Response of Eggplant as Rootstock for Tomato

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ABSTRACT

With the aim of determining whether grafting could improve the agronomic behavior of tomato, an open field experiment was carried out to determine growth, yield and fruit quality of tomato cv. 'ASVEG10' either non-grafted, self grafted or grafted onto two eggplant rootstocks cvs. 'EG203' and 'VFR Takii'. Vegetative growth tended to be depressed, the incidence of blossom end rot (BER) and soluble solid concentration (Brix) of fruits were increased by grafting on eggplant rootstocks. Total yield and average fruit weight were significantly influenced by eggplant rootstock, whereas no significant difference was observed on fruit number per plant. The increment in the total fruit yield of the non-grafted plant resulted into 14.23% and 12.62% more fruit weight per plant than the 'VFR Takii' and 'EG203', respectively. Both the fresh weight and dry weight of leaves, stems and fruits were significantly higher in non-grafted control. Reduction in fruit yield and /or fruit quality of tomato grafted on eggplant rootstock may have been due to differences in the requirements for assimilates and mineral nutrients between tomato and eggplant.

Key words: Blossom end rot, grafting; rootstock, yield

INTRODUCTION

Tomato (*Solanum Lycopersicum* L.*)* is a crop of high importance in many countries; according to FAOSTAT 125 million tons of tomatoes were produced in the world in 2005. China, the largest producer, accounted for about one-fourth of the global output, followed by United States and Turkey.

Viewing recent data concerning the Mediterranean area by Leonardi and Romano (2004), it was reported that Spain is the most important country for the spreading of vegetable grafting with mainly tomato and watermelon, with 40 and 52% of the total of 154 million plants in 2004, respectively. They also indicated that in Italy an increasing dissemination of the grafting technique increased the number of the vegetable grafted plants from 4 million in 1997 to 14 million in 2000.

Although in the beginning, tomato grafting was adopted to limit the effects of Fusarium wilt (Lee, 1994), the reasons for grafting have increased dramatically over the years. For example, grafts have been used to induce resistance against low (Bulder *et al.,* 1990) and high (Rivero *et al.,* 2003) temperatures; to enhance nutrient uptake (Ruiz *et al.,* 1997); to improve yield when plants are cultivated in infected soils (Bersi, 2002); to increase the synthesis of endogenous hormones (Proebsting *et al.,* 1992); to improve water use (Cohen and Naor, 2002); to increase flower and seed production (Lardizabal and Thompson, 1990); to enhance vegetable tolerance to drought, salinity and flooding (AVRDC, 2000; Estan *et al*., 2005). Moreover, many researchers reported that an interaction between rootstocks and scions exists resulting in high vigor of the root system and greater water and mineral uptake leading to increased yield and fruit enhancement (Lee, 1994; Oda, 1995; Bersi, 2002). On the contrary, Romano and Paratore (2001) stated that vegetable grafting does not improve the yield when the selection of the rootstock is not suitable, for example the self-grafted plant 'Rita x Rita' had a lower yield than the non-grafted plants. Also there

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are some contradictory results about the fruit quality traits and how grafting affects them. For example, Traka-Mavrona *et al*. (2000) reported that the solutes associated with fruit quality are translocated in the scion through the xylem, whereas Lee (1994) states that quality traits e.g. fruit shape, skin color, skin or rind smoothness, flesh texture and color, soluble solids concentration etc. are influenced by the rootstock. However, other researchers showed that grafting did not affect fruit quality (Romano and Paratore, 2001).

The aim of this study was to evaluate a popular Taiwanese commercial tomato ASVEG 10 self-grafted and grafted on two eggplant rootstocks (EG203 and VFR Takii) for yield and fruit quality attributes.

MATERIALS AND METHODS

Plant material

The commercial tomato (Solanum lycopersicum L.) hybrid cv. 'Taichung AVRDC No 10' (ASVEG 10) was used as self-grafted and non-grafted control, while two eggplants (Solanum Melongena L.) cvs. 'EG203' and 'VFR Takii' were used as rootstocks. To obtain equal stem diameters at grafting, seeds of eggplant were sown earlier than those of tomato. When the plants of eggplants and tomato had 3 to 4 unfolded true leaves, tomato scions were grafted onto tomato and eggplant rootstocks at first internode of the rootstock and scion by tube grafting (Oda, 1995). The later, an elastic tube was mounted on the slant cut end of the rootstock in the tube. The grafted plug seedlings were sprayed with water, placed in healing tunnel covered with a black polyethylene film to keep the relative humidity above 95% and create darkness inside the tunnel. After acclimatization, the grafted plug seedlings were kept under full sunlight in the greenhouse for 7 days and transplanted 14 days after the grafting to the open-field at the National Chung Hsing University on Nov. 8, 2008. Normal cultural practices were followed for irrigation, fertilizer and pesticide application. A randomized complete block design was adopted with 4 replications, each consisting of 12 plants, spaced at 0.5x1.0 m.

