Several variations of budding and cutting propagation methods were tested for use with filberts. Both summer budding and chip budding attempts were generally unsuccessful. However, the results of employing measures to retard desiccation of buds and increase callusing rates indicate possibilities for future success. Numerous sheathing, wrapping and sealing materials for prevention of bud drying were tested. Budding on current season's wood was employed to obtain more rapid callusing. Tenting of nursery trees was another method tried for both reducing desiccation and increased callusing rate by raising temperature.

Of the several root promoting treatments tested with semi-hardwood filbert cuttings, it was found that a quick-dip application of 2000 ppm indolebutyric acid gave the highest rooting percentage. When cuttings were rooted in a high humidity environment, bud survival was better than when they were allowed to root under an open
mist system. Gibberellic acid, N6 benzyl adenine and silver nitrate were used as foliar treatments to cuttings during the rooting period but they did not consistently improve bud survival.
Vegetative Propagation of the Filbert
(Corylus avellana L.) by Means
of Budding and Cuttings

by

Gregory Earl Hubert

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VEGETATIVE PROPAGATION OF THE FILBERT
(CORYLUS AVELLANA L.) BY MEANS
OF BUDDING AND CUTTINGS

INTRODUCTION

The ultimate goal of agricultural research is to maximize production. Also, production should be made as economical as possible. Plant propagation methods are important factors in reaching these goals.

Currently, the filbert only lends itself to commercial propagation by simple layerage. This method produces a large, well rooted tree, but it is inefficient when compared to other propagation techniques. Simple layerage requires much hand labor and is relatively inflexible in regards to the number of plants produced each year. Much time is required to introduce a new cultivar by the layerage system. This has placed a severe restriction on the development of new and better filbert cultivars.

It is the aim of this research to alleviate some of the problems of filbert production by developing more efficient and flexible propagating techniques. The primary areas of study are propagation by various types of budding and cuttings. Improvement of these methods should lead to more rapid evaluation of new filbert cultivars, and ultimately, to a flexible, economical system of commercial filbert propagation.
This thesis presents a limited history of filbert propagation including current knowledge of the subject. The methods used in experiments to attempt filbert propagation by budding or cuttings are described.

Vegetative or asexual propagation from a single plant will give rise to a group of genetically identical individuals, which are collectively called a clone. Vegetative propagation sometimes permits more rapid plant production than by sexual means. There are a large number of different asexual propagation methods available for use with herbaceous plants, but these become fewer in number when propagation of woody plants is considered (27). The feasible methods are reduced even further when the woody plant being considered is the filbert.

Layerage

The filbert has not been successfully propagated on a commercial scale by any technique other than layerage (4, 26, 32). Layerage is often employed with plants which are difficult to propagate by other means. Originally, filbert growers simply mounded soil around the base of an established tree and allowed the suckers to root (14, 32). Sometimes, commercial layering beds were established in old orchards by cutting off the trees at ground level and allowing the suckers to grow. Modern layering beds are specially prepared
using young trees planted about 3.7 m apart on the square. In early spring, stems, often grown to over 2 m in height during the previous season, are used for layering. They are stripped of their basal buds and flexed until limber enough to be bent down under the ground and up again, leaving 30 to 60 cm of the terminal exposed. This technique, known as simple layerage, maintains the normal polarity of the growing terminal. Roots develop on the buried portion of the stems during the growing season. After defoliation in autumn, the new trees are cut from the mother plants, graded, bundled, and heeled into sawdust (32).

The reason layerage is so effective with difficult to propagate species is that the individual plants being propagated remain connected to the mother plant. Thus, the root system of the mother plant supplies the moisture, nutrients, and other needed substances for its daughter plants until they develop roots of their own. The new plants are not removed from the mother plant until they are sufficiently established to survive on their own root systems.

While simple layerage is reliable, it has several disadvantages. Undesirable factors include a large requirement for hand labor, relatively slow production of new plants as compared to other methods, low plant yield, and a need for a large propagating area with suitable mother plants (17). Also, mother, or stool plants, must be maintained in propagating condition even though no market may be
available for a crop of new trees (34). Simple layerage of the filbert produces plants which are large, but have the undesirable, suckering growth habit (32).

Limited attempts have been made to air layer filberts (34). This propagating technique involves wounding an actively growing stem, packing a moist rooting medium around the wounded area, and wrapping with polyethylene sheeting to prevent drying. After the stem is rooted, the new tree can be severed from the original plant (14, 17). As with simple layerage, there is a skilled, hand labor requirement, and the layers must be examined periodically to make certain they do not dry, or that the additional weight does not break the branches being rooted. The success with this technique when applied to filberts has been limited (34).

Graftage

Grafting is a versatile and useful propagating technique. It permits the use of beneficial rootstocks (RS) or intermediate stocks, varietal changes in established trees, hastened growth of seedling selections, growth control and incorporation of disease resistance (17). In some cases it can reduce time and labor requirements in the nursery (35), and in special cases it can be used as an aid in rooting scion selections (48). The grafting of Corylus avellana, the European filbert, on C. columna L., the Turkish tree hazel, was first reported
in 1841 (2). There was an interest in filbert grafting in the 1920's, and though considerable difficulties were recognized, some felt that filbert grafting presented no problems (39, 53). In 1921, it was found that approximately 55% success could be achieved if grafting was done after 1 April. Several types of grafts were employed, but no particular advantages were attributed to any one method (43). A more recent study found wedge grafting more successful than various crown grafting methods (12). Wedge grafting has also been reported successful when one-year-old suckers are employed as scions (9). The importance of early collection and cold storage of scion wood, good grafting technique and general aftercare has been described (39, 40).

Recent research in filbert grafting has proven that consistently good results can be obtained. The use of good quality scion wood proved to be critical (21). Healthy, fully dormant wood, collected in January and stored moist at -1°C, and grafted on dormant, potted rootstocks in the greenhouse worked well. Use of the standard whip and tongue graft wrapped with a 1 cm wide rubber grafting band produced up to 100% success. Side grafting was also shown to work well. Machine grafting was attempted, but was found less successful than grafting done by hand (33).

Aftercare of grafts has been shown to be important in preventing desiccation of the callused union. Careful painting of the graft union,
or maintaining grafted plants in a grafting case, are methods shown
to be effective in preventing drying (6, 33).

Little information concerning root grafting of filberts is
available. Piece root grafting was not successful due to the lack of a
sufficient root system (34). Lack of success with forms of this tech-
nique may have led to its abandonment (7).

Budding

Budding is a form of grafting (40). The principles are essen-
tially the same for both budding and grafting; however, budding is
considered simpler and more efficient both in relation to speed and
use of propagating material. Summer budding is usually done from
June through August and may employ a technique such as T-budding,
which utilizes a bud on a thin sliver of wood. Chip budding, like
grafting, is normally done in the dormant season and employs a thick
sliver or "chip" of wood with the scion bud. A notch, corresponding
to the size and shape of the chip bud is cut into the RS and the whole
is usually wrapped with a flat band of rubber.

