Vegetable Grafting International Field Trip Report – Part II: Sicily, Italy
March 22-25, 2016
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Introduction
Vegetable grafting is an IPM tool and a cultural practice used to manage soil-borne diseases, pests and abiotic stresses problematic in production. As part of a Vegetable Grafting project funded by USDA Specialty Crop Research Initiative (SCRI, Award Number 2011-51181-30963), we organized two international field trips for U.S. stakeholders to visit selected nurseries and grower fields to learn about commercial vegetable grafting worldwide. In 2015 the field trip went to Taiwan and Japan, see http://www.vegetablegrafting.org/wp/wp-content/uploads/2013/12/Vegetable-Grafting-International-Field-Trip-Report-2015-Taiwan-and-Japan.pdf for that trip report. In 2016, our field trip went to Italy (Sicily) during March 22-25 with 9 participants. The itinerary is shown in Table 1.

Italy is second only to Spain in production of vegetables in the European Union (12% and 13%, respectively) (FAO, 2014). Grafted tomato were first grown in Europe in 1962 but only after 1990 did use of grafted solanaceous and cucurbit crops increase significantly in Spain, Italy, Greece, France, and Netherlands (Lee et al., 2011). In a survey of 16 Italian nurseries (accounting for approximately 80% of transplant production in Italy), in 1999 just less than 10 million grafted plants were produced and this increased to just more than 60 million plants produced in 2011 (Leonardi, 2016). Based on this same survey, the numbers of grafted plants produced in Italy in 2010 were 34% tomato, 23% eggplant, 23% watermelon, 15% melon, 3% pepper, and 2% cucumber. A significant portion of greenhouse production uses grafted plants:
100% melon, 85% eggplant, 78% cucumber, 58% watermelon, 20% tomato, and 8% pepper. Additionally, high tunnel production includes 37% watermelon and melon. Common grafting methods used by commercial nurseries are splice-graft for solanaceous crops and one-cotyledon splice graft for cucurbit crops. Healing chambers include plastic covered tunnels arranged on benches in greenhouses and indoor facilities with highly controlled environment. Some interesting aspects of protected cultivation in Sicily include: high tunnel structures are simple with passive ventilation and little climate control, relatively inexpensive, and are replaced annually (Figs 2 & 3); production occurs September through June, and the ground is rested July and August due to high temperature. Historically, producers tended to be small-scale (1-2 ha) with low/no marketing organization; however, today there are also growers of medium-scale (30-40 ha) with marketing contracts. The region is along the coast with periods of high wind; well water has salt water intrusion thus irrigation water has high salinity (Leonardi, 2016).

Table 1. 2016 vegetable grafting field trip itinerary.

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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<tr>
<td>Day 1 (3/22, Tue)</td>
<td>• Arrive in Sicily Catania-Fontanarossa International Airport (CTA)</td>
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<td>Day 2 (3/23, Wed)</td>
<td>• Visit University of Catania</td>
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<td>• Presentation by Prof. Cherubino Leonardi, Sicilian Horticulture and</td>
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<td>Grafting</td>
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<td>• Visit melon growers in Pachino area</td>
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<td>Day 3 (3/24, Thu)</td>
<td>• Visit Centro Seia Nursery</td>
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<td>• Tour facilities and visit various stages of grafted plant production</td>
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<td>• Discussion</td>
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<td>• Visit growers in Vittoria area</td>
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<td>Day 4 (3/25, Fri)</td>
<td>• Visit tomato growers in Vittoria area</td>
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<td>• Visit growers in Licata area</td>
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<td>Day 5 (3/26, Sat)</td>
<td>• Leave Sicily</td>
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1. University of Catania: Learning more about current status of grafted vegetable production in Italy. At DISPA (Department of Agricultural and Food Science), Prof. Cherubino Leonardi, a leading scientist of vegetable grafting, provided an introduction to vegetable production and grafting use in Italy.

Grafting was first used primarily as an alternative to methyl bromide, and is combined with soilless cultivation. Protected cultivation began in the region in 1980. Profit margin for tomato is now 2-3% which is much decreased from previous years, and small farms are being replaced by larger farms of 30-40 hectares.

