Teaching Methods

Use of Tropical Hibiscus for Instruction in Grafting

Kenneth W. Mudge,[1]
Kelly Hennigan,[2] and
Peter Podaras

ADDITIONAL INDEX WORDS. **bud grafting, budding, distance learning, *Hibiscus rosa-sinensis*, online, laboratory instruction, scion, stock**

SUMMARY. An instructional system involving tropical hibiscus (*Hibiscus rosa-sinensis*) was developed for teaching hands-on grafting skills as part of a traditional comprehensive course in plant propagation and also as part of an online grafting course. The advantages of using tropical hibiscus include the following: the absence of phenological constraints associated with seasonal changes in temperate woody species; the comparative ease of grafting hibiscus, assuring positive reinforcement of the student's learning experience; and the ease of propagating and growing hibiscus in the greenhouse for use at any time of year. The three methods included in these laboratory exercises are top wedge grafting—selected for its ease and high rate of success—T-budding, and chip budding. In addition to development of hands-on skills, the exercises are designed to teach students three of the most important requirements for successful grafting of any species, regardless of method. These requirements include cambial alignment, application of pressure between stock and scion, and avoidance of desiccation. An online rating tutorial and lab report form was developed for students to self-evaluate their grafted plants.

Department of Horticulture, Cornell University, Ithaca, NY 14853.

The authors wish to thank the greenhouse staff of the Department of Horticulture, Kenneth Post greenhouse complex, at Cornell University.

[1] Associate Professor. To whom reprint requests should be addressed. E-mail address: kwm2@cornell.edu.

2 Instructor, Department of Horticulture, SUNY Morrisville, College of Agriculture & Technology, Morrisville, NY.

In the agricultural sciences, including horticulture, many essential skills require the use of tools or one's own hands to manipulate plants, animals, or their environments. Grafting is one such skill. It is an important topic for any well rounded course in plant propagation, or for other courses that deal with propagation-related issues. Grafting has a long history in the development of agriculture and it continues to play a significant role in modern horticulture (Hartman et al., 2002). Its major uses are to maintain the clonal identity of cultivars that are otherwise difficult to propagate asexually, to create compound genetic systems in order to optimize specific scion and rootstock genotypes on a single plant, and to avoid undesirable seedling-related rejuvenation in fruit tree and other crops.

Not only is grafting important in commercial horticulture, it is also a subject that fascinates both students preparing for careers in horticulture and amateur gardeners seeking advanced horticultural skills. However, seasonal constraints limiting the availability of suitable plant material, the relative difficulty of grafting some species, and the considerable amount of practice required for mastery of certain grafting methods, all present pedagogical and logistical challenges to instructors and students of grafting. Given that teaching schedules rather than plant phenology often dictate when grafting is taught, and the desirability of providing students with a positive, successful learning experience, the ideal species for grafting instruction should be available and suitable for grafting year round and be relatively easy to graft by a variety of different methods. Tropical hibiscus meets these criteria.

ADVANTAGES OF TROPICAL *Hibiscus*. For grafting instruction, tropical hibiscus is an attractive alternative, both pedagogically and logistically, to the commonly used temperate woody species such as apple (*Malus ×domestica*), or herbaceous species such as cactus (e.g., *Gymnocalycium* spp.). Tropical hibiscus can be grown in a greenhouse at any time of year, without the interruption of seasonal dormancy. It is easily propagated from cuttings, which may also be another useful hands-on lesson in propagation. The three methods for grafting hibiscus described below range in difficulty from very easy to moderately challenging. Thanks to amateur breeders, an abundance of unpatented cultivars with large showy flowers in a wide range of colors is available. Students are often impressed with the novelty of grafting multiple scion cultivars that will bear differently colored flowers on a single understock. The commercial practice of using grafting to propagate fancy, polyploid cultivars of this species, which tend to be difficult to root from cuttings, contributes relevance to the exercise.

Three specific grafting and budding methods are subsequently described, including top wedge grafting (TWG), T-budding (TB), and chip budding (CB), but many other grafting methods can be successfully performed on tropical hibiscus to achieve similar instructional goals (Morgan, 2002).

