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Effect of rootstocks on growth, yield and fruit quality of cherry tomato

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Abstract It was found that the stem diameter of grafted plants varies significantly, especially during the days after transplanting (DAT) 15 DATs, 45 DATs and 60 DATs. The Long green eggplant (LGE) rootstock showed the greatest stem diameter at the early stage compared to the other rootstocks and self-grafted plants. No significant differences were observed among the treatments at 30, 45, and 60 DATs in plant height. Moreover, grafting tomato plants onto different rootstocks was significantly different at ($P<0.01$). The data indicates that: the LGE rootstock led to the highest number of fruits per plant (100.00) and the total yield per plant (1328.70g). However, the number of inflorescences per plant, number of flowers per plant and fruit weight will not be affected by grafting. According to the result, most parameters of fruit qualities showed non-significant differences ($P>0.05$). However, the TSS of LGE and Sida (SD) rootstocks had the highest percentage (9.82%) and (9.60%), indicating the sweeter or more flavorful fruit compared to other rootstocks. Based on this study, it could be concluded that eggplant cultivars showed higher tolerance to flooding, produced more yield, and also affected some valuable fruit qualities after grafted.

Keywords: Plant propagation, Rootstocks compatibility, *Solanum lycopersicum* L.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most important crops for humans worldwide. It began in western South America, and domestication is allowed to have passed in Central America. Tomatoes have been bred to improve crop productivity, fruit quality, and resistance to biotic and abiotic stresses (Kimura and Sinha, 2008). Bred are being made by public and private sectors to develop tomato cultivars with the capability to perform optimally under constraint conditions through parentage and biotechnological tools, although these require considerable time. One alternative approach is grafting, which emerged as a potential tool to quickly enhance the efficiency of high-yielding

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genotypes for wider adaptability or resistance to different stresses (Singh *et al*., 2017).

Grafting has been successfully implemented under adverse environments with abiotic stresses such as salinity, low and high-temperature stress, water stress, and heavy metals, and also to enhance water-use efficiency, nutrient uptake, fruit yield, and quality (Singh *et al*., 2017). In grafting, the rootstock is the base and root portion of a grafted plant. It's grafted onto the scion, which is the flowering or fruiting part of the plant, to create a new plant with superior qualities. It's the main part that allows the plants to overcome biotic and abiotic stresses; the use of appropriate rootstocks can enhance plant yield through an increased accumulation of soil nutrients, an avoidance of soil pathogen infection and a tolerance to soil drought, flooding, salinity (Xiaohui *et al*., 2019). The rootstock-scion combination plays an important role in affecting most tomato quality characteristics, which is in keeping with the findings obtained for other vegetables. The interactions and communications between the rootstock and the scion are highly complex and bidirectional, affecting scion growth through the xylem and phloem. The rootstock and the scion may exchange water and metabolic substances, including nutrients, small organic molecules and signaling molecules, such as hormones, which may cause large biological effects. In tomatoes, long-distance movement of gibberellic acid from the rootstock to the scion alters leaf morphology. Moreover, large molecules, such as protein or RNA, can also be transported to affect the growth of scions (Zhou *et al*., 2022).

Grafts have been used to induce resistance against low and high temperatures, enhance nutrient uptake, improve yield when plants are cultivated in infected soils, increase the synthesis of endogenous hormones, improve water use, increase flower and seed production, enhance vegetable tolerance to drought, salinity and flooding (Khah *et al*., 2006). Grafting thus provides an effective management tool for growers to control soil-borne pathogens and cope with environmental stressors. It represents a viable strategy to mitigate such biotic stresses and has been successfully employed to combat Fusarium wilt disease, root-knot nematode, and other diseases. Grafting on compatible and resistant rootstocks has a greater potential to overcome soil-borne diseases including tomato Fusarium wilt disease. It also improves growth, yield, and quality even in the absence of a disease as a result of tolerance against abiotic stresses. This can therefore be exploited as a positive alternative crop management strategy to reduce postharvest losses by using rootstocks that can enhance fruit quality attributes of the scion with increased yields (Mahbou *et al*., 2022). With new rootstocks becoming available for grafted tomato production, comparative studies are still more important for better understanding the degree and mechanisms of possible rootstock influence on fruit quality. However, research is lacking as to whether the plant growth modifications as a result of grafting with vigorous rootstocks could also lead to marked changes in fruit quality properties especially with field-grown, large fruit-size tomato cultivars (Djidonou *et al*., 2016).

