Transplant Production

Tuesday afternoon 2:00 pm
Where: Grand Gallery (lower level) Room E-F
Recertification credits: 1 (1B, PRIV OR COMM CORE)
CCA Credits: PM(1.0) CM(1.0)

2:00 p.m. Vegetable Transplant Tactics for Improved Crop Establishment
- Mark Bennett, Horticulture & Crop Science Dept., Ohio State Univ.

2:30 p.m. Greenhouse Insects of Concern on Transplants
- Daniel Pavuk, Integrated Vegetable Extension Educator SE Michigan and NW Ohio

3:00 p.m. Grafting of Tomatoes for High Tunnel and Open Field Production
- David Francis, OARDC, Ohio State Univ.

3:30 p.m. Transplant Diseases - Identification and Control
- Mary Hausbeck, Plant Pathology Dept., MSU
VEGETABLE TRANSPLANTS: TACTICS FOR IMPROVED CROP ESTABLISHMENT

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Vegetable transplants in plug trays should be viewed as a growing system with high management inputs. Decisions made on structure design, equipment needs, and seeding through plant hardening and plant delivery all impact transplant quality. Evaluating vegetable transplant quality is somewhat in the eye of the beholder. The ultimate test, however, is how well the plant responds to transfer from the greenhouse environment into the field, and how quickly it starts new and vigorous growth after transplanting. The plant must be of sufficient size to fit the type of transplanter being used. The stem must be thick and rigid enough to hold the plant in position during the handling and planting process and be upright after planting. These conditions are visible. The following conditions are less visible, but are extremely important for plant regrowth.

A plant must have the necessary internal constituents to add strength to the stem. This usually means relatively slow growth in the greenhouse to allow the cell wall constituents to accumulate and form thick cell walls. There must also be sufficient reserves of carbohydrates and other nutrients to maintain the plant during the handling and planting process and to have sufficient energy to promote new roots and shoots after planting. Carbohydrate reserves are greatly influenced by the growth rate of the plant; the faster the growth, the lower will be the carbohydrate reserves. Growth rate is primarily affected by excessive nitrogen fertilization and high growing temperatures. One of the main reasons for hardening transplants just prior to planting is to cause an increase in carbohydrate reserves. Hardening is accomplished by exposing plants to lower growing temperatures, wind, or a reduced amount of nitrogen fertilizer.

There must also be sufficient nitrogen (N) compounds in the plant which are available for building new cell constituents. This means that a plant must have a continuous supply of N available during its development, although it may be slightly reduced during the hardening period. Research, however, has indicated that N need not be reduced during the production of plug type transplants, if temperatures can be lowered during the hardening phase. It also appears beneficial to provide a dose of fertilizer (e.g., 9-45-15) in irrigation a day or two before transplanting to be certain the plant does contain sufficient nutrients for quick recovery and regrowth.

Height Control
Sunlight can significantly influence the growing of vegetable transplants. It provides the energy for the plants to make carbohydrates and it also supplies heat that can greatly influence plant growth rate. The general response to low light intensity with a normal level of fertilization is one of plant stretching. This can also occur with high sunlight if the temperature also increases greatly. Reduce the rate of fertilization and temperature during periods of cloudy weather to minimize plant stretching. A successful grower of plug-type transplants must have excellent growing facilities and possess outstanding management skills to
consistently produce high quality plants. A single error in judgment can result in plants which will not respond satisfactorily following field planting. Foliar applied synthetic ABA and PEG granules incorporated into Metro Mix (20 g PEG/liter mix) successfully reduced pepper transplant height in 2006, but not in 2007 studies (Table 1). ABA and PEG treatments reduced tomato ('BHN 685') transplant heights in both years (data not shown). No differences in final yield data were detected for either year. More research is needed to assess the effects of height control compounds on various vegetable crop species and cultivars within crops. A newly released supplemental label for Sumagic (uniconazole) allows foliar sprays on some vegetable transplants (tomato, pepper, eggplant, tomatillo, other solanaceous crops). While this new label is quite restrictive (max. allowed is 10 ppm at 2 qts/1,000 sq. ft.) and cautious use is warranted, Sumagic sprays hold promise to allow better quality transplants for commercial and home consumer use (R. Schnelle, Univ. of Kentucky).

