trees, that is enough for about 10 ha. These trees are now well established.

A glasshouse grower rooted cuttings in 9 cm pots in August 1980. The cuttings were overwintered in a glasshouse and, in the spring, repotted into 16 cm pots. The plants were, during the summer of 1981, grown on a container bed in the open and overwintered on this container bed. In the spring of 1982 the plants were planted. About 75 per cent of the original cuttings were planted. I think the grower would have done even better if he had started rooting the cuttings a month earlier, that is about July 1.

To sum up, experimental as well as commercial experience shows that the 'Stevnsbaer' sour cherry can be propagated by cuttings. It is also known that 'own-rooted' trees can yield well. The propagation methods may need some adjustments so that they are more suited to the growers' equipment and experience. We are at present working on these problems at Hornum.

# ESTABLISHMENT IN CONTAINERS OF WOODY ORNAMENTALS PROPAGATED FROM DORMANT LEAFLESS CUTTINGS

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**Abstract.** Data are presented on the rooting of February-taken, dormant, leafless cuttings in heated bins and on their subsequent establishment in containers.

Both rooting in the bin and survival at the end of the season were highly correlated with the degree-weeks of temperature which the cuttings had experienced in the bins.

The survival of *Acer saccharinum* cuttings markedly decreased with increase in the number of degree-weeks. This response was not as marked for *Laburnum* × *vossii* and *Platanus* × *acerifolia*, suggesting that *Acer* cuttings rapidly become depleted of their carbohydrate reserves.

Survival of *A. saccharinum* cuttings in containers was markedly increased by placing them under mist enclosed by polyethylene in a netting tunnel.

Difficult-to-root species such as *Acer platanoides* 'Drummondii' and *Prunus* 'Shirofugen' responded poorly even when mist was used to assist cutting survival.

## REVIEW OF LITERATURE

The propagation of woody ornamentals from dormant, leafless (hardwood) cuttings is a traditional technique for easily rooting genera in cold frames or the open ground (see Sheat, 19). The rooting of more difficult species and cultivars, some of which are traditionally grafted, in heated compost in insulated bins, has been attempted by a number of workers and recently reviewed (24). The technique was developed for fruit rootstock production by Garner and Hatcher (8,9,10) following observations that cuttings lined out in the field rooted well when soil temperatures were high. Initially they constructed bins of straw bales with thatched covers, where the rooting compost was heated by soil warming cables to a temperature of about 7°C. Subsequently a higher temperature (21°C) for a shorter period was found to be advantageous, Howard and Garner, (14).

Howard then went on to investigate the factors contributing to the success of the technique such as management of stock plants, type of cutting, time of taking cuttings, hormone concentrations, rooting temperatures and storage requirements of cuttings (11,12,15).

A major modification was the raising of the rooting-medium temperature (14). This allowed a greater throughput of cuttings but subsequently presented problems associated with planting and establishment in the field. Two major rooting periods were clearly identified, i.e. October-November and February-March (16). Optimum treatments and times for the successful rooting of a wide range of fruit rootstocks have subsequently been listed (13).

Cuttings of many woody ornamentals, for example *Ribes*, *Forsythia*, *Salix*, root readily when inserted in open ground in the autumn. It was assumed that genera more difficult to root would respond to the heated-bin technique as used for fruit rootstocks (17,18,20). This proved not to be the case and it became evident that for ornamentals more accurate control of rooting medium temperature, irrigation of cuttings in the bin, and lower hormone concentrations were required (21,22,23).

Furthermore, ornamentals are in general more difficult to manage (1) — not surprisingly as fruit rootstocks have been bred and then clonally selected over long periods of time. Fruit rootstocks often contain preformed root primordia; indeed, preformed roots occur on the stems of stock plants of some genera. *Malus* rootstocks appear to tolerate a wider range of conditions during rooting when propagated alongside ornamental species (21).

A problem with field production of fruit rootstocks has been carbohydrate depletion (13). This may well contribute to some of the poor establishment observed with field-planted ornamentals (21). One method of alleviating the problem has been the use of a shorter rooting period, even as little as two weeks. Plants so rooted usually have fewer roots. This is beneficial as the majority of the roots will be produced into the medium in which the cuttings will grow undisturbed for the first season.

As ornamentals appear more sensitive to desiccation and carbohydrate depletion than fruit crops, they should benefit from being grown in an environment which can be more easily regulated than a field one. As a large number of species are now grown in containers it seemed appropriate to grow rooted dormant, leafless cuttings in such a system. Initially plants were grown in a sheltered situation only (25) and subsequently under protected environments in a netting tunnel structure. The experiments reported were done over four years. The objectives were twofold: to investigate the physiology of the rooting of dormant, leafless, woody cuttings and to attempt to develop a commercially useful technique.

## MATERIALS AND METHODS

**Propagation procedures.** Cuttings of the species listed in Table 1 were taken from the basal 30 cm of branches, after Garner and Hatcher (8) of hedge-pruned stock plants (six years old in 1979) in February of each year. The bases of cuttings were trimmed and dipped for 15 sec 10 mm deep in 1500 ppm 4-(3-indoyl)butyric acid (IBA) in 50% ethanol. Fifty cuttings per treatment were generally used, although this number did range from 40 to 90 cuttings per treatment for some experiments.

