Effect of Grafting on Yield and Quality of Hybrid Tomato (*Solanum lycopersicum* Mill.) Cultivars

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Abstract

Grafting has proven to mitigate some soil-borne diseases and abiotic stresses as well as improve plant growth, yield and fruit quality. However, in Tanzania the effect of grafting on plant growth, yield and fruit quality of hybrid tomato cultivars is not yet fully explored. Therefore, the objective of this study was to evaluate the effect of grafting eggplant rootstocks on plant growth, yield and fruit quality of hybrid tomato cultivars grown in Tanzania. The study was conducted at Sokoine University of Agriculture in Morogoro, Tanzania, and the experiment was laid out in a Randomized Complete Block Design with eight treatments each replicated three times. Hybrid tomato cv. Assila and Monica were each cleft-grafted onto eggplant EG190, EG195 and EG203 rootstocks and transplanted in the open field. Ungrafted plants of the same tomato cultivars were used as controls. Data were subjected to Analysis of Variance using GenStat v.14 statistical package (VSN International, UK) and treatment means were separated based on Tukey's Test at P≤0.05. Results reveal that grafting eggplant EG190, EG195 and EG203 rootstocks significantly reduced total fruit yield (p = 0.001) and marketable yield (p = 0.001) for all tomato cultivars but significantly (p = 0.001) increased total soluble solids contents for all tomato cultivars, and titratable acidity for Monica in comparison to ungrafted controls. Further studies are required to determine rootstocks that are vigorous enough to carry scions of these hybrid tomato cultivars for yield improvement.

Keywords: Marketable yield, Diameter, Firmness, Assila, Monica, Total soluble solids, Titratable acidity

Introduction

Tomato (*Solanum lycopersicun* Mill.) is Tanzania's most important vegetable crop, contributing to 51% of total vegetable production (Mamiro *et al.,* 2015). It is the most important crop for cash and domestic uses produced mostly by small and medium-scale farmers in Tanzania Mainland (Meya *et al.,* 2014). Tomato production is largely constrained by diseases, especially during the rainy seasons (Msogoya and Mamiro, 2016). Pesticide application is the major pest management strategy of tomato pests in the country (Maerere *et al.,* 2010; Mamiro *et al.,* 2015) usually applied on a weekly or bi-weekly basis (Mtui *et al.,* 2015). This frequent application of pesticides exacerbates both the costs of production and danger to human health and the environment (Maerere *et al.,* 2010; Meya *et al.,* 2014; Mtui, *et al.,* 2015). Ineffectiveness of some pesticides, unaffordability by resource limited farmers and inadequate know-how on their appropriate use are other appreciable setbacks (Mtui *et al.,* 2010; Meya *et al.,* 2014). Disease resistant varieties are limited (Minja *et al.,* 2011) and can be overwhelmed under high disease pressure and by novel pathogens (Cerkauskas, 2005; Louws *et al.,* 2010; Michel *et al.,* 2010). This leaves farmers with few options for managing diseases.

Grafting technology can be employed by farmers that cannot afford soil steaming and pesticides as well as to reduce dependency on pesticides. Presently, grafting is also being employed to enhance crop response to a variety of abiotic stresses (Louws *et al.,* 2010; King *et al.,* 2010; Schwarz *et al.,* 2010; Rivard and Louws 2011), thereby improving plant growth,

yield and fruit quality. For example, Black *et al.* (2003) recommends rootstocks EG195 and EG203 to manage tomato fusarium wilt disease under hot arid and wet conditions. However, there is limited information regarding plant growth performance, yield and fruit quality of hybrid tomato cultivars when grafted onto eggplant rootstocks in the Tanzania environment. Therefore, the objective of this study was to evaluate the effect of grafting eggplant rootstocks on yield and fruit quality of hybrid tomato cultivars.

Materials and Methods

Description of the study area

The study was conducted at Sokoine University of Agriculture (SUA) in Morogoro, Tanzania. The study area was located 6°05'S, 35°37'E and at an elevation of 568 m above the sea level. The experiment was conducted in the open field between March and July 2017. The rainfall pattern in the study area was bimodal with the short rains falling from November to December and long rains from February to May. The annual rainfall ranges between 800 and 950 mm (Kisetu and Teveli, 2013).

