

## **Grafting tomatoes on disease resistant rootstocks for small-scale organic production.**

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### **Summary**

Herbaceous grafting is a site-specific management tool that can be tailored to the challenges of individual production systems based on rootstock and scion selections. The objectives of this study were to investigate the use of grafting to enhance organic field production of tomatoes at Black River Organic Farm in NC. At this farm, high disease pressure from bacterial wilt (caused by *Ralstonia solanacearum*) has resulted in the grower abandoning open-field fresh-market tomato production. Preliminary studies in 2007 indicated that 'Celebrity' scion grafted onto 'RST-04-105-T' (D. Palmer Seed Co., U.S.A) rootstock and 'Dai Honmei' (Asahi Seed Co., Japan) rootstock demonstrated complete and intermediate levels of resistance, respectively to bacterial wilt. In 2008, the study was duplicated and expanded to include two additional rootstocks and to assist the grower with propagating grafted transplants on-farm.

In 2008, we compared 'Celebrity' scion grafted onto four different rootstocks (RST-04-105-T, Dai Honmei, BWR, and Sweet Olive) compared to non-grafted and self-grafted (scion grafted back onto itself) controls. In 2008, soilborne disease pressure was very high as anticipated, but southern blight, caused by *Sclerotium rolfsii*, was the dominant disease rather than bacterial wilt. The rootstocks utilized in this study were selected for resistance to bacterial wilt, but demonstrated a range of resistance to southern blight. 'Celebrity- RST-04-105-T' grafts had the lowest incidence of southern blight and AUDPC values were significantly lower among

the three rootstocks than the self-grafted and non-grafted controls. Grafting effects on leaf nutrient concentrations did not indicate greater nutrient uptake ability of grafted treatments although significant differences among treatments for selected nutrients including phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), copper (Cu), and boron (B) were present.

The greatest total fruit yields were achieved with ‘Celebrity- RST-04-105-T’ grafts (19.5 T/A), followed by ‘Celebrity-BWR’ grafts (14.4 T/A), ‘Celebrity-Dai Honmei’ grafts (13.9 T/A), ‘Celebrity-Sweet Olive’ grafts (6.7 T/A), ‘Celebrity’ non-grafted (5.4 T/A), and ‘Celebrity’ self-grafted (4.6 T/A). A cost and benefit analysis based on variable costs of grafted transplant production at the 1-acre scale, estimated \$2,275 of additional transplant costs when grafted plants were utilized. The per acre net returns of the top yielding scion-rootstock combination, ‘Celebrity-RST-04-105-T’ was \$59,635 and the non-grafted ‘Celebrity’ crop generated \$8780 per acre. Because the grafted plants were able to maintain production under severe soilborne disease pressure, this cost-benefit analysis reflects the ability of disease resistant rootstock to reduce the risk of pathogen outbreaks and therefore add to on-farm economic stability. Overall, the grower was very pleased with the results of this study and in 2009 continued to propagate and utilize grafted plants on-farm.

## **Introduction**

Organic tomato production is a challenging endeavor in the Southeast due to weathered soil structure, high foliar and soilborne pathogen pressure, and mild winter temperatures. Grafting offers an innovative cultural practice that can be used to manage soilborne disease pressure, achieve greater fruit yields, and increase nutrient uptake efficiency. Grafting has been

implemented as an IPM tactic in commercial tomato production in Asia, the Mediterranean, and northern Africa (Kubota et al., 2008; Lee, 1994; Oda, 1995, 2002).

This trial was carried out at Black River Organic Farm located in Ivanhoe, North Carolina. Currently this farm is not able to successfully produce field tomatoes due to heavy soilborne and foliar disease pressures. Rootstocks were selected based on dominant soilborne disease profiles and scions for market preference and early maturation to manage foliar disease pressure. This project will evaluate the use of grafting for tomato in small-scale organic field production for: 1) soilborne disease resistance, 2) fruit yield and quality, and 3) nutrient uptake efficiency.

The evaluation of grafted plant performance in a typical southeastern organic system will strengthen the ability of organic growers to expand and optimize their tomato production practices. Small growers across the United States stand to benefit from increased economic security and sustainability by research-based trialing of rootstock-scion selections and by learning how to produce their own grafted transplants.

## **Objectives**

- 1) Evaluate disease resistance of commercial rootstock cultivars under organic production in naturally-infested soils.
- 2) Trial grafted transplant propagation at a small-scale organic farm greenhouse facility.
- 3) Observe crop productivity and nutrient uptake of grafted heirloom tomatoes in organic field production.
- 4) Assess the performance of a variety of rootstock/scion combinations in organic field production.
- 5) Develop cost and benefits analysis on small-scale on-farm grafting transplant production.

6) Develop and disseminate research-based knowledge regarding grafting that can be used by organic growers to successfully and profitably adopt this emerging technology into current growing practices.

## **Materials and Methods**

The trial was located in a certified organic, open-field production system. For the replicated research trial, rootstocks were selected to manage bacterial wilt (*Ralstonia solanacearum*), and the scion ‘Celebrity’, was selected by the grower according to market preferences (farmer’s markets, CSA, and Co-op) and early maturation to manage foliar disease pressure. This trial was centrally-located on two rows within a ½ acre tomato block.

