

# *Cedar Meadow Farm*

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## **Final report: FNE08-636**

### **1. Project name and contact information**

**Project Title:** Grafting tomatoes in multi-bay high tunnels as a way to overcome soilborne diseases

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### **2. Goals**

This project had three primary objectives. 1) To evaluate tomato rootstock for its ability to manage verticillium wilt (race 2) and other soilborne diseases in multi-bay high tunnels. 2) To determine the optimum cultural management of grafted and non-grafted tomato to increase per plant productivity, and ultimately help mitigate the added cost of grafted transplants. 3) To convey the findings and importance of this study to farmers in the Northeast region through an aggressive outreach program.

### **3. Farm profile**

Cedar Meadow Farm consists of 215 acres on hilly land in southern Lancaster County, Pennsylvania. 100 acres is devoted to vegetables, 60 acres consists of agronomic crops and 55 acres is used for cover crop seed production. Produce is marketed locally to 65 stores, restaurants, and wholesalers. I also maintain a website, [cedarmeadowfarm.com](http://cedarmeadowfarm.com), which details my farming practices. I currently have 2 acres of multi-bay Haygrove high tunnels. These tunnels are very productive, but I have been forced to use chemical fumigation due to verticillium wilt (race 2). Grafting could potentially eliminate the need for fumigation as a way to overcome soilborne diseases.

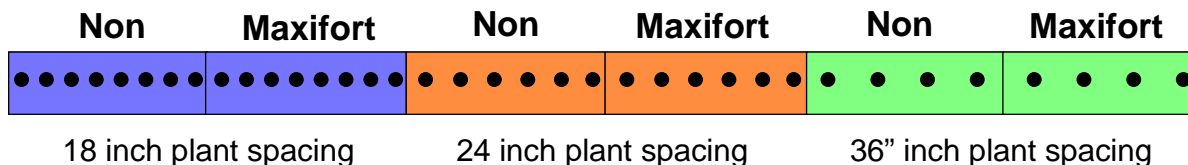
### **4. Participants**

The technical advisor for this project was Cary Rivard, who is a graduate research assistant working with Dr. Frank Louws at North Carolina State University. Cary coordinated transplant production, experimental design, data collection and statistical analysis. Dr. Michael Orzolek, Penn State University, arranged for Steve Groff to discuss the results of the trial in a session about grafting and coordinated the grafting clinic held at the Mid-Atlantic Vegetable Convention.

### **5. Project activities**

Grafted and non-grafted plants were produced at North Carolina State University. 'Maxifort' rootstock was utilized as a vigorous rootstock to manage verticillium wilt. 'BHN 589' was used for the scion in grafted treatments and non-grafted controls. The research trial was located within

two 300' rows. One was fumigated and the other was not. Each row was planted in a split-plot design comprising a total of 48 plots, twelve feet in length. Within each row, the main plots consisted of cultural treatments. Plants were spaced at 18", 24", and 36", and pinching was carried out to encourage the growth of two dominant leaders. Within these main plots, the 12' sub-plots contained non-grafted plants and those with 'Maxifort' rootstock at each planting density. Each row had four replications and main plots and subplots were randomized and re-randomized within each replication. A diagram below shows how the main plots and subplots were arranged for one replication. Each color represents the three main plots and the black dots indicate the number of plants in each 12' sub-plot.

