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Project co-ordinator:	**Mr. C. Woods**
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FACTORS DETERMINING BUD-TAKE IN ORNAMENTAL TREES

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*The work on containerisation was completed earlier, with a Final Report submitted in December, 1994. This report, the final from a series of HDC budding projects, incorporates previously unpublished information whose relevance and importance can now be seen in the context of this final stage.

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NB. **Although evidence is presented in this report that fungicide treatment to *Acer platanoides* 'Crimson King' budwood and rootstocks benefits bud-take, and to some extent *Robinia pseudoacacia* 'Frisia' also, the fact that these treatments have not been refined in terms of choice of fungicide and concentration applied, with implications for label considerations, prevents recommendation of fungicide treatments for grower use at present.**

RELEVANCE TO NURSERYMEN AND PRACTICAL APPLICATION

Application

The objectives of this project were to understand why bud-take in various ornamental trees, such as *Acer platanoides* 'Crimson King', *Betula pendula* 'Dalecarlica' and *Robinia pseudoacacia* 'Frisia', was generally difficult, and often inconsistent between nurseries and between years, and to recommend improved methods.

The difficulty in overcoming these problems is explained in general terms by there being a number of interacting responsible factors, which may or may not all be present in any nursery or year, and which made the interpretation of experiments difficult in years when hitherto unrecognised adverse factors were present, or when treatments failed to give clear differences because relevant factors were not operating.

Despite these difficulties major constraints to bud-take were identified in all subjects.

In particular, it was essential to ensure that rootstocks grew well into late summer to provide the necessary cambial activity for union formation, coincident with the availability of mature budwood. In the case of *Acer* 'Crimson King' there was a direct benefit of ensuring that root systems continued to grow actively. For subjects with prominent buds, such as various ornamental cherries and *Betula* 'Dalecarlica', it was essential to avoid damaging the scion-bud by compression under the bud-tie, but in *Robinia* 'Frisia' maximum compression was needed to ensure that the union formed properly. For *Acer* 'Crimson King', and to a lesser extent *Robinia* 'Frisia', a pre-budding fungicide spray to the rootstock stem was beneficial, but cannot be recommended without further research and label considerations.

Improved bud-take will result from nurserymen recognising and responding to the different requirements which are critical to the success of particular subjects. There are no recommendations which lead to additional work, but all recommendations require each stage of production to be done with a specific objective in mind. This will increase the cost-effectiveness of the work by increasing significantly the chances of success.

Summary

Most production costs in raising field-budded trees, such as preparation of land, purchase, planting and maintenance of rootstocks, production of scionwood, and budding itself, are met, irrespective of the success rate and proportion of first-grade trees harvested.

The cost-effectiveness of this type of nursery work depends greatly on the success rate, and it often becomes more *cost-ineffective* because nurserymen plant and bud more rootstocks of difficult subjects in order to achieve the required number.

It is much more cost-effective and hence profitable, to improve production techniques and achieve consistently high yields, effectively 'doing less to obtain more'.

Consistently high production is now possible in subjects hitherto considered to present

occasional difficulties, or which are regularly inconsistent between nurseries and between years.

Acer platanodies 'Crimson King'

Two factors in particular combined to increase the chance of budding success. Rootstocks needed to be grown in soil conditions that encouraged rapid extensive root growth through the period of union formation in August, and there was benefit from spraying the rootstock stem with a mixture of 4 g per litre each of Benlate (benomyl) and Rovral (iprodione), with wetter. Rootstocks should never be grown in pots for budding *in situ*, and should be lifted with dormant buds from the field for containerisation. Buds should be obtained from a severely pruned source, budded in late July or early August, with the entire chip-bud covered with the polyethylene tie. Delaying planting the rootstocks delays the period of maximum growth rate, but in conditions where optimum growth cannot be guaranteed the bud-tie should be left in place for 6 weeks for this slow union-forming subject.

Planting *A. platanoides* rootstocks on 17th May 1995, budding on 1st August with 'Crimson King' budwood from a hard-pruned source, having sprayed the rootstock stem with the Benlate-Rovral fungicide mixture, gave 86% success in 1996, compared to 46% when rootstocks were planted on 6th March, not sprayed with fungicide, and budded on 16th August with budwood from a non-pruned source; this difference was achieved despite all rootstocks benefitting from being grown in conditions conducive to good root growth, and all chip-buds tied with polyethylene strips covering the 'eye'. The different responses were significant at the 0.1% level of probability.

Contrary to the view held by many nurserymen, sap bleeding from the budding wound in the rootstock stem was not associated with budding failure, and conditions conducive to high bud-take often encouraged the frequency and intensity of sap flow.

Robinia pseudoacacia 'Frisia'

There is no physiological importance attached to the size of rootstock planted, but because rootstocks grow very vigorously it is sensible to avoid planting ones thicker than about 6 mm, because the bud-chip can be difficult to match physically with the rootstock. Late-planting ensures that budding occurs at the time of greatest cambial activity.

Because rootstock stems thicken rapidly during the budding year they are easily constricted by the budding tie, and some may break above the scion bud in summer gales. For this reason there is a tendency to use relatively non-restricting rubber ties, but this is a mistake. Under these conditions *Robinia* produces excessive rootstock callus around the margins of the rootstock cut, which envelops the edges of the bud-chip, but apparently does not differentiate into the conducting tissues needed to form a union. *Robinia* buds are sunken and not subject to damage, and should be tied with polyethylene tape, completely covering the bud-chip.

Nurserymen whose conditions lead to very vigorous rootstock growth might wish to try the system whereby early-planted and well-established rootstocks are cut-back to 15 cm in early May and a new shoot selected for later budding, giving 100% take in the East Malling experiment. There was some evidence of benefit from spraying the budding face of *Robinia* rootstocks before budding with a mixture containing 4 g per litre of Benlate and of Rovral, with wetter.

Betula pendula 'Dalecarlica'

Rootstocks must be encouraged to grow well into late summer, and this should not be prejudiced by excessive shoot trimming or exposure to herbicide damage, because birch tends naturally to stop growing sooner than many other rootstocks. This natural tendency to stop growing early can be offset by delaying planting rootstocks until mid-May, as long as good jacketed cold store conditions, careful planting, and irrigation if required, ensure good establishment.

Budding should not be delayed until late-August in the mistaken belief that budwood needs to mature, and all bud-scales turned brown. Budwood should be grown on trees specifically for the purpose, pruned to obtain a limited number of strong annual shoots with large buds produced above the zone where side shoots develop. Bud-wood should not be subject to water stress.

'Dalecarlica' buds are large and must not be physically damaged by the bud-tie. Degradable rubber ties are preferred, and ties should not cover the 'eye'. Rootstocks planted on 17th May 1995 and budded on 8th August without covering the bud gave 83% bud-take. In this particular year this was only a modest (but significant, $P < 5.0\%$) improvement over the 74% obtained by planting on 6th March and budding on 24th August with bud covered. It is typical of *Betula* 'Dalecarlica' that the adverse response to the non-recommended treatment combination can vary greatly between years, explaining why it took a number of years to identify treatments that are important, and underlining the risk that nurserymen face by, for example, covering the bud, or budding relatively late, which might be successful in some years but disastrous in others, as shown in the Experimental Section.

Prunus 'Pink Perfection' and *P. sargentii*

Ornamental cherries should give consistently good results, and a major consideration when budding onto 'Colt' rootstock is the need to plant sufficiently early, in mid-winter, to avoid the problem of these early-leafing rootstocks failing to establish. Once established, 'Colt' grows vigorously and is tolerant of a wide range of conditions.

Ornamental cherry buds are subject to physical damage, and should not be covered by the bud-tying material, which exerts increasing pressure on the often prominent 'eye' as the rootstock stem continues to swell. Chip-buds should be tied with polyethylene strip avoiding the actual bud, but taking care to cover the cut interface of bud-chip and rootstock.

Action points for growers

Acer platanoides 'Crimson King'

- Delay planting rootstocks until mid-May if good establishment and growth can be guaranteed.
- Use only fields with deep, open fertile soil to encourage good root extension.
- Grow bud-wood trees specifically, severely-pruned in winter.
- Do not delay budding beyond early August.
- Tie the chip-bud with polyethylene strip, covering the eye, and retaining for up to six weeks.

Robinia pseudoacacia 'Frisia'

- Do not plant excessively thick rootstocks, and avoid damage from residual herbicides, to which *Robinia* is prone.
- Delay planting rootstocks until mid-May if good establishment and growth can be guaranteed.
- Bud by early August at the latest.
- Tie-in the bud with polyethylene tape covering the actual 'eye'. A sheltered site will reduce the risk of stem constriction causing the rootstock head to break off in strong winds.

Betula pendula 'Dalecarlica'

- Plant in conditions which will sustain good rootstock growth into late-summer.
- Delay planting rootstocks until mid-May if good establishment and growth can be guaranteed.
- Take bud-wood from pruned trees designed to give relatively few strong annual shoots.
- Avoid damaging the prominent bud by using degradable rubber ties, not covering the 'eye'.

Prunus 'Pink Perfection' and *P. sargentii*

- Avoid planting 'Colt' rootstocks after mid-winter so as to maximise establishment.
- Bud mid-to late August, with polyethylene ties avoiding the actual 'eye'.

Practical and financial benefits

By putting into practice packages of practical measures designed to overcome the constraints in species with bud-grafting difficulties nurserymen will increase significantly their chances of success. This will reduce wastage, which is the largest single factor determining cost-effectiveness in this currently least profitable area of nursery stock production. The opportunity exists to reduce the size of nurseries and hence most of the annual production costs, while increasing the output of high quality trees. A similar benefit was achieved for fruit tree production in the mid-1970s following the introduction of chip-budding. Chip-budding provides the basis of improvements to ornamental tree budding, but the particular characteristics of individual species and varieties requires other factors to be taken into consideration, as described in this Report.

EXPERIMENTAL SECTION

Introduction

The production of amenity and ornamental trees is an important part of the hardy nursery stock industry, with the retail market being supplied largely through garden centres via container-grown or containerised trees. Part of this project was to identify the most efficient way of containerising difficult-to-produce ornamental trees, and the advantages of potting-up rootstocks with dormant-scion buds and growing the maiden in the container have been reported (Howard, 1994).

Field-production of ornamental trees has been less attractive in recent years for two main reasons. Firstly, the Public Authority market, at which the majority of these trees is aimed, has declined due to cuts in local government expenditure, and secondly, yearly inconsistency in budding success means that it has been difficult to develop marketing schedules and cost-effective production of many desirable subjects. A high bud-take and production of good quality trees is essential because most costs of land preparation, rootstock purchase and planting, and of budding are incurred irrespective of whether a saleable tree is produced or not. The alternatives of bench grafting, or making-good failures by field-grafting, are expensive and inconvenient.

It is clear that given improved yields of good quality trees, nurserymen could increase their profit margins by doing less to greater effect, and not increasing the inherent level of inefficiency by budding many more trees than needed in the hope of providing an adequate safety margin to guard against failures.

In these investigations different examples were used to represent a range of problems. These included easy-to-produce subjects where occasional large scale failure can occur (e.g. *Prunus sargentii* budded on 'Colt' rootstock), and subjects of intermediate difficulty represented by *Betula pendula* 'Dalecarlica'. The most difficult subjects, where large scale losses are common place, were represented by *Robinia pseudoacacia* 'Frisia' and *Acer platanoides* 'Crimson King'.

With the most difficult subjects it was necessary to challenge nurserymens' conventional wisdom as to reasons for budding failure. For example, it has already been reported that the annual fluctuations in success with *Acer platanoides* 'Crimson King' attributed by nurserymen to weather are due to the field used for the nursery in that particular year (Howard, 1993). Furthermore, it appears that budding success in 'Crimson King' is influenced by micro-organisms, and especially fungi, present on the scion wood and rootstock, which appear to debilitate the bud-chip, so preventing union formation (Howard, 1992; Rose and Harris, 1995). New insights such as these provide important new direction for research, and so, for example, in the case of *Acer* 'Crimson King' there has been emphasis on soil conditions and fungicide treatments.

Budding experiments are made difficult by the two year cycle whereby results from the previous year's treatments are not fully apparent when the following year's experiments must be planned and started. This is exacerbated by the nature of research into inconsistent effects, which may or may not be operating in a year when they are being investigated, or where results of planned treatments are swamped by other detrimental factors, which then need identifying so as to optimise the direction of the work. This necessitates a flexible research approach in which apparent success or failure is considered in a qualified way so as to ensure the development of robust techniques on the one hand, without stopping certain lines of enquiry prematurely on the other.

Because this report marks the end of a sustained programme of wide-ranging budding research (with subsequent work likely to be focused on specific aspects), it extends beyond the immediate objectives of HNS 45, to put into context earlier unreported work from project HNS 7a, which can now be better understood following the continuation of the programme. Although not claiming to be definitive we believe that the main constraints to budding success in the range of species studied have been identified, and that this work provides the basis for extrapolation to many other subjects through the extended awareness of the many new factors that are implicated in budding success.

Materials and methods

Generally relevant information is given here, with details specific to particular work given with the results of those experiments.

Field conditions:

Although differing slightly, the nursery sites at East Malling used for these investigations were generally light sandy loams of the Barming and Malling series overlying ragstone, as described by Furneaux (1954 and 1960). In the autumn the soil was sterilized with chloropicrin and the heavy-duty black polyethylene cover left in place until planting the following late winter, early spring. This provided excellent planting into moist, non-compacted soil.

Planting:

Rootstocks were planted at 35 cm spacing in the row and in double row beds with 70 cm between rows, except for the vigorous *Robinia*, where single rows were used.

Plant material:

The species used represented different degrees of difficulty experienced by commercial nurserymen, especially in their ability to obtain consistent results from year to year, as follows.

Relatively consistent - *Prunus* 'Colt' rootstocks, budded with the scion 'Pink Perfection' or *P. sargentii*.

Variously inconsistent - *Betula pendula*, budded with 'Dalecarlica'.

Robinia pseudoacacia, budded with 'Frisia'.
Acer platanoides, budded with 'Crimson King'.

Rootstocks were obtained from a commercial source, and budwood was collected from winter-pruned mother trees or hedges grown at East Malling.

Budding:

Unless otherwise stated, budwood was collected on the morning of each experiment and kept cool and moist by wrapping in damp hessian. Unused budwood was thrown away at the end of the day. Budding was at 15 cm height (to allow stem measurements below) by the chip method (Howard, 1974, Howard, *et al.*, 1974), and tying by 25 mm wide clear polyethylene strip, covering small buds, but leaving the actual buds (eyes) of large-budded species exposed, while taking care to protect the junction between scion chip and rootstock. Questions such as the desirability of covering buds and the effect of different tying materials often featured as experimental treatments. Ties were released after 4 to 5 weeks, except for *Acer* 'Crimson King', which was released after 6 to 7 weeks as a safety precaution for this slow union-forming subject.

Management:

Fertilizer was applied in spring to the planting strip as determined by soil and sometimes leaf analyses, most commonly using K-Nitro (25% N, 16% $K_2 0$ at equivalent rate of 100 kg/ha), and Kieserite (25% Mg0, at equivalent rate of 200 kg/ha).

Trickle irrigation was applied to the rows as thought necessary.

