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Grafting onto African eggplant enhances growth, yield and fruit quality of tomatoes in tropical forest ecozones

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Abstract

Field experiments were conducted at the Teaching and Research farm of the University of Ghana Forest and Horticultural Crop Research Centre (FOHCREC), Okumaning-Kade to investigate the effect of grafting on growth, yield, disease resistance and fruit quality of tomatoes grafted onto two different African eggplant rootstocks. Two commercial tomato varieties ('Tropimech' and 'Roma') were used as scions and two African eggplant varieties ('Aworoworo' and 'Green') were used as rootstocks. The scion/rootstock combinations or treatments were 'Roma/Green', 'Tropimech/Green', 'Roma/Aworoworo', 'Tropimech/Aworoworo', 'Roma/Roma', 'Tropimech/Tropimech', and Roma non-grafted (control) and Tropimech nongrafted (control). The results indicated that, grafted tomatoes on African eggplant rootstocks performed better in terms of growth, yield, earliness, disease incidence and shelf life than non-grafted or control plants. Pooled mean data indicated significant differences in terms of percent fruit set, fruit number and weight among the treatments. Percent fruit set was higher for tomato on Africa eggplant (67.9) compared to the self grafted (58.7) and the control (52.6). Fruit number/plant and yield of tomato on the African eggplant was 16.2 and 1120.7g/plant compared to the control (10.8 and 916g/plant) while the self grafted had 13.2 and 1064.9g/plant, respectively. The shelf life of grafted tomatoes onto egg plant was significantly higher (25.4 days) compared to control (13.6 days). Grafting did not significantly affect Brix (%), pH and acidity of tomato. Grafted plants significantly recorded low disease incidence compared to non-grafted ones. The study indicated that the use of grafting on eggplant in the humid forest zone of Ghana can boost tomato production considerably.

Key words: Grafting, African eggplant, *Solanum lycopersicum*, *Solanum aethiopicum*, rootstock, scion, tomato, yield

Introduction

Tomato (*Solanum lycopersicum*) is an important vegetable crop and the fruit is used worldwide in almost every home in soups, stews, as garnish and in salads. This popular and widely used vegetable crop is cultivated on a wide range of soil types and in different ecological zones. Production of tomatoes in the hot humid tropical regions, especially in the forest zone is bedevilled with low plant stand populations, high disease incidence due to soil borne pathogens, low yields and poor fruit quality. Many studies have thus been conducted especially on how to combat the high incidence of soil borne diseases that limit tomato production. This include crop rotation, use of soil fumigants and breeding programs among others (Yetisir and Sari, 2004; Rivero *et al.*, 2003). These strategies however have limitations.

Utilisation of grafting in vegetable production has been observed to be an appropriate tool that improves yield/production, limits the effects of *Fusarium* wilt, enhances nutrient uptake (Ruiz *et al*, 1997; Khah, 2006), improves water use as well as enhance vegetable tolerance to drought, salinity and flooding (AVRDC, 2000; Bersi, 2002; Estan *et al*, 2005 and Lee, 1994). Other studies have identified wild eggplant genotypes as resistant rootstocks to bacterial wilt as well as root-knot nematodes (Matsuzoe *et al.*, 1993; Oda, 1999). Interaction between rootstock and scion has resulted in vigorous root system and higher absorption of water and minerals resulting in improved fruit yield and quality (Lee, 1994; Oda, 1995; Bersi, 2002; Leoni *et al.*, 1990).

In Ghana, very little studies on grafting in vegetables is documented. Grafting is now being encouraged to enhance tomato production especially in the forest regions and other parts of the country that have challenges in the production of the crop. The local garden egg (African eggplant- *Solanum aethiopicum*) thrives well in the forest regions and is well adapted to the environment making it an ideal rootstock for tomato production. The aim of this study was, therefore, to evaluate the agronomic performance, yield and fruit quality characteristics of two popular Ghanaian commercial tomato varieties grafted onto selected garden egg varieties as rootstock. The technique is expected to be an appropriate intervention in the quest to increase tomato production in the forest regions not only of Ghana but other parts of the humid tropics as a whole.

Materials and methods

Two field experiments were conducted at the Research Farm of the University of Ghana Forest and Horticultural Crops Research Centre (FOHCREC), Kade, in the Eastern Region of Ghana about 135km North-West of Accra. FOHCREC lies in the deciduous forest zone and is 114 m above sea level on latitude 6^{o}.0854'N and longitude 0^{o} 5400'W. The dominant soil is Haplic Acrisol with an annual rainfall ranging between 1300-1800 mm and a temperature range of between 25-38^{o}C (Ofosu-Budu, 2003). The area has a bimodal rainfall pattern, the major season (April-July) with maximum rainfall in June and the minor season (September-November) with the maximum rainfall in October. The two experiments were conducted during the minor seasons of 2010 and 2011. The total rainfall amount recorded were 724.8 mm in 2010 and 680.3 mm in 2011.