*Transplant production.* Seedlings for the research trial were grafted using the ‘Japanese tube-grafting’ method at NCSU Southeastern Plant Environment Laboratory (Rivard and Louws, 2006). Self-grafted plants were produced by grafting ‘Celebrity’ scion back onto its own root system. Self-grafts served as an experimental control for assessing the physical effect of grafting. The average grafting success rate was more than 95%. Once grafting and subsequent healing had taken place, all seedlings were transplanted into 4” pots and allowed to grow in the greenhouse for 10 days prior to planting in the field. Crop yield, disease incidence, and leaf tissue concentrations were recorded over the course of the growing season. A number of response variables were measured over the course of the growing season such as fruit weight, number of fruit, leaf nutrient concentration of the most recently mature leaf tissue (MRML), and disease incidence.

Additional grafted transplants were produced at Black River Organic Farm to determine the feasibility and economic costs associated with grafting tomatoes for a small-scale farming

operation. Suzanne O'Connell and Cary Rivard assisted with grafting tutorials and constructing a small healing chamber (30" x 48") located inside the grower's propagation greenhouse. Approximately ~1000 grafted transplants were produced in three batches of ~400 plants with an overall success rate of 50%. The first batch was not successful due to a problem with the cool-mist humidifier. The second batch was highly successful. The third batch was not successful due to difficulties controlling higher than optimum temperatures within the healing chamber when ambient greenhouse temperatures rose above 90°F. Cultivars 'Celebrity', 'Pink Beauty', 'Taxi', BHN 444', and 'Jubilee' were grafted to the rootstock 'RST-04-105-T'. These seedlings were not included in the formal research trial but were planted by the grower and observed over the course of the growing season.

*Experimental Design.* The study was a randomized complete block design with 7 plants in each plot and 4 replications. Six treatments were evaluated among 4 replications located within two 154' long rows. Seedlings were transplanted into 21" in-row spacing on raised beds covered in plastic mulch. Drip irrigation was used. Lower leaves were pruned up to 'one leaf below the first fruit' and plants were trellised using the stake-and-weave system. Pre-plant fertilizers and soil amendments included: incorporated dwarf essex rape and crimson clover cover crop residue, feathermeal, sulfate of potash, NatureSafe pellets, and boron. Fruit was harvested over 7 weeks and fruit was graded according to on-farm standards. Fruit number and weight were recorded for marketable and non-marketable grades.

The six treatments were: 1) 'Celebrity' non-grafted controls, 2) 'Celebrity-Celebrity' self-grafted controls, 3) 'Celebrity- RST-04-105-T' grafts, 4) 'Celebrity-Dai Honmei' grafts, 5) 'Celebrity-BWR' grafts, and 6) 'Celebrity-Sweet Olive' grafts. Three of the 4 rootstocks (RST-

04-105-T, BWR, and Dai Honmei) are hybrids developed specifically for use as a tomato grafting rootstock. Both 'RST-04-105-T' and 'Dai Honmei' are commercially available as untreated seed. The DeRuiter line 'BWR' is an unreleased cultivar with bacterial wilt resistance that is under development. 'Sweet Olive' is a small-fruited grape tomato that has been grown at Black River Organic farm. Previous experience by the grower indicated that it may confer intermediate resistance to bacterial wilt so it was included as a potential rootstock in 2008. A list of scion and rootstock selections with additional information is shown in Table 1.

*Statistical Analysis.* A linear model was used to compare grafting effects for non-repeated measures such as total cumulative yield and disease incidence (PROC GLM) (SAS Institute, Cary, NC). Repeated measures models were used to evaluate treatment response to fruit yield and leaf nutrient concentrations over time (PROC MIXED) (SAS Institute, Cary, NC). Time was treated as a categorical variable with a compound symmetric covariance model due to nonlinear trends. Linear hypotheses were used to test pair wise differences for fixed factors such as grafted versus non-grafted plants, and 'RST-04-105-T' rootstock versus other grafted treatments ('Estimate Statements', SAS Institute, Cary, NC). An alpha level of  $P \leq 0.05$  was applied to all analyses along with the Tukey multiple comparison test for means separation.

*Economic Analysis.* A cost and benefit analysis based on variable costs of non-grafted and grafted organic tomato production at the 1-acre scale was developed using standardized equipment costs, organic practices, and regional labor rates for managerial and hourly staff. The estimated budget does not include fixed costs (i.e. greenhouse infrastructure, land, etc.). Grafted transplant production was estimated by inclusion of any additional equipment, labor, seed costs, etc. associated with grafted transplant production. For both grafted and non-grafted plants, an

80% germination rate was assumed and in the case of the grafted plants, grafting success was estimated at 90%. Seeds were sown into 512-cell seedling trays and transplanted into 50-cell trays before grafting and/or subsequent field planting. Grafting labor costs were estimated at 200 grafts/hour/person. A year-long production budget was developed that followed cultural practices, labor needs, and equipment costs typical of those utilized for organic open-field tomato production at Black River Organic Farm. Harvest returns were calculated based on gross market returns (\$2.00/lb) minus harvesting costs (labor, boxes, transportation, and marketing) and used to deduce the net returns for the top performing grafting treatment ‘Celebrity-RST-04-105-T’ compared to the non-grafted ‘Celebrity’ control.