The herbicide programme in the budding year was adjusted annually as determined by the perceived need and the availability of products, as follows:

Year	Material	Active Chemical	Rate product/ha
1989	Surflan	oryzalin	6 litres
1990	Surflan	oryzalin	6 litres
1991	Butisan +Treflan	metazachlor trifluralin	2.5 litres 2.3 litres
1992	Venzar	lenacil	2.8 kg
1993	Sovereign +Simazine	pendimethalin simazine	4 litres 2.2 litres
1994	Sovereign +Simazine	pendimethalin simazine	4 litres 2.2 litres
1995	Flexidor 125 +Butisan S	isoxaben metazachlor	2 litres 2.5 litres

Appropriate pesticides and fungicides were applied both prophylactically and in response to problems, the main ones being aphids (especially cherry black aphid) and powdery mildew (especially of *Acer* 'Crimson King' scion hedges).

During early summer rootstock shoots were removed to a height of approximately 40 cm to provide a clean budding 'leg' and access for various measurements of stem thickness. In late winter, following budding, rootstock heads were removed, cutting to the scion bud. Rootstock shoots developing below the scion bud were removed progressively as the maiden tree developed, and trees were supported by canes as required.

Statistics:

Data were analysed statistically by appropriate methods. The probability values attached to data in tables of 0.1, 1.0 and 5.0% are the likelihood of treatments differing by chance (NS - no significant difference). Therefore, a 5% probability implies a 95% chance that differences are due to treatments and not to random effects. To assist in comparing data the least significant difference (LSD) is given. This is the smallest difference between any two mean values that is significant at the 5% level of probability.

Results

Prunus 'Colt' budded with 'Pink Perfection' or *P. sargentii*

Background

From experience at East Malling and discussions with nurserymen, the most relevant questions for this subject included effects of rootstock planting date, and the extent to which budding failure might be due to the tie physically damaging the scion bud as the stem swells rapidly after budding. These were investigated initially as single factors, and subsequently in terms of how they interacted together and with other aspects of nursery management. A hitherto unreported trial from 1986 is used to illustrate the single factor effect of tying technique, because this was part of an interactive set of treatments in more recent trials.

Time of planting rootstocks

The objective was to investigate the flexibility available for planting rootstocks over an extended period of time from late winter to late spring, with a view to reducing peak labour needs. At the request of Panel Members the value of treating roots before planting with the proprietary seaweed-based product 'Alginure', at the recommended rate of 1+3 parts water by volume, was assessed also.

Rootstocks were held in a jacketed cold store until removed for planting, with or without Alginure root dip, on:

22nd February, 1993
5th April, 1993
17th May, 1993

When subsequently budded on 23rd August the actual 'Pink Perfection' bud was not covered by the polyethlene tie.

The most noticeable effect due to delayed planting was the progressive increase in the number of rootstocks failing to establish, associated with the early leafing-out of this subject. Rootstock failures for February, April and May plantings were 11, 14 and 24% averaged over ± root dipping, with no consistent effect from the Alginure treatment.

Table 1. Growth of *Prunus* 'Colt' rootstocks, 'Pink Perfection' bud-take and maiden tree production

Planting dates	22 February		5 April		17 May		*P*		LSD
Root-dip	-	+	-	+	-	+	Planting date	Root-dip	(5%)
Rootstock stem diameter at budding (mm)	17.7	18.2	15.2	17.1	13.6	14.0	0.1%	1.0%	1.08
Rootstock stem diameter increase during budding (%)	11.6	11.4	12.6	11.7	15.5	15.2	0.1%	NS	1.83
Bud-take %	100	97	97	95	96	100	NS	NS	8.4
Maiden height (cm)	124	124	122	123	124	127	NS	NS	7.9
No. of laterals per tree	8.3	8.4	8.0	8.9	6.7	6.8	0.1%	NS	1.48
Height of lowest lateral above union (cm)	3.5	8.5	6.4	5.2	9.7	13.6	0.1%	NS	5.0

Late planting reduced the thickness of the rootstock stem as measured at the end of the summer, and stocks grew slightly better following the Alginure root dip. The late-planted rootstocks were growing more vigorously at budding, as measured by the increase in stem thickness between budding and tie release.

Despite these differences in rootstock size and growth, at least 95% of surviving rootstocks in any treatment gave a successful bud-take, with 100% being obtained in both February and May plantings. Similarly, neither planting date nor root-dipping affected maiden height, which from the union ranged only from 122 to 127 cm across all treatment combinations. On the other hand, lateral emergence was delayed in the trees produced on May-planted rootstocks, resulting in fewer laterals, and with them starting higher above ground to leave a longer section of clear stem above the union. The main effects are shown in Table 1, from which it is concluded that the only constraint to obtaining a high yield of 'Pink Perfection' on 'Colt' is if rootstocks fail to establish and are therefore not available for budding.

Bud tying materials and method:

In an attempt to explain occasional significant reductions in bud-take, the extent to which the actual bud (eye) could be physically damaged by pressure exerted upon it by the tie as the rootstock stem swells, was investigated. Rootstocks were budded on 12th August, 1986, with the eye covered or not by either the usual polyethylene strip, or by a degradable rubber strip of similar dimensions. The extent to which the bud was squashed was measured.

'Pink Perfection' buds are reasonably prominent, projecting on average 1.7 mm (24 bud sample), which was equivalent to 32% of the thickness of the rootstock stem itself in the sample of rootstocks measured. When ties were released the buds that had been covered were significantly squashed compared to the non-covered buds, especially when covered by polyethylene (Table 2). There were no differences in the rate at which stems swelled during the period that ties were in place, so the squashing effect was due entirely to covering the actual eye.

Bud-take was not depressed by the bud tying treatment, but squashed buds resulted in many multi-shooted maidens developing, presumably because the main eye had been killed and lateral eyes grew in its place. Those shoots were not trimmed off to produce a single shoot, and therefore maiden height was significantly reduced. Covering the buds reduced the number of laterals produced by an almost significant amount, irrespective of the tying material used, and the length of laterals per tree was significantly reduced by covering the bud. These effects are shown in Table 2.

Table 2. Effects on buds, budtake and maiden growth of tying method and materials for *Prunus* 'Pink Perfection'

Bud covered	+		-		*P*		LSD 5%
Tying material	Poly-ethylene	Rubber	Poly-ethylene	Rubber	±Bud covering	Polyethylene v. rubber	
Bud prominence after tie release (mm)	1.5	2.2	2.6	2.3	0.1%	NS	0.51
Bud-take (%)	96	96	100	92	-	-	-
Number of multi-shoot maidens (%)	54	16	17	4	5.0%	5.0%	29.6
Maiden height (cm)	130	137	153	151	0.1%	NS	15.7
Length of laterals per tree (cm)	366	336	441	476	0.1%	NS	97.6

Effects of covering or not the scion bud with polyethylene related to time of budding

Although the chip method allows budding to take place later in the summer than for T-budding, because it is not essential that the 'bark' continues to lift easily in the former method, nurserymen tend to bud cherries reasonably early because scionwood becomes available sooner than for some other species. Given that covering buds with polyethylene budding ties can physically damage the eye, it is reasonable to suppose that this will be more serious if covering buds with polyethylene coincides with the maximum rate of stem thickening in early to mid-summer. The interaction of ± bud covering for early or late budding was therefore investigated.

Budding was on 5th August (early) v 2nd September (late) 1991, with buds covered or not with polyethylene strip as described previously.

When budded in September rootstock stems were significantly thicker than those budded earlier, but the rate of stem diameter increase during the period that ties were in place was significantly greater for early budded stocks.

Bud-take in all treatment combinations was within the range 94 to 100%, but maiden height was least (125 cm) from early budding with the eye covered. The largest number of top grade trees was produced from late-budding without covering the bud (86%) and the least from early budding with bud covered (66%), although the effect of bud covering was minimal for the late-budded set.

This experiment was effectively repeated in 1992, budding 'Pink Perfection' onto 'Colt' on 10th August and 7th September with all combinations of polyethylene or rubber ties covering or not covering the bud. There were no significant effects of treatments on bud-take or maiden growth.

The response of *P. sargentii* to different budding and tying methods

Because 'Pink Perfection' appeared not to be a particularly sensitive variety in its response to the use of different tying materials and methods, beyond the reduction of maiden tree quality in some years, nurserymen suggested that *P. sargentii* might be more appropriate, on the basis of their experience of its inconsistent performance.

Because this variety had not been investigated previously budding methods of chip v T v inverted T were compared, all with polyethylene or rubber ties covering or not covering the actual eye. Budding was done relatively late in the summer on 26th August, 1993.

Although at the time the 'Colt' rootstocks were budded there were no differences in stem thickness, the chip-budded rootstocks increased in stem diameter at a faster rate compared to the T- and inverted T-budded rootstocks, so that they were thickest when ties were removed. The reason for this effect of budding method on rootstock stem thickness is unclear, but is likely to be due to the cross cut of the T- and inverted T-methods interrupting the downward movement of carbohydrates compared with the possibly lesser interruption caused by the chip cut, aided by the fact that the chip rapidly reforms a complete stem. Although differences were significant due to the low variation present in the experiment, the magnitude of the effect was small, with stem diameter increases for Chip, T and inverted T methods of 13.0, 9.8 and 9.7% respectively.

The major response to treatments was a significant reduction by 30% in bud-take and numbers of maidens harvested, when buds were covered by the tying material, compared to when the eye was left uncovered. The largest effect was in the chip-budded set, where covering with polyethylene reduced bud-take from 90% to 43%, but with rubber having no detrimental effect. In T- and inverted T-budded treatments covering with either polyethylene or rubber were equally detrimental, and the lowest yield of 30% was obtained by covering T-buds with rubber ties (Table 3). Overall, polyethylene ties gave 10% higher success than rubber ties, and this might indicate that rubber ties were less able to produce adequate pressure for optimal union formation in these relatively late-budded rootstocks where stems were thickening only slowly. If this is so there is only a narrow balance between creating excessive or inadequate pressure for optimum bud survival and union formation, a problem considered further with *Robinia* 'Frisia'.

Table 3. Maidens of *P. sargentii* on 'Colt' harvested as percentage of rootstocks budded

Bud covered	+		-		*P*			LSD (5%)
Tying material	Poly-ethylene	Rubber	Poly-ethylene	Rubber	Budding method	Tying material	Covering the eye	
Budding method								
Chip	43	73	90	68	)			
T	47	30	83	77	} NS	NS	0.1%	35.1
Inverted T	67	37	83	73	)			
Means	52	47	85	73				

Overall, maiden height was depressed most seriously by covering the bud with the tie, reflecting the bud-take situation, and inverted T-budding gave the tallest maidens overall because these trees produced fewer laterals, whereas chip-budded trees were 10% shorter, but produced 46% more laterals.

<u>Time of planting 'Colt' rootstocks related to time of budding 'Pink Perfection'.</u>

Rootstocks were planted out of jacketed cold store on 1st March and 16th May, 1994, and budded on 2nd August and 6th September, in all combinations of planting and budding dates. Chip-budding was used throughout, and buds were tied with polyethylene strip without covering the eye.

Rootstock stems were thicker when budded in September compared to August, but the rate of growth during the budding period when ties were in place was faster for the early-budded treatments and for the late-planted rootstocks, so that the combination of late planting and early budding was associated with the fastest increase in rootstock stem thickness. Late budding depressed bud-take and hence yield of maidens significantly, but only from 99 to 94% overall. Late planting and early budding gave 100% bud-take, reflecting the most rapid rate of stem thickening, and hence cambial activity, during the budding period. On the other hand, maiden height was depressed by delaying the planting of rootstocks until mid-May, associated with those rootstocks remaining smaller through the season compared to those planted earlier. Lateral production reflected maiden height, with few laterals produced on maiden trees raised on the late-planted rootstocks. Effects are shown in Table 4.

Table 4. Growth of 'Colt' rootstock, and 'Pink Perfection bud-take and maiden growth, related to rootstock planting and budding dates

Rootstock planting dates	1 March		16 May		*P*		LSD
Budding dates	2 Aug	6 Sept	2 Aug	6 Sept	Planting	Budding	(5%)
Stem diameter increase (%)	20.9	9.6	28.4	10.6	1.0%	0.1%	3.5
Maidens harvested (%)	98	93	100	95	NS	5.0%	6.8
Maiden height (cm)	162	160	149	149	1.0%	NS	9.5
No. of laterals per tree	6.8	7.2	4.7	5.6	0.1%	NS	1.2

Soil conditions:

In 1993 'Colt' rootstocks were planted in soil cultivated deeply to 30 cm, normally to 20 cm or into non-ploughed cereal stubble. Penetrometer measurements showed the unploughed soil to be 46% more resistant than the ploughed soils and data are shown in the section of this report dealing with *Acer platanoides*. Rootstocks were budded on either 9th August or 6th September and tied either with polyethylene tape covering the eye, or rubber strip not covering the eye. Rootstock stems thickened at a significantly faster rate during the early budding period compared to the later period (August 19.8%, September 5.6% increase in stem diameter, respectively), but bud-take was not affected by any treatment overall, and with 100% being obtained in both deep and non-cultivated soils. The lowest bud-take of 87% was obtained in August-budded rootstocks, tied with rubber not covering the eye, in the shallow-cultivated soil, but no significance is attached to this. There were no significant effects on maiden height, but the September-budded and rubber-tied treatment combination gave the largest trees at all levels of cultivation, with tree size being identical under all cultivation conditions.

In 1994 rootstocks were planted into soil treated with post-planting herbicides at different times, or through a black polyethylene mulch to avoid using herbicides. Budding was done on 8th August, using polyethylene ties with the eye covered, or rubber ties with the eye not covered.

Frequent leaf symptoms of herbicide damage were obtained in one treatment where application was by manufacturers recommendation, and although the reason is not clear it provided a marked and significant contrast (79% stocks affected) with other areas (9%

affected) and the polyethylene mulch area with no herbicide application. This did not affect the increase in stem diameter during the budding period which was greater in the presence of herbicide symptoms and 100% bud take was obtained in that set when tied with polyethylene. The lowest bud-take of 93% was obtained in the polyethylene-mulch treatment with buds tied-in with rubber, but differences were not significant. Differences in maiden height were small and non-significant, ranging between 159 and 165 cm.

Conclusions

As a rootstock 'Colt' is tolerant of a wide range of herbicide treatments (even when causing leaf symptoms) and of soil conditions. As an early leafing rootstock 'Colt' is best planted as early as possible in the winter to avoid establishment losses. Dipping roots in 'Alginure' on removal from cold-store gave no consistent benefits. Although failure of rootstocks to establish becomes the overriding consideration there was evidence of an interesting physiological response whereby late planting combined with early budding resulted in the fastest rate of stem thickening, and hence presumably cambial activity, at budding, which may be of relatively greater importance in more difficult-to-bud species. However, late planting reduced the size to which the rootstock was able to grow by the autumn, which resulted in smaller maiden trees in the following year.

Tying chip-buds with polyethylene strip covering the eye compressed it, and while this did not reduce bud-take in 'Pink Perfection', it caused multi-stemmed maidens to form, presumably because the primary bud was killed and lateral buds developed in their place. Maiden height and lateral production were depressed by covering the bud with both polyethylene and rubber ties, especially the former. 'Pink Perfection' is also tolerant of budding over an extended time period during August and early September in terms of bud-take, but later budding without covering the bud facilitates the production of large-grade trees as long as budding takes place before bud-take declines.

In contrast, *P. sargentii* is very sensitive to the bud being covered by the tying material, especially polyethylene, with large and significant losses in bud-take and maiden tree size.

Given this degree of understanding as to reasons for budding failure in *Prunus* 'Pink Perfection' and *P. sargentii* there should be no reasons why regular stands of high quality trees cannot be obtained.

Betula pendula 'Dalecarlica'

Background

'Dalecarlica' worked on *B. pendula* rootstocks is an example of a subject which gives inconsistent results from field-budding, and which nurserymen tend to bench-graft. Using *B. papyrifera* rootstocks gave no improvement and was often less effective than *B. pendula* in experiments at East Malling.