Growth of grafted plants and Stem thickening at scion bottom

Stem length (cm) from graft interface, number of leaves, circumference (mm) at the thickest part of the stem (G) at the graft union, 3cm above (S) and below the graft interface were measured on 12 grafted plants in each scion/rootstock combination at three different dates 26, 44 and 62 days after grafting. Index of stem thickening (IST) was calculated as follow: IST = G/S.

Fruit quality and yield

Fully-mature fruits were harvested on the same day and juice of sample fruits were used directly for the determination of total soluble solids (TSS) using refractometer (N-1, Atago Co. Ltd.,Tokyo) and expressed as Brix%. Six fruits (first fruit of first cluster) were harvested from each replication and were used for determination of Brix percent before that the same fruits were used to determine the fruit firmness using Sun Rheo meter Compact-100 (Scientific Co., LTD.) and expressed as (Kg/cm2).

For the determination of vitamin C the equipment RQflex Reflectometer was used. Fully-mature six fruits from each treatment from cluster 3 and 4 were randomly selected and sliced along the equator at 1cm thickness. Twenty-four fruits from each treatment were used for the measurement of pericarp thickness with the used of instrument digital vernier caliper.

Fruits were harvested at the mature stage starting from Feb. 10 to 23 March, 2009. Yield was measured from the 12 plants from each treatment. The harvested fruits were counted and weighted to determine number of fruit per plant and fruit weight up to 140 days after grafting. BER percentage was measured on the harvested fruits from the 12 plants from each treatment. The infected fruits were counted to determine the percent BER per plant.

Fresh weight and dry weight

The fresh weight was determined for plants that were harvested at graft union and separated into leaves, stem but in case of fruits immediately after harvest weight and took it to oven dry. Samples of 8 plants from each treatment were used for fresh and dry weight. For the dry-weight determination, the plant tissues were dried in a ventilated oven at 90oC for 48h.

Inorganic mineral nutrient concentrations

From the eight plants, three sample leaves (just below the pinched portion after fifth cluster) of each of the graft combinations were collected together with final harvest 140 days after grafting.

Total nitrogen content of plant samples was determined by Kjeldahl method (Bremner *et al*., 1965). Total phosphorus contents of plant samples were estimated by perchloric acid digestion assay method (Yamakawa, 1992). Total K, Ca, Mg, Fe, Mn, Zn & Cu contents of plant samples were determined by Atomic Absorption Spectrophotometer digestion assay.

Statistical analysis

All data were analyzed using Analysis of Variance (ANOVA) and a mean separation test was carried out by using procedure of statistic Analysis System (SAS; SAS Institute, Cary, NC USA; version 9.1) followed by least significant difference (LSD) test ($P < 0.05$).

RESULTS

Growth of grafted plants and stem thickening at scion bottom

Both the Plant height and number of leaves of non-grafted were significantly greater than the eggplant rootstocks at three different dates 26, 44 and 62 days after grafting (Table 1). The maximum plant height 117.81cm was gained by non-grafted plant and 'VFR Takii' gained lowest height 87.75cm at 62 days after grafting. Furthermore, the non-grafted plant always showed the highest value of plant height than all other grafted plants in all above three days. The highest number 13.37 of leaves per plant was noted in non-grafted which were statistically identical with self-grafted 13.18 and the lowest number of leaves 12 was found in 'VFR Takii' at 62 DAG. Both eggplant rootstocks showed the statistically identical leaf

Table 1: Leaf number and plant height of the tomato (cv. ASVEG10) plants

Treatments	Days After Grafting		
	26	44	62
Leaf number			
Non-graft	5.2	9.9	13.4
Self-graft	5.4	9.1	13.2
EG 203	5.0	8.2	12.1
VFR Takii	5.4	8.0	12.0
LSD0.05	0.4	0.7	0.7
Plant height (cm)			
Non-graft	28.0	69.5	117.8
Self-graft	27.6	68.3	112.9
EG 203	21.4	51.7	91.3
VFR Takii	20.3	49.6	87.7
LSD0.05	1.81	3.30	2.97

number at 44 and 62 DAG (Table 1). At the beginning, 26 DAG the leaves number of no-graft and self- grafted tomato plants were statistically identical to ‘VFR Takii’ but that was different with ‘EG203’.