Table 1. Use of ABA and PEG 8000 to control pepper ‘Wahoo’ transplant height, Fremont, OH.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Stem diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5D after application (at transplant)</td>
<td>3 WAT</td>
</tr>
<tr>
<td>Control</td>
<td>16.1</td>
<td>6.5</td>
</tr>
<tr>
<td>ABA 100 ppm</td>
<td>12.6</td>
<td>10.8</td>
</tr>
<tr>
<td>ABA 200 ppm</td>
<td>13.2</td>
<td>11.3</td>
</tr>
<tr>
<td>ABA 400 ppm</td>
<td>12.6</td>
<td>10.6</td>
</tr>
<tr>
<td>PEG</td>
<td>11.2</td>
<td>6.6</td>
</tr>
<tr>
<td>LSD</td>
<td>1.32</td>
<td>NS</td>
</tr>
<tr>
<td>p value</td>
<td>-</td>
<td>0.666</td>
</tr>
<tr>
<td>C.V.</td>
<td>13.8</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Cell Size and Volume

In choosing transplant containers and cell sizes consider economic and transplant quality factors. Ask yourself the following questions: 1) what is the minimum number of plants needed to economically raise transplants?, and 2) what is the maximum number of plants I can raise and still produce quality transplants based on available greenhouse space?

There are many tray shapes, sizes and colors to choose from. The largest practical cell size for processing tomato transplants for example is probably a 200 square tray with dimensions of 1 1/4” inside diameter (ID) x 1 to 2” deep, but cell size responses can vary with cultivar and other factors (Table 2). This size cell may provide a plant with more reserves and better survive stresses of early planting. Below this size, trays are available as small as 1/4” ID. However, once you reach a cell size below 3/4” ID tomato transplant quality can be adversely affected. Common cell sizes in the Great Lakes region processing tomato industry at present are 288 and 338 square. Smaller cells (392, 406, others) can be used, but growing plants in smaller cell sizes will require more intensive management of nutrients, water, light, and diseases.
Table 2. Processing Tomato Cell Size Study – 2004
North Central Agricultural Research Station, Fremont, OH.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Cell Size</th>
<th>Red T/A</th>
<th>Green T/A</th>
<th>Culls T/A</th>
<th>Percent Red Fruit</th>
<th>Avg. Fruit Size (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEM 611</td>
<td>200</td>
<td>27.8</td>
<td>3.3</td>
<td>2.9</td>
<td>82</td>
<td>0.14</td>
</tr>
<tr>
<td>GEM 611</td>
<td>288</td>
<td>26.7</td>
<td>3.1</td>
<td>2.5</td>
<td>83</td>
<td>0.15</td>
</tr>
<tr>
<td>GEM 611</td>
<td>338 D</td>
<td>26.7</td>
<td>3.6</td>
<td>2.4</td>
<td>82</td>
<td>0.14</td>
</tr>
<tr>
<td>H7983 (early O.P.)</td>
<td>200</td>
<td>22.5</td>
<td>1.6</td>
<td>4.5</td>
<td>79</td>
<td>0.15</td>
</tr>
<tr>
<td>H7983</td>
<td>288</td>
<td>23.5</td>
<td>1.4</td>
<td>4.3</td>
<td>80</td>
<td>0.15</td>
</tr>
<tr>
<td>H7983</td>
<td>338 D</td>
<td>21.6</td>
<td>1.2</td>
<td>3.7</td>
<td>81</td>
<td>0.15</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>2.89</td>
<td>1.43</td>
<td>1.20</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>C.V.</td>
<td></td>
<td>12.0</td>
<td>56.0</td>
<td>32.3</td>
<td>4.5</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Cell shape (e.g., round cells vs. square cells) can influence field survival and vigor. Plants can become root bound in the round cells, especially when plants are held due to unfavorable environmental conditions. When dealing with small cell sizes, this becomes more critical due to less volume for root growth. Even though at times tray costs are less with round cells, we strongly recommend only using trays that contain square cells.

**From Greenhouse to Field**

Direct transfer of plants from the greenhouse environment to field conditions can sometimes result in injury or death. Transplant shock can be reduced by hardening the plants prior to field transplanting. This can be done simply placing the trays outside and allowing the environment (light, wind, temperature, humidity) to condition plants before field setting. Research from Canada indicates that a minimum of three days and a maximum of six days is adequate to “harden-off” processing tomatoes, but don’t completely stop growth in hardening.

For early season plants, hardening can be achieved in the greenhouse by cool (48-50°F) temperatures. Many greenhouse producers feel that moving trays just for hardening prior to shipping is impractical. Plant growing structures which allow for maximum ventilation by opening outside walls or ends of the house are useful for hardening transplants.

