FIELD GRAFTING GRAPEVINES IN WASHINGTON STATE

Introduction

As with many fruit crops, consumer preference often dictates the varieties of wine grapes grown. But in a perennial cropping system like grapes, it is difficult to satisfy evolving markets and changes in consumer preferences. Planting a new vineyard to a newly popular variety is a significant investment. The time between variety choice and vineyard planting, until the first partial harvest of fruit, is two to three years; it takes up to five years before a vineyard is at full production. However, an in-vogue variety may fall out of favor well before the investment in a new vineyard has been recouped. During periods of rapid industry growth in response to consumer demands, basic aspects of vineyard site selection and establishment can be overlooked. Alternatively, within a few years of planting, it may be recognized that a site is not as suitable as was thought during original inspection. Discrepancy between vineyard microclimate and planted varieties are sometimes not evident for many years, at which time producers face the expensive prospect of vineyard replanting or renewal.

Field grafting is one strategy that is commonly used in other perennial crops that can help grape growers overcome both the rapid changes in consumer preferences and the less-than-optimal location–variety combinations. Field grafting takes advantage of the established root system of the existing vines, leaving it intact to function as the rootstock, while removing the upper architecture of the plant and replacing it with a more desirable grape variety (Figure 1). With field grafting, the rootstock is generally from one of two conditions: (1) the rootstock is an older vine and the intent is to rapidly change the variety or (2) a rootstock is intentionally planted for field grafting, allowed to develop for a year or two, and then grafted with the scion.

The use of grafted vines has additional advantages. Specific rootstocks can impart pest and disease resistance to an otherwise susceptible scion (Bettiga et al. 2003; Shaffer et al. 2004). By using rootstocks that reduce negative responses to soilborne pests or abiotic pressures, growers can produce scion varieties on sites where they might otherwise be limited. For example, rootstocks can have a wider range of tolerances to soil challenges such as sub-optimal pH, salinity, or water stress (both too much or too little); they can also impart various horticultural attributes like altered scion vigor, changes in the timing of grapevine development (such as budbreak, flowering, and ripening), and altered cropping potential. Historically, in the case of Washington State, most grafted vines are field grafted, and while the rootstock and scion may be different grape varieties, they are still both *Vitis vinifera*. These grafted vines lack the added advantage of having used a rootstock bred to express certain advantageous traits. In this situation, field-grafted vines only provide a change in a scion variety. The only way to gain

A few definitions to understand the process of field grafting.

grafting—The process of joining two plant parts together to grow as one.

scion—The desirable portion of the plant that will bear the harvestable crop. In the case of grapes, this would be the variety associated with the fruit (e.g., Riesling, Cabernet Sauvignon, Chardonnay).

rootstock—The below-graft portion of the vine consisting of the trunk and root system. In the case of grapes, this consists of the previously planted vine variety, or a specific selection utilized for pest resistance or tolerance to specific soil conditions.

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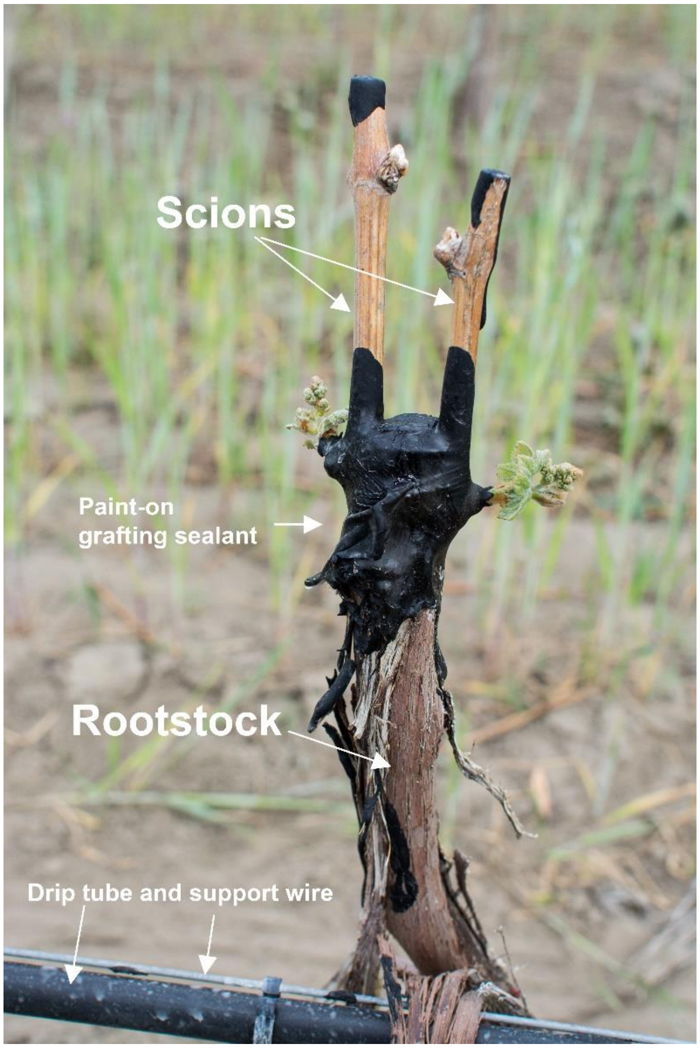

Figure 1. A field graft comprising a previously cut rootstock and new scions. Photo by Eric Gale, Ste. Michelle Wine Estates.

the full benefits of rootstock use is to initially plant the vineyard with bench grafted vines or to remove the current own-rooted vineyard and replant with bench grafted vines. Current concerns over increased numbers of plant parasitic nematodes and possible phylloxera infestation will likely facilitate an increased incidence of plantings on resistant rootstocks in future Washington vineyards.