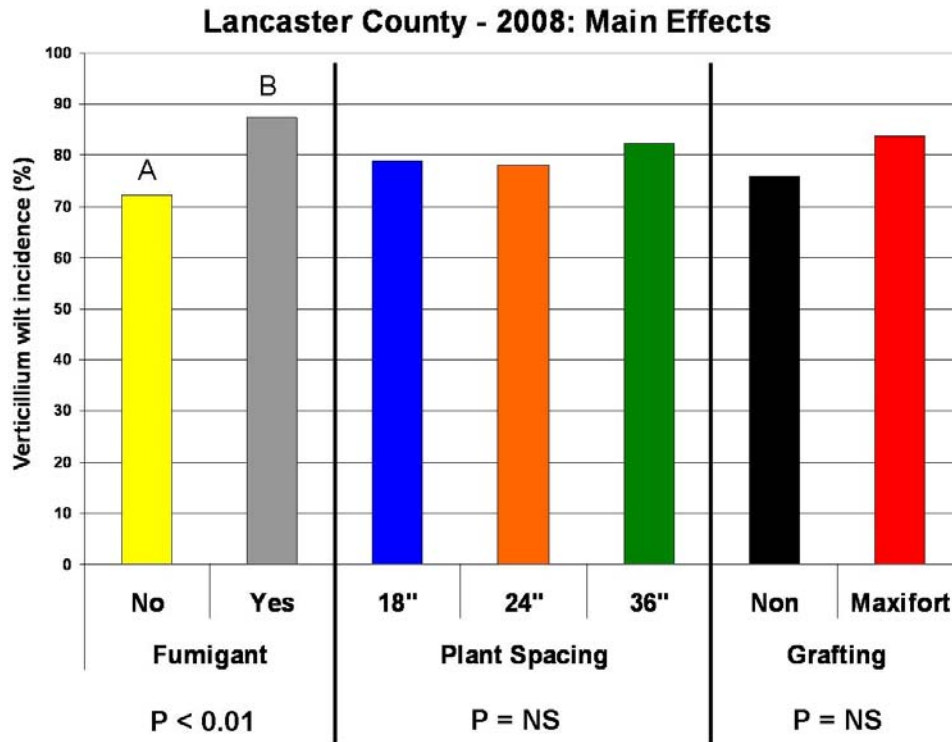


The research trial was planted on May 9<sup>th</sup>, 2008 and harvesting was carried out from July 29<sup>th</sup> until October 24<sup>th</sup>. A field day was held at my farm to showcase the grafting research trial and high tunnel management on July 9<sup>th</sup>, and Cary Rivard and myself described the research trial objectives to the audience. During his visit, Cary trained myself and Kaitlin Dye, my summer intern, to carryout disease ratings and yield data collection. Kaitlin and myself oversaw day-to-day management as well data collection throughout the harvest season. Marketable fruit number and weight were recorded for each of the 48 plots and harvesting was carried out weekly. Plant samples were also collected at terminal harvest for diagnostic verification of *Verticillium dahliae* within symptomatic plants. Statistical analysis utilized split-plot factorial ANOVA, and a protected LSD test was used to separate the means of significant main and simple effects.

