Organic Farming Research Foundation

Project Report: Grafting Vegetables for Soil-Borne Disease Resistance

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Project Summary

This study evaluated grafting to manage Verticillium wilt in organic eggplant, tomato and watermelon. The effect of three healing chamber designs on the survival of grafted eggplant, tomato, and watermelon was also evaluated. In this study, smaller healing chamber dimensions maintained consistently higher relative humidity and a humidifier did not increase relative humidity or graft survival. Grafted tomato survival was high in all healing chamber designs whereas watermelon graft survival was low, indicating that grafted tomato is tolerant of lower relative humidity during graft union formation and watermelon is not. Studies were conducted in 2010 and 2011 at organic field sites in the Columbia Basin (irrigated dryland) and western Washington (high annual rainfall) with confirmed *V. dahliae* soil populations. Each crop was non-grafted, self-grafted and grafted onto two commercially available rootstocks chosen for possible *V. dahliae* resistance as available. For all three crops, rootstock-grafted, non-grafted, and self-grafted plants had equivalent yield, fruit size, and fruit quality. Eggplant was grafted onto 'Beaufort' interspecific tomato hybrid and *S. aethiopicum*. 'Beaufort'-grafted had reduced Verticillium wilt severity as compared to non-grafted, self-grafted, and *S. aethiopicum*-grafted eggplant; *V. dahliae* was isolated from all treatments. Tomato was grafted onto 'Beaufort' and 'Maxifort' interspecific tomato hybrids. Verticillium wilt symptoms were not observed in any treatments at either location in either year. Watermelon was grafted onto 'Emphasis' bottle gourd and 'Strong Tosa' interspecific squash hybrid. Non-grafted and self-grafted watermelon plants had significantly greater Verticillium wilt severity than 'Emphasis' and 'Strong Tosa'-grafted watermelon in western Washington both years; but again, *V. dahliae* was isolated from all treatments. Plant growth was increased and Verticillium wilt severity was reduced in 'Beaufort'-grafted eggplant and 'Emphasis' and 'Strong Tosa'-grafted watermelon, indicating these rootstocks may be partially resistant to *V. dahliae* and may effectively control Verticillium wilt. Common tomato and eggplant grafting techniques are described in new WSU Extension factsheets and in narrated PowerPoint presentations, as an outcome of this project and are posted on our website. Other new information posted on our website includes handouts regarding rootstocks, seed sources and grafting supplies. One new journal article was published describing a successful healing chamber environment for northwest Washington.

Introduction

Organic tomato, eggplant and watermelon production in Washington is limited by soilborne diseases such as Verticillium wilt. Disease control in organic systems relies on use of resistant varieties, but selection is limited and varieties are often not the ones best suited for the region. Grafting with resistant rootstock is a relatively simple and organically-acceptable technique for disease management and is used throughout Asia, Europe and Canada with excellent results, but has not been explored in the northwest United States. Additionally, the literature includes conflicting results and recommendations regarding how best to provide a healing environment that results in high rates of grafting success.

This project included a greenhouse study to identify effective healing chamber environments and management strategies, a field study to evaluate effectiveness of grafting tomato, eggplant and watermelon for Verticillium wilt management, and a follow-up greenhouse inoculation study to demonstrate that isolations from the field study are pathogenic. New information has been developed regarding vegetable grafting techniques, healing chamber structures, vegetable rootstocks and their sources and costs, and sources and costs of vegetable grafting supplies. This project has the potential to expand the opportunities for growers to either purchase grafted transplants or create their own using inexpensive, scale-appropriate techniques.

This study was the thesis research project for a WSU M.S. graduate student, Sacha Johnson. Funding sources for the project included the Washington State Commission on Pesticide Registration (WSCPR), WSU Department of Horticulture, Pacific Northwest Vegetable Association (PNVA), Center for Sustaining Agriculture and Natural Resources (CSANR), Northwest Agricultural Research Foundation (NARF), George Clough at Oregon State University, and the Organic Farming Research Foundation (OFRF). Growers contributed information, financial support, field space, and in-kind support (field plot establishment, maintenance and harvest) for this project.