Field Grafting: Advantages and Disadvantages

When compared to replanting a vineyard, the biggest advantage of field grafting is how quickly the vineyard can "change variety" and return to full production. Following replanting, which includes an additional year of preparation, grapevines typically require three to five years to achieve full production, during which time many management decisions are focused on promoting strong root growth. With field grafting, a strong rootstock is already in place and the vineyard often returns to full production in two years (Cowham 2008). Additionally, in many replant situations, vineyard trellis and portions of the irrigation system needs to be removed to accelerate vine removal. When replacing a block via field grafting, often the only portion of the irrigation system or trellis that needs to be replaced is the cordon wire, a minimal expense compared with full trellis replacement. With estimated full replanting costs around $8,000 to $10,000 per acre (Hansen 2012), one large producer in Washington found that the costs associated with field grafting were lower than replanting and the payback period was shorter (Table 1). This favorable cost analysis has been reported elsewhere (Cowham 2008; Rayapati and Ball 2018). The shorter time to economic return coupled with the opportunity to select a more desirable or valuable scion variety can make field grafting an excellent option for growers who are not otherwise limited by soilborne pests or other limits to vine growth and productivity.

Field grafting, however, does not come without challenges. Field grafting is both a science and a craft; selecting the proper timing and process for field grafting can be challenging for some, and the risk of graft union failure is high for first-time grafters. The high demand for professional field-grafting crews necessitates advanced planning and often requires a waiting period. Intensive management of field-grafted vines is necessary for the subsequent growing season, and failure to do so will result in a high proportion of failed graft unions (Hansen 2011). The fragility of field-grafted vines during the first season is not conducive to management through mechanization, so nearly all labor is handwork (Chapman 2018). In a market where field labor can be difficult to procure, the high labor requirement could prove cost-prohibitive.

A unique disadvantage of field grafting in Washington State is associated with most vineyards being planted to vines on their own roots. This means that when renewing a vineyard by field grafting, a grower fails to capitalize on the advantage of using pest or disease resistant rootstocks. If a limiting factor at an existing vineyard is related to soilborne pests or diseases, or other soil issues, then replanting the vineyard to bench grafted (pre-grafted) vines may be best. If bench grafted vines are chosen, be aware that pre-grafted materials often require lengthy pre-order periods, and, frequently, popular scion clones can be sold out. Therefore, field grafting can be an alternative to planting bench grafted stock. If the desired scion is unavailable, it is possible to plant the rootstock in year one and then field graft in year two but, in this case, a desirable rootstock is in place ahead of time.

Table 1. Actual grafting costs in 2017 for a commercial 100-acre vineyard with 10 ft by 6 ft spacing (approximately) in Washington. Costs include all vineyard materials and labor during year one. Cost does not include laborer benefits, payroll taxes, or equipment purchases. Hand labor in a grafted vineyard is intensive in the year following grafting, demonstrated by the number of manual labor passes. To compare with the cost of planting a new vineyard, please visit the Northwest Grapes Cost of Production Calculators (Washington Winegrowers Association 2020).

Field Grafting Costs (2017)			
	Per Unit Cost	**Per Acre Cost**	**Partial Totals ($/acre)**
Materials and Grafting Costs			**Materials and Grafting Costs**
Scion wood	$0.32–$0.52	$400.00	$1,435.50
Trellis supplies (wire, clips, etc.)	n/a	$128.00	
Grafting service	$1.25	$907.50	
Pre-grafting Field Labor			**Pre-grafting Field Labor**
Cut vines—hydraulic shear		$90.00	$484.00
Cordon and cordon wire removal		$263.00	
New cordon wire installation		$131.00	
Post-grafting Field Labor			**Post-grafting Field Labor**
Reseal grafting sealant		$40.00	$751.00
Graft success/failure count		$5.00	
total seal and count		*$45.00*	
Suckering pass 1		$51.00	
Suckering pass 2		$121.00	
Suckering pass 3		$142.00	
Suckering pass 4		$73.00	
total suckering		*$387.00*	
Sap bleeding pass 1		$16.00	
Sap bleeding pass 2		$16.00	
total bleeding		*$32.00*	
Tying pass 1		$53.00	
Tying pass 2		$48.00	
Tying pass 3		$93.00	
Tying pass 4		$4.00	
total tying		*$198.00*	
Vine training pass 1		$50.00	
Vine training pass 2		$32.00	
Vine training pass 3		$7.00	
total vine training		*$89.00*	
Regrafting Failed Grafts (5% failure)			**Regrafting Failed Grafts (5% failure)**
Recutting failed graft vine trunks		$4.50 (5% of $90.00)	$59.10
Regrafting failed grafts		$34.60 (5% of $692.00)	
Scion wood for regrafts		$20.00 (5% of $400.00)	
Projected Total Cost per Acre—Field Grafting			**$2,748.10**

There are potential advantages to starting with rootstock plantings and grafting a year later. Growing rootstock for a full season before field grafting allows a robust root system to develop. Partial vineyard production will still occur in year three despite the lack of scion wood until year two, a financially beneficial situation. Another advantage is the ability to graft the scion wood at a specific height, which is often higher than what is available for bench grafted materials. Having a graft union that is higher above the ground could prevent cold damage as the colder air sinks closer to the ground. The closer proximity of the delicate scion growth to the trellis support wire is also advantageous, with fewer vines lost due to environmental damage such as wind (Coe et al. 2006; Keller et al. 2007). Additionally, having sufficient time to source scion materials allows the grower to look for the best available wood, rather than risking having insufficient access to material, or having to accept less-than-optimal scion wood for grafting.