The study aimed to determine the effects of different rootstocks to improve growth, fruit yield and fruit quality of cherry tomatoes.

Materials and methods

The experiment was conducted under greenhouse conditions at the Faculty of Agriculture, Ubon Ratchathani University, Warinchamrap, Ubon Ratchathani, Thailand, 34190. The experiment was started in May 2023 and finished in December 2023. Hybrid tomato cultivar ‘Sweet girl’ (SG) was used as scion and self-graft, while 5 tomatoes ‘SG’, ‘Sida’ (SD), ‘Sweet prince’ (SP), ‘Maha mongkol’ (MM) and ‘Sweet boy’ (SB) and 3 eggplants cultivars ‘Round eggplant’ (RE), ‘Long purple eggplant’ (LPE), ‘Long green eggplant’(LGE), were used as rootstocks. Tomato seeds were sown in trays with cells 5.1 x 6.4 cm filled with peat substrate. When the plant produced the third true leaf, a tube grafting technique was performed. After grafting, the plant were kept in the healing chamber for 7 days covered with the polyethylene sheet and sprayed with water 2-3 times a day. After that, the polyethylene sheet was removed and kept the plant in a shady place for another 7 days until full recovery. After 2 weeks of grafting, the plastic tube used for the cohesion of the plant interaction was removed. The grafted plants were transplanted to the greenhouse and grow in a basket that is full of nutrients. Plants were spaced at 50 cm with a 100 cm walkway between replications. The experiment was carried out under a drip irrigation system. Fertilizers and pesticides were applied after transplanting.

The experiment was separated according to a Completely Randomized Design (CRD) with 8 treatments and 5 replications each consisting of 1 plant. The scion of all treatments was ‘SG’. Rootstock consisted as follow: T1 = Self-grafted, T2 = LPE, T3 = RE, T4 = LGE, T5 = SD, T6 = SP, T7 = MM and T8 = SB. This research collected the data such as survival rate, plant height, stem diameter, number of inflorescences per plant, number of flowers per plant, number of fruits per plant, yield per plant, fruit set, fruit weight, fruit length, fruit diameter, fruit color, fruit firmness, titratable acidity (TA) and total soluble solid (TSS). All obtained data were analyzed by ANOVA according to the CRD by using a statistical program. Data collected was analyzed using one-way ANOVA. Data were subject to analysis of variance, using the F-test at 95% and 99% probability levels. Means were compared by Duncan’s New Multiple Range Test at 95% probability level. The effects were considered to be significant at P < 0.05 and declared as a trend at 0.05 < P < 0.10.

Growth weather conditions inside the healing chambers were recorded starting from 19 July 2023 until 10 August 2023. According to the result in Chamber 1 showed that the maximum humidity was 95.5% and the minimum was 69%. On the other hand, the maximum temperature inside the chamber was $37^{0}C$ and the minimum was $22^{0}C$. The weather inside the healing chamber 2 revealed that the maximum humidity inside the chamber was 99% and the minimum was 68%. Moreover, the maximum temperature was $37.5^{0}C$ and the minimum was $22^{0}C$.

Results

Survival rate

A higher survival rate was found in eggplant rootstocks compared to that in tomatoes at 14 days after grafting (Figure 1). The result revealed that LPE (96.67%) showed the highest survival rate compared to SB (26.67%) showed a smaller one.

