EFFECTS OF GRAFTING AND HIGH TUNNEL TOMATO PRODUCTION ON PEST INCIDENCE, YIELD AND FRUIT QUALITY IN SMALLHOLDER FARMS IN CENTRAL KENYA

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ABSTRACT

Tomato, (*Solanum lycopersicum L.*) is one of the most valuable local market vegetable in Kenya. Production of the crop is constrained by abiotic and biotic stresses. The major pests include bacterial wilt caused by *Ralstonia solanacearum*; tomato yellow leaf curl virus; whiteflies, *Bemisia tabaci*; thrips, *Frankliniella occidentalis* and *F. Schultzei*; aphids, *Aphis gossypii*; mites, *Tetranychus spp* and bollworms, *Helicoverpa armigera*. To address these constraints, tomato grafting and use of high tunnels was evaluated in collaboration with smallholder tomato growers in Kirinyaga County. The aim of the trials was to compare grafted with un-grafted tomato and high tunnel with open field production on pest incidence, yield and fruit quality. The treatments included tomato seedlings of a common variety Onyx, grafted on a bacterial wilt resistant MT56 and un-grafted Anna F1 hybrid. The tomato crops were simultaneously grown in the high tunnel and open field for two seasons in a two-factor randomized complete block design. Results showed that tomato grown in the open field had higher infestation of whiteflies ($P<0.05$), thrips and aphids than tomato grown in the high tunnel where no aphids and very slight whitefly and thrips infestations were recorded. Grafting the bacterial wilt susceptible var. Onyx on Mt 56 resulted in lower disease incidence in both high tunnel (15%) and open field (25%) compared to 90% and 88% disease incidence in the un-grafted Onyx in the open field and high tunnel respectively($P<0.05$). There was no difference in disease incidence between the production systems ($P<0.05$). Higher yields were recorded from high tunnel crop than the crop in open field. Tomato in the high tunnel had superior quality in terms of peel thickness, percent brix and vitamin C.

Key words:Arthropod pests, grafting, high tunnel, *Ralstonia solanacearum*, tomato

INTRODUCTION

Tomato, (*Solanum lycopersicum L.*) is one of the most valuable local market vegetable in Kenya. It is an important dietary component, contributing to improved nutrition and livelihood for both the rural and urban population. The major nutritive ingredient in a tomato fruit is lycopene and high vitamin C and A. As an antioxidant, vitamin C reduces the risk of arteriosclerosis, cardiovascular diseases and some forms of cancer (Benton, 2008).

Approximately 30% of the households in Kirinyaga County are involved in tomato production occupying about one-third of the cultivated area (Waiganjo *et al.*, 2008). Most of the tomato consumed in Nairobi is grown by the smallholder farmers in Kirinyaga County. Production of the crop is however constrained by pests (Varela *et al.*, 2003), poor agronomic practices, and various abiotic stresses such as drought, waterlogging and salinity (Black, 2003). With access to irrigation, growers in this area keep their land in continuous cultivation resulting in disease and pests build up and resurgence.

The major tomato diseases include bacterial wilt, *Ralstonia solanacearum*; whitefly transmitted tomato yellow leaf curl virus; root knot nematodes, *Meloidogyne spp.*; and late and early blights caused by *Phytophthora infestans* and *Alternaria solani* respectively. Important arthropod pests include whiteflies, *Bemisia tabaci*; thrips, *Frankliniella occidentalis* and *F. schultzei*; aphids, *Aphis gossypii*; mites, *Tetranychus urticae* and *T. evansi* and bollworms, *Helicoverpa armigera* (Varela *et al.*, 2003; Waiganjo *et al.*, 2008). Control of these pests is mainly through routine pesticide application that is associated with the well known negative effects to the environment and consumers, besides the pest resistance development. Moreover, management of bacterial wilt is particularly difficult since chemical control is not effective. However, use of grafted plants and high tunnels has been proven valuable components of integrated crop management in many regions of the world (Burleigh *et al.*, 2005; Jett and Read, 2003; Rich, 2010). High tunnel production systems have been reported to address diminishing land sizes, climate change and provide other benefits