Table 2: Circumference of stems, scion/rootstock ratio and stem thickening index in the tomato (cv. ASVEG10) plants 26 and 80 days after grafting

Rootstock	Stem circumference (mm)			Ratio of scion and rootstock (S/R)	Index of stem thickness (G/S)
	Root (R)	thickest part (G)[a]	scion (S)		
26 days after grafting					
Non-grafted	8.3	9.2	9.0	1.09	1.02
self-grafted	7.0	9.3	7.8	1.10	1.21
EG203	5.1	7.6	5.9	1.17	1.31
VFR Takii	4.5	7.5	5.9	1.31	1.28
LSD	0.6	0.8	0.8	0.10	0.08
80 days after grafting					
Non-grafted	14.4	14.5	14.5	1.01	1.00
self-grafted	13.4	17.1	13.6	1.02	1.27
EG203	11.5	20.7	13.6	1.23	1.53
VFR Takii	11.1	20.1	14.4	1.26	1.40
LSD	1.1	1.6	1.3	0.09	0.09

[a] 3-cm above and below the graft interface.

Circumferences at the thickest part of the stem (G), at around graft interface, at 3cm above (S) and below (R) the grafts interface, 26 and 80 days after grafting onto eggplant rootstocks are shown in Table 2. At the beginning (26 DAG) circumference at G was smallest 7.51 mm in VFR Takii rootstock and largest 9.41 mm in tomato rootstock. As increasing the days the circumference at G was increasing on the two eggplant rootstocks. At 80 DAG circumference at G was significantly smallest 17.26 mm in self-grafted plants. Likewise those at S and R were also significantly different between tomato and two eggplant rootstocks in all cases. The ratio of S/R was almost one in self-grafted plant at 80 DAG onwards. But the ratio of S/R in eggplant rootstocks remains higher than selfgraft. The index of stem thickening (G/S) was smaller in tomato graft on tomato rootstock than both eggplant rootstocks. In comparison to eggplant rootstocks ‘EG203’ rootstocks showed the higher G/S value in all consecutive days. These results show that stem thickening at the graft union differs, depending on rootstocks used. In plants grafted on eggplant rootstocks, stem diameter of the rootstocks was smaller than that of tomato scion.

Fruit yield

The number of fruits harvested per cluster was statistically not significant among the rootstocks. Maximum fruit numbers of 31.56 were harvested from non-grafted (Table 3). Present study showed that the number of fruits per plant was not significantly difference among the rootstocks as shown in Table 3. The highest number of fruit of 31.56 was recorded in non-grafted and the lowest number of fruit of 28.9 was recorded in self-grafted. There were significant differences between the tomato and eggplant rootstocks in respect of average fruit weight. Maximum fruit weight of 137.42 g was found in non-grafted tomato which was statistically identical to self-grafted of 135.9 g however, the tomato grafted on eggplant rootstock showed almost same weight of 128.2 g that was significantly difference with that non-graft and self-graft (Table 3).

Fruit yield records of tomato plants grafted on eggplant rootstocks revealed that yield on eggplant rootstocks was significantly lower than that on tomato rootstocks (Table 3). The highest yield of 4336 g/plant was recorded in non-grafted which is significantly higher than from two eggplant rootstocks. Interestingly, the lowest yield of 3719 g/plant was recorded in 'VFR Takii' and was statistically identical to self-grafted and 'EG203'. Rootstock did not significantly impact fruit per cluster and number of fruit harvested (Table 3). Yield differences were just because of small size fruit.

A negative effect of grafting was shown when eggplants were used as rootstock. The total fruit yield of non-grafted plants was significantly higher in comparison with that of the plants grafted onto both rootstock cultivars. Finally, these increases in the total fruit yield of the non-grafted plant resulted into 14.23% and 12.62% more fruit weight per plant than the 'VFR Takii' and 'EG203', respectively, whereas self-grafted plants show not significantly different production to both eggplant rootstocks (Table 3).

Table 3: Fruit number, weight and yield from the tomato plants (cv. ASVEG10)

Rootstock	Total yield (g/plant)	Fruit no /plant	Fruit /cluster	Average fruit weight(g)
Non-grafted	4336	31.6	6.18	137.4
Self-grafted	3925	28.9	5.98	135.9
EG203	3789	29.6	5.91	128.2
VFR Takii	3719	29.0	6.00	128.2
$LSD_{0.05}$	385	3.1	0.62	8.6

Fruit quality

The fruit size (horizontal and vertical diameter) of tomato grafted on eggplant rootstock was significantly smaller in eggplant rootstocks than non-grafted and self-grafted. Both horizontal and vertical diameter of the fruits of nongrafted and selfgrafted possesses significantly higher vale than tomato grafted on eggplant rootstock. The highest value of horizontal diameter was found in nongrafted of 6.33cm and vertical diameter was found on selfgrafted of 5.48 (Table 4).