The University of Catania held its first training school on vegetable grafting in September 2014. Price per grafted watermelon plant (seeded cultivars) is 0.7 Euro including costs for seeds and shipping. Manual grafting is more efficient and effective than robots, due to the small order sizes reflecting the small farms. New diseases in the region include Phytophthora nicotianae and Rhizoctonia solani which are both attacking plants grafted on Solanum lycopersicum x S.
habrochaites. Possible control strategies include disinfecting the soil and treating with specific fungicides. Research at the university includes adapting growing techniques to adapt to modified plant behavior and requirements due to grafting, such as water and nutrient supply. The management techniques have also been modified to make grafting more economically viable such as reducing plant density, adjusting pruning and growth/production cycle. For example, training a single tomato stem to a 90° angle for about half a meter just above the media/soil line appears to increase yield. Tomato is a primary grafted crop in greenhouses in Sicily. Many greenhouses in Sicily are unheated and passively ventilated for cooling. Non-grafted tomato crop (mini-plum type, trade name Piccolo) has 8-9 clusters per plant, plant density is 10,100-12,150 per acre, and yield is 32-36 tons per acre, while grafted tomato has 15-20 clusters, plant density is 5,060-6,070 per acre, and yield is 36-41 tons per acre. However, for cultivar Rita, grafting with some rootstocks (ES 99-265, Linea 9242, PG 99, Robusta) produced equal yield to non-grafted. Some rootstocks produced lower yield (Energy, Firefly, Linea 9243, Nico) and others produced higher yield (Beaufort, He-Man, Joint, P1614, RS 1427). In general with ‘Rita’ fruit, °Brix declined from 6.8 to 5.5 as fruit size increased from 50 g to 110 g. For heirloom tomato varieties that have weak growth, such as Cuore di Bue, rootstocks increase plant vigor. The high EC (electrical conductivity) of irrigation water in the production region due to salt water intrusion appears to result in increased °Brix of tomato fruit. Non-grafted watermelon plant density is 1,600-2,500 per acre and yield is 16 tons per acre, while grafted watermelon plant density is 800-1,250 plants per acre and yield is 25-33 tons per acre. Cucurbit plants grafted on Lagenaria have lower vigor and increased earliness compared with squash rootstocks, so Lagenaria is preferred for early transplanting dates. Dr. Leonardi is coordinating the chapter on fruit quality in the new book being written by scientists on the COSTA grafting project.

2. Centro Seia Nursery
At Centro Seia our host was Giovanna Causarano, R&D Manager. Centro Seia has its roots as a nursery in 1978, but in 1992 it evolved into its current company, http://www.centroseia.it/english/index.htm. Centro Seia is located in Ragusa, with sister companies in Marche-Cingoli Italy, France, and Bosnia-Herzegovina, and is a leading company that sells quality seedlings. In Sicily, there are about 50 nurseries for vegetable seedlings, out of which 20 nurseries produce grafted plants. Centro Seia is the largest grafting nursery and the company employs 20 agronomists, and there are 40 sales representatives in Italy. SIS is the parent company and soil fumigation with methyl bromide was its primary business. Grafting was first done in 1999 with about 100,000 plants, as an alternative to manage soil-borne diseases when methyl bromide was phased out. The annual seedling production capacity of Centro Seia is about 60 million plants, out of which 20 million plants are grafted including tomato, pepper, eggplant, melon, watermelon, and cucumber. However, in 2015 about 87 million plants were shipped and 40 million (46%) were grafted: 38% tomato, 26% eggplant, 21% melon, 9% watermelon, 3% pepper, and 3% cucumber. In tomato, grafting is primarily used to manage nematodes. An issue with shipping tomato seedlings is that temperature shock can cause the loss of the first cluster of fruit. While 11-12 °C is a good shipping temperature, temperature is increased during shipping. Main markets are France, Switzerland, Austria, Hungary, Romania, and the Balkans. The area of protected production in Sicily is approximately 6,000 ha, and for this production system all the watermelon and eggplant transplants produced by Centro Seia are grafted.
Centro Seia employs approximately 200 workers to graft vegetable seedlings manually. Seeds are germinated for 2-3 days at 24 °C with dry fog (pepper takes 5 days). Eggplant was being grafted on 'Emphasis' in 336-cell trays (16 x 21; 4 mL per cell), with every other cell empty. Watermelon plants were being grafted on rootstocks in 112-cell trays (8 x 14) with every other cell empty. Each person can graft 250 tomato plants per hour when plants are pre-sorted and 120 plants per hour when plants are not pre-sorted. Each person can graft 100 watermelon plants per hour. Cucurbit plants are grafted either with or without roots. For rootless watermelon grafting, rootstock hypocotyl is cut 4 cm long and the graft cuttings are inserted about 1 cm deep into the new cells with growing media for healing and root regeneration.