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including high yields and quality (Fintrac, 2008). In combination, grafted plants and high tunnels can significantly increase farm productivity, efficiency and sustainability (Lee, 1994; Peregrine, 1982). However, information on these technologies in Kenya is scarce (Kleinhenz *et al.*, 2011). As a result, there is limited technical knowledge among resource poor smallholder farmers on the appropriate high tunnel structures and their utilization. The objectives of this study were to carry out participatory research with a smallholder tomato farmers group in Kirinyaga County to assess the effects of high tunnel and grafting on tomato pests, crop yield and fruit quality. The project aimed at empowering farmers in grafting technology, ideal high tunnel structures and their utilization for improved tomato productivity.

MATERIALS AND METHOD

Tomato trials were set in an open field and a high tunnel in a farmer's field in Kirinyaga County, Kenya during the year 2011. The trials were carried out in a smallholder farm for two growing seasons in collaboration with Bayer tomato growers group. Three tomato treatments including grafted and un-grafted seedlings of variety Onyx and var. Anna F1 hybrid were used. The variety Onyx was selected due to its susceptibility to bacterial wilt and preference in the open fields and local markets while Anna F1, an indeterminate variety is the most commonly grown in high tunnel systems in Kenya.
Establishment of grafted tomato seedlings

The bacterial wilt susceptible variety Onyx was grafted onto a bacterial wilt resistant Mt56 using cleft grafting. Proper hygiene and sanitation was observed in the grafting exercise. Grafting blades (surgical blades) mounted on stainless steel handles; clips, grafting tapes, gloves, disinfectant (Jik®) and clean water were used. The work was carried out under a grafting shed on benches. After grafting, the seedlings (raised in polybags) were kept inside a healing chamber consisting of a frame covered by polyethylene sheeting for acclimatization which kept the humidity level high during the healing process. The chamber was covered with black polythene to block all available sunlight from entering the chamber, until the leaves of the newly grafted transplants no longer showed signs of moisture stress.

The grafted and un-grafted seedlings were transplanted after one month of sowing using the recommended 30 x 60 cm spacing, in a two factor randomized complete block replicated four times in each of the two systems (open field, high tunnel). Similar fertilizer application, pruning, weeding, irrigation and other agronomic practices were carried out by the farmer group similarly in the high tunnel and open field. The high tunnel used in these experiments had a width and length of 8m and 15m respectively, an exclusion-double door and a foot bath to ensure disinfection into the high tunnel, while the sides were made of 50 mesh insect proof netting.

Data Collection

Arthropod pest population was recorded fortnightly from five randomly selected tomato plants per plot. Insect populations were estimated by 0-5 score representing no infestation (0), slight (1), mild (2), moderate (3), high (4) and severe (5) for whiteflies and aphids (Waiganjo *et al.*, 2008). Insect counts on thrips (adults and larvae) were recorded from five plants per plot. Bacterial wilt incidence was assessed by examining all the plants in each plot for the presence or absence of the disease. The number of infected plants per plot was recorded and the percent disease incidence calculated in each treatment in the two production systems (high tunnel and open field). Yield data was taken by harvesting from all plants per plot and calculated for each treatment on hectare basis. To assess quality, 10 marketable fruits were randomly selected from each treatment in each of the two production systems to carry out fruit quality analysis. The parameters included peel thickness using a vernier calper, total titratable acidity, vitamin C and total soluble solids. Total soluble solids were measured using a digital refractometer, while vitamin C was determined using titration method. Fruit acidity was analyzed by taking 1 ml of the fruit pulp; adding 5 ml of water and then 0.1 ml MR Indicator. The solution was titrated using 0.1N Sodium hydroxide and total acidity calculated and expressed as percent citric acid.

Data Analysis

Data on insect numbers were log transformed (x'=log 10 (x+1) during analysis while insect scores were converted into additive components by calculating the mean score plot. Data was analyzed using Genstat statistical software and means where significant, separated by Student-Newman-Keuls test at $P<0.05$.