Many greenhouse operators will water, fertilize and load plants the day before delivery, while others will load plants within hours of the local growers call, if possible. Plug transplants should be transported in well designed trailers which are tightly tarped during transit. Thorough watering of the plants prior to loading is important to avoid excessive drying during shipping.

Shipping containers for plug plants typically hold 16 flats per shelf. A full container has 10 shelves (total capacity = 160 flats/container). The tarp used in transit should be rolled up to expose the transplants to air movement and some light once the shipment arrives. Designate 1 person to care for the plants, and check every few hours, depending on the weather. Plants should be watered when leaves begin to wilt; do
not allow stems to wilt and become intertwined. Low light conditions will cause plants to 'stretch', while sunlight will keep plants compact. If it is necessary to unload flats from the shipping containers, group the flats together on the east or south side of a building. Three-sided buildings (open to east or south) with good cross-ventilation have also worked well for on-farm, short term storage of plug plants in trays. Keep flats together and use barriers (1” X 8” boards, straw, other) to reduce water loss from the edge plants. If necessary, plug plants (in tray) should hold for up to 10-14 days without fertilizer or fungicide applications, if plants are not overwatered and the foliage remains dry most of the time. Rainy weather or overwatering will leach fertilizer from the plugs, so apply fertilizer (20-20-20 or 20-10-20 at 2-4lbs/ 100 gal. water) if plants are held for a week or more.

For plug plants which are pulled and shipped in waxed cardboard cartons, do not water until needed. As with plants in flats, boxed plants need access to ventilation and moderate light, so open upon arrival. When some leaf wilting is noted, put a hose down the side of the box to apply needed water to root systems and avoid wetting the foliage.

Many vegetable growers soak trays (from bottom up) just prior to planting to add weight to the plug and assist the drop through carousel transplanters. Avoid wetting plant tops, however, as this may cause the plug to get caught up in the carousel.

With a 5-6” tomato transplant, good results are observed with setting plants 2-3” deep. Check plants regularly during the transplanting operation to ensure good seedling establishment. The furrow should be firmly closed around the plant, and the rootball should be covered by at least one inch of soil. Moisture will be rapidly removed from any seedling with a partially exposed root system. Moving across different soil types in a field can lead to poor establishment unless the crew or equipment is properly instructed/adjusted.
Vegetable transplants are especially vulnerable to numerous greenhouse insect and mite pest species.

It is critical to control these pests to prevent serious damage to transplants.

A variety of control tactics are available; the use of these tactics in an integrated manner is referred to as integrated pest management, or IPM.

Integrated Pest Management of Pest Insects and Mites in Greenhouses includes:

- Cultural practices (e.g., sanitation, host plant resistance)
- Biological control (e.g., predatory arthropods, parasitoids, insect pathogens)
- Chemical control (e.g., insecticides, miticides, insect growth regulators)

Successful IPM in the Greenhouse Requires Careful, Thorough Monitoring and Scouting

- Trapping: yellow, blue, and “hot-pink” sticky traps
- Regular Inspection of Plants to Detect Infestations of Insects and Mites

What are the major greenhouse insect and mite pests of vegetable transplants?

- Aphids
- Thrips
- Whiteflies
- Two-spotted spider mite
Common Pest Aphids in Greenhouses
- Green peach aphid, *Myzus persicae*
- Cotton or melon aphid, *Aphis gossypii*
- Potato aphid, * Macrosiphum euphorbiae*
- Rose aphid, * Macrosiphum rosae*
- Foxglove aphid, *Aulacorthum solani*

Description and Biology of Aphids
- Adult aphids: 1/16 inch in length; soft-bodied
- Vary in color from light green to pink or black
- Aphids feed by inserting piercing-sucking mouthparts into plant tissue and removing fluids
- In greenhouses, aphids are usually females that produce live young called nymphs (these are also females; parthenogenetic reproduction)

Description and Biology of Aphids
- Each adult female aphid can produce 50 or more nymphs!
- Nymphs mature to adults in 7-10 days, start reproducing
- Adult aphids will grow wings when populations become very large and crowded

The green peach aphid tends to be the most serious on greenhouse crops because:
- Wide host range
- Worldwide distribution
- Vector of numerous viruses that cause plant diseases
- Difficult to control

Green peach aphids on cabbage

Aphids, such as the green peach aphid, can build up enormous populations on host plants very quickly!