Bundles of cuttings were then inserted 15 cm deep in a rooting compost of equal parts of Irish moss peat and Chichester grit (maximum particle size 5 mm). The bases of cuttings were then 9 cm above the heating cables. The temperature of the rooting medium was measured by four semiconductor diode junctions (Nobel Engineering Ltd) per $m^2$ of bin area and controlled electronically (26). The temperatures achieved were independently monitored by a Honeywell Versaprint 12-point recorder using platinum resistance sensors in 1979 and 1980, and by a 20-channel Grant recorder using type C thermistor probes in 1981 and 1982.

**Experimental designs.** Four bin temperatures (5°, 10°, 15° and 20°C) were factorially combined with three lifting times (2, 4 and 6 weeks). The combinations differed from one year to the next according to the nature of the experiments, which are listed in Table 1. The cuttings were tied and inserted into the rooting medium in bundles of five. The treatments were randomly allocated to plots within each bin and, on each lifting date, two adjacent bundles of cuttings were lifted and scored.

**Table 1.** Rooting temperatures, growing-on environments, and species used in the experiments.

| Year | Rooting temperature | Object of experiment | Growing-on regime | Species and cultivars used |
|---|---|---|---|---|
| 1979 | 5°, 10°, 15°, 20° C | Comparison of rooting temperatures and lengths of times in the bins | Outside, but sheltered on 3 sides by glasshouse structures | *Acer saccharinum*<br>*Laburnum* × *vossii* |
| 1980 | 5°, 10°, 15°, 20° C | Detailed investigations into water and carbohydrate relationship of cuttings | same as above | *Acer saccharinum*<br>*Laburnum* × *vossii*<br>*Prunus subhirtella* 'Autumnalis'<br>*P.* 'Shirofugen'<br>*Acer platanoides* 'Crimson King' |
| 1981 | 20° C | Plant survival as affected by duration of time in the bins and subsequent growing regime | "Nicofence 31", 40% shade tunnel. With mist and shaded polyethylene (as described in text) | *A. saccharinum*<br>*Platanus* × *acerifolia*<br>*P. subhirtella* 'Autumnalis' |
| 1982 | 20° C | Plant survival as affected by duration of time in the bins and growing regime. Rooting of more difficult genera | As above, but with additional shading over "misted" treatments | *Acer* spp.<br>*Prunus* spp.<br>*Betula* spp.<br>*Sorbus* spp.<br>*Crataegus* spp. |

The cuttings were scored for root development on a 0-5 ranking basis and potted into 14 cm diameter black polyethylene containers of 3 liter capacity. The compost used in the containers was 75% Irish moss peat and 25% sand, with fertilizer additions (per $m^3$) of "Osmocote" slow release fertilizer (18-11-10), 750 g; single superphosphate, 750 g; magnesium limestone, 2400 g; and fritted trace elements (WM 255), 300 g.

**Growing-on environments.** In 1979 and 1980, containers were placed in blocks on a gravel base, in open outdoor frames, sheltered from wind by adjacent glasshouses on three sides. During 1981 and 1982 they were placed on drained subirrigated sand beds inside a tunnel structure clad with "Nicofence 31", 40% shading material, to allow for greater environmental control. Within the tunnels the cuttings were given different environments i.e. 1) control (no additional protection), 2) shaded polyethylene, 500 gauge (125 $\mu$) polyethylene as an enclosed tent and shaded with "Rokelene" 40% shade cloth (1981 only), and 3) "mist" under a similar polyethylene structure. Except for a few days at the start of the growing on period of the experiments in April and May, with high radiation (daily integrals ca. 18-26 MJ/$m^2$), the mist was unshaded in 1981. During 1982, 40% shade cloths were used over the mist as the radiation was about 30% higher than in the previous year during April, May, and June. Mist control was by timeclock set to operate from about 1.5 h after sunrise to 1.5 h before sunset.

**Recording and analysis of data.** Measurements of temperature at the base of the cuttings showed that the values achieved were sufficiently close to the set ones to use the latter in all experiments. Examples are given in Whalley and Loach (25). Mean air temperatures 1 m above the bins gradually increased during propagation; for example, in 1979 the mean temperature for the first two weeks of February was 3.1 °C, whilst for the first two weeks of March it had reached 7.5 °C. The effects of bin temperature on temperatures experienced by the above-ground portion of the cuttings were minimal. Sensors placed in the centres of bundles of cuttings, 5 cm above the rooting medium, differed by only 1 degree C from the coolest (5 °C) to the warmest (20 °C) treatments and differed little from air temperatures 1 m above the bins.

On lifting from the bins in March, cuttings were scored for root number, degree of callus, and of any basal browning. During the growing season bud development and extension growth were recorded, together with the numbers of the cuttings which survived.