Objectives

The objectives of this study were:

1. Evaluate in the greenhouse different healing environments for grafted tomato, eggplant and watermelon.
2. Test grafted tomato, eggplant and watermelon in two Washington organic fields (Mount Vernon and Eltopia), each with high *Verticillium* wilt pressure.
3. Evaluate fruit quality of grafted tomato, eggplant, and watermelon.
4. Publish information for growers and peers on vegetable grafting methods and techniques.

Materials and Methods

We conducted a healing chamber design study to compare survival rates of grafted tomato, eggplant and watermelon in three healing chamber designs. The experimental design was a split plot replicated three times from January 24, 2011 to February 21, 2011. Each replication consisted of three treatments: 1.) high added humidity design (as used by most researchers in the U.S.); 2.) low tunnel with hand misting (as seen at a commercial vegetable transplant grafting operation in Canada in October 2010; Figure 2); and 3.) a simplified design which was shadecloth only and hand misted. Each treatment consisted of 72 plants each of grafted eggplant, tomato, and watermelon. Plants were propagated from seed and self-grafted using the splice-grafting technique. Graft survival was measured from day 3 to day 15 after grafting.

In 2010, a field study was conducted at WSU Mount Vernon NWREC (tomato, eggplant and watermelon), Eltopia, WA (tomato and eggplant), and Hermiston, OR (watermelon). In 2011, a field study was conducted with tomato, eggplant and watermelon at WSU Mount Vernon NWREC and Eltopia. The field research site both years at WSU Mount Vernon NWREC was certified organic since 2007 by Washington State Department of Agriculture Organic Food Program (WSDA OFP). The field site at Schrieber and Sons at Eltopia, WA, was certified organic in 2010 (certifier was WSDA OFP), and the field site in 2011 was in its third year of transition to organic and was certified in September 2011. The field site at Hermiston, OR was conventional.

In 2010, resistant commercial rootstocks and seeding dates were identified, grafting techniques tested and selected for each crop, and a field study was conducted at both sites. In 2011, the field study was repeated at both sites. Treatments both years were: ‘Cherokee Purple’ (CP) heirloom tomato grafted onto ‘Maxifort' and ‘Beaufort’ rootstocks; ‘Epic’ eggplant grafted onto ‘Beaufort’ and *Solanum aethiopicum* rootstock; ‘Crisp’n Sweet’ triploid watermelon grafted on ‘Strong Tosa’ and ‘Emphasis’ rootstocks; and self-grafted and non-grafted controls for each crop. The rootstocks used in this study were each the standard rootstocks used for grafted vegetable production throughout the United States and worldwide. Tomato and eggplant were grafted using the splice grafting technique; watermelon were grafted using the one-cotyledon splice grafting technique. Both years, plants were grafted in April and May and transplanted into the field in May and June at Eltopia and Hermiston, and in June at Mount Vernon. At all locations both years, the experimental design was a randomized complete block with 5 replications and 6 plants per plot (Figure 1). However, the number of replications for watermelon at Eltopia in 2011 was reduced to 2 due to high winds after transplanting (plants snapped at the graft union).

Incidence and severity of *Verticillium* wilt symptoms were rated biweekly in the field at all locations. Tomatoes were also rated biweekly for incidence and severity of physiological leaf roll, a physiological disorder causing in-rolling of the leaves, as this could potentially be exacerbated by constricted vascular tissue at the graft union in grafted tomato plants. This data was used to generate an area under the disease progress curve (AUDPC) to quantitatively assess *Verticillium* wilt disease and physiological leaf roll progress and intensity over the growing season. Plant height (tomato, eggplant) and stem diameter (tomato, eggplant, and watermelon) were measured in 2011 on July 6, July 22, Aug 8, and Aug. 22 at WSU NWREC and June 8, July 19, Aug. 2 and Aug. 16 at Eltopia. Stem diameters were measured using a digital caliper, approximately 1 inch above soil line, unless there was a significant difference in diameter between scion and rootstock. Difference in diameter of rootstock and scion indicates graft incompatibility and can affect water transport. When a significant difference in rootstock and scion was observed, the diameters of scion and rootstock were measured separately and averaged.