Mechanical aides are likely the first stop towards mechanized grafting. Healing tents are set up on greenhouse benches with temperature maintained at around 26 °C, while water is added to the tent before placing plants inside so that RH is >80%. However, there is no free water during healing, bottom heat is provided, and shade cloth (60%) is placed over the tent. Healing for tomato is 5 days, and 6 days for watermelon, then the chamber is opened. Grafted plants are kept in the healing tent for 8 days. Transition from healing chamber to the greenhouse bench is 2 days for tomato and 3 days for watermelon with 50-75% shade. Then plants are transitioned to a second greenhouse with 20% shade. For double stem tomato, plant is pinched within 2 weeks of grafting. Overall loss of plants from grafting is 1% (plants do not survive healing). Steam sterilization is applied for healing tents after their use. To load plants, trucks drive through a shaded greenhouse. Greenhouse tomato plants are transplanted in August and September. In one of the production systems viewed on the tour, yield of double-stem tomato was 30 kg per stem or 9 kg/m² for grafted plants, and 8 kg/m² for non-grafted plants. In-row spacing for non-grafted plants was 2 ft (1815 plants per acre) and in-row spacing for grafted plants was 3 ft (1,198 plants per acre). A challenge for grafted vegetable research was discussed during the visit: If grafted plants need to be managed differently, how do you trial this in a traditionally managed field?

Centro Seia is a partner in the company TriHishtil, which recently opened a new grafting facility in North Carolina. The 40 acre (16 ha) site currently includes 1 ha of plastic-covered greenhouses with room for expansion. One million grafted vegetable plants were shipped in the U.S. in the first year of operation (2015).

3. Visiting tomato and melon growers in Pachino, Vittoria, and Licata.

Wednesday afternoon 23 March – Pachino area

1) Farm Name: Cicciarella Paolo
   - Total farm area 40 ha
   - Crops: Tomato (Cherry and green picking) 12-13 ha (greenhouse); Melon 20-22 ha (Tunnels + greenhouse), 70% grafted on 'Shintosa'.

This company uses grafted plants mainly for melons (~70%) in order to mitigate Fusarium wilt with limited crop rotation. Growers explained that initial management of water and fertilization was critical to maintain grafted plants that were less vegetative and produced more floral structures. Specifically they would reduce the irrigation rate and N:K ratio for the grafted plants compared with non-grafted plants.
2) **Farm Name: Candiano Fratelli**
- Total farm area 100 ha

**First transplanting**
- Zucchini 94 ha
- Eggplant 3 ha
- Tomato 3 ha

**Second transplanting**
- Zucchini 20 ha
- Grafted melon 55 ha
- Mini watermelon 10 ha

The grower of this company demonstrated how grafted melon plants were pinched after five leaves on the main stem to induce lateral shoots to set fruits. They also apply flower and fruit pruning to limit the number of fruits to 6-8 per plant. Using grafted plants helped reduce pesticide use and maintain fruit size during the late harvest season.

3) **Farm Name: Tomasi Massimo**
- Total farm area 20 ha

**First transplanting**
- Zucchini 20 ha

**Second transplanting**
- Grafted watermelon 9 ha
- Zucchini 9 ha

This company first tested grafted plants 20 years ago, but experienced failure due to delayed fruit ripening. Nine years ago, they started using grafted watermelon plants again using squash rootstock. The grower emphasized that water and fertilizer management is critical. When managed properly with less irrigation and low P:K ratio, the grafted watermelon plants set female flowers after 11 leaves, while the first female flower could be delayed to 17-18 leaves without proper management. The growers also apply pinching and limit the number of fruits to 3-4 per plants. The average fruit weight is 14 kg and the typical planting density for grafted watermelon is 2,800 plants per ha.

4) **Farm Name: Spadaro Rosario**
- Total farm area 80 ha
- Zucchini + grafted tomato 50 ha
- Grafted eggplant and other crops

Typical cropping cycle in this company is July to January for tomato, and February to May for melon. The company was also experimenting with high-wire melon production with 4-5 melon fruits each of two leads (vines) per plant.