Earlier research (Howard, 1992), and previously unpublished results, describe the nature of the problem. Union formation, as measured by the apparent fusion of the scion chip to the rootstock stem, can reach 90% consistently as long as the chip matches the rootstock cut reasonably closely. However, the ability of the scion bud to grow from these apparently successful unions is much reduced, and less than 60% might produce maiden trees. In individual experiments successful bud-take (i.e. growing maiden trees) ranged from virtually 0 to 100%, underlining the inherent inconsistency of this subject, but indicating the potential for success given an understanding of the causes.

The inability of buds to grow can either be total, with no maiden tree produced, or partial, in that growth is much delayed and the resulting maiden tree is small. It is not clear whether the latter results from partially damaged main buds, or the further development of lateral or supplementary buds to replace the main bud if killed completely.

The situation is complicated further by the problems of chip failure or bud failure occurring at different intensity depending on the season of budding. Early budding favoured chip-take but increased bud-failure, while the reverse was the case for later budding. The maiden trees produced by the relatively few surviving late-budded chips are invariably larger than those produced from earlier budding. This parallels the response in apple and is attributed to the late scion bud not becoming as deeply dormant under the influence of less vigorous rootstock shoot growth over a shorter period, compared to earlier in the season.

Nurserymen take the development of brown bud-scales on the scion as an indication of when to bud, but it was not possible to show a direct causal relationship between bud appearance and bud-take via a mechanism such as increased resistance to desiccation. Brown bud scales may mark changes in budding potential from other causes, but appear not to be implicated directly themselves. The view that bud-maturity *per se* is not a major factor in success is supported by the fact that buds from all positions on the scion shoot, both above and below the zone of lateral shoot development, appeared to have an equal chance of taking when budded systematically from along the scion stick.

Against this background the experimental approach, primarily aimed at resolving the apparent conflict between chip-take and bud-growth, has focused on understanding how best to synchronise the optimum state of rootstocks and scionwood to achieve union formation, and how to ensure that the bud remains viable and is not physically damaged.

When changing the time of budding to test rootstocks and scionwood of different maturity, it was recognised that year effects could lead to inconsistent responses, in that the ideal time in one year might be too early or too late in another. Budwood was described and rootstock growth measured in an attempt to quantify optimal conditions. In this context removing the shoot apex, or removing leaves two weeks prior to budding in an attempt to reduce the dormancy of the axillary bud, and so increase its growth potential, failed to give a consistent or large response.

Effects of rootstock growth

In 1989 *B. pendula* rootstocks, planted either in winter 1987/88 (two year rootstocks) or in 1988/89 (one year rootstocks) were differentially pruned five weeks before budding to give four treatment combinations comprising trimming-off most side shoots on the rootstock stems to give a clean leg averaging 33 cm (+ trimming), or trimming off few shoots to 19 cm (- trimming), together with cutting down the rootstock top by approximately half (+ pruning) or not cutting down (- pruning). The resulting size of rootstocks and whether they remained actively growing during budding were recorded (Table 5).

As would be expected, the more severe the pruning and the younger the rootstock, the greater was the reduction in size, although just trimming side shoots off 1-year rootstocks encourages the development of sub-laterals in the crown, which enhanced the size and performance of these rootstocks, compared to pruned but not trimmed 2-year rootstocks.

In general, the rate of stem diameter increase during budding reflected the size of rootstock within each age category. Fewer 1-year plants had active shoot tips during the budding period compared to the 2-year stocks. The actual increase in stem diameter during the budding period was closely correlated with the number of shoots remaining after pruning and with total shoot length.

Bud-take on 2-year rootstocks was hardly affected by pruning treatments, ranging between 68 and 78% (Table 6), presumably because these rootstocks were well-established and affected relatively little by pruning and trimming. It is likely that bud-take was more affected by the ability to match the scion chip to a thick rootstock stem.

On the other hand, for 1-year-old rootstocks, as used normally by nurserymen, bud-take was depressed, especially by the combined pruning and trimming treatment. There was a close correlation between bud-take and the actual increment in stem thickness during budding as affected by pruning and trimming (Figure 1).

Maiden height was consistently greater after budding onto 2-year rootstocks than on 1-year stocks, and consistently reduced by pruning back the head of the rootstocks, especially in 1-year stocks. Trimming the rootstock stem while retaining the complete head of 1-year rootstocks gave 90% bud-take and trees averaging 214 cm in height.

In 1992 1-year rootstocks were pruned to approximately 4, 8 or 16 main branches and with sub-laterals removed on 27th July, three weeks before budding. Effects on rootstock size before budding in August, and when ties were released in early September, are shown in Table 7. Target treatments were achieved closely and lateral length per plant, and hence leaf number, reflected numbers of laterals. The main effect of growth during budding was to increase the length of existing shoots, especially in the most severely pruned treatment.

Actual and percent increase in stem diameter during the budding period were positively correlated with the number of shoots in the rootstock head (Table 7).

Table 5. Effects on *B. pendula* rootstock size and regrowth following ± trimming side shoots and/or ± pruning the rootstock head

	1-year rootstocks				2-year rootstocks					
Trimming Pruning	+ -	+ +	- -	- +	+ -	+ +	- -	- +	*P*	LSD (5%)
Number of laterals and sub-laterals per plant	43.4	8.0	25.4	16.2	77.0	27.8	104.0	37.6	Rootstock age 0.1% Stem trimming NS Head pruning 0.1%	28.3
Total shoot growth per plant (cm)	800	91	658	178	1617	385	2117	620	-	-
Actual increment in stem diameter during budding (mm)	2.1	1.2	1.9	1.3	3.3	2.2	3.3	2.0	Rootstock age 0.1% Stem trimming NS Head pruning 0.1%	0.47
% increase in stem diameter during budding	20.4	18.3	16.7	16.3	25.3	20.4	23.2	17.1	-	-
% plants with active shoot tips 1 week after budding	46	47	54	56	77	100	82	100	-	-

Table 6. Bud-take (%) and maiden tree height (cm) of *B. pendula* 'Dalecarlica' on differentially pruned rootstocks

	1-year rootstock				2-year rootstocks					
Trimming	+	+	-	-	+	+	-	-		LSD
Pruning	-	+	-	+	-	+	-	+	*P*	(5%)
% bud take	90	37	80	66	76	74	78	68	Stock age NS Stem trimming NS Head pruning 0.1%	21.2
Maiden height from the ground (cm)	214	189	223	186	226	219	233	217	Stock age 0.1% Stem trimming NS Head pruning 0.1%	21.0

Table 7. Size and growth of *B. pendula* rootstocks following pruning

	Target lateral number	4	8	16	*P*	LSD (5%)
Pre-budding	Mean number of laterals	4.7	8.1	15.8	-	-
	Mean number of sub-laterals	3.1	0.3	0.2	-	-
	Mean lateral length per plant (cm)	204	419	851	-	-
	Mean sub-lateral length per plant (cm)	10	9	3	-	-
Post-budding	Mean number of laterals	4.9	8.1	19.0	-	-
	Mean number of sub-laterals	5.6	2.1	0.3	-	-
	Mean lateral length per plant (cm)	237	470	906	-	-
	Mean sub-lateral length per plant (cm)	51	24	4	-	-
Actual stem diameter increase during budding (mm)		0.6	1.1	2.4	-	-
% stem diameter increase during budding		4.7	8.2	16.7	0.1%	4.79

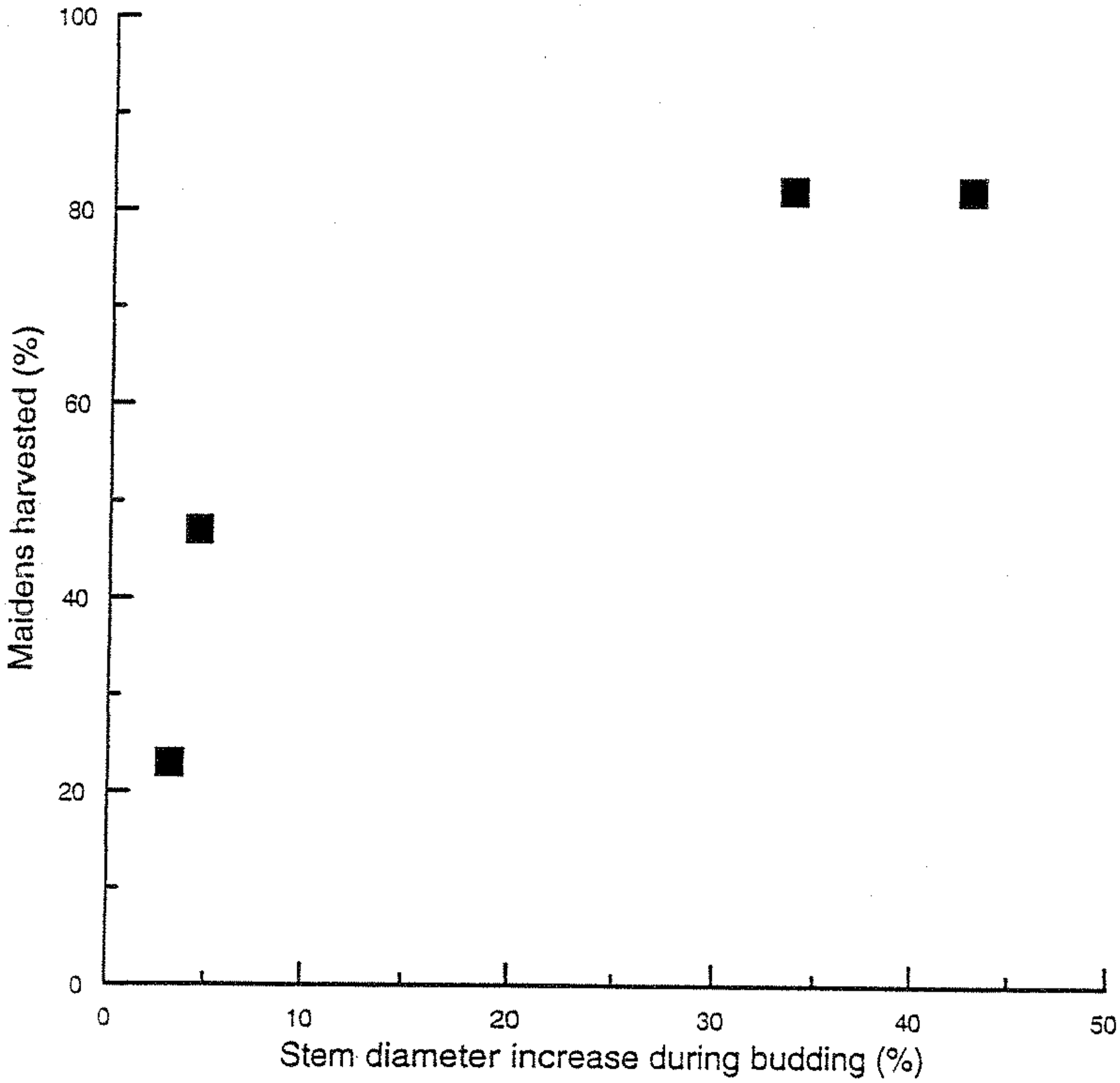

Fig. 1 Relationship between the numbers of maiden trees harvested and rootstock stem diameter increase during the budding period for *B. pendula* 'Dalecarlica'

Bud-take, in terms of the numbers of maidens harvested was high in the 8- and 16-shoot treatments, but severely depressed in the 4-shoot treatment. Maiden height increased progressively with the former increase in rootstock shoots, but the range was only 11 cm, and there was no effect on numbers of laterals (Table 8).

Table 8 . Effects on bud-take and maiden tree size of *B. pendula* 'Dalecarlica' in relation to earlier rootstock pruning

Rootstock target lateral number	4	8	16	*P*	LSD (5%)
Bud-take (%)	67	91	91	5.0%	19.6
Maiden height (cm)	182	192	203	1.0%	9.4
Number of laterals	18.2	17.8	18.4	NS	2.1

Trimming to remove all lateral roots from each main root before planting in late winter 1992 had no effect on the number of maidens harvested two years later, being 87% for normal and 85% for pruned roots.

Effects of budwood source

In 1990 'Dalecarlica' budwood was collected from the usual field-grown mature 'hedge' source, from the laterals of maiden trees growing in the nursery, from potted trees growing on Efford capillary sandbeds, and from similar trees growing on Efford beds inside a polythene (Filclair) house. Budding was on 22nd August and buds were tied with degradable rubber strips. The performance of rootstocks assigned to the different treatments was not significantly different on the basis of stem diameter measurements prior to the start of maiden growth in spring 1991.

Bud-take, in terms of the number of maiden trees harvested, was higher for field-grown scionwood than that grown in pots, but only the potted-polythene house source gave significantly reduced take, associated with a relatively large water deficit that may have stressed the scion wood (Table 9). An earlier assessment of bud-take as scions began to grow in June gave similar trends, but higher values, indicating a small amount of wastage through the season.

Maiden trees from the field sources grew away quickly in spring, as assessed by the percentage of large grade maidens in June, but final maiden height differed little between treatments (Table 9).

Table 9. Effects of different sources of 'Dalecarlica' budwood on bud-take and maiden growth

Budwood source	Potted-poly-thene house	Potted-outside	Field-maiden trees	Field-hedge	*P*	LSD (5%)
Maidens harvested (%)	40	60	73	78	5.0%	23.0
Apparent leaf water deficit (%)	21.0	14.4	15.8	14.6	almost 5.0%	5.2
Large grade maidens (June -%)	28	34	64	70	5.0%	26.1
Final maiden height (cm)	188	182	189	199	NS	19.9

Budding date and tying method

In 1991 *B. pendula* rootstocks were budded with 'Dalecarlica' on 8th August or 5th September. On the earlier occasion buds were tied with either polyethylene or rubber strip, with the eye covered or not with the tying material, in a factorial set. In addition, the rubber tie + bud-covered treatment combination, and the polyethylene tie + not-covered treatment combination were repeated with the rootstock head partially reduced in size on 8th September, in an attempt to reduce the level of dormancy imposed on the scion bud.

On the later budding occasion a restricted set of treatment combinations was imposed comprising rubber ties with bud covered, and polyethylene ties with bud exposed. A 20 plant sample of the partially cut down rootstocks, spread over stocks in all size categories, showed that shoot growth was reduced by 65%.

But-take was depressed by a factor(s) external to the trial, with numbers of maidens harvested ranging from 44 to 59% and with no significant treatment effects.

In terms of maiden height, however, it was clear that quality was depressed by covering the bud in early August with either rubber or polyethylene strip, whereas not covering with polyethylene or covering with rubber in September gave the best trees (Table 10).

Table 10. Effects of budding time and tying treatments on bud-take and maiden tree quality of *B.pendula* 'Dalecarlica'

Budding time Tying material	August Rubber	August Rubber	August Polyethylene	August Polyethylene	August Rubber	September Polyethylene	September Polyethylene	Late Rubber	 *P*	LSD (5%)
Covered	✓	X	✓	X	✓	X	X	✓	(for comparison of all treatment combinations)	
Rootstock pruned	X	X	X	X	✓	✓	X	X		
% maidens harvested	44	51	52	56	47	59	56	55	NS	27.7
Maiden height (cm)	136	170	122	152	149	153	190	186	5.0%	42.0
Lateral length per tree (cm)	47	59	43	51	45	42	63	58	5.0%	14.7

In 1992 a further experiment was carried out to investigate the effects of budding time and tying materials by budding on 10th August, 24th August and 7th September, with buds tied with either polyethylene or rubber strip, each either covering the actual bud or not. The twelve treatment combinations formed a complete 3 x 2 x 2 factorial set.