Two commercial tomato cultivars 'Tropimech' (T) and 'Roma' were used as scion while two African eggplants (Local garden eggplant); 'Aworoworo' (A) and and 'Green-fruited line' (G) were used as rootstocks.

The grafting combinations were: i) 'Roma' as scion on Green rootstock (R/G); ii) 'Tropimech' as scion on Green rootstock (T/G); iii) 'Roma' as scion on 'Aworoworo' rootstock (R/A); iv) 'Tropimech' as scion on 'Aworoworo' rootstock (T/A); v) Roma self-grafted (R/R); vi) 'Tropimech' self-grafted (T/T); vii) 'Roma' non-grafted (Control) and viii) 'Tropimech' non-grafted .

Seeds of the garden egg rootstocks were sown on September 2 of each season in seed trays (66 cells) in a nursery greenhouse covered with transparent film three weeks earlier than the seeds of the two tomato scions to ensure similar stem diameters at the grafting time due to differences in growth vigour. Garden egg initial growth is slower compared to tomato. The carbonated rice husk was used as a substrate for nursing the seeds and the seedlings were irrigated with nutrient solution with E.C. of 0.76 mS. Seedlings were grafted by hand using the whip/splice/tube method as reported by Oda (1995). Grafting was done when the scion had 2-3 true leaves and the rootstock 3-4 true leaves. The stems of the scion and the rootstock were cut at an angle of 30^{0}. Grafted seedlings were immediately kept in a humidifying chamber with controlled conditions. The relative humidity (RH) and temperature in the chamber ranged between 90-95% and 24-26^{0}C, respectively. Temperature and relative humidity were measured with an electronic thermo-hygrometer. The grafted plants were kept in a grafting chamber for 9 days for curing and thereafter kept in the greenhouse for 7 days before they were transplanted to the open field on October 14, 2010 and 2011.

Weeding was carried out whenever necessary. Standard management practices were employed for the duration of the growing seasons which lasted for 4 months. Plants were watered with a sprinkler irrigation when necessary and fertilized with 15-15-15 NPK fertilizer at the rate of 6 g/plant at the vegetative stage and 3 g/plant of sulphate of ammonia at the flowering stage. The treatments were arranged in a randomized complete block design and replicated three times. Each treatment had 14 plants spaced at 0.6 m intra row and 1.0 m inter row. Ten (10) plants per treatment were tagged and used for data collection. Data collected included plant height, number of leaves per plant, days to 50% flowering, number of fruits per plant, average fruit weight, total fruit yield per plant, Brix, pH, titratable acidity, shelf life and fruit firmness.

Plant height was measured from the ground level to the raised leaf-tip with a meter ruler; total number of leaves and branches were counted per plant and stem diameter was measured using vernier calipers. Days to 50% anthesis was recorded as the number of days after transplanting to the time 50% of flowers have opened. Number of fruits per plant was recorded as the number of fruits counted from record plants; fresh fruit yield was determined as the total yield of ripe fruits harvested from record plants. Fruit firmness defined as the resistance of the fruit pericarp to pressure and was measured when fruits were harvested at the breaker stage with a penetrometer (FT327-8 mm) (Plate 2). The reading was calibrated to zero and the plunger pressed against the skin of the pericarp of the fruit up to a specified depth in the fruit. The reading was recorded as kilogram (kg). Disease incidence was rated from 0-5 in an ascending order (*i.e.* the higher the value, the more severe the disease). Fruit total acidity was determined according to AOAC (1995) and the sugar content (Brix) was determined with a digital pocket refractometer (ATAGO POCKET PAL-1) and pH was determined with a digital pH meter (ATAGO DPH-1). Shelf life was measured as the number of days for the fruits to start rotting. Yield measurements were recorded on ripe fruits, which were hand harvested, counted and weighed. 6-8 harvests were carried out between 55-76 days after transplanting.

Data analysis: Statistical analysis were perfomed using a computer software and the differences among the means were separated using Duncan's Multiple Range Test (DMRT) and LSD (P=0.05).

