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

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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.

Problems inherent in this technique which has been used "successfully" over the years are incidence of fungus disease, and high labor and maintenance costs. Modifications of this basic method include use of plastic in place of glass (5, 12) and with the use of overhead mist when handling deciduous stock. It must be accepted that regardless of the method used and the plant material being grafted, the human element becomes apparent in terms of experience, labor costs, and efficiency. When to air the Wardian Case, when to reduce or increase bottom heat, when to apply or remove shading, and when to reduce mist intensity become environmental control factors in terms of dollars and cents based on available labor. The success of a given crop can be seriously affected by inattention at any period during callus formation. Further modification of the Wardian Case method is the use of newspaper (14), or Kraft paper, on grafts such as *Picea pungens* 'Moerheimi'. We have found the use of Kraft paper to be extremely adaptable and now graft all our cryptomeria and retinospora varieties in open benches covered during bright sunny days with Kraft paper.

The problems incidental to environmental control in root grafting are somewhat easier to control since we normally are using dormant scion wood so light intensity and ventilation are not as pertinent. The incidence of fungus disease may become a factor if too much moisture is present in the media or if the rootstock or scion is not clean. The standard propagation procedure currently in use at our establishment is to store completed root grafts in cool storage areas until planting time. Care must be taken that the sphagnum moss used for root-graft storage is only damp, not wet and, if a refrigerator is used for winter storage, the temperature controls are reliable. We use a recording thermometer in our cooler to insure that root grafts are not injured by too low a temperature and that growth does not commence too early in the spring.

Our techniques in stem grafting have not radically changed over the years and are still basically modifications of the Wardian Case. However, control of the environment begins well ahead of placement in the case if we apply the principles of environmental control which I mentioned earlier. Once scions have been cut from dormant stock during the winter, we must insure that they are protected from freezing, kept moist, and not subject to rapid changes in temperatures. We store all scion wood in a cooler at a constant temperature of 34° F until we are ready to graft them. Scions are often taken as much as 3 to 5 days in advance of grafting if weather conditions are unfavorable for daily harvest. Material is brought into the work area only as needed and is prepared as rapidly as possible for grafting. Scions are kept cool and moist during preparation but are normally dry during the grafting operation since we do not want external moisture present when the scion is affixed to the understock (10).

If we apply my principles of environment control in a strict manner, we must consider personnel as well as plant material. I believe that the immediate area surrounding the work force must be as pleasant, comfortable and clean as possible since these factors also contribute to the overall success of the propagator. We attempt to provide an adequate work area for each grafter which is well-lighted, well-ventilated and comfortably heated. Work bench surface should be at a comfortable height and should be cleansed each morning prior to the day's grafting operation. All rubbish and debris should be removed from the work area floor daily. These factors may seem trivial to the average nurseryman but, believe me, anything that can be done to improve the environment of the work force substantially improves production and ultimate success.

We do all stem grafting at a work bench where light and temperature are adequate and may be manually controlled. A flat of potted understocks is brought from the greenhouse to the work bench, grafted and immediately taken to the grafting case. Completed grafts are plunged in the dampened spagnum moss and then covered with glass sashes. At this point in the operation, environmental control becomes critical!

Light, temperature, and moisture must be manipulated to give us the highest possible yield on grafted stock. Cotton cloth is unrolled over the glass sash on bright sunny days and is left in place from 9 a.m. to 4 p.m. The grafting cases remain unopened for the first week but, thereafter, are opened briefly each morning for airing. Bottom heat is maintained at a constant 72 to 74° F which allows sufficient humidity to promote rapid callus formation. When grafts are sufficiently callused, sashes are raised and all material is syringed two to three times on sunny days. Air circulation is gradually increased as the completed grafts are taken out of the sphagnum moss and spaced. This operation normally takes place about 4 weeks after setting. Shading paint is applied to the greenhouse glass in early February as the sun intensity begins to increase with the lengthening day. Humidity is no longer a critical factor, but temperature and moisture must be controlled until the grafts are hardened off for planting.

These techniques used in stem grafting junipers are modified somewhat in our open bench grafting; we replace the glass sash with plastic tents when handling Japanese maples and dogwoods. When all grafts have been made and plunged in moist sphagnum moss, a temporary frame of 1 x 2 inch strips is erected over the bench containing the Japanese maples and dogwoods. We then staple 4 mil poly to the framework across the top, over both ends and along the sides. This poly forms a temporary moisture chamber which allows sufficient light without shading and at the same time creates an atmosphere with controlled humidity. The poly tent is aired once a week for the first 15 days then twice a week for the next 2 weeks. After 4 weeks, the poly is completely removed.

Cryptomeria, retinospora, and beech are open-bench grafted but are covered with Kraft paper during sunny days until callus formation is adequate to insure success of the graft, usually after three weeks. Top moisture is a critical factor in these three species and we strive to keep the scion and stem as free as possible from external moisture until callus formation is well advanced. This is particularly true of the beech varieties where blackening of the stem occurs if excessive water is applied to the plunged grafts. We prefer to have the potted understock well soaked prior to graftage and to have the sphagnum moss only slightly dampened when pots are plunged.