## **Results**

*Fruit Yield.* The ‘Celebrity- RST-04-105-T’ grafts had the highest total fruit yield of all treatments although it was statistically similar to the ‘Celebrity-BWR’ and ‘Celebrity-Dai Honmei’ treatments. The ‘Celebrity- RST-04-105-T’ grafts had statistically greater fruit yield than the ‘Celebrity-Sweet Olive’, self-grafted, and non-grafted treatments ( $P \leq 0.05$ ) (Fig. 1). During the last 3 weeks of the harvest period, the ‘Celebrity-#04-105’ grafts produced more fruit compared to ‘Celebrity-Sweet Olive’ grafts, non-grafted, and self-grafted controls ( $P \leq 0.05$ ) (Fig. 2). Fruit number and size were affected significantly by grafting for total and marketable yield, but fruit marketability was not affected (Table 2).

*Disease Incidence.* Although high levels of bacterial wilt were seen in 2007, very few plants were diagnosed with this disease in 2008. The most prevalent soilborne disease in 2008 was southern blight (caused by *Sclerotium rolfsii*). A disease progress curve was plotted using disease incidence (# infected / total plants) (Fig. 3) and an Area Under the Disease Progress

Curve (AUDPC) was calculated (Fig. 4). Disease pressure was severe and 96-100% of the non- and self-grafted controls were killed by *S. rolfsii*. Furthermore, two weeks after first harvest >80% of the non- and self-grafted plants had been infected. The three rootstock-specific hybrids had lower southern blight incidence (54-64%) than the non- and self-grafted controls (Fig. 3) and the severity of the epidemic was significantly lower among these rootstock as indicated by the AUDPC ( $P \leq 0.05$ ) (Fig. 4). Early blight (caused by *Alternaria solani*) was also present but no treatment effects were observed.

*Nutrient Uptake.* Grafting effects on leaf nutrient concentrations did not indicate greater nutrient uptake ability of grafted plants compared to non-grafted although significant differences among treatments for selected nutrients were present. However differences for phosphorus (P), potassium (K), magnesium (Mg), zinc (Zn), copper (Cu), and boron (B) concentration in the leaf tissue were present among treatments ( $P \leq 0.05$ ) (Fig. 5, 6, & 7).

*Economics.* Grafted tomato transplants have higher associated variable costs compared to non-grafted transplants due to increased seed costs, grafting materials and labor, and the requirements of growing a rootstock and scion crop separately prior grafting. (Table 3). Overall, grafted organic transplant production required \$2,275 of additional investment. Once the tomato plants were in the ground, non-grafted and grafted production costs were equivalent (Table 4). At a selling price of \$2.00/lb., the non-grafted 'Celebrity' plants generated a net profit of ~ \$8,880 per acre compared to the top yielding scion-rootstock combination, 'Celebrity-RST-04-105-T' with ~\$59,640 per acre (Table 5).

## **Conclusions/Discussion**

The results of this study highlight several important factors related to grafting for small-scale organic tomato production. First, on-farm grafted tomato transplant production was successful and the results of the economic analysis indicate that using grafting onto commercially available hybrid rootstocks can increase on-farm net returns by approximately \$50,000 when soilborne disease pressure is high. In this case-study, the grower faced particularly severe disease pressure from southern blight and the use of resistant rootstock enabled fruit production for seven weeks while >80% of non-grafted plants were killed within the first two weeks of harvest ( $P \leq 0.05$ ) (Fig 2). Although the three rootstocks utilized in this study were susceptible to varying degrees to southern blight disease, they reduced the incidence and severity of the epidemic through the course of the growing season. Although this disease pressure may not be typical, it highlights the potential of grafting to allow for open-field organic tomato production where otherwise it is not cost-effective.

Originally, leaf tissue samples were to be collected on 5 dates over the course of the growing season. However, we were only able to sample on 3 dates in 2008 (5/14, 6/11, and 6/25) due to the heavy disease pressure experienced. The concentrations of diseased and stressed plants often do not contain predictable values of nutrients and therefore introduce data interpretation errors. Nutrient sampling was aborted when more than 50% of a treatment group was affected by disease. In this trial, more than half of the control treatments were severely diseased just as the harvest period began in the middle of June and leaf tissue sampling was terminated (Fig. 3). Differences among leaf tissue nutrient concentrations for P, K, Mg, Zn, Cu, and B suggests that specific scion-rootstock pairings can be a useful tool for managing selected fertility challenges. Additional grafted tomato field trials in NC indicate that there is a positive grafting effect on

nutrient uptake including nitrogen when disease pressure is low to moderate (O'Connell, 2008; O'Connell unpublished data).

This study highlighted the importance of rootstock selection and the difficulty in predicting disease problems prior to the growing season. The rootstocks used in this study were chosen for resistance to bacterial wilt based on farm history and although this disease was present in the field, southern blight was dominant the year this trial was conducted. The rootstocks we trialed conferred intermediate resistance to southern blight and were capable of maintaining crop productivity under severe disease pressure. Southern blight is an especially difficult disease to manage in organic tomato production. It colonizes and survives on organic matter in the soil, and in NC, we see this disease more frequently during particularly hot summers. Furthermore, southern blight results in total plant collapse and yield losses can be especially acute. Because no resistance is known in commercial tomato cultivars (McCarter, 1991), all hybrid and heirloom varieties are susceptible to this disease. Therefore, grafting with resistant rootstock for management of southern blight in organic systems which rely heavily on host resistance for disease management will be instrumental.