PEDAGOGICAL FOCUS ON REQUIREMENTS FOR SUCCESSFUL GRAFTING. Teaching a particular set of hands-on grafting skills is merely the most obvious objective of these laboratory exercises, but not necessarily the most important. Using these exercises to reinforce classroom learning about the universal requirements for successful grafting by any method is even more important. Liberty Hyde Bailey succinctly stated three of the most important requirements in his *Standard Cyclopedia of American Horticulture* (1928):

"The ways or fashions of grafting are legion. There are as many ways as there are ways of whittling. The operator may fashion the union of the stock and the cion to suit himself, if only he apply cambium to cambium, make a close joint, and properly protect the work."

Grafting of hibiscus can be used to reinforce these three requirements for successful grafting: cambial alignment, application of pressure, and avoidance of desiccation. Additional requirements for scion–stock compatibility and seasonal considerations are not directly addressed by these exercises. After completing this series of laboratory exercises, students should be able to confidently transfer their new grafting skills to other methods and other species. These universal requirements are first presented to students in one or more lectures titled "Requirements for Successful Grafting and Budding" that include numerous examples taken from a range of different species and grafting methods. Subsequent hands-on learning of the three methods with hibiscus, presented below, reinforces the connection between principles and practices. Students can then apply these same criteria to different species and different grafting methods. They learn that successful grafting by any method must satisfy each of the requirements in one way or another depending on different combinations of prevailing factors including method, species, seasonal considerations, and horticultural goal.

Materials and methods

Several different hibiscus cultivars are maintained in the greenhouse throughout the year to provide a source of cuttings for propagation of understock plants, and to serve as scion-donor plants for student grafting exercises. For propagation of understocks, leafy, semi-lignified, auxin-treated cuttings are rooted in 4 to 6 weeks and grown on in 4-inch (10.2 cm) plastic pots (Kord Products, Toronto). Optimal plant size for student grafting—about 3.3 ft (1 m) in height and 0.4 inch (10 mm) in stem diameter at 7.9 inches (20 cm) above the soil line—is achieved in about 16 to 20 weeks. Regular removal of lateral shoots and flower buds is recommended to obtain whips of sufficient height and diameter in the shortest time possible.

The grafting and budding exercises described below can be adapted to any of several teaching situations and methods of presentation. We have used these exercises in the laboratory portion of a traditional face-to-face general plant propagation course, and as part of two different online grafting courses (Mudge, 2003), one for university students and another for advanced gardeners. Regardless of venue, each student receives three or four understock plants about 3.3 ft tall and 0.4 inch in basal diameter. With each plant, the student performs one terminal TWG, one CB, and one TB. The two bud grafts are evenly spaced on opposite sides, along the basal half of the stem, where the diameter and degree of lignification meet the criteria described below.

For evaluation of student learning, in the traditional face-to-face class, students are required to perform a graded demonstration of proficiency for the instructor, as well as a post hoc critique and performance evaluation 4 weeks after grafting. Online students do the 4-week evaluation only. Statistical analysis of student self-evaluation ratings was performed using the Proc GLM procedure (SAS Institute, Cary, N.C.). In addition, to reinforce the relationship between universal requirements and hands-on grafting techniques, students are asked to write about the relationship between the three essential requirements and the specific sequence of tasks involved in each method. This is done as an online discussion board topic or as an essay question on an exam.

Supplies necessary for students to perform the exercises include a grafting knife, pruning shears, and 5-inch (12.7 cm) × 0.25-inch (0.64 cm) × 0.016 gauge latex rubber budding strips (FarmHardware.com, Sacramento, Calif.). For TWG they also need an 3.2 × 7.9-inch (8 × 20 cm) polyethylene bag and twist-tie for each graft.

The general carpentry associated with each of these methods is apparent from Figs. 1 and 2, which show the shape of cuts and fitting together of scion and stock. The details of each method, which vary with respect to practitioners, species, and other factors, have been described in detail in a number of widely available resources on grafting, including Garner (1958), Hartman et al. (2002), and MacDonald (1986).

TOP WEDGE GRAFTING. This nonrind grafting method is used widely in the propagation of tropical fruit trees, especially avocado. The basic carpentry involved in TWG is illustrated in Fig. 1A. The base of a multinode scion, from which leaves greater than 0.4 inch (1 cm) long have been removed, is cut to a tapered wedge that is inserted into a vertical cleft cut down the center of a decapitated understock plant. The scion–stock junction is wrapped with a budding rubber. An 3.2 × 7.9-inch polyethylene bag, the inside of which has been sprayed lightly with water, is then placed over the scion and fixed with a twist tie about 1 inch (2.5 cm) below the scion–stock junction. Post-grafting management of the grafted plant involves growing it under about 70% shade on a greenhouse bench.

