Washington and is affiliated with the Western Washington Research and Extension Service. It is a pleasure to introduce to you at this time, George Ryan.

SELECTION AND TIME OF COLLECTION OF MATERIAL FOR STOCKS AND SCIONS

G. F. RYAN

Western Washington Research and Extension Center

Puyallup, Washington

The selection of stock and scion material varies with plant species or cultivar. For convenience in the discussion that follows, plants will be grouped under three headings: deciduous species, coniferous evergreens and broadleaf evergreens. There are some similarities in grafting procedures within these groups, but differences will also be noted. Plants of a wide climatic range, from temperate to tropical areas, will be considered under broadleaf evergreens.

Deciduous species. Grafting of deciduous species is most commonly done in late winter or spring using scion wood from shoots that grew the previous season. One-year wood is preferable in most cases, but two or three-year-old wood can be used. For example, two-year wood is acceptable or even preferred for figs (*Ficus*) and olives (*Olea*), and Leiss (18) reported that with *Fagus sylvatica* two and three-year-old wood gave best results.

The usual recommendation is to select wood from moderately vigorous shoots, and to use the lower or middle two-thirds. Some grafters prefer terminals, but this portion may be less well-matured and lower in stored carbohydrates or other reserve materials than the lower portion. The scion wood is collected while dormant and stored at low temperature until used.

Rootstocks may be seedlings or vegetatively propagated clonal material. Having the rootstocks well established in pots is important for indoor grafting. In some cases digging and potting in the fall allows enough time (4, 7), but a longer period for root development is preferred. Hess (10) suggested potting of beech seedling rootstocks (*Fagus sylvatica*) a year before grafting, but reported that if necessary they could be dug and potted in early September before leaf drop, and placed under intermittent mist for a week. This results in very little interruption of root activity, and the root system is reestablished in the pot before grafting time.

Grafting onto bare root stocks may sometimes be successful, but as noted by Humphrey (13), results may be unsatisfactory. When the growth rate of grafts onto established understocks was compared with grafts onto bare root stocks, the growth on the established stocks was considerably greater.

Timing of the grafting operation with deciduous species is based on evidence of activity in the rootstock. For example, Davis (3) grafts pecans when the terminal buds are swelling on the most advanced seedlings. This is before the cambium has become active enough for the bark to slip. Sometimes the start of root growth is used as an indication of when to graft.

For grafting in the nursery row, the stage of activity is dependent on the weather. Potted rootstocks can be brought to the proper stage of activity whenever desired by bringing them into a greenhouse or grafting shed a few weeks prior to grafting, or by adding heat if they are already in a cool house.

Rapid callus formation occurs when the rootstocks are ready to start growth. Sussex and Clutter (26), working with pieces of stem tissue cultured on agar, found that callus formation was greatest in the spring when new growth occurred. Activity decreased later in the season, and began to increase again during the winter, reaching a peak at the time of bud break.

Not all deciduous plants have to be grafted only in winter or early spring. One that is successfully grafted in the summer is grape (*Vitis*). Green-wood scions from slightly lignified shoots can be grafted in July or early August onto rootstock cuttings that are planted in the spring. Having the cuttings rooted and making good top growth was essential for success in studies by Harmon and Snyder (8, 9). Grafts made during July matured enough scion growth to be satisfactory for field planting.

Leiss (18) described summer grafting of *Aesculus hippocastanum*, and other deciduous plants grafted in the summer were listed by Leiss in a report by Halward (7).

Coniferous evergreens. Having the stocks well established in pots is considered essential for success with coniferous evergreens, the same as with deciduous species. Hess (11) suggested pine rootstocks should be potted in the spring—before the grafting season—rather than in the fall. Holst, *et al.* (12), Nienstaedt (20) and Wells (27) also recommended that stocks for pine and spruce should be potted nearly a year, or at least one full growing season, before grafting. Kyle (16), however, reported excellent results from grafting junipers (*Juniperus*) and other plants onto unpotted seedlings with the roots packed in peat.

Winter or early spring is the preferred time for grafting many coniferous species. Immediately prior to or just as root growth starts is considered to be the best stage of activity of the rootstock (2, 15, 24).

Pines, on the other hand, are successfully grafted in the summer, using semi-mature current season growth (21, 24, 25). Leskinen (19) in

Finland found summer grafting of pines during the period June 20 to July 15 to be superior to spring grafting.