At one time, budded filbert trees were available commercially
(7, 16, 39). However, no detailed account of a method for budding
*Corylus* with consistent success has been found. One technique has
been described as successful, though neither the extent of its use nor
its effectiveness have been recorded. The method is a type of summer
budding, employing young seedlings with stems of about pencil size as RS (34). Recent attempts to bud filberts have met with little success, but some of the problems have been identified (34). One of the major problems is drying and death of the bud itself, before adequate vascular connection between the shield and RS has been established. Another is in obtaining a vascular connection. Studies have shown that callusing in filbert is greatly influenced by temperature, and that at temperatures below $21^\circ$C, callusing is very slow (33).

A limited number of chip budding experiments have been carried out with filberts, one of which utilized a chip budding machine, placing dormant buds into dormant RS. The procedure utilized bareroot stocks. Callusing was promoted by placing the budded stems over heating cables buried in sawdust. Success was limited for two reasons: first, buds on relatively thin chips tended to dry before callusing could take place; second, buds which did callus tended to begin growth early due to the elevated temperature. When trees bearing these forced buds were planted in the field, low temperatures of early spring would damage or kill the new growth (33).

**Cuttage**

Propagation by cuttings involves removing a portion of a plant and regenerating the lost part separate from the parent plant. It is a useful technique in that many new plants can be started in a limited
space from relatively few stock plants. It can be done simply, rapidly and inexpensively (17). With Corylus, this method of propagation has not been consistent. Early literature on filbert cuttage reveals that propagation by this method is feasible, yet only one account described how the cuttings were rooted and grown (3). Later, more extensive studies of filbert cutting propagation have provided detailed information. These studies have shown that propagation of filberts by cuttings is influenced by environment (7, 47, 50), chemical treatment (5, 10, 29, 36), and physiological age of the cuttings (6, 45, 46).

Details of specific methodology for rooting Corylus cuttings successfully are limited. One early report only specifies moist sand as a rooting medium (3). More recent studies have shown benefits of highly aerated rooting media (30, 32), and detailed work in 1969 indicated coarse perlite to be superior for use in rooting leafy filbert cuttings (31). In a method described for hardwood cuttings, a combination of peat moss and coarse sand was found suitable (23).

Several mist propagation systems have been tested, but with inconsistent results (19, 41, 44, 45). Misting may reduce bud survival on cuttings (32, 34). As an alternative, humidification has been tried with softwood cuttings of a number of species (49). While this method was found to enhance rooting with several plants, it was found to reduce that of Corylus (15).
Light and temperature are both important factors in rooting (28, 54). With all types of cuttings bottom temperatures up to 26\(^{\circ}\)C can aid rooting (8, 15). Leafy cuttings benefit from ample light and reduced foliar temperature (15, 19).

Use of hormone treatments with *Corylus* cuttings has increased rooting. Indoleacetic acid (IAA) treatment has resulted in rooting up to 22\%, while no rooting was obtained with untreated material (10, 29). Increased rooting was obtained with applications of indolebutyric acid (IBA) in other investigations (11, 20, 32, 50). Application techniques, including powder dips, concentrated solution dips and dilute soaks have been tried with various concentrations of rooting hormones. Concentrated solution dips of IBA of 1000 to 4000 ppm for up to 30 seconds were found to be useful for obtaining rooting of leafy filbert cuttings (32). Lower concentrations have been tested as basal soaks for varying lengths of time (50). With some species, variations in the ability of cuttings to root have been shown to be due to specific site of hormone application at the cutting base (cut surface only vs. epidermal contact) (25, 42). The drying position at the time of hormone application and composition of hormone solvent may also influence rooting ability (24). No information of such detail has been found for filberts.

The physiological age of cuttings influences their ease of rooting as found in a number of species which root more easily when juvenile
material is used (22, 46). This was shown specifically with hardwood filbert cuttings. The juvenile cuttings rooted with 50% success, while the next best type gave 20% rooting (23). A similar result was found with pecan (38). Both investigations used cuttings from the same type of source. For filbert, juvenile cuttings were taken from basal shoots of C. avellana stool plants growing in a woodland area. Such shoots would normally be juvenile, assuming the wild plants were seedling trees. Mature cuttings were taken from upper branches of adult trees. Juvenile pecan cuttings were made from watersprouts at the base of a seedling tree, again a juvenile region (38).

Increased rooting ability of juvenile over mature stems has been attributed to differences in chemical relationships (1). For example, it has been noted that mature apple and pear trees have higher concentrations of reducing sugars and starch, and lower concentrations of N and minerals than do juvenile trees (13). The shift from juvenile to adult form is accompanied by an increase of carbohydrate and N in the leaves of some annuals (18). While such factors have been shown related to rootability, their overall effect on the rooting response is not fully understood (1).

The season of collecting cuttings, relative to this physiological condition, has also been shown to be important to rooting ability. This has been illustrated with filberts and other tree species (51, 52). Some of the most recent work with semi-hardwood filbert cuttings has
shown that mid-June to mid-July is the optimum time for cutting collection. The importance of an actively growing terminal has been stressed (32).

Aside from rooting, a problem exists in the total regeneration of leafy Corylus cuttings. During the rooting process, filbert cuttings lose their terminal growing point and lateral buds (32). The reasons for these phenomena remain obscure (6, 36). The result is a rooted cutting without growing points for further stem growth. Similar phenomena have been observed with softwood cuttings of pecan (47). Bud abortion has been attributed to misting, which causes water to be constantly present in the leaf axils, in contact with the lateral buds. Having no growing points remaining, and following leaf drop, the cuttings eventually die (32). The death of potted cuttings which have already rooted has been attributed to excessive moisture due to misting; however, this problem has been remedied to some extent by precise control of minimal misting (52). It has been suggested that if newly rooted cuttings can be forced into growth before the end of the rooting season, losses can be reduced (6). Also, potting or planting rooted Corylus cuttings out in beds and encouraging strong rooting before winter allows for accumulation of food reserves. These practices result in aiding cutting survival into the next growing season, when new buds may be formed (36).
Possibly the failure of buds on filbert cuttings is not primarily a result of environmental factors such as misting. The balance between auxin and numerous other internal factors in plants controls organ formation such as rooting in cuttings (56). Plant growth seems to be primarily controlled by the relative amounts of hormones present. It is not unreasonable to consider that cuttings of any species may fail to totally regenerate due to an inhibition or lack of a substance necessary for normal growth (55).
MATERIALS AND METHODS

Due to the general lack of knowledge concerning budding, the experiments with this method were largely of a survey nature. Several budding techniques, successful with other plants, were tested in an effort to determine factors that could improve filbert budding success. Factors which appeared to enhance success were repeated and varied in attempts to further improve budding so that this method of filbert propagation would become practical on a commercial scale.

Problems of filbert cuttage could be approached more directly than those of budding. Considerably more research of greater detail has been published to serve as a base for initiating research on filbert cuttage.

Summer Budding

Summer budding experiments in 1974 were designed to test the effect of budding height, bud wrapping materials, and two budding methods. Nursery planted 'Daviana' rootstocks were used and budded with 'Barcelona'. The scion buds were collected shortly before use and held in a vasculum. A total of 380 buds was placed in August, which is the normal time of budding for most orchard trees. Buds were placed at two different heights, 5 to 8 cm and 25 to 35 cm. Two
buds, one at each height, were placed in each RS. The budding methods were the T-bud and the inverted T-bud. All buds were routinely placed on the northwest side of the stocks to avoid direct sun during periods of highest temperature.