In this study, the dramatic effect that grafting with resistant rootstocks has on the net returns is reliant on the significant impact that southern blight had on fruit yield and the high value of certified organic tomatoes. Using grafted plants increased transplant costs by approximately 24% (Table 3). However, this investment resulted in a difference of more than \$50,000 in net returns per acre. Even if the costs associated with grafting were to triple, the net returns would be reduced only slightly compared to using non-grafted plants. Mr. Hartmann had previously quit growing open-field tomatoes at his farm due to high disease pressure from

soilborne diseases. However, by using grafted plants that are resistant to soilborne diseases, Mr. Hartmann has the option to grow certified organic tomatoes and fulfill this important market.

## **Outreach**

In 2008 and 2009, the authors presented more than a dozen tomato grafting workshops and outreach events. The trial conducted at Black River Organic Farm provides an excellent example of what a grower can expect to gain by utilizing grafting technology and the challenges of producing on-farm transplants. In July, 2008, Stefan Hartmann, Suzanne O'Connell, and Cary Rivard gave an invited seminar highlighting our research during a 90 minute lunch at the National Association of County Agriculture Agents Conference held in Greensboro, NC. The audience consisted of more than 100 extension agents from nearly every state. Mr. Hartmann spoke about his experience with grafting as well as collaborating with on-farm research trials.

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***Presentations/Workshops:***

National Association of County Agriculture Agents Conference, 'SARE-funded Research at CEFS: Grafting Heirloom Tomatoes for Disease Resistance in Intensive Farming

Systems'. Presenters: S. O'Connell, C. Rivard, S. Hartmann. Greensboro, NC. July 15, 2008.

