AN ANALYSIS OF WHY BUD-GRAFTING GIVES POOR AND INCONSISTENT RESULTS FOR MANY ORNAMENTAL TREES. (RELATING TO HDC HNS PROJECTS 7 AND 7A).

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ABSTRACT

Experiments were designed to discover the reasons for inconsistent and often low yields of ornamental trees produced by summer bud-grafting (budding), as an essential first step towards improving nursery management and technology. In particular, we need to know what is meant by 'poor bud take', and whether it is due to deficiencies in plant material or technique, in order to correctly focus future work.

It became increasingly apparent during the course of this project, especially with *Acer* 'Crimson King', that a major 'year effect' exists, in which the level of success is governed by factors outside the experiments. There is a pressing need to understand its cause, not only for the benefit of nurserymen, but because it undermines the interpretation of experimental treatments and may interact with other more quantifiable factors. Subject to confirmation, weather appears not to be the main cause of 'year effects', although the amount of water available to the rootstock may be important in some situations. **The location (i.e. field or experimental plot) appears to be more relevant to budding success, especially in terms of its effect on root development of the rootstock.** This view is supported by looking back over experiments since 1973, in which poor bud-take was associated with soils that impeded root growth.

Within the constraints imposed by the fluctuating 'year' (site) effect it was shown that fruit-related species such as *Malus tschonoskii* and *Prunus* 'Pink Perfection' can be budded with a greater chance of success than ornamental species such as *Acer platanoides* 'Crimson King', *Betula pendula* 'Dalecarlica' and *Robinia pseudoacacia* 'Frisia'.

It was shown that there are two basic causes of failure that fall within the scope of this study (i.e. excluding damage from machinery, pests and other non-physiological or technical causes). Firstly, the union between chip-bud and rootstock stem fails to form in a high percentage of trees typified by *Acer* 'Crimson King' and possibly *Robinia* 'Frisia'. Exhaustive experiments with *Acer* indicate that this is not due to physiological or pathological incompatibility between some of the genetically different seedling rootstocks and the clonal 'Crimson King' scion. However, there is good evidence that the variability of seedling rootstocks contributes to poor 'bud-take', but in a way which is not yet understood.

A potentially important new problem was discovered. In some circumstances the bud-chips of *Robinia* 'Frisia' and *Acer* 'Crimson King' appear to be killed by fungi and bacteria. These micro-organisms can be present in large numbers on scionwood and appeared to proliferate in favourable conditions under the bud tie. Pretreating scionwood by dipping in a proprietary copper fungicide/bactericide reduced losses, and this aspect is being studied further in detail.

The second cause of failure is that even when a union appears to have formed, the scion bud fails to grow the following year, or it grows late, or slowly, thus not producing a saleable tree. This situation is typified by *Betula pendula*, 'Dalecarlica' and *Malus* 'Queen Cox'.

Based on this analysis of the problem the thrust of on-going work must be to understand and control these 'year effects' and to make technical and management improvements to minimise chip failure in subjects such as *Acer* 'Crimson King', and bud failure in subjects such as *Betula* 'Dalecarlica'.

INTRODUCTION

Almost all deciduous trees which have characteristics needing to be perpetuated by vegetative means are propagated by bud-grafting a scion onto a rootstock. The normal method is summer dormant-bud grafting, in which budding takes place in the field in July and August and the scion produces a maiden tree the following year. For various reasons, including the unreliability of field-budding, some deciduous trees are produced by winter bench-grafting under glass in pots, along with evergreen and coniferous species.

Failures from summer field-budding are costly because of the wasted resources incurred. Land preparation, often including costly fumigation, the cost of rootstocks and scionwood, labour for planting, budding and some plant maintenance, and the cost of sprays and machinery, all apply on an area basis, irrespective of whether a saleable tree is produced or not at each position in the row. The problem of wasted ground is exacerbated by many tree crops requiring three to four years until harvested.

The budding process itself was raised to a sound technical level by the development and introduction of chip-budding to replace traditional T- or shield-budding. The advantages of chip-budding are an improvement in the juxtaposition of the critical cambium tissue in the stock and scion to increase the speed and reliability of union formation and quality of scion growth (Howard, *et al.*, 1974). It is estimated that switching to this technique has resulted in an annual cost benefit for UK nurserymen of almost £1m. Because virtually all producers have adopted chip-budding it provides a sound technical base for further improvements.

The present situation is one of marked inconsistency and unreliability in different nurseries and different years. Against this background there are varieties and species that are reasonably reliable, through many which are attempted with no guarantee of success, to those which are considered too difficult to attempt.

It was the purpose of these studies to improve this longstanding problem and so make an important contribution to this often unprofitable sector of HNS production.

The first stage, which forms the substance of this first report, was to describe clearly the nature of 'poor bud take' in ways that research could address, and to point the direction of that research.

METHODOLOGY

Nursery

Different sites were used at East Malling, usually of a light sandy loam soil fumigated by chloropicrin prior to planting rootstocks. Seedling rootstocks were obtained each year from the same commercial source and clonal rootstocks were produced by the East Malling Nursery Section. Scionwood was selected from good commercial sources and raised as hard-pruned hedges or individual mother trees. All fruit-related ornamental scions and rootstocks were of EMLA virus-free status. Rootstocks were planted in rows with 0.4 m in-row spacing and 1.6 m between rows for vigorous subjects such as *Robinia*, and with double or multiple rows spaced 0.8 m apart for less vigorous subjects.