Results and discussion

The study compared the growth performance of tomatoes grafted onto the African eggplant to self grafted tomatoes and control plants. The results indicated that plant height, leaf number and plant diameter were significantly affected by grafting in both years (Table 1). Pooled data also showed significant differences (P=0.05) in terms of plant height and diameter at 35 Days after transplanting (DAT) (Table 1). Tomatoes grafted onto garden egg rootstocks had significantly greater plant height (50.3cm) compared to the self grafted (47.3cm) and the control plants (42.2cm) at 35 DAT (Table 1). This result is in agreement with the findings of Lee (1994) and Ioannou *et al.* (2002) who reported that grafted plants were taller and more vigorous than the self-rooted ones. The African eggplant is very vigorous and this may have been impacted onto the tomato scions. The differences in plant height of the two garden egg types, 'Aworoworo' and Green rootstocks as well as the non-grafted may be due to their genetical characterstics or differences in plant vigour and growth rate. It has also been observed that garden egg plants are generally taller and more robust than tomato plants and this may have resulted in the taller plants observed in the grafted tomatoes compared to the non-grafted types. Stem diameter of grafted plants at 35 DAT revealed significant differences between the grafted and non-grafted treatments. This may be due to the fact that grafted ones were more vigorous than the non-grafted plants (Leonardi and Giuffrida, 2006).

Flower number increased from the first truss, peaked at the 3rd and declined at the 4th truss stage (Table 2). Flower number per plant in both seasons was highest in tomatoes grafted onto garden egg compared to that of self-grafted and the control. Pooled data showed that tomato on garden egg had more flowers (24) compared to that for the self-grafted (22) and the control (20) (Table 4). Percent fruit set was significantly higher in plants grafted on the African eggplant (67.9%) compared to the self-grafted (58.7%) and the control (52.6%) (Table 4).

There were significant differences in the number of days to 50% flowering among the treatments in both seasons (Table 3). Number of days to first harvest was significantly affected by grafting. Tomato grafted onto garden egg matured significantly earlier and this was followed by the self grafted tomato. The control took the longest period to first harvest (Table 3). Pooled

Table 1. Plant growth parameters of grafted and non-grafted tomato plants

Treatment (Scion/ Rootstock)	Plant height (cm)		Leaf number		Stem diameter (mm)	
	21DAT	35DAT	21DAT	35DAT	21DAT	35DAT
			2010			
R/G	42.2b	56.6d	10.3a	22.5a	7.02c	7.98c
T/G	41.7b	53.2c	12.3a	23.2b	6.67b	7.12b
R/A	40.4b	55.3c	11.9a	22.1a	7.17c	7.90c
T/A	42.1b	54.6c	11.9a	21.2a	6.40b	7.10b
R/R	40.4b	55.3c	13.2a	27.9c	7.00c	7.98c
T/T	38.1ab	47.1b	12.3a	23.3b	6.57b	7.00b
R (control)	36.6a	42.9a	12.3a	25.0bc	6.03a	6.43a
T (control)	36.4a	41.9a	11.7a	25.7bc	5.73a	6.37a
			2011			
R/G	36.5c	49.8c	9.03a	20.5a	6.00c	7.13c
T/G	31.3a	45.9b	9.03a	21.3a	5.67b	6.47b
R/A	30.4a	44.3b	9.77b	22.1a	6.87c	7.12c
T/A	30.1a	42.6ab	9.27a	23.2b	5.40a	5.40a
R/R	33.4b	45.3b	10.00b	21.8a	5.70a	6.67b
T/T	33.7b	41.5a	9.83b	20.3a	5.57a	6.04a
R (control)	32.6b	40.9a	8.33a	21.5a	5.83b	6.12b
T (control)	28.4a	42.9ab	8.67a	21.0a	4.93b	5.87a
			Mean for 2010 and 2011			
Tomato on garden egg	36.8a	50.3b	10.4a	22.1a	6.4a	7.0b
Tomato self-grafted	36.4a	47.3a	11.3a	23.3a	6.21a	6.9b
Control	37.1a	42.2a	10.3a	23.3a	5.63a	6.2a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05). DAT: Days After Transplanting, R/G: 'Roma/Green', R/A:Roma/Aworoworo', T/G: 'Tropimech/Green', T/A:Tropimech/ Aworoworo', R/R: Roma/Roma', T/T:'Tropimech/Tropimech', R:'Roma', T: 'Tropimech'.

