Performance of Conventionally- and Organically-grown Grafted 'Celebrity' Tomato in Ohio in 2008

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Introduction

Abiotic and biotic stresses preclude crop varieties from displaying their full genetic potential and fuel the development of new, improved varieties. New varieties offer superior yield and/or quality but variety development is time-consuming, expensive, technically-demanding, and marked by compromise since gains in one attribute can be offset by declines in another. Grafting is a proven technique for enhancing crop genetic potential but it is under-utilized in U.S. field and high tunnel vegetable production. Grafting quickly and directly combines the traits of rootstocks and scions, bypassing some barriers to variety improvement but raising questions dealing with the compatibility of rootstocks and scions, performance (e.g., vigor, yield) of grafted plants relative to their ungrafted counterparts, fruit quality (e.g., sensory, chemical makeup), and other issues. Consensus views are that grafted plants often outperform ungrafted control plants under stressful conditions, that additional work is required to enhance the use of grafted plants on U.S. vegetable farms and that fresh market tomato is an excellent system for the study and wider implementation of grafting. Therefore, our team set out to (1) facilitate tomato rootstock development; (2) explain rootstock, scion, soil, and production system effects on plant responses to stress; and (3) equipped with novel research-based information, contribute to increases in the knowledge and use of grafting. As an early step, we documented the yield of conventionally and organically grown grafted and ungrafted 'Celebrity' in 2008. Rootstock-scion compatibility, plant vigor, and fruit quality were also evaluated but are not reported here.

Materials and Methods

Production of Grafted Seedlings

A total of 33 lines or varieties were used in this project as either a rootstock (RS), scion (SC), or both. Twenty-nine lines (FGH02-188, FL 7775, H 7998, LA 1589, LA 407, LA 716, MR 13, SGHO7-303, SGHO7-304, SGHO7-305, SGHO7-310, SGHO7-312, SGHO7-313, SGHO7-314, SGHO7-315, SGHO7-316, SGHO7-317, SGHO7-318, SGHO7-319, SGHO7-320, SGHO7-321, SGHO7-323, SGHO7-326, SGHO7-327, SGHO7-332, SGHO7-333, SGHO7-335, SGHO7-336, and SGHO7-338) and one variety ('VFNT Cherry') were contributed by the OSU-OARDC Francis Tomato Breeding and Genetics Program and used exclusively as rootstocks. 'Maxifort' and 'Beaufort' were supplied by Deruiter Seed Company and used only as rootstocks. 'Celebrity' supplied by Johnny's Selected Seeds was grafted to 'Celebrity" and all other rootstocks as the scion and grown ungrafted. All seed was untreated and some was certified-organic. Note that

‘Celebrity’ was the only SC and was grafted to 33 RS, including itself. Hereafter in this report, “genotype” refers to a unique RS-SC combination.

All operations were completed in a climate-controlled greenhouse using certifiable organic methods. Scion seed was sown seven consecutive weeks from February 25 to April 7, 2008, and RS seed was sown five consecutive weeks from March 3 to 31, 2008. Forty-cell trays were used for the first RS seeding, while 288-cell trays were used for all subsequent seedings of RS and SC. Five weeks after sowing RS seed, RS seedlings were transplanted to 40-cell flats containing a 1:3 v:v mixture of organic potting soil and compost. One week later, RS and SC seedlings were grafted using the cleft graft method.

Major steps of the cleft method here included:

1. Select healthy RS and SC seedlings containing a similar stem diameter
2. Use a new, clean razor blade to decapitate RS seedlings with a horizontal cut approximately 5 mm below the cotyledons
3. Bisect the truncated RS stem at its widest diameter to a depth of 4 mm
4. De-root SC seedlings with a horizontal cut approximately 5 mm above the cotyledons
5. Trim the cut surface of the SC seedling to the shape of a wedge containing sides approximately 4 mm long
6. Insert the trimmed SC into the vertical slit of the RS
7. Secure graft with a 12-19 mm-long clear plastic clip cut from 3/32 inch ID Tygon-brand plastic tubing (tubing lengths cut lengthwise to allow wrapping around graft)

Newly-grafted plants were placed in a high humidity chamber consisting of a 5.5 m x 1.2 m greenhouse bench topped with 0.08-mm thick plastic, 3-mm thick capillary mat and a 5.5 m x 1.2 m x 0.7 m frame made of 3/4-inch PVC covered with 0.08-mm thick clear plastic and shade cloth (60% reduction in ambient light intensity). The capillary mat and grafted plants were kept moist with distilled water and plants remained in this chamber for five to nine days after grafting. Thereafter, plants were transferred to a similar chamber lacking the capillary mat and shade cloth and more infrequently watered (chamber 2, medium light and humidity) and held for one week. Approximately two weeks after grafting, plants were transferred to ambient greenhouse conditions typified by lower humidity and higher light levels and held until being placed outdoors under a shaded patio in preparation for planting in the field.