All budding was by the chip method and was done by the same person throughout. Further details are given with the results of the different experiments.

Experimental layout

Experimental treatments were imposed along the rootstock rows in linear plots, usually of 10 rootstocks which comprised the basic treatment unit. Treatments were replicated (usually five times) and randomised in designs appropriate for the experiment.

Records included features of rootstock growth such as diameter increment and shoot growth in the budding year, and the number of successful unions, maiden growth (height, number and length of laterals) and other relevant measurements in the maiden year.

Data were examined by the appropriate statistical analyses.

RESULTS

Experiment 1; 1987-8

The object was to compare fruit- and non-fruit-related species and seek evidence for incompatibility between individual seedling rootstocks and the clonal scion. This was done by budding a chip from each individual rootstock onto itself, compared to using the conventional scion bud. Because the rootstock chip had no bud, but the scion chip contained the scion bud as normal, any effect due to the presence of the bud was investigated by including a link treatment of a scionwood chip without a bud. All treatments were repeated with rubber and polythene ties covering the bud to see whether such technical details affected the main responses. Results were assessed in terms of apparently successful unions between chip and rootstock stem, taken as a live chip being held firmly in place after tie removal. In treatments where a scion bud was present scion growth was recorded. Results are given below for the different species tested.

Acer platanoides 'Crimson King'

The highest percentage of unions was formed when a chip from a seedling rootstock was inserted into the stem of the same plant. The least number of unions formed when the bud-less 'Crimson King' scion chip was used. The normal scion chip with axillary bud present gave intermediate results. The use of polythene tape was superior to rubber throughout (Table 1).

Table 1 - Percent union formation between chips and rootstock stems in *Acer platanoides*.

	Polythene ties	Rubber ties
Chip from the same plant	68	40
Chip of 'Crimson King'	12	4
Chip and bud of 'Crimson King'	35	14

Treatment differences due to source of chip are highly significant ($P<0.01$)

Treatment differences due to tying materials are highly significant ($P<0.01$)

Betula pendula 'Dalecarlica'

At least 90% of all chips formed unions, except where a scion chip of 'Dalecarlica' without a bud was secured with rubber (Table 2).

Table 2 - Percent union formation between chips and rootstock stems in *Betula pendula*.

	Polythene ties	Rubber ties
Chip from the same plant	90	98
Chip of 'Dalecarlica'	90	68
Chip and bud of 'Dalecarlica'	90	90

Treatments did not differ significantly, except for the interaction of 'Dalecarlica' chip and rubber tie, whose low value was highly significant ($P<0.01$).

Malus tschonoskii/MM.106 rootstock

At least 97%, and usually 100% chips formed unions irrespective of chip source, presence of scion bud, or type of tying material.

Prunus 'Pink Perfection'/Colt rootstock

All 300 bud-grafts formed unions, with no failures in any treatment combination.

Robinia pseudoacacia 'Frisia'

Union formation was depressed by using rubber ties, and the trend whereby the rootstock chip performed best and the scion chip without bud performed worst was again evident (Table 3).

Table 3 - Percent union formation between chips and rootstock stems in *Robinia pseudoacacia*

	Polythene ties	Rubber ties
Chips from the same plant	100	98
Chip of 'Frisia'	91	55
Chip and bud of 'Frisia'	95	68

Treatment differences due to source of chip and for tying material for 'Frisia' are highly significant (P<0.01).

***Tilia x Euchlora/T. cordata* rootstocks**

Grafting *T. cordata* with its own chip gave higher levels of success than when using a chip of *Euchlora*. The type of tying material had no effect (Table 4).

Table 4 - Percent union formation between chips and rootstock stem in *Tilia x Euchlora / T. cordata*.

	Polythene ties	Rubber ties
Chip from the same plant	93	97
Chip of *Euchlora*	72	76
Chip and bud of *Euchlora*	70	67

Treatment differences due to source of chip are very highly significant (P<0.001).

Treatment differences due to tying materials are not significant.

Tilia x Euchlora/T. platyphyllos

This combination performed similarly to *Betula*, wherein the combination of a budless chip of *Euchlora* and rubber tie gave a noticeable reduction in union formation (Table 5).

Table 5 - Percent union formation between chips and rootstock stem in *Tilia x Euchlora / T. platyphyllos*

	Polythene ties	Rubber ties
Chip from the same plant	100	100
Chip of *Euchlora*	100	80
Chip and bud of *Euchlora*	100	90

The combination of *Euchlora* chip and rubber tie gave a significantly lower chip take than other treatment combinations ($P<0.05$).

Interim conclusion

At first sight the superior performance of the fruit-related species involving clonal rootstocks selected for their compatibility with scions, compared to the varied and poorer performance of non-fruit related species involving seedling rootstocks, suggests that incompatibility is present in the latter situation. This would appear to be endorsed by the superior performance of chips taken from the same seedling rootstocks compared to those from the clonal scion.