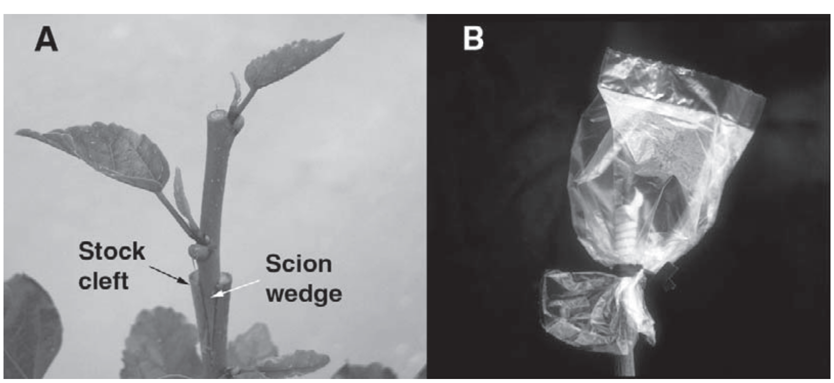

Fig. 1. Top wedge grafting of hibiscus showing (A) the tapered wedge of a freshly grafted scion inserted into the vertical cleft of the understock, and (B) the completed graft, wrapped with a budding rubber and bagged to avoid desiccation of the scion.

T-BUDDING. This rind bud grafting method is used for propagation of fruit trees, shade trees, and other nursery stock of both temperate and tropical species. Although the historical origin of bud grafting, like that of most grafting methods, is obscure, inoculation, a

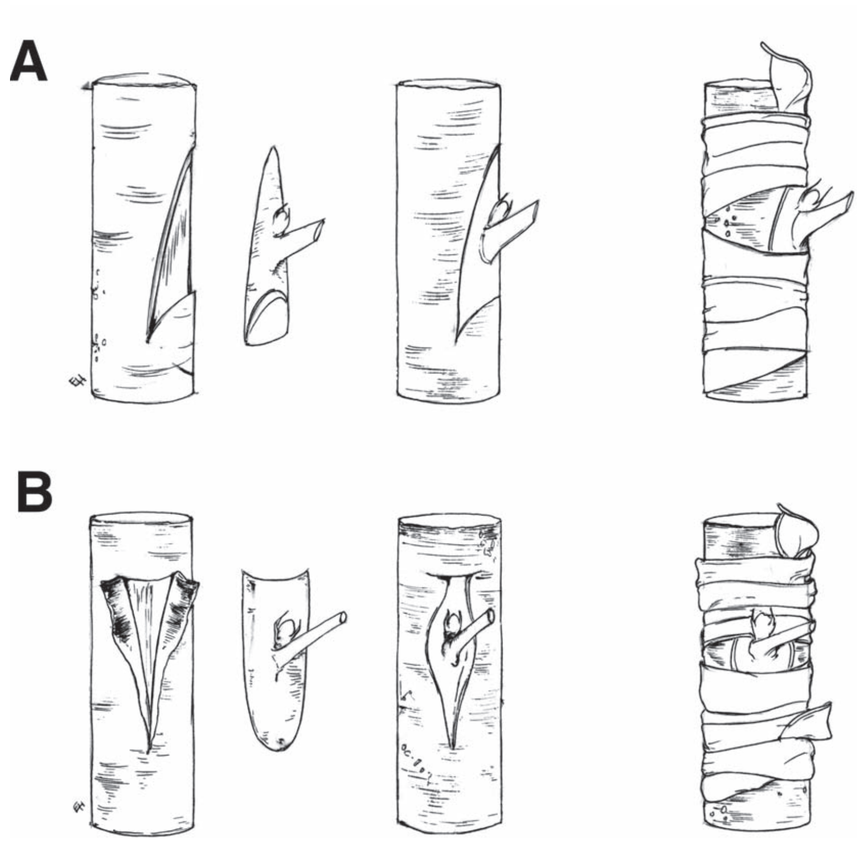

Fig. 2. (A) Chip budding showing the apically tapering scion bud and a complementary space in the understock (left), and the bud tied firmly into place (right). (B) T-budding showing the basally tapering scion bud and the t-shaped pouch in the understock (left) and the bud inserted and tied into place (right). Illustration by Eric Hsu.