Seedling production

Scion seeds of indeterminate hybrid tomato cv. Monica and semi-determinate Assila were purchased from local agro-dealers in Morogoro. Rootstock seeds of EG190, EG195 and EG203 were obtained from Asian Vegetables and Research Development Centre in Taiwani. Seeds were sown in seedling trays filled with compost before pricking them into 7.0 cm diameter and 10.0 cm long polythene tubes. Cleft grafting was performed when rootstock and scion seedlings were 42 and 21 days old, respectively (Black et al, 2003; Johson *et al.,* 2011; Ozores-Hampton and Frasca, 2013; Tamilselvi and Pugalendhi, 2017). The grafts were healed for three days in a dark healing chamber and further three days in a transparent healing chamber. Thereafter, the grafts were hardened off for seven days in the nursery with a shade that allowed 30% of the light.

Experimental design and crop management

The experiment was laid out in a randomized complete block design with eight treatments each replicated three times. The treatments were EG190/Asilla, EG190/Monica, EG195/Asilla, EG195/Monica, EG203/Asilla and EG203/Monica graft combinations as well as ungrafted tomato cv. Asilla and Monica as controls. Each replication comprised 12 plants, spaced at 60 cm x 60 cm with 100 cm wide walkway between adjacent replications. The experiment was carried out under a drip irrigation system. NPK compound fertilizer (17:17:17) was applied as top dressing at the rate of 150 kg per ha three weeks after transplanting. All cultivars were staked three weeks after transplanting. Suckers developing below the graft interfaces were removed on a weekly basis to protect the scion shoots. Ridomil Gold® (Metalaxyl-M 40g/kg + Mancozeb 640/kg) was applied weekly against fungal diseases at a rate of 3 g L^{-1} of water. Coragen 20 SC (Chlorantraniliprole) was applied at a rate of 0.25 ml L^{-1} of water against South American leaf miner (Tuta absoluta). Sumectin 10 EC (Emamectin benzoate) was also applied to manage other insect pests. Weeding was done using hand hoe to maintain the plots weed-free for the duration of the crop.

Data collection

Yield and yield components: Data were collected on number flowers per truss, number of fruits per truss, number of fruits per plant, fruit weight per plant (kg) and yield per ha (t). Harvesting was done weekly at fruit breaker stage. The data on number of fruits per plant and yield per hectare were computed as follows:

Marketable Fruit yield: Fruit marketable yield was assessed based on visual observations considering quality acceptable quality in local markets. Fruits free from cracks, blossom end rot and disease symptoms were considered marketable (Estan *et al.,* 2005) while fruits with these defects were consequently considered unmarketable.

Fruit diameter: Twenty fruits per sample were measured for diameter using a digital vernier calliper (USDA-AMS, Burlingame, CA).

Fruit firmness: Twenty defect-free fully ripe tomato fruits were selected for firmness measurement. A penetrometer (Wagner Fruit Test™ FT, Wagner Instruments and Greenwich,

CT) was used for firmness testing. A disc of a peel was removed from two opposite sides of the equatorial area of the fruit before measurements were taken as described by OECD (2009).

TSS, TA, and TSS/TA: Ten defect-free tomato fruits at red stage were selected for measurements of total soluble solids (TSS) and titratable acidity (TA). Longitudinally cut slices were homogenized into a composite sample using a blender. TSS was measured using a hand-held digital refractometer (Mettler Toledo, Model LXC 59107, Japan) as described by OECD (2009) and values were expressed in ◦Brix. Titratable acidity was determined by titrating 10 ml of tomato juice extract with 0.1M NaOH, and the results were expressed as a percentage of citric acid in the juice (OECD, 2009).

Data analysis

Data were subjected to Analysis of Variance (ANOVA) using Genstat v.14 Statistical package (VSN International, UK) and treatment means were separated based on Tukey's Honest Significant Difference ($p \leq 0.05$).

Results

Effect of grafting on yield components

Grafting technology reduced the number of flowers per truss (p=0.001), number of fruits per truss (p=0.001), number of fruits per plant (p=0.001) and yield per plant (p=0.001) in tomato cv. Assila and Monica compared to the ungrafted controls (Table 1).