However, there are two results which suggest caution in reaching such a conclusion, bearing in mind the considerable implications that this would have for rootstock selection and improvement. It is important to note that technical and physiological factors affected the level of 'apparent incompatibility'. The success of union formation was altered markedly and consistently by the type of tying material used and whether or not the scion chip included the axillary bud. Rubber ties and absence of the bud often depressed union formation, and these combined to give minimal success.

The question of whether incompatibility exists needs to be investigated more fully and results of further studies are given later in his report.

Bud growth 1987-8

It did not always follow that an apparently successful union between chip and rootstock would result in the scion bud developing into a maiden tree. Most notable were *Betula* 'Dalecarlica', *Robinia* 'Frisia' and *Tilia x Euchlora* on *T. platyphyllos*. Results given in Table 6, showing the number of buds which had grown by the end of the maiden year, are an over-estimate of success, because many of these buds began to grow too late in the summer to produce a tree worth selling or growing-on, as typified by *Betula*.

Although not part of this set of experiments many Queen Cox buds high-worked on M.9 rootstocks also failed to grow despite apparent successful union formation. For every 1 cm increase in budding height the chance of the bud failing to grow increased by approximately 10%.

Results in Table 6 also show that the ability of buds to grow was sometimes favoured by the use of rubber ties, in contrast to the general benefit from polythene ties for union formation shown in earlier tables.

Table 6 - Percentage of successfully united chips whose axillary scion buds grew during the year. Values in brackets are for an interim July recording.

	Polythene ties	Rubber ties
Acer 'Crimson King'	93	100
Betula 'Dalecarlica'	59(6)	78(46)
Malus tschonoskii/MM.106	100	100
Prunus 'Pink Perfection'	100	100
Robinia 'Frisia'	59	48
Tilia x Euchlora / T. cordata	90	100
T. x Euchlora / T. platyphyllos	79	88

Treatment differences for *Betula* were very highly significant ($P<0.001$) at the July recording and significant ($P<0.05$) by the end of the season.

Interim conclusion

Apparently successful union formation, in terms of the chip appearing healthy and firmly adhering to the rootstock with obvious callus, does not necessarily enable the scion bud to grow. Neither is there any link between union formation and bud growth in particular species; for example, *Acer* 'Crimson King' has a low frequency of union formation (Table 1), but almost all united chips gave rise to trees (Table 6). On the other hand, *Betula* 'Dalecarlica' gave high levels of union formation (Table 2), but many buds failed to grow (Table 6). There is likely to be more than one reason for buds failing to grow. The tying material appears to be implicated in *Betula* 'Dalecarlica' and the rootstock in *Tilia x Euchlora*. A separate report will implicate the rootstock for Queen Cox budded onto M.9.

Further investigation of apparent incompatibility in *Acer* 'Crimson King'.

Re-budding: Over a number of years prior to and during the period of this contract seedling rootstocks of *Acer platanoides* whose chip of 'Crimson King' failed to unite during the summer of one year were re-budded with the same scion source the following year. In 12 separate small assessments 11 resulted in some initial failures forming successful unions at the second attempt. Despite not all rootstocks with failed buds being in a suitable condition to re-bud the following spring, an overall initial success rate of 26% was improved to 51% following re-budding.

Multiple budding 1988-9: The success rate for union formation in any population of rootstocks should not be affected by the number of scion chips grafted onto each rootstock if the source of the problem is seedling rootstock incompatibility, and assuming that the random planting of rootstocks and the randomised application of treatments (i.e. 1, 2 or 3 'Crimson King' chips per stock) didn't distribute putative incompatible and compatible rootstocks unequally among treatments.

An experiment to test this hypothesis gave 70% chip-take when one chip per rootstock was used as normal, and 94% rootstocks with at least one chip-take when two chips were inserted at opposite sides of the rootstock. (The results for three chips per rootstock was 80%, the reduction compared to using two chips being associated with rootstock debilitation caused by the three chip cuts in effect ringing some of the smaller rootstocks).

The use of specially developed statistical procedures showed that incompatibility was not present, but that the ability of bud chips to form unions was determined by individual rootstocks, and this variability was distributed at random within the row. The final number of maiden trees was highly significantly improved ($P<0.01$) by double-budding each stock (94%) despite single budding giving reasonably high bud-take (70%) in 1988.

Rootstock clones of *Acer platanoides*

Progress with propagating cuttings of difficult species, including *Acer platanoides*, made in HDC HNS Project HO/9 (Cutting propagation), has enabled individual seedling rootstocks to be propagated vegetatively, and a number of clonal rootstocks of each raised over a number of years. When these were budded with 'Crimson King' various success rates were obtained which were not exclusively 0 or 100%. If the seedling rootstocks from which cuttings were taken were either compatible or incompatible, the success rates of their clones would be expected to be zero, or close to 100%, which was not the case.

Clonal propagation of previously failed rootstocks: 1989/90

Cuttings were taken in 1988 from rootstocks whose 'Crimson King' chips had failed to form unions in 1987. These cuttings were raised as rootstocks for budding in 1989. All 30 individual vegetatively propagated cuttings from previously unsuccessful seedlings formed unions and produced maiden 'Crimson King' trees.