procedure similar to modern TB, was illustrated and described in Robert Sharrock's *History of the Propagation and Improvement of Vegetables...* (1672), and is still widely practiced. The basic carpentry of TB is illustrated in Fig. 2B. For TB, as with other rind grafting techniques like patch budding, four-flap grafting, etc., it is important that the bark of the understock is slipping to allow the bark flaps created by the T-shaped cut to separate easily from the underlying wood when lifted away with the back side of the knife. This condition occurs during periods of active shoot growth of the understock, which can be maintained throughout the year with well watered and fertilized greenhouse-grown hibiscus. This offers a considerable advantage over the bark of temperate nursery stock, which ceases to slip just before natural defoliation occurs and hence cannot be T-budded at that point. The bud shield should be cut from a scion-donor plant at a subterminal node at a point on the stem where the corky outer bark is incompletely formed, as characterized by discontinuous patches. The bud shield is then inserted under the bark flaps created by the T-shaped cut in the stock at a point on the stem exhibiting similar bark development. This corresponds to a stem diameter of ≥0.3 inch (7 mm), which is the minimum necessary for successful TB. Next, a budding rubber is wrapped around the area from about 1 cm below the bottom of the T cut and ending about the same distance above it. The rubber should cover the T-budded area completely, except for a small space from which the scion bud or growing point protrudes.

Chip budding. Although TB is still a common budding method used worldwide, CB has become the preferred budding method for propagating temperate fruit trees and many ornamental shade tree cultivars. For a nonrind grafting method like CB, it is not necessary that the bark be slipping. For temperate woody species like apple, CB can therefore be used during late summer and early fall budding for several weeks after T-budding is no longer feasible due to cessation of cambial activity associated with the later stages of shoot dormancy. Another reason for the increased popularity of CB is more rapid bud union formation, resulting in better over-winter survival rates. Figure 2A shows the shape and relative size of the scion bud chip and of the complementary space cut into the stock. Both are cut through the bark and into the underlying wood, unlike TB, in which the bud shield is placed on the surface of the wood just under the bark flaps.

Results

Student self-evaluation. In addition to real-time instructor evaluation of student grafting proficiency, which is part of the traditional instructional setting but not of the online setting, students in either setting perform a self-evaluation of their grafts 4 weeks after grafting. Self-evaluation involves applying a numerical rating system and producing a written narrative. The criteria for the numerical rating are the technique-related requirements for successful grafting and budding described above. These are presented to students not only as general principles during oral or web-based lectures, but also as they apply specifically to hibiscus. Figure 3 shows the online self-evaluation tutorial and lab report submission form. The web site, devoting a separate page to each method, includes pictures and descriptions of correctly performed grafts as well as of the most common errors (Mudge and Hennigan, 2003a, 2003b, 2003c). Students use this online lab report form, or a printout followed by electronic submission, to numerically rate their grafts. They perform at least four grafts using each method and then choose the three best grafts for each method which are to be rated. This is accompanied by a short narration for each method that is a self assessment of the extent to which the student feels he or she has mastered the technique and understands how and what needs improvement. The reliability of the numerical self-evaluation system has been verified by independent instructor inspection and rating of the same grafts rated earlier by the students.

Linear regression analysis of a comparison between student self-evaluation and instructor evaluation indicated a moderately high correlation between the two for TWG (r^2 = 0.75), CB (r^2 = 0.68), and TB (r^2 = 0.70) (Mudge and Way, 1999). Table 1 summarizes student numerical self-evaluation and

