# Grafting Manual:
## How to Produce Grafted Vegetable Plants

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**Synopsis:**
An overview and some examples of the costs that need to be considered when evaluating the economic feasibility of grafting plants. Regardless of the scale of production, producers face the same major cost categories.

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

## Cost Analysis for Vegetable Grafting

This chapter aims to provide an overview and some examples of the costs that need to be considered when evaluating the economic feasibility of grafting plants. In general, transplants are produced in commercial nurseries or on-farm. Farmers produce transplants for their own use, while commercial nurseries produce and sell transplants to different farms; hence, the scale of transplant production is normally greater for commercial nurseries, translating to higher investment costs. Regardless of the scale of production, both types of producers face the same major cost categories, particularly: *variable costs*, those expenses that vary with output within a production period, and result from the use of purchased inputs and owned assets; and *fixed costs,* those expenses that do not vary with the level of output.

### Cost categories

A propagator of grafted plants will incur the same *variable costs* as for non-grafted plants — potting media, seedling trays, fertilizer, chemicals, heating, cooling, water, labor for seeding and general clean-up, maintenance and repairs; and the same *fixed costs* — greenhouse, land, insurance, management, and depreciation on fixed capital. However, there will be additional costs when grafting plants.

Twice as much space will be needed for producing grafted transplants as compared to non-grafted transplants. Other additional costs include grafting supplies (e.g., razor blades, grafting clips), healing chamber, and labor to graft and monitor the plants and care for the healing chamber (Rivard et al. 2010). The additional greenhouse space and the healing chamber are capital investment costs that are generally classified as fixed costs. However, these costs can also be considered as variable to a conventional nursery that is just starting a grafting operation (Lewis et al. 2014). By classifying these items as variable costs, they will vary depending on the size of a nursery's grafting operation. This analysis is appropriate for growers in the U.S. where grafting is generally an uncommon practice and thus a relatively new endeavor.

Currently, there are limited studies that investigate the economic costs of grafting vegetable plants. Examples of these studies include Barrett et al. (2012) who estimated the cost of producing 1,000 grafted organic heirloom tomato plants compared with non-grafted plants in a small-scale operation in Florida. Another study is by Galinato et al. (2016) who estimated the production costs of 146,000 grafted seedless watermelon plants in Washington. Rivard et al. (2010) examined the production costs of grafting tomato transplants at a farm in North Carolina and another farm in Pennsylvania, where one thousand transplants and 10,000 transplants were grafted respectively at these sites. Lewis et al. (2014) examined the production costs of grafting tomato and watermelon in Florida given two production sizes and technologies — a production volume of one million plants per year using manual grafting that was considered as "low" volume (~20,000 grafts per week), and a high volume production of 100 million plants per year using automated grafting (~200,000 grafts per week).

The distribution of costs for the production of grafted transplants is presented in Table 1. Generally, the highest input cost is attributed to labor particularly when grafting is done manually, as it is with low volume production. In high volume production by Lewis et al. (2014), the cost of the structure and equipment are higher than those of other studies because a larger scale operation requires relatively more resources and it involved the use of grafting robots.

Table 2 shows the estimated production costs of the aforementioned studies, with the cost of non-grafted transplants included for comparison. In general, the per unit cost to produce a grafted plant is more expensive relative to a non-grafted plant, which is due to the additional costs associated with grafting. Particularly on the grafted plants, the estimated cost per plant appears to be lower when the volume of production is higher such as for the conventional production of tomato plants (i.e., estimates by Lewis et al. 2014 and Rivard et al. 2010).

Table 1. Distribution of costs for producing grafted transplants.

| Study | Crop and study location | Materials[A] | Labor[B] | Structure & equipment[C] | Utilities[D] |
|---|---|---|---|---|---|
| Galinato et al. (2016) | Seedless watermelon (WA) | 35% | 48% | 13% | 3% |
| Rivard et al. (2010) | Certified organic tomato (NC) | 41% | 42% | 6%[E] | 10% |
| | Tomato (PA) | 31% | 49% | 5%[E] | 15% |
| Lewis et al. (2014) | Tomato - low volume[F] (FL) | 21% | 40% | 6% | 34% |
| | Tomato - high volume[G] (FL) | 16% | 15% | 26% | 43% |
| | Watermelon - low volume[F] (FL) | 19% | 60% | 4% | 16% |
| | Watermelon - high volume[G] (FL) | 24% | 18% | 23% | 35% |

Notes:
Percentages of cost distribution may not add up to 100% due to rounding.
NC – North Carolina; PA – Pennsylvania; WA – Washington.
A. Materials include grafting supplies (razor blades, clips), fertilizer, trays, sanitizer, and other consumable items. Seeds are excluded for comparability of data across studies (i.e., only Rivard et al. included seed costs in their calculations). Seed costs differ based on the cultivar and quantity purchased, and crop producers typically provide seeds to the nursery.
B. Cost of all labor in greenhouse production of plants, including grafting labor and healing chamber care.
C. Includes greenhouse, healing chamber, seeding machine, and other equipment.
D. Includes water, and electricity for heating.
E. Data are available for healing chamber only.
F. Low volume refers to production of 1 million grafted transplants by manual grafting.
G. High volume refers to production of 100 million grafted transplants by automated grafting (i.e., use of grafting robots).