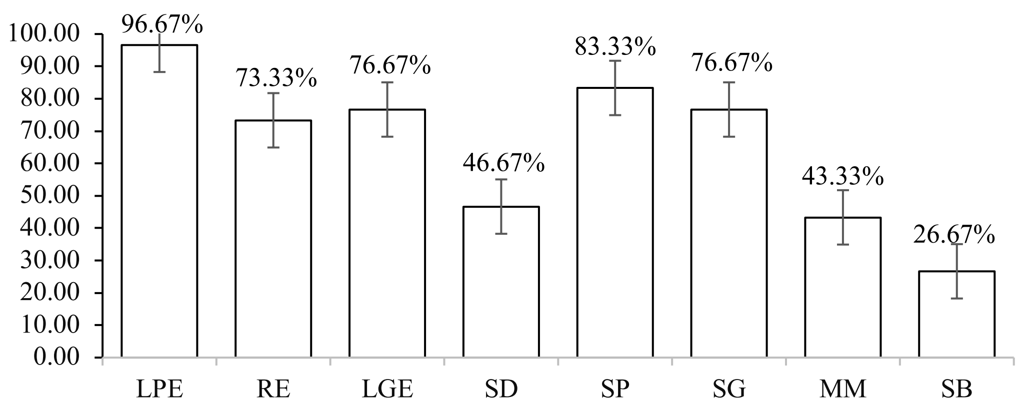

Figure 1. Grafted survival rate. LPE = Long Purple Eggplant, RE = Round Eggplant, LGE = Long Green Eggplant, SD = Sida, SP = Sida Pink, SG = Sweet Girl (control), MM = Maha Mongkol and SB = Sweet Boy

Growth traits

Plant height and stem diameter were measured and the results are presented in Table 1. The result revealed that plant height in 30 DATs, 45 DATs, and 60 DATs between all treatments were non-significant differences (P>0.05).

The stem diameter of grafted plants revealed a significant difference at a day after transplant (DATs), 15 DATs, 30 DATs, 45 DATs, and 60 DATs (P<0.05). SG/LPE showed the highest stem diameter at DATs (5.64 mm), 15 DATs (6.18 mm), 30 DATs (7.31 mm) while compared to self-grafted SG/SG (4.62 mm, 4.83 mm, 5.53 mm, 7.19 mm, and 7.74 mm), respectively. At 30 DATs, SG/LPE (7.31 mm), SG/LGE (7.06 mm), SG/SD (7.05 mm), SG/RE (6.83 mm), and SG/SP (6.78 mm) revealed the greatest compared to the self-grafted plant. At 45 DATs, SG/LGE (8.64 mm) showed the highest stem diameter compared to other grafted and self-grafted plants. Thereafter, stem diameter was non-significant different at 60 DATs.

Table 1. Effect of different rootstocks on plant height and stem diameter of grafted plants

Treatment	Plant height (cm)			Stem Diameter (mm)				
	30 DATs	**45 DATs**	**60 DATs**	**DATs**	**15 DATs**	**30 DATs**	**45 DATs**	**60 DATs**
SG/LPE[1/]	143.03	209.76	279.10	5.64a[3/]	6.18a	7.31a	8.48ab	8.99
SG/RE	136.28	200.42	238.85	4.91ab	5.73ab	6.83a	8.24ab	8.66
SG/LGE	136.58	199.49	269.30	4.69b	5.99ab	7.06a	8.64a	9.14
SG/SD	140.90	218.75	283.68	5.17ab	6.01ab	7.05a	8.30ab	8.92
SG/SP	131.55	208.58	280.02	5.29ab	5.35abc	6.78a	7.93abc	8.47
SG/SG	128.38	201.56	271.15	4.62b	4.83cd	5.53b	7.19c	7.74
SG/MM	131.42	208.98	270.89	4.40b	5.23bc	6.11ab	8.05abc	8.25
SG/SB	123.78	198.60	269.84	3.42c	4.39d	5.50b	7.49bc	8.26
F-test[2/]	ns	ns	ns	**	**	**	*	ns
CV (%)	8.53	6.56	11.66	13.20	10.43	11.40	7.86	8.82

[1/]: SG/LPE = Sweet Girl/Long Purple Eggplant, SG/RE = Sweet Girl/Round Eggplant, SG/LGE = Sweet Girl/Long Green Eggplant, SG/SD = Sweet Girl/Sida, SG/SP = Sweet Girl/Sweet Prince, SG/SG = Sweet Girl/ Sweet Girl, SG/MM = Sweet Girl/Moha Mongkol, and SG/SB = Sweet Girl/Sweet Boy.
[2/]: * Significant at $p \leq 0.05$; ** significant at $p \leq 0.01$; ns = non-significant
[3/]: Means followed by the different letters are statistically significant at P<0.05 using DMRT