RESULTS

The effect of high tunnel and grafting on tomato arthropod pest incidence

The major pests observed in the tomato crop in both seasons were whiteflies, *Bemisia tabaci*; thrips, *Frankliniella occidentalis* and *F. Schultzei* and aphids, *Aphis gossypii* (Table I). Significantly higher infestation by all the pests occurred in the open field than in the high tunnel. In the open field, the tomato crops were moderately to highly infested with whiteflies (3-4), slightly infested with aphids (1), while the mean thrips numbers ranged from 5-8/plant. There was no significant difference in pest populations between the grafted and un-grafted tomato (Table I)

Within a column, means marked with the same small letter are not significantly different by Student Newman's Keuls (SNK) test @ $P<0.05$.

The effect of grafting on tomato bacterial wilt incidence in the open field and high tunnel

Bacterial wilt occurred in tomato grown in the two production systems (Table II). Grafting the bacterial wilt susceptible variety Onyx on resistant Mt56 resulted in significantly less disease incidence among the tomato types in both high tunnel (15%) and open field (25%) compared to near total crop loss (90% and 88%) in the un-grafted Onyx in open field and high tunnel respectively. Grafted Onyx recorded significantly least percent bacterial wilt incidence (25.45% and 15.00%) in the open field and high tunnel respectively. However, no significant difference in disease incidence occurred between the open field and high tunnel production systems.

Within a column, means marked with the same small letter are not significantly different while means marked with the same capital letter within a row are not significantly different by SNK @p<0.05

There were significant differences in yields between the tomato varieties and the production systems (Table III).

Yield assessment of the marketable tomato showed that var. Ann F1 hybrid which is an open pollinated, indeterminate variety had higher (p<0.0001) yield in open field and high tunnel than the determinate grafted and un-grafted Onyx. All the tomato varieties recorded significantly higher yields in the high tunnel than in the open field. The grafted Onyx did not demonstrate significant difference in yield when grown in high tunnel compared with open field. However, the grafted Onyx yielded significantly higher than the un-grafted Onyx in both open field and high tunnel.

Within a column, means marked with the same small letter are not significantly different while means marked with the same capital letter within a row are not significantly different by SNK @p<0.05

The effects of high tunnel and grafting on tomato fruit quality

The results (Table IV) indicated that fruits under high tunnel production had higher peel thickness and higher levels of vitamin C but not different (p=0.213) from tomato produced in the open field. Among the tomato varieties, Anna had the highest level of Vitamin C (60.3mg/100g) but the variety had the lowest level of Brix (5.25%). However, the differences were not significant.

DISCUSSION

The study has established that use of high tunnel significantly reduced crop infestation by the major arthropod pests namely whiteflies, thrips and aphids and increased tomato yield and the quality of the fruit. It is evident that use of high tunnel with insect proof netting and double doors reduced pest entry and consequent crop infestation. This study therefore confirms reports by Black (2003) and Pottorf *et. al.* (2009), who showed that properly managed microclimate high tunnels can limit

TABLE I - EFFECTS OF HIGH TUNNEL AND GRAFTING ON TOMATO ARTHROPOD PESTS INCIDENCE S.E

Production System	Tomato type	Whiteflies	Thrips	aphids
Open field	Onyx	4.02±0.19a	8.03±3.09a	1.11±0.01a
	Grafted Onyx	3.57±0.19a	6.05±3.08a	1.24±0.01a
	Anna F1	3.46±0.19a	5.18±5.08a	1.36±0.01a
High tunnel	Onyx	0.11±0.01b	1.14±0.03ab	0.0b
	Grafted Onyx	0.0b	1.01±0.03ab	0.0b
	Anna F1	0.0b	0.0b	0.0b
P		<0.001	0.012	<0.001
% C.V		23.5	44.7	15.8

Within a column, means marked with the same letter are not different P<0.05

TABLE II- THE EFFECT OF GRAFTING ON PERCENT TOMATO WILT INCIDENCE± S.E.