The most thoroughly examined factor in the 1974 budding trials was the bud wrapping material, primarily as a means of preventing moisture loss. Following is a list of the wrapping materials tested, including notes of explanation on non-standard techniques.

List 1. 1974 Summer budding wrapping materials.

1. Rubber budding band, 0.5 x 12.5 cm.
2. Parafilm, an elastomeric plastic sheeting, applied as an overlapping spiral wrap covering all cuts and the bud itself.
3. Parafilm "bubble," as in 2, with film stretched slightly at the point of contact with the bud to avoid direct pressure.
4. Parafilm/aluminum foil, as in 2, with a loose fitting, cylindrical foil sheath approximately 3 cm diam. x 15 cm lgth.
5. Parafilm/paint, as in 2, with one coat of white, water base paint.
6. White polyethylene, 2 x 30 cm strip of 4 mil sheeting applied as an overlapping spiral wrap covering all cuts.
7. Clear polyethylene, as in 6.
8. Vinyl grafting tape, a green, translucent tape, 5 mil thick x 1 cm wide, applied as an overlapping spiral wrap covering all cuts.
9. Plastic flagging, approximately 3 cm wide polyethylene tape applied as an overlapping spiral wrap covering all cuts.
Wraps were removed four to five weeks after budding. Evaluations were made and where buds appeared alive, a polyvinyl acetate (PVA) paint was used to seal the exposed bud unions. Buds which appeared alive at the end of the growing season were re-evaluated in the spring of 1975.

In 1975, 'Daviana' nursery planted RS were again employed and both 'Barcelona' and 'Daviana' were used as scion buds. A portion of the RS budded in 1975 was planted in early 1974. These were cut to ground level after the end of the 1974 growing season and 1975 summer budding was done on the strongest of the shoots which developed. One bud was placed on each stock at a height of 5 to 8 cm. Two wrapping methods were used: a 0.5 x 12.5 cm rubber budding band, and black plastic electrician's tape with a coating of petroleum jelly. Budding in 1975 was done in early September. Bud collection and positioning on the RS were as previously described.

In 1976, summer budding trials were directed toward testing the influence of RS. Buds were placed on nursery planted stocks, container grown stocks, and on branches of mature trees. Differences due to budding on current season's shoots and older wood were also tested. Budding was done on 1 and 8 September. 'Barcelona' was the cultivar used for both budwood and RS in all 1976 budding experiments. The T-buds were wrapped with 1 x 20 cm rubber grafting bands. Treatments are outlined in List 2.
List 2. 1976 Summer budding treatments.

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<th>Rootstock</th>
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<tr>
<td>1</td>
<td>1 year old potted cutting, greenhouse</td>
<td>Main stem</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>2</td>
<td>2 year old potted cutting, can yard</td>
<td>Main stem</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>3</td>
<td>Commercial layered tree, nursery</td>
<td>Main stem</td>
<td>T-bud, 1 x 20 cm band wrap</td>
</tr>
<tr>
<td>4</td>
<td>Commercial layered tree, nursery</td>
<td>Current season's shoot</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>5</td>
<td>Commercial layered tree, nursery</td>
<td>Current season's shoot</td>
<td>T-bud, 1 x 20 cm rubber band wrap, plus polyethylene sheath</td>
</tr>
<tr>
<td>6</td>
<td>Mature, multiple stemmed tree, orchard</td>
<td>Current season's shoot, north side of row</td>
<td>T-bud, 1 x 20 cm rubber band wrap, plus polyethylene sheath</td>
</tr>
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The polyethylene sheath used in two of the treatments was made of 3 mil thick, clear film wrapped loosely around the stem being budded. A cylinder approximately 3 cm in diameter x 15 cm long was formed by fastening the plastic above and below the budded area with wire ties.

Evaluation of 1976 summer budding tests was done eight weeks after budding. Buds which appeared green and capable of growing were recorded as successful.
Chip Budding

Chip budding is a form of grafting; therefore, it was possible to utilize information obtained from studies of the latter technique.

During 1975, filbert chip budding trials were done both in the greenhouse and in the nursery. Greenhouse tests, which permitted more strict environmental control and therefore, reduction of stress, commenced on 19 April. 'Daviana' RS, potted in one gallon cans, were placed in the greenhouse in January. 'Barcelona' budwood included suckers and stems originating at least 1 m above the ground. Two chip budding techniques were employed--the notch bud and the circular shield (Figure 1). Two heights, 5 to 8 cm and 25 to 35 cm, were tested in addition to the several wrapping methods presented in List 3.

The primary objective in testing wraps was to find a material or combination of materials which would prevent moisture loss while the callus union was forming. Phytotoxic properties of the sealing materials or difficulties with their application were noted.

Budding was done over a four week period and evaluated on 18 June. Buds which were green or growing were classified as successful.

Nursery chip budding tests in 1975 were initiated on 22 May. Budding was done by three individuals, each using the notch bud
Fig. 1. Diagram of chip budding techniques (left to right), circular shield, notch bud, "Liliput" machine bud.

1. Rubber grafting band, 1 x 20 cm.

2. Rubber budding band/PVA paint, 0.7 x 12.5 cm band plus paint to cover all exposed cuts.

3. Rubber budding band/water base paint, as in 2, using white, water base paint.

4. Rubber budding band/rubber cement, as in 2, replacing paint with commercially available rubber cement.

5. Rubber budding band/white glue, as in 2, replacing paint with water soluble white glue.

6. Rubber budding band/"Tree Saver" compound, as in 2, replacing paint with an asphalt emulsion wound dressing.

7. Rubber budding band/petroleum jelly, as in 2, replacing paint with petroleum jelly and covering entire budded area.

8. Vinyl grafting tape, as in 8, List 1.

9. Vinyl grafting tape, as in 8, List 1, except colorless type.

10. Rubber budding band/gauze/PVA paint, 0.7 x 12.5 cm band followed by several turns of 2.5 cm width cotton gauze, then thoroughly covered with paint.

11. Rubber budding band/gauze/rubber cement, as in 10, replacing paint with commercially available rubber cement.

12. Rubber budding band/gauze/"Tree Saver" compound, as in 10, replacing paint with an asphalt emulsion wound dressing.

13. Rubber budding band/gauze/petroleum jelly, as in 10, replacing paint with petroleum jelly.

14. Rubber grafting band/petroleum jelly, as in 1, covering entire budded area with petroleum jelly.

15. Black plastic electrician's tape, applied as a spiral wrap.

16. White teflon thread sealing tape, non-adhesive, applied as a spiral wrap.
method. Nursery planted 'Daviana' RS were utilized and 'Butler', 'Ennis' and 'Lansing' comprised the scion varieties. Budwood was collected during the previous January and stored at -1°C. Nine wrapping materials or RS treatments were tested and are shown in List 4.

List 4. 1975 Nursery chip budding treatments.

1. Rubber budding band/hot wax, 0.7 x 12.5 cm band, plus a coating of commercial grafting wax over the entire budded area.