Increase in stem diameter during the budding period (from budding to tie release) was similar for both August dates, but greatly reduced as growth slowed down after September budding (Table 11a). Buds were squashed most in the early August budding when covered with the tying material. Later budding damaged buds less when covered, but even then their prominence was reduced to almost half that of non-covered buds (Table 11b).

Early indications of apparent chip-take in April of the maiden year showed it to be generally high, especially for the late budding time and with buds covered by the tying material (Table 11c). Bud-take, as indicated by early scion growth in June, also favoured the late budding occasion, but overall, rubber ties not covering the actual bud were marginally better than polyethylene ties covering the bud (Table 11d). This early indication was confirmed when maiden trees were lifted, the highest percentages being associated overall with late budding, rubber ties, and non-covering of the bud. The specific combination of these treatments gave the highest yield of 97% (Table 11e).

Maiden height increased variously with later budding, the use of rubber ties and not covering the bud, the value of not covering the bud being mainly with the use of polyethylene in August (Table 11f). The number of trees producing multi-shoot maidens requiring pruning to a single stem, instead of the normal natural single stem, increased with the use of polyethylene ties and covering the bud (Table 11g). The highest number of multi-shoot trees (62%) resulted from budding in early August using polyethylene to cover the bud, and reflects the physical damage caused to the main bud, with growth occurring from axillary buds. This constraint will have contributed to the smaller maiden trees from early bud-covered treatments. The numbers of laterals per tree (Table 11h) and length of individual laterals reflected tree height, being greatest for late-budded, rubber ties and non-bud-covered treatment combinations overall.

Table 11. Rootstock growth, bud-take and maiden growth of *B.pendula* 'Dalecarlica' budded in 1992

a) Stem diameter increase (%) during the budding period

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	22.4	22.9	25.6	19.6)	
24th August	27.5	23.1	21.1	19.6}	6.3
7th September	4.4	4.6	5.2	4.3)	

P: Budding time = 0.1%

Tying material = NS

± covering bud = NS

b) Actual bud prominence (mm) at tie release

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	1.6	3.6	1.7	3.5)	
24th August	2.6	3.9	2.0	4.4}	0.66
7th September	2.5	4.3	2.1	4.3)	

P: Budding time = 0.1%

Tying material = NS

± covering bud = 0.1%

c) Apparent chip-take (%) in April 1993

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	94	84	84	78)	
24th August	88	73	85	66}	18.8
7th September	100	91	97	97)	

P: Budding time = 1.0%

Tying material = NS

± covering bud = 1.0%

d) Apparent bud-take (%) in June 1993

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	56	50	59	63)	
24th August	47	70	64	63}	22.1
7th September	72	88	94	97)	

P: Budding time = 0.1%

Tying material = 5.0%

± covering bud = NS

e) Maiden trees harvested (%)

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	29	48	63	66)	
24th August	64	67	64	64}	22.6
7th September	75	88	91	97)	

P: Budding time = 0.1%

Tying material = 5.0%

± covering bud = NS

f) Maiden height from the union (cm)

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	156	182	200	193)	
24th August	147	222	188	231}	35.1
7th September	218	215	221	222)	

P: Budding time = 0.1%

Tying material = 1.0%

± covering bud = 1.0%

Time x cover = 1.0%

g) Maiden trees with multishoot stems (%)

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	62	23	11	18)	
24th August	52	16	18	10}	29.7
7th September	22	7	14	6)	

P: Budding time = NS
Tying material = 5.0%
± covering bud = 5.0%

h) Numbers of laterals per tree

Budding ties	Polyethylene		Rubber		LSD (5%)
Buds covered	+	-	+	-	
Budding time					
10th August	16.4	18.7	18.7	19.7)	
24th August	15.1	19.6	18.1	20.2}	2.7
7th September	19.7	20.3	20.8	19.5)	

P: Budding time = 5.0%
Tying material = 5.0%
± covering bud = 1.0%

In 1993 the apparent importance of budding time was again investigated by budding on 9th August and 6th September, using rubber ties not covering the bud, which performed well in the 1992 experiment. Attempts to modify rootstock growth were made by planting into soil cultivated to a depth of 30 cm, 20 cm or into unploughed cereal land (soil resistance to penetration is described in the section of this report on *Acer platanoides*). Scionwood was compared from non-pruned and lightly-pruned budwood trees.

Rootstocks grew much more actively during the August budding period compared to September. The effect of soil cultivation depth was variable and non-significant (Table 12a).

Early assessment of bud-take in June and final numbers of maiden trees lifted were virtually identical. In marked contrast to the previous year, August budding was much more successful than September budding, with effects due to cultivation and budwood pruning being non-significant (Table 12b).

The number of maiden trees with multi-stems was greater in the August budded treatment than in the September budded set (28.4 v. 2.5% respectively, $P < 5.0\%$). This is likely to have contributed to the reduction in maiden height from the earlier budding (Table 12c), although the use of the unpruned budwood source improved overall maiden height by an even greater extent. The largest maiden trees were produced by September budding using the unpruned scion source, irrespective of cultivation depth.

Table 12. Rootstock growth, bud-take and maiden growth of *B. pendula* 'Dalecarlica' budded in 1993

a) Stem diameter increase (%) during the budding period

Budding time	9th August		6th September		LSD (5%)
Budwood source	Unpruned	Lightly pruned	Unpruned	Lightly pruned	
Cultivation					
None	8.5	13.3	2.1	2.0)	
Shallow	9.8	12.0	3.8	2.9}	6.4
Deep	10.2	9.5	8.8	2.1)	

P: Budding time = 0.1%

Cultivation = NS

Budwood source = NS

b) Maidens harvested (%)

Budding time	9th August		6th September		LSD (5%)
Budwood source	Unpruned	Lightly pruned	Unpruned	Lightly pruned	
Cultivation					
None	90	74	15	10)	
Shallow	75	89	30	35}	26.5
Deep	85	80	21	5)	

P: Budding time = 0.1%

Cultivation = NS

Budwood source = NS

c) Maiden height (cm)

Budding time	9th August		6th September		LSD (5%)
Budwood source	Unpruned	Lightly pruned	Unpruned	Lightly pruned	
Cultivation					
None	173	186	216	204)	
Shallow	200	190	218	178}	18.0
Deep	183	177	211	158)	

P: Budding time = 5.0%

Cultivation = NS

Budwood source = 1.0%

Time x budwood = 5.0%

The number of laterals produced per tree was significantly greater in the shallow- compared to deep-cultivated soil, with an intermediate response in the non-cultivated area. Lateral length followed trends for maiden height, with the longest laterals produced from September budding.

Herbicide damage

In 1994 a further management trial was carried out in an attempt to determine whether damage from the application of residual herbicides contributed to reduced bud-take. Sovereign (pendimethalin) at 4 litres per hectare, and Simazine at 2.2 litres per hectare were applied after planting the rootstocks, either to wet soil as recommended (in a duplicate set) or to dry soil, where it would be expected not to be held at the surface and so be washed down to the root zone in heavy rain. For comparison, rootstocks were planted through a black polyethylene mulch and not treated with herbicide. An unpruned and hard-pruned budwood source were compared, and budding was on 15th August, using rubber ties with the actual bud not covered.

At budding the budsticks from the hard-pruned source were thicker (7-8 cm) than those from the unpruned source (5 cm), but in both sources the actual buds exceeded 10 mm in length, with brown scales beginning to form.

Herbicide symptoms were virtually absent from the polyethylene-mulched plants, but their apparent presence at very low frequency suggests that other leaf symptoms may have been mistakenly recorded, or that residual herbicides from previous crops were present, which is considered unlikely. Unexpectedly, approximately 90% of rootstocks showed apparent leaf symptoms of herbicide damage following application to wet soil, and about 60% when the application was to dry soil. The severity of herbicide damage did not adversely affect stock size at budding or stem thickening during budding (Tables 13a and b)

The unpruned budwood source gave the highest bud-take, which reflected the number of maiden trees harvested, but herbicide treatment had no significant effect and the polyethylene-mulch set actually gave the fewest trees (Table 13c).

In the absence of different bud-tying treatments there was no treatment effect on the frequency of maiden trees with more than one stem, and no treatment combination had a significant effect on maiden height (Table 13d).

On the other hand both pruning and soil management affected the number of laterals, with a significant but small increase in the pruned budwood source and the polyethylene mulch treatment.

Table 13. Rootstock growth, bud-take and maiden growth of *B. pendula* 'Dalecarlica' budded in 1994

a) Frequency (%) of rootstocks showing herbicide damage

Soil conditions at herbicide application	Dry	Wet	Wet	Polyethylene mulch	LSD (5%)
Budwood source					
Hard-pruned	51	98	80	0)	
				}	21.5
Non-pruned	65	98	80	5)	

P Soil conditions = 0.1%

Budwood source NS

b) Rootstock stem diameter increase (%) during budding

Soil conditions at herbicide application	Dry	Wet	Wet	Polyethylene mulch	LSD (5%)
Budwood source					
Hard-pruned	12	15	13	12)	
				}	6.3
Non-pruned	9	16	13	13)	

P Soil conditions NS

Budwood source NS

c) Maiden trees harvested (%)

Soil conditions at herbicide application	Dry	Wet	Wet	Polyethylene mulch	LSD (5%)
Budwood source					
Hard-pruned	55	57	61	49)	
				}	20.1
Non-pruned	78	84	80	64)	
P Soil conditions NS					
Budwood source = 0.1%					

d) Maiden height (cm)

Soil conditions at herbicide application	Dry	Wet	Wet	Polyethylene mulch	LSD (5%)
Budwood source					
Hard-pruned	221	213	225	223)	
				}	20.4
Non-pruned	201	220	217	232)	
P Soil conditions NS					
Budwood source NS					

Time of planting rootstocks

In 1993 an alternative approach to identifying optimum conditions for budding was investigated by planting rootstocks out of a jacketed cold-store on the 22nd February, 5th April and 17th May, so that they were at different stages of growth when budded on 19th August, using budwood from non-pruned or lightly-pruned trees, and tying with rubber strip not covering the bud. At each time of planting half the rootstocks received root-dips of the seaweed based proprietary product 'Alginure' at the recommended rate of 1+3 parts water by volume.

Almost all rootstocks established, with 7.5% failures from February planting, and 10% from May planting. Failures were confined to rootstocks which did not receive an 'Alginure' root-dip. Herbicide damage in the form of stunted growth, leaf yellowing, necrosis and sometimes abscission was seen in a few rootstocks, largely confined to the February planting. On a scale 1 (mild) to 3 (severe) the score for February-planted rootstocks without 'Alginure' root-dip was 1.2, and with root-dip was 0.4. April-planted rootstocks without root-dip gave a score of 0.2 and no damage was recorded in the April planting with root-dip, and in neither of the May plantings. By budding time in mid-August the February- and April-planted rootstocks had grown much more than those planted in May, as indicated both by shoot growth and stem diameter measurements, but the markedly greater stem diameter increase of the May-planted stocks over the budding period indicated that they were growing more vigorously than earlier-planted stocks at this crucial time. Late planting effectively delayed the period of rapid growth until budding, with the advantage of having a smaller rootstock at the time of budding (Table 14).

Table 14. *B. pendula* rootstock growth, 1993 and subsequent bud-take

Planting date	22nd February		5th April		17th May			LSD (5%)
Root-dip	-	+	-	+	-	+	*P*	
Shoot growth (cm)	1124	1449	1287	1118	790	704	-	
Stem diameter at budding (mm)	14.9	16.3	15.8	14.9	11.5	10.9		1.1
					Planting dates		0.1%	
					Root dip		NS	
Stem diameter increment during budding (%)	9.8	9.2	9.4	12.5	21.2	18.6		2.7
					Planting dates		0.1%	
					Root dip		NS	
Maidens harvested (%)	39	63	48	48	64	68		24.7
					Planting dates		(5.0%)	
					Root dip		NS	

Bud-take success, in terms of numbers of maidens harvested, was only moderate, but the late-planted rootstocks gave the highest take, with differences on the borderline of significance and with treatments separated by the LSD (Table 14). Budwood source had no overall effect on bud-take, and data are not shown in the table, being 54 and 56% for the lightly-pruned and non-pruned sources respectively, when averaged over other treatments.

Treatments had no effect on maiden growth.

Time of planting rootstocks and budding

In 1994 the relationship between rootstock growth at budding, as influenced by time of planting, was investigated further by interacting two times of planting (1st March v. 16th May) with early and late budding (2nd August v 6th September). All buds were tied with rubber strips not covering the actual eye.

There was marked contrast in the appearance of the budwood when collected. The early sample comprised shoots which were only just beginning to produce laterals in the proximal zone, and whose axillary buds were only just beginning to produce brown scales; this scionwood was considered to be immature. In contrast, the late sample comprised thicker shoots with proximal buds developed into laterals, and lower leaves turning yellow and sometimes abscissing.

Rootstock growth also was markedly different at the two budding times, with stems so thick in September that it was not always possible to accurately fit the chip.

Early budding and late rootstock planting were both associated with greater rootstock stem increase (equivalent to cambial activity) during the budding period when ties were in place, and their combination gave very rapidly growing rootstocks (Table 15). Results were virtually identical when assessed as actual increase in stem diameter, and percentage increase, taking into account the thickness of rootstock stem at the time of budding. The early-planted rootstocks more frequently showed herbicide damage in the form of partial leaf chlorosis (Table 15), but this did not appear to reduce their overall growth, although it might have contributed to their relatively early cessation of growth in late summer, compared to later planted ones.

Treatment combinations resulted in a wide spread of bud-take, from 23 to 82% in terms of maidens harvested. The major benefit was from early budding, further enhanced by late planting of the rootstocks (Table 16).

Maiden tree height, on the other hand, along with numbers of laterals, were enhanced by late-budding (Table 16), possibly contributed to by the production of more than one maiden stem in the early budding treatment (Table 16).

Table 15. Rootstock growth during budding, and herbicide damage in *B. pendula*

Planting dates	1 March		16 May			LSD (5%)
Budding dates	2 Aug	6 Sept	2 Aug	6 Sept	*P*	
Stem diameter increase during budding (%)	33.5	3.1	42.7	4.5		3.4
			Planting date		0.1%	
			Budding date		0.1%	
			Planting x budding dates		1.0%	
Herbicide damage (%)	60.8		29.2			14.1
			Planting date		1.0%	

Table 16. Bud-take and maiden growth of *B. pendula* 'Darlecarlica' in response to different budding dates and rootstock planting dates in 1994

Planting dates	1 March		16 May			
Budding dates	2 Aug	6 Sept	2 Aug	6 Sept	*P*	LSD (5%)
Maidens harvested %	82	23	82	47		19.8
			Planting date		NS	
			Budding date		0.1%	
Maiden height (cm)	207	232	204	229		25.9
			Planting date		NS	
			Budding date		1.0%	
Lateral number	16.0	20.7	16.3	19.2		2.6
			Planting date		NS	
			Budding date		0.1%	
Multistems (%)	14.8	0	6.1	0		9.0
			Planting date		NS	
			Budding date		5.0%	

The correlation between increase in rootstock stem diameter and budding success in an earlier experiment (Figure 1) suggests that small increases in growth are critical, with no further gains when rootstock stems are growing rapidly.

Conclusions:

The most important requirement for budding success in *Betula* is that rootstocks are growing rapidly, with the implication that the cambium is at its most active. Rootstock growth and stem thickening were depressed by reducing the number of rootstock shoots before budding, and in the normal one-year-old rootstock this reduced bud-take.