For a summary of field grafting advantages and disadvantages, refer to Table 2.

How Grafting Works

The grafting process begins with the cutting of both rootstock and scion wood, exposing freshly damaged tissue. These two disparate pieces are then mechanically attached with the goal of aligning the vasculature of both pieces. Initially, damaged cells along the cuts rupture and intact cells nearest the cut adhere to the opposing tissue (Melnyk and Meyerowitz 2015). Following the initiation of this cellular damage response, a proliferation of undifferentiated cells, called callus, begins to form around the wound. Over time, some of these callus cells differentiate into xylem and phloem cells, connecting the vasculature of the rootstock and scion and effectively forming one continuous plant (Melnyk and Meyerowitz 2015). To promote this response, active vascular elements in the cambium need to be exposed in the scion and the rootstock and then placed into direct contact. The cambium comprises the layer of actively growing cells directly underneath the bark, sandwiched between the outer phloem elements and the inner xylem; all three of these components comprise the vasculature system of the vine. If improper grafting cuts are made, or if this green-colored tissue layer is not mechanically joined accurately in the graft union, the tissues will be unable to fuse and grow together, causing the graft to fail.

Field Grafting Styles

There are many styles of field grafting. A few of the more common grafting styles are presented below. It is important to note that professional grafting crews may modify these grafting styles. The key to all successful grafting is that the union between rootstock and scion is well aligned and that the timing is optimal to promote adequate fusion of the graft union.

Chip Bud Grafting

Individual buds are cut from dormant shoots of the scion variety (Figure 2A). A cut matching the shape of the bud is cut into the rootstock (Figure 2B) after which the bud is wrapped securely to the cut in the rootstock (Figure 2C). The process is explained in detail by Olmstead and Keller (2007).

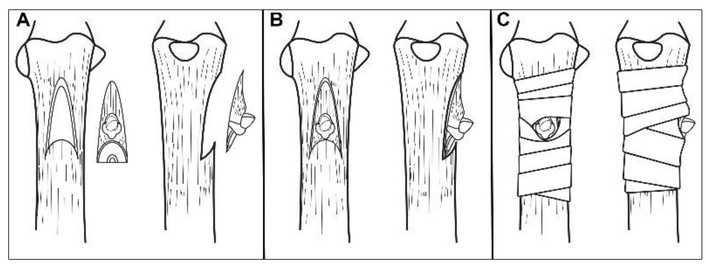

Figure 2. Chip bud graft. Line drawings by Charlotte Oliver, Washington State University.

Table 2. Overview of advantages and disadvantages of field-grafted grapevines compared with a traditional vineyard replant.

Summary of Field Grafting Advantages and Disadvantages	
Advantages	**Disadvantages**
Retain trellis and irrigation system.	Limited ability to use pest, disease, or abiotic-stress resistant rootstock.
Potential cost savings over traditional replant.	Extensive hand labor requirement in the grafting process.
Faster return to full production.	Potential for introducing vineyard variability due to incomplete graft take.
Quickly change grape variety to fulfill market demands.	Long term planning required to schedule a competent grafting crew.
Quickly mitigate poor scion choices for the site.	Potential for inducing a latent rootstock disease, such as grapevine viruses or crown gall at the graft union.

T-bud Grafting

This is similar to chip bud grafting in that only buds from the scion are used (Figure 3). T-bud grafting departs from chip bud grafting in how those buds are joined to the rootstock. When T-budding, the scion bud is removed with a shallower cut than chip budding to expose the cambium layer opposite the bud. The rootstock receives two cuts: one parallel to the ground and one perpendicular, forming a “T” and extending only through the rootstock bark (Figure 3A). The bark is then peeled back and the scion bud is slipped into the void (Figure 3B). This type of graft needs to be well-taped to hold the bud firmly in contact with the rootstock cambium (Figure 3C). It is imperative that this type of grafting take place during the “bark slip” stage or the graft will not heal properly (Cowham 2008). “Bark slip” occurs in the spring, once sap is flowing in the rootstock vasculature and the bark easily peels away from the trunk.

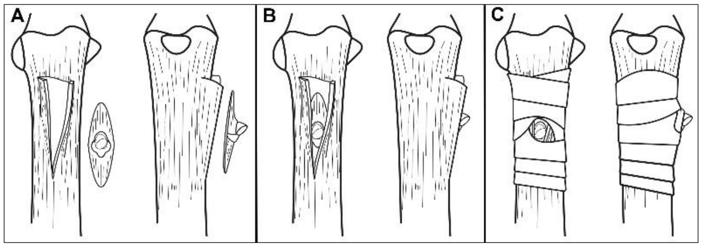

Figure 3. T-bud graft. Line drawings by Charlotte Oliver, Washington State University.

Whip Grafting

More commonly used as a style of bench grafting, whip grafting can be used for field grafting of young vines when the rootstock is not large enough for notch, wedge, or cleft grafting (Figure 4). This grafting style is one of the more challenging, as skillful cuts are necessary to accurately match up the cambium layers between rootstock and scion. To whip graft, the rootstock is cut at an angle to expose as much cambium as possible; this cut should be 1.5 to 2 inches long, depending upon the diameter of the grafted parts (Figure 4A). Thicker parts require longer cut surfaces to account for the longer surface contact needed to securely tape a larger graft union. A complementary sloped cut is made on the scion, then both the scion and rootstock receive a small face cut to create two interlocking “tongues” that help lock the two halves of the graft together (Figure 4B). Following the fusing of the rootstock and scion, grafting tape and paint should be applied (Figure 4C) (Jensen et al. 1981).