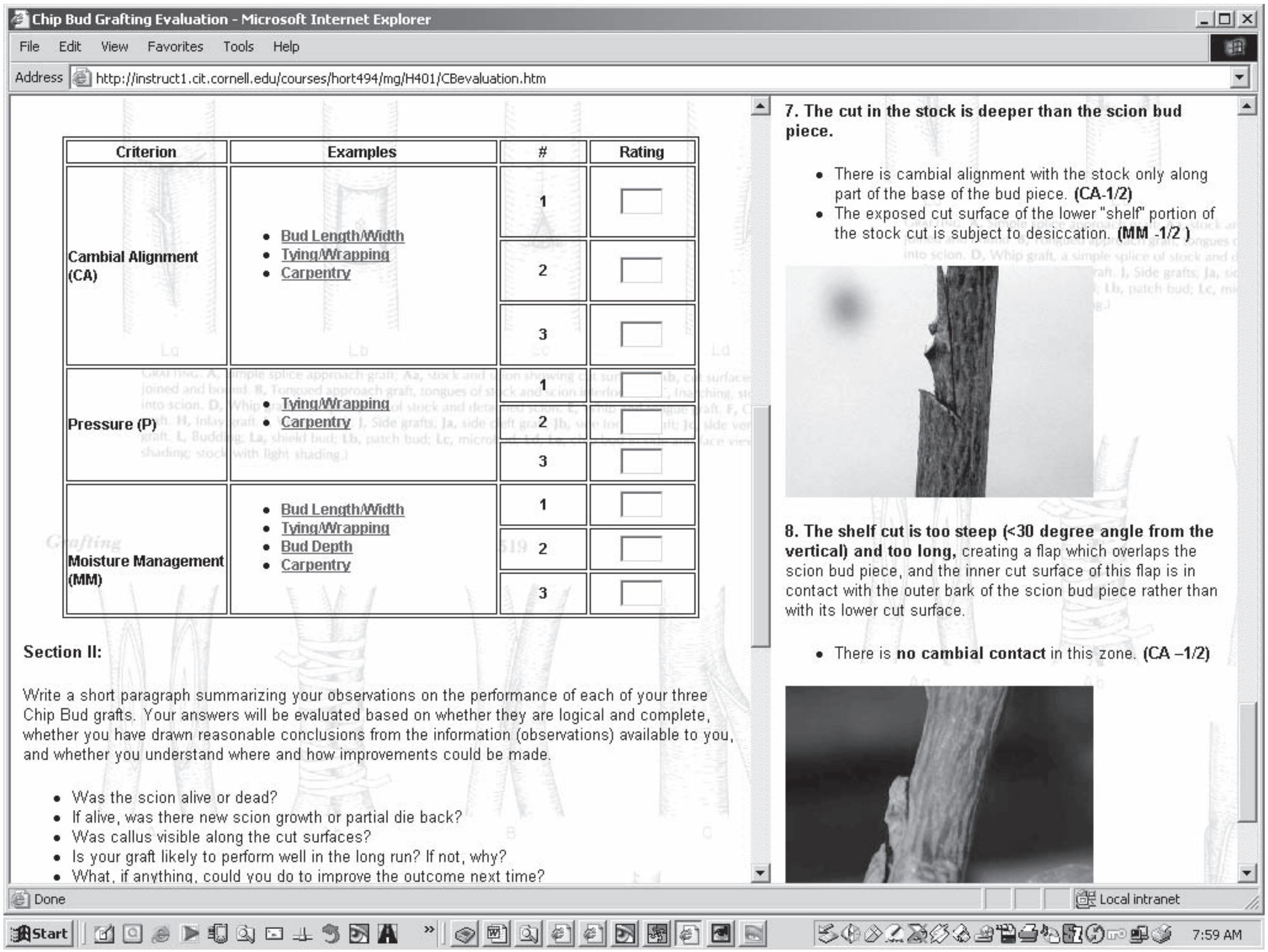

Fig. 3. Online lab report form and rating tutorial for student self-evaluation of chip budding (Mudge and Hennigan, 2003b). In the left frame, numerical ratings (0-3.0) are entered corresponding to each of the three requirements for successful grafting. Section II (lower left frame) includes questions for the student narrative. Examples of good and poor technique for each requirement are described and illustrated in the right frame. Suggested rating deductions for common errors are displayed in parentheses (CA = cambial alignment; MM = moisture management).

grafting success, expressed as percent survival, for a more recent class (Fall 2002, H400, traditional face-to-face instruction). Table 1 also shows average ratings for each of the three requirements for each method. Students rated pressure to be significantly less difficult than cambial alignment or avoidance of desiccation for TWG ($P \leq 0.05$), but for CB and TB, the differences were not statistically significant.

