The Use of Grafted Hybrid Tomatoes in the Absence of Soilborne Disease Pressure

RFR-A1830

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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 the quality of the produce. However, 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, and issues related to soil fertility and salinity. Vegetable grafting has been suggested as one of the tools to address these challenges. Grafting is accomplished by attaching a desired scion (top portion of the graft) onto a rootstock (bottom portion of the graft) that is bred for vigor or disease resistance.

Prior work conducted at Iowa State University in 2015 and 2016 indicated, in the absence of soilborne diseases, tomatoes grafted onto hybrid rootstock RST-04-106-T showed a minimal yield increase. Since these results were specific to the RST-04-106-T rootstock, further trials were needed to identify appropriate tomato rootstocks that meet the need of localized soil conditions in the Midwest, especially Iowa. This research was designed to identify appropriate tomato rootstocks and document their impact on high tunnel tomato production. Field research was conducted over two years (2017 and 2018) to compare the effect of grafting on tomato cultivar BHN 589 (hybrid determinate tomato). The rootstocks evaluated in this study were Arnold, Beaufort, DRO141TX, Estamino, Maxifort, RST-04-106-T, 946 TRS, and 980 TRS. The latter two are trial rootstocks from Sieger's Seed Company. This study was a randomized complete block design with five replications and included a non-grafted and self-grafted control.

Materials and Methods

Tomato seeding was staggered based on germination rate trials with seeding occurring between March 14-19, 2017, and February 26-March 4, 2018. All seedlings were grown in the Department of Horticulture greenhouses in Ames, Iowa. About three weeks after seeding when the seedlings were approximately 2 mm in diameter, seedlings 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. For the self-grafted treatment, a similar method was adopted but on the same seedling. All transplants then were placed in a high humidity, light blocking healing chamber for three days before being gradually re-acclimated to ambient greenhouse conditions seven days post-grafting. Non-grafted plants remained in ambient conditions for the entire transplant production period.

On April 21, 2017, and April 20, 2018, transplants were planted in a ClearSpan™ high tunnel with dimensions of 30 ft x 12 ft x 96 ft, and covered with 6 mm polyethylene film. Automated roll-up sides on the high tunnel had a set-point of 75°F. Each treatment included five plants. In 2017, plants were spaced in-row at 15 inches, and this was increased to 18 inches in 2018. Rows were replicated five times within the high tunnel.

All plants were grown using a stake and weave support system. A drip tape irrigation system was utilized to water in 300-gallon increments for up to 600 gallons weekly. The entire high tunnel was mulched to a depth of six inches using switchgrass mulch. A 50 percent shade cloth was installed on the high tunnel to reduce light levels and lower temperature June 14-August 23, 2017, and June 19-August 16, 2018.

Harvest took place 13 times each season during July 5-September 25, 2017, and July 25-September 25, 2018. Tomatoes were harvested at the breaker stage of ripeness and were graded utilizing USDA standards (Grade 1 = diameter greater than 2 ¾ inches; Grade 2 = between 2 ¾ and 2 ½ inches, and Grade 3 = between 2 ½ and 2 ¼ inches). Non-marketable tomatoes included fruit with diameter smaller than 2 ¼ inches, fruit damaged by blossom end rot, cat-facing, yellow shoulder, insects, or other surface defects. Fruit count and weight was recorded for all categories of fruit for each harvest.

Post-harvest fruit quality was determined by collecting samples of marketable fruit for lab analysis during both years. One fully-ripe whole fruit from each plot was blended in a food processor and sampled using a refractometer to measure soluble solids content (SSC, ^{o}Brix) and a Hanna Mini Titrator was used to measure total titratable acidity (TTA, percent citric acid).

At the end of each season, three plants/plot were measured for stem diameter at either 2 cm above the soil (non-grafted) or 1 cm above the graft union. The same three plants were measured for plant height from the soil line to highest growing point. Shoot and root biomass also was collected at the end of the season from the same three plants measured for stem diameter and height (data not shown). Data was analyzed using PROC GLIMMIX of SAS Version 9.3.