Interim conclusion:

There is no evidence that individual *Acer platanoides* seedlings fail to form a union with 'Crimson King' because they are genetically or pathologically incompatible. However, chip failure was linked to variability in the sub-population of seedling rootstocks, and the reason for this, and ways of identifying potentially poor rootstocks, becomes a high priority. Until this is resolved, budding two chips per stock is a practical way of improving final tree yield.

Annual fluctuations in bud-take

All of the ornamental species studied in this project showed large annual fluctuations in 'bud-take'. This was most obvious in *Acer* 'Crimson King', where both union formation and bud growth were affected similarly. Control treatments, in which no special conditions or unusual techniques were applied, gave 30% success in 1987 and 90% in 1989. In 1988 64% and 85% were obtained in different fields.

All rootstocks were obtained from the same commercial source, all scionwood was of the same clone, and all budding was done by the same person. Reference to earlier data shows that these results reflect the long-term situation. In 16 experiments during 14 years since 1973 bud-take of 'Crimson King' at East Malling has ranged from 22 to 94%, despite nursery management and budding procedures being comparable. Table 7 shows that only in half those years would the outcome have been reasonable in commercial terms.

Table 7 - Number of experiments over 14 years in which *Acer* 'Crimson King' bud-take fell into three classes of success.

% Bud-take	Number of experiments
67 - 100	8
34 - 66	4
0 - 33	4

Table 8 shows these years/experiments arranged in descending order of bud-take, together with data for soil temperature (which closely reflects ambient air temperature and is probably more physiologically relevant) and rainfall for the month of August, which is the period most relevant to union formation. The fields in which experiments were done are also shown.

Table 8 - Decreasing bud-take in *Acer* 'Crimson King' related to year, August weather and field location

Year	% bud-take	Soil temp. at 10 cm (°C)	Rain (mm)	General description	Field
1981	94	18.0	25.8	warm, moderately dry	Bradbourne
1989	90	19.3	26.0	warm, moderately dry	Crabtree
1983	88	19.2	14.5	warm, dry	Crabtree
1973	88	18.7	13.0	warm, dry	North Park
1974	88	16.6	90.2	cool, very wet	North Park
1988	85	17.6	31.3	moderately warm, moderately wet	North Park
1984	77	18.6	16.2	warm, dry	Crabtree
1975	68	20.0	24.5	warm, moderately dry	Larkfield
1988	64	17.6	31.3	moderately warm, moderately wet	Larkfield
1983	62	19.2	14.5	warm, dry	Larkfield
1986	60	16.2	75.9	cool, very wet	North Park
1980	41	17.7	61.1	moderately warm, very wet	Larkfield
1982	33	17.9	40.0	moderately warm, wet	Bradbourne
1976	31	19.1	13.9	warm, dry	Larkfield
1987	30	17.4	55.1	moderately warm, wet	Larkfield
1978	22	16.8	19.4	cool, dry	Larkfield

Yearly fluctuations in bud-take were more closely related to the fields in which the experiments were done than the weather conditions. Larkfield never gave better than 68% bud-take, with three years at 31% or less, and an average of 45%. Crabtree never gave results below 77% with an average of 85%. North Park never gave results lower than 60%, with an average of 80%. The poor results for Bradbourne in 1982 (33%) were associated with blackened, wet bud-chips at the time of tie release, in contrast to the highest value of 94% in 1981. Similar blackened chips were observed in 1990 when frequent trickle irrigation was applied across the nursery, but the significance of this is not fully understood, and will be considered in a later report.

High bud-take was often associated with warm dry weather in August, but there were years in which this apparent association broke down. In both 1973 and 1974 88% success was obtained in North Park despite the marked contrast in weather, with 1974 being cool and very wet.

Weather conditions were quite varied in 1976, 1978 and 1987 when consistently poor results were obtained in Larkfield. Furthermore, irrigation is applied in periods of low rainfall, so the amount of water available to the plants in those years is greater than is at first apparent.

Soils

Reference to descriptions of soils at East Malling (Furneaux, 1954 and 1960) shows that compared to other fields used in these experiments Larkfield has a high proportion of gravel and flints which causes the soil both to cap and pan, and to dry out quickly. In 1987 the mean shoot growth of a sample of 10 *Acer platanoides* rootstocks growing in this site was 42 cm, compared to 120 cm for plants in a nearby deep cultivated and less stony site. The soil of the poor growth area was x 1.6 more compacted than that of the good growth area, as measured by a cone penetrometer. When excavated, root systems in the poor growth area were found to be greatly restricted, which was associated with failed chips. A few rootstocks had developed extensive roots under the surface layer of moss and lichens aided by frequent trickle irrigation, and the highest frequency of bud-take was among these.

Site effects

In 1991 three locations were used to test various treatments aimed at investigating the relative importance of site and weather as components of 'year' effects, as follows.

a) Rootstocks were planted in sand tanks, with 75 cm depth of sand, irrigated daily with 4 litres per plant, and not irrigated, in addition to rain, which mainly fell just prior to budding.

b) Potted rootstocks were grown with their 2 litre pots either in direct contact with capillary beds, and with additional daily watering, contrasting with dryer conditions in pots raised on 15 cm columns of sand and watered only when absolutely necessary. This experiment was repeated inside and outside a polythene house.

c) Field-planted rootstocks received a wide range of treatments including daily irrigation (4 litres/plant) or no irrigation, and with some plants having rain-deflecting covers at soil level, which in the generally dry conditions during August and early September 1991 actually acted as a moisture conserving 'mulch'.