Green peach aphid nymph (left), wingless adult (middle), and winged adult (right)
Damage to Greenhouse Vegetable Transplants by Aphids

- Major damage caused by aphids sucking fluids from stems and leaves; causes:
  - Reduction in plant vigor
  - Curling and distortion of leaves
  - Yield reduction

Aphids are also notorious for transmitting viruses that cause plant diseases

- For example, green peach aphid transmits over 100 viruses! These include:
  - Potato leafroll virus and potato virus Y to solanaceous plants
  - Cauliflower mosaic virus and turnip mosaic virus to crucifers
  - Cucumber mosaic virus and watermelon mosaic virus to cucurbits

In addition to direct damage caused by aphid feeding, a black fungus called sooty mold grows on the sugary honeydew secreted by the aphids

- Sooty mold is unsightly and can cause plants and vegetables to be rejected by the buyer

It is critical to monitor for aphids in the greenhouse before they become a large problem!

- Visual observations: aphids, cast "skins", honeydew secreted by aphids, sooty mold (grows on honeydew) curled new leaves on plants, distorted plant growth, presence of ants on plants
- Examine foliage, stems, and new growth of key plants such as pepper, eggplant, and leafy greens to detect aphid infestations early
- Yellow sticky cards: detect presence of winged adults only
IPM control tactics for the green peach aphid and other pest aphid species

- Cultural controls:
  - Weed and old crop residue removal (sanitation)
  - Insect screening
  - Resistant plant varieties, if available

- Biological Control options:
  - Parasitoids
  - Lady beetles
  - Lacewings
  - Aphid midge

Aphidius matricariae, a parasitoid of 40 aphid species

Aphidius colemani laying eggs in green peach aphids

Lacewing Attacking and Eating Aphids
Lady Beetle (*Coccinella septempunctata*) Eating an Aphid

The Aphid Midge, *Aphidoletes aphidimyza*

**Chemical Control of Aphids on Greenhouse Vegetable Transplants (Registered Products)**
- *Azadirachtin* (Azatin, Ornazin, Neemix)
  - *Beauveria bassiana* (Botanigard)
- Insecticidal soap (M-Pede, Olympic)
- Spray-oil (Ultra-Fine Oil)
- Neem Oil (Trilogy 70%)
- Pyrethrins + piperonyl butoxide (1100 Pyrethrum TR)
- Endosulfan (Phaser, Thiones)

**Western Flower Thrips, *Frankliniella occidentalis*: The Most Important Thrips Pest of Vegetables in Greenhouses**
- Description and Biology of the Western Flower Thrips
  - Adults: 1/6 inch in length; narrow bodies, wings with long fringes of hairs
  - Thrips hide in flower buds
  - Rasping mouthparts
  - Females: reddish-brown; males: light tan to yellow
- Immatures: light yellow
- Female thrips insert eggs (several hundred per female) into plant tissue
- Immatures: feed, molt twice on plant; drop to soil, pass through two stages, adults emerge
- Egg to adult: 7-13 days, depending on temperature
Damage to Vegetable Transplants by the Western Flower Thrips in the Greenhouse

- Thrips feed by piercing plant cells with their mouthparts and feeding on plant fluids.
- The collapse of plant cells may cause deformed flowers, leaves, and shoots.
- Silvery flecked scars or small black "fecal" spots may also be observed on expanded leaves.

The Western Flower Thrips also vectors two tospoviruses:

- Impatiens necrotic spot virus (INSV)
- Tomato spotted wilt virus (TSWV)

Tomato spotted wilt virus infects many different vegetables, including tomato, pepper, lettuce, cucumber, and spinach.

Monitoring and Control of the Western Flower Thrips in the Greenhouse

- A scouting program that includes plant examinations and sticky traps is essential.
- A hand lens is useful to find live thrips.
- Look for signs of thrips feeding activity: black feces and silvery, flecked areas on leaves.
- Hot-pink sticky traps have been found to be the most attractive color for thrips, but blue traps can also be used.
- Place sticky traps 1-2 inches above crop canopy; one or two traps/1000 square feet.