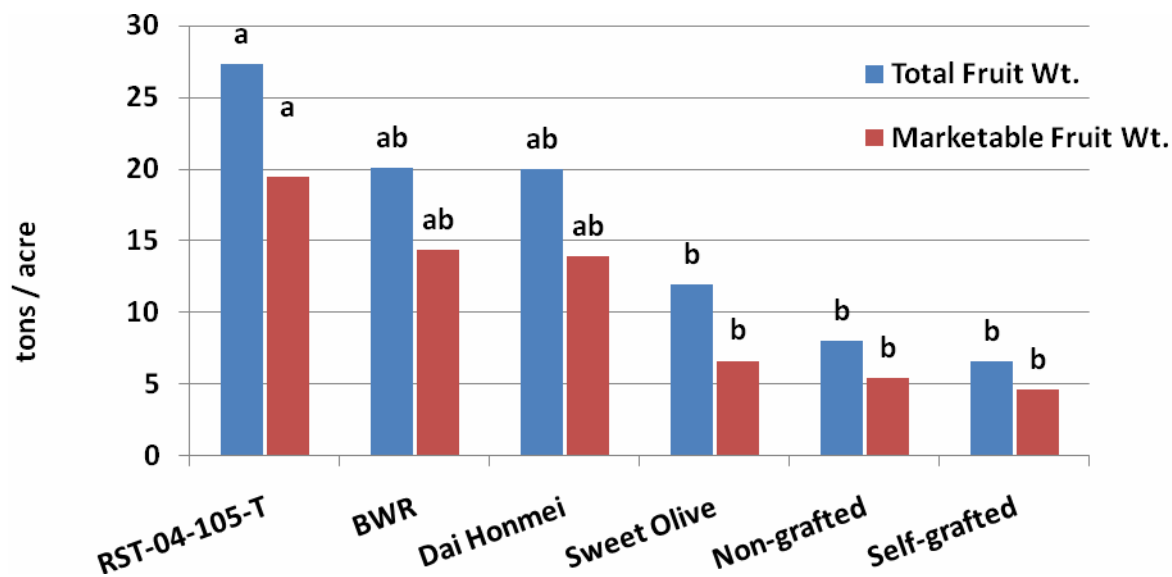
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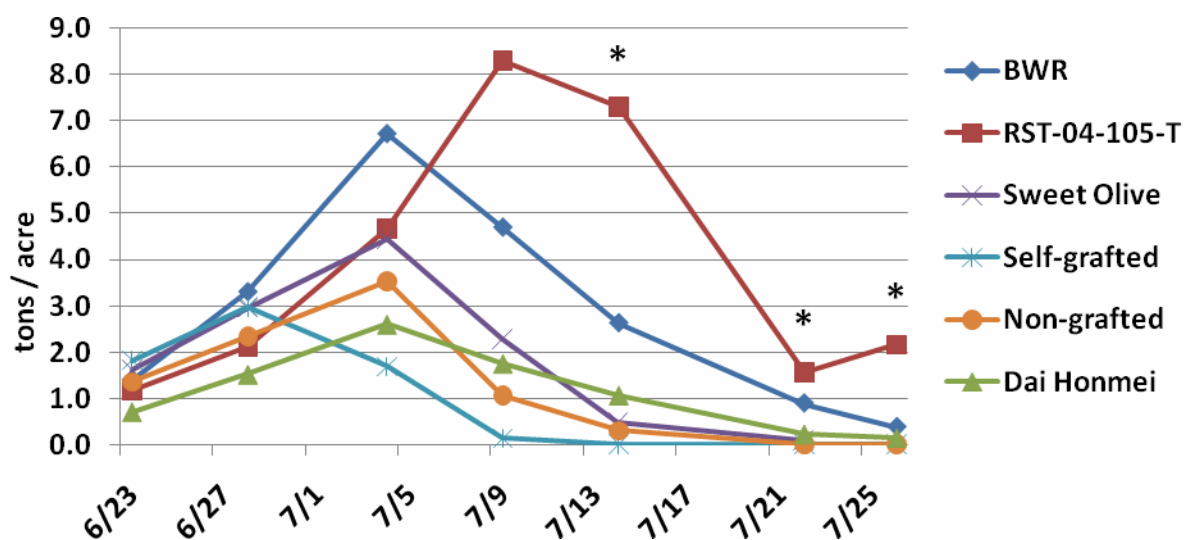
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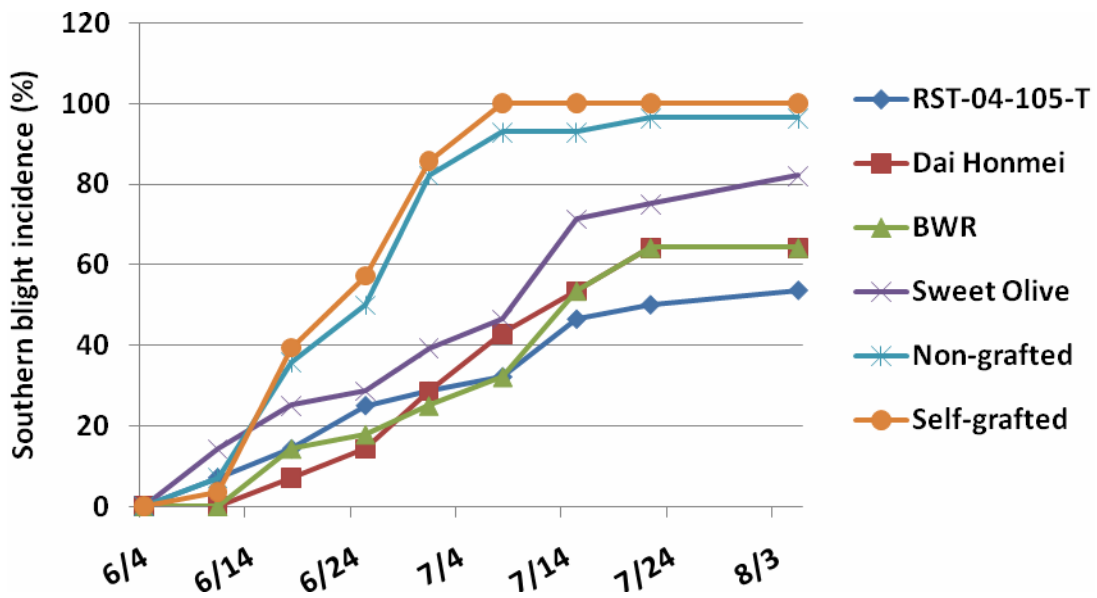
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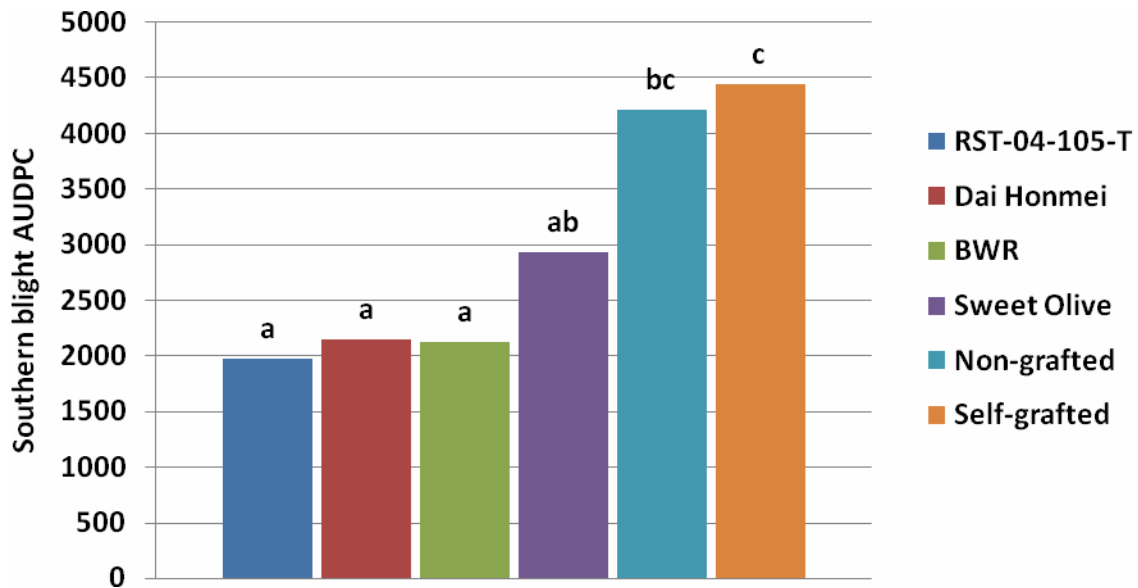
**Fig. 1. Fruit yield of grafted and non-grafted 'Celebrity' tomatoes under heavy disease pressure.** Columns are marked with the lowercase letters that represent significant differences between treatments based on Tukey's mean separation test at  $P \leq 0.05$ . Comparison among treatments for total fruit weight is distinct from comparison among treatments for marketable fruit weight. RST-04-105-T = 'Celebrity-RST-04-105-T' grafts; BWR = 'Celebrity-BWR' grafts; Dai Honmei = 'Celebrity-Dai Honmei' grafts; Sweet Olive = 'Celebrity-Sweet Olive' grafts; non-grafted = 'Celebrity'; self-grafted = 'Celebrity'.



