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Developing clonal rootstocks for ornamental trees and shrubs

HDC HNS 6a

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RELEVANCE TO NURSERYMEN AND PRACTICAL APPLICATION

Application

The purpose of this project was to investigate the opportunity to develop clonal rootstocks for ornamental trees from natural populations of seedlings used at present for rootstocks, or from fruit rootstock breeding and selection programmes for appropriate species.

A range of potential rootstocks for varieties of *Tilia* and *Acer platanoides* are in various stages of completion, embodying ease of propagation, production of uniform stands of maiden trees, and resistance to verticillium wilt in the case of *Acer*. *Sorbus* x *intermedia* is at an early stage of selection. Among fruit-derived rootstocks existing clones suitable for ornamental cherries, crabs and *Prunus mume* are identified, and new selections for *Pyrus calleryana* 'Chanticleer' and *Prunus tenella* 'Fire Hill' are described.

Commercial testing is possible now for a number of these clones, but the future direction of such long-term developments is discussed with a view to meeting the specialist needs of those nurserymen in favour of clonal rootstocks for ornamental trees.

Summary

HDC support for this project had a number of objectives within the general area of investigating the potential for emulating the fruit industry and developing clonal rootstocks for ornamental trees, especially with regard to the size, quality and uniformity of trees sold to specification through a tendering system.

In the case of *Tilia cordata*, *T.* x *europaea* and *T. platyphyllos*, and of *Acer platanoides*, the objective was to continue long-term work originally funded by MAFF until "near-market" withdrawal of funding.

New objectives introduced during the course of the project following internal reviews included adding *Sorbus* x *intermedia* with a view to increasing the range of compatibility within this genus. Also, opportunities to exploit fruit rootstock breeding and selection programmes were included, initially seeking a more fibrous rooted pear stock compatible with *Pyrus calleryana* 'Chanticleer', and a plum/apricot rootstock compatible with *Prunus tenella* 'Fire Hill'. Guidance on the use of existing commercially available rootstocks for ornamental cherries, crabs and plum was also to be touched on.

Although at an advanced stage for *Tilia* spp, and to some extent *Acer, Pyrus* and *Prunus*, a number of assessments are still being carried out, such as the effects of clonal rootstocks on transplanting and establishment. A low cost project (HNS 6b) has been established to ensure the completion of this work and the maintenance of this material until a decision is made as to its future development and of possible further studies. This decision will be based on evidence of progress so far and considerations of different approaches to developing clonal rootstocks for ornamental trees.

Rootstock development is long-term, requiring at least 20 years to produce commercially acceptable clones, even when derived from a breeding programme based on sound genetic insights.

The required genetic understanding is not available for ornamental trees (as it wasn't for the first selections of clonal fruit tree rootstocks) and selection among seedlings raised in the course of producing commercial seedling rootstocks has been undertaken, influenced by the fact that trees are notably outbreeding, exhibiting good mixing of genetic material.

For *Tilia* spp. individual genotypes initially chosen mostly for their ability to produce clean straight shoot growth suitable for hardwood cutting propagation have undergone a process of selection and short-listing. This involved ability to propagate by hardwood cuttings, in parallel with improving the propagation technique, and the ability to respond to blanching treatments as a pre-requisite for stoolbed production. As numbers of rootstocks within the more readily propagated clones increased with time, further selections were made based on bud-take, quality of maiden growth and uniformity of stand. During the programme *T. platyphyllos* was introduced as a more difficult but more commercially-relevant species compared to the initial *T. cordata* and *T.* x *europaea*. Although growing trees to beyond the maiden stage, and assessing their transplanting ability, is still in progress, three *T. cordata* clones and four *T. platyphyllos* clones are worthy of commercial consideration, along with four clones of *T. platyphyllos*, whose coloured annual wood deserves their consideration for use unworked.

A similar programme of work with *Acer platanoides* has identified three clones with higher-than-normal resistance to verticillium wilt, but a more commercially-relevant propagation method is being sought in place of the experimental use of late summer cuttings, which would make growing-on for rootstock use expensive. *Acer platanoides* clones are being found to root well on layer/stool beds.

