPV	24.80^b	67.16^b	103.90	119.33^a
T5 - hybrid	29.16^b	70.72^b	98.96	114.33^a
F - result	$p < .01$	$p < .01$	ns	$p < .05$

(a, b, c, d) are significantly different at the 1 % or 5 % level of probability according to Duncan's multiple range test (DMRT).

A similar significant trend ($p < 0.01$) was observed at 40 DAT. T1 remained the tallest (91.36 cm), followed T5 (70.72 cm), T4 (67.16 cm), T3 (61.33 cm) and T2 (59.96 cm). At 60 DAT no significant differences were observed ($p > 0.05$). Mean plant heights were 108.60 cm for T1, 91.00 cm for T2, 103.56 cm for T3, 103.90 cm for T4 and 98.86 cm for T5. At 80 DAT, significant variation was recorded ($p < 0.05$). Treatment T3, T4 and T5 were tallest recorded 119.70 cm, 119.30 cm and 114.30 cm, respectively. Treatment T2 and T1 were shorter, observed 106.20 cm and 110.30 cm, respectively.

It was noted that non-grafted tomatoes were initially taller at 20 and 40 DAT, but grafted plants regardless of rootstock reached or exceeded their growth potential by 80 days. Shorter early plant heights in grafted plants were explained, as a result of grafting stress, where both scion and rootstock were cut and reattached using small latex rubber tubes for support (9).

Number of branches per plant

As shown in Table 2, there was no significant variation in the number of branches per plant ($p > 0.05$), with means ranging from 3.96 to 5.20. Non-grafted plants produced a comparable number of branches to grafted plants, regardless of rootstock.

Number of fruits per plant

Significant differences were found ($p < 0.01$) in the number of fruits per plant. Tomatoes grafted onto wild green (T3), OPV (T4) and hybrid (T5) rootstocks produced the most fruits, with means of 38.10, 36.30 and 37.33, respectively. Wild red (T2) followed at 27.66 fruits per plant, while non-grafted tomato (T1) had the fewest at 5.33 (Table 2). These results align with previous findings (21), which reported that eggplant rootstocks confer greater tolerance to flooding, drought and bacterial wilt, thus improving fruit production.

Weight of fruits per plant

The significant differences ($p < 0.01$) in the fresh weight of fruits per plant were observed among treatments. The total fresh fruits per plant were produced by T3 and T5, with means of 1246.26 g and 1174.33 g, respectively. T4 produced fruits with a mean weight of 1023.86 g, while T2 resulted in a mean weight of 943.86 g. T1 yielded the least fresh fruit weight at 121.46 g (Table 2). The differences in fresh fruit weight can be attributed to the benefits of grafting, that tomato plants grafted onto eggplant rootstocks produce larger fruits and higher economic returns than non-grafted plants (6).

Fruit diameter

The diameter of individual fruits varied significantly ($p < 0.01$) among treatments. Treatment T3 produced the largest fruits, with a mean diameter of 5.33 cm. This was followed by the T2 (4.61 cm), T4 (4.34 cm) and T5 (4.34 cm). T1 produced the smallest fruits, with a mean diameter of 3.66 cm (Table 2). The larger fruit diameter observed in grafted tomatoes is attributed to the enhanced water and nutrient absorption efficiency of eggplant rootstocks (6).

Weight per fruit

Significant differences were also found in average fruit weight ($p < 0.01$). The heaviest fruits were produced by tomatoes grafted onto a wild green rootstock (T3) and a hybrid rootstock (T5), with means of 66.93 g and 58.20 g, respectively. The wild red rootstock (T2) also resulted in relatively heavy fruits (58.26 g), followed by the OPV rootstock (T4) at 53.26 g. The non-grafted tomato (T1) produced the lightest fruits, with a mean of 35.60 g. Grafting improves macronutrient uptake, particularly phosphorus and nitrogen, which enhances fruit development (10).

Fruit yield

Total yield showed highly significant variation ($p < 0.01$) in the total fruit yield per 1000 m^2 among the treatments. The highest fresh fruit yield was observed in T3 (3321.84 kg), followed by T5 (3129.88 kg), T4 (2727.32 kg) and T2 (2516.33 kg). T1 had the lowest fresh fruit yield at 323.81 kg (Table 2). Grafting improves stomatal conductance and nutrient uptake, contributing to higher yields (10).