At WSU Mount Vernon NWREC, no eggplant or watermelon fruit reached marketable size, and while tomato was harvested, there were insufficient fruit for statistical analysis; therefore no fruit yield or quality data were collected at this site. At Eltopia, eggplant and tomato were harvested weekly by field harvest crews both years and total and marketable yields (fruit number and weight) were recorded. Every two weeks we harvested fruit for quality analyses. We harvested watermelon three times both years and evaluated yield and fruit quality. Of the marketable fruit for all crops both years, three fruit were randomly selected, and fruit quality was measured as soluble solids (Brix) and firmness. Soluble solids (Brix) were measured using a digital refractometer (Palm Abbe™ digital refractometer) and firmness of internal flesh was measured using an Ametek drill-press penetrometer with a 4 mm cylindrical blunt-end tip. Average fruit dimensions (length and width) were also measured. After the final harvest at Eltopia and Hermiston, and at the end of September in Mount Vernon, the first three eggplant plants in each plot were cut at the soil line, dried for one week, and weighed as a quantifiable measurement of vigor. Plant dry weight was not measured for tomato or watermelon, as it was not possible to accurately sample tomato and watermelon plants due to their vining growth habits.

At the end of the growing season, plants were assayed for *V. dahliae*. One plant per plot was sampled, with roots and plant crown being removed. The bottom section of the plant, consisting of the root crown and 8-10 inches of the main stem, was surface sterilized in a 10% bleach solution and incubated for 3 weeks at room temperature. Vascular tissue was then examined under a dissecting scope for presence of microsclerotia. Stems that appeared to have microsclerotia in the vascular tissue were dried and processed for long-term storage. Microsclerotia from stems were plated onto semi-selective NP10 and ½PDA media. The characteristics of resulting colonies in pure culture helped to verify *V. dahliae*. Isolates were then sent to the WSU Puyallup Plant Diagnostic Lab and identified to species through DNA sequencing.

A controlled inoculation study was conducted at the WSU NWREC greenhouse facilities to evaluate disease resistance of the scion and rootstock cultivars used in the 2010 and 2011 eggplant field trials. The'MVEggplant301' *V. dahliae* isolate used as inoculum in the study was obtained in October 2010 from infected stem tissue of 'Epic' eggplant grafted onto *S. aethiopicum* in the 2010 field trial located at WSU NWREC in Mount Vernon, WA. The 'MVEggplant301' isolate was sequenced at WSU Puyallup Plant and Insect Diagnostic Laboratory and confirmed as *V. dahliae*. Pathogenicity of the 'MVEggplant301' isolate was confirmed through a preliminary eggplant inoculation trial conducted in Feb. and Mar. 2011. The preliminary trial consisted of five non-inoculated 'Epic' eggplant and five 'Epic' eggplant inoculated with the 'MVEggplant301' isolate.

To increase inoculum for the larger greenhouse inoculation study, the 'MVEggplant301' isolate was grown on ½-PDA with sterilized 6-mm filter paper disks. Once completely inoculated by the colony, filter paper disks were removed from the media, dried for 24 h under a laminar flow hood, and stored on desiccant at 5.5 ºC. The experimental design was a randomized complete block design with 3 replications of 6 treatments and 4 plants per treatment per replication. The experiment was repeated twice between September and November 2011. The 6 treatments were non-grafted 'Epic' eggplant, self-grafted 'Epic' eggplant, 'Epic' grafted onto *S. aethiopicum*, 'Epic' grafted onto 'Beaufort' interspecific tomato hybrid, non-grafted *S. aethiopicum*, and non-grafted 'Beaufort'. For each treatment and replication, four plants were inoculated and four plants were not inoculated as experimental controls. Plant material for the first study repeat was seeded on 21 July and grafted on 15 Aug. Plant material for the second study repeat was seeded on 24 Aug. and grafted on 16 Sept. Plant material for grafted treatments were grafted using the splice grafting technique and acclimation schedule described above for grafting plant material for field trials. 'MVEggplant301' isolates stored on 6-mm filter paper disks were increased on ½-PDA media for 6 weeks (study repeat 1) and 3 weeks (study repeat 2) in dark conditions at 22 to 23 ºC.