Hitherto unreleased selections of clonal pear rootstocks look promising for *Pyrus calleryana* 'Chanticleer', and a number of new *Prunus* rootstocks derived from 'Marianna' are being tested with *Prunus tenella* 'Fire Hill' for those nurserymen wishing to propagate this small shrubby tree in this way. (In the course of these trials 'Fire Hill' was found to propagate from softwood cuttings in moderately wet fog). Growers are reminded of the advantages of MM.106 for Crabs and 'Colt' for Ornamental Cherries. 'St. Julien A' was shown to be the preferred rootstock for *Prunus mume*.

Against the progress demonstrated here must be weighed the problems of long-term work of this nature. Not all nurserymen are convinced of the need for clonal rootstocks, which appeal mostly to large producers supplying Public Authorities to specification via tendering. The original justification, such as the unreliability of annual seed supplies and hence fluctuating supplies of *Tilia* seedling rootstocks, may be overcome by improved seed sowing technology, as has occurred to a large extent. On the other hand, precise targets such as resistance to soil-borne diseases, wider compatibility and more fibrous root systems are objectives which many nurserymen would support.

If justified, it may prove more cost-effective for the initial stages of selection, technique development and bulking-up to be done within the research framework, with the later stages of commercial development and selection against the needs of individual producers to be done in the commercial environment.

Meanwhile, *Tilia* rootstocks are available for commercial testing, given adequate notice for their propagation, and new and existing clonal apple, pear, cherry and plum rootstocks are available for production and transplanting tests. Given continued progress towards a more commercially-relevant propagation method clones of *Acer platanoides* with relatively high resistance to infection by verticillium wilt will be available shortly.

EXPERIMENTAL SECTION

Introduction

The development of clonal rootstocks for fruit trees is arguably the most important contribution that research has made to that sector. Benefits include standardisation of tree size to facilitate orchard planning and management, reduction in tree size and increase in precocity to facilitate intensification, and selection for resistance against soil-borne diseases. The production of all major temperate fruit and nut crops exploits the use of rootstocks, which also feature in citrus and other sub-tropical species (Rom and Carlson, 1987).

Attitudes towards the need for clonal rootstocks in HNS tend to be polarised. One view is that variation in size and form adds interest to landscape planting. A more pressing argument, which recognises the current difficulty of the Public Authority market, is that high quality uniform trees facilitate purchase to specification via tendering.

The work with *Tilia*, and to some extent *Acer*, has been in progress for many years, with HDC supporting its continuation after MAFF withdrew from near-market projects. Passage of time leads to changes that also affect attitudes. A major consideration initially was the unreliable supply and variable quality of seedlings due to fluctuations in availability of seed and germination problems. Improvements in seedling rootstock production and present-day stocks of reasonably uniform trees on seedling rootstocks reduce the emphasis on these general problems of seedling rootstocks, with more emphasis now being placed on overcoming species-specific problems such as fangy non-fibrous seedling root systems, which can lead to transplanting difficulties in certain genera.

The basic principle behind the approach adopted in this programme is that trees are outbreeding, recombining their genetic material during sexual propagation to produce heterogeneous progeny such that the resulting 'wild' seed batches may contain a variety of recombined genetic material similar to that expected from a controlled breeding programme, especially when, as in ornamental trees, there is little genetic information to direct formal breeding and selection.

The main question posed in this work is whether, and if so, to what extent, the seedling populations produced each year for use as seedling rootstocks and natural trees contain individual genotypes with the right combination of useful rootstock characteristics. Clearly, such genotypes need to occur relatively frequently to be picked-up in what must be a limited screening programme.

An ancillary approach adopted here, in response to needs identified by commercial nurserymen, was to exploit rootstock breeding programmes for fruit trees, remembering that the more vigorous rootstocks that emerge from these programmes are rejected for fruit, whereas they are likely to be relevant to fruit-related HONS.

Typically, a programme of selection and development from a natural seedling population will comprise a progressive series of objectives as set out below, which differ only slightly depending on the species or available starting material.

> Identify single genotypes with propagation ability initially from cuttings, and with shoots conducive to cutting production (e.g. many straight shoots). A balance must be struck between selecting too many, such that the subsequent escalating work becomes impossible, and allowing for rejects. Between 50 and 100 is considered sensible, but the larger the number of genotypes obtained from a variety of provenances, the higher the chances of success are likely to be.

Develop and improve the chosen propagation technique, identifying potential problems and creating a reasonably robust method. Later it may be sensible to recognise commercial preferences or opportunities to exploit sector skills (e.g. converting from hardwood cutting propagation to stoolbeds to exploit the range of fruit nursery methods not necessarily widely used in HONS nurseries).