Because 'Dalecarlica' budwood matures relatively late (exacerbated by many early-forming buds developing into laterals and not being available for budding), it is tempting to delay budding until the autumn. In 1992, when rootstocks were growing particularly well, budding in early September gave a high bud-take, but in 1993, when rootstocks grew less well, budding a month earlier gave optimum results. It appears that in seasons when later budding is preferable early budding results in bud-chips which appear to have united because they are held by callus, but they do not produce maidens, suggesting that unions were not formed.

The benefits of early budding can be increased by planting the rootstocks relatively late as long as they can be stored in good condition and established rapidly with irrigation if necessary. Late planting delays the period of optimal rootstock growth, providing additional opportunity for bud-wood to mature. Other factors influence success; budwood grown under water stress should not be used, and the tie should not be allowed to severely squash the actual eye. Degradable rubber strip is preferable to polyethylene.

Of the four species investigated, *Betula* 'Dalecarlica' has shown the least clear cut responses to treatments, suggesting that despite considerable progress, not all causes of poor bud-take have been identified, or that optimum conditions often fail to combine in a particular year.

Robinia pseudoacacia 'Frisia'

Background

Research into this subject is typified by modest levels of bud-take, in the order of 50%, irrespective of a wide range of treatments applied to rootstocks and scionwood. Experience suggests that a number of factors need to interact to create favourable conditions for union formation (bud-take), and that these may not be present in particular circumstances, making their identification difficult. Furthermore, *Robinia* is particularly sensitive to damage from post-planting residual herbicide application and 1992 experiments were abandoned following the death of many lined-out rootstocks treated with Venzar (lenacil).

Among responses already reported (Howard, 1992) are that different sources of budwood influence bud-take in 'difficult' years, but are of no consequence in years with generally high levels of success.

In parallel with *Acer platanoides*, budding success in *Robinia* appears to relate to the field being used as a nursery, which accounts more for apparent year effects than the weather in any particular year.

There is evidence also (Howard, 1992; Rose and Harris, 1995) that bud-take in *Robinia* is depressed by pathogens present on the scionwood and/or rootstock. Even though the aetiology is not yet fully understood, evidence is growing that Benlate and Rovral prophylactic sprays are beneficial.

The direction of research for this particular species may have been influenced unduly by the very rapid growth of the rootstock at the time of budding, causing the stem to be constricted severely when using polyethylene ties, causing the head of the rootstock to break off in high winds. Because of this, degradable rubber strips were used in the majority of experiments where the bud-tying material was not being considered as a treatment. As the research progressed it became obvious that an apparent high level of chip-take, approaching 100% when recorded in the winter after budding, was not confirmed by the development of maiden trees, which might be in the order of 50%. It appeared likely that bud-chips were simply being held in place by the development of copious rootstock callus. This problem was likely to be exacerbated by rubber ties if insufficient pressure was exerted on the callus to induce the formation of phloem and xylem.

The experimental results for *Robinia* are described, therefore, in two parts; firstly, where the tying material featured as a treatment, and secondly, where degradable rubber ties were used as part of the general background method. In retrospect, this latter situation may not always have provided the best conditions for the comparison of other factors.

Experiments investigating the use of different bud-tying materials

In 1986 budding was done on 23rd July and 19th August, with buds tied with either polyethylene strip or degradable rubber strip, and released after approximately four weeks.

Although the overall level of bud-take was low, the combination of early budding and polyethylene ties was markedly superior (Table 17).

The early-budded rootstocks almost doubled their stem diameter during the period that the ties were in place, and it was particularly noticeable that large 'shoulders' of callus along the edges of the rootstock cut enveloped the edges of the scion chip, firmly holding it in place. But at the same time these callus shoulders lifted the tying material off the actual scion chip, indicating the pressure to which the rootstock and scion callus were exposed. The polyethylene ties were lifted least (Table 17), supporting the observation that they exerted greater pressure on the developing union than the rubber ties, associated with differences in bud-take, although additional factors clearly undermined bud-take in this experiment.

The constricting effect of the polyethylene ties led to 24% of rootstocks breaking at the top of the tie in the early-polyethylene treatment combination, compared to none in the late-budded, rubber-tied treatment combination.

Table 17. Effects of budding time and tying material on rootstock growth and bud-take in *R.. pseudoacacia* 'Frisia'

Budding date	23 July		19 August			LSD (5%)
Tying material	Poly-ethylene	Rubber	Poly-ethylene	Rubber	*P*	
Stem diameter increase during budding (%)	97	84	32	34		11.0
				Date	0.1%	
				Ties	NS	
Prominence of callus shoulders (mm)	1.2	2.5	2.3	4.4		1.2
				Date	1.0%	
				Ties	1.0%	
Maidens harvested (%)	56	32	9	5		27
				Date	0.1%	
				Ties	NS	

In 1991 polyethylene and rubber ties were compared, with the actual eye covered or not, and the rootstocks irrigated or not by applying an additional 4 litres per plant on days without rain. Budding was done on 1st August.

No treatment affected rootstock growth in terms of increase in stem diameter during budding.

Bud-take, in terms of numbers of maidens harvested, was increased by using polyethylene ties compared to rubber, and especially by covering the actual eye rather than leaving it exposed. Irrigation had no effect on bud-take and at both levels of irrigation the combination of polyethylene tie and covering the bud gave the highest bud-take, which reached 83% in the non-irrigated plots (Table 18).

Covering the actual bud increased the number of plants which produced more than one scion shoot, from 24 to 43% overall, thereby necessitating more shoot singling, but there were no effects of treatment combinations on maiden height, with overall mean growth from the union reaching 273 cm.

Table 18. Numbers of *R. pseudoacacia* 'Frisia' maidens harvested (%) in response to bud-tying methods and additional irrigation

Ties	Polyethylene		Rubber			LSD (5%)
Bud covered	+	-	+	-	*P*	
No additional irrigation	83	47	57	23)		
				}		26.1
Additional irrigation	71	37	63	27)		
				Ties	5.0%	
				Bud covering	0.1%	
				Irrigation	NS	

The least gap between tying material and the scion chip was in the polyethylene tie, bud-covered treatment combination (mean 0.86 mm) and the largest gap was in the rubber tie, bud-exposed treatment combination (mean 1.43 mm), again linking maximum pressure with highest bud-take.

Experiments where buds in all treatments were tied routinely with degradable rubber strips

In 1989 *R. pseudoacacia* rootstocks were graded into four sizes and budded on 9th August. The original sizes at planting, and at budding, are shown in Table 19. Despite large differences in rootstock size and growth rate, with the largest rootstock being on average 54% thicker than the smallest when budded, but the smallest growing 118% more than the largest during the budding period, the effects on bud-take (in terms of maidens harvested) were relatively small (Table 19).

Table 19. Effects of rootstock grade on growth of rootstocks and bud-take in *R. pseudoacacia* 'Frisia'

Rootstock grades	Very large (1 year transplants)	Large	Medium	Small	*P*	LSD (5%)
Stem diameter at planting (mm)	12.2	7.8	6.0	4.6	-	-
Stem diameter at budding (mm)	20.1	18.7	16.5	13.0	0.1%	0.82
Stem diameter increase during budding (%)	29.4	37.9	44.5	64.0	0.1%	6.7
Maidens harvested (%)	63	79	71	79	NS	19.7

In 1993 rootstocks were planted out of a jacketed cold store on 22nd February, 5th April and 17th May, with or without dipping the roots in a proprietary preparation of 'Alginure'. Budding was done on 27th July and 10th August, with budwood dipped the previous evening in a mixture of 4 g l^{-1} Benlate and 4 g l^{-1} Rovral with wetter. The budding face of the rootstock had been sprayed to run-off with a similar mixture.

Herbicide damage, assessed on the basis of deformed leaves, was most frequent in the February-planted rootstocks (39%), decreasing in April to 11%, with no symptoms showing in the May-planted rootstocks ($P<0.1\%$). The score for severity of symptoms (0 to 3 - most leaves affected) followed the same pattern, *viz* February = 1.8, and April 0.5. Eight percent of the February-planted rootstocks failed to establish compared to 1% on the other dates. No other treatments influenced the appearance of herbicide damage symptoms. The pre-planting root-dip had no effect on any variate, so data in the table are the means of ± dipping.

April-planted rootstocks had the thickest stems when budded in July and August, whereas the May-planted rootstocks were growing fastest during the budding period, as were those budded in July compared to August (Table 20).

Bud-take in terms of maidens harvested was modest (Table 20) ranging from 14 to 58% between treatment combinations. February-planted rootstocks gave the highest bud take, despite suffering the most herbicide damage. It is likely that other factors not measured in this experiment determined bud-take. Overall, the tallest maiden trees were produced on the April-planted rootstocks (Table 20), which were the thickest when budded, but this was due to particularly good growth in the April-planted, August-budded set.

Table 20. Effects of planting date and budding time on rootstock growth, bud-take and maiden height of *R. pseudoacacia* 'Frisia'

Planting	22 February		5 April		17 May			
Budding	27 July	10 Aug	27 July	10 Aug	27 July	10 Aug	*P*	LSD (5%)
Rootstock stem diameter at budding in July (mm)	13.9	16.8	17.8	20.4	14.5	16.6		1.3
					Planting date		0.1%	
					Budding date		0.1%	
Stem diameter increase (%) during the budding period	33.2	23.4	27.1	21.8	37.7	28.2		3.4
					Planting date		0.1%	
					Budding date		0.1%	
Maidens harvested (%)	53	58	28	14	28	38		25.7
					Planting date		1.0%	
					Budding date		NS	
Maiden height (cm)	285	264	300	334	306	299		32.4
					Planting date		1.0%	
					Budding date		NS	

In 1993 rootstocks were planted into soil cultivated to a depth of 30 cm or 20 cm, or into unploughed cereal land (soil resistance to penetration is described in the section of this report on *Acer platanoides*). Budding was done on 28th July and 10th August, using budwood from severely pruned or lightly tipped scionwood trees, with treatments providing fully randomised factorial sets within each soil cultivation plot. Budwood pruning had no effect on any variate and the tabulated data are the means of the two budwood sources.

Rootstock stems grew most rapidly in terms of % stem diameter increase during the earlier budding period and in the non-cultivated soil, but actual differences in diameter increase were small, indicating that, in the case of the non-cultivation effect, the apparent rapid growth reflected initially poorly growing rootstocks (Table 21).

Despite differences in rate of stem thickening, and hence cambial activity, there were no treatment combination effects on bud-take when measured as yield of maiden trees. Trees grown in the non-cultivated soil were the smallest, the difference almost reaching the 5% level of significance, and the earlier budding gave longer laterals overall (Table 21), but no increase in numbers of laterals.

Table 21. Effects of soil cultivation and budding date on rootstock growth and maiden tree production of *R. pseudoacacia* 'Frisia'

Cultivation	None		20 cm		30 cm			
Budding date	28 July	10 Aug	28 July	10 Aug	28 July	10 Aug	*P*	LSD (5%)
Stem diameter increase (%) during the budding period	32	24	25	21	28	21		5.1
					Cultivation		5.0%	
					Budding time		0.1%	
Actual stem diameter increase (mm)	4.5	3.8	4.1	3.9	4.4	3.5		0.95
					Cultivation		NS	
					Budding time		5.0%	
Maidens harvested (%)	57	55	58	61	60	45		27.9
					Cultivation		NS	
					Budding time		NS	
Maiden height (cm)	269	223	290	325	295	297		73.2
					Cultivation		5.0%	
					Budding time		NS	
Lateral length (cm)	77	57	84	69	71	72		18.4
					Cultivation		NS	
					Budding time		5.0%	

In 1993 rootstocks established in the later-winter were cut down to 15 cm on 5th May, and a new shoot run-up to be budded on 28th July, placing the bud on its inner curve. The cut-down rootstocks, and the normal controls, were either sprayed with 4 g l^{-1} Benlate and 4 g l^{-} Rovral fungicides + wetter, and the budwood dipped in a similar mixture, or fungicides were not used. This gave a 2 x 2 factorial set(± cutting down x ± fungicide treatment to rootstock and scion).

When budded, the new selected shoot on the cut-down rootstock had a diameter close to the budding position of 10 mm, compared to nearly 13 mm on the original stem of the intact control rootstock. As expected, the application of fungicides prior to budding had no effect on rootstock growth.

Stem diameter increase during the budding period was greater for the new shoots on the cut-down rootstocks, but this was only significant in terms of % increase, reflecting the initially smaller thickness of these stems at budding (Table 22).

Bud-take, in terms of maidens harvested, was increased by cutting down and budding onto a new stem, and by the application of fungicides. The combination of cutting down and fungicide application gave 100% take, even when tied with rubber, whereas the normal non-cut down, non-fungicide control gave 63%, which is typical of many experiments using rubber ties. Because variation in this experiment was rather high the main effects due to cutting down and fungicide treatment were significant only at the 10% level of probability.

Trees were significantly taller when rootstocks were not cut down, but the actual difference was only 14 cm when averaged over the two levels of fungicide treatment (Table 22).

Table 22. The effects on *Robinia pseudoacacia* rootstock growth, 'Frisia' bud-take and maiden tree size, of cutting-down rootstocks prior to budding, and treating them and the scion wood with fungicide

Cut down	+		-			LSD (5%)
Fungicide	+	-	+	-	*P*	
Stem diameter at budding (mm)	9.7	10.5	13.1	12.5		1.5
				±cut down	1.0%	
				±fungicide	NS	
Stem diameter increase (%) during the budding period	44	41	27	29		13.6
				±cut down	1.0%	
				±fungicide	NS	
Maidens harvested (%)	100	84	83	63		27.3
				±cut down	(10.0%)	
				±fungicide	(10.0%)	
Maiden heights (cm)	273	288	292	299		18.2
				±cut down	5.0%	
				±fungicide	NS	

In 1994 rootstocks were treated with 4 g l^{-1} Benlate + 4 g l^{-1} Rovral (+ wetter) prior to budding with bud-wood treated or not with a similar fungicide mixture at various intervals before budding. The overall mean bud-take was 47%, with no significant treatment effect, underlining the fact that apparently beneficial treatments may not be effective if other circumstances (such as using rubber ties) dominate.

In 1994 rootstocks were planted on 1st March and 16th May out of cold store, and budded on 2nd August or 23rd August in a 2 x 2 factorial set.

The increase in stem diameter of the rootstock was significantly greater during the early budding period than for later budding, and also for the later planted rootstocks compared to earlier planting, but this effect was not significant.

Faster rootstock growth during the early budding period was even more marked when measured in terms of the percent increase in stem diameter because rootstocks were relatively thin at the start of the early budding period (Table 23).

Despite these differences bud-take (as maidens harvested) was modest, ranging from 46 to 51%. As is often the case, later budding gave significantly larger maiden trees, but the overall difference due to budding time was only 17 cm and appeared to be mainly due to the smaller size of the late-planted, early budded rootstock reducing the size of maiden tree (Table 23).

Probing with a scalpel those bud chips that failed to produce maiden growth indicated that the majority had not formed a union (Table 23) and were held in place by the overgrowth of rootstock callus.

