Cedar Meadow Farm

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1. Project name and contact information

Project Title: An Economic Comparison of Grafted Tomato Transplant Production and Utilization in multi-bay High Tunnels
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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 actual costs associated with commercial, large-scale grafted transplant production and evaluate the economic impact of grafting, fumigation, and in-row plant spacing on net revenue. 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, 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 for the research trials carried out in 2008 and 2009 at my farm. He also consulted with Chris Powell, collaborating transplant grower and owner of Good Harvest Farms, regarding the production of 10,000 grafted transplants at this location in the spring of 2009. 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 Transplant Production – In the spring of 2009, approximately 10,000 grafted plants were produced at Good Harvest Farms (Strasburg, PA). 'Maxifort' rootstock was utilized as a vigorous rootstock to manage verticillium wilt and several scion varieties were utilized. 'BHN 589' as well as various (>20) heirloom cultivars were grafted onto 'Maxifort' rootstock. The grafted plants were produced in three batches of ~3300 plants and the experiences gained from this process were used to develop a detailed economic production sequence to account for all variable costs required for grafted and non-grafted transplant production at Good Harvest Farms. The specific transplant production methods are shown below and slight variations may be seen at different locations or in different growing environments. Similarly, the experiences during the spring trials were used to provide an estimate of grafting rate and success for the purpose of budget development and subsequent economic analysis.

Assumptions of the economic model include grafting speed and success as well as hourly wages for grafting and other labor costs associated with transplant production. During the development of the model, it was also assumed that each "batch" of plants had a specific number of plants as an outcome. Therefore, seeds were "over sown" by 25% to account for plant uniformity and germination rate of rootstock and scion plants. Furthermore, grafting success was assumed to be 90%. Hourly wages for hired and managerial labor were $10/hr and $14/hr, but hourly rates of $11.79 and $16.39 were used to reflect the "true" cost of labor. Manual grafting labor was paid $14/hr and grafting speed was assumed to be 100 plants/hr.

Rootstock and scion seedlings were germinated by a local custom plug producer in 288-cell trays and allowed to grow for 3 days upon arrival. The seedlings were transplanted into 50-cell trays and allowed to grow for 21 days in the greenhouse before being grafted. Once grafted, the plants were immediately moved into a healing chamber for 7 days. The healing chamber was built on top of an "ebb-and-flow" greenhouse bench using wire hoops, plastic, shade fabric, and four cool-mist vaporizers. The grafted plants were monitored twice daily and light and humidity levels were maintained in accordance with current grafting protocols. Once the plants were moved back into the greenhouse, they were transplanted into an 18-cell tray and grown for 14 days before being hardened off in an unheated greenhouse for 7 days prior to sale.

On-farm Research Trial – In addition to the propagation study carried out at Good Harvest Farms, a research trial was located within my high tunnels at Cedar Meadow Farm to continue work initiated in 2008 (See FNE08-636). The trial was located within two 300' rows and included six replications in a split-plot design. The main factor was fumigation, and the sub-plot treatments included non-grafted 'BHN 589' and 'BHN 589' grafted onto 'Maxifort' rootstock. Between each main plot, four foot "buffer" areas were included to reduce inter-plot interference, and fumigation was carried out on April 6, 2009.

The research trial was planted on April 30th, and harvesting was carried out from July 8th until October 29th. A field day was held at my farm to showcase the grafting research trial and high tunnel management on July 7th, and Cary Rivard and I described the research trial objectives to the audience. During his visit, Cary trained myself and Kaitlin Dye, my high-tunnel manager, to carryout disease ratings and yield data collection. Kaitlin and I oversaw day-to-day management as well as 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.

Once the results were compiled from the transplant study, they could be combined with replicated data from the 2008 and 2009 growing seasons to assess the economic costs and benefits of grafting at my farm. Marketable fruit yield data was used to generate gross revenue estimates, and these values were used to compare grafting, plant spacing, and fumigation in a manner similar to partial budget analysis. These estimates included the cost of harvesting, grading, and packing materials. Although costs may vary slightly throughout the season and from year-to-year, we estimated that the selling price of tomatoes was $16 per 25 lbs box ($0.60/lb) and the actual economic benefit of fruit sale was $13 per 25 lbs box ($0.48/lb). Transplant costs were calculated based on the requirements of each plant spacing treatment, and the 18", 24", and 36" in-row spacing treatments resulted in planting densities of 4800, 3600, and 2400 plants per acre, respectively. These values were used to construct a partial budget that could be used to compare our specific research questions without addressing production costs.