IPM Control Tactics for The Western Flower Thrips on Vegetable Transplants in the Greenhouse

- Cultural Controls
  - Sanitation
  - Insect Screening

- Biological Controls
  - Predatory mites (*Neoseiulus, Hypoaspis*)
  - Adult minute pirate bugs (*Orius* species)
  - Parasitoid (*Thripobius semiluteus*)

The Predatory Mite *Neoseiulus* Eating a Thrips

*Orius insidiosus*: a predator of thrips, aphids, and whitefly nymphs.
Chemical Control for The Western Flower Thrips on Vegetable Transplants in the Greenhouse
- Azadirachtin (Azatin, Ornizin, Neemix)
  - Beauveria bassiana (Botanigard)
  - Insecticidal soap (M-Pede, Olympic)
  - Spray-oil (Ultra-Fine Oil)
  - Neem Oil (Trilogy 70%)
  - Pyrethrins + piperonyl butoxide (1100 Pyrethrum TR)
  - Endosulfan (Phaser, Thionex)

Whiteflies that Are Important Pests of Vegetables in Greenhouses
- Greenhouse whitefly, *Trialeurodes vaporariorum*
- Silverleaf whitefly, *Bemisia argentifolii*
- Sweetpotato whitefly, *Bemisia tabaci*

Greenhouse whitefly: adults and early nymphs

Silverleaf whitefly: adults and early nymphs

Sweet potato whitefly: adults

Whiteflies that Are Important Pests of Vegetables in Greenhouses
- Description and Biology of Whiteflies
  - Adults and immatures: piercing-sucking mouthparts; produce honeydew; especially problematic on tomatoes
  - Adults: 1/16 inch in length
  - Adults: undersides of youngest leaves
Description and Biology of Whiteflies

- Females: lay 150–300 eggs; hatch in ~ 1 week (first-instar nymphs, or crawlers)
- Crawlers move short distance; settle and feed
- Three molts; pupal stage; adult emerges in ~ 6 days
- Entire life cycle: 21–36 days (depends on temperature)

Damage to Vegetable Transplants by Whiteflies

- Low populations of whiteflies may not cause serious plant injury, but may result in rejection of plants by consumers
- At higher populations levels, plant foliage may become yellow and mottled
- Whiteflies suck plant sap, produce honeydew, which leads to growth of sooty mold

Damage to Vegetable Transplants by Whiteflies

- Whiteflies can also transmit viruses that cause plant diseases
  - The silverleaf whitefly transmits more than 60 viruses
  - The greenhouse whitefly has been associated with beet pseudo-yellows virus in cucumbers

Monitoring and Control of Whiteflies in the Greenhouse

- Place yellow sticky traps at rate of one every 1000 square feet, and additional traps near doors and vents
- Randomly examine plants at least weekly to detect presence of whiteflies and determine which stages are present

Monitoring and Control of Whiteflies in the Greenhouse

- Biological controls
  - The predatory lady beetle, *Delphastus pusillus*

Parasitoids of whiteflies

- *Encarsia formosa* attacks both greenhouse and silverleaf whiteflies; more effective against GWF. *Eretmocerus sp.* is more effective against silverleaf whitefly than *Encarsia formosa* is.
Products Registered for Whitefly Control in the Greenhouse
  - Azadirachtin (Azatin, Ornazin, Neemix)
  - Beauveria bassiana (Botanigard)
  - Insecticidal soap (M-Pede, Olympic)
  - Spray-oil (Ultra-Fine Oil)
  - Neem Oil (Trilogy 70%)
  - Pyrethrins + piperonyl butoxide (1000 Pyrethrum TR)
  - Endosulfan (Phaser, Thiones)

Two-Spotted Spider Mite (TSSM), Tetranychus urticae, is a Pest of Vegetable Transplants in the Greenhouse

Description and Biology
  - Adult females: 1/50 inch long, orange in color
  - Live about 1 month; lay 100-200 small, spherical eggs
  - Pale green to light yellow larvae hatch; 6 legs
  - Molt to 8-legged nymph stage
  - 7-21 day life cycle; depends on temperature
  - Hot, dry conditions lead to outbreaks

Two-Spotted Spider Mite Adult Female and Egg

Damage Caused to Vegetable Transplants by Two-Spotted Spider Mite
  - Spider mites pierce plant tissue and remove plant fluids; they feed on the undersides of leaves
  - Initially, a slight flecking or stippling (chlorotic spotting) occurs on the leaf
  - As mites continue to feed, leaves may turn yellow, bronzed, and drop from the plant
  - When large mite populations develop, fine webbing is produced by the mites

Monitoring and Control of The Two-Spotted Spider Mite in the Greenhouse
  - Weekly scouting and random plant inspection is necessary; inspect at least 10 plants per 1000 square feet
  - TSSM often develops as localized infestations on certain plants, such as beans, tomatoes, and eggplants
  - Look for mottling or flecking on upper leaf surfaces; turn leaves over and examine using a 10x hand lens
  - Visible webbing will be present when large populations of mites occur
  - Spider mites are not caught on sticky traps!