The student narrative part of the lab report has also proven to be an effective means of evaluating student learning. From student comments it is clear that in most cases they understand why a particular graft failed and how to avoid the mistake in the future, or how to improve on their technique even when the graft survived. For example, the comment "The scion dried out because it was too thin and there was no cambial alignment" suggests the student has accomplished the higher-order learning task of relating general principles about desiccation avoidance and cambial alignment to her specific failed attempt at chip budding (Bloom, 1956). The problems most commonly encountered by students are addressed below in the context of the three specific methods or in the context of their relationship to each of the three requirements for success.

GRAFTING METHODS. Since TWG is the easiest of the three methods to perform, it is the first lab exercise that students undertake. The rate of successful graft union formation is typically greater than 90% (Table 1). Although students have a high rate of success with this method because hibiscus is so forgiving of imperfect technique, students make, and it is apparent from Table 1 that they learn to recognize, a number of common mistakes that might contribute to graft union failure. Such mistakes are especially likely to occur when using a species that is more difficult to graft than hibiscus or a method that is more difficult to execute than TWG. In the case of TWG, new shoot growth from the scion is apparent within about 1 week after grafting. Callusing of the scion–stock junction is apparent within about 3 weeks, at which time one or two 0.8- to 1.2-inch-long (2 to 3 cm) slits are cut on opposite sides of the polyethylene tent to begin acclimation of the scion to the lower ambient humidity of the greenhouse. After an additional week, the bag and wrappings can be removed and the union inspected for survival, callus formation, scion growth, and otherwise evaluated as described above.

T-budding is perceived as the most difficult of the three methods

Table 1. Average numerical rating from student lab reports of the three requirements for successful grafting for each of three grafting methods performed on tropical hibiscus.

	Requirement for successful grafting[x]					
Method	Cambial alignment	Pressure	Avoidance of desiccation	Overall	Success (%)	n
Top wedge graft	2.5 b[y]	2.8 a	2.5 b	7.8	93.8	64
Chip budding	2.3 a	2.4 a	2.3 a	7.0	57.9	57
T-budding	2.3 a	2.2 a	2.1 a	6.6	50.0	58

[x]Rating scale 0-3.0 for individual requirements; overall rating is the sum of the individual ratings.
[y]Any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$, by Duncan's multiple range test.

by most students. In Fall 2002, the class reported 50% success (Table 1). New shoot growth was reported for less than half the surviving buds. This suppression of shoot growth is due to apical dominance from the actively growing terminal shoot tip rather than to a problem with the graft union. If the objective were to force new bud growth, as would be the case in most commercial nursery production situations, the portion of the understock shoot above the newly inserted bud would be cut off or bent back just above the bud, either several weeks after budding for tropical species such as avocado (*Persea americana*) and hibiscus, or in the early spring in the case of late summer and fall field-budded temperate crops such as apple or stone fruits (*Prunus* spp.). It is typical of multiple-grafted hibiscus that after several months a well joined TB or CB will initiate growth even without cutting back the terminal, which in this case is often a newly grafted TWG scion. Among the three methods, stem diameter, degree of lignification, and bark development are most critical for TB. If the stem of the understock is less than about 0.3 (7 mm) in diameter, the pouch created by the flaps of the T cut is too small to insert a scion bud shield. If it is much larger than about 0.4 inch in diameter, the corky outer bark or periderm is often too thick and inflexible for T-budding. In such a case, the bark flaps tend to split vertically along their outer edges when lifted away from the underlying wood, or when the bud shield is inserted into the pouch. In fact, this tendency of the bark of hibiscus to split is one of the more challenging aspects of this particular method for beginning students, and one of the few drawbacks to using this species.

The chip budding survival rate was 57.9% in the most recent course (Table 1). Some students report that the actual carpentry of CB is more challenging than that of TB, mainly because of difficulty encountered in cutting the scion bud shield to exactly the same dimensions as the complementary space cut into the stock plant. If this cut-out in the stock extends deeper radially than about 30 to 40% of the stem diameter, the stem of the understock can easily snap off at this point. Another common error is cutting the base of the scion bud chip or the complementary space in the stock at an angle of 90° to the long axis of the stem rather at a downward sloping angle of 30 to 45° to create a slightly recessed, rather than flat, shelf in the understock on which the inserted bud will sit securely to facilitate tying (Fig. 2A).