6. Results

Grafted Transplant Production – Overall, the propagation of grafted plants at Good Harvest Farms was highly successful. As a result of high temperatures in the healing chamber, one of three batches had a success rate of <80%, but the remaining two batches did well, and steps were taken to identify and correct this problem. Our experiences showed that grafting can easily be accomplished at a rate of 100 plants/hour. We found that one major factor that contributed to the speed of grafting was the uniformity and size of rootstock and scion transplants. Plants that were slightly too large or had poor uniformity, slowed the rate of grafting. However, high grafting success (>90%) was found in two of three batches, and our results showed that grafted plants could be produced for $1.25 as compared to $0.51 for non-grafted ones. The material costs and sources are listed in table 1. A summary of the variable costs for 1000 grafted plants is shown in table 2, and figure 1 shows the economic timeline of grafted and non-grafted plants. This timeline shows not only the variable cost (y-axis), but also the production timeline (x-axis) of grafted and non-grafted plants used at Good Harvest Farms during the course of the study.

The additional cost of producing a grafted plant ($TOTAL_{graft}$ – $TOTAL_{non}$) was $0.76 per plant (Figure 1) and the difference in the selling price was $1.12. These costs are the result of additional rootstock and scion seed costs, the direct costs of grafting (e.g. grafting labor, clips, healing chamber, etc.), and the indirect costs associated with growing a "second crop" prior to grafting. The distribution of these added costs are shown in figure 3. The distribution represents the additional cost of each factor divided by the total additional costs of grafting. For example, the extra seed costs required for grafted transplants represented 33% of the total additional required costs of grafted transplant production (i.e. $[(SEED_{graft} – SEED_{non}) / (TOTAL_{graft} – TOTAL_{non})] = 33\%$). During the study, seed costs (33%), combined indirect costs (30%), and grafting labor (24%) were the three most important variable expenses in relation to grafting.
An important note to consider is that growers wishing to utilize grafted plants will ultimately pay higher prices not only because grafted transplants require additional materials, but also because

transplant propagators will want to recoup additional revenue to offset the risk of the increased production costs. An unexpected finding during the economic analysis was that the grafted plants provided a better use of greenhouse space to the transplant grower than non-grafted plants. At this location, heating costs are directly related to the amount of space needed for the crop in the greenhouse (Table 1). Furthermore, for every $1.00 the grower invested in heating, non-grafted plants and grafted plants yielded $2.88 and $4.54 in mark-up, respectively (Table 2). Therefore, the grafted plants provided a more profitable use of greenhouse space, due to the added value of grafted plants. Although this trend would be similar regardless of the specific mark-up value, it is reliant upon the assumption that the mark-up value imposed on grafted and non-grafted plants is equal. Currently, there is little market availability of grafted transplants, but this new market may help US propagators retain profitability for commercial and retail tomato transplant production.

A relevant concern among US growers in relation to grafting is the high cost of labor. In this report, we found that grafting labor costs made up a relatively small portion of the added cost of grafting (Figure 2), and total labor costs were proportionally lower or similar among grafted plants as compared to non-grafted plants (Table 2). These results indicate that labor prices in the US may not be as important as previous speculations have suggested.

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 2008, our fall fumigation treatment was not effective. However, the results showed that ‘Maxifort’ maintained higher crop productivity under disease pressure from verticillium wilt (race 2). In 2009, spring fumigation was carried out and this resulted in higher marketable fruit yield than non-fumigated plots (Fig 1A). Therefore, fumigation was effective and could be used to compare the ability of ‘Maxifort’ to tolerate infection by *V. dahliae* (race 2).

Disease ratings were carried out through the course of the season, and similar to the 2008 study, verticillium disease incidence was not affected by grafting. Although ‘Maxifort’ rootstock may show reduced yield penalties from infection by *V.dahliae* (race 2), it is susceptible to the fungus and symptomatic plants were observed at similar levels as in non-grafted plants. However, similarly to the trial in 2008, plants grafted onto ‘Maxifort’ rootstock had the highest yield in 2009. Furthermore, the grafted and non-fumigated treatments had significantly higher fruit yield than non-grafted plants grown with fumigation (Fig 1B). Interestingly, the fumigation treatment had only a slight numerical effect on grafted treatments and was not statistically significant (Fig 1B). These results indicate that grafting does not have an equivalent additive effect in fumigated and non-fumigated soils, and may serve as an alternative to fumigation against verticillium wilt (race 2). Plants grafted onto ‘Maxifort’ rootstock had significantly increased fruit number ($P<0.05$), but average fruit size was similar (data not shown). Fumigation increased crop productivity midway through the harvest season (Fig 2A), and grafting increased productivity midway and late in the harvest season (Fig 2B). The grafted plants had slightly reduced yields early in the season and a similar trend was seen in the 2008 study (Fig 2B).