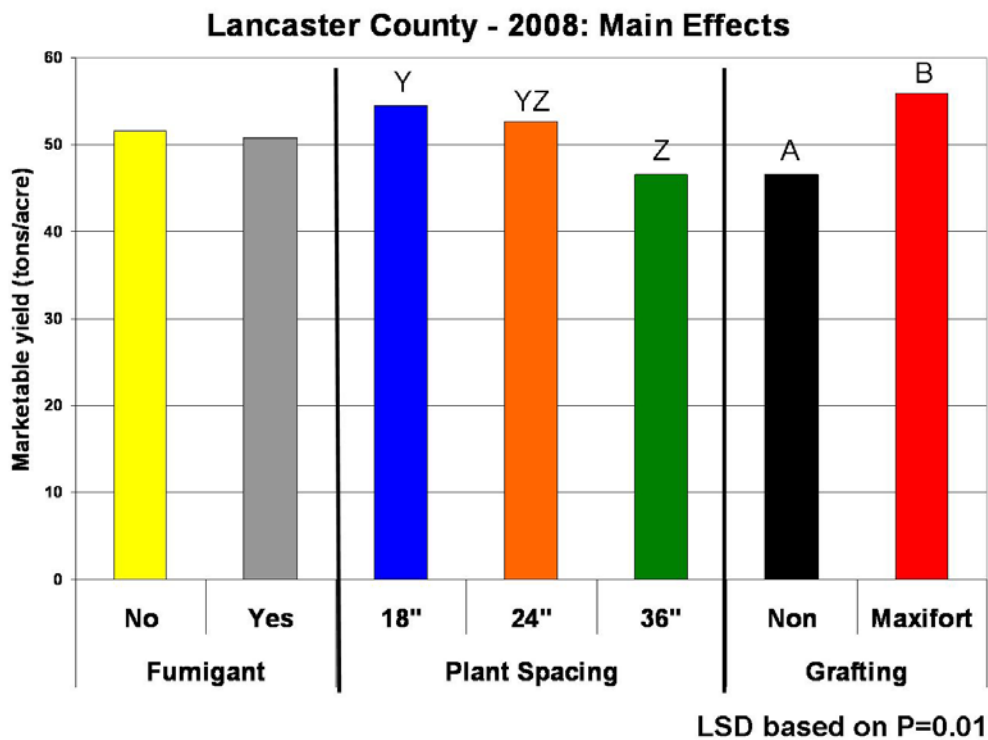
## 6. Results

**Soilborne disease management** – Preliminary research in NC showed that although 'Maxifort' rootstock was susceptible to verticillium wilt (race 2), fruit yield of grafted plants in un-fumigated soil was similar to non-grafted plants grown in fumigated soil. Therefore, the hypothesis is that yield reductions from this disease will be less severe when grafted plants are used. In this study, we saw a similar trend, but our fumigation treatment was not effective. The main effects of grafting show that 'Maxifort' has similar disease incidence compared to the non-grafted controls (Fig 1A) and the main effect of grafting showed significantly more fruit yield ( $P < 0.01$ ; Fig 1B). In this study we compared 'Maxifort' rootstock and plant spacing on fumigated and un-fumigated land. The fall fumigation treatment was not effective at reducing verticillium wilt disease incidence (Fig 1A) or increasing crop yield under disease pressure (Fig 1B), Therefore, it is difficult to interpret if the excess yield provided by 'Maxifort' was directly related to soilborne disease management or added vigor. If grafted plants on un-fumigated soil had performed similarly to non-grafted plants on effectively fumigated soil, we could make a better comparison of these two management strategies. However, the results show that 'Maxifort' maintained higher crop productivity under disease pressure from verticillium wilt (race 2). Another replicated study will be carried out in 2009 that asks a similar question regarding verticillium wilt management, but spring fumigation will be utilized. By understanding the interaction that occurs between fumigation and grafting, we can better determine how 'Maxifort' rootstock is able to manage crop reductions caused by verticillium wilt (race 2).

A



B

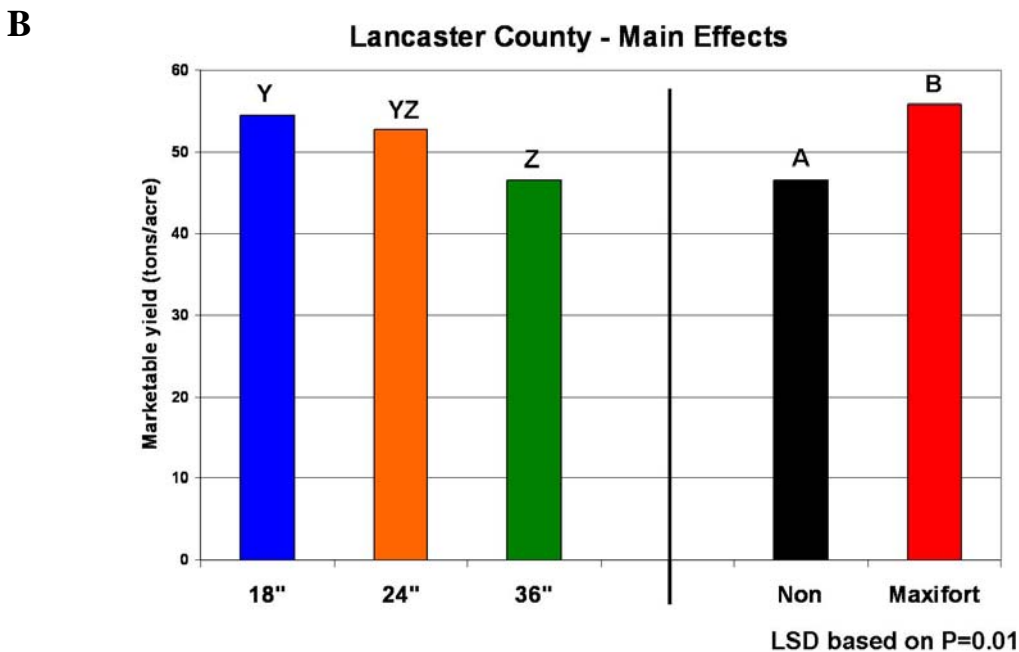


**Figure 1** – Main effects of fumigation, plant spacing, and grafting on (A) verticillium wilt incidence and (B) marketable fruit yield. Treatments with the same letter are considered statistically similar ( $LSD_{0.01}$ ).