Build-up the clone by planting stockplants as hedges or stools. There is a degree of self-selection at this stage, with easy-to-propagate clones multiplying rapidly and difficult ones often eliminating themselves unless they have particularly useful traits which justify specific work to improve propagation. It is important to monitor any progressive loss of rooting ability over a number of years that would indicate propagation problems as genotypes passed from the juvenile to adult phase.

Screen for resistance to diseases if appropriate, including soil-borne diseases in the case of potential rootstocks.

Carry out budding tests, identifying reasons for poor performance and producing a robust method.

Assess quality and uniformity of maiden trees. NB. It is virtually impossible to make a sensible judgement of relative quality, and particularly uniformity, when comparing trees grown on a small experimental and often somewhat variable sample of unique clonal plants, compared to seedling controls graded from many thousands of commercially-raised seedlings.

Grow trees to a larger size typical of commercial nurseries.

Assess transplantability of trees on clonal rootstocks compared to seedlings as a measure of their point-of-sale value.

In the early stages of rootstock development expediency often features more strongly than obtaining the "perfect" clonal rootstock. A case in point is the use of the fruiting cherry rootstock *Prunus avium* x *P. pseudocerasus* 'Colt', which has become widely used for all but the most vigorous ornamental cherries, even though it hardly featured in trials to select clonal rootstocks specifically for ornamental cherries. 'Colt' is exceptionally easy to propagate and was available before HONS-specific selections.

The object of the work reported here was to assess the opportunity for selecting from natural sources or from fruit breeding programmes, genotypes with potential as clonal rootstocks, but not necessarily perfect in every respect. For *Tilia* all the stages outlined above have been undertaken, at least for a sample of clones, but results are not yet available from stooling and transplanting trials. Brief reference to progress prior to HDC funding is made so that the current work is seen in the context of this long-term programme. The latter stages of experiments started in 1989 were picked up at the beginning of this project.

Material and methods

Initial genotype selection

Tilia spp: Commercial nurseries with extensive areas of 2-3-year-old unbudded seedlings of *T.* x *europaea*, *T. cordata*, and later *T. platyphyllos* were accessed between 1972 and 1980. Individual genotypes were sought on the basis of useful visual characteristics, such as the potential for producing many clean-stemmed hardwood cuttings. Selected plants were lifted, coded and replanted at East Malling; occasionally cuttings were collected if the entire plant was not available.

Acer platanoides: Initial selections of *A. platanoides* were made within an original population of more than 2000 seedlings planted at East Malling and subject to inoculation with verticillium wilt (*V. dahliae*). Propagation tests were subsequently made on surviving plants, about 100 of which were allowed to grow into small trees for increased cutting production. Further tests concentrated on the 14 most promising individually coded genotypes, with *A. platanoides* 'Crimson King', and sometimes *A. platanoides* 'Drumondii' also, as controls.

Additional material was screened at Luddington EHS for ability to propagate by hardwood cuttings. The majority of this material was transferred to HRI Efford when Luddington closed, and was assessed by the East Malling team in a joint programme of work with MAFF.

Sorbus x intermedia: The two-year shoot growth from the tops of lined-out budded rootstocks on a commercial nursery was collected to make hardwood cuttings in winters 1991-92, and 1992-93 prior to the rootstock tops being cut back to the scion bud. The fact that budding had already taken place risks contamination with any viruses carried by the scion. Little or nothing is known about virus infection and its effects on ornamental trees, and *Sorbus* varieties are not thought to exhibit symptoms suggesting infection. Any viruses present will eventually infect any clonal rootstocks so the initial risk was considered acceptable, and possibly a beneficial screen for sensitive genotypes.

Malus tschonoskii, Prunus mume, Prunus tenella 'Fire Hill', Pyrus calleryana 'Chanticleer': Apple, plum, pear and quince rootstocks being selected in East Malling breeding programmes, or already in use in commercial fruit growing, were tested for various ornamental species as appropriate.

Other species: On occasions a range of other species were tested by attempting to root hardwood cuttings, made from seedlings, to assess the level of cloning potential.