Although ‘Maxifort’ rootstock displayed effective tolerance in this study, it should be noted that this type of response by the plant does not slow or stop reproduction of *V. dahliae* in infested soils. Crop tolerance provides the ability to maintain fruit yield even though infection by a pathogen occurs. In this case, the use of tolerant rootstock may be complimented well with strategies that seek to reduce pathogen inoculum levels in the soil. These measures could include crop rotation, fumigation, bio-fumigation, or the use of suppressant cover crops.

Table 1. Material and equipment prices used for the production sequence

Item	Description	Unit	$/unit*	Lifespan	Source
Seed Costs					
BHN 589' (BHN Seed)	Scion / non-graft seed	1000 seeds	$62.50		Siegers Seed Co. (www.siegers.com)
Maxifort' (De Ruiter Seeds)	Rootstock seed	1000 seeds	$194.46		Johnny's Seeds (www.johnnyseeds.com)
Direct Grafting Costs					
2.0 mm silicone grafting clip	silicone grafting clip	200 clips	$8.40		Hydro-gardens (www.hydro-gardens.com)
Grafting knives, alcohol, etc	Grafting tools	per operator	$2.00	3	local / regional dept store
Wire hoops, fabric, plastic	chamber materials	per chamber^	$29.50	3	local / regional horticultural supply
Cool-mist vaporizer	4 vaporizers per chamber	per chamber^	$320.00	5	"
Ebb-and-flood bench	chamber materials	sq. ft	$3.50	10	"
Other Material Costs					
Custom plug costs	seedling germination	per plant	$0.05		local custom propagator
Potting media	per 50-cell tray	per tray	$0.28		local / regional horticultural supply
Potting media	per 18-cell tray	per tray	$0.45		"
DPS 50 trays	50-cell tray	case (100)	$45.00		"
1801 deep tray	18-cell tray	case (100)	$66.00		"
Web trays	18-cell tray only	case (100)	$36.00		"
Water-soluble fertilizer	applied through injector	per tray per week	$0.03		"
Heating	All greenhouse heat	per tray per day	$0.07		

** Based on prices during budget development*
^ healing chamber holds 3300 plants

Table 2. Summary of variable costs and selling price of for transplant production (per 1000 plants)

Description		Non-grafted		Grafted	
		Materials	Labor	Materials	Labor
Seed costs	Rootstock ('Maxifort')			$242.69	
	Scion ('BHN 589')	$72.92		$78.13	
Transplant production	Custom plug costs	$57.60	$1.38	$124.80	$2.95
	Potting mix	$30.65		$37.37	
	Plastic trays	$65.78		$76.58	
	Heating	$88.41		$138.04	
	Transplanting		$73.69		$104.15
	Transplant care	$5.68	$112.30	$6.96	$166.77
Grafting	Manual grafting				$180.29
	Grafting clips			$46.20	
	Misc. supplies			$1.33	
Healing chamber	Chamber supplies			$42.11	$3.93
Total		$321.04	$187.36	$794.20	$458.08
Total (materials and labor)		$508.40		$1,252.28	
Cost per plant		$0.51		$1.25	
Selling price (50% mark-up)		$0.76		$1.88	

