Evaluation of Grafted and Non-Grafted Hybrid and Heirloom Tomatoes in a High Tunnel

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Introduction

High tunnels have emerged as a tool for Iowa vegetable growers to extend the growing season, increase crop production, and improve quality of the produce, but production in this system does not come without challenges. Continuous cropping of tomatoes in the same high tunnel gives rise to recurring soilborne and foliar diseases, pest pressure, issues with soil fertility and salinity, and increased irrigation requirements. One tool to overcome these challenges may be the use of vegetable grafting. The process of grafting is accomplished by attaching a desired scion onto a rootstock that is typically bred for vigor and/or disease resistance.

Field research was conducted over two years (2015 and 2016) to compare the effect of grafting on Cherokee Purple (indeterminate heirloom tomato) and Mountain Fresh Plus (hybrid determinate tomato). The rootstock utilized in this study was RST-04-106-T, which is resistant to Fusarium Wilt, Bacterial Wilt, and Tomato Mosaic Virus. This study was a randomized complete block design to compare grafted and non-grafted plants of both tomato varieties.

Materials and Methods

Tomatoes were seeded in the Department of Horticulture greenhouse on March 19, 2015 and March 11, 2016. Three weeks after seeding, half the tomato plants were grafted using the splice grafting method. This required cutting the rootstock stem at a 45 degree angle below the cotyledon (seed leaf). The scion stem was cut at the same angle below the cotyledon. The two stems were joined together and held in place utilizing a silicon grafting clip (Figure 1). The transplants were placed in a high humidity, light blocking “healing chamber” for three days before being gradually re-acclimated to ambient greenhouse conditions.

On May 7, 2015 and April 29, 2016, transplants were planted in a ClearSpan™ high tunnel with dimensions of 30 ft W x 12 ft H x 96 ft L covered with six millimeter polyethylene film. Automated roll-up sides on the high tunnel had a set-point of 80^{o}F. The tomatoes were planted 18 in. apart with 10 plants in each of the four treatment plots (Figure 2). Rows were replicated four times within the high tunnel at a spacing of 5 ft. Mountain Fresh tomatoes were grown using a stake and weave support system. Cherokee Purple tomatoes were grown as a single leader using the lower-and-lean trellis technique supported on the Rollerhook® system. A drip tape irrigation system was utilized to water in 200 gallon increments for up to 600 gallons weekly. The entire high tunnel was mulched to a depth of 6 in. using switchgrass mulch. On July 27, 2015 and June 9, 2016, a 30 percent shade cloth was installed on the high tunnel to reduce light levels and lower temperature.

Harvest took place 10 times throughout the 2015 season July 22–October 12, and 14 times during the 2016 season July 6–October 3 (Figure 3). Mountain Fresh tomatoes were harvested at the breaker stage of ripeness and were graded utilizing size standards (Grade 1 = diameter greater than 2¾ in.; Grade 2 = between 2¾ and 2½ in.; and Grade 3 =

between 2½ and 2¼ in.). Non-marketable Mountain Fresh tomatoes included fruit with diameter smaller than 2¼ in. as well as fruit with major surface defects and insect and disease damage. Cherokee Purple tomatoes were harvested at the "pink to red" stages classified according to the USDA maturity standards. The fruit was graded visually to determine marketability. Non-marketable Cherokee Purple fruit was sorted into categories based on fruit cracking, damage from sunscald, scab as a result of cat-facing, severely misshapen fruit, and insect damage. Fruit count and weight was recorded for all categories of fruit for each harvest.

Plant vigor in response to grafting was evaluated using several parameters. During the peak of tomato production, five plants per treatment plot were sampled for chlorophyll content using an optimal spectrometer to determine an average SPAD reading (Figure 4). At the end of each season, five plants per plot were measured for stem diameter at a point 15 cm above the soil surface. Additionally, three plants from each plot were removed by collecting all shoot tissue and digging an 18 in. circumference hole to collect a uniform root sample. Roots and shoots from each plant were separated, dried, and weighed to compare biomass. Post-harvest fruit quality was determined by collecting samples of marketable fruit for lab analysis during both years. One whole fruit from each plot was blended in a food processor and sampled in a refractometer to measure soluble solids (Brix^{o}). In 2016, a penetrometer was used on marketable fruits to measure firmness. One measurement was taken on each fruit equatorially. Data were analyzed using PROC GLIMMIX of SAS Version 9.3.