Spruce varieties are open-bench grafted without the use of double glass, plastic, or Kraft paper, but require frequent overhead syringing during callus formation. We do not wax or paint the graft union but, once again, insure that the understock is well-soaked prior to grafting. Our technique here seems to vary somewhat from that of Willard (19) who prefers to have his understock well-dried prior to graftage. Free air circulation is allowed in the spruce grafts to reduce the incidence of fungal contamination.

During every step of the stem grafting operation, control of the environment involves the use of manpower; the success of the propagator is directly related to the experience of this manpower.

The budding operation presents perhaps the greatest challenge to the propagator in his attempts to control the environment (16, 18). Since most budding of fruit varieties, nut trees, and roses is carried out in the field (13), we can do very little in controlling such factors as light and temperature. We become more concerned with the immediate environment surrounding the bud and must be content to manipulate the moisture content of budwood and seedling. The humidity factor may be controlled to a small degree by proper wrapping or painting. I must confess that, commercially, I have never budded but after reading Davis' paper on the modified patch bud (2), I am tempted to try my hand.

Briefly, I have attempted to summarize the methods we utilize in controlling the environment for our grafting operations. I am satisfied that we are achieving a moderate degree of success with our root grafts and with our stem grafts. But of all the factors involved in the total operation, labor continues to be the most significant element which defies change. Here we must face the challenge of the future. How can we, as propagators, more efficiently control the environment for grafting?

In recent years we have had stimulating papers presented in this society which should have aroused the curiosity of even the most adventuresome horticulturist (4, 11, 17). We have been privileged to visit commercial establishments which are experimenting and innovating untried techniques. At the University of Minnesota and at Bachman's on our tour yesterday we saw modern structures and semiautomation combined to make environmental control attainable. Are these brief exposures and experiences sufficient, however, to shatter our lethargic complacency of continuing the day to day operation within our individual greenhouse establishments? I will never argue that one should change merely for the sake of change but is there anything wrong in being more successful!

Let me take your imagination for a few minutes and explore with you some innovative techniques in environmental control:

Imagine a tower greenhouse such as we saw in Ontario, Canada in 1968. Completed stem grafts are inserted in wire racks on the conveyor assembly and are never touched again until callus formation is complete. Each graft is exposed to uniform light and temperature conditions merely by operating the conveyor assembly through its cycle. Watering of the understock is fully automated, the humidity of the tower complex is automatically controlled, and disease and infection are minimized in the controlled environment. Carbon dioxide may be injected as required (9) and fertilizers and hormones could be applied through an automated misting system. Impractical, you say? Prohibitive in cost? Perhaps not when we consider the increase in production possible with a controlled environment.

Imagine stem grafting on unpotted understocks (14) or on unrooted cuttings (3). Mr. DeGroot presented a paper on this technique in 1960 and described his work with plants in the genus *Juniperus*. I experimented with this method using the genus *Rhododendron* and found that control of the environment was facilitated, incidence of *Phytophthera* was reduced, and percentage takes of 'Mrs. C.S. Sargent', 'Boule de Neige' and 'Dr. H.C. Dresselhuys' were substantially increased. Mr. Gerald Verkade is presently stem grafting juniper on unpotted rooted cuttings and has appreciably reduced the problems of environmental control in his grafting house.

Imagine the controlled environment Mr. Krizek was able to maintain in his facility when he presented his paper on seedling production in 1968 (11). His use of growth chambers would seem to be the ultimate in effectively controlling such factors as light, temperature, humidity, nutrition, and carbon dioxide. Although his research primarily related to bedding plants and vegetable crops, much of the data is applicable to ornamental woody plant production. Can we justify these elaborate growth chambers in our business establishments merely for the production of horticultural nursery crops? Perhaps we must.

The rapidly increasing national problem of air pollution may be a factor in the future with which we have not been concerned in the past. If ozone, hydrogen fluoride, and sulfur dioxide in the atmosphere are affecting the growth of street plantings and city parks (18) will not eventually this same deleterious effect be observed in our greenhouses? Will we ultimately have no choice but to graft only in growth chambers?

Is the future role of the grafter to be reduced in scope to one of a technician who will be more concerned with the mechanical operation of his growing complex than with the propagation of plants? Are we to become test tube scientists "budding" virus-free tissues in *in vitro* culture? (8, 17)

This then becomes the real challenge. How can we best control the conditions sustaining or contributing to the life or development of plant tissues? The answer must come from within our Society. This challenge can be met by you, the members from the British Region, the Western Region, and the Eastern Region. We are here in St. Paul to face this challenge. From our deliberations must come the solution to future problems in environmental control for grafting.

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MODERATOR SHUGERT: Larry, that was an outstanding paper. Larry expressed many ideas he feels strongly about and we all benefitted from it without question.

We are now going to hear from a gentleman who is with the Pershore College of Horticulture, in Pershore, England, the Editor of the Great Britain and Ireland Region of the International Plant Propagators' Society. Richard Martyr is now going to speak to you on "Hardwood Cuttage Practices in England". Richard Martyr.

HARDWOOD CUTTAGE PRACTICES IN GREAT BRITAIN — A REVIEW

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The term "hardwood cutting" in Britain is almost exclusively limited to denote the ripened wood of deciduous species and would not ordinarily include, for example, the autumn cuttings of narrow-leaved evergreen species — though technically this might be "ripened wood". Within this definition it is true to say that there is a much decreased (and probably still decreasing) use of hardwood propagation techniques in the production of ornamentals. In some nurseries it is a technique that has been dropped altogether and in most others it is