Table 4: Fruit diameters (cm) and blossom end rot of tomato (cv. ASVEG10) non-grafted, self-grafted and grafted onto 2 eggplant rootstocks

Rootstock	[y]Horizontal diameter(a)	Vertical diameter(b)	Diameter index(b/a)	BER[z] %
Non grafted	6.33	5.46	0.87	8.52
Self grafted	6.24	5.48	0.88	12.83
EG203	6.04	5.17	0.86	17.29
VFR Takii	6.05	5.15	0.86	22.03
$LSD_{0.05}$	0.18	0.16	0.03	6.18

[y] 48 fruits per treatment randomly selected from 3 and 4 cluster
[z]Blossom end rot, average from 12 plants/ treatment

The incidence of BER was increased significantly on eggplant rootstocks. With in eggplant rootstocks 'VFR Takii' showed the higher percent 22.03% BER than the rootstock 'EG203' which was recorded 17.29% BER. However, the incidence of BER was lowest 8.52% in non-grafted (Table 4). The incidences of BER on the fruit of tomato were quite different according to the harvesting season. At the early stage of the season (Feb 10 to 24) the incidence was quite lower than the BER incidence observed at the end of the season 29th March.

Analyses of fruits from tomato and eggplant rootstocks showed that soluble solid (0Brix) level was increased significantly on eggplant rootstocks (Table 5). The highest value of Brix was recorded on 'EG 203' of 6.04 which was identical to 'VFR Takii' of 5.90. Similarly, the lower value of brix was seen on nongrafted and selfgrafted which were 5.20% and 5.50 % respectively (Table 5). Vitamin C was increased significantly in 'VFR Takii' rootstock of 25.75 mg/100 g fresh weight but in the case of 'EG203' (21.70 %) was not significantly different to both non-grafted and self-grafted plants of 22.00 and 23.14 %

respectively. Fruit firmness and Pericarp thickness, both values were lowest tomato fruit grafted on eggplant rootstocks (Table 5).

Table 5: Soluble solid (Brix), vitamin C, and fruit firmness of tomato (cv.ASVEG10) non-grafted, self-grafted and grafted on 2 eggplant

Rootstock	Soluble solids (Brix %)	Vit. C (mg/100g FW)	Firmness (Kg/cm2)	Pericarp thickness (mm)
Non grafted	5.26	22.00	2.45	6.88
Self grafted	5.50	23.14	2.42	6.95
EG203	6.04	21.70	1.81	6.11
VFR Takii	5.90	25.75	2.13	6.10
LSD0.05	0.28	2.41	0.18	0.30

Dry and Fresh weight

From the data presented in Table 6, it is seen that there were significant differences between the fresh and dry weights of leaves, stems and fruits 140 DAG. The non-grafted plants, which bear a significantly higher fresh and dry weight of all plant parts (leaves, stem and fruits) than other three treatments. This might be due to the depressed growth of grafted plants specially in tomato grafted on to eggplant rootstock.

Table 6: Plant weight of the tomato (cv.ASVEG10) after 140 days of grafting

Treatments	Leaves		Stem		Fruits		Total		
	FW(g)	DW(g)	FW(g)	DW(g)	FW(g)	DW(g)	FW(g)	DW(g)	DW/FW%
Nongrafted	933	131	630	86	4574	377	6137	594	9.70
Selfgrafted	855	119	572	77	3578	326	5005	523	10.46
EG203	569	82	414	65	3044	273	4027	421	10.53
VFR Takii	590	83	474	70	3055	240	4120	393	9.55
$LSD_{0.05}$	142	25	86	15	758	63	852	77	0.62

Inorganic mineral nutrient concentrations

Major and trace elements concentration in grafted tomato plants at final harvest are presented in Table 7. Calcium (Ca) content varied from 2.11 % to 2.60 % and the highest concentration was found in non-grafted where as lowest was in eggplant rootstock cv. 'VFR Takii'. Self-grafted plant showed the moderate concentration of Ca and was not significantly different than others 3 rootstocks. The highest Phosphorus (P) concentration was found in 'VFR Takii', which was statistically different from self-grafted and non-grafted. Potassium (K) contents of the grafted tomato plant varied from 4.57 % in 'VFR Takii' to 4.07 % in 'EG203'. Manganese (Mn) concentrations were significantly lower in 'EG203' rootstock and the highest concentration was seen on self-grafted. The concentration of Zinc (Zn) and Cupper (Cu) were significantly higher in both eggplant rootstocks than non-grafted and self-grafted.

