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Synopsis:
Producing seedlings specifically to prepare grafted plants requires particular attention to procuring space and supplies, timing sowings, disease management, and modulating growth through irrigation, lighting, and temperature regimens.

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USDA United States Department of Agriculture National Institute of Food and Agriculture

Preparing Seedlings & Rootstocks to Graft

Most growers are familiar with how to produce seedlings to be used as standard transplants. However, an increasing number of people want to know how to produce seedlings specifically to prepare grafted plants. The two seedling production processes are similar but not identical. Producing seedlings to prepare grafted plants borrows a lot from producing seedlings as standard (non-grafted) transplants. However, specific details about the grafting process demand attention before and during seedling production. These details and steps that seedling and grafted plant suppliers may want to consider in creating 'feedstock' for grafting operations are the subject of this summary.

Numerous research-based resources regarding seedling production for use as standard transplants provide growers with an excellent foundation for producing seedlings for grafting. Growers are encouraged to consult reliable seedling production guides describing seeding methods, promoting germination and stand establishment, and maintaining healthy and disease-free plants (e.g., through fertility and irrigation and crop protection programs) through the point of transplant shipment or use. For grafting, however, growers and nurseries are encouraged to keep the following four major issues in mind.

Inputs increase

Grafting combines two plants into one. Therefore, two seedlings must be produced for each grafted plant to be used in production. In fact, it will be necessary to sow more than one rootstock seed for each grafted plant that is desired since rootstock seed may emerge at lower percentages and less uniformly than scion seed, although seed vigor and germination of many commercial rootstock cultivars have improved recently. In addition, it is necessary to sow more scion seeds than the number of desired grafted plants to ensure that there are enough scion seedlings of the appropriate size and desired quality at grafting time. Further, not all grafted plants will survive, so it is necessary to graft more plants than are needed.

In our laboratory's example, we consistently achieve 95% or greater survival in tomato, but only 80% for cucurbits and 85% for eggplant. Thus, the need for at least two seedlings per plant used in grafted vegetable production can more than double the materials, supplies, labor, and other inputs used to produce a given number of standard (non-grafted) seedlings. An online tool for calculating the number of seeds that must be sown (http://u.osu.edu/vegprolab/seed-to-grafted-plant-calculator/) includes assumptions about germination, and seedling health and selection. In addition to the number of seedlings required, growers are encouraged to verify that all tangible and intangible resources required to produce the desired number of seedlings are available.

Schedules change

Newly-grafted plants must heal before being shipped or set into production areas. Healing periods tend to last 7-14 days, depending on healing conditions and plant species and status. Therefore, if shipping or planting dates remain the same, seedling production may need to begin two or more weeks earlier than for standard transplant production.

Also, it is important for seedling growers to recognize that, for most cases, the stem diameters of rootstock and scion seedlings must be not only similar when grafted but also within a specific range (i.e., 1.5 mm – 3.0 mm in tomato, as measured just below the cotyledonary node). It is also important for growers to recognize that the vigor of rootstock and scion seedlings is often very different. That being true, the different growth rates of rootstock and scion seedlings may result in their reaching, staying in, and passing beyond the period when they are graft-eligible (i.e., 1.5 mm – 3.0 mm stem diameter) on different dates despite being sown on the same date. Therefore, seedling growers are encouraged to become familiar with the relative growth rates/vigor of seedlings of the cultivars to be used as rootstock and scion.

Growers can become familiar with cultivar-specific vigor values through their own experimentation and through the results of experiments completed by others. For example, the Vegetable Production Systems Laboratory at the Ohio State University-Ohio Agricultural Research and Development Center has published relative seedling vigor values for twenty-three tomato varieties (eighteen rootstock, five scion; http://u.osu.edu/vegprolab/files/2016/10/seedling-vigor-table-HT-dec-16-27nsssq.pdf). These results indicate that the difference in vigor can be 575 times greater for the most vigorous varieties compared to the least vigorous varieties.

Rootstock seedlings may emerge less uniformly (and over a longer period) than scion seedlings. However, once emerged, rootstock seedlings may grow more rapidly than some scion varieties. Overall, the different growth rates of seedlings before they are grafted and the need to heal grafted plants lead many seedling and grafted plant suppliers to seed multiple times (i.e., stagger seedings). Differences in growth between rootstock and scion seedlings also lead some growers to adjust the growing conditions and management practices for rootstock and scion seedlings so they reach graft-eligible status simultaneously. This approach allows growers to maximize the use of all seedlings to produce grafted plants.

Clean, disease free seeds and seedlings are essential

All seedling producers and users value clean, disease-free stock. However, for people producing grafted plants, it is even more essential.

Grafting requires wounding that, ordinarily, would be lethal. Also, seedlings, hands, tools, machines, and work surfaces are in contact with wounded seedlings and their exudates. Therefore, the grafting process is incredibly efficient at spreading disease from one to many plants and at exposing weak, newly-grafted plants to seedling diseases that ordinarily may be 'minor' concerns. Assuring that the plant growing, grafting, and healing areas are disease-free is vital. Good sanitation practices including clean hands and grafting tools throughout the grafting process is important.