Results and Discussion

During the 2017 and 2018 growing seasons, five of the rootstocks (Arnold, Beaufort, DRO141TX, Estamino, and Maxifort) significantly increased the average number ($P < .0001$) and weight of marketable fruit/plant ($P = 0.0004$) compared with the non-grafted and self-grafted controls and three additional rootstocks (946 TRS, 980 TRS, and RST-04-106-T) (Table 1). Marketable fruit includes all fruit from USDA Grades 1, 2, and 3. DRO141TX had an average of 38.0 fruit/plant with an average yield of 7.7 kg/plant. While this was the highest marketable yield, it was not different from the other four high-performing rootstocks at Fisher’s protected least significant difference at alpha 0.05. There was not a significant increase in the percentage of marketable fruit by either number or yield. Total fruit number/plant (marketable and non-marketable) followed the same trend as the marketable fruit/plant; however total fruit yield (kg) had a significant treatment-by-year interaction (data not shown).

The average marketable fruit weight (yield divided by number) was only significant in 2018 ($P < .0001$), which makes drawing conclusions on fruit weight difficult (Table 2). However, the use of Arnold, Estamino, or Maxifort rootstock may provide heavier (larger) fruit compared with non-grafted plants.

Analysis of fruit quality found no significant differences between SSC, TTA, or the SSC:TTA ratio (Table 3). The SSC:TTA ratio is used as a measure of consumer taste preference, with a higher value typically being perceived as better-tasting, although subtle differences are hard to detect by the average consumer. Some studies have shown a reduction in these fruit quality parameters due to grafting, but these results contradict that finding.

The same high-yielding plants (Arnold, Beaufort, DRO141TX, Estamino, and Maxifort) grew the largest in the field with an average height ranging from 191.4-206.3 cm (Table 4) compared with the other treatments. This volume of growth made it necessary for additional stakes to be used to support the plants in each season. Based on lessons learned in 2017, metal t-posts replaced wooden tomato stakes in 2018 to avoid collapse of the staking system and damage to the plants. Rootstock vigor was demonstrated through the stem diameter above the graft union (Table 4). DRO141TX, Arnold, Estamino, and Maxifort had stem diameters ranging from 17.3-18.4 mm.

Overall, the results of this study showed five rootstocks (Arnold, Beaufort, DRO141TX, Estamino, and Maxifort) should improve plant growth and fruit yield when grafted to a hybrid tomato cultivar even in the absence of soilborne disease. A 1.5-1.7-fold increase in fruit number/plant over non-grafted plants may make economic sense for producers, especially if tomato grafting is done on-farm. In situations in which growers are experiencing yield decline due to disease and pathogen build-up, grafting certainly is a game-changer to ensure profitable yield and quality.

Midwest growers looking to add grafted plants into their growing system should begin with one of the five high-performing rootstocks identified in this trial. On-farm performance for specific site conditions should be evaluated. If grafting is performed on-farm, the grafted transplants must be carefully managed since a successful graft union and robust growth attributes are keys to successful field production.

Acknowledgements

Thanks to fellow graduate students, especially Moriah Bilenky, and undergraduate research assistants Olivia Allen, Elli Boehm, Shannon Rauter, Sarah Steffen, Neel Solanki, Justin Wigdahl, and Ellena Wolff for their assistance with plot establishment and data collection. Thanks also to the entire ISU Horticulture Research Station staff for their technical support, and to Jenny Quiner, 2018 grower collaborator, who tested grafted tomatoes on her farm and provided valuable feedback.