Yield traits

Fruit weight, number of fruits per plant, yield per plant, and fruit set were significantly improved by grafting in different rootstocks. The result from the experiment showed that tomato plants grafted on suitable rootstocks exerted a positive effect on the fruit yield. Within the eight rootstocks compared, SG/MM had the highest fruit weight (9.94 g.) followed by SG/SG (9.17 g.), SG/SB (9.07 g.), SG/LGE (8.40 g.), SG/RE (8.40 g.), SG/SP (8.32 g.), SG/SD (7.84 g.) and

SG/LPE had the lowest fruit weight (6.62 g.). The total number of fruits per plant and total yield per plant were significantly different at (P<0.01). SG/LGE showed the highest number of fruits per plant (108.60) and total yield per plant (1394.8 g.) while SG/SD showed the lowest number of fruits per plant (59.00) and total yield per plant (681.06 g.). On the other hand, grafting with different rootstocks increased the percentage of fruit set in SG/RE (52.05%) compared to SG/SB (46.48%), SG/SG (40.21%), SG/LGE (36.61%), SG/MM (34.08%), SG/LPE (30.08%), SG/SP (27.75%), and SG/SD (22.61%), respectively. In addition, rootstocks did not show any significant effect on the number of inflorescences per plant and flowers per plant (Table 2).

Table 2. Effect of different rootstocks on yield traits of cherry tomato grafting

Treatment	Inflo./plant	Flower/plant	Weight/Fruit (g.)	Fruit/plant	Yield/plant (g.)	Fruit set (%)
SG/LPE [1/]	14.75	232.50	6.62 d[3/]	70.00 cd	683.82 d	30.08 cd
SG/RE	13.25	191.40	8.40 bc	88.00 b	1123.40 ab	52.05 a
SG/LGE	16.00	240.75	8.40 bc	108.60 a	1394.80 a	36.61 bcd
SG/SD	14.25	263.50	7.84 cd	59.00 d	681.06 d	22.61 d
SG/SP	14.33	238.67	8.32 bc	66.80 d	814.59 cd	27.75 cd
SG/SG	14.00	209.75	9.17 ab	90.00 b	1204.10 ab	40.21 abc
SG/MM	13.60	195.00	9.94 a	63.20 d	857.65 cd	34.08 bcd
SG/SB	13.67	184.50	9.07 abc	84.00 bc	1054.60 bc	46.48 ab
F-test[2/]	ns	ns	**	**	**	**
CV (%)	21.00	21.41	11.58	16.89	26.56	31.66

[1/]: SG/LPE = Sweet Girl/Long Purple Eggplant, SG/RE = Sweet Girl/Round Eggplant, SG/LGE = Sweet Girl/Long Green Eggplant, SG/SD = Sweet Girl/Sida, SG/SP = Sweet Girl/Sweet Prince, SG/SG = Sweet Girl/ Sweet Girl, SG/MM = Sweet Girl/Moha Mongkol, and SG/SB = Sweet Girl/Sweet Boy.
[2/]: ** significant at $p \leq 0.01$; ns = non-significant
[3/]: Means followed by the different letters are statistically significant at $P<0.05$ using DMRT

Fruit quality traits

The statistical analysis clarified that there were non-significant different amounts of fruit length, fruit diameter, fruit firmness, L, a, C*, H^0, and TA of all treatments. All the rootstock plants showed nearly similar of amount fruit qualities. The eggplant rootstocks tend to show the highest fruit length (27.67 mm), fruit diameter (19.33 mm), and fruit firmness (6.6 N) while tomato rootstocks showed a lower (22.2 mm), (16.12 mm) and (5.60 N), respectively (Table 3). Interestingly, L, a, C*, and H^0 values were greater in tomato rootstocks compared to eggplant rootstocks. On the other hand, SG/LPE showed the highest TSS (10.15%) followed by SG/LGE (9.82%), SG/SP (9.62%), SG/SD (9.60%),

SG/SG (9.39%), SG/RE (9.14%), SG/SB (9.10%), and SG/MM showed the lowest TSS (8.77%) (Table 3).