**Main effects of grafting and plant spacing on fruit yield** – Based on the results of verticillium wilt incidence and marketable fruit weight, fumigation did not have a significant impact on crop yield (Fig 1B). Therefore the results of the fumigated and un-fumigated rows were combined to illustrate main effects of grafting and plant spacing (Fig 2A,B). No statistically significant interactions were found between plant spacing and grafting, and the main effects of grafting illustrate the impact of grafting when averaged across the three plant spacing treatments. In this trial, the main effect of grafting showed that ‘Maxifort’ plants produced higher marketable fruit yield, through increased fruit number and size ( $P<0.01$ ; Fig 2A). Average yield of grafted plants was 55.9 tons/acre and was 46.5 tons/acre among non-grafted plants. The main effects of grafting on cumulative yield show that ‘Maxifort’ increased productivity in the second half of the harvest season (Fig 3A), and fruit yield was reduced slightly at second harvest ( $P<0.01$ ). The main effects of plant spacing also indicate that increased planting density resulted in significantly higher fruit yield and number ( $P<0.01$ ), but had no effect on average fruit size (Fig 2A). The effect of plant spacing on cumulative fruit yield was significant throughout the season ( $P<0.01$ ), and planting density had little impact on early vs late-season fruit yield (Fig 3B).

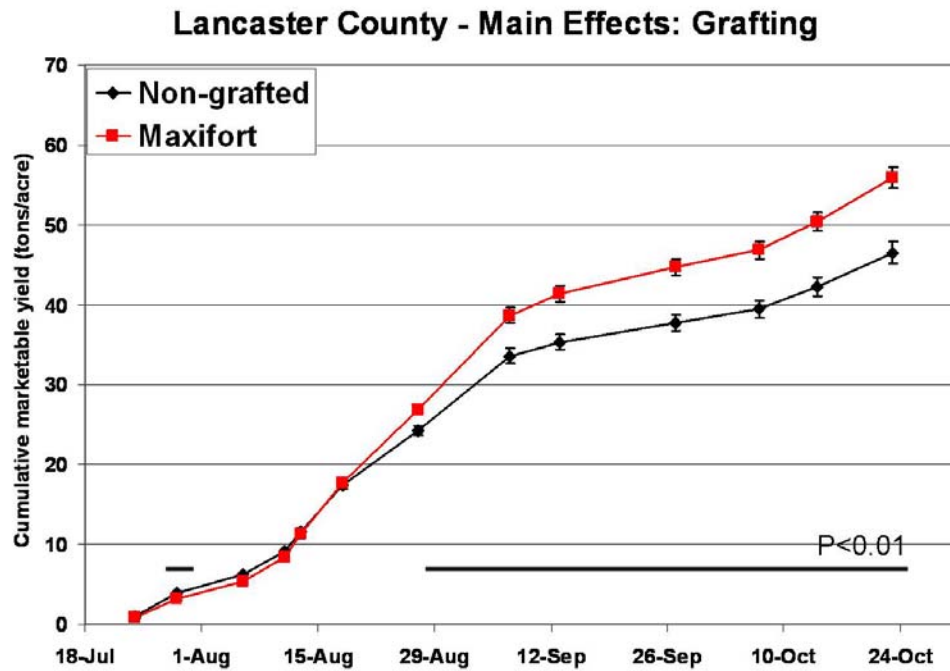
**A**

Lancaster County - Main Effects			
	Marketable yield (tons/acre)	Marketable fruit number	Average fruit size (lbs)
Non-grafted	46.53 A	347.83 A	0.449 A
Maxifort	55.92 B	394.17 B	0.473 B
18 " Spacing	54.44 Y	405.75 Y	0.447 Z
24" Spacing	52.69 YZ	376.63 Y	0.467 Z
36" Spacing	46.54 Z	330.63 Z	0.469 Z