Field Plot Establishment

Grafted transplants were employed in studies conducted at the OSU-OARDC North Central Agricultural Research Station (NCARS) in Fremont, Ohio and at the OARDC in Wooster, Ohio.

NCARS - Fremont

Consistent with its long-term history, land used in the NCARS project was managed conventionally. Plot establishment was preceded by fall 2007 and spring 2008 broadcast applications of 200 lb/A 10-52-0, 400 lb/A 0-0-60, and 10 lb/A 10% Boron (fall) and 350 lb/A of 28-0-0, respectively. The project contained twenty-three genotypes and the ungrafted ‘Celebrity’ control (Table 1); sixteen and seven genotypes were included in three and two replications, respectively.

The study area contained eight standard raised beds, each 188 feet long and punctuated every 32 feet by 20-foot-wide alleys and separated by adjacent beds by 2.5 feet. Single-row plots

measuring 16 ft long, containing eight plants of a given genotype and arranged in a randomized complete block design were established by hand on these beds on June 18. Plants were set such that the graft union remained approximately 2.5 cm above the soil line.

Plants were staked and twined using the Florida Weave system at planting and twined three additional times by August 6. All plants were pruned. Shoots below or at the graft union were removed on July 22 and August 19, and all secondary shoots above the graft union but within the first five nodes were removed on July 22.

Weed pressure was minimized with a pre-emergent herbicide and hand cultivation. Disease and insect pressure were minimized by the weekly use of labeled crop protectants between June 25 and August 21. Overhead irrigation totaling approximately 7.62 cm for the study period was applied through portable commercial sprinklers on August 7, 18, and 27. Total rainfall for the study period equaled 20.8 cm (http://www.oardc.ohio-state.edu/newweather/).

OARDC - Wooster

Consistent with its history since 2001, land used in the OARDC-Wooster project was managed using certifiable-organic methods. The project contained thirty-three genotypes and the ungrafted 'Celebrity' control (Table 2); twenty-nine and four genotypes were included in two and one replication(s), respectively.

The study area contained sixteen standard raised beds, each 110 ft long, topped with standard black plastic mulch and drip irrigation tape on June 2 and separated by adjacent beds by 2.5 ft. Plots measuring 20 ft long, containing ten plants of a given genotype and arranged in a randomized complete block design were established by hand on these beds on June 6. Plants were set through 10-cm diameter holes in the plastic such that the graft union remained approximately 2.5 cm above the soil line.

Grafted plants were hand-watered and fertilized (4 lb N/A via injection) at planting. Plants were staked and twined using the Florida Weave system at planting and twined five additional times by July 29. All plants were pruned. Shoots below or at the graft union were removed on July 14 and August 7 and all suckers above the graft union within the first five nodes were removed on July 10 and 16.

Weed pressure was minimized with hand cultivation and the establishment of an approximately six-inch layer of unaltered organic wheat straw to the study area by August 5. Disease and insect pressure were minimized by five applications of organically-labeled crop protectants July 11-September 3 if populations exceeded anticipated economic thresholds based on scouting. Drip irrigation totaling approximately 11.6 cm for the study period was applied in 14 installments June 6-September 22 with liquid 2-4-1 fertilizer (4 lb N/A) injected into all irrigation lines five times at weekly intervals July 17-August 4. The total rainfall for the study period was 35.5 cm (http://www.oardc.ohio-state.edu/newweather/).

Data Collection and Analysis

Fruit at stage 5 or 6 of the United Fresh Fruit and Vegetable Association-USDA-California Tomato Commission Ripeness Chart were removed by hand from all plants in each plot in Fremont and the center eight plants of each plot in Wooster and transferred immediately to "barn" conditions until evaluation beginning within 36 hours of removal. Plots were harvested six times in Fremont between August 29 and October 2, and seven times in Wooster between

August 26 and October 6. Direct measures of total fruit weight and marketable fruit weight were recorded for all genotypes for all harvests. All fruit were evaluated by the same two people for 12 of 13 harvests; fruit containing no-minimal evidence of physiological disorders (growth cracks, zippers, blossom end rot), sunburn or damage due to insects or diseases were considered marketable.