Table 3. Effect of different rootstocks on qualities traits of cherry tomato grafting

Treatment	FL (mm)	FD (mm)	FF (N)	L	a	C*	H^0	TA (%)	TSS (%)
SG/LPE[1/]	24.41	17.5	6.16	48.59	5.62	5.89	196.28	0.15	10.15a[3/]
SG/RE	24.56	16.93	5.93	54.86	5.42	5.64	241.28	0.16	9.14bc
SG/LGE	27.67	19.33	6.60	51.74	5.64	5.91	218.37	0.16	9.82ab
SG/SD	23.06	16.73	5.91	48.10	6.29	6.61	193.97	0.14	9.60ab
SG/SP	22.20	16.12	5.60	52.21	5.71	5.98	221.48	0.15	9.62ab
SG/SG	26.71	18.90	6.38	51.23	5.90	6.20	214.79	0.16	9.39abc
SG/MM	25.29	17.41	5.77	55.99	5.52	5.85	248.92	0.14	8.77c
SG/SB	24.91	17.38	5.75	52.61	5.71	6.04	223.63	0.14	9.10bc
F-test[2/]	ns	ns	ns	ns	ns	ns	ns	ns	**
CV (%)	28.34	28.14	29.31	43.29	43.19	42.51	72.16	27.55	14.10

[1]/: FL = Fruit length, FD = Fruit diameter, FF = Fruit firmness, L = lightness, a = Redness, C* = Chroma, H^0 = Hue angle, TA = Titratable acidity, TSS = Total soluble solid, SG/LPE = Sweet Girl/Long Purple Eggplant, SG/RE = Sweet Girl/Round Eggplant, SG/LGE = Sweet Girl/Long Green Eggplant, SG/SD = Sweet Girl/Sida, SG/SP = Sweet Girl/Sweet Prince, SG/SG = Sweet Girl/ Sweet Girl, SG/MM = Sweet Girl/Moha Mongkol, and SG/SB = Sweet Girl/Sweet Boy.
[2]/: ** significant at $p \leq 0.01$; ns = non-significant
[3]/: Means followed by the different letters are statistically significant at $P<0.05$ using DMRT

Discussion

In this study, we aimed to evaluate the effects of different rootstocks on cherry tomato plant growth, yields, and fruit qualities. Leonardi and Giuffrida (2006) reported that eggplant cultivars or accessions can be used as rootstocks for tomato grafting. The result indicated a higher survival rate in eggplant rootstocks compared to tomatoes at 14 days after grafting aligns with the findings of several studies. A study by Manickam *et al*. (2021) showed that eggplant rootstocks have been shown to provide increased survival rates advantages for grafted tomato plants. This is particularly evident under conditions of disease pressure, such as bacterial wilt, where eggplant rootstocks can significantly improve plant survival rate. It showed that the advantage of grafting tomatoes with resistant rootstock is in increased plant survival combined with yield advantages (Grieneisen *et al*., 2018). Additionally, the role of ethylene, another plant hormone, in root formation may contribute to the resistance of eggplant rootstock, as ethylene-insensitive tomato plants have been found to produce more below-ground root mass (Clark *et al*., 1999). The stem diameter of eggplant rootstocks tends to be larger than that of tomato rootstocks due to various growth characteristics and genetic factors. Eggplants (*Solanum melongena*) are known to have a robust growth habit and can develop thicker stems, which may contribute to their larger stem diameter when used as rootstocks.

In contrast, tomatoes (*Solanum lycopersicum*) may have a slenderer stem as part of their natural growth pattern. Additionally, the compatibility between the scion (the upper part of the graft) and the rootstock can influence the overall growth, including stem diameter. Latifah *et al*. (2021) reported that tomato grafted onto eggplant cv. 'Gelatik' produced the largest stem diameter due to the 'Gelatik' is a local eggplant variety that has the potential as a rootstock for tomatoes. A study by Ulas (2021) also revealed that the stem diameter of eggplant rootstocks is found to be larger than that of tomato rootstocks, leading to better growth and yield in eggplants. The similar plant heights observed could be due to the compatibility between the tomato scion and the eggplant rootstock, which allows for balanced growth. The rootstock can influence the vegetative growth of the scion, but if both the rootstock and scion are well-matched, they can grow at a similar rate, leading to uniform plant heights (Passam *et al*., 2005). The results were so different from the other researchers that grafting tomato onto eggplant rootstocks has been shown to significantly increase plant height (Leonardi and Giuffrida 2006; Consentino *et al*., 2022; Sanwal *et al*., 2022).