Table 23. Effects of *Robinia pseudoacacia* rootstock planting date and 'Frisia' budding date on rootstock growth, bud-take, and maiden growth

Planting date	1 March		16 May			
Budding date	2 August	23 August	2 August	23 August	*P*	LSD (5%)
Stem diameter increase (%) during the budding period	62	29	68	27		19.6
			Planting date		NS	
			Budding date		0.1%	
Maidens harvested (%)	46	49	51	49		26.5
			Planting date		NS	
			Budding date		NS	
Bud-chips failing to unite (%)	42	46	48	43		25.9
			Planting date		NS	
			Budding date		NS	
Maiden height (cm)	303	303	281	315		17.9
			Planting date		NS	
			Budding date		5.0%	

Conclusions:

Despite very large differences in the size of *Robinia* rootstocks when budded, and large differences in growth rate during the union-forming period due to time of planting and time of budding, the quality of rootstock appears not to influence bud-take of the 'Frisia' scion. Indeed, cutting the newly established rootstock back and budding onto the resulting new annual growth gave amongst the highest levels of success.

Rapid rootstock growth, however, may have obscured important responses associated with the choice of tying material with which to secure the bud-chip. For routine purposes degradable rubber strips were used so as to minimise the chance of the rootstock breaking where the tie constricted the rapidly swelling stem above the chip-bud, which was a frequent occurrence in some years when polyethylene ties were used. In many experiments only modest levels of bud-take were obtained with rubber ties, with treatment effects apparently masked. There is evidence that this was because bud-chips were held in place by 'shoulders' of rootstock callus at the edges of the rootstock cut, but that with rubber ties, especially when not covering the chip and the eye completely, there was inadequate pressure to cause vascular tissue to differentiate and a functional union to form.

Superior bud-take when polyethylene ties were used compared to rubber ties was associated with greater compression of the callus.

It also appears that prophylactic fungicide treatments to scionwood and rootstock are beneficial, and when combined with budding onto new annual rootstock shoots, gave 100% bud-take. The benefit of cutting down rootstocks to induce a new young stem to develop for budding may be partly due to the new shoot being less contaminated with micro-organisms, compared to the normal two-year-old stem.

Success with *Robinia* 'Frisia' appears to require the use of polyethylene ties to create pressure on the graft-union, and fungicide treatment to reduce micro-organisms that might debilitate the chip-bud before it is united with the rootstock. On the basis of the experiments carried out in this project many other factors do not influence *Robinia* budding, including size and growth rate of the rootstock, pre-planting root dips with 'Alginure', soil cultivation depth, irrigation and the degree of pruning applied to the scionwood trees.

Acer platanoides 'Crimson King'

Background

This subject is typified by large annual fluctuations in bud-take; when a union forms trees usually grow vigorously but with sparse lateral formation in the maiden year. Research has concentrated, therefore, on reasons why bud-take varies so markedly from year to year, and is often below commercially acceptable levels.

Nurserymen attribute low bud-take to poor weather, without identifying the nature of the adverse conditions, whereas earlier work reported in projects HNS 7 and 7a showed that the year effect was not linked to weather, but to the field that was used for the nursery in any particular year (Howard, 1992).

At the same time it was reported that there was no evidence for incompatibility between 'Crimson King' and any of the seedling *A. platyphyllos* rootstocks, but that a number of other factors, as yet unidentified, might exacerbate the low bud-take problem. This combination is slow to form a union and although not always essential, experience shows that it is sensible to leave the polyethylene bud ties in place for six weeks, compared to four weeks for most other species.

The rootstock produces most of the cambial callus, with little contribution from the bud-chip, giving the impression that it is the scion which is vulnerable to factors negating union formation.

There is evidence also (Howard, 1992; Rose and Harris, 1995) that bud-take is depressed by pathogens present on the scionwood and/or rootstock. Even though this problem is not fully understood in terms of the source and nature of the specific fungi and/or bacteria involved, there is growing evidence that Benlate and Rovral prophylactic sprays are beneficial.

Failed chips may be wet and stained black, explaining why nurserymen also associate budding failure with the xylem sap which bleeds profusely from the wounds incurred during budding. The chip-bud and portion of rootstock stem enclosed by the budding tie remain wet for many days.

It has been observed also, in experiments at East Malling, that bud-take is consistently low when budding potted rootstocks, even though they can be transferred into pots from the field with dormant buds of 'Crimson King' already healed-on, and then make vigorous maiden growth (Howard, 1994).

Against this background the main thrust of the work reported here was to use potted rootstocks and normal field-grown plants to investigate the effects of root restriction and plant water relations on bud-take, as affected by quality of rootstock growth and frequency/extent of xylem sap-bleeding. More 'routine' questions of rootstock grade and scionwood source were investigated also.

<u>Effects of rootstock grade</u>

In winter 1988/89 seedbeds on a commercial nursery were sampled to provide sets of large and small grade *Acer platanoides* rootstocks from the following sources, which themselves imposed further size differences:-

* Seedlings harvested after one season, with undercutting in mid-summer (I-UC).

* Seedlings harvested after two seasons, with undercutting in the spring of the second year (2-UC).

* Seedlings grown for one year in the seedbed and then transplanted to the field for one season (2-TP).

After planting in a fully randomised factorial design rootstocks were budded on 2nd August.

There were large differences at planting in the height of the large- and small-graded rootstocks from the different sources, and in the stem diameter of the different sources due to their growth over one or two years (Table 24).

Table 24. Rootstock height above ground and stem diameter after planting, related to the production method of *Acer platanoides* seedlings. LSDs are based on variation within a single ten-plant plot for each production method and size grade

	Size grade			
	Large		Small	
Production method	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)
1-UC Harvested after one season, with undercutting in mid-summer	74	6.8	34	5.0
2-UC Harvested after two seasons, with undercutting in the spring of the second year	72	9.4	40	6.1
2-TP Grown for one year in the seedbed and then transplanted to the field for one season	81	9.3	45	6.9
LSD (5%)	7.8	0.82	5.8	0.72

Between 94 and 100% rootstocks survived transplanting except in the large and small transplanted two-year source (2-TP), where by the end of June only 72% remained alive in each size grade. This was attributed to infection with verticillium wilt on the basis of typical olive green staining of the xylem, with yellowing and necrosis of leaves. *Verticillium dahliae* was confirmed in samples by isolation in the laboratory. Six percent infection was also found in the small plants from the two-year undercut source (2-UC). The incidence of verticillium wilt increased progressively through the budding and maiden years, with the highest frequency remaining in the transplanted rootstocks (Table 25).

Bud-take was assessed in late June 1990, excluding those rootstocks showing symptoms of verticillium wilt. With the exception of the worst infected source (large, two-year transplanted - 2-TP) bud-take was between 85 and 96% (Table 25). Despite excluding rootstocks with obvious verticillium wilt symptoms, bud-take in the 2-TP source was significantly depressed, suggesting that other rootstocks were less obviously infected.

The final size of maiden trees, excluding those with verticillium wilt symptoms, reflected the original rootstock size grades within sources, and not the production methods. Tree height from the union, and stem diameter at 50 cm above ground are shown in Table 25.

Table 25. Bud-take, maiden growth and verticillium wilt infection of *Acer platanoides* 'Crimson King' budded in 1989 on seedling rootstocks of different sizes and different seedbed production methods

	Size grade	Source 1-UC	2-UC	2-TP	*P*	LSD
Percent bud-take	Large	90	88	62		
	Small	85	96	87		
		Rootstock size			NS)	
					}	17.5
		Production method			5.0%)	
Maiden height from the union (cm)	Large	263	274	272		
	Small	251	249	258		
		Rootstock size			0.1%)	
					}	17.9
		Production method			NS)	
Stem diameter 0.5 m above ground (mm)	Large	19.0	19.6	20.5		
	Small	17.6	17.1	17.7		
		Rootstock size			0.1%)	
					}	1.6
		Production method			NS)	
Percent maiden trees with verticillium wilt symptoms at harvest	Large	10	12	57		
	Small	5	18	35		
		Rootstock size			NS)	
					}	22.4
		Production method			0.1%)	

Although infection of the rootstock with verticillium wilt can prevent a union forming with the 'Crimson King' chip, the source of the rootstock, and its initial size at planting, had little effect, a result confirmed in a further experiment in 1991.

Effects of budwood source and position of bud on the budstick

In 1989 three budwood sticks were taken from each of six sources of 'Crimson King', representing widely different methods of raising scionwood, ranging from micropropagated trees growing on their own roots under glass to normal bud-grafted trees growing in the field. After removing the immature apical section, one bud from each opposite pair was budded in sequence (proximal to distal) onto rootstocks lined out in the field, using one budstick of each source as a replicate in a randomised design.

Bud-take was relatively high in this year and all bud-chips from 8 of the 18 budsticks formed unions, and there was no preference for raising scionwood in a particular way, or using shoots of a particular length. The failed buds from the remaining 10 budsticks were generally scattered along their length (Table 26).

Similar investigations on other occasions, and with different sources, also failed to show the existence of particular zones on the scion shoot from which buds are likely to fail, despite buds being taken from successive growth flushes and from shoots of markedly different vigour.

Effects of irrigation

In 1990, few useful data were obtained from a series of experiments because the majority of bud-chips failed to take, and a high proportion were wet and stained black when the polyethylene ties were removed. This was the first year that the nursery was provided with regular trickle irrigation, and the possibility existed, therefore, that generous irrigation had caused the death of so many bud-chips, leading to a series of experiments investigating irrigation and water relations, including effects of xylem sap-bleeding.

However, when experimental treatments were ignored among the approximate 400 *Acer platanoides* rootstocks in the 1990 nursery, and rootstocks were categorised, at the time of tie release, as growing vigorously, moderately, or weakly, the respective bud-take was 31, 15 and 7%. This suggests that quality of rootstock growth influenced bud-take, but could not totally account for the overall poor effect.

In 1991, the effects of irrigation were investigated by applying 4 litres of water via a trickle system to each rootstock on days when no rain fell, from approximately 3 weeks before budding on 8th August until the polyethylene ties were released 6 weeks later. For comparison, the majority of rain was deflected from rootstocks over the same period by placing polyethylene-covered wooden frames against each side of the row, approximately 12 cm high adjacent to the rootstocks (budding height = 15 cm), and resting on the soil approximately 0.5 m from the row. Rootstocks received sufficient water from rain running down their stems to enable them to grow. Normal, untreated rootstocks were included as

Table 26. Location on the original 'Crimson King' budstick of chip-buds which failed to form a union with the rootstock (• = successful, ○ = failed)

Source	1	1	2	2	2	3	3	4	5	6
Shoot length (cm)	134	163	118	105	111	201	168	40	154	200
	•	•	○	•	•	•	•	•	•	•
	•	•	○	•	○	•	•	•	•	○
	○	○	•	•	•	•	○	○	•	•
	•	•	•	•	•	•	•	•	•	•
	•	•	•	•	•	•	•	○	•	•
	•	•	•	○	•	•	•		•	•
	•	•	•	○	○	•	•		•	•
	•	•	•	•	•	•	•		•	•
		○	•	○	•	○	•		○	•
		•	•	•	•	○	○		•	•
			•		•	•			•	•
					•	•			•	•
						•				○
						•				•
										•

Key to sources:

1. Grafted seven-year-old tree, grown in the field.
2. Self-rooted four-year-old tree, grown in the field.
3. Potted, grafted three-year-old tree, grown in the glasshouse.
4. Potted, grafted three-year-old tree, grown outside.
5. Potted, micropropagated two-year-old tree, grown in the glasshouse.
6. Potted, micropropagated two-year-old tree, grown outside.

controls, with all experimental plots comprising seven rootstocks with end guards. Treatments were repeated either with bud-chips being entirely covered with polyethylene typing tape, or with the bud being exposed, and the six treatment combinations were replicated five times in a randomised block design. Soil matric potentials at a depth of 13 to 19 cm were recorded using septum tensiometers (Nardeaux Humisol DTE 1000) and, as a guide to plant water content, leaf water deficits were estimated by measuring the gain in freshweight (FW) after rehydrating for 24 h.

A small subsidiary investigation examined the effect of soil wetness on sap production. Plants growing in constantly wet soil adjacent to a dripper nozzle, in non-irrigated soil and in intermediate conditions, were cut down to a stump of approximately 15 cm, with the cortex and bark removed from the distal 2.5 cm. A polyethylene tube pushed over the protruding xylem collected sap, the volume of which was measured at intervals in conjunction with observations on sap bleeding from the cut stems of the adjacent budded rootstock. Initially, plants with polyethylene rain deflectors experienced the highest soil water potential (i.e. were most stressed), but heavy rain, including 31 mm overnight prior to budding on 8th August, wetted the soil via stem run-off, after which the deflectors acted as a mulch, preventing the soil from drying rapidly. On the other hand, periods of hot dry and windy weather caused the non-irrigated, uncovered soil to dry. The irrigated soil was always visibly wet. Nineteen tensiometer measurements taken in each treatment between budding and tie removal gave the following mean values for soil matric potential, with readings on every occasion showing substantial differences from each other and always being in the same rank order:

normal = -51 kPa (driest)

rain deflectors = -24 kPa

irrigated = -6 kPa (wettest)

Leaf water deficits were not significantly different between treatments when replicated samples were measured on 19th August, with an overall mean FW gain of 7.9 (SE = 1.0).

Typical volumes of sap collected over a 24 h period after removing the head of the rootstocks were 4.9 ml, 0.8 ml and 0 ml from plants in wet, intermediate and dry soil respectively.

Despite large differences in soil moisture, the similar leaf water deficits were reflected in the fact that rootstocks in the different soil management treatments grew equally well during the budding year. There were no significant treatment differences in rootstock height, number of laterals, lateral length or number and area of leaves, when measured on 2nd October.

On the other hand, when recorded four days after budding, the incidence of sap bleeding from the xylem, as assessed visually by wetness inside the polyethylene tie, was increased significantly in the irrigated treatments compared to the rain-deflector treatment (bud covered), and both the rain-deflector and normal treatments (bud exposed). Five days later the significance was lost because over that period the incidence increased in the

Table 27. Frequency and intensity of xylem sap bleeding from the budding wound in *Acer platanoides* rootstocks growing in soils of different water content

	Normal	Polyethylene rain-deflector	Irrigation	*P*	LSD (5%)
Frequency %					
12th August					
Bud covered	66	34	74)		24.1
Bud exposed	49	37	76)		
17th August					
Bud covered	63	51	71)		25.8
Bud exposed	26	29	44)		
	Water treatment		12th August	0.1%	
			17th August	NS	
	Bud covering		12th August	NS	
			17th August	0.1%	
Score (2 = severe, 1 = mild)					
12th August					
Bud covered	1.4	1.0	1.4)		0.27
Bud exposed	1.3	1.1	1.2)		
17th August					
Bud covered	1.6	1.1	1.5)		0.36
Bud exposed	1.7	1.1	1.3)		
	Water treatments		12th August	1.0%	
			17th August	0.1%	
	Bud covering		12th August	NS	
			17th August	NS	

polyethylene rain-deflector treatment when buds were covered. During the same period the incidence of bleeding sap being retained inside the tie decreased where buds were exposed, so that on the second occasion this became significantly less than when buds were covered. The intensity of the wetness under ties was always least in the rain-deflector treatment (Table 27).

Despite obvious treatment effects on sap-bleeding as assessed by the presence of moisture inside the tie, and by the collection of sap, there were no significant effects of soil treatments on bud-take and trends were inconsistent and conflicting. For example, chip-take was lowest in the irrigated and exposed bud treatment combination (Table 28), where

Table 28. Chip-take after tie release, abscised buds during winter, and maiden trees harvested the following year of *Acer platanoides* 'Crimson King' grown in soils of different water content during the budding year.