Plant survivorship, height, and vigor measurements were taken twice at biweekly intervals at both locations before the first fruit harvest. Foliar and fruit disease ratings were recorded during active vegetative growth and at all harvests. For harvests three and four at each location, ten stage 6 fruit per plot were retained for measures of Brix (% solids), pH, and titratable acidity. And all green fruit of marketable size remaining on Wooster-grown plants after harvest on October 6 were removed on October 7 in order to develop estimates of total plant productivity. These data are reported elsewhere.

Fruit number and weight by category (total, marketable) recorded for each plot at each harvest were converted to yield (tons/A). Per-plot values were used to calculate harvest-specific genotype mean values. These means and their standard errors are given in Tables 1-4.

Results

The total and marketable yield of ‘Celebrity’ fruit varied with site, harvest, and rootstock. Variation between sites and among harvests is common in typical, ungrafted crops so the performance of grafted plants within harvests is the focus of this evaluation. Examining data from within each harvest at both locations reveals that the yield of grafted plants, regardless of rootstock, tended to be lower than the yield of ungrafted plants at the first harvest. However, this trend was reduced at subsequent harvests when, by the last two harvests at each location, the total and marketable yield from grafted plants exceeded the yield from ungrafted control plants in eighty of 220 cases. Also, grafting ‘Celebrity’ to experimental rootstocks often resulted in numerically or statistically higher yield values relative to grafting ‘Celebrity’ to either itself or the commercially available rootstocks ‘Beaufort,’ ‘Maxifort,’ and ‘VFNT Cherry,’ regardless of growing location.

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Table 1. Rootstock effects on the mean total yield (ton/A) of grafted 'Celebrity' tomato grown at the NCARS in Fremont, OH in 2008.

Rootstock	Total Fruit Yield (ton/A) by Harvest (H)[1]					
	H1	H2	H3	H4	H5	H6
Beaufort	0.26	0.26	6.31	1.72	1.71	6.51
Celebrity	0.13	0.28	3.65	2.41	1.61	2.78
FGH02-188	0.12	0.28	6.25	1.29	1.38	3.49
FL 7775	0.07	0.17	1.86	1.27	1.16	3.08
LA 1589	0.26	0.20	7.71	1.97	1.21	2.35
LA 716	0.06	0.14	2.54	0.64	0.71	1.94
Maxifort	0.17	0.26	2.84	2.37	1.76	6.01
MR 13	0.23	0.18	3.63	2.23	1.50	3.41
SGH07-304	0.16	0.25	6.08	2.23	1.55	3.58
SGH07-305	0.10	0.14	2.65	1.29	1.25	2.67
SGH07-313	0.13	0.24	5.87	2.59	1.59	5.35
SGH07-314	0.10	0.29	3.84	2.31	2.24	5.20
SGH07-316	0.05	0.41	3.13	2.12	2.25	4.64
SGH07-319	0.23	0.28	5.31	2.31	1.89	4.55
SGH07-320	0.01	0.33	4.63	2.49	2.08	9.76
SGH07-326	0.07	0.30	6.15	1.62	1.35	2.49
SGH07-327	0.13	0.21	3.75	1.97	1.76	2.95
SGH07-332	0.12	0.19	2.98	1.95	1.81	5.00
SGH07-333	0.14	0.21	5.02	2.11	1.68	3.88
SGH07-335	0.14	0.39	4.17	2.14	1.72	3.53
SGH07-336	0.13	0.19	3.80	2.14	1.75	4.21
SGH07-338	0.11	0.23	4.51	2.73	2.09	4.04
Ungrafted	0.55	0.40	6.98	1.17	1.92	3.95
VFNT Cherry	0.21	0.13	3.98	0.91	1.16	3.54
mean	0.15	0.25	4.48	1.92	1.63	4.12
standard error	0.02	0.02	0.32	0.11	0.08	0.34

Table 2. Rootstock effects on the mean marketable yield (ton/A) of grafted 'Celebrity' tomato grown at the NCARS in Fremont, OH in 2008.