The first and second study repeats were inoculated on 12 Sept. and 3 Oct. 2011 respectively. Plants were inoculated by clipping approximately 1 mm from root tips and dipping entire plant root system into the conidial suspension for 5 s. Non-inoculated plants (experimental controls) were similarly clipped and dipped in sterile water for 5 s. After the clip and dip treatment, plants were then transplanted into 800-mL containers filled with commercial sphagnum-peat-based growing media. Plants were rated weekly for disease severity beginning 2 weeks after inoculation when plants began exhibiting disease symptoms. Disease severity was rated as percent area of plant tissue exhibiting symptoms (Figure 3). Disease rating continued for 5 weeks. Plants were then cut at the soil line and weighed. One plant per treatment was assayed for *V. dahliae* in each replication using the stem assay protocol described above. Conidia from these stems were plated onto ½-PDA, water agar, and NP-10 semiselective media to confirm pathogenicity of the'MVEggplant301' isolate on plant material.

RESULTS

Healing Chamber Design. During the 7-d healing period, the industry design had the greatest fluctuation in temperature, the research design had the greatest fluctuation in RH, and the shadecloth only design had the least fluctuation in both temperature and RH. When the healing chambers were closed on day 2 after grafting, the industry healing chamber had higher mean temperature and RH (24.9 ^{o}C, 98%) than both the research (23.4 ^{o}C, 81%) and shadecloth only (23.3 ^{o}C, 52%) healing chambers. Mean graft survival in the industry (69%) and research (66%) healing chambers were similar, and both were higher than the shadecloth only healing chamber (52%). Tomato had the highest rate (98%), eggplant was intermediate (82%), and watermelon had the lowest mean survival rate (7%); there was no interaction between healing chamber and crop. Tomato graft survival was high in all three healing chambers (96-98%), suggesting that high RH is not essential for tomato graft survival. Eggplant graft survival decreased from 90% to 60% when RH was decreased, suggesting that high RH is essential for eggplant graft survival. This study was published in HortTechnology in 2011 (Johnson and Miles, 2011).

Eggplant. There was no consistent difference in plant dry weight among treatments at either field location either year. 'Beaufort'-grafted plants had greater stem diameter than the other treatments at Eltopia, and was greater than the other treatments except *S. aethiopicum*-grafted eggplant at Mount Vernon (P = 0.0004 and P = 0.007, respectively). 'Beaufort'-grafted plants tended to have greater plant height than the other treatments, although it was not significantly different to self-grafted plants at Eltopia and the other treatments at Mount Vernon (P = 0.0009 and P = 0.09, respectively). Total marketable weight of 'Beaufort'-grafted eggplant at Eltopia was 45% greater than the other treatments in 2010 (P = 0.009) and 28% greater than the other treatments in 2011 (P = 0.06). 'Beaufort'-grafted eggplant had significantly lower Verticillium wilt severity than the other treatments at both Eltopia and Mount Vernon in both 2010 (P = 0.006 and P = 0.003, respectively) and 2011 (P = 0.001 and P = 0.0002, respectively). In two greenhouse studies, inoculated plants had significantly lower fresh weight compared to non-inoculated plants (P = 0.01 and $P < 0.0001$). However, there were no consistent disease differences between grafted and non-grafted treatments. Inoculated 'Beaufort'-grafted eggplant and non-grafted 'Beaufort' had significantly lower disease severity than inoculated self-grafted eggplant, non-grafted eggplant, and non-grafted *S. aethiopicum* (P = 0.007 and P = 0.005, respectively) but disease severity was not significantly different to inoculated *S. aethiopicum*-grafted eggplant. This study is being prepared for submission to the Journal of Vegetable Science. Results from this study are being prepared as a plant disease report for submission to Plant Pathology.