Propagation

Tilia spp: The main method was by hardwood cuttings, which are large and lend themselves to use as rootstocks for budding. Basal cuttings were prepared to 60 cm length, usually during early February, bases treated with 2500 ppm IBA in 50% aqueous acetone to a depth of 8 mm for 5 seconds, and cuttings propagated in heated bins at 18-20°C bottom heat. During the course of this work various changes in propagation procedures were tested, and a general improvement resulted from placing the cut bases on the surface of a 20 cm drained sandbed, with Cambark 100 used only as a mulch, rather than planting the cutting bases in the Cambark itself. The distal two thirds of the bundles of cuttings were protected with a polythene sleeve. After callusing and the beginning of rooting, cuttings were established outside in raised beds of equal parts by volume of bark, peat, sand and grit with 1.5 kg m^3 Ficote 140. The following year the resulting plants were used to extend hedges, or to line-out for budding.

Rooting by summer softwood cuttings under mist or fog was tested in response to grower interest, and to investigate the effect of stem-blanching as an indication of likely benefits from stooling.

Stoolbeds were established in 1992/3 winter.

Acer platanoides: All methods described for *Tilia* were applied to *Acer*, but the hardwood and softwood cutting techniques were not sufficiently productive to guarantee regular supplies of established cuttings for verticillium wilt screening.

A satisfactory experimental method was developed in which terminal leafy cuttings were propagated after 1250 ppm IBA treatment in early September under wet fog and the cuttings were allowed to go dormant and lose their leaves after rooting, thus avoiding the problem of weaning leafy cuttings. Cuttings were either overwintered in polythene bags in the coldstore or left in the fog house after fogging ceased. Rooted cuttings were then planted into raised beds during the following April.

Sorbus x *intermedia*: The hardwood cutting method described for *Tilia* was used. However, in order to obtain cuttings of reasonable length, but never 60 cm, both annual and two-year wood was included in the cutting, the two-year base was split along its vertical axis for approximately 2 cm before IBA treatment to assist uptake and rooting.

Fruit related species: Already-developed rootstocks were provided from stoolbeds or cuttings as appropriate by the East Malling nursery. Experimental rootstocks of quince and pear for testing with *Pyrus calleryana* 'Chanticleer' were raised in this project by the hardwood cutting method as described above for *Tilia*.

Budding

Chip-budding was used throughout. Small-budded species such as *Pyrus* 'Chanticleer' were tied with polythene covering the actual eye, while large-budded *Tilia* x *euchlora* were tied with the eye exposed to avoid damage from compression.

Verticillium wilt screening

Appropriate parts of the *Acer* development project were encompassed in a genetic improvement programme funded by MAFF. This included the screening of *Acer* clones for verticillium wilt resistance by Dr. David Harris and Mr. D. Chambers of the Plant Pathology and Weeds Department.

The method involved planting the rootstocks provided by the Propagation Science Section into holes containing straw inoculated with a culture of *Verticillium dahliae*. Symptoms of olive-brown stained wood, and wilted necrotic leaves were recorded in the first and second seasons. Passing reference will be made to this work in this report to ensure a comprehensive picture.

Statistics

Where numbers allowed, comparisons were made in randomised and replicated layouts. 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 differences). Therefore, a 5% probability implies a 95% chance that differences are due to clones and not due to random effects. To assist in comparing the performance of different clones 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

Tilia spp:

Early screening for propagation ability of hardwood cuttings.

The first objective was to obtain evidence of responses that could be attributed to genotype within the background variation imposed by developing technology and causes not fully understood, generally referred to as 'year effects'. The second early objective was to eliminate as many clones as possible to allow resources to be concentrated on a short-list that would benefit from improved treatments.

Early evidence of genotype differences were reported (e.g. Howard and Shepherd, 1978). It is impossible nevertheless, to impose rigid criteria on the elimination and short-listing processes because of the unlikelihood of finding all optimal characteristics combined in a single genotype, leading to the need to trade-off good and bad points, the latter being the target for subsequent technical improvement.