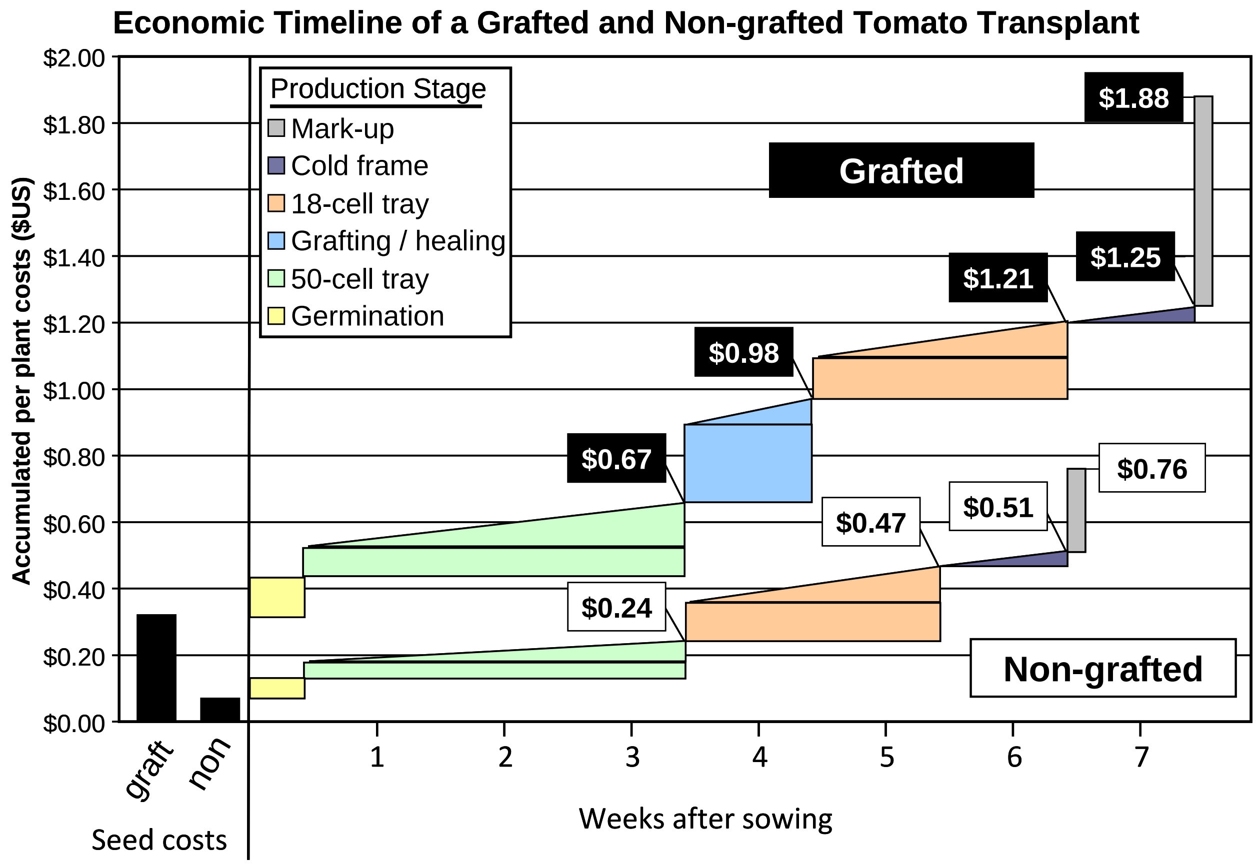


Figure 1 – Economic timeline of grafted and non-grafted tomato transplants at Good Harvest Farms. Squares and triangles scaled to represent discrete (e.g. transplanting labor, materials, grafting labor, clips, etc) and continuous (e.g. overhead, daily watering labor, fertilizer, etc) expenses, respectively.