## RESULTS

Results of the first year's experiments were interpreted using the product of time and temperature (degree-weeks). Similar results were obtained from combinations of low temperatures for long durations and from high temperatures for short durations; Thus, for *A. saccharinum* 4 wks at 15°C gave closely similar rooting to 3 wks at 20°C (both 60 degree weeks).

Rooting clearly correlated with accumulated temperature expressed in degree-weeks (Figure 1). For both *Acer* and *Laburnum* 50 to 60 degree weeks were required for rooting.

Plant survival (assessed at the end of the season in November) was closely and negatively related to rooting in the bin (Figure 2). A steep decline in percentage survival was associated with increasing percentage rooting, probably indicating a rapid depletion of reserves during rooting and the importance of such reserves for subsequent growth. Different patterns of survival of *Acer* and *Laburnum* were apparent when plotted against accumulated temperature (Figure 3). *Acer* showed a steep decline in survival beyond 40 degree-weeks, but there was less evidence for a decline with *Laburnum*. Cuttings which rooted well survived poorly in *Acer*, but rather better in *Laburnum* (asterisked values, Figure 3). However, the mean survival percentages were low, being 38 for *Acer* and 32 for *Laburnum*. In the best treatments just over 50% survived in both species.

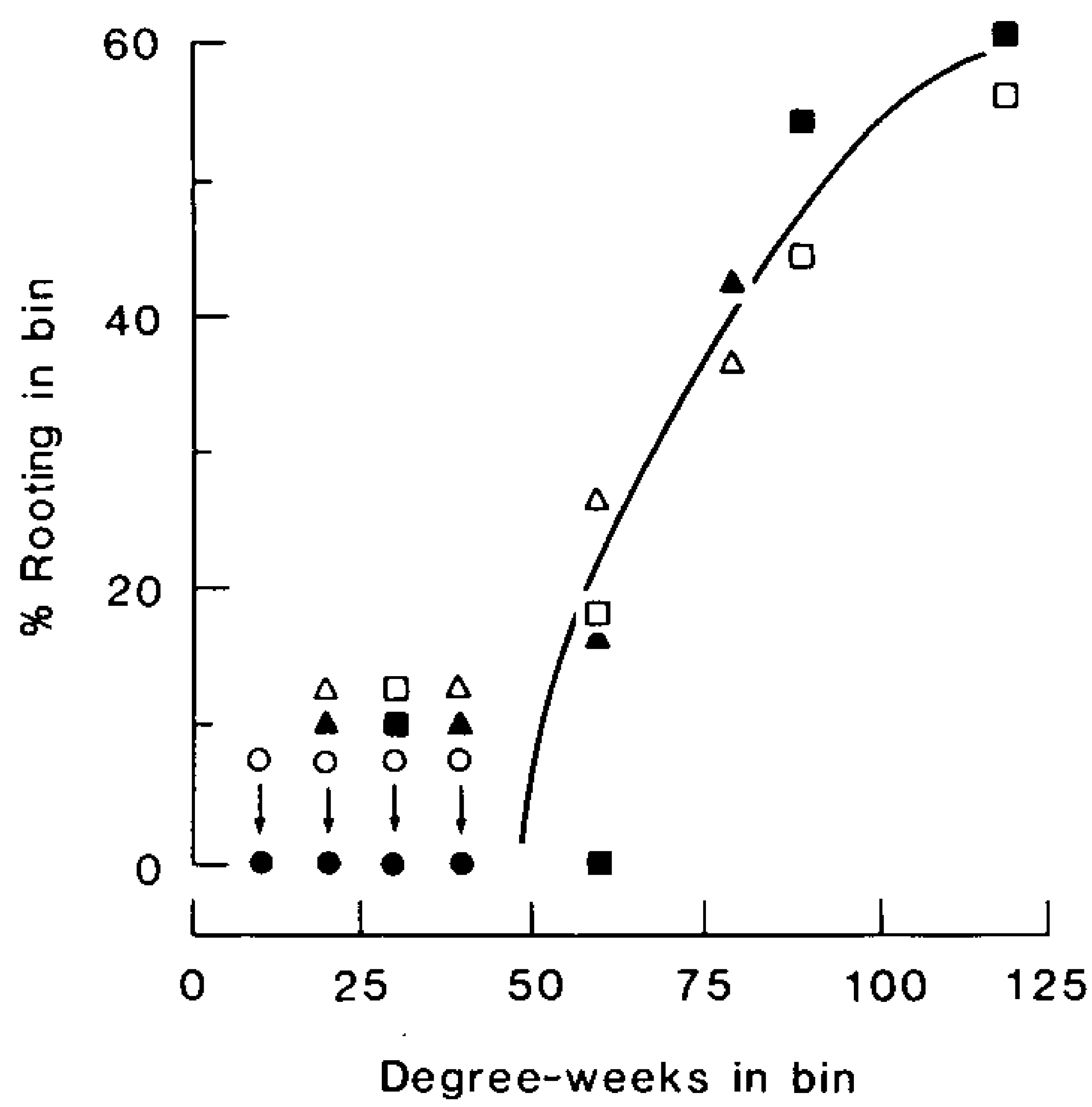


**Figure 1.** Relationship between percentage rooting and accumulated temperature (degree-weeks) in the bin. *Acer* shown by open and *Laburnum* by closed symbols. (○●) 2 weeks, (△▲) 4 weeks and (□■) 6 weeks. (No rooting occurred prior to 50 degree-weeks.)