Table 2. Mean number of flowers per cluster, total number of flowers, and percentage fruit set of grafted and non-grafted tomato plants

Treatment (Scion/ rootstock)	Number of flowers/cluster				Total flowers (no./plant)	Percent fruit set (%)
	1st	2nd	3rd	4th		
			2010			
R/G	6.1c	7.0b	8.1b	7.6b	28.8c	74.0c
T/G	5.3b	7.8b	8.4b	7.5b	29.0c	74.5c
R/A	5.2b	7.5b	8.2b	7.4b	28.3c	73.5c
T/A	5.7b	7.2b	8.1b	7.1b	28.1c	69.5c
R/R	5.3b	7.2b	7.6a	6.2a	26.3b	62.4b
T/T	5.4b	6.9b	7.6a	6.2a	26.1b	64.4b
R (control)	4.6a	5.2a	7.7a	6.2a	23.7a	54.4a
T (control)	4.9a	5.0a	7.8a	6.0a	23.7a	53.6a
			2011			
R/G	5.1c	5.2b	5.1b	4.3b	19.7c	62.4c
T/G	4.3b	5.8b	5.4b	3.3a	18.8b	64.4c
R/A	4.2b	5.5b	5.2b	4.2b	18.1b	61.9c
T/A	3.7a	5.2b	5.1b	3.5a	17.5ab	62.9c
R/R	3.3a	5.2b	4.6a	4.3b	17.4ab	55.7b
T/T	4.4b	5.6b	4.6a	4.2b	18.8b	52.1a
R (control)	3.6a	4.2a	4.7a	4.8b	17.3ab	50.9a
T (control)	3.9a	4.0a	4.8a	4.2b	16.9a	51.5a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05)

Table 3. Yield and yield components of grafted and non-grafted tomato plants

Treatment (Scions/ Rootstock)	Days to 50% flowering	Days to first harvest	Fruit number (no./plant)	Fruit weight (g/plant)
		2010		
R/G	20.2a	52a	21.3 c	1384.5 c
T/G	21.4a	54a	21.6c	1360.8b
R/A	20.6a	55a	20.8c	1200.0c
T/A	20.3a	58b	19.5c	1209.0b
R/R	20.4a	59b	16.4 b	1131.6 b
T/T	22.0b	60b	16.8b	1176.0b
R (control)	22.8b	62c	12.9a	967.5a
T (control)	22.4b	63c	12.7a	939.8a
		2011		
R/G	18.7b	56a	12.3b	934.8b
T/G	19.2b	67c	12.1b	968.0a
R/A	19.0b	56a	11.2b	940.8b
T/A	20.3b	62b	11.0b	968.0b
R/R	19.3b	62b	9.71a	970.0b
T/T	25.1a	62b	9.80a	982.0b
R (control)	17.7b	64b	8.80a	880.2a
T (control)	18.0b	67c	8.71a	876.4a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05)

data for the two years also showed a similar pattern (Table 4). Tomato/Garden egg significantly recorded the shortest period to first harvest (58 days) while the self-grafted (61 days) and the non-grafted did not differ significantly (64 days). Earliness or lateness in the days to 50% flowering in grfated plants have been attributed to inherited characters, early acclimatization to the growing area, healing of the cut surface as well as due to transplanting shock (Sam-Aggrey and Bereke-Tsehai, 1985).

Fruit number per plant, fruit weight and fruit yield were significantly affected by grafting (Table 3). Fruit number per plant was significantly higher in tomatoes grafted on garden egg while the non grafted had the lowest. A similar pattern was observed for fruit weight and yield. In Table 4, pooled mean data over the two seasons also indicated that the yield and yield components were significantly affected by grafting. Grafted tomatoes and garden egg had the highest fruit number per plant (16) and yield (18.7 t/ha) followed by self-grafted with fruit number per plant of 13 and a yield of 17.8 t/ha. The control or non-grated plants recorded the lowest number of fruits (11) and yield (15.7 t/ha).

The number of fruits per plant which was significantly higher in grafted plants confirms results reported by Leonardi and Romano (2004) and Leonardi and Giuffrida (2006) who reported that rootstocks influence growth, yield and product quality of fruits. Lee (1994) and Oda (1995) also reported that there is an interaction between rootstocks and scions which result in higher yields. The significantly greater yields of grafted plants may be attributed to the higher fruit numbers and larger fruit size (Passam *et al.*, 2005). The high yields in the grafted treatments have been reported to be due to good root characteristics and the ability to absorb water and nutrients into the plant (Gahoonia *et al.*, 1997; Ikeda *et al.*, 1986; Kim and Lee, 1989; Pulgar *et al.*, 2000; Ruiz *et al.*, 1997).

Table 5 shows that grafting had no significant effect on Brix (%), pH and acidity among the treatments. These observations agree with the work of other researchers who reported that fruit descriptive and qualitative characteristics were not affected by grafting (Yamasaki *et al.*, 1994; Alan *et al.*, 2007, Alexopoulos *et al.*, 2007).