Research workers in forestry have developed techniques for fall grafting of spruce and pine. Holst, *et al.* (12) were successful with fall grafting of Norway spruce (*Picea abies*) and white spruce (*Picea glauca*), and also with red pine (*Pinus resinosa*) and Scotch pine (*Pinus sylvestris*). Spruce scions from the uppermost part of the crown of middle-aged trees were preferred. Scions from the upper part of the tree gave a higher graft take, and produced grafts of more upright and better form than scions from the lower branches. Better quality scions of current season growth could be found on young or middle-aged trees than on mature trees.

Holst found pines more difficult to graft than spruces. Grafting in November and early December gave better results than in October. Nienstaedt (20) reported that Dr. C. Heimburger of the Southern Research Station at Maple, Ontario, had field-grafted white pine from mid-September to mid-October.

In his work on fall grafting of white spruce (*Picea glauca*), Nienstaedt started with the assumption that grafting success would depend on the amount of cambial activity of the rootstock and scion at the time of grafting and immediately thereafter. He therefore tried to control this activity through photoperiodic treatments and by chilling.

Contrary to expectations, dormancy at the time of grafting (mid-September), or during the following six-week period, did not interfere with graft take. Success was no greater with stocks that were active due to exposure to long days or ready to begin activity following chilling than with dormant, untreated stocks. Nor did chilling or exposure to long days immediately after grafting increase the graft take, as measured by survival the first year. However, breaking dormancy by chilling or exposure to long days was essential for ultimate growth of the scion and graft survival. Chilling plus long days resulted in maximum scion growth.

These results appear to differ from the observations with deciduous plants, that callus activity is greatest at the time growth starts in the spring. However, it may be possible that callus formation was slower with dormant than with chilled spruce stocks, but that there was enough activity for the grafts to be successful. Root activity of the chilled and the untreated spruce stocks was not mentioned. More information regarding the relationship between bud activity, root activity, and formation of the graft union in conifers and in other kinds of plants could perhaps lead to improved grafting procedures where satisfactory graft take is a problem.

Broadleaf evergreens. Plants such as *Camellia*, *Rhododendron* and *Ilex* are usually grafted in late winter or early spring before growth starts.

However, Leach (17) reported green-grafting of rhododendrons and found it was successful on some varieties that could not be propagated by dormant winter grafting. He used scions from half-ripe wood with leaves fully developed and firm, and protected the grafts with polyethylene bags. The period from June 20 to July 10 gave better results than later in the summer to early September.

Certain subtropical fruit and nut trees such as avocado (*Persea spp.*), litchi (*Litchi chinensis*), sapodilla (*Achras zapota*) and macadamia (*Macadamia spp.*) can be grafted at almost any time of year, but a greater percent of the grafts are usually successful in the spring than in summer or fall.

There is evidence that this seasonal difference in graft take is at least partially due to the amount of stored carbohydrates in the scion wood. Jones and Beaumont (14) found that girdling litchi scion wood 3 weeks before grafting greatly increased the amount of starch in the scions and resulted in 75 to 80% success with the grafts, compared with takes as low as 10% previously experienced with ungirdled scion wood. Beaumont and Moltzau (1) reported similar results with macadamia. Percent graft take was approximately in proportion to the amount of starch in the pre-girdled scion wood.

Fahmy (5, 6) reported that girdling increased the amount of starch and sugar in sapodilla and macadamia scion wood, and it increased the graft take at certain times of year. However, there was no definite relationship or correlation between carbohydrate content and graft take.

The Fuerte variety of avocado can be grafted with nearly equal success in spring or summer, while graft take with the Hass variety drops from 90% or higher in February to less than 50% in May, and then increases again later in the summer. Rodrigues, *et al.* (22) reported that carbohydrate content of the scions was higher in February than in May, but did not show an increase in August to correlate with the increased graft take.

Scion girdling increased avocado graft take to some extent at each of the three periods, and it also increased carbohydrate content, but again there was not a direct correlation between percent carbohydrates in the scions and grafting success. The effect of girdling was thought to be partly due to increased carbohydrate content and partly due to accumulation of some other material.

Further evidence that an accumulation of some material in the scion was critical for graft take was the greatly increased success when the length of the scion was doubled, from 3 inches to 6 inches.

Evidence that amount of carbohydrates was partly responsible for the seasonal variation in success came from an experiment in which the graft take during the summer months was increased 60 to 75% by applying a 0.3 molar (5%) glucose solution through the upper cut surface of the scion every 2 days for 6 weeks (Table 1).