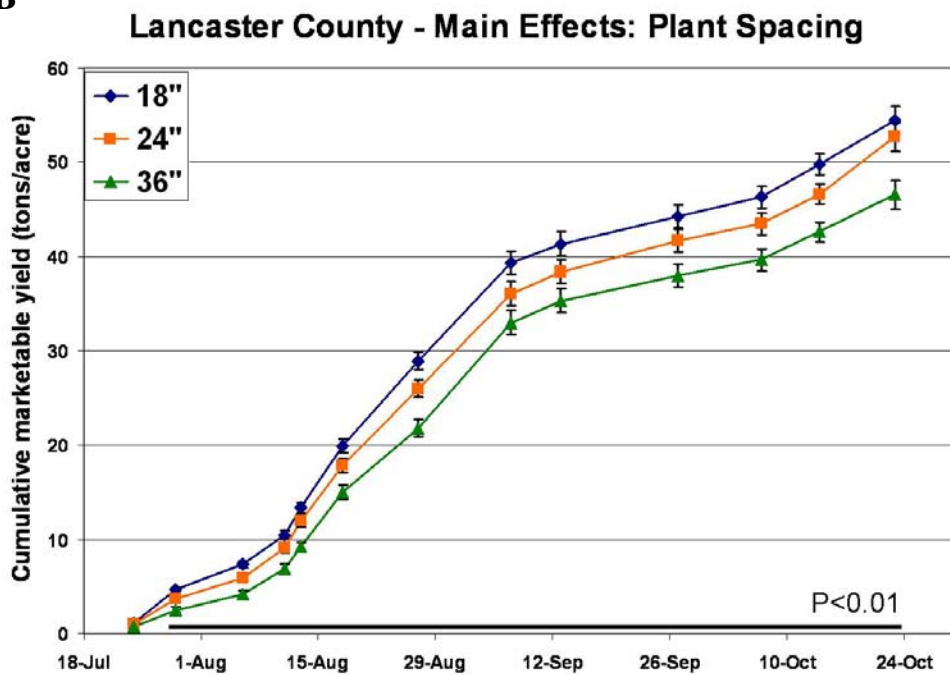


**Figure 2** – **A**) Table illustrating the main effects of grafting and plant spacing on marketable fruit yield, number and fruit size. **B**) Main effects of plant spacing and grafting on marketable fruit yield. Treatments with the same letter are considered statistically similar ( $LSD_{0.01}$ ).