Results and Discussion

In the analysis of harvest data from 2015 and 2016, the study found the grafted rootstock, RST-04-106-T, significantly increased the marketable number of fruit overall (Table 1). Grafting increased production by 16,200 fruits per hectare (p-value = 0.04). As expected, there was significantly more fruit produced by Mountain Fresh Plus compared with Cherokee Purple. However, when considering marketable weight, grafted rootstock did not have a significant effect. With the exception of Mountain Fresh Plus in 2016, grafting appeared to slightly lower average weight of individual marketable fruit. The percentage of marketable fruit was not affected by grafting, but was significantly more for Mountain Fresh Plus (85.9%) compared with Cherokee Purple (51.8%). Marketability of all treatments was significantly improved in 2016, although overall fruit numbers were less than 2015.

When considering plant vigor, we did not find any difference between the roots or shoot biomass of grafted and non-grafted plants (Table 2). This was somewhat surprising as the assumption was the improved rootstock would have more biomass and thus confer growth to the rest of the plant. However, this is not the case for RST-04-106-T. We did find a significant increase in stem diameter on the grafted plants–the increased stem diameter could be valuable for increased strength of the overall plant, especially under windy conditions of Midwest plains. The chlorophyll content of grafted plants had a significant interaction with cultivars. There was an increase in SPAD readings for grafted Cherokee Purple tomatoes, but a decrease in SPAD readings for Mountain Fresh Plus.

Our analysis of fruit quality (Table 3) showed there was an overall decrease of soluble solids (Brix^{o}) in grafted fruit (p-value = 0.04). This result is interesting, because our hypothesis was that grafting would increase sugars within the fruit. We also found grafting did not significantly increase the firmness of the fruit. Not surprisingly, Mountain Fresh Plus tomatoes were significantly firmer than Cherokee Purple.

Based on results from year one (2015), changes were made in 2016 in crop management. As the 2015 season progressed, we observed serious sun scalding on fruits in the high tunnel. A 30 percent shade cloth was immediately installed over the high tunnel during the week of July 27, 2015. In 2016, the shade cloth was installed June 9 to minimize crop injury due to sun scald and potential loss of marketable fruits. The issue of heat stress caused us to question how this may be best addressed through the use of shade cloth. A newly funded study will examine the effects of light and temperature reduction on colored bell peppers in 2017 and 2018.

During the 2015 season, there was high incidence of yellow shoulder, which is a physiological disorder that is characterized by discolored regions under the skin and yellow shoulder that reduce the quality of the fruit. A pre-plant application of 22 lb/acre potash was incorporated for the 2016 season to alleviate this issue.

Cherokee Purple tomatoes showed cracking in both 2015 and 2016, but irrigation was spread over 2-3 days/week in 2016 to reduce the incidence of cracking. Due to the diverse nature of the Horticulture Research Station, there are apple orchards located in close proximity to high tunnels. In 2016, an application of Paraquat was applied near apple trees with a resulting pesticide drift that damaged many tomato transplants at two weeks of growth in the high tunnel. Plant damage was assessed and plots were replanted as needed with plants recovering across treatments as the season progressed.

Overall, the results of this study showed use of the rootstock RST-06-104-T can have some benefits for yield and plant health, but it may not significantly increase marketability of fruit or contribute to improved fruit quality. It is important to look at multiple studies with a wide variety of tomato rootstocks bred for grafting to continue to drive sound management decisions. An offshoot experiment of this project was a study that evaluated appropriate environmental conditions for healing of the graft union. The experiment investigated the effect of light and root zone temperature on health and quality of grafted tomato plants. A transplant with successful graft union and robust growth attributes are key for successful field production.

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Table 1. Marketable fruit, total fruit, and marketability of grafted and non-grafted Cherokee Purple and Mountain Fresh Plus tomatoes grown in 2015 and 2016 at the ISU Horticulture Research Station, Ames, IA.