Table 1. Marketable yield, percent marketable yield and total yield of fruit from non-grafted, self-grafted, and grafted BHN 589 to eight different rootstocks.*

	Marketable fruit/plant		Marketable fruit of total harvest (%)		Total fruit/plant
Treatment	**No. of fruit****	**Yield (kg)****	**No. of fruit**	**Yield (kg)**	**No. of fruit****
Non-grafted	22.0 b	4.5 b	61.7	78.6	36.7 b
Self-grafted	24.3 b	4.1 b	62.4	75.9	38.7 b
946 TRS	23.6 b	4.7 b	61.4	77.6	39.3 b
980 TRS	24.7 b	5.0 b	63.2	79.1	39.5 b
Arnold	33.4 a	7.1 a	58.0	73.3	58.9 a
Beaufort	34.6 a	7.3 a	64.5	77.3	54.5 a
DRO141TX	38.0 a	7.7 a	63.9	80.3	61.3 a
Estamino	34.3 a	7.4 a	63.1	80.8	55.1 a
Maxifort	35.5 a	7.2 a	60.7	76.9	60.3 a
RST-04-106-T	24.8 b	4.9 b	62.7	78.8	40.4 b
P value	<.0001	0.0004	0.2839	0.5234	<.0001

P values indicate significance of the main effect of treatment based on F-test.
There was no significant treatment-by-year interaction.
*Shown as treatment in table. Harvest occurred 13 times each season July 5–September 28, 2017, and July 3–September 25, 2018.
**Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ based on Fisher's protected least significant difference test.

Table 2. Mean fruit weight of marketable fruit from non-grafted, self-grafted, and grafted BHN 589 scion to eight different rootstocks.*

	Fruit weight (g)	
Treatment	**2017**	**2018****
Non-grafted	192.2	175.4 d
Self-grafted	187.1	180.8 cd
946 TRS	209.4	181.6 cd
980 TRS	218.5	190.1 cd
Arnold	200.1	230.3 a
Beaufort	211.1	209.0 bc
DRO141TX	201.1	208.1 bc
Estamino	214.1	216.9 ab
Maxifort	197.0	213.2 abc
RST-04-106-T	202.2	190.9 cd
P value	0.0662	<0.0001

P values indicate significance of the main effect of treatment based on F-test.
*Shown as treatment in table.
**Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ based on Fisher's protected least significant difference test.

Table 3. Soluble solids content (SSC), total titratable acidity (TTA), and their ratio (SSC:TTA) of non-grafted, self-grafted, and grafted BHN 589 scion to eight different rootstocks.*

Treatment	SSC (°Brix)	TTA (% citric acid)	SSC:TTA ratio
Non-grafted	5.10	0.32	16.56
Self-grafted	4.98	0.37	13.83
946 TRS	5.14	0.40	13.00
980 TRS	5.23	0.37	14.16
Arnold	4.88	0.32	15.94
Beaufort	5.10	0.34	15.45
DRO141TX	5.00	0.34	14.82
Estamino	5.01	0.36	14.30
Maxifort	4.73	0.34	14.41
RST-04-106-T	5.24	0.32	17.30
P value	0.1280	0.2183	0.2326

P values indicate significance of the main effect of treatment based on F-test.
There was no significant treatment-by-year interaction.
Treatment x year interaction significant at P = 0.0021.
*Shown as treatment in table. Fully ripe fruit were harvested 125 days after transplanting (DAT) in 2017 and 116 DAT in 2018.

Table 4. Final height and stem diameter of non-grafted, self-grafted, and grafted BHN 589 scion to eight different rootstocks.*†

Treatment	Height (cm)	Stem diameter (mm)**
Non-grafted	152.6 b	14.9 d
Self-grafted	152.5 b	15.6 cd
946 TRS	154.9 b	15.8 cd
980 TRS	143.9 b	14.9 d
Arnold	198.8 a	17.4 ab
Beaufort	191.4 a	17.0 bc
DRO141TX	200.2 a	18.4 a
Estamino	203.8 a	17.3 ab
Maxifort	206.3 a	18.2 ab
RST-04-106-T	163.7 b	15.6 cd
P value	0.0007	<.0001

P values indicate significance of the main effect of treatment.
There was no significant treatment-by-year interaction.
*Shown as treatment in table.
†Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ based on Fisher's protected least significant difference test.
**Stem diameter was measured 2 cm above the soil for non-grafted treatments and 1 cm above the graft union in grafted plants. Measurements were taken September 20, 2017, and September 25, 2018.