2. As in 1, RS defoliated.

3. As in 1, RS cut back to bud.

4. Rubber budding band/rubber cement, as in 4, List 3.

5. Rubber grafting band/petroleum jelly, as in 7, List 3, using 1 x 20 cm band.

6. Rubber grafting band, 1 x 20 cm size.

7. Vinyl grafting tape, as in 8, List 1.

8. Black plastic electrician's tape, as in 15, List 3.

9. White teflon thread sealing tape, as in 16, List 3.

Evaluations of 1975 nursery chip budding were carried out four and eight weeks after budding.

In 1976, both nursery and greenhouse chip budding experiments were performed. Rootstock treatments and various "bud environments" were examined.
Three groups of plants were chip budded and held in the greenhouse. In the first group, the notch bud was used to place 'Barcelona' buds on 'Daviana' RS. Budwood was collected in early January and stored as previously mentioned. Rootstocks were potted in two-gallon containers in mid-winter and held in the greenhouse. Rubber grafting bands were used for tying. Treatments are shown in List 5.

The purpose of drilling the RS (Treatment 2) was to reduce bleeding. Treatment 12 was an attempt to totally eliminate moisture loss by the addition of water.

Budding was done 19-21 April. Evaluations were made 8 and 12 weeks after budding.

A second group of plants was chip budded in the greenhouse on 17 May. 'Barcelona' RS potted in mid-winter were budded with a "Liliput" chip budding machine. All buds were tied with rubber grafting bands. Treatments were similar to those in the April trials, except that numbers 3, 4, 12 and 13 were deleted. An additional treatment included top removal and an application of 100 ppm 2, 4-D in PVA paint. Evaluations were made four and eight weeks after budding.

A third chip budding trial during 1976 included both greenhouse and nursery planted trees. On 21 May, bareroot 'Barcelona' RS were budded with the "Liliput" machine using 'Barcelona' and 'Jemtegaard #5' buds as scion cultivars. In various combinations, treatments were
List 5. 1976 Greenhouse chip budding treatments, group I.

1. Notch bud only, placed at approximately 10 cm height.

2. Drilled, two 5-mm holes made perpendicular to each other through the RS at 4-5 cm height.

3. Defoliated, all leaves removed from the RS.

4. Debudded, all buds removed, leaves intact.

5. Defoliated and debudded.

6. Top removed, RS cut back to bud.

7. Top removed/auxin application, as in 6, cut surface painted with PVA paint containing 25 ppm 2,4-D.

8. Paper sack cover, as in 1, 25 cm high, kraft paper sack inverted and placed to cover bud and RS base.

9. White polyethylene tube, open top, as in 1, approximately 5 cm diam x 25 cm high, 4 mil polyethylene cylinder placed around RS base.

10. White polyethylene tube, closed top, as in 9, top of cylinder secured around RS, above bud, with wire tie.

11. Clear polyethylene tube, open top, as in 9.

12. White polyethylene tube/peat moss, as in 1, approximately 5 cm diam x 15 cm high polyethylene cylinder surrounding the bud and secured below it, filled with moist peat.

13. As in 1, bud placed at 60-75 cm height.
Fig. 2. Polyethylene tent constructed for protection of nursery row, 1976 chip budding trials.
established to make comparisons between two scion cultivars, two wrapping materials (rubber grafting band and green vinyl grafting tape), and two RS treatments (intact stock and stock cut back to bud). Polyethylene sleeves were placed over half of the trees in the greenhouse test (as in 9, List 5). For the nursery test, a 4 mil white polyethylene tent was constructed over half the trees. The tent, of A-frame design, was approximately 80 cm high x 60 cm wide at the base, supported by 12 gauge steel wire (Figure 2). The plastic walls were attached to the wire with clothespins which could be easily removed to ventilate the tent during high temperature periods. Evaluations were made four and eight weeks after budding.

Final nursery chip budding tests were initiated 26 May 1976. They were designed to evaluate modifications of the environment in the immediate vicinity of the chip bud and over the entire budded tree. Rootstock treatments were also included. 'Barcelona' RS and budwood were used, the latter collected the previous winter and stored as formerly described. The "Liliput" chip budder was used throughout. Buds were tied with rubber grafting bands. Specific treatments involving the RS and/or environment are shown in List 6.


1. Machine bud only, placed at approximately 10 cm height.

2. Drilled.
3. Top removed.

4. White polyethylene tube, open top, as in 9, List 5.

5. White polyethylene tube, closed top, as in 10, List 5.

6. Clear polyethylene tube, open top, as in 11, List 5.

7. Paper sack cover, as in 8, List 5.

8, 9, 10. As in 1, 2, 3, respectively, with a 4 mil white polyethylene tent constructed over the nursery row. Similar to the tent previously described, 150 cm height x 80 cm wide at the base.

The buds were evaluated after four and eight weeks.

Semi-hardwood Cuttings

Semi-hardwood cuttings consist of leafy stems of partially matured wood. Experiments dealing with filbert cuttings of this type were carried out during three growing seasons. Trials done in 1974 were of a survey nature.

In all semi-hardwood cutting experiments several factors were held constant: the rooting medium was a mixture of perlite, peat and vermiculite (6:1:1 by volume) approximately 12 cm deep. Continuous bottom heat of 21-24°C was provided by thermostatically controlled electric heating cables. Heating cables were overlaid with bronze screen both for their protection and to provide uniform distribution of heat. All cuttings were taken with actively growing terminals. Terminal cuttings of approximately 30 cm in length were collected
from orchard trees and placed in water filled vials for transportation to the propagating area. Maximum time from taking cuttings until placement in the rooting bed, or sticking, never exceeded six hours. When conditions made desiccation a possibility, cuttings were sprayed with water and covered with large plastic bags. For sticking, cuttings were trimmed to about 18 cm in length. Lower leaves were removed, allowing one fully expanded leaf, one or two smaller leaves and the growing terminal to remain. Cuttings were handled in groups of 25, trimmed, treated with a root promoting chemical and placed in the rooting bench. Liquid root promoters were applied as 10 to 15 second dips. Hormone powders were applied by first dipping the cuttings in water, then in the hormone preparation. Throughout, dipping depth was 3 cm. Cuttings were thoroughly watered after sticking, with light, daily waterings thereafter.

Semi-hardwood cutting experiments in 1974 were designed to determine the relative effectiveness of various root promoting treatments, two foliar environments, and the comparative rooting potential of several filbert types. Root promoters were tested with 'Barcelona' cuttings in two foliar environments. Treatments are shown in List 7.

List 7. 1974 Semi-hardwood cuttings, root promoting treatments.

1. Control (no treatment).
2. Indolebutyric acid (IBA), 4000 ppm.
3. IBA, 2000 ppm.
4. IBA, 1000 ppm.
5. IBA, 250 ppm.
6. Hormodin No. 1 (0.1% IBA).
7. Hormodin No. 2 (0.3% IBA).
8. Hormodin No. 3 (0.8% IBA).
9. Naphthalene acetic acid (NAA), IBA, 250 ppm each.