Fruit shelf life was significantly affected by grafting (Table 6). Grafted plants on garden eggplant could be stored longer (22- 29 days) followed by self grafted plants (20-23 days) and the control had the least shelf life of 14 days. Pooled results for the two years showed significant differences. Fruits of tomato grafted onto garden eggplant could be stored for 25 days, followed by self-grafted (22 days) and the control recorded the least of 14 days (Table 7). The African eggplant has a tough skin and this may have impacted on the fruit of the tomato skin causing it to last longer compared to those not grafted on the garden egg.

Significant differences were observed in disease incidence of the various treatments in the field (Table 7). Grafted plants recorded the lowest rate of disease incidence (wilt) compared to the non-grafted treatments. This was attributed to the fact that the African eggplant has been observed to tolerate a wide range of soil borne diseases and hence its use as a suitable rootstock. Fruit firmness was significantly higher in tomatos on garden egg (5.0) compared to the self-grafted (4.0) and the control (3.5) (Table 6). This may be due to the fact that the African eggplant has been observed to have fruits with tough skin which may have impacted on the the tomato fruit.

It can be concluded from the study that grafting of tomatoes on the African eggplant or local garden egg rootstocks increased yield and yield components of tomato. The African eggplant shows promise in its adoption for use as rootstock for tomato production in the hot humid tropics, especially in Ghana.

Table 5. Mean values for % Brix, pH and titratable acidity for grafted and non-grafted tomato fruits

Treatment (Scion/ Rootstock)	Brix (%)		pH		Titratable acidity (%)	
	2010	2011	2010	2011	2010	2011
R/G	5.21a	5.15a	4.60a	4.53a	0.46ab	0.31a
T/G	5.20a	5.22a	4.25bc	4.12ab	0.33b	0.31a
R/A	5.13a	5.15a	4.37abc	4.32ab	0.55a	0.31a
T/A	5.05a	5.25a	4.10c	4.00b	0.41ab	0.32a
R/R	5.10a	5.17a	4.35abc	4.28ab	0.50ab	0.35a
T/T	5.20a	5.22a	4.26abc	4.15ab	0.49ab	0.34a
R (control)	5.07a	5.11a	4.59ab	4.41ab	0.53a	0.37a
T (control)	5.20a	5.23a	4.25bc	4.19ab	0.51a	0.32a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05)

Table 6. Mean values for fruit shelf life and disease incidence of grafted and non-grafted tomato plants and fruit

Treatment	Shelflife (days)		Disease incidence		Fruit firmness (kg)	
	2010	2011	2010	2011	2010	2011
R/G	29.0c	25.0c	1.00a	1.00a	5.2c	5.1c
T/G	28.0c	28.0c	1.22a	1.33a	5.1c	5.2c
R/A	22.0b	24.0b	1.00a	1.00a	4.8b	5.0c
T/A	28.0c	27.0c	0.50a	0.20a	4.9b	4.7b
R/R	20.0b	21.0d	2.33b	2.00b	4.0a	4.1b
T/T	23.0b	22.0b	2.42b	2.33b	4.1a	3.9a
R (control)	14.0a	13.0a	3.24c	2.67b	3.5a	3.5a
T (control)	14.0a	14.0a	3.00c	2.67b	3.6a	3.4a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05)

Table 7. Fruit quality characteristics and disease incidence of tomato grafted on garden egg, tomato self-grafted and control plants (mean values for 2010 and 2011)

Treatment	Brix (%)	pH	Titratable acidity	Shelf life (days)	Disease incidence	Fruit firmness (kg)
Tomato/ Garden egg	5.17a	4.29a	0.38a	25.0c	0.82a	5.0b
Tomato self grafted	5.17a	4.26a	0.42a	22.0b	2.27b	4.0a
Control	5.15a	4.36a	0.43a	14.0a	2.90b	3.5a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05)

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Table 4. Yield and yield components of tomato grafted on garden egg, tomato self-grafted and control plants (Data are mean value for 2010 and 2011)

Treatment	Days to 50% flowering	Days to first harvest	Total number of flowers (no./ plant)	Percent fruit set (%)	Fruit number (no./plant)	Fruit weight (g/ plant)	Yield (t/ha)
Tomato/Garden egg	20.0a	58.0a	24.0b	67.9c	16.2c	1120.7c	18.7c
Tomato self grafted	22.0a	61.0b	22.0a	58.7b	13.2b	1064.9b	17.8b
Control	20.0a	64.0b	20.0a	52.6a	10.8a	916.0a	15.7a

Means in each column followed by the same letter are statistically not different based on Duncan's multiple range test (P=0.05)

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