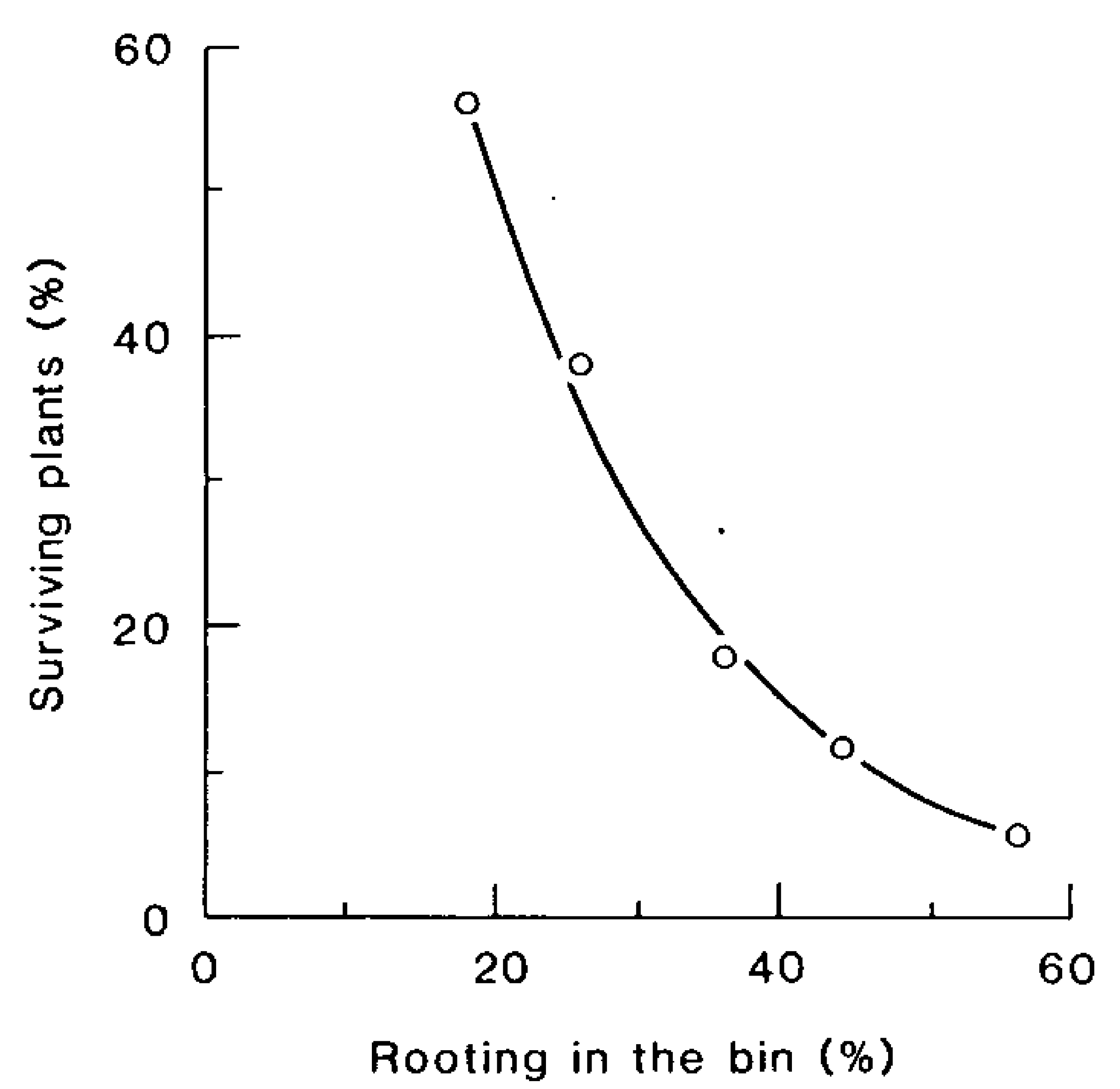


**Figure 2.** Survival of plants in November as a function of rooting in the bin. All data for *Acer saccharinum*.

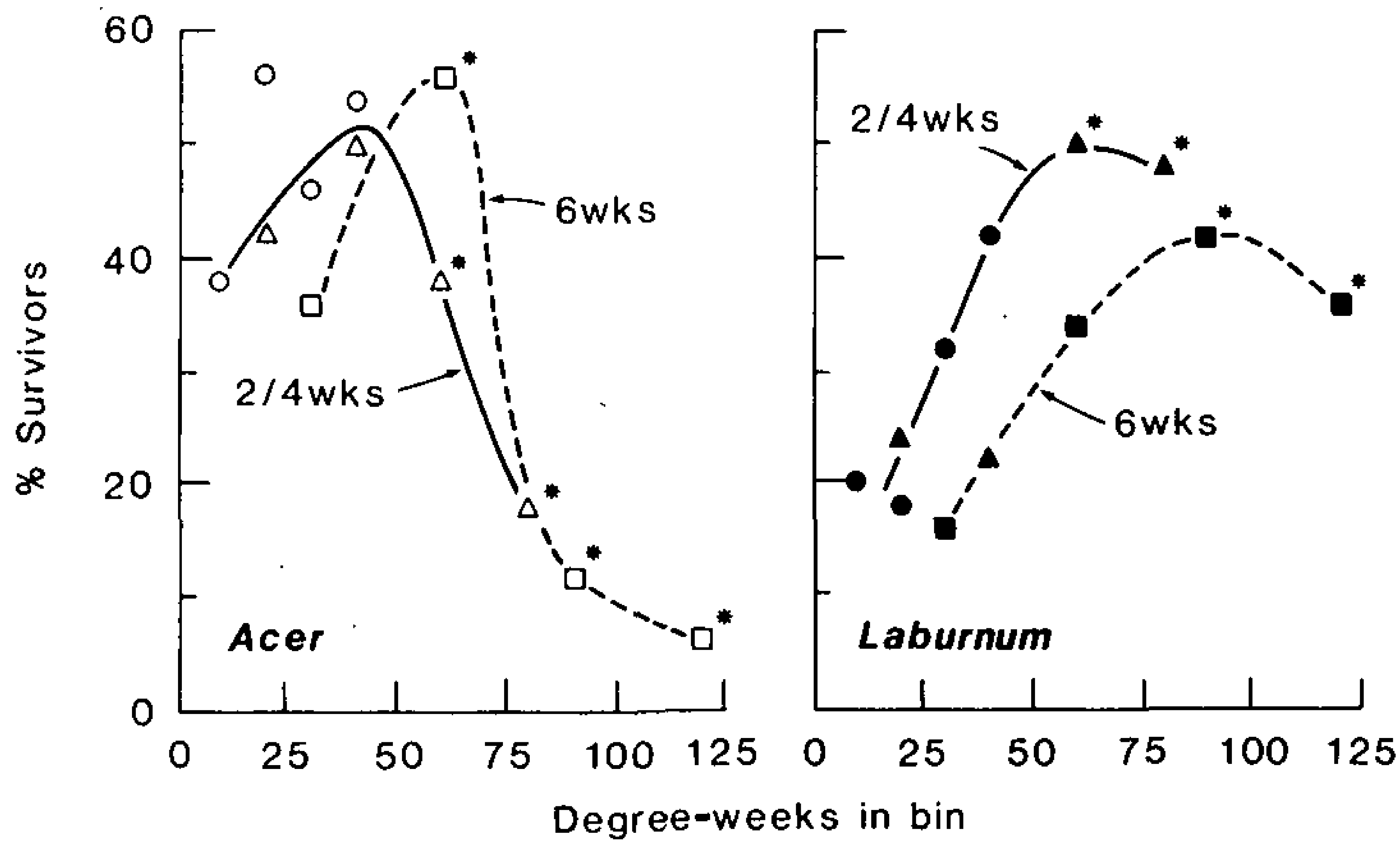


**Figure 3.** Relationship between percentage survival (assessed on 5 November 1979) and the number of degree-weeks the cuttings received in the bins. Symbols for *Acer* (O) 2 weeks, (△) 4 weeks, and (□) 6 weeks, (Left). Symbols for *Laburnum* (●) 2 weeks, (▲) 4 weeks, and (■) 6 weeks (Right). * = treatments with rooted cuttings at potting.

There was a definite separation of the 2/4-week and the 6-week treatments (see Figure 3). Similar separations were also seen for bud development data (25).

The 1980 experiments investigated water and carbohydrate changes in greater detail and will be separately reported (Loach and Whalley, in preparation). However, some of these results are described briefly here.

To obviate the carbohydrate depletion observed in *Acer*, cuttings were supplied with sucrose in solution during and after rooting via small wells made in the top of the cutting. Surprisingly, this resulted in 100% plant mortality, possibly the result of damaging high osmotic potentials, assuming the sugar was mobilised.

*Laburnum* cuttings gained in fresh weight when propagated at high temperatures, mainly because of water uptake by the roots (Figure 4). Respiratory depletion at high temperatures was found to be negligible (25). The curves for rooting obtained when the data were plotted against degree-weeks were similar to those of the previous year (Figures 1-3). Overall percentage establishment figures for *Acer* and *Laburnum* were again low, being 48% and 28%, respectively. In the best treatments, 58% survived in *Acer* and 95% in *Laburnum*. However, subsequent extension growth was poor in *Laburnum*, probably as a result of the "fuzzy-top" syndrome. This disorder affected all of six clones submitted to a clonal selection scheme, (2) and its cause is unknown.