Table 1 summarises many years' work of building-up clones from a single genotype, and identifying those whose performance was reasonably consistent in line with their use as clonal rootstocks. During the ensuing period largely covered by this report the main objectives were to investigate the effects of 'improved' propagation procedures, to assess consistency of performance relative to early screening, to bulk-up promising clones for replicated trials, and to produce rootstocks for lining-out for budding tests by switching emphasis from rooting test to establishment success

Table 1. Developmeht of potential clonal rootstocks for *Tilia*

	No. of original genotypes which were screened	Clone numbers of those short-listed for propagation by hardwood cuttings
First wave		
T. x *europaea*	19	6
T. cordata	23	6,21
T. platyphyllos	17	none
Second wave		
T. cordata	28	203
T. platyphyllos	31	201, 229, 231
Totals	**118**	**6**

Technical improvements, confirmation and bulking-up

From 1989 onwards, variations in cutting treatment were tested, including the benefit of basal splitting to enhance IBA uptake, the level of bottom heat, and whether cutting bases should be stood in the granulated pine bark (Carmbark 100) rooting medium, or on the underlying bed of drained sand, with the bark used as a mulch in an attempt to control water content of basal tissue, and basal rotting.

The most important effect was due to placing cutting bases directly on the sand. Table 2 shows that with nine clones, predominantly of the difficult-to-propagate *T. platyphyllos*, all established in greater numbers when planted directly onto the sand, than in the granulated pine bark.

The effect of varying the level of bottom heat was also instructive (Table 3). Clones *T. cordata* 21 and *T. platyphyllos* 231 established better after being rooted at 15°C, whereas two selections of *T. cordata* 6 established in greater numbers after propagation at 20°C. The clonal interaction was shown to relate to the extent to which basal buds were induced to sprout during propagation. In general, these relatively difficult-to-root clones benefit from the induction of roots at the relatively higher temperature before planting-out, but this benefit is negated if as a consequence resources are redirected to sprouting basal buds, as in the case of *T. cordata* 21 and *T. platyphyllos* 231. Effects due to wounding were clone-specific and no general conclusions could be made.

Table 2. Effects on establishment (%) of planting cutting bases on the drained sand bed (sand) or in the granulated bark (bark) during rooting at 20°C basal heat

Clone	Sand	Bark
T. cordata 6	56	30
T. cordata 6A	69	45
T. cordata 21	55	43
T. cordata 203	33	8
T. platyphyllos 201	18	4
T. platyphyllos 213	25	3
T. platyphyllos 228	35	6
T. platyphyllos 229	33	13
T. platyphyllos 231	23	2
Mean	**39**	**17**

Table 3. Effects on establishment (%) of propagating cuttings at 15°C or 20°C basal heat (mean of sand and bark base contact)

	15°C	20°C	State of basal buds
T. cordata 6	27	43	not sprouting
T. cordata 6A	22	57	not sprouting
T. cordata 21	77	49	advanced sprouting
T. platyphyllos 231	42	13	moderately sprouting

Rooting and establishment of hardwood cuttings was compared from the original source plants (25 per clone) and from commercial-scale hedges (300 per clone) to check whether propagation was affected as source plants progressed through early vegetative generations. Table 4 shows that the order of merit of four clones remained similar when propagated from the original source plants and from subsequent hedges, and that overall establishment was somewhat improved in cuttings from hedges.

Table 4. Comparison of hardwood cutting establishment (%) from representative original genotype source plants, and hedges derived from them subsequently.

Clone	Original genotype (25 cuttings/clone)	Derived hedge (300 cuttings/clone)
T. platyphyllos 231	76	82
T. cordata 21	68	81
T. platyphyllos 201	51	56
T. x *europaea* 6	44	74
T. cordata 6	31	23
Means	**54**	**63**

In 1991 short-listed clones and others for comparison were propagated and established in large numbers (250 per clone) from second and third 'generation' hedges to confirm their selection, and also to investigate whether the grade of plant produced differed to any extent in particular clones.

Table 5 confirms that all short-listed clones performed well. The distribution of plant size was consistent in so far as the largest single class for all clones was the medium grade suitable for lining-out for budding, but it did not follow that the more ready-propagating plants always produced a relatively high proportion of large plants. When cuttings establish at high density mutual competition often suppresses the growth of individual plants

Table 5. Confirmation of the previously short-listed clones (*) in terms of establishment (%), with breakdown into grades.