Crystalline IBA was first prepared as a stock solution of 100,000 ppm in 95% ethyl alcohol and then diluted with distilled H₂O. The potassium salt of IBA, when used, was dissolved directly in H₂O. Hormodin, a commercial rooting powder, was available in the IBA concentrations shown in List 7. The combination of NAA and IBA was prepared similarly to the IBA solutions. Jiffy-Grow, a commercial liquid preparation containing NAA and IBA, was used in a 1:20 dilution, yielding a 250 ppm concentration of each growth regulator.

The two foliar environments tested in 1974 were open mist and high humidity. The open mist system consisted of an outdoor, ground level bench. Mist was controlled by a Solatrol light measuring device adjusted to allow misting for five seconds of every 120 seconds at full sun from 0530 to 2100 daily. The entire bench was enclosed by clear, 6 mil polyethylene sheeting to prevent wind disturbance of the mist pattern. This outdoor structure was amply ventilated.
A standard greenhouse bench was used to construct the high humidity foliar environment. For humidification, a Model KS-2B Bete Fog Nozzle, an industrial type humidifier, controlled by a Bete GCH humidistat was used. To maintain high relative humidity (RH), the bench was enclosed by a 1.5 m high tent of 4 mil clear polyethylene. A 15 cm squirrel cage fan provided ventilation. Saran cloth was suspended over the entire structure to provide 50% shade to aid in temperature control. The humidistat was adjusted to maintain 90% RH.

Species and cultivar tests were in some cases limited by available plant material. List 8 gives types tested in both foliar environments.


1. 'Daviana'.
2. 'Butler'.
3. 'Ennis'.
4. 'Lansing'.
5. 'Hall's Giant'.
6. C. a. contorta.
7. C. a. fusco-rubra.
8. C. a. pendula.
9. *C. columna*.

10. 'Barcelona'.

The root promoting treatment used throughout the species and cultivar tests was a 10-15 second dip in a solution of 2000 ppm IBA.

In all tests, rooting was determined by visual inspection of individual cuttings. Those adequately rooted were potted in 10 cm square plastic pots using a medium of perlite, peat and vermiculite (1:1:1 by volume). Cuttings which showed no signs of rooting after 50 to 60 days were discarded. During the rooting period dead or dying plant material was removed from the propagating benches in an effort to avoid disease problems. In the 1974 trials, benches were drenched weekly with Captan, Benlate or Agrimycin 100; one pesticide was used each week in a three week cycle.

Observations were made to determine cutting survival. In this and all other semi-hardwood cutting trials, survival was indicated by new growth or the presence of viable buds. Cuttings which had rooted and remained alive but had lost all growing points were classified as not surviving.

In 1975, cutting experiments again employed two foliar environments. One was the high humidity system used in the 1974 trials, modified by a reduction of tent height to 1 m, reducing the volume of air to be humidified. The open mist system was eliminated and a second high humidity system was constructed, utilizing the same basic
Humidification was achieved using a Flora Fume Fogger, a device normally used for spraying insecticides in closed areas. Fogging was controlled by time clocks, adjusted to operate the device for 40 seconds every 15 minutes from 0600 to 2100 daily.

Cuttings were collected and handled as previously described. A root promoting treatment of 2000 ppm IBA, applied as a 10 to 15 second dip, was used throughout. Cutting collections were made on two dates, 25 June and 25 July. A portion of the cuttings collected on 25 July were treated with N6 Benzyl adenine (BA) two weeks after sticking, in an effort to retard their deterioration during the rooting period. The BA solution was applied as a foliar spray with a small, hand pump sprayer. The solution was prepared by dissolving 0.2 g BA in 60 ml, 0.1 N HCl. The pH was adjusted to 6.02 with 74.2 ml, 0.1 N NaOH and diluted with \( \text{H}_2\text{O} \) to yield a final BA concentration of 100 ppm. A control solution without BA was prepared and applied in a manner similar to the test spray. Potting and evaluation of cuttings were done as in 1974 experiments.

Cutting experiments in 1976 were similar to those of 1975 with some changes. Greater emphasis was placed on the use of foliar chemical sprays applied after sticking (List 9). The high humidity system employing the Flora Fume Fogger was adjusted to operate at intervals of 12 minutes. All other factors were maintained as before.

1. Control (no treatment).
2. AgNO₃, 50 ppm.
3. AgNO₃, 100 ppm.
4. AgNO₃, 250 ppm.
5. AgNO₃, 500 ppm.
6. Gibberellic acid₃ (GA₃), 100 ppm.
7. GA₃, 200 ppm.
8. BA, 20 ppm.
9. BA, 40 ppm.

Cuttings were collected on two dates, 30 June and 21 July, with all treatments being applied equally with the exception of deletion of treatments 2 and 7 from the 21 July group.

All foliar chemical treatments were applied as aqueous solutions one week after sticking; therefore, no control solution application was made.

An additional treatment was included by applying 2000 ppm IBA to the terminal buds at the time of sticking. This was done by dipping the terminal for 10 to 15 seconds in the IBA root promoting solution. The purpose was to determine if such an auxin treatment applied to the top of the cutting would elicit any effects related to rooting or shoot growth.
Potting and evaluation of results were as previously described.
RESULTS

Summer Budding

In the 24 September evaluation of the 1974 summer budding trials, success rates from 8 to 70% were recorded for the treatments in List 1. Most promising were treatments 6 and 7, yielding 55 to 70% success, respectively. However, by 10 May 1975, of the total 380 buds placed in the entire experiment, only ten had survived. Buds which appeared alive and callused in the fall, generally failed to survive the winter. Neither evaluation date showed a significant benefit for a specific budding height or method.

In the limited summer budding tests of 1975, which included budding current season’s stems and also RS of the type used during the previous year, results were disappointing. Within three weeks of budding, all the buds were dead.

Summer budding trials in 1976 produced more encouraging, though not definitive results than those conducted during the prior two years. Percentage success for the budding treatments is shown in Figure 3. Statistical analysis following application of the arcsin square root transformation does not indicate any significant differences between treatments at the 0.95 level. However, differences were noted at approximately the 0.80 level. Buds placed on wood two years old or older (Treatments 2 and 3) gave less success than those
Fig. 3. 1976 Summer budding. Percentage success by treatment. Treatments as follows:

<table>
<thead>
<tr>
<th>Trt.</th>
<th>Rootstock</th>
<th>Bud Position</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 yr. old potted cutting, greenhouse</td>
<td>main stem</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>2</td>
<td>2 yr. old potted cutting, can yard</td>
<td>main stem</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>3</td>
<td>commercial layered tree, nursery</td>
<td>main stem</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>4</td>
<td>commercial layered tree, nursery</td>
<td>current season's shoot</td>
<td>T-bud, 1 x 20 cm rubber band wrap</td>
</tr>
<tr>
<td>5</td>
<td>commercial layered tree, nursery</td>
<td>current season's shoot</td>
<td>T-bud, 1 x 20 cm rubber band wrap, plus polyethylene sheath</td>
</tr>
<tr>
<td>6</td>
<td>mature, multiple stemmed tree, orchard</td>
<td>current season's shoot, north side of row</td>
<td>T-bud, 1 x 20 cm rubber band wrap, plus polyethylene sheath</td>
</tr>
</tbody>
</table>

For each treatment, n = 40. No significant differences between treatments detected.
Figure 3.
placed on current season's growth. It should be noted that all previous summer budding, with the exception of a few instances in 1975 tests, was carried out placing buds on stems two or more years of age.