**Thursday afternoon 24 March**– Vittoria area

1) **Farm Name: Fratelli Giocolano**
- Total farm area 8.5 ha
- Crop: Grafted eggplant

Eggplant plants are grafted onto torvum rootstock (Fig. 4). They also experimented with tomato as rootstock for eggplant but found that this combination did not work well in unheated greenhouses, because of the difference in low temperature tolerance between eggplant scion and tomato rootstock. Torvum (Solanum torvum) is a widely used rootstock for eggplant in Italy.
2) **Farm Name: Fondacaro Angelo**
- Total farm area 4 ha soil and soilless
- Crops: Grafted tomato 3.85 ha; Standard tomato 0.15 ha

A double-leader system was used for grafted tomato plants. The plant can produce 60 trusses with 30 trusses per leader. These growers are getting 9 kg/m² yield with high brix (9) using nutrient solution with EC of 6.5 dS/m (water EC is 5 dS/m). Their wholesale price is 2 Euro per kg, higher than typical average price (1 Euro per kg).

Friday morning 25 March – Licata area
1) **Farm Name: La Tenutella, cooperative**
- City: Butera
- President of cooperative Massimo Bonvissuto
- 5 Members
- Total farm area 22 ha
- Greenhouses 1 ha
- Tunnels 21 ha
- Crops: tomato, pepper, zucchini, melon, watermelon
- Visit: melon (cantaloupe) ‘Fiola’ grafted on ‘Shintosa’
- Transplanting date: 15 January 2016
- Bees: 22 February 2016
- Harvesting forecast: 22 April 2016

The primary reason this farmer uses grafted melon plants is for Fusarium wilt control. Plants are spaced 1.3 m apart in the row in a tunnel which is 3 m wide and 1.7 m tall (Fig. 5); plastic on the high tunnel is changed every 2 years, and the tunnel is moved every 2-3 years to flush salt from the soil. Irrigation water EC is 4-5 dS/m. They have been using grafted melon plants for at least 10 years, ‘Shintosa’ was the first rootstock they used. There is a concern of sugar content reduction and possible squash flavor in melons due to grafting with squash rootstocks.

However, at this time melons at this farm are primarily grafted with squash rootstock and flavor does not appear to be an issue. It was pointed out that scion cultivar selection and fertigation management could help solve the potential fruit quality problem with grafted plants. Out of 9,000 plants, 100 plants have rootstock regrowth (1%). Fruit is harvested twice, yield is 6-7 fruit per plant, fruit weight 1.8 kg each, total fruit weight per plant is 12 kg on average. Fruit harvested later are larger for grafted plants. In general, grafted melon plants can yield 20% higher than non-grafted plants.

2) **Farm Name: Russo Angelo**
- City: Butera
- Total farm area 7 ha
- Greenhouses 0.5 ha
- Tunnels 4.5 ha
- Open field 2.5 ha
- Crops: tomato, pepper, zucchini, melon, watermelon, artichokes
- Visit: watermelon ‘Talete’ grafted on ‘Shintosa’
- Transplanting date: 8 January 2016
- Bees: 26 February 2016
- Harvesting forecast: 10-15 April 2016

Mini watermelon, rootstock is ‘Shintosa’, this is the grower’s second year using grafted plants. Only need to use half the number of plants with grafting, in-row plant spacing is 1.2-1.6 m (non-
grafted spacing is 70-80 cm). Hollow heart is decreased with grafting, and also by providing even fertilization and irrigation. There are galls (due to nematodes) on rootstock roots, but the vigorous root system appears to provide plant resiliency. Yield is 3-4 fruit per plant, fruit weight is 3-4 kg, fruit are picked twice. Price is 1 euro per kg for early fruit, and this decreased to 0.3-0.4 euro later in the season. Fig. 6 shows water in a holding pond that is used for irrigation.

3) **Farm Name: Demetra Gold**
- City: Butera
- Total farm area 34 ha
- Soilless cultivation 4 ha
- Tunnels 25 ha
- Open field 4 ha
- Crops: tomato, zucchini, melon, watermelon
- Visits: melon ‘Bacir’; transplanted 28 December 2015; melon ‘Sienne’ transplanted 10 January 2016

Melons are grown in a tunnel structure 3.5 m wide, 1.5 m tall, and 60 m long; tunnel length is adjusted to fit available land. Plant population is 4,000 plants per ha for standard (non-grafted) plants and 3,200 plants per ha for grafted plants.