Tomato. In the field studies, ‘Beaufort’ and ‘Maxifort’ had significantly larger stem diameter than non-grafted and self-grafted plants at both Eltopia ($P = 0.0003$) and Mount Vernon ($P = 0.006$). There was no difference in plant heights at Eltopia, but ‘Beaufort’-grafted plants were significantly taller than plants in the other treatments at Mount Vernon ($P = 0.004$). Grafting did not impact total marketable fruit number, weight, or total unmarketable fruit number and weight. There were no significant differences in fruit firmness, soluble solid content, or lycopene content among grafted and non-grafted plants. Grafting also did not affect fruit diameter, length, or weight. Physiological leaf roll was not observed at Eltopia in either year. At Mount Vernon, the severity of physiological leaf roll was significantly greater for ‘Beaufort’-grafted plants than other treatment plants in 2011 ($P = 0.0019$), although no differences were observed in 2010 ($P = 0.16$). Verticillium wilt symptoms were not observed at either location in either year, despite site histories of Verticillium wilt and *V. dahliae* soil populations in the range of 2.5 to 18.0 cfu/g of soil, and Verticillium wilt symptoms in adjacent eggplant and watermelon plots.

Watermelon. At Hermiston, grafting did not impact total marketable fruit number or mean fruit weight. Grafting also did not affect fruit diameter, length, or weight, and there was no significant difference in fruit firmness, soluble solid content, or lycopene content among grafted and non-grafted plants. At Mount Vernon, ‘Emphasis’ and ‘Strong Tosa’ had significantly larger stem diameter than non-grafted and self-grafted plants in both 2010 ($P = 0.0002$) and 2011 ($P = 0.007$). Verticillium wilt symptoms were not observed at Eltopia or Hermiston. However at Mount Vernon, ‘Emphasis’ and ‘Strong Tosa’-grafted plants had significantly lower Verticillium wilt severity than non-grafted and self-grafted plants in both 2010 and 2011 ($P < 0.0001$). Microsclerotia were observed in non-grafted, self-grafted, ‘Emphasis’-grafted, and ‘Strong Tosa’-grafted stems collected from Eltopia and Mount Vernon. *V. dahliae* was isolated from non-grafted and ‘Emphasis’-grafted stems at Eltopia and non-grafted, self-grafted, and ‘Strong Tosa’-grafted stems at Mount Vernon.

Conclusions and Discussion

Healing Chamber Design. The results of the healing chamber study indicate that grafted tomato plants are tolerant of low and inconsistent RH in the healing chamber environment. A humidifier is not a necessary component of a healing chamber for high graft survival in our region. The RH of the healing chamber environment is affected by the internal volume of the healing chamber and structural dimensions should be minimized to maintain high RH. A different grafting technique, healing chamber environment, or acclimation method is necessary to obtain adequate survival for grafted watermelon.

Eggplant. The reduced disease severity and increased yields of ‘Beaufort’-grafted eggplant suggest that ‘Beaufort’ rootstock may be partially resistant to Verticillium wilt or not affected by the isolate used for inoculation. Grafting onto *S. aethiopicum* was not advantageous, as S. aethiopicum-grafted eggplant did not have significantly different yield or Verticillium wilt severity compared to non-grafted and self-grafted plants. Grafting eggplant onto rootstocks which are partially resistant to Verticillium wilt reduces disease severity without compromising yield or plant health and may be an effective strategy for managing Verticillium wilt in Washington.

Tomato. This study indicates that grafting heirloom tomatoes onto interspecific tomato rootstocks does not impact marketable tomato yield, fruit quality or fruit size. Since typical symptoms of Verticillium wilt caused by local *V. dahliae* populations were not obtained on either grafted or non-grafted tomatoes during the study, intensive strategies such as soil fumigation may not be necessary for managing Verticillium wilt in tomato in these two production areas.