Biological Control of the TSSM in the Greenhouse
  - Predatory mites:
    - Phytoseiulus persimilis
    - Neoseiulus californicus
Phytoseiulus persimilis (orange mite) among TSSM

The Predatory Mite, Neoseiulus californicus

Examples of Products Registered for Control of TSSM on Vegetable Transplants in the Greenhouse

- Abamectin: tomato, cucurbits, peppers
- Beauveria bassiana (Mycotrol O, Botanigard, Naturalis): all vegetables (do not use Botanigard ES on tomatoes)
- Bifenazate (Floramite SC): tomato, and possibly other fruiting vegetables (check with state for 24c label)
- Insecticidal Soaps (M-Pede): all vegetables
- Pyrethrum + Piperonyl butoxide: all vegetables
- Paraffinic Oil: all vegetables

Conclusions

- There are numerous insects and mites that are pests of vegetable transplants in the greenhouse.
- It is important to use an Integrated Pest Management approach to control these pests.
- Careful, regular monitoring and scouting are keys to successful management of insect and mite pests of transplants.
- Using a diversity of control methods will ensure effective management.
GRAFTED TOMATOES FOR PRODUCTION IN FIELD AND HIGH TUNNEL SYSTEMS

David M. Francis, Mathew Kleinhenz, Sally Miller, S. A., Brian McSpaden-Gardner, B., The Ohio State University; Albert Markhart, University of Minn.; Frank Louws and Mary Peet, University of North Carolina.

Grafted tomatoes have been used in production systems ranging from high input hydroponic greenhouses to subsistence agriculture. We tested 35 commercial and experimental root stocks (RS) in Ohio, North Carolina and Minnesota. The specific objectives this year were to 1) test the feasibility of using RS in soil-based production systems, including organic production; 2) quantify the effects of grafting and RS on yield and quality; 3) provide growers with research based information relative to grafting; 4) provide growers with information on the best practices for grafting.

Significant differences were observed between RS for seed germination and percent success of grafts. In the field, location and replicate within location were highly significant for both total yield and marketable yield. The RS by location interaction was also significant for both total and marketable yield. Tests for the fixed effect of RS were significant for total yield and marketable yield (range P = 0.0307 to P < 0.0001). Significant rootstock by location interactions for total and marketable yields suggested rank shifts in the performance of varieties. Despite significant genetic effects for total yield, only a few RS proved better than the un-grafted or self-grafted control and several performed worse. In NC where Southern Blight was present, there were clear advantageous to using RS as several experimental RS appear tolerant to the disease. The significant RS by location interaction makes it difficult to select a RS that performed the “best” across environments. Despite differences between locations, several RS emerged as high performers across locations. RS developed from “wide” crosses had slow initial growth, but had vigorous later growth. Improved RS growth translated into improved scion growth. The results suggested several points where selection might be implemented in a RS breeding program or selection program.

Key control points for growers wishing to benefit from grafted plants are: (1) seed treatment and sanitation to minimize the spread of disease during the grafting process; (2) synchronizing germination between rootstock and scion; (3) control of temperature and humidity during graft healing and hardening of grafted plants. We have created a project web-page (http://www.oardc.ohio-state.edu/graftingtomato/) in order to provide information on the grafting process. This site contains links to “quick guides”, illustrations, and videos demonstrating the process of grafting. Information is available for both “cleft graft” and “Japanese method” techniques.
Disease prevention and prompt diagnosis are key components in vegetable seedling production because there are relatively few fungicides registered for controlling diseases on these crops. As long as the greenhouse use is NOT prohibited and the specific vegetable is listed on the label, the fungicide can be used in the greenhouse.

**Damping-off** (caused by *Pythium* spp., *Phytophthora* spp. and *Rhizoctonia* sp.) affects all vegetable seedlings and is also common among flowering bedding plants. Damping-off results in collapse of the plant at the soil surface. The fungicide Terraclor controls *Rhizoctonia* and lists broccoli, brussels sprouts, cabbage, cauliflower, peppers, and tomatoes on its label. Previcur Flex is labeled for use in the greenhouse on tomato, leaf lettuce, cucurbits, and peppers for prevention of root rot and damping-off caused by *Pythium* spp. and *Phytophthora* spp. To prevent damping-off, avoid over-watering because some fungi that cause damping-off prefer wet conditions.