A

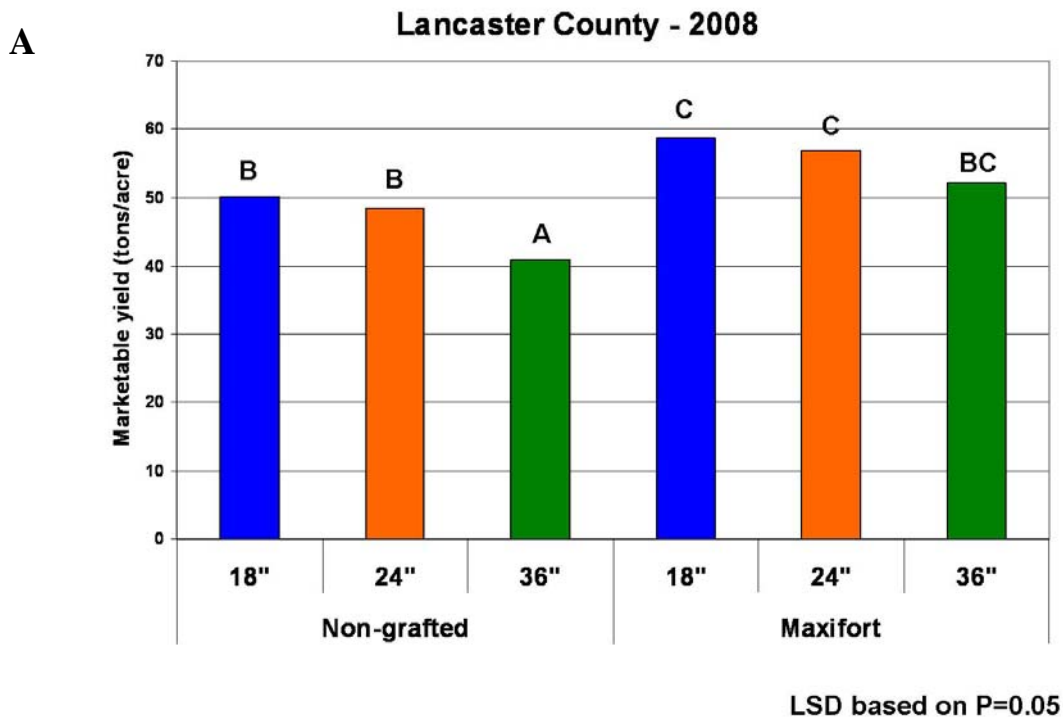


B



**Figure 3** – Main effects of (A) grafting and (B) plant spacing on cumulative marketable fruit yield. The horizontal bar represents statistically significant separation at given harvest points (P<0.01). Error bars represent standard error of the mean.

**Comparison of grafted plants at various plant spacings** – Although the lack of statistical interaction between plant spacing and grafting indicates that the effect of grafting was similar across the three plant spacings, an important component of this study was to determine the optimum planting density of grafted plants and compare the productivity of grafted plants at reduced planting densities with those of the standard, non-grafted system (Fig 4A). Tomatoes are typically planted at 18” in-row spacing for high tunnel production. In this trial, we saw that plants grafted onto ‘Maxifort’ rootstock produced significantly higher fruit yield at 18” and 24” plant spacing than non-grafted plants at 18” (Fig 4A). Therefore, not only is yield significantly higher with ‘Maxifort’ at standard spacing, but planting density can be reduced by 25%, and the “per acre” yield benefit is still significant ( $P < 0.05$ ). Furthermore, plants grafted onto ‘Maxifort’ at 36” spacing produced similar yield to non-grafted plants at 18” spacing (Fig 4A). This comparison highlights the importance of plant spacing when utilizing grafted plants as ‘Maxifort’ rootstock was able to maintain high yield even with half the number of plants per acre. Per plant productivity and gross income was also calculated based on the results of this trial and are shown below (Fig 4B). The economic relevance of grafting and spacing will be discussed in further sections of this report.



**B**

	Per Plant Productivity			
	Marketable Yield		Gross Income	
Plant Spacing	Non	Maxifort	Non	Maxifort
18"	20.89	24.48	\$ 10.03	\$ 11.75
24"	26.95	31.59	\$ 12.94	\$ 15.16
36"	34.12	43.45	\$ 16.38	\$ 20.86

**Figure 4** – A) Simple effects of plant spacing, and grafting on marketable fruit yield. Treatments with the same letter are considered statistically similar ( $LSD_{0.05}$ ) B) Per plant productivity and gross income calculated from 2008 data and estimated market price (\$.48/lb).

## 7. Conditions

Overall, the growing conditions for this trial were favorable. The research plot was located within tomato blocks in my high tunnel production site. The plot was centrally located within the width and length of the tunnel, reducing “edge” effects, and the research plot was very productive. The replicated factorial design utilized in the study allowed for a very comprehensive analysis of the impact of grafting on tomatoes grown at various plant spacings. Our data showed little variation and we saw strong treatment effects, allowing us to draw direct conclusions from the data.

## 8. Economics

The main effect of grafting showed that plants grafted onto ‘Maxifort’ rootstock produced 55.9 tons/A and non-grafted plants produced 46.5 tons/A. Therefore, the main effect of grafting was an approximate 20% increase in yield. This yield increase represents:

- 9.4 more tons per acre
- Or, 752 more boxes per acre
- @ \$12.00 per box (#1’s and #2’s) = \$9,024 increase
- Or, \$1.88 per plant increase

The 20% yield increase translated into an additional gross income of \$9,024 per high tunnel acre or \$1.88 per plant. This is based on \$12 per box (#1’s and #2’s combined) or \$.48 pound. The average per plant productivity and gross income was calculated based on the results of this trial and are shown in Fig 4B. It seems clear that plant spacing will be an important factor in determining the economic relevance of grafting for high tunnel production. In order to understand the direct costs of grafting, it is important to identify those associated with grafted transplant production. For small growers that would potentially graft their own transplants, additional costs associated with grafting have not been determined, but reports in the literature suggest the cost of producing a grafted transplant could range from \$.50-\$1.00 per plant. We will be looking at the cost of commercial grafting with a 2009 SARE grant. For a grower that has is trying to manage crop reductions by verticillium wilt, a profit of at least \$.88 per plant or \$4,224 per acre could be realized at the estimated price of \$1.00 per plant. The results of this trial will play an important role in determining how plant spacing fits in with the economics of grafting, and the results of the 2009 study (in progress) should help to describe the direct costs of grafting for growers in the Northeast.