Production system	Onyx	Grafted Onyx	AnnaF1	P- value
Open field	90.05 ±5.31aA	25.45 ±0.06ab	74.35±2.6aA	0.0013
High tunnel	88.7±0.05aA	15.00±0.00aB	56.02±0.08aAB	<0.0001
P-value		0.256	0.134	<0.001
% C.V		29.8	43.6	25.2

Within a column, means marked with the same letter are not significantly different while means marked with the same capital letter within a row are not different P<0.05

TABLE III-EFFECTS OF HIGH TUNNEL TOMATO PRODUCTION AND GRAFTING ON TOMATO YIELD (TON/HA)

Production system	Onyx	Grafted Onyx	AnnaF1	P- value
Open field	1.39±0.55aC	10.67±1.05aB	19.21±0.68bA	<0.0001
High tunnel	2.15±3.06aC	15.4±2.9aB	26.82±2.51aA	<0.0001
P-value		0.0651	0.027	0.0024
% C.V		45.2	34.8	28.6

Within a column, means marked with the same letter are not significantly different while means marked with the same capital letter within a row are not different by SNK @p<0.05

TABLE IV- PHYSICAL AND CHEMICAL CHARACTERISTICS OF TOMATO UNDER HIGH TUNNEL AND OPEN FIELD PRODUCTION SYSTEMS

Tomato Production system	Tomato variety	Peel thickness (mm)	Brix (%)	Vitamin c (mg/100g)	Total citric (%)
High Tunnel	Onyx	7.59	6	13.72	0.63
	Grafted Onyx	6.80	6	12.5	0.66
	Anna	7.4	5.25	60.275	0.61
Open field	Onyx	7.75	6. 3	11.8	0.62
	Grafted Onyx	7.07	6.75	10.3	0.6
	Anna	7.89	5.75	9.975	0.58
P		0.213	0.082	0.124	0.112
% C.V		58.3	23.45	15.97	29.97

the incidence and severity of diseases or the prevalence of weed and pest pressure and the percentage of off-quality fruit. This finding has an implication in the use of pesticides which would be greatly reduced compared to the open field resulting in higher food safety. High tunnels therefore have a key role for small farms and limited-resource farmers in reducing the needs for pesticides (USDA, 2009). In this study, tomato grafting significantly controlled bacterial wilt incidence resulting in significantly higher tomato yield among the grafted tomato than the un-grafted tomato. Using the tomato Mt56 bacterial wilt resistant rootstock, similar findings were reported by Ssonko (2007). Grafting has been reported to be a simple technique that growers could use to increase soil borne disease resistance in tomatoes without chemical fumigants or pesticides (Rivard and Leuws, 2008; Kleinhenz, 2010). Furthermore, research worldwide has demonstrated increased yields from grafted vegetable plants in comparison to non-grafted plants (Black, 2003, Ssonko, 2007). Grafting had significant increase on yields in both production systems. However, grafting had no significant effect on the arthropod pest incidence. Generally, in all treatments the tomatoes showed values within the standard range of Total Soluble Solids (5-7%) and Total Titratable Acidity (0.7-0.9%) as pointed out by Benton (2008). Klein and Perry (1982) reported that cultural practices such as pruning and thinning influence the crop load and also nutritional composition.

High tunnel production systems and grafting therefore may offer an opportunity for tomato production in diminishing farms especially in peri-urban areas and densely populated areas. High tunnel systems may therefore spur popularization of grafted vegetable plants in this region. This has been witnessed in the recent surge in high tunnels construction among the small holder farmers in Kenya.

CONCLUSION AND RECOMMENDATIONS

The study has established that use of high tunnel significantly reduced arthropod pest infestation, increased tomato yield and the fruit quality. On the other hand, tomato grafting significantly reduced bacterial wilt incidence resulting in increased crop yield in both production systems. The use of grafted plants and high tunnels has many positive effects on tomato crop and its productivity. The use of the technologies does not require an extensive array of sophisticated technical information or equipment. This study established that grafting is a valuable and practicable disease management technique for tomato which could ensure fruit quality while keeping disease resistance high for tomato production systems with soil borne disease pressure. Smallholder tomato farmers should be empowered with the appropriate technologies to improve their tomato production. To optimize this possibility, further evaluation of grafting rootstocks is required to identify suitable rootstocks for high tunnel production.

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