Effect of grafting on total and marketable yield

Results reveal that grafting markedly reduced total yield (p=0.001), marketable yield (p=0.001) and increased nonmarketable yield (p=0.001) for tomato cv. Assila compared to the ungrafted controls (Table 2). Moreover, grafting significantly (p=0.001) reduced total yield for Monica.

Effect of grafting on fruit quality

Grafting significantly (p=0.001) decreased fruit diameter for EG190/Assila, EG195/Assila, EG 203/Assila and EG190/Monica compared to the ungrafted controls (Table 3). Moreover, grafting decreased fruit firmness (p=0.001) for EG190/Monica in comparison to the ungrafted control. On the contrary, grafting increased TSS (p=0.001) for all Monica and Assila graft combinations, TA content (p = 0.001) for EG190/ Monica and EG203/Monica graft combinations, and TSS/TA ratio (p=0.001) for EG190/Assila compared to the ungrafted controls.

Means in the same column within each tomato cultivar followed by the same letter are not

Table 1: Effect of grafting on yield components of hybrid tomato cultivars

Treatment	Number of flowers truss^{-1}	Number of fruits truss^{-1}	Number of fruits plant^{-1}	Yield plant^{-1} (kg)
EG190/Assila	5.7ab	2.4ab	10.6ab	0.6a
EG195/Assila	5.9b	2.1ab	15.1bc	1.1bc
EG203/Assila	5.5ab	2.7b	11.0ab	0.7ab
Assila	7.0c	4.3cd	29.4f	2.9f
EG190/Monica	4.9a	1.7a	8.6a	0.5a
EG195/Monica	6.3bc	2.5ab	14.1bc	1.2bc
EG203/Monica	6.3bc	2.3ab	12.3b	1.0bc
Monica	9.3e	4.3d	20.3de	2.0ef
Grand mean	6.9	3.5	14.6	1.3
CV (%)	10.7	19.1	25.5	31.6
P-Value	0.001	0.001	0.001	0.001

Means in the same column within each tomato cultivar followed by the same letter are not significantly different ($p \leq 0.05$) based on Tukey's Honest Significant Difference. CV= coefficient of variation

Table 2: Effect of grafting on total yield, marketable and nonmarketable yield of hybrid tomato cultivars

Treatment	Total yield (t ha^{-1})	Marketable yield (t ha^{-1})	Nonmarketable yield (t ha^{-1})
EG190/Assila	6.4ab	4.9a	1.5ab
EG195/Assila	12.9bc	9.5bc	3.4de
EG203/Assila	7.9ab	6.9ab	1.0a
Assila	33.8df	17.6e	16.2g
EG190/ Monica	3.6a	2.9a	0.7a
EG195/Monica	13.6bc	9.4bc	4.2e
EG203/Monica	12.2bc	10.9bcd	1.3ab
Monica	23.3e	14.7de	8.6f
Grand mean	14.2	9.8	4.4
CV (%)	31.9	14.7	7.6
P-Value	0.001	0.001	0.001

Means in the same column within each tomato cultivar followed by the same letter are not significantly different ($p \leq 0.05$) based on Tukey's Honest Significant Difference. CV= coefficient of variation.

Table 3: Effect of grafting on fruit quality of hybrid tomato cultivars

Treatment	Fruit diameter (mm)	Firmness (kg/cm^2)	TSS (%)	TA (% citric acid)	TSS/TA
EG190/Assila	47.7b	1.82bc	6.65cd	0.44abc	15.11c
EG195/Assila	52.2de	2.10c	5.65bc	0.48abc	11.77bc
EG203/Assila	49.3bc	2.0bc	5.59bc	0.46abc	12.15bc
Assila	55.8f	1.98bc	3.90a	0.41ab	9.51ab
EG190/Monica	47.4b	1.30a	7.02d	0.53de	13.24bc
EG195/Monica	53.7ef	1.76b	5.77bcd	0.49abc	11.77bc
EG203/Monica	52.9de	1.87bc	5.89bcd	0.52bc	11.33b
Monica	53.3de	1.87bc	4.15a	0.38a	10.92ab
Grand mean	52.9	1.85	5.30	0.5	10.62
CV (%)	7.49	5.7	8.3	7.4	12.5
P-Value	0.001	0.001	0.001	0.001	0.008