Clones (in order of merit)	Overall establish-ment	Large (suitable for planting hedges)	Medium (ideal for budding)	Small	Dead
T. cordata 203*	97	34	53	10	3
T. cordata 6*	94	16	61	17	6
T. cordata 21*	90	30	50	10	10
T. x *europaea* 6*	86	6	56	25	14
T. platyphyllos 229*	86	31	43	12	14
T. platyphyllos 231*	79	17	50	12	21
T. platyphyllos 201*	75	21	41	13	25
T. platyphyllos 213	58	17	33	8	42
T. platyphyllos 228	43	9	23	11	57
T. platyphyllos 211	35	9	20	6	65
T. cordata 201	32	11	15	6	68
Mean		**18**	**41**	**12**	**29**

Statistical probability for overall establishment = 0.1%
LSD for overall establishment = 12.4

In 1992 the short listed clones and others for comparison were re-propagated, with 200 cuttings of each one being divided between treatment combinations to assess the effect again of basal split-wounding before IBA treatment, and the duration of bottom heat at approximately 18°C, on subsequent establishment.

Table 6 shows that **overall** there was no effect on establishment of pre-IBA wounding, and that the overall advantage of 3 weeks rooting over 5 weeks was small. However, specifically, higher establishment occurred after 3 weeks rooting for 9 of the 12 clones and virtually no basal sprouting was recorded after this duration of basal heat. Those that preferred 5 weeks included *T. cordata* 6 for which basal sprouting has already been noted as not being a problem. It is of interest that for both *T. cordata* 6 and *T. cordata* 21, the consistent benefit from split-wounding was associated with a delay in the onset of bud-sprouting for a reason not understood. These results confirm that short-listed clones perform relatively well in terms of propagation by hardwood cuttings and that, given rapid removal of excess water by planting cutting bases directly onto the sand bed, the most important requirement is to find the clone-specific compromise between inducing root development without inducing excessive basal sprouting as a competing sink for resources. The alternative strategy of propagating in autumn before buds have been chilled, and hence before sprouting could become a problem, has been tested on a number of occasions, but results have never matched those of early-February propagation.

Table 6. Establishment (%) of *Tilia* clones in raised beds related to previous conditions in heated propagation bins (short-listed clones indicated by *).

Clones in order of merit	Duration in rooting bins (wks)	3	3	5	5	Mean
	Basal split wound	+	-	+	-	
T. x *europaea* 6 *		78	78	**82**	80	80
T. cordata 203 *		**88**	86	68	60	76
T. cordata 21		**78**	64	76	42	65
T. platyphyllos 229 *		66	**74**	48	60	62
T. cordata 6 *		54	26	**64**	54	50
T. platyphyllos 231 *		30	**60**	38	48	44
T. platyphyllos 201 *		42	**52**	38	40	43
T. platyphyllos 206		36	**40**	28	34	35
T. platyphyllos 208		**42**	34	34	24	34
T. platyphyllos 212		28	**38**	18	34	30
T. cordata 201		20	12	**36**	30	25
T. platyphyllos 213		16	**30**	16	14	19
Mean		**48**	**50**	**46**	**43**	

Statistical probability for clones = 0.1%, bin duration and wounding, not significant
LSD for clones = 12.0

Propagation by leafy softwood cuttings

For plants destined to become rootstocks to be lined-out, propagation by softwood cuttings is not realistic because of their initial small size. and hence increased production time and cost before being available for budding.

On the other hand, softwood cuttings can be used to obtain insights into the likely benefits of stem-blanching and etiolation on rooting, as a way of assessing the potential of raising clonal *Tilia* rootstocks by stooling, which involves stem-blanching. Stooling will provide an alternative to the higher-technology hardwood cutting technique, and provide an opportunity for nurserymen raising apple-rootstocks by the stoolbed methods to direct their expertise to the production of clonal rootstocks for ornamental trees.

Work over a number of years with various clones of *T.* x *europaea*, *T. cordata*, and *T. platyphyllos* showed that the proximal section of a growing shoot had almost 40% higher rooting potential than the distal section, which would be conducive to basal rooting of stool shoots. *Tilia* species generally showed a beneficial response to pre-etiolation and blanching, with an overall improvement of 71% in terms of rooting percentage, and a doubling of numbers of roots per rooted cutting.

On the basis of this evidence in support of these clones being amenable to stooling the following clones were established as test stoolbeds in 1992/3 winter. The difficult-to-propagate *T. platyphyllos* 213 (see Table 6) was added to the confirmed short-listed clones to investigate whether an alternative propagation method could overcome recalcitrance.

Tilia clones established as stoolbeds 1992/3

T. europaea 6	*T. cordata* 6	*T. platyphyllos* 201
	T. cordata 21	*T. platyphyllos* 213
	T. cordata 203	*T. platyphyllos* 229
		T. platyphyllos 231

Other approaches to propagation

It was found that for clones which produced very vigorous annual shoots on the hard-pruned hedges, hardwood cuttings could be made from strong laterals to usefully increase production.