The experiment's findings suggested that the total number of fruits per plant and the total yield per plant were significantly different, with eggplant rootstocks showing the highest number of fruits per plant and total yield per plant, while tomato rootstocks had the lowest in both categories. These results are significant at ($P<0.01$), indicating a strong statistical relevance. This result was agreed with Musa *et al*. (2020); Passam *et al*. (2005); and Nkansah *et al*. (2013) that eggplant rootstocks resulted in higher fruit yield and improved fruit characteristics. Eggplant rootstocks have demonstrated an ability to improve tomato plant performance under salt-stress conditions. For instance, one study showed an increase in the average fruit yield of grafted plants was 24.41% and 55.84%, respectively, with a specific eggplant rootstock (Sanwal *et al*., 2022). Manickam *et al*. (2021) also reported that grafting tomatoes onto resistant eggplant rootstocks can result in greater yield per plot compared to grafted plants on susceptible eggplant or tomato rootstocks. This is because the plants grafted on resistant eggplant were less or unaffected by bacterial wilt (BW) in the field. Bayındır and Kandemir (2023) also agreed that eggplant rootstocks can provide a more vigorous root system architecture (RSA), which is beneficial under various stress factors. Studies have found that all rootstocks used for grafting positively affected yield components, with the highest yield per plant being obtained from certain eggplant rootstocks. Moreover, grafting onto eggplant rootstocks seems to result in a lower fruit weight. While eggplant rootstocks can offer benefits such as disease resistance and adaptability to various soil conditions, they may not always promote the same level of fruit weight increase as tomato rootstocks (Latifah *et al*., 2023; Kumbar *et al*., 2021). On the other hand, grafting onto suitable rootstocks can have a positive impact on fruit yield. This finding is aligned with research suggesting that grafting tomatoes onto tomato rootstocks can significantly increase fruit weight, which is a desirable trait for marketability and economic value (Riga, 2015). Poudel and Lee (2009) also found that the requirements for assimilates and mineral nutrients differ between tomato and eggplant, which may have affected the fruit yield.

The statistical analysis indicated that the variation in fruit quality attributes such as length, diameter, firmness, and color parameters (L, a, H^0) as well as titratable acidity (TA) across different treatments was not statistically significant. This suggests that the rootstock plants used in these treatments produced fruits with similar qualities, regardless of the treatment applied. This result was agreed with Kodama *et al*. (2021); Flores *et al*. (2010); and Djidonou *et al*. (2016) that no significant differences in fruit development and quality between grafted tomato plants on different rootstocks. Tomato grafting can have a significant impact on fruit quality, with rootstocks playing a key role in mitigating stress symptoms and enhancing growth and yield (Schwarz *et al*., 2013). However, Riga (2015) observed that while rootstocks did not mitigate the negative effects of low temperature and light conditions on fruit production, they did affect the chemical composition of fruits and leaves, leading to lower construction costs and changes in fruit quality parameters. On the other hand, grafted tomatoes with eggplant rootstocks, have been found to exhibit increased total soluble solids, a key indicator of fruit quality. This suggests that while some rootstocks may enhance certain aspects of fruit quality, they may also lead to a trade-off with other desirable traits (Turhan *et al*., 2011; Grieneisen *et al*., 2018). This improvement in fruit quality is further enhanced by the application of organic fertilizers, which can significantly increase tomato yield and quality, including total soluble solids (Gao *et al*., 2023). This increase in fruit quality may be attributed to the higher vigor and mineral uptake of plants grafted on eggplant rootstocks, as observed by Cassaniti *et al*. (2011).

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Conflicts of interest

The authors declare no conflict of interest.

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