Rootstock	Marketable Fruit Yield (ton/A) by Harvest (H)[1]					
	H1	H2	H3	H4	H5	H6
Beaufort	0.07	0.09	3.49	0.96	0.80	2.83
Celebrity	0.04	0.11	1.49	0.90	0.44	0.88
FGH02-188	0.02	0.13	4.14	0.52	0.69	1.53
FL 7775	0.04	0.00	0.91	0.45	0.63	1.26
LA 1589	0.10	0.06	2.72	0.46	0.54	0.78
LA 716	0.01	0.02	0.85	0.21	0.37	0.54
Maxifort	0.04	0.07	1.26	1.31	1.01	2.52
MR 13	0.06	0.06	1.55	1.19	0.71	1.33
SGH07-304	0.04	0.06	2.94	1.31	0.69	1.39
SGH07-305	0.00	0.05	0.94	0.30	0.37	0.69
SGH07-313	0.02	0.13	2.73	1.73	0.60	2.68
SGH07-314	0.04	0.10	1.98	1.19	1.34	2.50
SGH07-316	0.00	0.14	1.34	0.92	1.22	1.58
SGH07-319	0.07	0.05	2.96	1.52	1.09	2.05
SGH07-320	0.00	0.15	2.38	1.33	1.05	4.00
SGH07-326	0.01	0.15	3.58	0.78	0.86	1.12
SGH07-327	0.03	0.09	2.26	1.06	0.74	1.27
SGH07-332	0.05	0.04	1.32	0.70	0.78	1.95
SGH07-333	0.02	0.11	2.89	1.06	0.88	1.63
SGH07-335	0.06	0.16	2.41	1.07	0.99	1.66
SGH07-336	0.06	0.08	1.95	1.23	0.84	2.19
SGH07-338	0.03	0.10	1.99	1.60	1.15	1.94
Ungrafted	0.17	0.15	4.71	0.61	1.01	1.86
VFNT Cherry	0.13	0.07	2.29	0.14	0.65	1.70
mean	0.05	0.09	2.29	0.94	0.81	1.74
standard error	0.01	0.01	0.21	0.09	0.05	0.16

Table 3. Rootstock effects on the mean total fruit yield (ton/A) of grafted 'Celebrity' tomato grown organically at the OARDC in Wooster, OH in 2008.

Rootstock	Total Fruit Yield (ton/A) by Harvest (H)[1]						
	H1	H2	H3	H4	H5	H6	H7
Beaufort	0.27	0.49	1.21	3.29	3.25	1.33	0.85
Celebrity	0.28	0.31	1.42	2.52	3.27	2.68	0.99
FGH02-188	0.24	0.49	1.05	2.59	3.74	1.51	0.62
FL 7775	0.06	0.12	0.72	2.18	2.85	1.82	1.22
H 7998	0.17	0.33	0.64	1.88	3.05	4.35	1.16
LA 1589	0.27	0.34	1.47	2.96	3.50	1.54	0.92
LA 716	0.21	0.43	1.15	2.57	2.67	1.94	0.42
LA 407	0.03	0.12	0.52	1.47	1.35	0.82	0.77
Maxifort	0.06	0.15	0.74	1.40	4.46	3.15	1.54
MR 13	0.25	0.44	1.10	2.24	4.64	3.22	0.89
SGH 07-303	0.23	0.48	1.52	2.60	2.49	1.30	0.38
SGH 07-304	0.13	0.29	0.75	2.75	4.04	2.16	0.66
SGH 07-305	0.12	0.26	0.96	1.42	2.68	1.24	0.15
SGH 07-310	0.32	0.49	0.74	2.96	3.93	2.76	1.30
SGH 07-312	0.31	0.40	1.17	2.92	3.06	1.47	1.11
SGH 07-313	0.30	0.40	0.57	1.47	5.32	2.98	0.98
SGH 07-314	0.18	0.39	1.11	2.68	4.07	3.31	1.09
SGH 07-315	0.11	0.81	1.48	2.44	2.64	1.74	1.67
SGH 07-316	0.33	0.54	0.99	3.38	3.13	2.09	1.00
SGH 07-317	0.27	0.44	1.07	2.29	3.85	1.82	1.13
SGH 07-318	0.13	0.72	1.95	2.37	2.15	0.88	0.44
SGH 07-319	0.42	0.61	0.94	2.54	4.32	1.66	1.47
SGH 07-320	0.19	0.44	0.64	3.49	4.19	1.84	1.51
SGH 07-321	0.16	0.44	1.04	2.31	4.79	1.78	1.81
SGH 07-323	0.21	0.18	0.56	1.74	3.30	1.12	1.11
SGH 07-326	0.29	0.51	1.54	2.41	2.76	1.59	1.23
SGH 07-327	0.18	0.60	1.37	3.06	3.15	1.48	0.51
SGH 07-332	0.13	0.23	0.78	3.39	4.23	1.94	0.97
SGH 07-333	0.09	0.49	0.96	2.10	3.15	2.09	1.42
SGH 07-335	0.39	0.46	1.09	2.47	3.04	1.87	0.70
SGH 07-336	0.36	0.48	0.84	2.79	3.20	2.30	0.84
SGH 07-338	0.18	0.45	1.05	2.26	3.04	1.83	1.58