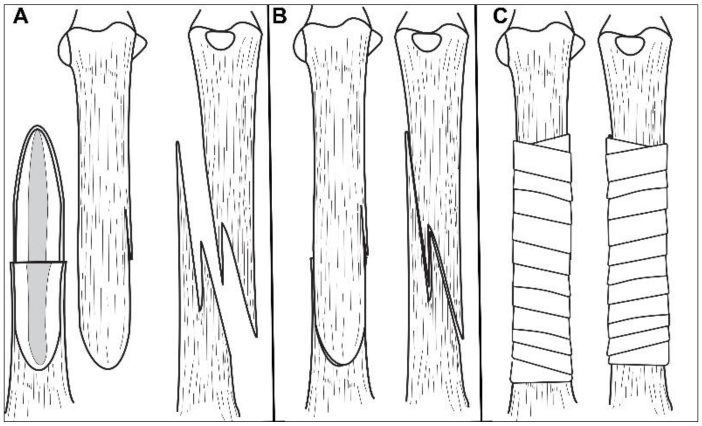

Figure 4. Whip graft. Line drawings by Charlotte Oliver, Washington State University.

Notch or Wedge Grafting

Requiring more skill, notch or wedge grafting cuts a vertical, triangular wedge from the rootstock (Figure 5). The widest part of the wedge is at the top of the rootstock, with the tip of the wedge 1 to 1.5 inches below the top of the cut trunk. The base end of the scion is cut to a complementary wedge, then the scion is fitted into the wedge cut in the rootstock (Alley 1975b). This grafting style requires grafting tape and paint to hold the scion wood in place (Jensen et al. 1981).

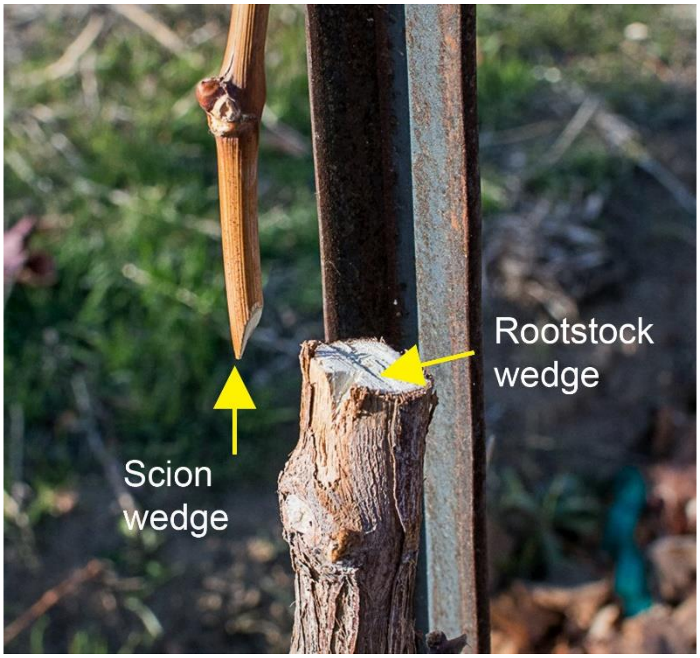

Figure 5. Notch or wedge graft. Notice the wedge-shaped cutout in the rootstock and the matching wedge-shaped cuts of the mating scion. Photo by Eric Gale, Ste. Michelle Wine Estates.