The tension with which moisture was held in the soil or compost (equivalent to the force required by rootstocks to extract water) was measured, along with apparent leaf water deficiency, being the amount of water taken up by leaves when placed in a saturated environment. These data, together with rootstock growth and bud-take data are shown as appropriate in the following tables.

Table 9 shows that daily irrigation in the sand tank reduced the leaf water deficit only slightly, and enhanced growth by very little, the main effect being the unexplained small size of rootstock budded at 15 cm and receiving only rain. The likely explanation of the small irrigation effect is that heavy rain at the end of July and beginning of August (26 mm) provided a reservoir of water at the bottom of the slowly draining non-irrigated tank, so that differences in water availability were less than expected. Bud-take was high in all treatments, irrespective of different rootstock growth.

Table 9 - *Acer* 'Crimson King' grown in sand tanks

	4 litres of irrigation/ plant/day + rain		Rain only	
Budding height (cm)	15	30	15	30
Leaf water deficit as % DW	28.3	25.6	33.1	29.9
Rootstock height at end of season(cm)	124	101	91	116
Rootstock diameter (mm) at 20 cm ht.	11.2	10.1	8.8	10.4
Mean leaf area (cm^2) per rootstock	7796	6806	3562	6141
Bud-take (%)	89	100	100	88

Table 10 shows that the outside potted rootstocks raised on a 15 cm sand column experienced a higher soil moisture deficit (associated with exposure to wind) compared to both the wet pots outside and all those inside the polyhouse. This reduced markedly the number of rootstocks with sap bleeding at the budding wound one week after budding, but also gave the lowest bud-take. The greatest leaf water deficit developed in plants with raised pots inside the polythene house, where, despite only a small increase in soil moisture deficit, the elevated temperatures (Table 11) caused slight tip wilting on sunny afternoons. As expected, plants inside the polyhouse grew larger than those outside, but these differences were not associated with large differences in bud-take, which was generally very low and equivalent to the worst field conditions shown above in Table 8.

Table 10 - *Acer* 'Crimson King' grown in pots

	Inside polyhouse, pots with capillary bed contact	Inside polyhouse, pots raised on sand above bed	Outside, pots with capillary bed contact	Outside, pots raised on sand above bed
Soil moisture tension (bars)	-.06	-.07	-.06	-.64
Leaf water deficit (% DW)	8.1	18.2	9.5	8.5
Rootstock height (cm)	105	134	79	77
Stem diameter (mm) at 20 cm height	7.8	8.1	7.0	7.2
Total leaf area (cm^2) per plant	3034	3553	2055	2446
Chip cuts bleeding sap 1 week after budding (%)	66	38	34	12
Bud-take (%)	48	30	33	28

Table 11 - Average daily temperatures (°C) inside and outside the polyhouse during union formation

	Max.	Min.	Mean
Outside beds	31.4	5.3	17.4
Polyhouse beds	39.7	9.2	22.0

Table 12 shows that in the field the soil moisture deficit reflected the application of irrigation, and the moisture conserving effects of the polythene rain-shedding frames in a particularly dry period. Leaf water deficits in these outdoor environments were similar, as was rootstock growth, the slightly greater growth in plants with polythene frames possibly relating to raised soil temperatures under the frames. There were no trends that could explain differences in bud-take, which fell between those for the sand tanks and the pots.

Table 12 - *Acer* 'Crimson King' grown in the field

	Normal (rain only)	Polythene rain-shedding/ mulching canopies	Irrigation at approx. 4 litres/ plant/day
Soil moisture tension (bars)	-.62	-.38	-.06
Leaf water deficit (% DW)	7.0	8.6	8.2
Stock height (cm)	90	95	85
Leaf area/stock (cm^2)	3143	3668	3327
Bud take (%)	77	54	66

Treatments designed to intercept sap flow to the budding wound, by making various forms of incisions into the xylem below the chip-bud, had no beneficial effect in either dry or daily irrigated sections of row.

Root growth

The most obvious effect of the different locations on plant growth was that root growth was extensive in the sand tanks where bud-take was high, and restricted in the pots where bud-take was low, with intermediate root growth and bud-take values in the field.

The length of extension roots was greatest in plants from the sand tanks (Table 13), reflecting also differences in total root dry weight, suggesting that budding success is related to conditions which encourage continuous and extensive root growth. Typical roots systems are shown in plate 1.

Table 13 - *Acer* 'Crimson King' mean root growth per plant

	Sand tanks	Field	Pots
Extension roots (m)	12.6	5.8	4.2
Total dry weight (g)	29.9	19.4	16.0

Interim conclusion

Marked annual fluctuations in bud-take of *Acer* 'Crimson King' are most likely caused by the nature of the soil in which the rootstocks are planted and hence the nursery location. Deep moisture-retaining soils that encourage root extension are linked to high levels of bud-take, and stony, compacted rapidly drying soils are associated with large scale failure.