Requirements for successful grafting. The importance of cambial alignment is best illustrated by TWG and CB, where the width of the scion or scion bud chip should closely match that of the space cut in the stock to receive it. It is acceptable to use a scion or chip that is narrower than the stem diameter (TWG) or space cut into the stock to receive the chip (CB) if it is placed flush to one side so the cambia align on that side only. Misalignment due to centering a narrower scion is a common error. Another carpentry-related error that can influence cambial contact occurs when the cut faceof the scion tapered wedge (TWG) or scion bud chip (CB) is not perfectly flat, but instead concave or irregular due to whittling of the surface. The goal is to produce one smooth, continuous cut. In either case there will be one long gap or multiple smaller gaps between stock and scion if cut surfaces are not perfectly flat. Such gaps can be overcome, up to a point, by the pressure created by tightly wrapping the scion–stock junction, which pulls their cut surfaces more closely together.

In addition to generating junction pressure by wrapping the stock and scion tightly together with a budding rubber, for TWG the natural elasticity of the wood of the split ends of the stock cleft creates pressure against the inserted scion (Fig. 1A). Wrapping is the only source of pressure in the case of the budding methods. Wrapping acts not only to create pressure but also to minimize water vapor loss from the wet, freshly cut surfaces of stock and scion, as well as deterring the entry of liquid water, microorganisms, etc., from the outside. This is accomplished by overlapping the budding rubber slightly with each successive turn, as can be seen through the plastic bag in Fig. 1B. For most methods, including CB and TB, wrapping should proceed from the bottom up so that the overlapping turns create a shingling effect that more effectively excludes water (Fig. 2). In the case of TWG, however, wrapping from the bottom up tends to squeeze the tapered wedge of the scion upwards. To prevent this, it is acceptable to wrap a TWG from the top down, beginning with one or two turns around the scion, to hold it firmly in place. In this case, the polyethylene tent prevents liquid water entry. Pressure created by the carpentry or by tying serves not only to draw the cambia of stock and scion into closer alignment when cut surfaces are not perfectly flat, but also to induce alignment of the planes of cell division in the developing callus to give rise to spatially organized tissues of cambium, xylem, and phloem during the graft union formation process (Barnett and Asante, 2000). In the case of the budding methods, excessive wrapping pressure can crush the scion bud shield or chip, especially if its radial thickness is less than 0.1 inch (2.54 mm) at its thickest point. Budding failure, in which the bud desiccates and dies for no apparent reason, can often be attributed to crushing a thin bud shield by wrapping it too tightly.

Scion desiccation before, during, or after the actual grafting is one of the leading causes of hibiscus graft failure (Mudge, personal observation), although it often has little to do with carpentry per se. In many situations, especially those involving temperate species, avoidance of desiccation begins with stock and scion donor phenology. This includes dormant scion grafting and other seasonal considerations, but greenwood grafting of greenhouse-grown hibiscus can be performed any time of year as long as students practice appropriate moisture management. For all three of these exercises, students learn the importance of properly humidified storage of scion wood before grafting and the need to remove leaves greater than 0.4 inch long from bud or scion wood shortly after collection. Postgraft shading of grafted or budded plants is an important aspect of moisture management, especially in the case of TWG, since the interior of the polyethylene tent quickly overheats if exposed to direct sunlight. The bud failure described above, associated with crushing due to excessively tight wrapping of insufficiently thick buds, is exacerbated due to excessive desiccation related to the relatively higher surface-to-volume ratio of a thinner scion bud shield or chip.

Discussion

The particular combination of species and methods described here is recommended as an instructional system for teaching grafting and budding. It emphasizes the application of the universal requirements of successful grafting to a set of specific grafting methods using a relatively easily grafted species that virtually assures some measure of success for students. The three different methods were chosen because they complement each other in at least three instructionally significant ways: grafting vs. budding (TWG vs. TB, CB), rind vs. nonrind (TB vs. TWG, CB) and easy vs. more difficult (TWG vs. TB, CB).