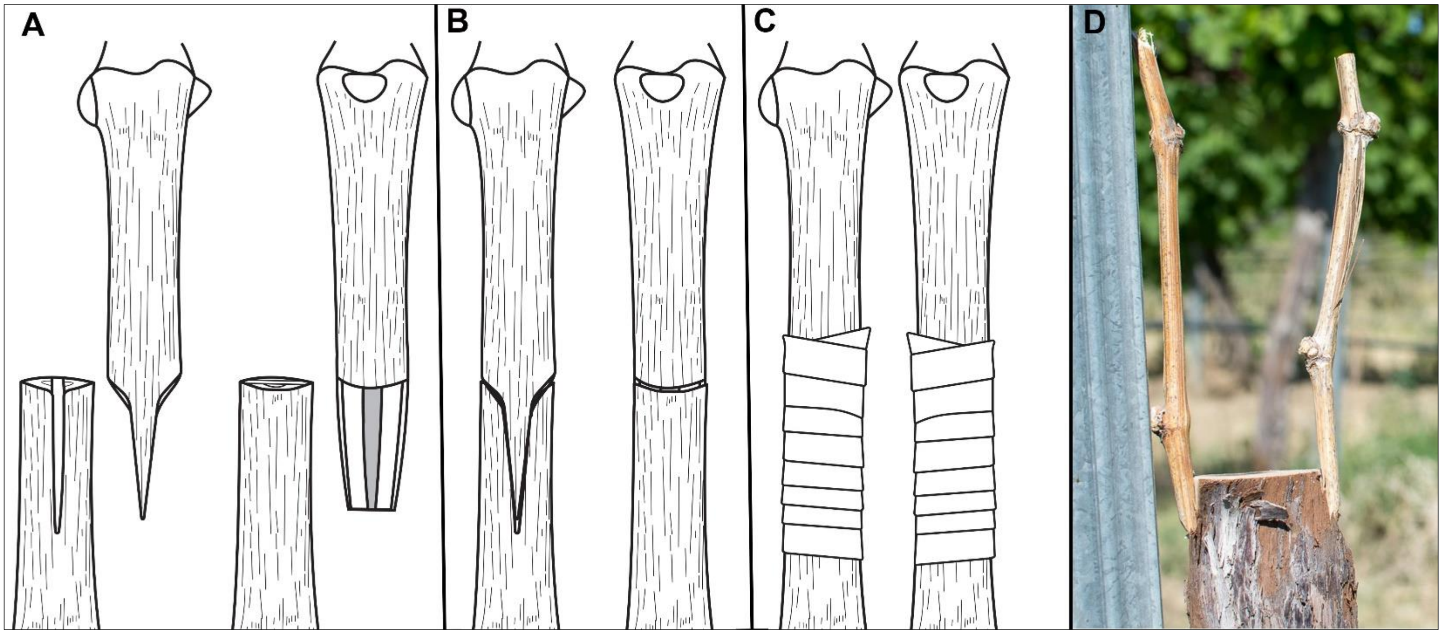

Figure 6. (A–C) Cleft graft and (D) modified cleft graft (or side whip graft) prior to the application of grafting tape and sealant. Line drawings by Charlotte Oliver, Washington State University. Photo by Eric Gale, Ste. Michelle Wine Estates.

Cleft Grafting and Modified Cleft Grafting

This is a relatively simple grafting style where the entire circumference of the rootstock trunk is cut and then split open longitudinally using a splitting blade or chisel (Figure 6). The scion wood, which should be of similar diameter as the rootstock, receives two angled longitudinal cuts to create a wedge (Figure 6A) which is then inserted into the split rootstock trunk (Figure 6B). While a simple procedure, true cleft grafting is not recommended for field grafting in most woody perennials because it is often difficult to source scion wood similar in diameter to the rootstock (Jensen et al. 1981).

Modified cleft grafting (Figure 6D), or side whip grafting, is a more common form of cleft grafting in vineyards and orchards as this style maximizes cambium contact when the rootstock and scion material are of different sizes. In this grafting style, the rootstock trunk is cut, then two face cuts and "tongue" cuts are made on opposite sides of the rootstock, parallel to the cordon wire. Two two-bud scions are then cut to match, tapped into place to interlock the tongues, and then taped and painted to protect the graft (Alley 1975a). This grafting style is presented in detail with photographs in The Field Grafting Process—Modified Cleft Grafting section below.

Preparation for Field Grafting

Certain characteristics of both the rootstock and the scion need to be considered when deciding upon the feasibility of a grafting project. By fully understanding the grafting styles and carefully considering potential pitfalls, the success rate will increase. Several basic steps should be taken when considering any grafting work.

Step 1: Check the disease status of rootstock and scion wood.

Virus diseases are transmissible between rootstock and scion, so it is important to test a block prior to field grafting. Otherwise, the rootstock might be a source of virus that will infest the newly-grafted scion (Rayapati and Ball 2018; Rayapati et al. 2008), limiting both the longevity of the new block and graft take (Hoare 2007; Uyemoto and Rowhani 2015). Likewise, sourcing virus-free scion wood is essential. Be sure to inquire with your nursery about getting certified virus-free scion stock, as not all stock is certified. If you are going to gather budwood from another vineyard rather than purchase from a nursery, make sure that you have the vines tested for virus before collecting the wood.

Transmission of *Agrobacterium vitis*, the bacterium responsible for grapevine crown gall, can also occur between the rootstock and the scion (Burr et al. 1998). Following vine damage, in this instance trunk cutting and grafting, *A. vitis* can hijack the vine's cellular machinery, causing a proliferation of growth around the wound site (graft union) (Figure 7). This undifferentiated tissue growth, called a gall, will disrupt the flow of water and nutrients from the rootstock to the scion, resulting in graft union failure.

Step 2: Selection and preparation of the rootstock and vineyard infrastructure.

Before beginning a grafting project, the viability of the block needs to be assessed. Certain characteristics, including established disease issues or old vines with low vigor, limit the chances of successful grafting (Melnyk and Meyerowitz 2015). Once grafting has been deemed viable, the future training system must be considered because graft height can be adjusted to match the desired system. Ideally, shoots from newly-grafted vines need to be secured to the trellis system to reduce wind or other mechanical damage until the graft union fully heals. Even unsupported shoot growth can be heavy enough to cause graft union separation and eventual failure. Because of this, in-field vines (the future rootstock) are often cut at a height that puts new scion growth as close to the cordon wire as possible, without being too high. Grafts that are too high could require an acute bend that would result in broken shoots or grafts when new growth is secured to the wire. Somewhere around 8 to 12 inches below the cordon wire is preferable. Higher grafting positions can be advantageous in other ways, from providing a more comfortable working height for the grafting and vineyard crews to potentially increasing winter survival compared with lower grafts (Jensen 1971; Keller et al. 2007).