Sometimes bud failure is associated with blackened wet chips at the time of releasing the polythene ties, and it is likely that there are some circumstances in which excess rain or irrigation is detrimental to bud-take, but this is not always the case, so another factor may trigger the 'wet' response. In most experiments irrigation treatments which affected soil water availability, leaf water content and frequency of sap bleeding from chip cuts had relatively little effect on bud-take.

Micro-organism contamination of scionwood: 1988

The key physiological requirement for successful union formation between rootstock stem and scion chip is rapid cambial callus development followed by the production of new cambium to link that of the rootstock and scion (Howard *et al.*, 1974, Skene *et al.*, 1983).

Plate 1. Roots of *Acer platanoides* stocks grown in:

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

An attempt was made to quantify callus potential in sections of rootstock stem, and in chip-buds of *Acer platanoides* 'Crimson King', *Betula pendula* 'Dalecarlica', *Robinia pseudoacacia* 'Frisia' and *Tilia x Euchlora* by culturing tissue *in vitro* under conditions similar to those developed for micropropagation (HDC HNS Project H0/10).

Despite stringent double decontamination procedures using calcium hydroxide and mercuric chloride it was impossible to obtain *in vitro* cultures of *Acer* and *Robinia* free of serious fungal and bacterial contamination (Plate 2).

This raises the possibility that chips sometimes fail to unite in these species because they are attacked by microorganisms in the moist warm conditions provided by the polythene tie, and that the inability of some chips to survive in a suitable physiological condition contributes to union failure. To test this further, in 1988 a normal field source of 'Crimson King' scionwood was treated with either liquid copper fungicide/bactericide (cupric carbonate at 0.05% Cu + Tween 20 wetter) in an attempt to decontaminate the buds, or with a suspension of bacterial spores (+ mannoxol nonionic wetter) isolated and cultured from a field source of 'Crimson King' (Plate 3), in an attempt to depress chip-take. Results in Table 14 show that union formation was improved by the copper pre-dip and worsened by dipping in the bacterial suspension. Budwood collected from scionwood trees grown under glass, and which typically carries a lower micro-organism population than the field source (Table 15), performed as well as the copper-treated scionwood.

Results for union formation were reflected in the total number of maiden trees produced, although treatments had less effect on the number of trees which reached 1.5 m in height (graded 1st class).

Table 14 - *Acer platanoides* 'Crimson King' scionwood treatments

	Scionwood Source			
	Normal field	Field + copper dip	Field + bacterial dip	Glasshouse
% union formation	76	90	65	88
% maiden trees	64	82	69*	82
% 1st grade trees (1.5 m)	52	58	53	72