**Chip Budding**

As shown in List 3 in the Methods section, 16 treatments were tried in the 1975 greenhouse chip budding trials. Surveying such a large number of variations of a basic technique permitted the placement of only 16 buds for each treatment. Statistical analysis of results was prohibited by random deaths of several RS, resulting in unequal applications of other factors.

Using success percentages as measures of treatment effectiveness, only treatments 8, 9 and 14 showed 50% or greater success based on samples of at least ten individuals. Success rates with other treatments where ten or more buds could be evaluated ranged from 7 to 36%. Rootstock mortality also prevented the analysis of results for specific budding methods or budwood types. Percentages indicated that the notch bud and the circular shield yielded 38% and 42% success respectively, averaged over all treatments. Viewed in the same manner, buds obtained from suckers produced 46% success, while those from upper limbs yielded 33%.
Effects due to the height of bud placement were more reliably represented than the above factors, because the death of any rootstock would eliminate one similarly treated bud from each height category. Buds placed at 25 to 35 cm were 49% successful, while those placed at 5 to 8 cm gave 30% success. A significant difference at the 0.95 level was not indicated.

Results of the 1975 chip budding tests carried out in the nursery were also disappointing. Evaluation of all treatments eight weeks after budding showed that none of the 405 buds had survived.

In the 1976 greenhouse chip budding experiments, statistical analysis of the first group was not carried out. In each of the 13 treatments only five buds were placed. No single treatment gave distinctly higher success. Treatments are outlined in List 5. Treatments 6, 10 and 13 were totally unsuccessful, and the remaining treatments resulted in only one or two live buds.

In the second group of 1976 greenhouse chip budding tests, eight buds were used per treatment. While this number was small, it was sufficiently large to allow the use of Clopper and Pearson charts of confidence belts for proportions, thus giving a means for determining differences between treatments, if any. Success percentages ranged from 0 to 50, with treatments 1 and 2 (List 5), each at 50%. No differences were noted at the 0.95 level of confidence.
The third 1976 chip budding trial, as mentioned in the Methods section, included plants budded to bareroot RS and placed in the greenhouse or the nursery. None of the buds on the greenhouse trees survived. Of 100 trees budded and planted in the field, only two buds were classed as takes. Nursery trees experienced a high mortality rate, possibly as a result of late planting.

Results of the fourth chip budding trial in 1976 conducted in the nursery were dramatic in comparison to earlier experiences. Treatments 8 and 9 gave 83% and 50% success, respectively, significantly superior to all other treatments at the 0.95 level. No success was obtained with any of the other treatments. It is notable that the two successful treatments were made on trees enclosed by the polyethylene tent. Buds which were successful appeared to be callused uniformly well. In some cases, the primary bud had died, but was replaced by the growth of one or more accessory buds.

**Semi-hardwood Cuttings**

Rooting results for semi-hardwood cuttings taken in 1974 trials are shown in Figure 4. Ranges shown for mean population rooting percentages with 95% confidence were obtained using standard tables of binomial confidence limits, and are presented to allow an estimate of the reliability of the percentage success obtained. Treatment 3 was the only treatment that yielded over 90% rooting in both environments.
Fig. 4. 1974 Semi-hardwood cuttings, rooting hormone treatments. Rooting percentages showing 0.95 confidence ranges for population rooting based on \( n = 25 \) for each treatment. The circled numbers refer to the treatments, as follows:

1. Control (no treatment).
2. IBA, 4000 ppm.
3. IBA, 2000 ppm.
4. IBA, 1000 ppm.
5. IBA, 250 ppm.
6. Hormodin No. 1 (0.1% IBA).
7. Hormodin No. 2 (0.3% IBA).
8. Hormodin No. 3 (0.8% IBA).
9. NAA, IBA, 250 ppm each.
Figure 4.
In a comparison of corresponding treatments by a method of testing differences between two proportions, the open mist system gave superior rooting in six treatments. The high humidity system was superior only with treatment 7. For three treatments, equal rooting was obtained in both environments. Overall, percentage of cuttings surviving, that is, cuttings with growing points remaining after the rooting period, was 13.6% under the high humidity system and 5.2% under open mist. The high humidity system proved to be statistically superior. As before, all inferences are based on a 0.95 confidence level.

Rooting of the various filbert species and cultivars tested is shown in Figure 5. Percentages vary over a wide range, with 'Barcelona' consistently giving the best results. Comparisons between environments show high humidity superior to open mist with only one cultivar, both systems equal with seven types, and the mist system superior with two types.

Survival of lateral buds on the cuttings was practically nil in the 1974 species and cultivar trials. With 'Butler', the high humidity system produced 16% bud survival, and 20% with 'Barcelona', compared to 0 and 4%, respectively, under open mist. No statistical differences between environments were detectable for these types, or for 'Hall's Giant', C. a. fusco-rubra or C. a. contorta, which showed
Fig. 5. 1974 Semi-hardwood cuttings, species and cultivars. Rooting percentages showing 0.95 confidence ranges for population rooting based on n = 25 for each treatment. The circled numbers refer to the species or cultivar, as follows:

1. 'Daviana'.
2. 'Butler'.
3. 'Ennis'.
4. 'Lansing'.
5. 'Hall's Giant'.
6. *C. a. contorta*.
7. *C. a. fusco-rubra*.
8. *C. a. pendula*.
9. *C. columna*.
10. 'Barcelona'.
Figure 5.
token success. No bud survival was obtained in either environment with the five remaining types tested.

Results of 1975 semi-hardwood cutting experiments are shown in Tables 1 and 2.

At the 0.95 level, the 87% rooting shown in Table 1 was significantly better than any of the other values obtained. Sample percentages for both groups indicate superior rooting with the fogging system, though no other statistical differences exist.

For the results shown in Table 2, no statistical differences for bud survival exist between the environmental systems; however, under the Flora Fume system the BA treatment is significantly superior to the control. An anomaly exists in that, according to the sample percentages, under the Bete system, bud survival of the control treatment exceeded the survival of buds in the BA treatment. However, this was not statistically significant.

It is notable that the levels of survival vary considerably between the June and July collection dates under both environmental systems. The improvement in survival at the later collection date is significant at the 0.99 level.

Rooting of semi-hardwood cuttings in the 1976 trials is shown, by treatment, in Table 3. Rooting obtained under the Flora Fume system was higher than under the Bete system, significant at the 0.99 level for cuttings stuck on both dates. Inconsistent with earlier
Table 1. 1975 Semi-hardwood cuttings, rooting.

<table>
<thead>
<tr>
<th>Date Stuck</th>
<th>n</th>
<th>Percentage Rooting</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Bete System (humidification)</td>
</tr>
<tr>
<td>25 June</td>
<td>400</td>
<td>73</td>
</tr>
<tr>
<td>25 July</td>
<td>300</td>
<td>72</td>
</tr>
</tbody>
</table>

Table 2. 1975 Semi-hardwood cuttings, bud survival.