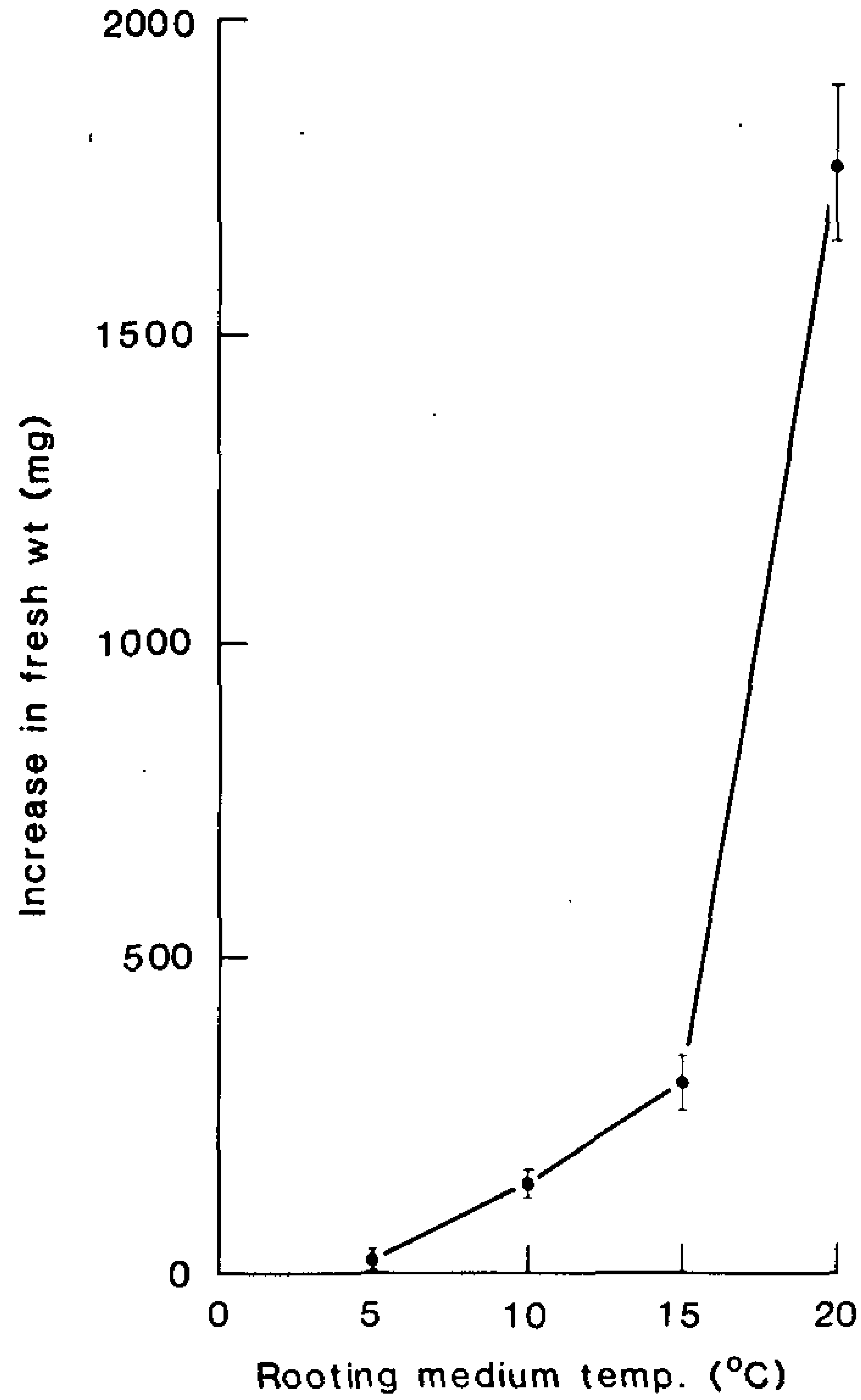


**Figure 4.** Change in fresh weight of *Laburnum* × *vossii* cuttings after four weeks in the rooting medium at 5°, 10°, 15°, and 20°C. Vertical bars represent standard errors of means.

The 1981 experiments concentrated on post-bin treatments designed to protect the developing foliage of cuttings with little or no root development.

Results for the three systems: Control, Shaded Polyethylene, and Mist under Polyethylene, are given for *Acer* in Table 2. This shows the superiority of the misted system and also the decline in survival with a longer duration in the rooting medium.

By contrast, plants of *Platanus* in the same experiment had a much higher percentage survival (mean 89%) although the misted system was still superior.

As providing a suitable environment for cuttings of this type by misting at an early stage appeared to be beneficial, the 1982 experiments compared more difficult-to-root species against *Acer saccharinum* as a standard. Table 3 again shows the superiority of the mist under polyethylene system for *A. saccharinum*. These data clearly illustrate that the post-rooting

**Table 2.** Percentage survival of *Acer saccharinum* and *Platanus* × *acerifolia* under three different systems (recorded September, 1981).

a) Overall percentage survival in the three systems

| | Control | Shaded polyethylene | Mist under polyethylene |
|---|---|---|---|
| *Acer* | 25% | 27% | 60% |
| *Platanus* | 78 | 94 | 94 |

b) Percentage survival of *Acer* after different lengths of time in the bin

| | Control | | | Shaded polyethylene | | | Mist under polyethylene | | |
|---|---|---|---|---|---|---|---|---|---|
| Weeks in bin | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 |
| Degree-weeks | 40 | 60 | 80 | | | | | | |
| Percentage survival | 45 | 19 | 11 | 41 | 30 | 11 | 76 | 58 | 45 |

Data based on 74 cuttings per treatment for *Acer* and 90 cuttings per treatment for *Platanus*.

environment is the most important factor. Of the cuttings which had not been placed in the heated bins, but had been directly inserted into the compost of the containers, 84% survived to form good plants, compared with 30% of the controls. Furthermore, of all the controls, those without bin treatment established best, a steady decline being seen with increased duration of the time in the bins.