Number of priming

Number of priming differed significantly among treatments ($p < 0.01$). The grafted tomato onto a wild green rootstock (T3) obtained the highest number of priming, with a mean of 6.67, followed by the grafted tomato onto a wild red rootstock (T2), hybrid Casino 901 rootstock (T5) and the long violet rootstock (T4), which had means of 5.26, 5.50 and 4.93 priming, respectively. The non-grafted tomato recorded the least number of priming, with a mean of 2.61. This result aligns with the findings, stated that grafted plants are highly effective at overcoming abiotic stresses, leading to prolonged fruiting time and increased harvesting frequency (10).

Number of damaged plants per plot

The number of damaged plants infected with bacterial showed significant variation ($p < 0.01$) among treatments. All grafted tomatoes, regardless of variety (T2, T3, T4 and T5), had comparable numbers of damaged plants, ranging from 1.00 to 1.40. This suggests that there was minimal bacterial wilt damage in grafted tomatoes due to their hardened root system. In contrast, non-grafted tomatoes (T1) exhibited bacterial wilt damage with a mean of 4.20, indicating that four or more plants were infected with the disease. These findings corroborate the study, reported that grafting is highly effective in overcoming abiotic stresses and enhancing stomatal conductance in tomatoes when grafted onto vigorous rootstocks (10).

Conclusions and recommendations

The results of this study indicate that grafting tomatoes onto different rootstocks significantly enhances their growth performance, resistance to bacterial wilt and fruiting potential. Among the treatments, treatment T3 exhibited the highest number of priming, while all grafted treatments demonstrated significant resistance to bacterial wilt compared to non-grafted tomatoes. These findings validate previous studies emphasizing the advantages of grafting in mitigating abiotic stresses and improving plant vigor. The use of appropriate rootstocks plays a crucial role in optimizing tomato production and ensuring sustainable cultivation practices. While the results suggest potential benefits for resilience and commercial use, such claims should be interpreted cautiously and would require further validation through economic analysis and longer-term field trials across varying environments. The use of appropriate rootstocks remains an important strategy for optimizing tomato production and supporting sustainable cultivation practices.

Based on the findings of this study, the following recommendations are proposed:

1. Farmers should consider adopting grafting techniques using the wild green rootstock (T3) for improved fruiting performance and yield.
2. Grafting tomatoes onto resistant rootstocks such as wild red (T2), wild green (T3), Long Violet (T4) and hybrid Casino 901 (T5) should be promoted as an effective strategy for controlling bacterial wilt.
3. Further research should be conducted to evaluate the economic viability of grafted tomato production under varying environmental conditions.
4. Additional studies should explore the compatibility of other tomato varieties with different rootstocks to identify the most suitable combinations for local farming conditions.
5. Extension programs should be implemented to educate farmers on proper grafting techniques and the benefits of using disease-resistant rootstocks for sustainable tomato production.

Table 2. Growth, yield and resistance performance of different tomato treatments

Treatments	Branches (number)	Fruits per plant (number)	Weight of fruits per plant (g)	Fruit diameter (cm)	Weight per fruit (g)	Fruit yield/ 1000 m^2 (kg)	Priming (number)	Damaged plants	
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Qualitative rating
T1 -non grafted	3.96	5.33[c]	121.46[d]	3.66[b]	35.60[c]	323.81[d]	2.61[c]	4.20[b]	Susceptible
T2 -wild red	4.2	27.66[b]	943.86[c]	4.61[a]	58.26[a]	2,516.33[c]	5.26[b]	1.00[a]	Resistant
T3 -wild green	5.2	38.10[a]	1246.26[a]	5.33[a]	66.93[a]	3,321.84[a]	6.67[a]	1.00[a]	Resistant
T4 -OPV	4.9	36.30[a]	1023.86[b]	4.34[a]	53.26[b]	2,727.32[b]	4.93[b]	1.40[a]	Resistant
T5 -hybrid	4.8	37.33[a]	1174.33[a]	4.34[a]	58.20[a]	3,129.88[a]	5.50[b]	1.00[a]	Resistant
F - result	Not significant	Significant at 1 %	Significant at 1 %	Significant at 1 %	Significant at 1 %	Significant at 1 %	Significant at 1 %	Significant at 1 %	

(a, b, c, d) are significantly different at the 1 % or 5 % level of probability according to Duncan's multiple range test (DMRT).

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Compliance with ethical standards

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT in order to improve language and readability. After using this tool/ service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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