If time or other considerations necessitate choosing a single method, TWG is recommended not only because it is the easiest but also because it most clearly illustrates the role of environmental management in the avoidance of desiccation. The carpentry involved in preparing stock and scion for TWG is straightforward and requires only a minimum of manual dexterity to assure an adequate degree of cambial alignment. The nearly guaranteed success with TWG, juxtaposed with the somewhat more challenging budding methods, is a pedagogically useful contrast. The positive reinforcement of the former enhances the learning experience, while the comparative difficulty of the budding methods gives students an appreciation of the level of skill involved in effective grafting. It demonstrates the need for considerable practice to achieve full proficiency.

This particular hands-on instructional system can be combined with appropriate lecture and reading assignments to give students a solid understanding and appreciation of the art and science of grafting. On postcourse evaluations students almost invariably indicate a high degree of satisfaction with these laboratory exercises, and most report that the hands-on grafting labs were their favorite part of the course. Many past students have subsequently communicated their pleasure and pride in being able to take their successfully grafted, multicultivar and multiflower-color plants home where they are easy to grow in a moderately well-lit environment.

Since hibiscus can be readily grafted by many other methods in addition to those described here (Morgan, 2002), students can be encouraged to try other grafting methods after completing the basic three, and many have done so. For example, a particularly interesting project that has been undertaken by several students over the past three years is the use of approach grafting with hibiscus to create living sculptures, as described by Reames (2003).

Literature cited

Bailey, L.H. 1928. Standard cyclopedia of American horticulture, Macmillan, NewYork.

Barnett, J.R. and A.K. Asante. 2000. The formation of cambium from callus in grafts of woody species, p. 155–168. In: R.A. Savidge, J.R. Barnett, and R. Napier (eds.). Cell and molecular biology of wood formation, BIOS Publ., Oxford, U.K.

Bloom, B.S. (ed.). 1956. Taxonomy of educational objectives: The classification of educational goals: Handbook I, cognitive domain. Longmans, New York.

Garner, R.J. 1958. The grafter's handbook. Oxford Univ. Press, New York.

Hartman, H. T., D. E. Kester, F.T. Davies, and R. L. Geneve. 2002. Plant propagation: Principles and practices. 7th ed. Prentice Hall, Upper Saddle River, N.J.

MacDonald, B. 1986. Practical woody plant propagation for nursery growers. vol. I. Timber Press, Portland, Ore.

Morgan, W. 2003. Ganmor Gardens, Grafting techniques, 9 Mar. 2003, <http://www.australianhibiscus.com/info/graft.htm>.

Mudge, K.W. 2003. The how, when, and why of grafting, a distance learning approach, 7 Sept. 2003, <http://instruct1.cit.cornell.edu/courses/hort494/mg/>.

Mudge, K.W. and K.H. Hennigan. 2003a. HWWGG top wedge grafting laboratory evaluation form, 7 Mar. 2003, <http://instruct1.cit.cornell.edu/courses/hort494/mg/H401/TWevaluation.html>.

Mudge, K.W. and K.H. Hennigan. 2003b. HWWGG Chip bud grafting laboratory evaluation form, 7 Mar. 2003, <http://instruct1.cit.cornell.edu/courses/hort494/mg/H401/CBevaluation.html>.

Mudge, K.W. and K.H. Hennigan. 2003c. HWWGG t-bud grafting laboratory evaluation form, 7 Mar. 2003, <http://instruct1.cit.cornell.edu/courses/hort494/mg/H401/TBevaluation.html>.

Mudge, K.W. and D.G. Way. 1999. Web-based distance learning for university-level instruction in horticulture with emphasis on psychomotor skill development. Proc. 15th Annu. Conf. Distance Teaching and Learning. 4–6 Aug. 1999, Madison, Wis. p. 327–332.

Reames, R. 2003. Arborsculpture, Mar. 9, 2003. < http://www.arborsmith.com>.

Sharrock, R. 1672. The history of the propagation and improvement of vegetables by the concurrence of art and nature: Shewing the several ways for the propagation of plants usually cultivated in England, as they are increased by seed, off-sets suckers, truncheons, cuttings, slips, laying, circumposition, the several ways of graftings and inoculations, as likewise the methods for improvement and best culture of field, orchard and garden plants, the means used for remedy of annoyances incident to them, with the effect of nature and her manner of working upon the several endeavors and operations of the artist / written according to observations made from experience and practice. Oxford Univ., U.K.