**Table 3.** *Acer saccharinum* - percentage survival of good quality plants (August 1982).

| Rooting period (weeks) | Holding period (weeks) | Control plants in "Nicofence" tunnel only, no additional protection | Mist under polyethylene within plastic structure in "Nicofence" tunnel |
|---|---|---|---|
| 0 | 0 | 30% | 84% |
| 2 | 0 | 28 | 88 |
| 2 | 1 | 24 | 78 |
| 4 | 0 | 16 | 54 |
| 4 | 1 | 2 | 58 |
| | Mean | 20 | 72 |

Data based on 50 cuttings per treatment.

*A platanoides* 'Drummondii' cuttings survived poorly (overall mean 11%; highest was the mist under polyethylene treatment, 30%). Early lifting of cuttings from the bin to minimise carbohydrate depletion was effective to a limited extent for *Prunus subhirtella* 'Autumnalis'. Misting was ineffective for P. 'Shirofugen' (Table 4).

Leaching of nutrients from leaves was found to be a slight problem in both the years the mist was used, despite the use of supplementary liquid feeding when deficiency symptoms appeared.

Rooting of cuttings of species normally grafted was disappointing. *Betula pendula* 'Youngii', *B. pendula* 'Dalecarlica', Sorbus cvs 'Red Tip', 'White Wax', and 'Scarlet King' all failed to root or did so to a minimal extent. *Crataegus oxycantha* 'Paul's Scarlet', and *C. oxycantha* 'Rosea' callused but failed to root as observed previously (21).

Slightly more promising results (best treatment 18%, mean of all treatments 8%) were obtained for *Acer platanoides* 'Crimson King'.

**Table 4.** Percentage survival of *P. subhirtella* 'Autumnalis' and *P. serrulata* 'Shirofugen' as a function of accumulated temperature in the rooting medium.

| | | | | | |
|---|---|---|---|---|---|
| *P. subhirtella* 'Autumnalis' (recorded April 1980)* | | | | | |
| Degree weeks in bin | 20 | 40 | 60 | 80 | 120 |
| Percentage survival | 13 | 23 | 53 | 13 | 0 |
| *P. subhirtella* 'Autumnalis' (recorded August 1982)† | | | | | |
| | Control | | Mist under polyethylene | | |
| Degree weeks in bin | 40 | 80 | 40 | | 80 |
| Percentage survival | 24 | 4 | 22 | | 4 |
| *P. serrulata* 'Shirofugen' (recorded August 1982)† | | | | | |
| Degree weeks in bin | 40 | | | 40 | |
| Percentage survival | 20 | | | 8 | |

* 40 cuttings per treatment.
† 50 cuttings per treatment.

## DISCUSSION

The leafless (hardwood) cutting technique for ornamentals offers simplicity, low-cost, rapid growth rates and managerial convenience. However, problems remain both at the rooting stage and in the subsequent establishment of bin-treated cuttings in the field. Despite many refinements in bin technique, species found to be difficult to root a decade ago (21), still present problems, as evidenced by our 1982 rooting results for *Betula*, *Sorbus* and *Crataegus* supp., *Prunus* 'Shirofugen', *Acer platanoides* 'Drummondii' and our 1980 results for *A. platanoides* 'Crimson King'. Further, there are problems of inconsistency; species rooted easily in one year can root poorly in others (Table 5). Weather-induced variations in the endogenous hormone levels of the stock plant and/or uncontrolled variations in the rooting environment are presumably responsible.

Establishment problems have been attacked in several different ways, e.g. by planting cuttings in more protected conditions than the open field or nursery beds, (7), and by retaining cuttings in the bin, with the heat switched off, for some weeks after the root-inducing heat treatment (6). Cheffins (3), and Cheffins and Howard (4), demonstrated that the level of carbohydrate remaining after heated-bin treatment influenced establishment. Active buds on rooting cuttings appeared to be a

**Table 5.** Yearly variability in the rooting percentage of dormant, leafless cuttings.

| Subject | Year 1972 | 1973 | 1974 |
|---|---|---|---|
| *Ulmus hollandica* 'Commelin' | 90% | 92% | 12% |
| *Viburnum* × *bodnantense* 'Dawn' | 23 | 84 | 92 |

In all years, the two cultivars were rooted in the same bin controlled at 15°C, after dipping with 1500 ppm IBA; 30 cuttings of each species in 1972, 25 cuttings in 1973 and 1974.

preferential sink for carbohydrate, so Cheffins and Howard (5), recommended planting cuttings before buds became active, either by timely handling or propagating at low ambient air temperatures.