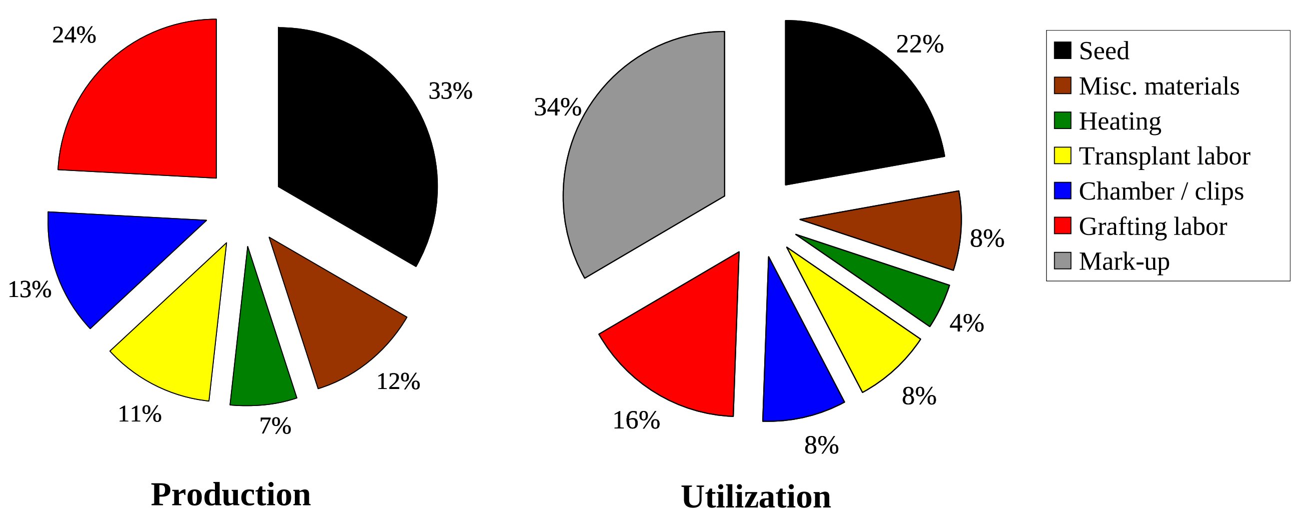
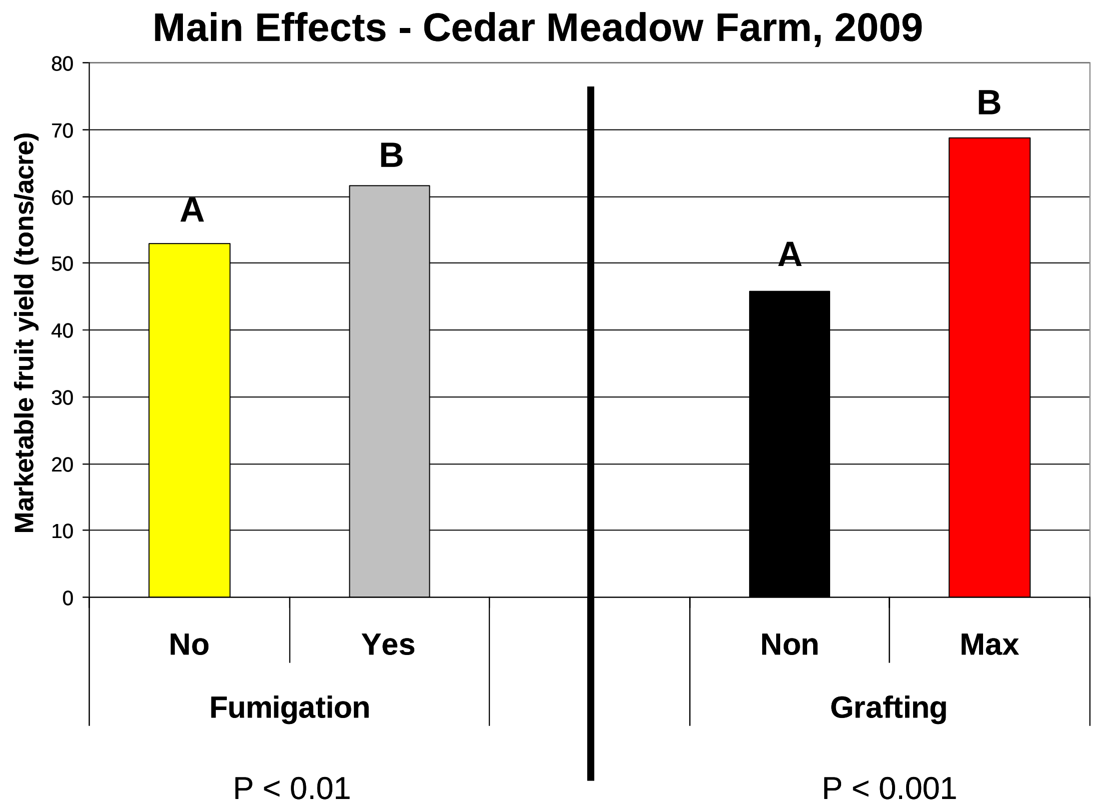


Figure 2 – Distribution of the added costs of grafting for transplant production and utilization. Added cost of grafting for transplant production was $0.74 per plant and final production costs were $1.25 per plant. Added cost of grafting for transplant utilization at Cedar Meadow Farm was $1.12 and price of grafted plants was $1.88 per plant.