**Friday afternoon – Vittoria area**

4) **Farm Name: Fondacaro**
- Total farm area 50 ha
- Active greenhouse soilless: 20 ha
- Traditional greenhouses soilless 30 ha (7 ha with minimum heat)

Tomato grown in a plastic covered greenhouse with rockwool cubes on coco-coir slabs using ‘Kaiser’ rootstock (from Rijk Zwaan seed company) (Figs. 7 & 8). They used to use ‘Big Power’ rootstock but discontinued (rootstock seeds may have been infected). Plastic for greenhouse is double layer and inflated, and changed every 3 years. Disposal for rockwool is 20 euro/m³. Well water EC is 2.4 dS/m and irrigation nutrient solution EC with fertilizer is 4.7 dS/m (drainage EC is 7 dS/m). Their production cycle is 11 months. At the end of production cycle, total vine length reaches 18 m, with 4.3 vines (stems) per m² and 47 trusses per stem. Pruning requires 3-4 workers per ha. Yield is 16 kg/m² over the 11-month production. Markets are Sainsbury and Waitrose in England, and Liedle in Germany (Fig. 9); so use English, German and Swiss pest management recommendations – Global GAP Certified. Inspectors from supermarkets (their customer) visit the greenhouse production periodically. Pest management includes spot treatments for Botrytis using a Certis spray aerosol.

5) **Farm Name: Dorilli Farm (SIS farm)**
- Greenhouses area 10 ha
- Crop: tomato ‘Kamarino’
- Soilless cultivation system

The farm is designed as a learning and demonstration farm, so they can learn how to grow grafted plants and extend this information to other growers. Coco fiber is used in this greenhouse operation. The plants in the greenhouse receive heat via pipes of hot water suspended in the canopy. Fruit are packed for high-value grocery stores in England, Germany and Holland (Fig. 10). Irrigation water is 1 dS/m, drip irrigation is 4.5 dS/m. The rootstock is
‘Optifort’ (Monsanto). With ‘Maxifort’ rootstock the fruit were too orange. Fruit has a °Brix value of 11%. Plants are pruned every week to remove 3 leaves for each truss that is harvested.

Summary
Grafting is used extensively today for greenhouse vegetable production in Sicily (100% melon, 85% eggplant, 78% cucumber, 58% watermelon, 20% tomato, and 8% pepper), and was first used as an alternative to methyl bromide in high tunnel production systems to manage Fusarium wilt. As production has shifted from small-scale (1-2 ha) to medium scale (30-40 ha), tomato production in particular has shifted from soil-based systems to soilless media, and the rootstocks have changed based on this shift in production needs. Irrigation water in the region is characterized by high salt levels (>2.4 dS/m), and rootstocks provide a means of tolerating levels that are too high for non-grafted crops. Planting density is reduced for grafted plants to optimize production efficiency and cost effectiveness. Much of the grafting is done by hand though mechanization does exist in the region but was not available for viewing on this tour. Overall, the tour members learned the importance of high quality seedling production as well as the proper irrigation and fertilization management when grafted plants are used.

Acknowledgement
This field trip was conducted as part of outreach activities funded by USDA NIFA SCRI (Award Number 2011-51181-30963). The authors would like to gratefully acknowledge Dr. Giovanna Causarano, R&D Manager, Centro Seia for hosting our visit and sharing the technical information of production and use of grafted plants in Sicily.

References


Fig 2. Acres of high tunnels along the south coast of Sicily.

Fig 3. Burying sides and ends to secure high tunnels against heavy winds.
Fig 4. Grafted eggplant at Fratelli Giocolano farm.

Fig 5. Grafted melons at La Tenutella cooperative farm.

Fig 6. Pond water captured from surface runoff and rainfall, being pumped for irrigation at Russo Angelo Farm.
Fig 7. Tomato with double stems grown in soilless media at Fondacaro Angelo farm.

Fig 8. Tomato grown in rockwool cubes on coco-coir slabs, suspended approximately 0.2 m above the ground, at Fondacaro Farm.
Fig 9. Tomato grown and packed for European market.

Fig 10. Packing tomato for market at Dorilli farm.