Special attention needs to be given to common seedling diseases as well as diseases that can be spread by contaminated seed, by contact, and/or transmitted from root to shoot or shoot to root. These include viruses known to be in tobacco products. Therefore, tobacco users should have no contact with tomato scion or rootstock seedlings, or contact only after very specific conditions are met. Additional resources are available (see below) to assist growers in achieving and maintaining disease-free seedling stock.

Seedlings may need specific management, including just prior to grafting

Surgery often leads to better outcomes when patients are prepared beforehand, sometimes beginning days in advance. Likewise, grafted plants may be prepared more effectively and the success rate can be increased when seedling management is altered prior to grafting. This is an active area of research and more details are expected. However, currently, experienced growers often reduce or withhold irrigation and fertigation, especially of rootstock seedlings, for 1-2 days before grafting. This step helps reduce root pressure, allowing firmer contact at the rootstock-scion interface. Figure 1 depicts squash and tomato rootstock seedlings immediately prior to the attachment of the scion section. Note that sap is visible as a droplet at the cut surface of each rootstock seedling.

While all cut surfaces are expected to glisten with moisture, high root pressure in the rootstock may show up as excessive moisture (a droplet) that interferes with setting and maintaining rootstock-scion contact at the graft union. Therefore, steps to lessen root pressure at grafting are needed. However, seedlings should not be stressed to the point of severe wilt prior to grafting.

There is also growing research evidence that altering light intensity or spectral composition

Figure 1. A squash (left) and tomato (right) rootstock seedling containing a sap droplet at the cut surface immediately before grafting due to high root pressure. *(Photos by P. Devi, WSU and K. Chamberlain, OSU-OARDC, respectively)*

before grafting may enhance the success and efficiency of the process. Specific modifications of the light environment before grafting are relatively uncommon in commercial practice. However, growers should pay attention as new information may reveal that such modifications can increase grafting success.

Adjustments beginning earlier in seedling production may also be needed to accommodate the unique needs of grafted plants and different grafting methods. For example, vegetable producers often prefer standard non-grafted transplants to be stocky and thick-stemmed. While grafted plants must also be sturdy, they may need to be taller than standard transplants because grafted plants should be set into production areas so that their graft union remains above the soil line.

In the case of tomato, seedlings are often grafted near the cotyledonary node when seedlings have three or four true leaves. Increasing the length of the rootstock stem (hypocotyl) so that a large portion of it extends upward above the soil-line appears to have two benefits. First, the rootstock stem may resist infection by some bacterial and fungal diseases more reliably than the scion stem. As the transfer of inoculum from soil to plant can occur by rain splash, a taller rootstock stem may provide additional protection. Second, some vegetable producers prefer to set large transplants (i.e., ones with a greater than average number of

Figure 2. Tomato plants grafted immediately below the rootstock cotyledonary node (left) and three and five nodes above the rootstock cotyledons (middle and right, respectively). Yellow circles surround the rootstock-scion graft union. The longer rootstock stem section provides the grower with potentially useful options (e.g., planting deep, increasing the length of stem over which diseases resistances may persist). However, so-called “high-grafted” plants are more time-consuming and may be more difficult to prepare. *(Photo by M. Kleinhenz and M. Soltan)*

nodes and leaves) deep into the soil, especially in high tunnels, to facilitate plant establishment by encouraging adventitious root development. In these situations, longer rootstock stems are required to allow for deeper planting while avoiding contact between scion stem and soil.

Under these circumstances, growers may graft onto rootstocks 3-5 nodes above the cotyledons, as in Figure 2 (plant in middle and at right). The left plant in Figure 2 is grafted immediately below the cotyledonary node of the rootstock seedling (the most common practice) whereas the plants in the middle and at right are grafted three and five nodes above the cotyledons of the rootstock seedling, respectively. Secondary shoots below these nodes were removed when very small and grafting was completed where the rootstock seedling was the correct diameter at the point of grafting.

Regardless of the number of nodes that the rootstock contains, grafted plants should be set into the soil at a depth allowing the graft union to remain above the soil. “High grafting” adds costs to the production of the grafted transplants as suppliers must care for rootstock seedlings for longer periods and adjust grafting areas and methods to accommodate larger rootstock seedlings, and end producers will need to scout for and remove rootstock shoots (suckers). Seedling and grafted plant suppliers may also choose to “stretch” scion seedlings prior to grafting in order to match their stem diameters to rootstock seedlings, as referenced earlier.

Regardless of why vegetable growers desire grafted plants with elongated rootstock stems, it may be necessary to modify pre-grafting seedling production methods or conditions in order to lengthen the rootstock stem before grafting. For example, if grafting is to be done near the cotyledonary node, then temperature, light, fertility, irrigation, and/or other treatments may be required to increase typical rootstock stem (especially hypocotyl) length, and these specific requirements appear to differ among cultivars.

Finally, when double-leader tomato plants are required in production, they are ‘pinched’ after grafting, thereby adding an additional step in grafted plant preparation. For all these reasons, producing seedlings to be grafted requires adjustments in pre-grafting seedling production methods and timelines.

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