A



B

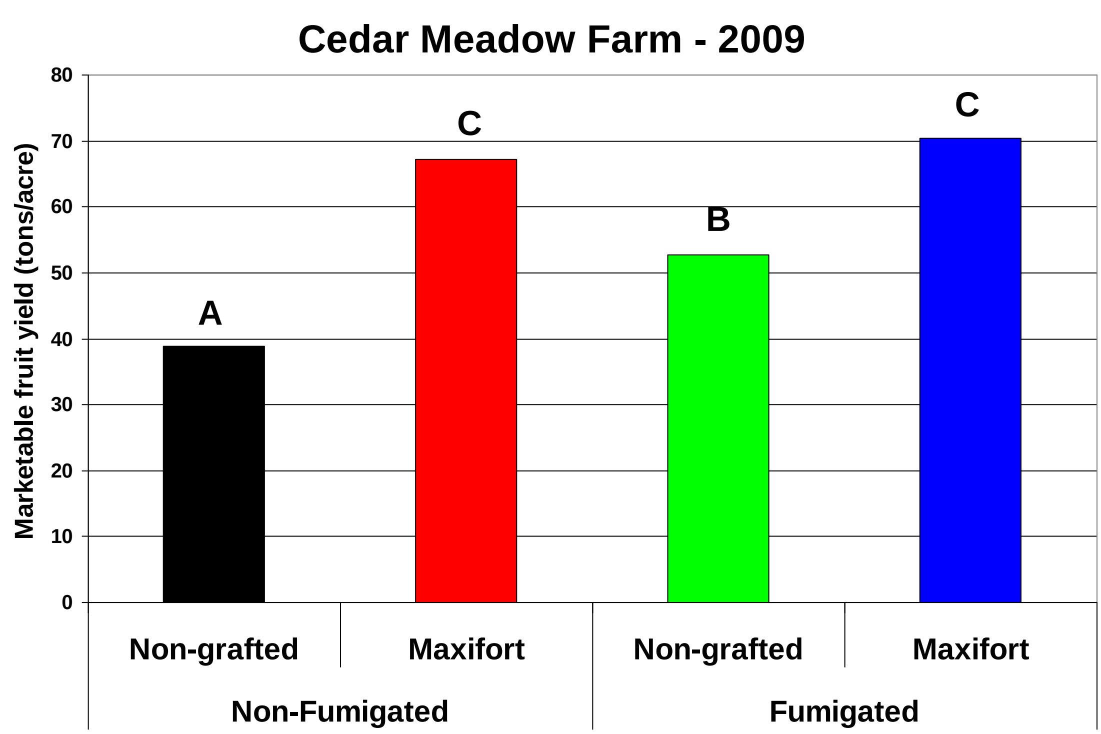
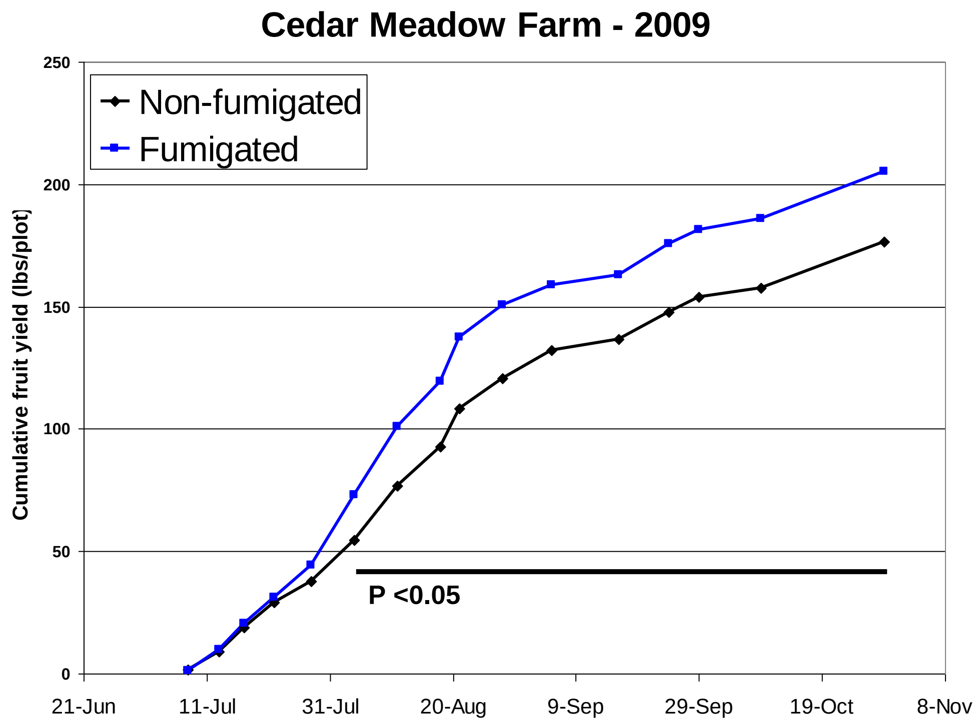


Figure 3 –Main **(A)** and simple **(B)** effects of fumigation and grafting on marketable fruit yield of grafted and non-grafted tomato plants with and without fumigation under disease pressure from verticillium wilt. Treatments with the same letter are considered statistically similar ($LSD_{0.05}$).