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Table 3 (*continued*)

Rootstock	Total Fruit Yield (ton/A) by Harvest (H)[1]						
	H1	H2	H3	H4	H5	H6	H7
Ungrafted	0.54	0.70	0.72	2.12	3.97	1.98	0.90
VFNT Cherry	0.28	0.31	0.79	1.55	3.59	2.26	0.54
mean	0.23	0.42	1.02	2.43	3.44	2.00	1.00
standard error	0.02	0.03	0.06	0.10	0.14	0.13	0.07

Table 4. Rootstock effects on the mean marketable yield (ton/A) of grafted 'Celebrity' tomato grown organically at the OARDC in Wooster, OH in 2008.

Rootstock	Marketable Fruit Yield (ton/A) by Harvest (H)[1]						
	H1	H2	H3	H4	H5	H6	H7
Beaufort	0.11	0.32	0.70	2.36	2.53	1.10	0.66
Celebrity	0.08	0.18	0.90	2.00	2.54	2.10	0.71
FGH02-188	0.08	0.24	0.60	1.85	2.80	1.09	0.34
FL 7775	0.01	0.08	0.38	1.37	1.71	1.22	0.73
H 7998	0.03	0.20	0.36	1.09	2.14	2.99	0.73
LA 1589	0.05	0.25	0.91	2.40	2.79	1.35	0.62
LA 716	0.00	0.13	0.49	0.98	1.16	0.88	0.13
LA 407	0.01	0.16	0.40	1.58	1.55	1.11	0.56
Maxifort	0.00	0.03	0.43	0.93	3.14	2.01	0.79
MR 13	0.08	0.15	0.67	1.59	3.40	2.40	0.61
SGH 07-303	0.02	0.28	0.77	1.59	1.75	0.93	0.19
SGH 07-304	0.04	0.17	0.37	1.79	3.24	1.68	0.48
SGH 07-305	0.00	0.07	0.31	0.67	1.29	0.84	0.05
SGH 07-310	0.00	0.40	0.34	2.31	2.98	1.83	0.66
SGH 07-312	0.05	0.20	0.85	2.13	2.36	1.02	0.62
SGH 07-313	0.07	0.21	0.46	1.04	3.59	2.04	0.58
SGH 07-314	0.06	0.22	0.70	1.91	3.25	2.04	0.65
SGH 07-315	0.00	0.47	0.74	1.68	1.94	1.02	0.49
SGH 07-316	0.13	0.35	0.77	2.63	2.37	1.51	0.68
SGH 07-317	0.10	0.19	0.67	1.54	2.73	1.40	0.59
SGH 07-318	0.00	0.32	0.88	1.72	1.47	0.57	0.13
SGH 07-319	0.19	0.42	0.70	1.81	3.37	7.91	0.84
SGH 07-320	0.02	0.20	0.34	2.68	2.93	1.24	0.82
SGH 07-321	0.07	0.25	0.60	1.60	4.06	1.40	1.20
SGH 07-323	0.00	0.07	0.26	0.98	1.80	0.42	0.49

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Table 4. Rootstock effects on the mean marketable yield (ton/A) of grafted 'Celebrity' tomato grown organically at the OARDC in Wooster, OH in 2008.

Rootstock	Marketable Fruit Yield (ton/A) by Harvest (H)[1]						
	H1	H2	H3	H4	H5	H6	H7
SGH 07-326	0.10	0.35	0.97	1.73	2.16	1.18	0.62
SGH 07-327	0.09	0.37	0.84	2.39	2.47	1.07	0.29
SGH 07-332	0.02	0.13	0.47	2.30	3.00	1.54	0.70
SGH 07-333	0.04	0.28	0.56	1.59	2.40	1.55	0.70
SGH 07-335	0.05	0.27	0.42	1.47	1.87	1.01	0.40
SGH 07-336	0.10	0.23	0.44	1.62	2.39	1.54	0.47
SGH 07-338	0.03	0.21	0.47	1.50	2.27	1.37	0.84
Ungrafted	0.16	0.41	0.37	1.41	2.72	1.37	0.68
VFNT Cherry	0.04	0.16	0.33	0.83	2.12	1.23	0.32
mean	0.05	0.23	0.57	1.68	2.48	1.59	0.57
standard error	0.01	0.02	0.04	0.09	0.12	0.21	0.04