<table>
<thead>
<tr>
<th>Date Stuck</th>
<th>Treatment</th>
<th>n</th>
<th>Percentage Bud Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bete System (humidification)</td>
</tr>
<tr>
<td>25 June</td>
<td>-</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>25 July</td>
<td>-</td>
<td>300</td>
<td>25</td>
</tr>
<tr>
<td>25 July</td>
<td>BA, 8 Aug.</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>25 July</td>
<td>Control, 8 Aug.</td>
<td>25</td>
<td>56</td>
</tr>
</tbody>
</table>

Table 3. 1976 Semi-hardwood cuttings, rooting.

<table>
<thead>
<tr>
<th>Date Stuck</th>
<th>n</th>
<th>Percentage Rooting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bete System (humidification)</td>
</tr>
<tr>
<td>30 June</td>
<td>450</td>
<td>53</td>
</tr>
<tr>
<td>21 July</td>
<td>350</td>
<td>36</td>
</tr>
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</table>
results, rooting of cuttings collected on 30 June was significantly better (0.99 level) than that of the 21 July group, under the Bete system.

Figure 6 illustrates bud survival on cuttings in 1976 tests. Again, the Flora Fume system gave superior results, significant at the 0.99 level for both cutting dates. The Student-Newman-Keuls' test was applied to data from each cutting date under each foliar environment, resulting in comparisons within four groups. By determining the presence or absence of significant differences between the treatments shown in List 9, it is possible to judge whether or not specific treatments are superior based on the original percentage data. Before analysis of 1976 cutting data, the arcsin square root transformation was applied. The Student-Newman-Keuls' multiple range test showed that no significant differences existed for bud survival at the 0.95 confidence level between any treatments of the cuttings taken on 30 June 1976. Some differences were indicated in the 21 July group, as can be seen in Table 4. Even when significant differences between treatments were observed, those differences were not consistent under each system.

Results of the treatment consisting of 2000 ppm IBA application to cutting terminals were not included in the graphs and tables. In all cases, the IBA application killed the terminal growing points within
Fig. 6. 1976 Semi-hardwood cuttings. Percentage survival by treatment at two collection dates. For each treatment at each collection date, n = 50. Treatments, as follows, were applied as foliar sprays one week after sticking.

1. Control (no treatment)
2. AgNO₃, 50 ppm
3. AgNO₃, 100 ppm
4. AgNO₃, 250 ppm
5. AgNO₃, 500 ppm
6. GA₃, 100 ppm
7. GA₃, 200 ppm
8. BA, 20 ppm
9. BA, 40 ppm

Statistical relationships are indicated in Table 4.
Figure 6.
Table 4. 21 July 1976 semi-hardwood cuttings, bud survival rates compared for foliar chemical treatments.

<table>
<thead>
<tr>
<th></th>
<th>Bete System</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Flora Fume System</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Treatment no.</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Bud survival</td>
<td>35.66</td>
<td>31.89</td>
<td>27.07</td>
<td>25.07</td>
<td>24.80</td>
<td>17.56</td>
<td>13.99</td>
<td></td>
</tr>
<tr>
<td>(transformed)</td>
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<td>3</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Bud survival</td>
<td>60.67</td>
<td>55.95</td>
<td>53.41</td>
<td>47.30</td>
<td>46.16</td>
<td>42.70</td>
<td>39.21</td>
<td></td>
</tr>
<tr>
<td>(transformed)</td>
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</tbody>
</table>

Values underscored by the same line are not significantly different at the 0.95 level.
one week of treatment. A total lack of rooting, and therefore, bud survival, was the ultimate result.
DISCUSSION

Budding

The budding failures in this study were consistently similar. The major cause for the poor results obtained appeared to be desiccation and subsequent death of the buds before the formation of a callus union could occur. The characteristically slow callusing of the filbert (33) permitted the chips or slivers of wood on which the buds were borne to dry sufficiently to prohibit bud survival. It is likely that once drying begins, healing becomes more difficult because the cambial cells on and below the cut surfaces would be the first to succumb. In attempting to increase filbert budding success, it would seem logical to: (1) provide the best possible conditions for rapid callus formation; and (2) prevent moisture loss from the buds.

Because of the temperature influence on filbert callusing, it would be important to hold newly budded trees at 21°C or above to promote rapid callusing. Temperatures close to 21°C were most consistently obtained in the 1975 and 1976 greenhouse chip budding trials. Though the degree of success achieved in those tests was not outstanding, percentages of buds surviving exceeded those in field tests using unprotected rootstocks. Where well-established nursery planted stocks were protected by a polyethylene tent, as in treatments 8 and 9 (List 6) of the 1976 nursery chip budding tests, success was
markedly increased. Temperature comparisons for a 15-day period showed that temperatures inside the tent averaged approximately 26°C maximum, 3 to 6°C higher than outside. Minimum night temperatures were nearly equal both inside and outside the tent. The records also showed that the interior of the tent warmed faster and cooled more slowly than the ambient air.

Along with temperature, the nature of the plant material involved could influence callusing ability. It would seem that morphologically less mature wood, especially that of shoots most recently in active growth, would callus more rapidly than older portions of the RS. This is supported by the results of the 1976 summer budding experiments. Though not statistically significant, 18 to 40% higher success was obtained when buds were placed on stems less than one year old and in active growth, instead of on older wood. In the cases where younger parts of the RS were utilized, healing was rapid and appeared to be complete, with the scion buds remaining in excellent condition throughout the healing period.

Although budding on current season's shoots gave encouraging results, some difficulties were encountered with that method. The small size of the shoots required that the buds be cut correspondingly smaller than normal, and were therefore difficult to handle. Care had to be exercised in making the budding cuts and applying the wrap to avoid breaking the fragile stems.
It would be of little benefit to speed callusing by increased temperature, if, at the same time, drying also occurred at a faster rate. In filbert grafting, it is important that the freshly made grafts be well-wrapped to prevent desiccation or failure will result (33). It is possible that measures adequate to protect graft unions from desiccation would not be suitable for single buds. While a small amount of water lost from a three-bud scion might have little effect, the same amount lost from a single bud could prove fatal. Results from the 1974 summer budding trials showed that polyethylene wraps gave the highest degree of success, though later evaluations following overwintering indicated all wrapping materials were equally ineffective. The 1976 summer budding tests on current season's shoots showed fair results using rubber bands, like those used in filbert grafting. Success was increased when polyethylene sheaths were added to protect the buds from desiccation. In 1975 greenhouse chip budding tests, wraps of vinyl tape or rubber grafting bands and petroleum jelly gave the best results. Nursery chip budding trials of 1976 showed good success using the rubber band wrap only where the newly budded trees were protected by the polyethylene tent previously described. Effects of both tenting and the use of polyethylene sheaths in summer budding trials were probably similar in reducing moisture loss under field conditions. Both acted as direct barriers to moisture escape, as well as to reduce desiccation by wind. It is notable that
greenhouse budding, while not giving outstanding success, routinely produced better results than field trials. This is also true with filbert grafting, and is probably due, in part, to a reduction of the stresses related to water loss normally encountered in field situations. Wind, relative humidity, solar radiation and irrigation are factors that can be better controlled in the greenhouse than in the nursery. The result is a decreased tendency for newly placed buds to dry and increased chances for success.