Watermelon. Based on the significantly lower Verticillium wilt severity as compared to non-grafted and self-grafted plants, 'Emphasis' and 'Strong Tosa' rootstocks appear to have partial but not complete resistance to *V. dahliae*. Grafting onto these rootstocks did not reduce marketable fruit yields or fruit size and did not impact fruit quality. Although unfavorable weather conditions for watermelon production prevailed at study locations, the results imply that grafting may effectively control Verticillium wilt in triploid watermelon production in soils contaminated with *V. dahliae* in Washington.

OUTREACH

Field days, demonstrations, and workshops:

Grafting vegetables for disease resistance, WSU Field Plant Pathology class, 20 participants, June 15, 2012, Mount Vernon, WA.

Growing great tomatoes. Island County Master Gardener training, 20 participants, March 24, 2012, Oak Harbor, WA.

Growing great tomatoes. Clallam County Master Gardener conference, 60 participants, March 17, 2012, Sequim, WA.

Extending the vegetable production season. WSU Growing Groceries volunteer mentor training, 25 participants, March 10, 2012, Everett, WA.

Research updates: tomatoes, grafting and biodegradable mulch. WSU Master Gardener State Conference, 120 participants, September 22, 2011, Ocean Shores, WA.

WSU Mount Vernon NWREC Field Day, 158 participants, July 14, 2011.

Tilth Producers of Washington Farm Walk, 70 participants, WSU Mount Vernon NWREC, June 13, 2011, (Figure 4).

Grafting workshop, Orcas Island organic growers, 14 participants, Eastsound, June 10, 2011 (Figure 5).

Vegetable grafting demonstration, Oak Harbor elementary school, science class visit at WSU Mount Vernon NWREC, 45 students, May 25, 2011 (Figure 6).

Presentations at grower meetings:

Grafting vegetables for increased production, Northwest Sustainable Agriculture Conference, 20 participants, March 19, 2012, Lynden, WA.

Grafting tomatoes for disease resistance, Oregon State University Small Farm Conference, 20 participants, February 25, 2012, Corvallis, OR,.

Pacific Northwest Vegetable Association annual conference, 100 participants, Kennewick, WA, November 16-7, 2011.

Presentations at science meetings:

Miles, C., and S. Johnson. 2012. Vegetable grafting in Washington for Verticillium control. International research conference on methyl bromide alternatives and emissions reduction; Symposium: Development of grafting technology to improve sustainability and competitiveness of the U.S. fruiting industry. Nov. 9, Orlando, FL. *Invited speaker*.

Johnson, S., and C. Miles. 2011. The effect of grafting on vigor, yield and verticillium wilt of eggplant (*Solanum melongena* L.) in open field production. ASHS annual conference, Miami, FL, Aug. 3, HortScience 47(10):*in press*.

Johnson, S., and C. Miles. 2011. The effect of humidity in healing chamber environments on the survival of grafted eggplant, watermelon, and tomato. ASHS annual conference, Waikoloa, HI, Sept. 27, HortScience 46(10):S224.

Johnson, S.J., C.A. Miles, P.A. Kreider, and J. Roozen. 2011. Effect of healing chamber design on the survival of grafted eggplant, tomato, and watermelon. 2011 International Plant Propagators' Society North American Western Region Annual Meeting, Sacramento, CA, Sept. 21-24, Vol. 61:50.

Extension publications:

Johnson, S., C. Miles, P. Kreider, and J. Roozen. 2011. Vegetable grafting: eggplants and tomato. Washington State University extension publication FS052E.

Johnson, S., C. Miles, P. Kreider, and J. Roozen. 2011. Vegetable grafting: the healing chamber. Washington State University extension publication FS051E.

Web publications:

Revised and updated our web site http://vegetables.wsu.edu/graftingVegetables.html.