Means in the same column within each tomato cultivar followed by the same letter are not significantly different ($p \leq 0.05$) based on Tukey's Honest Significant Difference. CV= coefficient of variation

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Discussion

Effect of grafting on yield and marketable yield

Grafting markedly impacted negatively on the number of flowers, number of fruits, yield and marketable yield for tomato cv. Assila, EG 190/ Monica and EG195/Monica in comparison to ungrafted controls as a result of limited plant growth of the graft combinations. Abdelhafeez *et al.* (1975) also observed limited plant growth and lower yields in eggplant/tomato graft combination as compared to self-rooted plants. It has been established that grafting scions onto non-vigorous rootstocks decreases plant growth by reducing the uptake and translocation of water and nutrients (Davis *et al.,* 2008; Lee, 2010;

Martinez-Ballesta *et al.,* 2010). Consequently, low yields have been reported when scions are grafted on on-vigorous rootstocks (Davis *et al.,* 2008; Martinez-Ballesta *et al.,* 2010; Rivard and Louws, 2011). The low marketable fruits in grafted tomato cv. Assila, EG190/Monica and EG195/Monica may be due reduced plant vigour. Oda *et al.* (1996) reported an enhanced incidence of fruit blossom end rot, small-sized fruits and decay for tomato grafted onto on non-vigorous Solanum integrifolium rootstocks. This is supported by Di Gioia *et al.* (2010); Schwartz *et al.* (2010) and Turhan *et al.* (2011) who stressed that lower marketable yield in grafted plants is mainly due to limited water and nutrient uptake by vigorous rootstocks.

Effect of grafting on fruit quality

Grafting in this study reduced fruit diameter for all eggplant/Assila and EG 190/Monica graft combinations. The reduced fruit diameter observed in this study concurs with observations by Bletsos and Olympios (2008) who found that tomato and eggplant grafted onto Datura patula exhibited less growth and smaller fruit size in comparison to self-rooted plants. The small fruit diameters could be due to limited water and nutrient uptake as a result of small rootstock root systems and impaired vascular systems. Conversely, Yetisir *et al.* (2007) reported that watermelon grafted onto interspecific squash hybrid had increased fruit size by 52%. Turhan *et al.* (2011) also indicated that fruit weights of grafted plants were significantly higher than those for control plants. This implies fruit size of grafted tomato cannot be generalized as it depends on the unique biological characteristics of rootstocks and scions.

Grafting significantly reduced fruit firmness in EG190/Monica but did not significantly affect the remaining graft combinations. Contradictory reports regarding fruit firmness as observed in this study have surfaced elsewhere. For example, Lee *et al.* (1999) reported a decrease in firmness of grafted fruits whereas Khah *et al.* (2006) observed a non-significant difference between graft combinations with respect to tomato fruit firmness. The influence of rootstocks on vegetable fruit firmness may be ascribed to a variation in cell turgor, chemical and mechanical properties of cell walls of the fruit as a result of changing water relationships and nutritional status of scions (Rouphael *et al.,* 2010).

The increase in TSS in Assila and Monica graft combinations and TA in Monica graft combinations in the current study could be attributed to limited water uptake as a result of low vigour of the eggplant rootstocks. Bletsos and Olympios (2008) reported that partial graft incompatibility between tomato cultivar and Solanum intergrifolium rootstock resulted in high TSS due to impaired water flow through the graft interface. A decrease or non-alteration in flavour compounds as observed in this work has also been observed elsewhere. For instance, Khah *et al.* (2006) observed that TSS, TA and TSS/TA ratios in tomato fruits were not altered by grafting under field and greenhouse conditions.

Conclusion and Recommendations

Grafting hybrid tomato cv. Assila and Monica onto the eggplant EG190, EG195 and EG203 rootstocks can improve fruit flavour components at markedly expense of total and marketable yield. Therefore, it is recommended that farmers should avoid grafting hybrid tomato cv. Assila and Monica onto rootstocks EG190, EG195 and EG203. Further studies are required to determine rootstocks that are vigorous enough to carry these scions in order to improve yield and fruit quality of hybrid tomato cultivars.

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