Table 7: Nutrients content in the tomato (cv. ASVEG10) leaves after 140 days of grafting

Rootstock	Major elements (%)					Trace elements (PPM)			
	Ca	N	P	K	Mg	Fe	Mn	Zn	Cu
Non-grafted	2.60	2.17	0.28	4.08	0.65	165.11	101.08	16.59	7.00
Self-graft	2.29	2.24	0.28	4.36	0.62	184.55	110.26	18.91	6.55
EG203	2.16	2.41	0.31	4.07	0.59	149.44	70.18	29.61	21.10
VFR Takii	2.11	2.46	0.37	4.57	0.68	164.33	101.85	33.13	18.76
LSD0.05	0.33	0.36	0.07	0.37	0.14	33.29	33.61	6.17	3.22

DISCUSSION

Plant heights leaf number and maximum leaf length all were significantly smaller in eggplant root stocks. These results indicate that grafting tomato plants on eggplant rootstock depresses the growth of the plants. Tomato stem swelled immediately above the union. This overgrowth is a characteristic of graft incompatibility which is associated with poor connection of vascular bundles between the scion and rootstock (Hartmann and Kester, 1975). The small stem diameter of rootstocks may have resulted in poor development of the root system. Therefore, that water deficiency in plants on eggplant rootstocks was caused by poor connection of vascular bundles and/or a small root system. The growth of scions was depressed and that stems at the graft union thickened markedly 18 weeks after heterografting (Oda *et al*., 2000).

Numbers of fruit per plant in the tomato/eggplant grafts were as high as those of the tomato/tomato grafts; however, reduced fruit yields, smaller fruit, higher percentages of BER, and increased SSC values were observed in tomato fruit in the tomato/eggplant grafts, compared with the tomato/tomato grafts (Kawaguchi *et al*., 2008). Previous research conducted by Cheng and Chua (1976) also revealed reduced yields and smaller fruit sizes in tomato/eggplant grafts.

Soil conditions such as low moisture content (Mitchell *et al*., 1991b), salinity (Mizrahi and Pasternak, 1985;) and low osmopotentials (Ohta *et al*., 1991) generally increase soluble solids or sugar content of tomato fruits but retard vegetative growth of plant and thus fruit production. Water deficiency, salinity and water stress in plant did not reduce solute accumulation but impaired net water import into tomato fruit (Mitchell *et al*., 1991a). These findings indicate that water stress to plants generally increases soluble solids and sugar content of fruits but depresses growth and fruit yield.

Low Ca concentrations in tomato/eggplant scions might result in an increased incidence of BER in this graft combination, as BER is generally thought to be caused by Ca deficiency (Pilbeam and Morley, 2007). Deficiency (Otsuka, 1960b) and increasing concentration (Yamazaki *et al*., 2000) of Ca appeared in tomato scion depending on rootstock species. Increased concentrations of P (Otsuka, 1968) were also observed in heterograft combinations. In melon plants grafted on Cucurbita spp., low nitrate concentration with high nitrate reductase activity, low free amino acid and soluble proteins and high organic N were detected in their leaves (Ruiz and Romero, 1999).

The yield advantage of grafted plants has been shown to be clear when they are grown on infested soil (Poffley, 2003; Besri, 2002). In this experiment, there was no obvious advantage of grafted plants, because the plants were grown in pathogen-free soil. Thus, grafting with resistant rootstocks is recommended only when the risk of the disease is high, because the yield increase might not be significant when disease pressure is low, as we observed in this study. During the field experiments, slower vegetative growth and changes of fruit quality, including smaller size, more blossom end rot, and higher soluble solids were observed when eggplant rootstock was used compared with tomato. When using scarlet eggplant (*Solanum integrifolium* Poir.) as rootstock for tomato, similar results were observed and attributed to poor connection of vascular bundles at the graft union or a poor root system making the plant water deficient (Oda *et al*., 1996). These results highlight the need for screening to identify the scion and rootstock combination with the least detrimental effect on fruit quality as well as the need to develop proper management practices for grafted tomato plants using eggplant rootstocks, such as maintaining higher soil moisture.

The fact that the grafted plants produce better results than non-grafted ones when grown on infested soils indicates the potential economic value for a grower of growing grafted plants (Bletsos, 2003). Since grafting gives increased disease tolerance (Besri, 2002, Poffley, 2003), it should be useful for low-input sustainable horticulture of the future.

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