Table 1. Effect of glucose treatment on graft take with Hass avocado. From Rodrigues, *et al.* (22).

Month grafted	Control	Glucose [1]	Water [2]
February	90	85	—
May	40	70	—
September [3]	60	95	45
September [4]	60	85	26

[1] The top of each grafted scion was wrapped with plastic tape to form a cup in which 0.3M glucose solution was applied every 2 days for six weeks.

[2] Water was supplied instead of glucose solution

[3] Scion wood from spring growth

[4] Scion wood from growth flush of previous fall.

In another experiment with avocado, the physiological condition of the scion wood, or its favorable balance of materials, was retained during 3 months of cold storage, but not after 5½ months (Table 2). Two years previously, graft take with stored scion wood was essentially as good after 7 months as after 3 months.

Table 2. Graft take with Hass avocado scion wood stored at 40° F. From Rodrigues, *et al.* (22).

Date grafted	Freshly-cut scions	Stored scions
February 9	92	—
May 13	30	90
July 28	78	60

Pre-girdling the scion wood contributed to success in grafting *Eucalyptus ficifolia* (23). Another consideration was the vigor of the rootstock. The observation was made that a higher percent of grafts were successful on young vigorous seedlings than on older less vigorous ones. An attempt was then made to influence the vigor of young seedlings by supplying different amounts of nitrogen. The N content of leaves varied from 1.2% in the low N treatment to 4.1% in the high N treatment. In two experiments, the percent graft take was highest with the lowest foliar N level, 1.2 to 1.3% nitrogen. Some other aspect of vigor besides response to an abundance of N apparently was involved in the initial observation. These results do indicate, however, that vigor and nutritional status of the rootstocks may also be important to the success or failure of a graft.

Further study of this aspect, and also of the physiology of the scion wood, could contribute information that would help to increase grafting success, particularly with difficult plants.

In any discussion of selection of scions and stocks, mention should be made of selecting scion wood true-to-type and free from viruses or other diseases. These are equally important in selecting material for rootstocks to be propagated vegetatively. Since most viruses do not come through the seed, freedom from virus diseases usually is less of a problem with seedling rootstocks. Trueness-to-type in the seed source is important, at least to the extent of using seed of the proper species for the desired rootstock effect. Where there is considerable botanical or horticultural variation within the species, selection of a particular variety or cultivar as a seed source may be important.

LITERATURE CITED

1. Beaumont, J. H. and R. T. Moltzau. 1937. Nursery propagation and topworking of the macadamia. *Hawaii Agr. Exp. Sta. Cir.* No. 13.
2. Cesarini, Joe. 1968. Dwarf conifers. *Proc. Int. Plant Prop. Soc.* 18: 255-258.
3. Davis, Ben II. 1967. Outdoor grafting of pecan. *Proc. Int. Plant Prop. Soc.* 17: 272-273.
4. Dummer, P. C. R. 1968. Birch grafting. *Proc. Int. Plant Prop. Soc.* 18: 69-72.
5. Fahmy, Ibrahim. 1952. Grafting studies on macadamia and sapodilla in relation to carbohydrates, using pre-girdled scions. *Proc. Fla. State Hort. Soc.* 65: 190-193.
6. Fahmy, Ibrahim. 1953. A study of the relation between carbohydrate content of scions and graft union in certain tropical fruit trees, and the diffusable auxin content of the scions. Ph.D. dissertation, Univ. of Fla.
7. Halward, Ray. 1962. Collection, storage and use of dormant scionwood. *Proc. Int. Plant Prop. Soc.* 12: 144-145.
8. Harmon, F. N. 1954. A modified procedure for green-wood grafting of vinifera grapes. *Proc. Amer. Soc. Hort. Sci.* 64: 255-258.
9. Harmon, F. N. and E. Snyder. 1948. Some factors affecting the success of green wood grafting of grapes. *Proc. Amer. Soc. Hort. Sci.* 52: 294-298.