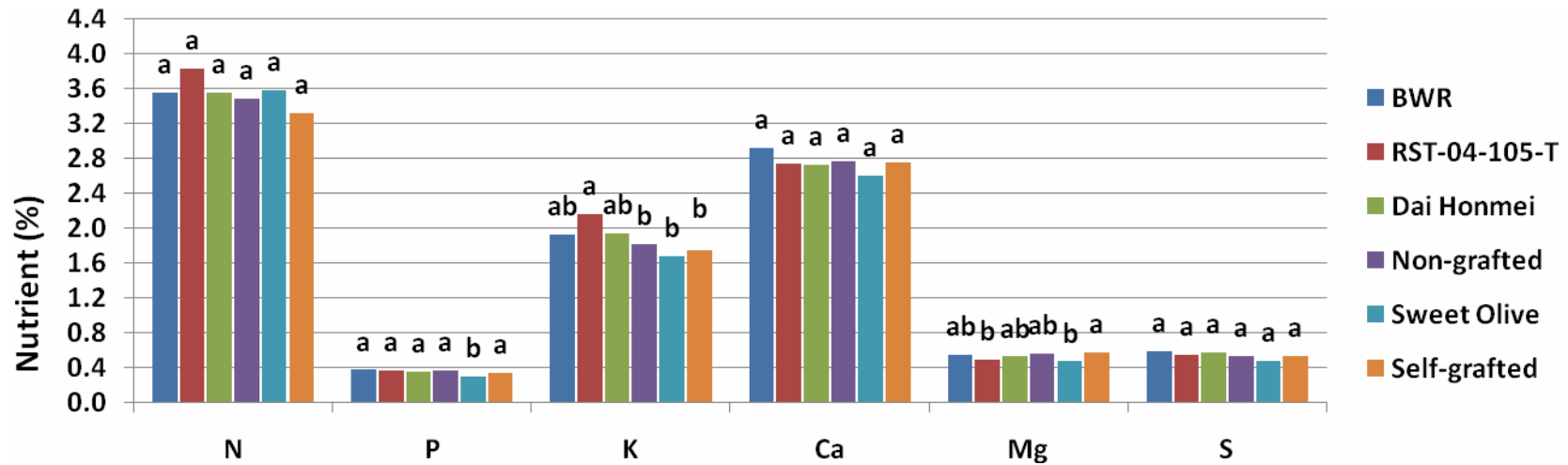
**Fig. 2. Total weekly fruit yield for grafted and non-grafted 'Celebrity' tomatoes over time.** Points marked with an asterisk indicate that on the corresponding sample date the 'Celebrity-RST-04-105-T' grafts had significantly greater values compared to the 'Celebrity-Sweet Olive' grafts, non-grafted, and self-grafted treatments ( $P \leq 0.05$ ). RST-04-105-T = 'Celebrity-RST-04-105-T' grafts; BWR = 'Celebrity-BWR' grafts; Dai Honmei = 'Celebrity-Dai Honmei' grafts; Sweet Olive = 'Celebrity-Sweet Olive' grafts; non-grafted = 'Celebrity'; self-grafted = 'Celebrity'.



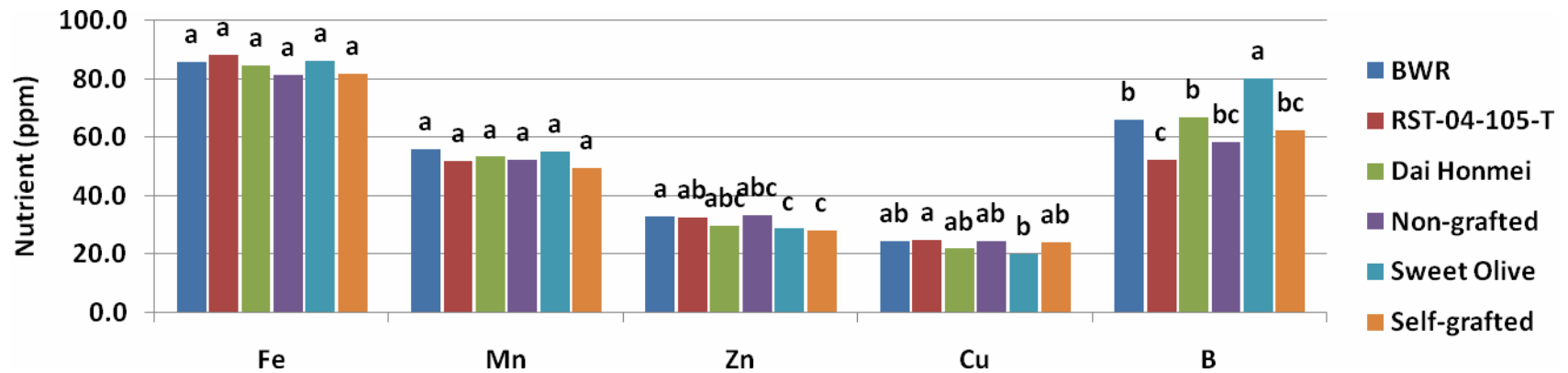
**Fig. 3. Southern blight disease progress curve.** RST-04-105-T = ‘Celebrity-RST-04-105-T’ grafts; BWR = ‘Celebrity-BWR’ grafts; Dai Honmei = ‘Celebrity-Dai Honmei’ grafts; Sweet Olive = ‘Celebrity-Sweet Olive’ grafts; non-grafted = ‘Celebrity’; self-grafted = ‘Celebrity’.