Good sanitation is the key and ensures that root rot problems from one crop are not carried over to another crop. Root rot pathogens survive in the greenhouse in soil particles or plant parts clinging to containers, benches, walkways, and equipment. If root rot occurs, remove and destroy the diseased plants. Also, remove healthy-appearing plants that are immediately adjacent to the dead plants because the disease may have already spread to them although they are not yet showing symptoms. Plug sheets containing diseased transplants should not be reused.

**Botrytis** gray mold can infect all vegetable transplants causing an irregular brown spotting or “blight” of leaves and stem cankers. This is the same *Botrytis* that infects a wide range of floriculture crops producing gray masses of powdery spores. In vegetable transplants, *Botrytis* is a threat when plants grow and form a canopy of leaves keeping the relative humidity high which favors disease. Since the fungus that causes gray mold depends on water to germinate on the plant surface, increasing air circulation through fans and reducing the relative humidity by venting or heating (depending on outside temperatures) will help prevent condensation of water on plant surfaces and thereby reduce the occurrence of gray mold. Watering early in the day will help ensure that the plants dry by evening, reducing the occurrence of disease. The fungicides Scala, Botran, and Decree can be used on tomatoes in the greenhouse to protect against *Botrytis*. Although Botran 75-W is registered to control *Botrytis* on tomato seedlings, this fungicide should be used with caution due to concern regarding occasional sensitivity of the plant stem. Decree can also be used on cucumber transplants.

**Alternaria** blight is caused by a fungus of the same name and causes leaf spotting and a stem canker on tomato and other vegetable transplants in the greenhouse. This disease is not as common as gray mold, but can be destructive when conditions are wet and the foliage thick. Often, *Alternaria* blight does not become a problem until the plants are held in the greenhouse for an extended period of time due to a delay in planting, shipping or selling.

Fungicides are available to control *Alternaria* diseases on tomato seedlings and some other vegetable seedlings. The fungicide Dithane is also registered for use on tomato and other vegetable
Bacterial diseases can infect tomatoes and peppers resulting in blighting. Not all spotting on the foliage is caused by fungi. It is important to distinguish between spots caused by fungi and bacteria because disease management differs. On tomato transplants, three bacterial diseases can be problems and include bacterial canker, bacterial speck, and bacterial spot. Peppers are affected by bacterial spot only. Of the bacterial diseases that cause problems on tomatoes, bacterial speck is probably the easiest to identify because of the small, dark-brown spots surrounded by a yellow “halo” that occur on the leaves. Bacterial spot that occurs on tomato and pepper is not as easy to identify as bacterial speck. Bacterial spot disease results in spots or blotches on the leaves and stems. These are larger than those caused by bacterial speck. Symptoms of bacterial canker on tomato transplants include small, tan “blisters-like” lesions on the leaves and petioles and progress to form brown streaking and cankering. A diagnosis from an extension agent or other knowledgeable professional is often warranted to separate symptoms of bacterial diseases from symptoms caused by fungi or other causes.

Tomatoes with bacterial diseases should be immediately removed from the greenhouse and destroyed. In addition, tomato seedlings immediately adjacent to those showing symptoms should also be removed and destroyed. In some situations, all tomatoes within a block or greenhouse will have to be destroyed. Although epidemics may seem to appear overnight, chances are it began in just a few plants and progressed unnoticed for a couple of weeks. Plug sheets containing infected transplants should not be reused. Removing infected transplants from the greenhouse is the most critical component of managing bacterial diseases once they’ve been introduced.

Bacteria move readily in a film of water and can spread through splash droplets. It is important, therefore, to water plants early enough in the day to ensure that the foliage dries completely by evening. Good ventilation, circulation, and low relative humidity are also important in helping to maintain dry foliage. Clipping, pruning, or any other type of injury provides a means for the bacteria to enter the plant and should be avoided.

Until recently, growers have had to manage bacterial canker as it occurred in the field. Our research team approached this problem by testing fungicide applications to transplants while in the greenhouse. The greenhouse was targeted because the spread and increase of bacteria is favored by the wet, humid conditions of the greenhouse and the close spacing of tomato transplants. Multiplication and spread of the bacterium is less likely in the field because of the lowered relative humidity and increased plant spacing. Also, it is more economical and efficient to spray transplants while in the greenhouse than to spray plants once placed in the field.

We focused on the health of tomato transplants because it has been our observation that establishing a field with transplants that are infected with the bacterium responsible for bacterial canker results in devastating yield losses. Transplants can be infected while in the greenhouse, yet appear healthy at the time of planting in the field.