10. Hess, C. W. M., Jr. 1958. Copper beeches by grafting. *Proc. Plant Prop. Soc.* 8: 69-71.
11. Hess, Hans. 1961. Pines by grafting. *Proc. Int. Plant Prop. Soc.* 11: 35-36.
12. Holst, M. J., J. A. Santon, and C. W. Yeatman. 1956. Greenhouse grafting of spruce and hard pine at the Petawawa Forest Experiment Station, Chalk River, Ontario, Canada Dept. North. Affairs and Natl. Resources, Forestry Branch, Forest Res. Div., Tech. Note 33.
13. Humphrey, B. 1966. Some aspects of woody plant propagation in England. *Proc. Int. Plant Prop. Soc.* 16: 170-174.
14. Jones, W. W. and J. H. Beaumont. 1937. Carbohydrate accumulation in relation to vegetative propagation of the litchi. *Science* 86: 313.
15. Klapis, Andrew J., Jr. 1964. Grafting junipers. *Proc. Int. Plant Prop.Soc.* 14: 101-103.
16. Kyle, Thomas B. 1955. Grafting *Juniperus virginiana* varieties without potting the understock. *Proc. Plant Prop. Soc.* 5: 60-62.
17. Leach, David G. 1960. Outside green grafting of rhododendrons under polyethylene. *Proc. Int. Plant Prop. Soc.* 10: 90-92.
18. Leiss, Joerg. 1967. Grafting outdoors, deciduous and broadleaf. *Proc. Int. Plant Prop. Soc.* 17: 303-305.
19. Leskinen, V. 1960. Experience in grafting pines in Finland. Metzat. Arkak: 399-406. *(Forestry Abst.* 22: 3034 1964) (Cited from O'Rourke, 1961).
20. Nienstaedt, Hans. 1958. Fall grafting of spruce and other conifers. *Proc. Plant Prop. Soc.* 8: 98-104.
21. O'Rourke, F. L. S. 1961. The propagation of pines. *Proc. Plant Prop.Soc.* 11: 16-22.
22. Rodrigues, J., G. F. Ryan and E. F. Frolich. 1960. Some factors influences grafting success with avocados. *Yrbk. Calif. Avocado Soc.* 44: 89-92.
23. Ryan, G. F. 1966. Grafting *Eucalyptus ficifolia.* The Plant Propagator 12(2): 4-6.
24. Snyder, John C. 1964. Grafting evergreens. *Proc. Int. Plant Prop. Soc.* 14: 300-305.
25. Spaan, John. 1961. Grafting pines out-of-doors. *Proc. Int. Plant Prop. Soc.* 11: 36-38.
26. Sussex, I.M. and M.E. Clutter. 1959. Seasonal growth periodicity of tissue explants from woody perennial plants *in vitro. Science* 129: 836.837.
27. Wells, James S. 1955. Grafting pine and spruce. *Amer. Nurs.* 101(1): 15, 16, 54-59.

MODERATOR SHUGERT: Thank you very much, George, for a very comprehensive and interesting paper. Most of us met the gentleman who is going to speak to us next, the year the meeting was held in Newport, Rhode Island. He is a propagator for the Rhode Island Nurseries in Newport and is a very dedicated contributor to the Society, an excellent nurseryman and a good personal friend. Speaking on "Environmental Control for Grafting", Larry Carville, from Rhode Island Nurseries. Larry.

ENVIRONMENTAL CONTROL FOR GRAFTING

LAWRENCE L. CARVILLE

Rhode Island Nurseries

Middletown, Rhode Island

Webster's dictionary defines environment as "that which environs; the surrounding conditions, influences or forces which influence or modify." The plant propagator defines environment as the conditions sustaining or contributing to the life or development of plant tissues. In our present age, it is fashionable to be concerned with our environment and much is being said pertinent to the national environment. As propagators, we are vitally concerned with this subject matter since proper management of the environment within our business establishment is a matter of necessity if we are to be successful in our profession.

A review of the Proceedings of the Society supplies a wealth of material dealing with all aspects of graftage dating back to the first published papers in 1952. I read with much interest these papers by Hoogendoorn (2), McGill(16), Burton (1) and Mattoon (15) and was amazed to find that environmental control in grafting presented the same problems then as face us today. The variety of plant materials dealt with in these papers is practically unlimited and the methods involved range from the most simple to the more complex. This review of the literature however merely serves to emphasize the realization that we have actually made relatively little progress in the field of environmental control for grafting. In view of the tremendous advances in horticultural techniques and construction, the real impetus in this presentation is to stimulate you to apply these newer techniques, to experiment with novel construction methods, and most importantly, to innovate with an inquiring mind. Truly, what does the future hold in the area of environmental management?

In my approach to this subject matter, a review of our accomplishments as propagators must be divided into three areas: stem grafting, root grafting, and budding.

The conditions or influences which we strive to control in stem graftage are temperature, light, moisture content of the media and humidity of the immediate surroundings. Initially, the accepted method used to control the environment was the Wardian Case.