	Normal	Polyethylene rain-deflectors	Irrigation	*P*	LSD (5%)
Chip-take (%)					
Bud covered	69	63	77)		
			}		21.5
Bud exposed	83	77	48)		
		Water treatments		NS	
		Bud covering		NS	
Abscised buds (%) as a proportion of all failures					
Bud covered	45	19	45)		
			}		44.6
Bud exposed	64	84	69)		
		Water treatments		NS	
		Bud covering		1.0%	
Maiden trees harvest (%)					
Bud covered	77	54	66)		
			}	23.3	
Bud exposed	60	49	46)		
		Water treatments		NS	
		Bud covering		5.0%	

frequent sap-bleeding due to irrigation was offset by rapid reduction in the numbers of wet budding ties when buds were exposed. The three treatments with highest chip take represented each of the soil treatments, which in turn had large and significant effects on sap-bleeding. During the winter after budding a number of buds abscised from apparently healthy chips (Table 28). The proportion doing so was increased significantly in treatments where the bud had been exposed at tying, such that the largest and most consistent effect on the production of maiden trees was due to exposing the bud, and not to soil treatments. The higher frequency of bleeding-sap on 17th August for covered buds (Table 27) was associated with the higher yield of trees in each treatment combination (Table 28).

There was a marked effect of blocks ($P<0.05$) on bud-take, which reached 86% at the lower north end of the row (Block IV) compared to 43% at the higher southern end (Block II), indicating that the already observed effects arising from differences between nurseries also existed between different areas of the same nursery.

A second experiment in 1991 examined the effect of rootstock water status further by applying treatments at the time of budding designed to interrupt the flow of sap to the bud. The following treatments were applied in an irrigated and non-irrigated row in a replicated and randomised experiment.

1. A chip of the rootstock stem below the scion chip was cut and replaced immediately.

2. As in 1. but on the opposite side of the rootstock to the scion chip.

3. The stem was incised at an angle similar to the lower lip of the chip-budding cut, immediately below the scion chip.

4. As in 3. but on the opposite side of the rootstock.

5. Normal chip-bud with no additional incisions (control).

Additional wounds were covered by a polyethylene tie as with the scion chip-bud.

Neither rootstock growth, as measured by stem diameter at the end of the growing season, nor the number of scion-chips forming unions with the rootstock, nor the number of maiden trees produced, were affected by treatments aimed at investigating the effect of bleeding sap in either the irrigated or non-irrigated row.

However, rootstocks grew increasingly strongly towards the northern (and lower) end of the rows (block effect, $P<0.1\%$), and this was associated with an increased frequency of xylem sap-bleeding (block effect $P<5.0\%$), especially in the irrigated row. When examined by regression analysis the increasing stock growth, as measured by rootstock stem diameter accounted for most of the within-row variation ($P<0.1\%$) and block effects disappeared. Trends for chip-take and maiden tree production also tended to favour the northern part of the row, but block effects were not significant for these variables (Table 29).

Table 29. Within-row block effects for rootstock growth, xylem sap-bleeding, chip-take and maiden tree production in *Acer platanoides* 'Crimson King'

	Block							
	I (South)	II	III	IV	V	VI (North)	*P*	LSD (5%)
Rootstock stem diameter (mm), October 1991	6.4	6.6	6.4	8.0	8.7	8.0	0.1%	1.03
Frequency of severe xylem sap-bleeding, (%) 14th August 1991	17	31	22	35	47	44	5.0%	18.2
Chip-take (%), October 1991	71	72	76	83	86	78	NS	17.7
No. of maidens harvested (%), winter 1992-3	63	61	70	75	75	64	NS	19.5

<u>Root restriction</u>

In 1991 a series of experiments was started to investigate the effects of root growth on bud-take in *Acer platanoides*, following observations that where roots appeared to be restricted, for example when rootstocks were planted into poorly cultivated stony soil, bud-take was depressed severely except in plants that developed extensive surface rooting in the lichen and liverwort encouraged by fertigation applied to ameliorate the problem.

Growing and budding rootstocks in pots provides an opportunity to restrict root growth severely. In 1991 200 rootstocks were potted into 2 litre pots containing a peat and crushed grit compost (3:1 by volume) ameliorated with calcium and magnesium limestone, slow release fertiliser (Osmocote 18.11.10) and fritted trace elements.

Pots were stood either directly on the surface of a capillary sand bed comprising 8 cm of sand over a polyethylene membrane with an adjustable water table, or on an additional 15 cm column of sand contained in a 2 litre pot stood on the bed. These treatments were repeated inside a polythene house and outside, and the four treatment combinations were replicated five times with 10 plants per replicate. Budding was done on 31st July 1991 and ties were removed on 12th September.

During the union-forming period in August and early September the mean ambient air temperature was raised in the polythene house by 8.3°C (max), 4.6°C (mean) and 3.9°C (min) compared to shaded screen temperatures outside. Pots on the raised sand columns outside lost water most rapidly and required occasional direct watering to the compost to prevent it shrinking from the side of the pot. Compost in pots placed directly on the capillary sand bed remained near field capacity with a low water potential. The highest evapotranspiration, as

Table 30. Rootstock growth, leaf water relations, xylem sap-bleeding and bud-take in potted rootstocks of *Acer platanoides*

Location	Outside		Polyhouse				
Sand depth (cm)	23	8	23	8		*P*	LSD
Rootstock height (cm), mid-September	77	80	134	125			
					Location	0.1%	
						}	14.6
					Sand depth	NS)	
Leaf water deficit (% DW) mean of 9th and 19th August	8.3	10.0	15.8	9.8			
					Location	5.0%)	
					Sand depth	NS}	4.3
					Location x sand depth	5.0%)	
Frequency of xylem sap-bleeding, 5th August	12	35	38	66			
					Location	1.0%)	
						}	20.2
					Sand depth	1.0%)	
Bud-take (%)	26	33	33	40			
					Location	NS)	
						}	23.4
					Sand depth	NS)	

demonstrated by plants in pots on the raised sand columns outside, is attributed to the effect of wind, whereas the largest and significant apparent leaf water deficit was obtained inside the polythene house in plants grown on the additional sand columns, which were observed to wilt temporarily in the early afternoons on particularly sunny days. This did not impair rootstock growth, and plants grown in the polythene house were taller, with thicker stems and more leaves, but with no increase in lateral branches compared to those outside. The frequency of xylem sap wetting the inside of the budding ties was greatest in the pots grown in the polythene house directly on the bed at the lower water potential. There were many blackened chip-buds when ties were released and differences in bud-take were not significant, and did not reflect the constantly larger rootstocks grown in the warmer polythene house, nor the large differences in water relations and xylem sap-bleeding (Table 30).

As a contrast to 1991 field and pot experiments, rootstocks were planted in two 75 cm deep drained beds containing medium grade sand (125 to 500 micron). Rootstocks in one bed were watered by trickle irrigation at 4 litres per plant per day in split applications at 0800 h and 1600 h, and similarly in the other bed at 1 litre per plant per day. Irrigation was applied from 16th July to 30th September, but the lower rate was omitted after periods of heavy rain from 31st July. Piezometer and bore-tube samples showed free-water to be constantly present at the base of the heavily irrigated bed and the sand to be moist but with no free-water at the lower level of irrigation. Nutrients were applied with the irrigation at the rate of 200 ppm N, 48 ppm P, 210 ppm K and 130 ppm Ca, together with micronutrients.

Budding was carried out on 31st July, with 25 rootstocks in each bed being budded at a height of 15 cm, and 25 budded at 30 cm so that water relations might differ at the budding position. At the end of the budding season an initial record of chip-take was made and then all rootstocks were lifted to observe root growth, and replanted in a compost comprising equal parts by volume of peat, granulated bark, grit and sand to confirm the initial bud-take record. Transplanting rootstocks with dormant chip-buds has no detrimental effect on their further development (Howard, 1994). At lifting, two typical root systems from the low/nil irrigated treatment were measured in terms of their fine and main roots, using a Comair root length scanner (Commonwealth Aircraft Corporation Ltd., Melbourne, Australia), followed by oven drying.

At budding the stems of rootstocks were easy-to-cut, and most bled profusely from the budding wound. The initial chip-take record ranged from 86 to 95% across the four non-replicated treatment combinations. Subsequent bud-take assessed from the number of scions growing on the transplanted rootstocks was 89%, rising to 100% in each of the high irrigation treatments.

These high levels of success were obtained against a background of considerable variation in the growth and water relations of rootstocks. Most noticeable was that the main roots were particularly long with relatively little fine root. Roots grown in 2 litre pots and in the field were sampled for comparison, showing that extension roots, but not total roots, were longest from the sandbed and shortest from the pots (Figure 2). Main root length equated closely with root dry weight (Table 31).

Table 31. Root length and dry weight of *Acer platanoides* rootstocks lifted from three locations after budding

Location	Sandbed	2 litre pot	Field
Total root length (m)			
Sample 1	224	308	113
Sample 2	253	332	132
Mean	238.5	320.0	122.5
Main root length (m)			
Sample 1	11.8	4.2	5.6
Sample 2	13.3	4.2	5.9
Mean	12.60	4.20	5.75
Dry weight total roots (gm)			
Sample 1			
Sample 2	31.7	14.4	18.8
Mean	28.1	17.7	20.0
	29.9	16.1	19.4

The effect on bud-take of the severe root restriction in 2 litre pots was followed up in 1992.

The same beds were used again, but with the roots of half the number of rootstocks confined in 2 litre plastic pots filled with sand from the bed. Rooting through the drainage holes was discouraged by placing a disc of woven polypropylene (Mypex) in the bottom of each pot. Eighty rootstocks were graded into pairs with respect to the size of their tops and roots so that similar quality rootstocks could be used to compare free roots versus restricted roots. All plants were irrigated by dripper nozzles at 2 litres per day (split between midnight, 0800 h and 1600 h) and with occasional feeding by balanced soluble fertiliser injected into the irrigation. Budding was done on 4th August.

Compared to the 1991 sandbed experiment, overall bud-take was depressed in 1992, but was 43% for the free-rooting stocks, and only 14% for those with roots confined in pots. Differences were significant at the 10% level and nearly reached the 5% level of probability. An identical trend was obtained when the experiment was repeated in beds of compost with bud-take of 30 and 13% for free- and restricted-root treatments, respectively.

A more comprehensive experiment was done also in 1992 to examine the effect of root restriction by budding potted rootstocks.

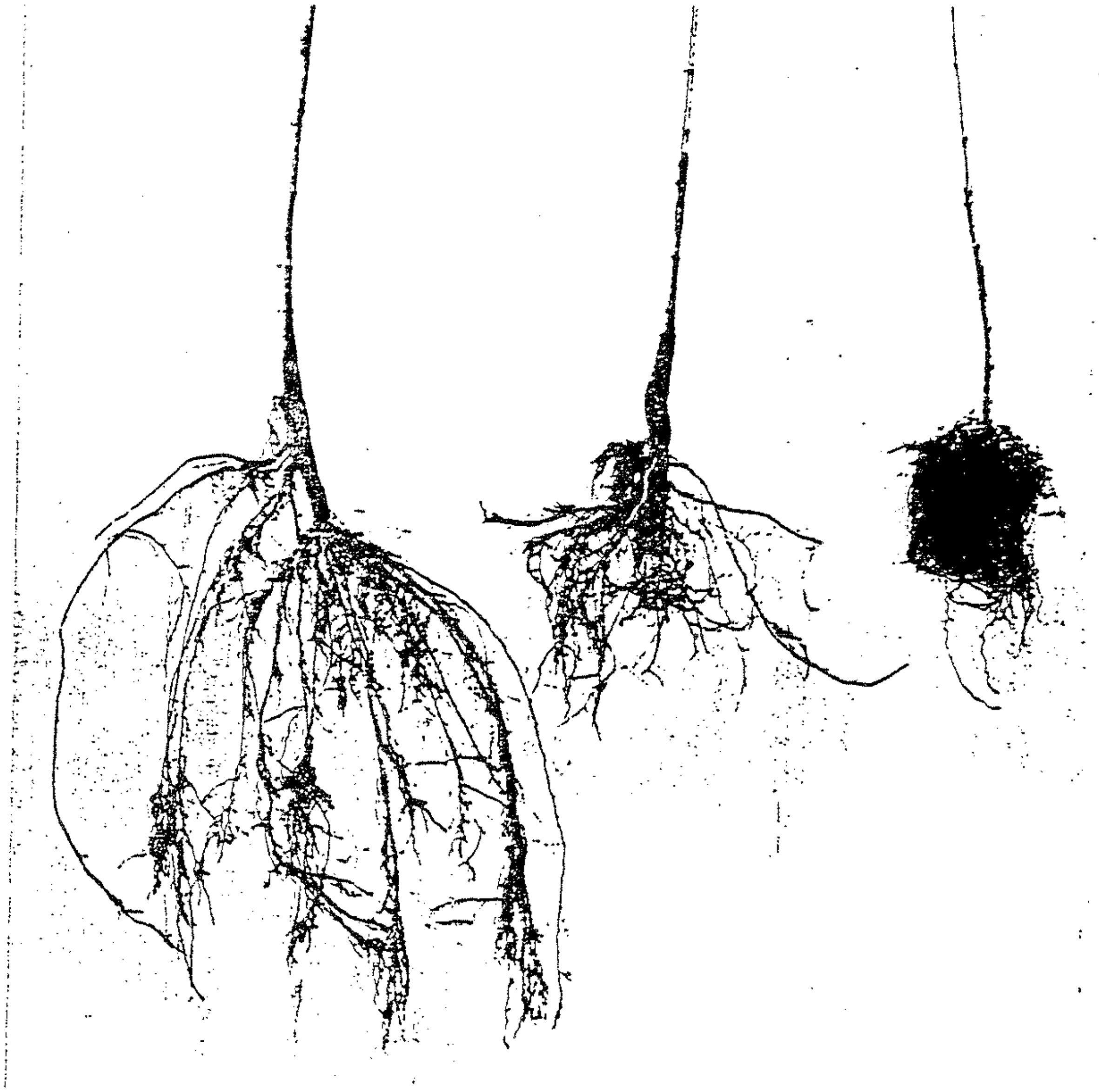

Figure 2. Roots of *A. platanoides* stocks grown in

left - a 75 cm deep sand tank
centre - field soil
right - a 2 litre pot

(Taken from Howard 1992, reproduced here in context)

Six hundred and forty rootstocks were allocated to four grades with equal numbers of each grade planted in sand, or in compost. Plants were further subdivided within each grade and growing medium to provide either one plant in a 2 litre pot, or 7.5 litre pot, or two plants in a 7.5 litre pot to increase root competition.

All pots were placed on an 8 cm deep capillary sand bed, with all treatment combinations further divided between the polythene house and outside. The size grades acted as replicates in a fully randomised factorial design with 10 pots per plot.

Plants in sand grew poorly because it took up excessive amounts of water, and these pots were moved to a separate bed where the water table was lowered, compared to that needed for the compost treatment. Rootstocks were budded on 3rd and 4th August and ties removed after six weeks.

Plants grown in sand were assessed for provisional bud-take and then destructive samples were taken for root growth assessment. Those growing in compost were carried-over to the next season and their scion development confirmed.

Rootstocks grew significantly better in the 7.5 litre pots than in the 2 litre pots; a small reduction in size occurred when two plants were grown in the larger pot, but this was not significant. As would be expected, growth was also better in compost than in sand, and in the polythene house than in the open. Rootstocks grown in compost in 7.5 litre pots in the polythene house combined all advantages and grew the most. The effect of pot size on rootstock growth is shown in Table 32 averaged over all other factors.

Initial chip-take followed the same trends, being highest in the 7.5 litre pot treatment, and higher in compost compared to sand, and in the polythene house compared to outside.

The overall effects due to pot size shown in Table 32 were confirmed in the compost-grown sample when scion-buds grew the following spring.