		Marketable fruit			Total fruit			Marketability (%)	
Cultivar	Graft	Yield (Mg ha^{-1})	No. of fruit (no. ha^{-1} x 1,000)	Fruit Size (g)	Yield (Mg ha^{-1})	No. of fruit (no. ha^{-1} x 1,000)	Fruit Size (g)	Yield	No. of fruit
					2015				
Cherokee Purple	Grafted	35.2 c[z]	118.7 c	295.7 ab	67.5 bc	219.3 d	306.0 ab	52.3% bc	54.0% c
	Non-grafted	29.7 c	97.8 c	308.4 a	64.7 bc	203.9 d	319.9 a	45.8% c	47.3% c
Mountain Fresh Plus	Grafted	103.5 a	380.0 a	272.2 bc	121.9 a	482.9 a	252.7 cde	84.8% a	78.8% b
	Non-grafted	102.4 a	352.0 a	292.0 ab	115.4 a	416.1 b	279.1 bcd	89.0% a	85.0% ab
					2016				
Cherokee Purple	Grafted	37.1 c	120.8 c	302.7 ab	65.3 bc	219.7 d	295.3 ab	55.5% b	53.8% c
	Non-grafted	30.3 c	99.2 c	306.8 ab	53.8 c	188.8 d	284.4 abc	56.0% b	52.0% c
Mountain Fresh Plus	Grafted	65.2 b	268.9 b	242.3 cd	70.6 b	295.2 c	238.8 de	92.5% a	91.3% a
	Non-grafted	62.0 b	274.3 b	224.7 d	69.5 b	309.6 c	223.2 e	89.5% a	88.5% a
					Significance				
Cultivar (C)[y]		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Graft (G)		0.117	0.040	0.560	0.063	0.021	0.677	0.565	0.472
Year (Y)		0.022	0.071	0.115	0.017	0.027	0.083	0.052	0.043
C x G		0.440	0.502	0.653	0.544	0.878	0.814	0.382	0.095
Y x G		0.749	0.272	0.166	0.768	0.110	0.056	0.976	0.564

[y]P values based on F test.

[z]Mean separation (across years in columns) based on least significant differences at $P \leq 0.05$.

Table 2. Plant biomass, stem diameter, and chlorophyll readings of grafted and non-grafted Cherokee Purple and Mountain Fresh Plus tomatoes grown in 2015 and 2016 at the ISU Horticulture Research Station, Ames, IA.

Cultivar	Graft	Shoot biomass (g/plant)	Root biomass (g/plant)	Stem diameter (mm)	SPAD
			2015		
Cherokee Purple	Grafted	111.7 b[z]	5.8 c	15.4 a	44.4 cd
	Non-grafted	115.6 b	5.8 c	14.7 ab	43.4 cd
Mountain Fresh Plus	Grafted	339.8 a	14.9 a	15.2 ab	45.7 bc
	Non-grafted	346.2 a	12.9 ab	14.3 b	47.0 b
			2016		
Cherokee Purple	Grafted	154.6 b	8.0 c	15.1 ab	44.0 cd
	Non-grafted	145.2 b	7.5 c	14.4 ab	42.8 d
Mountain Fresh Plus	Grafted	338.8 a	11.6 b	15.2 ab	47.9 ab
	Non-grafted	334.0 a	10.9 b	14.3 ab	49.5 a
			Significance		
Cultivar (C)[y]		<0.0001	<0.0001	0.556	<0.0001
Graft (G)		0.975	0.162	0.005	0.725
Year (Y)		0.467	0.570	0.689	0.168
C x G		0.838	0.340	0.708	0.047
Y x G		0.773	0.719	0.978	0.958

[y]P values based on F test.

[z]Mean separation (across years in columns) based on least significant differences at $P \leq 0.05$.

Table 3. Soluble solids and firmness of grafted and non-grafted Cherokee Purple and Mountain Fresh Plus tomatoes grown in 2015 and 2016 at the ISU Horticulture Research Station, Ames, IA.

Cultivar	Graft	Soluble solids (Brix°)	Firmness (kgf)[x]
		2015	
Cherokee Purple	Grafted	5.1 ab[z]	-
	Non-grafted	5.3 a	-
Mountain Fresh Plus	Grafted	4.5 c	-
	Non-grafted	5.4 a	-
		2016	
Cherokee Purple	Grafted	5.0 ab	2.4 ab
	Non-grafted	5.1 ab	1.8 b
Mountain Fresh Plus	Grafted	4.7 bc	2.8 a
	Non-grafted	4.5 c	2.6 a
		Significance	
Cultivar (C)[y]		0.003	0.017
Graft (G)		0.036	0.088
Year (Y)		0.074	-
C x G		0.508	0.424
Y x G		0.006	-

[x]kgf = kilogram-force.

[y]P values based on F test.

[z]Mean separation (across years in columns) based on least significant differences at $P \leq 0.05$.

Figure 1. Newly grafted tomatoes April 1, 2016.

Figure 2. Students planting tomatoes in the high tunnel April 29, 2016.

Figure 3. An intern assisting with harvest of tomatoes.

Figure 4. Undergraduate research assistants collect chlorophyll leaf content data.