**Cuttings**

For semi-hardwood filbert cuttings, problems of rooting are less perplexing than those of bud survival. Information obtained from past work was employed in selecting a rooting medium, root promoting hormone treatment and time for taking cuttings. Trials in this study have confirmed the usefulness of a highly aerated rooting medium with bottom heat, basal application of 2000 ppm IBA as a quick-dip, and the importance of collecting cuttings of sufficient maturity while the terminal buds are in active growth, which is roughly mid-June to late July in western Oregon. In all cases, acceptable rooting was obtained under the aforementioned conditions with the cultivar Barcelona. Other filbert types responded inconsistently. In the 1974 tests, the 2000 ppm IBA root promoting treatment resulted in the best overall rooting, and was used in all later tests. The importance
of the actively growing terminal was emphasized in the 1976 trials when cuttings which had the terminals killed by an excess application of IBA failed to show any signs of rooting.

The major problem encountered with semi-hardwood cutting propagation of filberts has been the loss of growing points, or buds, during the rooting period. Observations on bud survival made during the past three years of study and by earlier investigators indicate that the problem is related to the amount and method of water application to keep the cuttings alive during the rooting period. Water application by a conventional mist propagation system (cycle: mist 5 seconds/120 seconds at full sun) was used in 1974. This system maintained a film of water over the entire exposed portion of the cuttings, including the buds. Under these conditions, buds took on a water soaked appearance and eventually abscised, leaving a rooted stem with no growing points.

The Bete high humidity system employed in all three seasons of testing was an attempt to reduce cutting transpiration by increasing RH. While this system resulted in a greater number of cuttings retaining viable buds than under open mist, the quantity of bud survival was still not adequate for practical usage. The nature of bud failure was different from the water soaking created with fogging or open mist. With the Bete humidification system, buds showed a great deal of drying, many finally appearing shrunken and brown
to black in color. This was due to the humidifier being incapable of maintaining the 90% and above RH level desired. Hygrothermograph records showed that during daylight hours, RH was often less than 60%, dropping to 40 or 45% during high temperature periods. The drying effects of the lower humidity levels were apparent, not only on the buds, but also on the overall appearance of the cuttings. Necrosis at leaf margins was noted, and many leaves dried completely and abscised.

Use of the Flora Fume system described for the 1975 and 1976 experiments caused problems similar to those encountered with conventional misting, but to a lesser extent. Overall, less water was applied than by the open mist system, yet cuttings remained turgid and in good condition, and good rooting was obtained. However, many buds still became water soaked and were lost.

From the differences in the nature of bud losses in the foliar environments tested, it became apparent that the amount and method of water application to cuttings had an influence on retention of growing points. Additional testing with more rigidly controlled foliage environment systems is necessary before definitive statements can be made concerning conditions required for optimum filbert cutting survival.

The effects on bud survival due to foliar chemical applications tested in 1975 and 1976 were inconclusive. Trials using BA conducted
in 1975 showed a great increase in bud survival under the Flora Fume system. However, under the Bete system, the control spray provided for an increased percentage of cutting survival, though the results were not statistically significant. The 1976 results were also inconclusive, though slightly improved survival rates were obtained with BA treatments in both foliage environments for both cutting dates. Results of AgNO₃ treatments were inconsistent, as were those for treatments of GA.

An interesting phenomenon occurred to a limited extent with the GA treated cuttings under the Flora Fume system, which could be of importance. Normally, the terminal buds of semi-hardwood filbert cuttings begin to deteriorate and abscise within six weeks of sticking. With four of the cuttings to which GA was applied, this did not occur. The terminals continued to grow and all lateral buds remained in good condition. Root growth occurred to a lesser extent than on cuttings which did not exhibit shoot growth. This might be expected as the growing terminal could represent a competing sink (24). Hormone treatments applied to obtain adequate rooting create a strong sink at the cutting base. It is likely that the foliar application of GA created "countersinks" in the upper parts of the cuttings and allowed the terminals to continue growing. This might be explained by the effect of GA on stem elongation, or, in many cases, apical dominance (55).
Overall, maintenance of cutting buds was better under the Flora Fume system. This resulted because cuttings under the Bete system exhibited considerable drying, while those under the Flora Fume system remained turgid and showed few signs of drying.

Influences of cutting collection date were essentially opposite between foliar environments in 1976 trials. Under the Bete system, survival was better with the 30 June group, while the 21 July group was superior in the system humidified by the Flora Fume Fogger. In tests conducted during the prior year, cuttings taken on the July collection date survived better in both environments than did those of the earlier collection. Generally improved survival of cuttings collected later in the growing season could result from a greater capability to withstand stress due to greater morphological maturity.

Sticking cuttings at later dates requires that they withstand the more intense heat of mid-summer during the initial stages of rooting. However, development of better temperature control would eliminate that problem.
CONCLUSIONS

The results of this study substantiate that the filbert is difficult to propagate. Most of the results obtained were negative or highly variable. In particular, they showed that filbert buds are sensitive to the stresses encountered during budding and semi-hardwood cutting propagation.

It is clear that summer budding, such as is used for many fruit trees, will not yield a practical degree of success with filberts. Likewise, standard methods of chip budding do not work.

In budding propagation, moisture within the buds must be maintained at a level adequate for survival until tissues which facilitate water movement from the RS are formed. Most of the methods tested to retard water loss, alone, did not seem to be adequate for even moderate success. However, when provisions were made to attempt to speed callusing by increasing temperature or using young RS material, along with measures to retard desiccation, success was increased. Further testing of the use of current season's shoots as RS material and the covering of newly budded stems with polyethylene sheaths for summer filbert budding, and the use of polyethylene tents for chip budding, is needed. While the results of this study indicate that these factors aid in increasing budding success, duplications of the more positive results obtained are required to confirm the usefulness of the treatments involved.
Semi-hardwood filbert cuttings require a hormone treatment before they will root satisfactorily. Maximal rooting is obtained using a quick-dip application of 2000 ppm IBA. For rooting to occur, actively growing terminals must be present at the time the cuttings are collected. These terminals routinely abscise within six weeks of sticking.

The maintenance of lateral buds on filbert cuttings seems to be related to water application to prevent drying during the rooting period. Excess water causes axillary buds to take on a water soaked appearance, soften, discolor and eventually abscise. An opposite effect is obtained when the system employed provides an amount of moisture which is less than adequate to prevent all but minimal drying of cuttings. In such a situation, lateral buds develop symptoms of severe desiccation even before the foliage. The buds dry, harden, and take on a brownish to blackish color.

The results of this study indicate that propagation of filberts by semi-hardwood cuttings can be accomplished. If a rooting environment were provided to prevent desiccation, but not maintain a film of water on the cuttings, it is possible that survival rates adequate for commercial propagation could be obtained.

The objective of this study was to continue the testing of several variations of filbert propagation in an effort to eliminate those with little practical usefulness or success potential. At the same
time, variations showing some promise were incorporated into later experiments for testing, and those have been discussed. As yet, cutting and budding propagation of filberts is not feasible on a commercial basis. Beginning with the methods which now appear to be most successful, further development and testing is necessary to arrive at propagation systems for practical application.
BIBLIOGRAPHY


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