A



B

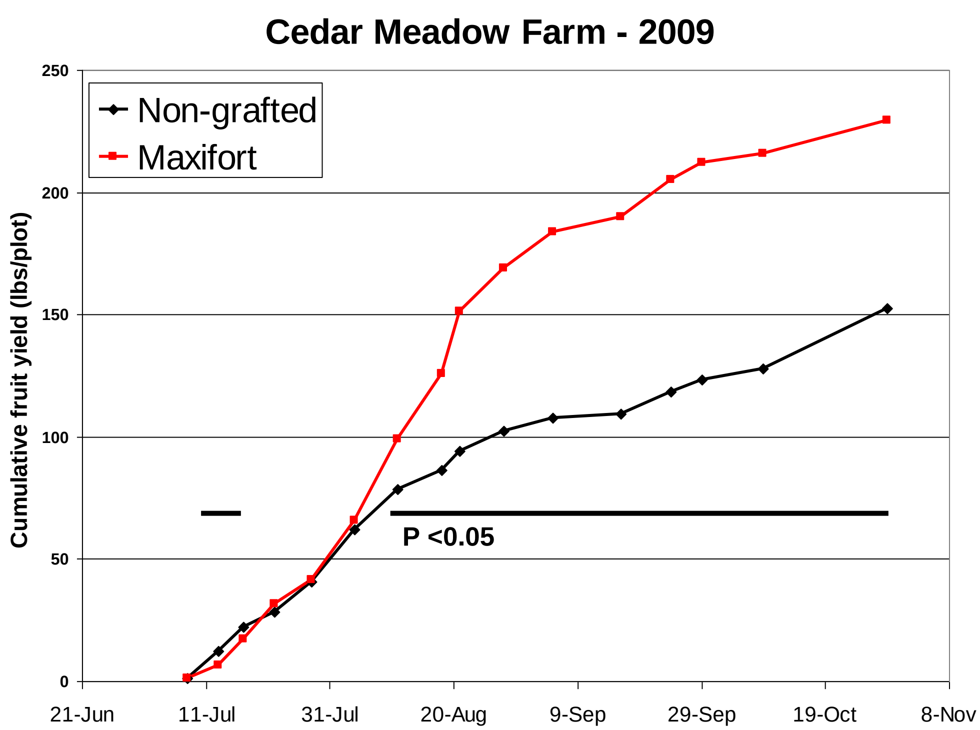


Figure 4 – Main effects of fumigation **(A)** and grafting **(B)** on cumulative marketable fruit yield under disease pressure from verticillium wilt.

7. Conditions

Overall, the growing conditions for this trial were favorable. The research trial 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 and fumigation on tomato production. Our data showed little variation and we saw strong treatment effects, allowing us to draw direct conclusions from the data.

8. Economics

One of the primary objectives of this project was to determine the actual variable costs associated with grafted transplant production and use these values to determine any economic benefit of grafting for multi-bay high tunnel production. Furthermore, data was available from 2008 to determine the optimum plant spacing for economic efficiency. Therefore, transplant production budgets generated in 2009 were applied to data from the 2008 and 2009 growing season. The net returns of grafting are listed in Table 3. These values represent calculated gross revenue minus any harvesting costs in addition to transplant and fumigation costs. Production costs are assumed to be equal for grafted and non-grafted plants, and at various plant spacings.

Table 3. Economic effects of grafting, fumigation, and plant spacing on net revenue ($ per acre)

Treatment / Description		Yield (t/a)	Gross Returns[W]	Plant Costs[X]	Fumigant Costs[Y]	Net Returns[Z]
2008	Non, 18" (Std)	50.1	$48,125	$3,648	NA	$0
	Non, 24"	48.5	$46,560	$2,736	NA	-$653
	Non, 36"	40.9	$39,302	$1,824	NA	-$6,999
	Graft, 18"	58.7	$56,390	$9,024	NA	$2,889
	Graft, 24"	56.9	$54,595	$6,768	NA	$3,350
	Graft, 36"	52.1	$50,045	$4,512	NA	$1,056
2009	Fum, Non, 24" (Std)	52.8	$50,650	$2,736	$350	$0
	None, Non, 24"	38.9	$37,306	$2,736	$0	-$12,994
	Fum, Graft, 24"	70.5	$67,642	$6,768	$350	$12,960
	None, Graft, 24"	67.1	$64,445	$6,768	$0	$10,113

[W] Gross Returns = (Gross revenue - harvesting costs)