Ornamentals may well have less stored carbohydrate than the fruit rootstocks used in Cheffins and Howard's experiments, so that establishment problems could be correspondingly more severe. The clear inverse relationship between rooting percentage and percentage survival in *Acer saccharinum* (Figure 2) strongly suggests carbohydrate deficiency as a cause. Since bud growth was negligible at the end of the heated-bin treatment, the drain on carbohydrates was most likely to have been principally caused by root growth. If carbohydrate deficiency was responsible for this decline in survival, it would appear to be less of a problem for *Laburnum* and *Platanus* than for *Acer*. The green *Laburnum* stems might contribute sufficient photosynthate to affect survival but this seems unlikely for *Platanus*.

The difficulty then is to synchronise root and shoot growth so that root growth does not outstrip shoot growth, which could severely deplete the cuttings of carbohydrates; nor should shoot growth outstrip root growth as this may lead to problems of an adequate supply of water to the shoot, resulting in desiccation. The extreme situation occurs when bin-formed roots die after potting into containers. This has been observed by Whalley and Loach (25) and the roots may well have been non-functional before death. Removing cuttings from the bin after 50 degree-weeks of heat treatment brings them to the point of incipient rooting which gave best survival (Figure 3).

To ease any ill-effects caused by a sharp drop in soil temperature from the heated bin (20°C) to the netting tunnel (around 9°C), some cuttings were retained in the bin for one week after switching off the heat. This treatment proved detrimental rather than beneficial (Table 3).

Beyond this point, further protective treatments were evolved to support the soft, new bud growth in cuttings with few roots. A simple, inexpensive mist line under a polyethylene tent proved extremely effective for *A. saccharinum* (Table 2) and *Platanus* × *acerifolia* (though untreated cuttings also gave reasonable survival in this species), and somewhat effective for *A. platanoides* 'Drummondii'. However, in the latter species, the problem of initiating roots remains paramount.

In *A. saccharinum* the bin treatment proved non-essential if the cuttings were placed in a mist/polyethylene tunnel (Table 3). For this species, root initiation is clearly less of a problem than survival, and the data for control plants, where cuttings with least bin treatment survived best, support this conclusion.

The mist/polyethylene tunnel treatment was quite ineffective for *P. subhirtella* 'Autumnalis' and was detrimental for *P.* 'Shirofugen' (Table 4). Neither rooted very strongly and it may be that conditions under the tunnel were unsatisfactory, with the high air temperatures in spring causing rapid and early bud break, suggesting a possible corresponding carbohydrate depletion at a critical time for root development.

There have been other reports from time to time of individual species rooting well, i.e. Adam (1) and Ward (20). For these, the merits of the post-bin treatments outlined in the present experiments need testing as aids to survival. The evidence suggests that such treatments could prove beneficial where survival presents the major problem and rooting is less difficult (e.g. where carbohydrate reserves are inadequate or cuttings are susceptible to desiccation).

For easier species, such as *P.* × *acerifolia*, or the slightly more difficult *Hibiscus* and *Ulmus* (22,23) and *Sorbus intermedia*, *Tilia cordata*, *T. platyphyllos*, and *Prunus padus* (1), the benefits may be less cost-effective.

Although in some seasons plants grown in the tunnels for the duration of the experiment were of good quality, there was some inconsistency with *A. saccharinum* and *P.* × *acerifolia*. A problem may well be the gauging of the correct transfer time from the shade tunnel to an unshaded, non-wind-protected environment. Earlier removal than our end-of-season practice might allow for greater stem strength and improved quality in the final plant.

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## 1982 IPPS ORDINARY NATIONAL DIPLOMA PRIZE

(Two students, Hilary Schonbeck and Tracy Lunn, shared the 1982 award presented by the G.B.&I. Region for the best Ordinary National Diploma in Horticulture student project. The reports of their projects follow).

## IS STRIPPING OF CUTTINGS NECESSARY?

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This project was secondary to a main college project, and I decided to examine the need for stripping cuttings before insertion, as the topic had been questioned at last year's Conference. As it had to commence in September, of necessity I worked with evergreens, but did do some successful work with soft-woods.

I questioned the three main reasons normally given for stripping cuttings, and my findings were as follows:

(1) "The lower leaves decay and this decay spreads to the stem."

Largely this was not true. Either there was no decay (examples *Spiraea* × *bumalda* 'Goldflame', *Viburnum tinus* and *Hebe* 'Eversley Seedling') or decay did not spread (examples, *Pernettya mucronata*, *Erica herbacea* (Syn.: *carnea*), and *Elaeagnus pungens* 'Maculata'). An exception was autumn struck *Ceanothus*, where decay from decaying stems did not spread to the stem.

(2) "Cuttings are difficult to insert."

This statement is true of large, thick-leaved species such as *Rhododendron* and *Skimmia*. It even takes longer to insert unstripped cuttings of heathers, *Pernettya*, etc., but this time