Produced and posted new narrated PowerPoint presentations:

History of Vegetable Grafting: Why graft vegetables? http://breeze.wsu.edu/historyofgrafting/

Vegetable Grafting: How to graft eggplant and tomato http://breeze.wsu.edu/howtograft/

Vegetable Grafting: The healing chamber http://breeze.wsu.edu/healingchamber/ http://breeze.wsu.edu/healingchamber/

Produced and posted new handouts for vegetable grafting:

Grafting supplies <http://vegetables.wsu.edu/Grafting-Supplies-3-1-11.pdf>

Retail rootstock and seed suppliers <http://vegetables.wsu.edu/Retail-Rootstock-Suppliers-3-1-11.pdf>

Science publications:

Johnson, S. 2012. Grafting eggplant, tomato, and watermelon to manage Verticillium wilt caused by *Verticillium dahliae*. Washington State University M.S. thesis. 149 pp.

Johnson, S., C. Miles, and D. Inglis. 2012. Plant growth, yield and Verticillium wilt reactions of grafted eggplant. Journal of Vegetable Science. *In preparation.*

Johnson, S., C. Miles, and D. Inglis. 2012. Verticillium wilt in watermelon rootstock. Plant Disease Reports. *In preparation.*

Johnson, S., and C. Miles. 2011. The effect of humidity in healing chamber environments on the survival of grafted eggplant, watermelon, and tomato. HortScience 46(10):S224.

References

Davis, A., King, S., Zhang, X., Levi, A., Perkins-Veazie, P., & Hassell, R. 2008. Grafting Effects on Vegetable Quality. HortScience,43(6): 1670-1672.

Hamm, P.B., R.E. Ingham, J.R. Jaeger, W.H. Swanson, and K.C. Volker. 2003. Soil fumigant effects on three genera of potential soilborne pathogenic fungi and their effect on potato yield in the Columbia Basin of Oregon. Plant Disease, 87, no. 12: 1449-1456.

Hibar, K., Daami-Remadi, M., Jabnoun-Khiareddine, H., & El Mahjoub, M. 2006. Control of fusarium crown and root rot of tomato, caused by Fusarium oxysporum f. sp. radicis-lycopersici, by grafting onto resistant rootstocks. Plant Pathology, 5(2): 161-165.

Kubota, C., McClure, M., Kokalis-Burelle, N., Bausher, M., & Rosskopf, E. 2008. Vegetable Grafting: History, Use, and Current Technology Status in North America. HortScience, 43(6):1664-1669.

O'Connell, S. 2008. Grafted Tomato Performance in Organic Production Systems: Nutrient Uptake, Plant Growth and Yield. M.S. Thesis, North Carolina State University.
Rivard, C., & Louws, F. 2008. Grafting to Manage Soilborne Diseases in Heirloom Tomato Production. HortScience, 43(7), 2104-2111.

ADDENDA

Rose, V. Grafting Tomatoes. Skagit Valley Herald. March 25, 2011. Available at http://skagit.wsu.edu/MG/2011AA/032511.pdf.

Figure 1. Field trials established at Schreiber and Sons Farm in Eltopia, WA (left) and WSU Mount Vernon NWREC (right) in 2011

Figure 2. Low-tech healing chamber at WSU Mount Vernon NWREC found to be successful for vegetable grafting.

Figure 3. 'Epic' eggplant from 2011 greenhouse inoculation trial exhibiting one-sided chlorosis and wilting, characteristic symptoms of *Verticillium dahliae*.

Figure 4. Sacha Johnson (forefront right) describing vegetable grafting research to 70 participants at the Tilth Producers of Washington Farm Walk at WSU Mount Vernon NWREC on June 13, 2011.

Figure 5. Grafting workshop at Eastsound, Orcas Island on June 10, 2011.

Figure 6. Sacha Johnson (right) demonstrating vegetable grafting to 45 elementary students from Oak Harbor at WSU Mount Vernon NWREC on May 25, 2011.