## Cost variations

The variations in the costs associated with grafting mainly come from the following factors: size of the nursery operation, and prices of inputs (including labor and seeds). The size of operation will determine the resources needed such as land, labor, horticultural structures, and technology. Different volumes of production certainly will have different requirements for space, as well as machinery, labor, and management. For example, the high volume production (100 million plants/year) in Lewis et al. (2014) involved fully automated grafting while the low volume production (1 million plants/year) involved manual grafting. Total capital costs were estimated at $115,127 and $118,974 for low-volume, manual grafting of tomato and watermelon plants, respectively. The per plant costs are more than a hundredfold greater for high-volume, automated grafting of tomato and watermelon plants at $21.6 million and $16.7 million, respectively.

Prices of some inputs, such as fertilizer, seeds, and supplies are determined by the amounts purchased, which can benefit from discounts when buying in bulk or large quantities. Furthermore, the prices of vegetable seeds also depend largely on the cultivar (Lewis et al. 2014). Per unit costs of land, labor, water, and energy depend on the geographic locations. For example, a greenhouse operation in California does not have the same value as an operation in Florida. Water, heating/cooling costs as well as electricity differ by location as well. For example, electricity rate is extremely high in Hawaii and low in Washington, compared with averages in other states. The wage rates likewise differ. Each state has its own prevailing minimum wage rate. Also, the wages charged depend on the laborer's skill, and availability of labor in the particular location of the nursery operation.

## Other Considerations

***Potential cost savings.*** Economies of scale, that is when there are cost savings gained by an increased level of production, may be obtained by fully using existing resources (such as machinery, capital and management). Fixed costs per unit of output are lowered by using specialized resources or technology that increase the efficiency of getting the job done at less cost (Kay et al. 2012), and by gaining more experience in grafting. There is a learning curve

Table 2. Variable production costs per plant*, grafted versus non-grafted.

| No. of plants | Tomato | | Watermelon | |
|---|---|---|---|---|
| | Grafted | Non-grafted | Grafted | Non-grafted |
| 1,000[A] | $0.45 | $0.13 | | |
| 1,000[B] | $0.31 | $0.10 | | |
| 10,000[C] | $0.93 | $0.44 | | |
| 146,000[D] | | | $0.19 | $0.04 |
| 1 mil[E] | $0.15 | $0.02 to $0.03 | $0.20 | - |
| 100 mil[F] | $0.12 | $0.02 to $0.03 | $0.09 | - |

Notes:
*Seed costs differ based on the cultivar and quantity purchased, and crop producers typically provide seeds to the nursery. Seed costs are excluded for comparability of data across studies.
A. Organic heirloom production in FL (Barrett et al. 2012).
B. Certified organic tomato production in NC (Rivard et al. 2010).
C. Conventional tomato production in PA (Rivard et al. 2010).
D. Seedless watermelon production in WA (Galinato et al 2016).
E. Manual grafting production in FL (Lewis et al. 2014).
F. Automated grafting production in FL (Lewis et al. 2014).

in grafting transplants, and a "trial and error" in the propagator's horticultural and management practices would help them find the best method that would yield their desired quantity and quality of grafted plants. Capitalizing on the increased knowledge and experience can lower the average costs of production and improve the success rate of grafting.

***On-farm production of grafted plants.*** Grafting can be done by both commercial greenhouse transplant producers and crop producers, such as those who typically grow their own non-grafted transplants since they already have some of the required resources (e.g., seeding machine, small tools, etc.). The choice of a crop producer between on-farm grafting and sourcing the grafted plants from a nursery will depend on the cost to produce them versus the cost to purchase them, and should also take into consideration shipping costs.

Note that costs do not only refer to financial costs but also to the opportunity costs of a crop producer in terms of their resources such as capital and time. These resources are limited and have to be efficiently allocated among competing, individual crop enterprises. Opportunity costs are defined as revenue foregone by not investing in the next best alternative; for example, spending money to invest in the stock market or pay off an outstanding loan (Hinman 2002). In terms of owned land, the opportunity cost is what an owner-producer could earn from renting out the land instead of being used by the producer to construct an additional greenhouse.

***Returns relative to non-grafted plants.*** The various costs of production associated with grafting have been discussed earlier but the revenue is another important component when examining the economic feasibility of a grafting enterprise. For the suppliers of grafted plants, there has to be a market for their output and the price charged should enable them to, at least, recoup all their production costs.

For the consumers of grafted plants, the higher purchase cost relative to non-grafted plants can be acceptable if using the grafted transplants would improve their crop yield and quality, provide a viable alternative to chemical use in managing soil-borne diseases, or both, which would subsequently boost their profit. There are studies that demonstrated potential higher economic returns for the field utilization of grafted plants instead of non-grafted plants, due to improved yield and cost savings or costs avoided in field fumigation (e.g., Barrett et al. 2012; Djidonou et al. 2013; Galinato et al. 2016; Louws et al. 2010; Rivard and Louws 2011).

**Summary**

The economic feasibility of producing grafted vegetable transplants is contingent on two components: production costs and revenues. All costs need to be considered given the investment outlays to start and maintain a grafting enterprise, which can be expensive depending on the size of the operation.

Ultimately, the choice of a specialty crop producer to use grafted over non-grafted transplants will depend on whether or not the benefits gained by utilizing grafted transplants outweigh the cost of acquiring these plants; and whether or not the net benefits (or profit) of using grafted transplants is greater relative to using non-grafted transplants. Potential benefits include improved yield, and effectiveness of the grafted transplants as alternative to using chemicals in controlling soil-borne disease, which can translate to reduced or avoided costs. Additionally, crop products produced without the use of pesticides may bring a higher price in the market, thus this added profitability factor should also be considered.

References cited in this article include more in-depth information about the cost estimates of producing grafted vegetable transplants, as well as the costs and benefits of the field utilization of grafted as opposed to non-grafted transplants.

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