When the sand-grown rootstocks were washed out of their pots the most frequent occurrence of plants graded with extensive roots was in the 7.5 litre, polythene house treatment combination (43%) compared to none in the 2 litre, polythene house treatment combination. Further (covariate) analysis showed that the effect of pot size on chip-take could be almost entirely accounted for by differences in root dry weight, overall effects being shown in Table 32.

Despite trends which indicated that root extension growth is important in determining chip-take, all experiments involving pots as a root-restricting treatment gave relatively low levels of bud-take, and in 1993 investigations moved to the field using differences in soil cultivation, and enclosing roots in mesh bags as ways of restricting root growth.

Table 32. Effects of pot size (averaged over different growing media and enviroments) on shoot and root growth of *Acer platanoides* rootstocks, and chip-take of the 'Crimson King' scion

Pot size	2 litres	7.5 litres	7.5 litres		
Plant number	1	1	2	*P*	LSD (5%)
Rootstock shoot growth (cm	20	46	38	0.1%	9.0
Root dry weight (g)	0.9	5.6	3.6	5.0%	3.4
Chip-take (%)	28	46	44	5.0%	11.4

Seven hundred and twenty *Acer platanoides* rootstocks were planted across three sites, ploughed to approximately 30 cm, 20 cm, or left as unploughed cereal stubble, but disturbed during the planting operation. At the end of the budding season the soil resistance to penetration was measured at 3.5 cm intervals to a depth of 31.5 cm using a Bush Cone Penetrometer (Findlay Irvine) with a 30°, 12.9 mm diameter cone. Half the number of rootstocks was planted in the normal way, while the remainder had their roots enclosed in nylon mesh bags measuring 12 x 20 cm and with a 50 to 60 μ mesh pore size. The neck was folded over and stapled, but some roots escaped, mainly via the opening, and data were analysed with these trees either included or eliminated. Within each site and planting treatment two 'Crimson King' scionwood treatments were compared. Budwood from a severely-pruned source was used as normal, compared to the same source treated with a 4 gl^{-1} Rovral and 4 gl^{-1} Benlate fungicide mixture. The equivalent rootstocks were treated prior to budding with fungicide also, so that scionwood and rootstock stems were protected in appropriate treatment combinations.

Budding was done by using one budwood source on each of the three days from 2nd August, with each treatment combination represented by four replicates each of 10 rootstocks.

Averaged over nine depths between 3.5 and 31.5 cm and 10 locations along the row, the non-cultivated soil was significantly more resistant to penetration than both cultivated soils as follows:

Deep cultivation	0.61 MPa
Shallow cultivation	0.65 MPa
No cultivation	0.92 MPa
$P < 0.001$, LSD (5%)	0.12

Rootstock shoot growth was depressed in the non-cultivated soil, and even more so when roots were enclosed in the mesh bags, such that bagged-rootstocks in the non-cultivated soil grew very poorly (although the interaction was not significant). Stem diameter increase (both actual and percent), as a measure of cambial activity during the period in which budding ties were in place, was also depressed by non-cultivation and the mesh bags, and especially when these two factors were combined (Table 33).

Bud-take, as measured in May, and as the number of maiden trees harvested at the end of the growing season, was not affected by soil cultivation treatments, but was depressed severely when roots were enclosed in mesh bags, and was improved by fungicide treatments. The severity of the bag treatment combined with the lack of fungicides was emphasised when trees with roots escaping from the mesh bag were eliminated from the analysis (Table 34).

The quality of maiden trees was reduced when grown in the non-cultivated soil, and with roots enclosed in mesh bags, as would be expected, but it was interesting to note (Figure 3) that some trees with restricted root systems were able to grow well.

A small experiment budded on 5th August, 1993, compared prophylactic Benlate and Rovral treatments to the budwood and the rootstock in all combinations. Bud-take was generally high, but the combination of fungicide treatment to stock and scion gave 85% bud-take, with neither treated giving 68% take. Over the course of this work generally, there is the suggestion that treating the rootstock is the more effective. Further work needs to be done to investigate alternative fungicides and lower rates of application in relation to efficacy and operator safety before recommendations can be made for the practical use of fungicides for rootstock and budwood treatment.

Time of planting rootstocks and of budding

In 1993, the final phase of this work considered opportunities for delaying the planting of rootstocks by planting out of a jacketed cold store on 22nd February, 5th April and 17th May, treating the roots with a proprietary mixture of 'Alginure', or not, immediately prior to planting. Rootstock stems and scionwood from severely- and lightly-pruned sources were treated with a mixture of 4 g l^{-1} Benlate and 4 g l^{-1} Rovral, with wetter, immediately prior to budding on 29th July.

Prolonged storage had no ill-effect on rootstock quality. Late planting reduced the size of rootstock, bud didn't increase the rate of growth during the budding period (Table 35a).

Under the conditions of this experiment overall bud-take was high, with no effect on budding of either the root dip or planting time, and a small but significant benefit from using the severely-pruned bud-wood source (Table 35b).

Maiden tree height was reduced significantly from 221 cm to 204 cm by delaying rootstock planting from February until May, and this was reflected also in a reduced number and length of laterals. No other treatments affected the quality of harvested trees.

Figure 3. *Acer platanoides* rootstocks, from left to right, free rooting and with roots escaping by decreasing amounts from porous nylon bags. Note the growth of the tree on the far right where roots are totally confined.

Table 33. Effects on *Acer platanoides* rootstock growth of planting into non-cultivated soil and enclosing roots in nylon mesh bags

Cultivation	none		shallow		deep				LSD (5%)
Mesh bags	-	+	-	+	-	+		*P*	
Shoot growth (cm)	124	25	161	55	183	61			
							Cultivation	1.0%)	} 38.6
							Bags	0.1%)	
Stem diameter increase during union formation (%)	40	13	42	21	43	25			
							Cultivation	0.1%)	} 4.7
							Bags	0.1%)	

Table 34. Effects on 'Crimson King' bud-take of enclosing rootstock roots in nylon mesh bags, and treating the budwood and rootstocks with fungicide (averaged over all levels of cultivation)

Bags	-		+				LSD (5%)
Fungicide	-	+	-	+		*P*	
All maidens harvested (%)	79	90	50	76			
					Bags	0.1%)	} 14.0
					Fungicide	0.1%)	
Maidens harvested, eliminating trees with roots escaped from the bag (%)	79	90	13	43			
					Bags	0.1%)	} 18.2
					Fungicide	1.0%)	

In 1994 two times of planting (without Alginure root dip) were compared on 1st March and 16th May, with each set of rootstocks budded on either 2nd or 23rd August in a fully randomised block factorial design. The severely pruned scionwood source was used throughout, and all scionwood and rootstock stems were treated with the Benlate and Rovral mixture.

A greater frequency of apparent herbicide damage in terms of leaf symptoms was noted in the early-planted rootstocks (43%) compared to the late-planted ones (14%).

When budded on 2nd August rootstocks were still growing rapidly as measured by the rate of stem thickening during the budding period, with slightly faster growth in the later planted rootstocks. At the later budding date of 23rd August, rootstocks were growing significantly less than on the earlier occasion.

Table 35. The effect on (a) growth of *Acer platanoides* rootstock and (b) on 'Crimson King' bud-take of rootstock planting date and budwood source (averaged over ± root dip)

a)

Planting date	22nd February	5th April	17th May	*P*	LSD (5%)
Rootstock diameter July (mm)	12.3	11.8	9.8	0.1%	0.56
Stem diameter increase during union formation %	36	34	38	NS	4.8

b)

Planting date	22nd February		5th April		17th May			LSD (5%)
Budwood pruning	severe	light	severe	light	severe	light	*P*	
Maiden trees harvested (%)	95	85	98	90	100	93		
					Planting date		NS	10.4
					Budwood source		1.0%	

Initial bud-take, and the number of maiden trees harvested, were affected most by budding date and to a lesser extent by rootstock planting date, with the combination of late planting and early budding giving the highest yield of trees, showing a good correlation with the rate of rootstock growth at budding (Table 36). The quality of maiden trees in terms of height was not affected by any treatment, but the combination of early planting and late budding reduced the number of laterals significantly to 1.4, from an average of 2.6 across other treatments.

Table 36. Effects of *Acer platanoides* rootstock planting dates and of 'Crimson King' budding dates on rootstock growth at budding and budding success.

Rootstock planting date	1st March		16th May				
Budding dates	2nd August	23rd August	2nd August	23rd August		*P*	LSD (5%)
Rootstock stem diameter increase during union formation (%)	35	11	42	14			
					Planting dates	1.0%)	
						}	5.2
					Budding dates	0.1%)	
Maidens harvested (%)	83	52	92	55			
					Planting dates	NS)	
						}	21.8
					Budding dates	0.1%)	

Conclusions:

Acer platanoides rootstocks need to be growing well at the time they are budded. This is achieved by budding relatively early (late July/early August), and if establishment can be guaranteed, there is a potential additional benefit from planting rootstocks later than normal, in mid-May, because this delays the period of maximum rootstock growth, although this effect is not so marked in *Acer platanoides* as it is in, for example, *Betula pendula*.

Experiments in pots and in the field showed that unrestricted root growth was the essential factor in achieving good rootstock growth, leading to high bud-take. Bud-take was always depressed when roots were restricted, but high bud-take was not always guaranteed by good shoot growth, although in the majority of cases good shoot and root growth occur together. Observed differences in bud-take between fields, and in different parts of fields, is likely to be caused by differences in the ability of roots to grow vigorously. It is possible that a chemical plant growth regulator is produced in rapidly growing roots which maintains the viability of the bud-chip until a union has formed. Bud-take is enhanced by treating the rootstock stem and the bud-chip with fungicides just prior to budding.

Although these experiments have shown that a number of factors interact to determine budding success, many others were found not to be important.

There was little effect due to the location on the budstick from which the 'Crimson King' bud was taken, or the way in which the tree supplying the buds was grown. There was, however, a small but significant benefit from encouraging vigorous bud-wood by pruning the source plants relatively severely.

Other factors found to be unimportant were the size and history of the rootstock, as long as it was not infected with verticillium wilt, and not physically too large to achieve a good match with the bud-chip. Various treatments aimed at altering the water status of rootstocks at budding showed this to be unimportant also. Contrary to the view held by nurserymen, the frequent and considerable bleeding of xylem sap for a week or two after budding is not the cause of budding failure, despite many failed buds being wet and stained black at the time ties are released. To the contrary, xylem sap bleeding is evidence of an active root system, and was correlated more with budding success than failure.

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Glossary

Chip-budding	A bud grafting method in which a chip with bud from the scion stem is substituted for a similar chip of rootstock stem, ensuring good cambial contact between scion and rootstock and improved tree quality.
Eye	A term sometimes used by nurserymen to distinguish the actual vegetative bud from the stem tissue present in a scion chip-bud.
Inverted-T budding	As for T-budding, with the cut made upside down. Because the best cambial relationship occurs at the cross cut of the T, this benefit is retained below the scion bud, which often produces a stronger maiden tree than in T-budding.
Jacketed cold store	A store with the low temperature compartment cooled by

circulating cold air in a cavity behind the walls, roof and sometimes the floor. The large cooling surface avoids a large temperature difference relative to the air in the store, avoiding moisture being frozen out of the air, and so maintaining a high relative humidity of about 95% at 2°C.

Leaf water deficit	The increase in weight, usually as a percentage of the dry weight, in a leaf rehydrated by keeping it in a wet environment for 24 h.
Maiden	The first year's growth from the scion chip-bud making a small nursery tree.
Soil matric potential	A method of describing the energy required to remove water from the soil. The larger the negative value, the more difficulty the plant has in obtaining water.
T- or shield-budding	A bud grafting method in which the cortex (bark) of the rootstock is lifted with a T-shaped cut and a shield-shaped piece of scion with bud is slid behind the bark. This does not result in good juxta-position of the cambium.

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Contract between HRI (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

PROPOSAL

1. **TITLE OF PROJECT** **Contract No: HNS/45**

MANAGEMENT OPPORTUNITIES IN THE BUDDING NURSERY FOR PLANTING LINERS AND GROWING TREES FOR CONTAINERISATION

2. **BACKGROUND AND COMMERCIAL OBJECTIVE**

This proposal addresses some potentially key questions in a number of management - and quality - related areas.

a) Ideally, liners for budding should be planted in the autumn for optimum establishment, but this is rarely achieved because rootstocks are not available, land is being fumigated, and labour is engaged in lifting the current crop. The common practice is to plant out of cold store in late winter, when there are again conflicts over labour for work such as grafting, and pruning stockplants. There could be management advantages in spreading labour demands, and establishment benefits from higher soil temperature, by planting in late April or May. An assessment of proprietary root dips claimed to aid establishment would be relevant in this context.

b) Nurserymen who containerise field-produced maiden trees often find that their root systems are difficult to fit into the appropriate size pot. Customers find that many well-grown trees are difficult to fit into the family car. There could be advantages for both production and at point of sale by containerising August-budded rootstocks with dormant buds which would develop in the container, or May/June-budded trees that have produced only a single leader by the end of the first season from planting and would continue to develop during the container year.

3. **POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY**

The essence of these proposals is to ask whether there are opportunities to change traditional nursery practice for the benefit of management, improved output, better quality and customer convenience. The assumptions required in terms of these proposals leading to new practices make attempts at cost benefits inappropriate. It is relevant, nevertheless, that the topics relate to the central activities of this sector, namely, container production and field-budding.

4. **SCIENTIFIC/TECHNICAL TARGET OF THE WORK**

As appropriate:-

a) Compare late-winter v spring planting of liners in relation to soil temperature and root growth, with or without the benefits of irrigation and alginate root dips, and with reference to condition of plants during storage. Test the suitability of the established liners for budding.

b) Investigate the potential success of May/June budding and compare the size and quality of maiden trees grown in containers, when containerised as dormant-budded rootstocks or May/June-budded whips, with reference to trees containerised as fully grown maidens.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

HNS 7a is concerned with improving budding success rates and tree quality. It is particularly relevant that the project is pointing to the importance of active, rapidly growing root systems as a determining factor for bud-take success. This has implications for delayed establishment of liners and for May/June budding. Strategic understanding of key processes is provided by MAFF projects L102A and Z01E.

6. DESCRIPTION OF THE WORK

Progress will be determined by initial success and the nature of the questions raised from the restricted range of treatments, with the opportunity to increase or reduce effort in any topic as progress and industry interests dictate. One option will be to use this project for an extension of budding work generally at little extra cost when HNS 7a terminates in summer 1993.

Liner establishment Liners of *Acer platanoides, Betula pendula* and *Robinia pseudoacacia* held in cold store with ± benomyl pre-storage dip and ± Alginure pre-planting dip, will be planted in late February or late April/May in relation to monitored soil temperature. Rootstock growth and bud-take/maiden growth will be assessed.

Tree containerisation Four species of contrasting shape and size, such as *'Acer Crimson King', Betula 'Dalecarlica', Robina 'Frisia'* and *Prunus 'Pink Perfection'* (or other recommended flowering cherry) will be either May/June-budded with cold-stored scions or August-budded with dormant buds, and, where successful, containerised as whips or budded stocks with field-grown maidens for comparison. Most material will be started in the field, but a limited amount will be grown in raised beds to give very fibrous root systems, so as to assess the importance of this factor on establishment in containers.

Subsequent years' work will follow a review of opportunities identified in the first year.

7. **COMMENCEMENT DATE AND DURATION**

January 1993 for 3 years.

8. **STAFF RESPONSIBILITIES**

Within the general supervision of Drs.B.H.Howard and R.S.Harrison-Murray, HRI East Malling, subject to restructuring and providing additional leadership in conjunction with other projects.

9. **LOCATION**

HRI-East Malling.