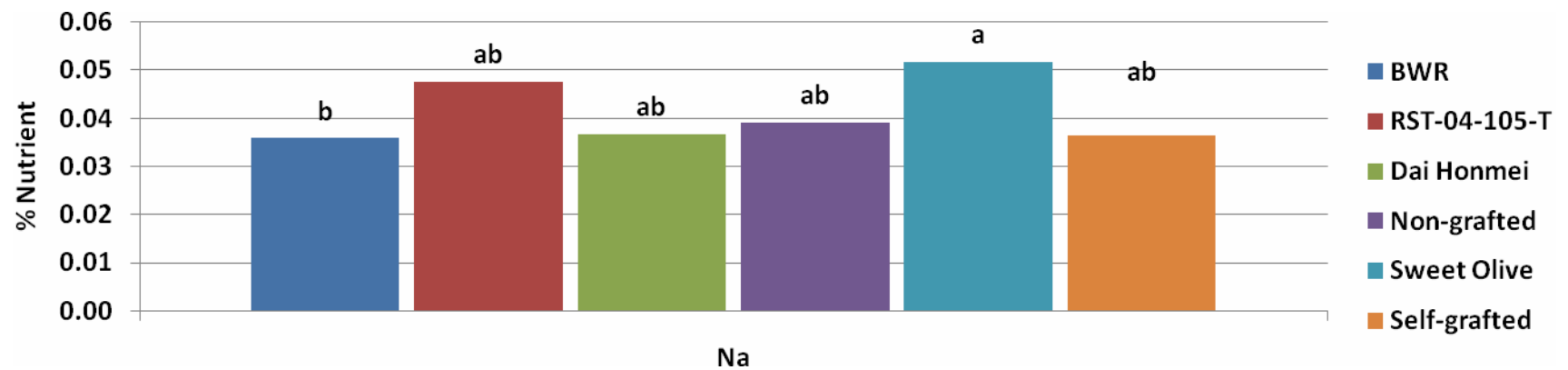
**Fig. 4. Southern blight AUDPC.** Columns are marked with the lowercase letters that represent significant differences between treatments based on Tukey’s mean separation test at  $P \leq 0.05$ . RST-04-105-T = ‘Celebrity-RST-04-105-T’ grafts; BWR = ‘Celebrity-BWR’ grafts; Dai Honmei = ‘Celebrity-Dai Honmei’ grafts; Sweet Olive = ‘Celebrity-Sweet Olive’ grafts; non-grafted = ‘Celebrity’; self-grafted = ‘Celebrity’.



**Fig. 5. Mean leaf macro-nutrient concentration.** Columns are marked with the lowercase letters that represent significant differences between treatments based on Tukey's mean separation test at  $P \leq 0.05$ . RST-04-105-T = 'Celebrity-RST-04-105-T' grafts; BWR = 'Celebrity-BWR' grafts; Dai Honmei = 'Celebrity-Dai Honmei' grafts; Sweet Olive = 'Celebrity-Sweet Olive' grafts; non-grafted = 'Celebrity'; self-grafted = 'Celebrity'.



**Fig. 6. Mean leaf micro-nutrient concentration.** Columns are marked with the lowercase letters that represent significant differences between treatments based on Tukey's mean separation test at  $P \leq 0.05$ . RST-04-105-T = 'Celebrity-RST-04-105-T' grafts; BWR = 'Celebrity-BWR' grafts; Dai Honmei = 'Celebrity-Dai Honmei' grafts; Sweet Olive = 'Celebrity-Sweet Olive' grafts; non-grafted = 'Celebrity'; self-grafted = 'Celebrity'.



**Fig. 7. Mean leaf Na concentration.** Columns are marked with the lowercase letters that represent significant differences between treatments based on Tukey's mean separation test at  $P \leq 0.05$ . RST-04-105-T = 'Celebrity-RST-04-105-T' grafts; BWR = 'Celebrity-BWR' grafts; Dai Honmei = 'Celebrity-Dai Honmei' grafts; Sweet Olive = 'Celebrity-Sweet Olive' grafts; non-grafted = 'Celebrity'; self-grafted = 'Celebrity'.

**Table 1. Scion and rootstock selections<sup>z</sup>.**

Cultivar	Seed Source	Disease Resistance
'Celebrity'	Johnny's Selected Seeds, U.S.A	F <sub>1</sub> , F <sub>2</sub> , N, V <sub>1</sub>
'RST-04-105-T'	D. Palmer Seed Co., U.S.A	BW, F <sub>1</sub> , F <sub>2</sub> , F <sub>3</sub> , N, Pl, V <sub>1</sub>
'Dai Honmei'	Asahi Seed Co., Japan	BW, F <sub>1</sub> , F <sub>2</sub> , For, V <sub>1</sub>
'BWR'	DeRuiter Seeds, U.S.A	BW, F <sub>1</sub> , F <sub>2</sub> , For, N, Pl, V <sub>1</sub>
'Sweet Olive'	Johnny's Selected Seeds, U.S.A	unknown

<sup>z</sup> Organic seeds used when available, otherwise untreated seeds used.