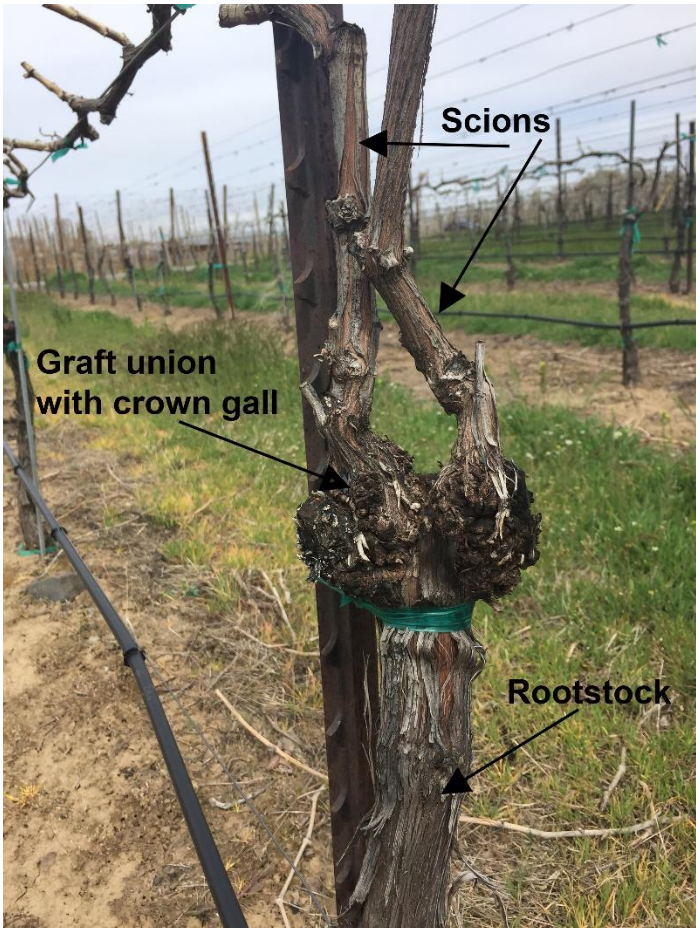

Figure 7. One of the biggest challenges of grafting onto old vines is the expression of crown gall at the graft union. Often, older vines are infected with the bacterium that causes crown gall, but they have yet to experience the disease due to lack of an event (e.g., cold damage) that would induce crown gall expression. Field grafting provides that wound event, and galls will often rapidly form at the graft site. In the image above, the two scion whips have severe crown gall formation at the graft union. In this vineyard, the presence of crown gall resulted in graft union failure of over 50%. Photo by Michelle Moyer, Washington State University.

Step 3: Selection and preparation of the scion wood.

The scion wood must be carefully prepared to avoid graft union failure. If wood is to be collected by the grower and the virus status of the block has been confirmed as negative, careful selection of robust canes should take place during the dormant season prior to any major freeze events. Collect scion wood that is from a healthy section of the vineyard, free of pest damage, and between 5/16 and 9/16 inch in diameter (Coe et al. 2006). Enough wood should be collected to provide two, two-bud scion pieces per grafted vine plus an extra 15% to provide the crew with plenty of healthy options on grafting day. This excess will also serve as available material for regrafting any failed unions. If wood is to be procured as dormant cuttings from a nursery, verify the virus status of mother plants, the quality of storage conditions, and the overall health status of mother block vines.

Scion wood should be bundled and placed into polyethylene bags along with a moist (but not wet) media such as wetted newspaper, paper towels, or sawdust. It should then be stored at temperatures just above freezing (34 to 36°F) (Perry 2014). Depending on the collection date, it may be necessary to rewet the scion stock throughout cold storage. If too much moisture is added to the stored wood, mold will become an issue. Likewise, if the stock is stored too dry, desiccation injury will occur (Perry 2014). Scion wood should not be used if it was collected earlier than the preceding dormant season.

The Field Grafting Process—Modified Cleft Grafting

For most commercial grafting projects, a skilled grafting crew is necessary. While grafting *could* be done successfully by a vineyard crew, the skill required to achieve a high grafting take comes from experience. The speed and efficiency with which professionally-trained crews work often mitigates any cost savings that could be incurred by grafting with in-house labor.

Timing

The timing of grafting is important in achieving a high success rate. The ideal time is in spring, after the threat of frost has passed and about a month after budbreak but before rapid shoot growth (Coe et al. 2006; Jensen 1971) or when maximum daytime temperatures hover around 60°F (Hansen 2011). In Washington, this usually occurs between early April and mid-May. Grafting before these conditions are met can reduce success due to slow callus development in low temperatures. Grafting later than the ideal window can also reduce success due to heat and water stress on the scion before vascular tissue is fully formed. There is still a risk of graft union failure when it is done during the optimum window. If there is excess sap flow, pressure can build within the vasculature, dislodging the scion. This is more common after a wet winter. In this situation it would be better to graft towards the latter part of the ideal window when there is less winter moisture in the soil. The best way to manage the timing of a grafting project is to be disciplined; if a grafting crew is unavailable during the desired window or weather conditions are not conducive to success, consider postponing the project until the following season.

Preparing the Existing Rootstock for Grafting

Early preparation of vines that will serve as a rootstock is a must for large-scale projects. Often, the cordon wire and old cordons of the vines must be removed prior to grafting. A grower can do these initial cleanup cuts up to several months in advance; the final cuts to rootstock trunks that will be used for grafting should occur immediately before the grafting crew arrives (Coe et al. 2006).

Preparing the Scion Wood

The day before grafting, remove the scion wood from cold storage and allow it to slowly return to ambient temperature; only remove enough material for a single day's work. After acclimating to ambient temperatures, the scion wood should be rehydrated by soaking in water for several hours.