* 4 maidens developed from partially united chips

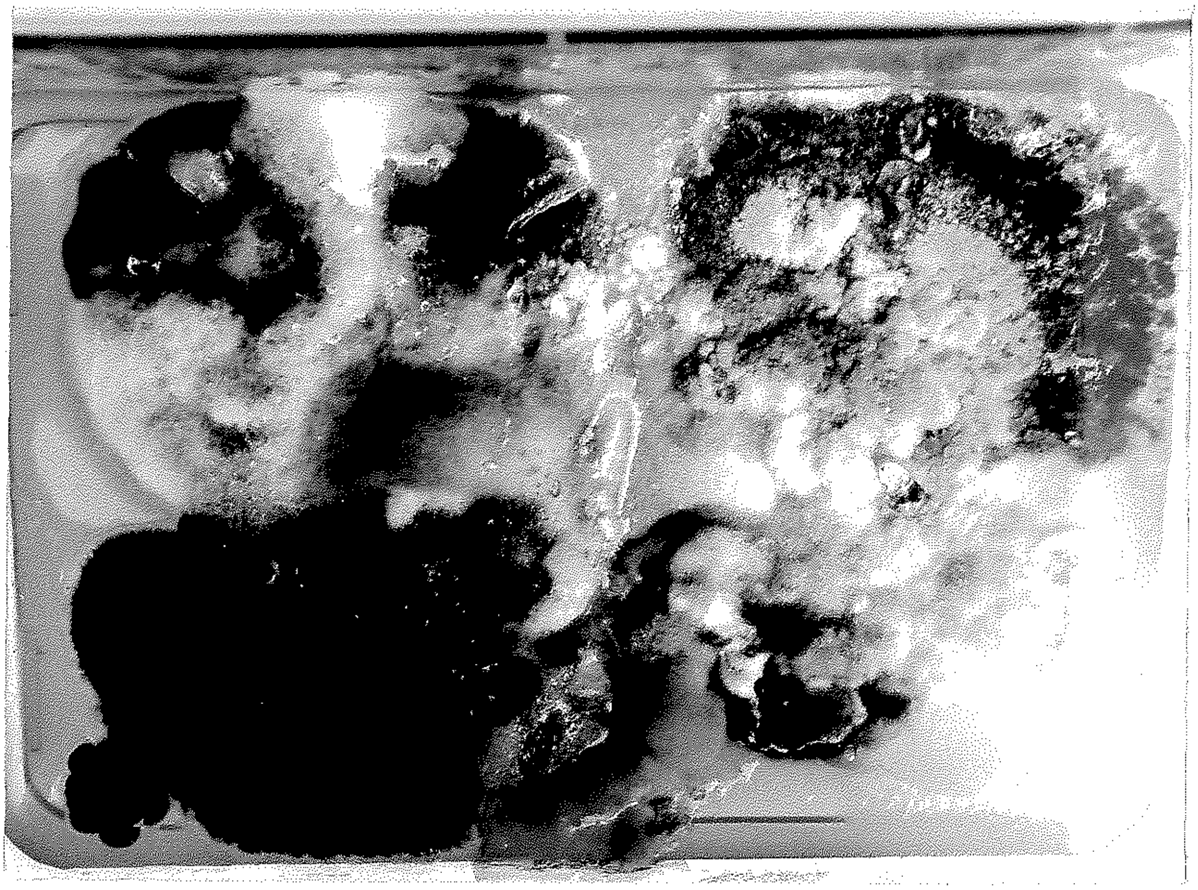

Plate 2. Fungi and bacteria growing on *Acer* 'Crimson King' chip-buds cultured on sterile agar, as viewed through the base of the culture box.

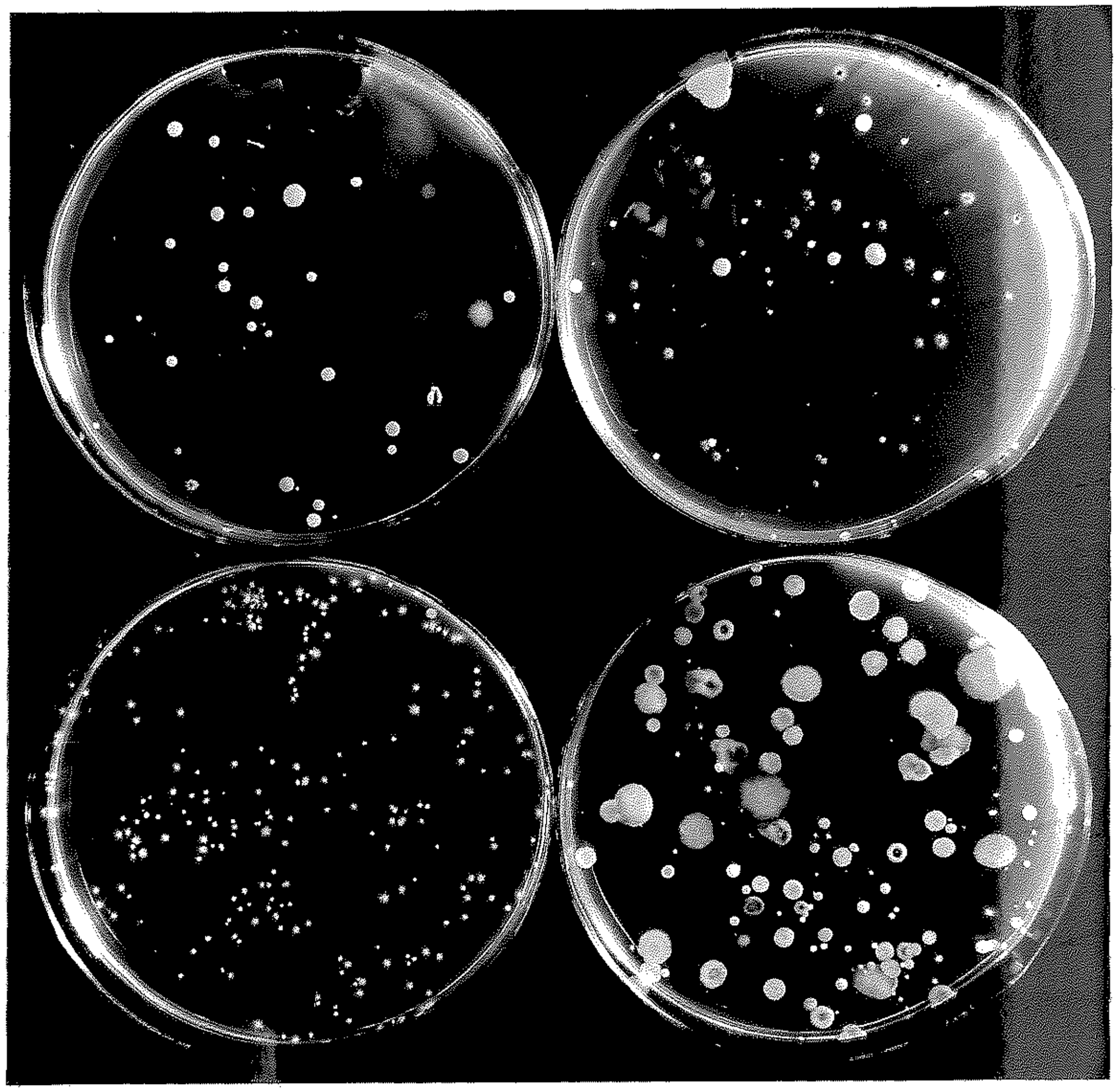

Plate 3. Separation by plating before making a suspension with which to treat budsticks.

Table 15 - Microorganism contamination of scionwood grown in the field or under glass (number washed from 1 cm nodal section)

	Acer 'Crimson King'		*Robinia* 'Frisia'	
	Field	Glass	Field	Glass
Bacteria	2250	45	1750	0
Fungi	2800	350	2500	166

The trial was carried out also with *Robinia* 'Frisia', using a *Robinia* bacterial isolate for the contamination treatment. Table 16 shows that similar trends were obtained to those of *Acer*, but the beneficial effect of the copper solution was relatively less and the detrimental effect of the added contamination relatively greater. The effects on union formation were reflected in both total and first-grade tree production.