[X] Based on 2009 propagation study

[Y] Fumigation not effective in 2008

[Z] Net Returns = $[(RETURNS_{TRT} - COSTS_{TRT}) - (RETURNS_{STD} - COSTS_{STD})]$

In all cases and at all plant spacings, the cost of transplants was offset by higher fruit yield. In 2008, grafting increased farm profit by $1,056-$3,350 per acre. Furthermore, the 36" plant spacing offers a unique opportunity for growers to utilize grafted plants without dramatically increasing transplant costs. The cost of non-grafted transplants grown at 18" was $3,648/acre and the cost of grafted plants at 36" was $4,512/acre. Based on the transplant cost determined in 2009 combined with the yield data from 2008, it appears that 24" in-row spacing is the most efficient production system for grafted plants. Marketable fruit yield of grafted plants at 18" was only 1.8 t/a higher than grafted plants at 24" (Table 3), and the reduction in transplant costs resulted in $461 more profit per acre than grafted plants grown at 18". Furthermore, at 24" in-row spacing, transplant costs were increased by 85% compared to 147% when utilizing grafted plants at 18” in-row spacing, thereby reducing early-season costs.

The results from 2009 showed strong evidence that grafting helped to increase net revenue and ultimately added profitability to the farm. When used in combination with fumigation, grafted plants resulted in an added $12,960 per acre in profit. Furthermore, this increase in net revenue dramatically increased farm-gate income. When grafted plants were grown without fumigation, the net return of grafting in comparison with fumigated, non-grafted plants was $10,113. More importantly, the fumigation treatment had a lesser economic impact on grafted plants. The introduction of fumigation into the non-grafted production system increased per acre profit by $12,994. However, a similar comparison of fumigation within the grafted treatments shows that fumigation contributed $2847 per acre when grafted plants were utilized. These results suggest that grafting can be used as an alternative to fumigation to manage verticillium wilt without the use of chemical fumigants. Furthermore, they suggest that the adoption of grafting in multi-bay high tunnels adds substantial per acre profit.

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 is 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 similar studies should be repeated to determine the mechanism behind the fruit yield increase seen in these trials..

10. Adoption

With tomato yield results totaling over 50 tons/acre from the 2009 season, where 95% of our high-tunnel tomatoes were grafted, we are planning to repeat this again in 2010. Chris Powell, our transplant grower, has upgraded his grafting system for 2010 with higher powered humidifiers and a more easily accessible healing chamber. He is planning on grafting 2500 more plants in addition to the ones for me to be sold to neighboring farmers who would like to try them.

Here at Cedar Meadow Farm this coming season, we will still use fumigation in combination with the grafting because of the slight edge in economic profitability when used together and for insurance against the verticillium specifically for those non-grafted that will be planted. In the future, we will take a year-by-year evaluation of our need for fumigation.

Outreach

The results of this study have been extended to a wide array of audiences. We hosted a field day on July 7th attended by >30 farmers. A handout was provided that explained the trial and a grafting factsheet was given to attendees (both included). I spoke and gave a presentation at the New Holland Vegetable Day, New Holland, PA on January 19th. 40 were present. The evening of February 4th, 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 5th, 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 research and extension presentations given at several grower-based conferences in NY, PA, GA, TN, and NC to date. We also developed a grafting video during the spring and it will be posted on the web this spring and links will be posted on my website – www.cedarmeadowfarm.com. The information collected during the propagation study at Good Harvest Farms is also under preparation for publication. This data will be combined with another propagation study carried out in NC and will be submitted as a marketing and production report to HortTechnology. It is currently under re-vision by co-authors and will be submitted this spring.

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. Furthermore, grafted plants were produced at a local commercial propagation facility to determine the actual costs and benefits of grafted transplant production and utilization for 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 in both years ($P<0.01$). Furthermore, in-row plant spacing was manipulated to reduce the economic constraints of grafting, and our results suggest that 24" in-row spacing is the optimum plant spacing for grafted plants. Plant spacing is an important consideration for growers wishing to use grafted plants as they are more expensive that non-grafted plants. Our results showed that grafting increased production costs by $1.12 per plant. In 2009, the fumigation treatment was effective, and the results from this trial suggest that grafting with 'Maxifort' rootstock provides tolerance to *V. dahliae* through increased plant vigor. However, further research is needed to verify this trend.. This study also showed that although grafting substantially increases transplant costs, it is an economically effective management strategy. The top performing treatment in 2009 provided $12,960 more profit per acre in comparison with my standard non-grafted systems. Furthermore, the results from the research trial show that I can eliminate fumigation from my farming system and still retain profitability.

Submitted by,

Steve Groff
5-5-10