**Table 2. Grafting effects on tomato yield.**

Treatment <sup>z</sup>	Total Yield			Marketable Yield			
	Wt. (T/A)	# of frt./A	Avg. frt. size (lb.)	% Marketable	Wt. (T/A)	# of frt./A	Avg. frt. size (lb.)
<b>Non-grafted</b>	8.02 b <sup>y</sup>	42,668 c	0.38 a	68% a	5.42 b	26,668 b	0.41 a
<b>Self-grafted</b>	6.61 b	34,490 c	0.38 a	70% a	4.63 b	21,512 b	0.43 a
<b>RST-04-105-T</b>	27.34 a	102,404 a	0.53 a	71% a	19.47 a	71,825 a	0.54 a
<b>Dai Honmei</b>	20.00 ab	84,626 ab	0.47 a	70% a	13.94 ab	53,158 ab	0.52 a
<b>BWR</b>	20.06 ab	84,448 ab	0.47 a	72% a	14.38 ab	54,936 ab	0.52 a
<b>Sweet Olive</b>	11.98 b	62,580 bc	0.38 a	56% a	6.65 b	30,224 b	0.44 a

<sup>z</sup> RST-04-105-T = 'Celebrity- RST-04-105-T' grafts; BWR = 'Celebrity-BWR' grafts; Dai Honmei = 'Celebrity-Dai Honmei' grafts; Sweet Olive = 'Celebrity-Sweet Olive' grafts; non-grafted = 'Celebrity'; self-grafted = 'Celebrity'.

<sup>y</sup> Columns are marked with the lowercase letters that represent significant differences between treatments based on Tukey's mean separation test at  $P \leq 0.05$ .

**Table 3. Summary of variable costs for grafted and non-grafted organic tomato transplant production (per 5000 plants).**

Description	Non-grafted		Grafted	
	Materials	Labor	Materials	Labor
<b>Seed Costs<sup>z</sup></b>				
	'RST-04-105-T' (D. Palmer Seeds)		\$1,166.73	
	'Celebrity' F1	\$180.00	\$200.01	
<b>Seedling Production<sup>y</sup></b>	Potting mix and fertilizer inputs	\$79.20	\$148.80	
	Plug trays	\$52.80	\$99.20	
	Heating	\$160.00	\$160.00	
	Transplanting			\$216.49
	Seedling care			\$82.81
<b>Grafting<sup>x</sup></b>	Manual grafting			\$325.33
	Grafting clips		\$382.25	
	Misc. supplies		\$10.00	
<b>Healing chamber<sup>w</sup></b>	Chamber supplies		\$33.35	
	Cool-mist humidifiers		\$67.68	
<b>Total</b>		\$472.00	\$2,271.91	\$666.03
<b>Grand Total (cost per plant)</b>		<b>\$663.06 (\$0.12)</b>	<b>\$2,937.94 (\$0.53)</b>	

<sup>z</sup> Over-seeding by 20%.

<sup>y</sup> NOP allowable potting media and fertilizers. Organic seeds used when available, otherwise untreated seeds used. Direct seeding into re-useable 512-cell trays and then transplanted up to 50-cell trays before grafting and/or transplanting to field.

<sup>x</sup> Assuming a 90% grafting success rate and manual grafting rate of 200 grafts/hour/person.

<sup>w</sup> Chamber supplies and humidifiers estimated to last for 3 years.

**Table 4. Summary of variable production costs per acre of organic tomatoes<sup>z</sup>.**

Description	Equipment	Materials	Labor	Total
Off-Season	\$20.63	\$220.50	\$247.32	\$488.45
Land Prep / Planting	\$154.51	\$3,115.30	\$482.93	\$3,752.74
Irrigation	\$949.81	\$0.00	\$1,100.19	\$2,050.00
Pruning	\$0.00	\$0.00	\$851.76	\$851.76
Stringing / Staking	\$4.82	\$62.50	\$1,102.56	\$1,169.88
IPM scouting/ Pest sprays	\$3.96	\$321.83	\$317.97	\$643.75
<b>Total</b>	<b>\$1,213.73</b>	<b>\$4,112.13</b>	<b>\$4334.76</b>	<b>\$9,660.61</b>

<sup>z</sup> Summary does not include transplant production, harvesting, or marketing costs.

**Table 5. Cost and benefit analysis of grafted and non-grafted tomatoes in field with high disease pressure<sup>z</sup>.**

Treatment	Transplant Costs <sup>y</sup>	Production Costs <sup>x</sup>	Gross Income <sup>w</sup>	Harvest Costs	Net Returns <sup>v</sup>
Non-grafted 'Celebrity'	\$663.06	\$8,997.55	\$21,814.00	\$3,239.55	<b>\$8,913.84</b>
'Celebrity-RST-04-105-T' grafts	\$2,937.94	\$8,997.55	\$77,880.00	\$6,308.85	<b>\$59,635.66</b>

<sup>z</sup> Based on selling price of \$2.00/lb.

<sup>y</sup> See Table 3.

<sup>x</sup> See Table 4.

<sup>w</sup> = (marketable wt. \* 2.00/lb).

<sup>v</sup> = (Gross income - harvesting costs).