Field Grafting—The Day-Of Activities

Both the scion and the rootstock need to be cut the day of grafting to create fresh, clean wounds that will be more likely to fuse. The entire grafting process using the modified cleft (also called side whip graft) grafting technique is detailed on pages 9 through 12.

Expected success rates of field grafting in eastern Washington range from 90 to 95% under ideal circumstances. Even with this high success rate, it is recommended that the block be assessed after one to two leaves have opened on the new scion shoots. Failed grafts can be regrafted immediately after assessment, provided upcoming weather conditions are favorable for grafting. While immediate regrafting of failed grafts is the ideal, it is often impossible to reschedule the grafting crew on such short notice. In these situations, suckers from the rootstock may need to be retained to serve as a grafting point the following season. Managers need to think carefully about what amount of regrafting is acceptable the following season. Invariably, there will be occasions where field grafting does not achieve the expected 90–95% success rate. In these instances, managers will have to decide among several management responses. The first is to retain suckers and attempt to regraft the block the following season. The second is to pull out individual vines where grafting has failed and replant into those individual locations either in the same season or the following season. The third is to remove the entire block and replant it. While this third option is not ideal, fighting the variability that individual replanting induces can be a management nightmare.

Managing Vines after Field Grafting

The management of newly-grafted vines is time sensitive and labor intensive. It is imperative that grafted blocks receive adequate attention due to the fragile nature of the graft union and the speed at which scion wood can grow.

Managing sap flow is one of the major challenges that needs to be addressed immediately following grafting (Chapman 2018). With too little sap flow, scion wood will not be able to push buds and grow; with too much sap flow, scion wood can be disconnected from the rootstock cambium, and the union will not heal (Coe et al. 2006; Cowham 2008; Hoare 2007). Irrigation management also plays a role in sap flow and vine vigor. Short duration, high frequency irrigation sets are recommended in newly-grafted vineyards to avoid extreme sap pressure and excessive vine vigor. Just like too much water, too little water also can be problematic. Do not water stress the vines, as that will result in the slow-down or outright reduction of callus formation, which will prevent the graft wound from healing. Balanced vine growth is one of the greatest challenges of a grafting project because of the inherent imbalance in vigor between rootstock and scion in a field-grafted vineyard.

Vine sucker management is important in a newly-grafted vineyard. Because field-grafted vines have a large, mature root system, they can impart excess vigor to shoots. To reduce this vigor, vine suckers are intentionally retained through mid-season in the first growing season of field grafting (Figure 8).

Figure 8. In some cases, shoots from the rootstocks are intentionally retained (base of trunk—light red/pink) to manage vigor in the first season of grafting. However, it is important to remove these shoots mid-to-late season that same year to avoid confusing them with scion shoots and accidently training them up to the fruiting wire during the winter. Photo by Eric Gale, Ste Michelle Wine Estates.

Field Grafting—The Day-Of Activities

Cutting the Rootstock

Step 1

On the day the vines are to be grafted, cut the trunks about 6 to 12 inches below the cordon wire to locate new growth in a position that can quickly be tied to the wire for support.

Step 2

Following this large cut, face cuts are made on either side of the rootstock trunk, parallel to the vine row. These cuts should be shallow to expose actively growing cambium tissue.

Step 3

Two additional vertical cuts are made into the face cut:

Left—one near the base of the face cut, and
Right—one near the top.

These cuts, in conjunction with mating cuts on the scion, form a locking interaction to mechanically secure the graft union.

Step 4

To mitigate excessive sap flow pressure, make two cuts near the base of the trunk that extend just into the cambium (approx. 0.25 inches deep). Make these cuts when grafting. Refresh the cuts or make fresh cuts any time these basal cuts cease to bleed, or bleeding at the grafting site increases.

Photos by Eric Gale, Ste. Michelle Wine Estates.

Cutting the Scion

Cuts need to be made on the scion that complement the cuts made to the rootstock. This facilitates the mechanical join-ing that is necessary for graft union success. These are often referred to as “mating cuts.” Before making any cuts to the scion, be sure it is oriented correctly: all cuts are made on the basal end.

Step 1

First, a sloping face cut is made on the scion.

Step 2

The length of this cut matches the length of the face cut on the root-stock.

Step 3

Next, a cut perpendicular to the face cut is made to provide a “tongue” to interlock with the rootstock.

Step 4

Finally, a face cut from the opposite face of the scion is made, forming a wedge that seats into the lower rootstock face cut.

Photos by Eric Gale, Ste. Michelle Wine Estates.

Fusing the Rootstock and Scion

Step 1

Following the cuts to the rootstock and the scion, the two parts can be pushed together.

Step 2

The rootstock and scion are then tapped into place using the handle of the grafting knife. Once the scion is fully seated into the rootstock the sound of the tapping will change to a dull thud.

Step 3

On larger diameter rootstocks, the scion wood should be placed near one edge of the face cuts to maximize scion-rootstock cambium-to-cambium contact. If cambium-to-cambium contact is not achieved, the resulting callus tissue will not fuse properly, and the graft union will fail.

Photos by Eric Gale, Ste. Michelle Wine Estates.

Field Grafting—The Day-Of Activities

Protecting the Graft

While the interlocking “tongues” provide some mechanical strength between the scion and rootstock, grafting tape further protects the scion from dislodging from the rootstock, leading to graft failure.

Step 1

Tape immediately following the fusing of the rootstock and scion. The grafting tape can be left in place until it breaks down naturally from exposure to the elements. For examples of different tape products, please see Singha (1990).

Photos by Eric Gale, Ste. Michelle Wine Estates.