Applying a copper hydroxide product alone or in combination with a mancozeb fungicide at five-day intervals to transplants in the greenhouse once true leaves had emerged, even when a bacterial canker epidemic occurred, resulted in transplants that produced yields comparable to that of healthy plants. In our studies, these copper applications were not continued once the transplants were planted in the field. For tomatoes, the efficacy of the copper fungicides may be enhanced by mixing them with a mancozeb-based fungicide. Although mancozeb does not have any action against bacteria, the combination of mancozeb + copper is considered by some to provide a synergistic action against these bacteria. This combination would also provide some control of the foliar diseases caused by fungi (such as Botrytis and Alternaria). While Agri-mycin alone or in combination with copper hydroxide was also effective in our studies, this product does not list greenhouse on its label. However, current interpretations indicate that this product can be used on seedlings in the greenhouse since the label does not prohibit this use. We have not determined whether a 7-day interval of bactericides affords the same protection as the 5-day
application interval that we tested. Applications of copper hydroxide or Actigard to transplants once in the field may be helpful in reducing bacterial occurrence and fruit spotting.

**Impatiens necrotic spot virus (INSV)** should be a primary concern of all growers who raise both vegetable transplants and flowering plants. This virus infects a large number of plant species and occurs frequently in bedding impatiens, New Guinea impatiens, dahlia, cineraria, cyclamen, gloxinia, and buttercup. This virus moves from infected flowering plants to healthy vegetable seedlings via western flower thrips. A grower may not know that plants are diseased because expression of symptoms may be slow. Meanwhile, if western flower thrips are present, the disease can be spread throughout the greenhouse. It is advisable, therefore, to keep vegetable and ornamental bedding plants separated within the greenhouse.

**Late blight** is caused by a water mold called *Phytophthora infestans* and is not considered a problem for tomato seedlings in the greenhouse. The late blight pathogen typically overwinters in potato cull piles and is often introduced to production fields via potato seed pieces. Commercial potato growers are vigilant each year for late blight as it is a common problem for them when the weather is cool and wet. The sporangia (seeds) of the late blight pathogen can be easily dislodged from the plant’s surface and carried long distances from one field (or growing region) to another via air currents and storm systems. Weather that is overcast, wet, rainy, and humid allows the late blight sporangia to survive its travels so it can cause disease if it lands on the surface of an unprotected host plant (i.e. tomato, petunia, and weeds such as nightshade). When conditions are bright, sunny, and dry, the late blight sporangium cannot survive long because the sunlight breaks it down and the low relative humidity causes it to shrivel and die.

Control measures for late blight are similar to those recommended for the other tomato diseases and include keeping the foliage dry, providing good air ventilation, spacing plants, and heating when needed to dry out the greenhouse. Fortunately, tomato transplant growers can protect against late blight with the same fungicides they use for *Alternaria* and *Botrytis*. In Michigan State University tomato field trials that I’ve run for the last several years (including 2009), the active ingredient in Dithane was excellent in protecting the tomato plants from late blight. The active ingredient in Heritage (azoxystrobin) was also very good. Revus (mandipropamid) is a new product (received a supplemental label that included tomato in August 2009) that has been outstanding against late blight in our outdoor field trials. The use of Revus is not prohibited in the greenhouse on tomato seedlings, but it may not be used on tomatoes for transplant production. Revus could be used in combination with one of the *Alternaria/Botrytis* products since Revus does not control *Botrytis* or *Alternaria*. Revus could be rotated with other helpful late blight fungicides including Curzate, Ranman, and Tanos. All late blight specific fungicides could be used in combination with one of the *Alternaria/Botrytis* products. Late blight fungicides, combined with one of the *Alternaria/Botrytis* products, can eliminate the potential occurrence of late blight when used properly and preventively at the greenhouse level.

**General guidelines:**

1) Dedicate operations for seedling/transplant production. Greenhouses that grow both tomato transplants and mature plants for fruit production are especially at risk of keeping diseases active in the greenhouse and available to infect new tomato seedlings.

2) Keep the relative humidity as low as possible (less than 85%) through heating and venting as appropriate.

3) Space plants to prevent pockets of high humidity from forming.

4) Use fans to move air and vent to exhaust moisture-laden air out of the greenhouse.

5) Scout seedlings 2x each week to ensure that problem are detected early when corrective measures can be taken.

6) If disease symptoms are detected, remove affected plants including adjacent healthy-appearing plants.

7) Water at a time of day when plants can dry quickly.

8) Apply fungicide preventively when weather conditions are favorably for disease (i.e. wet, humid).