## 9. Assessment

This project was very successful. We have demonstrated that grafting with ‘Maxifort’ rootstock is an excellent management tool to increase crop productivity for growers trying to manage verticillium wilt (race 2). The results of this study also indicate that grafting could be an economically-feasible technology for commercial high tunnel growers, and that plant spacing can be manipulated to reduce economic constraints. Further research that clarifies the interactions of grafting and fumigation will demonstrate the relationship that ‘Maxifort’ rootstock has with *V. dahliae* (race 2), and a comprehensive economic analysis of on-farm grafted transplant production will help to understand the economics of grafting. I was awarded a SARE grant for 2009 that addresses both of these questions.

## 10. Adoption

I plan to greatly expand the use of grafted tomato transplants for the 2009 season- increasing from 500 plants last year to 8,000 plants this coming year. In November 2008, my transplant grower, Chris Powell, and Kaitlin Dye attended a grafting workshop in Pittsboro, NC. Chris and Kaitlin are successfully grafting plants for the 2009 growing season and at least 10 other farmers have contacted Chris for grafted plants. Demand has been to the point where he is only offering trial samples in order to allow more growers to test what grafted tomato plants can accomplish.

## Outreach

The results of this study have been extended to a wide array of audiences. We hosted a field day on July 9<sup>th</sup> attended by >30 farmers. A handout was provided that explained the trial and a grafting factsheet was given to attendees (both included). Cary Rivard spoke about the trial and provided a discussion of the results at the Haygrove High Tunnel Meeting in Lancaster, PA on December 9<sup>th</sup>. There were >70 people in attendance. I spoke and gave a presentation at the New Holland Vegetable Day, New Holland, PA on January 19<sup>th</sup>. 40 were present. The evening of February 4<sup>th</sup>, a 3-hour grafting workshop was held at the Mid-Atlantic Vegetable Conference, led by Dr. Michael Orzolek and Cary Rivard. At least 50 people attended. On February 5<sup>th</sup>, at the Mid-Atlantic Vegetable Conference, I spoke and gave a presentation for about 100 people. Cary Rivard has also used the data generated from this trial for general extension presentations given at four other grower-based conferences in PA, GA, OR, and NC to date. The results of this trial will be posted soon on my website- [cedarmeadowfarm.com](http://cedarmeadowfarm.com).

## 12. Report Summary

This project evaluated 'Maxifort' rootstock for its ability to manage verticillium wilt (race 2) and other soilborne diseases in multi-bay high tunnels. 'BHN 589' was used for the scion in grafted treatments and non-grafted controls. The results of this study suggest that grafting with 'Maxifort' rootstock can increase yield for high tunnel growers in the northeast that face disease pressure from verticillium wilt (race 2). 'Maxifort' was susceptible to *V. dahliae*, but maintained high yields and the main effects of grafting showed significantly more fruit yield through increased fruit size and number ( $P < 0.01$ ). Furthermore, in-row plant spacing can be manipulated to reduce the economic constraints of grafting. Crop productivity (per acre) was not hindered when 'Maxifort' plants were grown at 36" compared to non-grafted plants at 18" and grafted plants at 24" spacing had increased fruit yield compared to non-grafted plants at 18". Plant spacing is an important consideration for growers wishing to use grafted plants as these transplants are more expensive than non-grafted plants. Because the impact of fumigation could not be assessed in the study, we were not able to determine if the yield increases seen as a result of grafting with 'Maxifort' rootstock are directly attributed to tolerance of *V. dahliae*. However, the results of this trial show that grafting with vigorous rootstock is effective at increasing fruit yield through increased fruit size and number, and that grafted plants maintain crop productivity under severe disease pressure from verticillium wilt. .

Submitted by,

Steve Groff  
3-23-09