Step 2

Following taping, major cut areas of the graft union are painted, including the cut, upright ends of the scion wood. The paint protects the cuts from desiccation and provides a barrier to fungal infections. Where desiccation is less of a concern, the graft is not painted. When not painted, the color of the grafting tape becomes important as clear grafting tape promotes excess heat buildup at the graft union during warm weather, leading to graft union failure (Cowham 2008). Recommended graft painting options include those sealants and waxes that are specifically designed for grafting. These are available at most orchard and vineyard supply retailors. Avoid using sealants that are designed for other purposes (e.g., latex paint, roofing tar) as they may cause phytotoxicity due to secondary ingredients.

Step 3

As sap begins to flow through the vasculature, pressure relief cuts should be made at the base of the trunk. These cuts prevent the upward sap pressure from pushing the graft union apart. Cuts should reach the cambium, approx. 0.25 inches deep. Refresh these cuts every two to three weeks during the first season, or when the scion wood begins to show increased sap bleeding.

There are several advantages to retaining rootstock suckers: (1) rootstock suckers divert some of the sap pressure from the healing graft union, (2) if the graft fails, rootstock suckers could provide a regrafting point, and (3) excessive vine vigor can be mitigated by keeping extra rootstock suckers to divert resources away from rapidly growing scion wood. For vineyard blocks that do not have historically high vigor, it can be appropriate to remove rootstock suckers once scion shoots have reached about one foot in length.

Because excessive vigor is a greater management concern than a lack of vigor on grafted sites, factors that can increase vine vigor, such as soil and vine nutrient management, need to be considered. Prior to grafting a site, soil tests for nutrient analysis should be done; if the timing is appropriate, tissue testing of the rootstock is also recommended. Assuming no serious nutrient deficiencies were present in the "to-be" rootstocks, post-grafting nutrient management needs to be based on managing vigor relative to that site. Nitrogen additions are the main consideration, and for fully mature and producing vineyards, nitrogen rate recommendations range from 10 to 60 lb N/acre depending upon factors such as the previous season's yield, soil type, and grape variety (Moyer et al. 2018). If grafting occurred in a low vigor site, 25 to 50% of the recommended nitrogen rates would likely be sufficient during the first year of graft healing. On higher vigor sites, even less nitrogen is likely needed; one application totaling 25% or less of the suggested yearly nitrogen requirements for a fully producing vineyard is recommended. In either situation, tissue nutrient analysis should be performed in the second season to determine vine nutrient status.

Managing yield on a newly-grafted vineyard in the first two years following grafting is key to promoting a strong graft union. From a physical standpoint, there is a risk that the cluster weights exceed what the healing graft union can support, resulting in a crack in the graft, or complete failure of the graft union. From a physiological standpoint, if a young vine is overcropped, it might divert resources from the healing graft union to the fruit. Alternatively, the vine may shut down growth and development too early in the growing season without adequate carbohydrate reserves—an open invitation for winter damage and poor growth the following season (Stergios and Howell 1977). Shoot and cluster thinning by hand are best for managing yield in the first few years after grafting (Cowham 2008). For an overview of a few areas of concern for grafted blocks, along with mitigation strategies, see Table 3.

Table 3. Concerns and management considerations in vineyards planted to grafted vines.

Concerns	Reason for Concern	Mitigation Strategy
	Pests and Diseases	
Plant Viruses	Virus infection is transferrable across the graft union.	Only graft with material that has tested negative for virus, or with certified virus-free nursery material.
Crown Gall	Grafting can lead to the development of galls at the graft union.	Do not field graft vineyards that have expressed crown gall symptoms in the past.
Powdery Mildew	Excessive mildew infection on newly-emerged shoots can stunt growth.	Follow a powdery mildew spray program to avoid infection.
Trunk Diseases	Large grafting wounds increase the surface area available for trunk disease infections.	Trunk cutting and grafting should be timed to avoid trunk disease spore release events.
Phylloxera	If a vineyard block is losing vigor due to a pest, such as phylloxera, top grafting will not induce greater vigor.	Remove own-rooted vines and replant with bench grafted vines on phylloxera-resistant rootstocks.
	Site and Plant Issues	
Winter Injury	Excessive crop load can limit winter hardiness; vines cannot be retrained from the rootstock without sacrificing variety changeover.	Shoot and cluster thinning to manage crop load during seasons two and three to limit overcropping.
Poor Graft Take	Low percentages of graft take can lead to uniformity issues in the block.	Regrafting areas of low take during the first or second season; replant the entire block if take is very low.
Spot Replanting	Irrigation delivery and established nematode populations make spot replanting challenging.	Consider replanting the entire block if a large percentage of vine grafts fail.
Graft Scion Rooting	If the graft union is at or below the soil line, the scion may root rather than joining the rootstock.	Make sure graft unions are well above the soil line.

Summary

Field grafting can be a cost-effective way to "quickly" adjust varieties to match changes in market demand. It is best used for changing scion varieties in older vineyards where production has been consistent and the vines are healthy. It is not recommended as a replacement for complete vineyard replanting when vineyards are poorly performing due to disease or poor site conditions. While there are a number of techniques for field grafting perennial fruit crops, the keys to a successful field grafting project are: (1) to know the disease status of both your scion and rootstock varieties, (2) plan ahead so you can graft during the window of optimal vine growth and weather conditions, (3) take the time to properly prepare your rootstock and scion wood, and (4) understand that management of a newly field-grafted vineyard requires a few more steps than management of an established, producing vineyard.

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