Table 16 - *Robinia pseudoacacia* 'Frisia' scionwood treatments

	Scionwood Source			
	Normal Field	Field+ copper dip	Field+ bacterial dip	Glasshouse
% union formation	62	75	18	53
% maiden trees	40	59	14	48
% 1st grade trees (2 m)	36	55	14	40

In 1989 the copper solution was applied to *Robinia* 'Frisia' bud-sticks as an instantaneous dip, compared with a 4 minute and 8 minute immersion. All dipping treatments give a higher bud-take than the untreated control (60%), and the instantaneous dip (85%) was not improved upon by longer dipping treatments.

Interim conclusion

A new cause of chip-buds failing to form unions appears to be micro-organism contamination of the budwood, the effects of which were reduced or increased by pre-treating scionwood with a solution of copper carbonate (0.05% Cu) or a limited number of bacterial isolates in aqueous suspension, respectively. In view of the potential importance of this discovery, the many bacteria and fungi that could be implicated, and the specialist nature of the pathological investigations required, this topic was given a separate project (HNS 30) in 1990.

Other scionwood sources

Except for possible micro-organism contamination the contribution by the scionwood to problems of union formation and maiden growth is likely to be less than that of the rootstock, because the former is clonal and the latter seedling in origin. Nevertheless, the maximum possible number of scion buds is used from a scion stick and their age and relative location are affected by the growth rate of the scionwood tree during spring and early summer, which cannot be ignored. The first attempt to modify scionwood conditions and growth involved comparing scions from field-grown hedges with those from potted trees in their second year of scion growth, the potted trees being grown on capillary sand beds inside and outside a polythene house.

Table 17 shows that in 1988 for both *Acer* 'Crimson King' and *Robinia* 'Frisia' a higher percentage of maiden trees was produced from potted scionwood trees. In the excellent year of 1989 high bud-takes were obtained from all sources and in 1990 *Robinia* again gave better results from potted trees. In *Acer* there was little effect of growing the scionwood under polythene or not, and for *Robinia* the preference was for protection in 1990 and for the outside capillary bed in 1988.

Interim conclusion

The way that scionwood is produced appears less important than factors affecting rootstock growth. Nevertheless, it is interesting that growing scionwood plants in pots is relatively more important than whether they are grown rapidly under protection, or normally outside. The reason for this needs to be understood. For example, it might relate to water relations of the scionwood, which are likely to differ in field and pot-grown plants, or be due to an experimental artefact such that potted plants are relatively smaller with fewer scionwood shoots than field-grown trees, which would point to ways of improving scionwood trees.

Table 17 - Maiden trees (as % of budded stocks) produced from scionwood grown either in the field or in pots under protection (1988 and 1989 - glass, 1990 - polythene) or in the open.

		Field	Protection (potted)	Outside (potted)
Acer 'Crimson King:	1988	69	80	76
	1989	92	95	100
Robinia 'Frisia':	1988	40	48	78
	1989	83	81	80
	1990	77	90	82
Overall mean		72	79	83

OVERALL CONCLUSIONS

1. There are major annual fluctuations in both union formation and bud growth which mask, or may interact with, other management and technical procedures. In 'good' years high success rates for most species are obtainable regardless of a wide range of experimental treatments which can affect success in years when bud-take is depressed. This 'year effect' must be understood because it is clearly a major controlling factor in determining budding success and because the importance of other technical improvements cannot be judged properly without being able to control the background level of success. Although needing further study **the nursery site and the soil conditions which influence root growth appear important in determining bud-take.**

2. There are major differences among ornamental tree species in their ability to form unions between stock and scion and/or the scion bud to grow once a union has formed. Less flexible ties (polythene) assist union formation, implicating the organisation of callus during cambial connection, and more flexible ties (rubber) favour bud growth to some extent, possibly implicating physical damage to the scion bud by polythene ties. These and other ways of ensuring maximum union formation and bud growth are being studied further.

3. The possibility of incompatibility between the clonal scion and some individual genotypes in the seedling population can be ruled out. However, the variable growth of seedlings affects success and this is being studied further with a view to identifying preferred types of rootstock from within seedling populations.

4. The way scionwood is grown can affect success, although this is likely to be less important than the condition of the rootstock, with the notable exception of micro-organism contamination. Failure of the chip associated with the development of bacteria and fungi under the tying material is likely to be a major factor determining success in *Acer* 'Crimson King' and *Robinia* 'Frisia' in some years, although the interacting 'year effect' is not necessarily due to the same factors which determine the observed general yearly fluctuations. For example, an hypothesis to be tested is that micro-organism damage requires the combination of both an external source of spores and excessive water under the tie.

6. Although this first report summarises work aimed at understanding the nature of the field-budding problem as a basis for technical improvement, demonstrations at East Malling Levy Payers' Days have shown that high success rates are possible, even though the reasons are not yet fully understood.

From a practical standpoint growers are likely to improve their output immediately by selecting sites which encourage free root activity, and in less favourable circumstances inserting two chips per stock.

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