Five clones were multiplied by micropropagation and some were transplanted into the field as hedges. There was some evidence of enhanced rooting in hardwood cuttings, but the most noticeable effect was the production of remarkably straighter shoots for use as cuttings, compared to those from a conventional hedge.

Budding

Results from budding tests in 1991 (recorded winter 1992/93) and 1992 (recorded 1993/94) are presented as a comprehensive base line against which to assess earlier results. Sufficient established cuttings were available for these last two trials to test a full range of rootstocks in fully replicated and randomised experiments, but the two nurseries performed differently. The 1991 nursery, towards the east end of the Research Station, was characterised by relatively poorly growing rootstocks, some of which showed shoot die-back during the summer of budding, but which nevertheless gave virtually 100% budtake on all clones. The cause of the deficiency in rootstock growth is not understood. In contrast, rootstocks grew well in the 1992 nursery, but contrary to expectation a number of buds failed to take, averaging 15% across the experiment but ranging from 2 to 43% depending on clone. Nearby *Robinia pseudoacacia* showed serious damage from the residual herbicide Venzar and it is likely that symptomless damage occurred in these *Tilia* rootstocks. It has been reported from our earlier work that for every 1% loss of rootstock growth from residual herbicide damage 1.4% reduction in bud-take can occur in *Tilia*. The overall reduction of approximately 10% vegetative growth accompanying the overall 15% bud failure would not have been noticeable, especially in a nursery with serious herbicide damage in adjacent sensitive species.

Budding results for 1991

Six of the short-listed clones were compared, with seedling rootstocks of *T. cordata* and *T. platyphyllos* from a commercial source as controls.

A visual assessment was made of rootstock vigour and establishment prior to budding, as follows:

very vigorous and uniform:	*T. platyphyllos* seedlings
vigorous and uniform:	*T. cordata* seedlings
moderately vigorous and uniform	*T. platyphyllos* clones 201 and 231
moderately vigorous and variable	*T. cordata* 21, *T. platyphyllos* 229
least vigorous and uniform	*T. cordata* 6
least vigorous and variable	*T.* x *europaea* 6

Table 7 gives more details of pre-budding rootstock growth. Applying the appropriate LSD it can be seen that *T. platyphyllos* clone 231 established less well than all the other

Table 7. Pre-budding establishment and growth of *Tilia* rootstocks

	Establishment (%)	Stocks with die-back (%)	Stocks in vigour grades (%)		
			vigorous	medium	weak
T. x *europaea* 6	100	78	0	10	90
T. cordata 6	100	54	2	24	74
T. cordata 21	100	59	20	55	25
T. cordata seedlings	98	2	69	25	6
T. platyphyllos 201	100	14	36	48	16
T. platyphyllos 229	96	4	29	29	42
T. platyphyllos 231	88	8	25	32	43
T. platyphyllos seedlings	100	2	96	4	0
Statistical probability	5%	0.1%	0.1%	1.0%	0.1%
LSD	5.8	15.6	15.0	23.4	17.2

clones and seedlings. Die back was significantly more frequent in *T.* x *europaea* 6 than in *T. cordata* 6 and *T. cordata* 21, which in turn had more affected rootstocks than both seedling sources, and *T. platyphyllos* clones 201, 229 and 231. The pre-budding shoot vigour indicated *T. europaea* 6 to be very weak growing, with *T. platyphyllos* seedlings being the strongest and with *T. cordata* seedlings the next strongest. *T. platyphyllos* clones grew less vigorously during the budding year than both seedling sources, but more strongly than *T. cordata* clones.

The extent of differences in vigour of growth of rootstocks in the budding year were not transmitted to maiden growth the following year, with the exception of *T.* x *europaea* 6 which produced significantly smaller maidens than all other rootstocks. Although seedling rootstocks of both sources produced the tallest trees, the differences between these and trees on clonal rootstocks (except *T.* x *europaea* 6) were not significant. *T. platyphyllos* seedlings, *T. cordata* seedlings, *T. cordata* clone 21 and *T. platyphyllos* clone 201 produced the significantly thickest maiden stems (Table 8), to a large extent reflecting the production of the greatest number of laterals in the maiden year (Table 8).

The quality of trees on *T. cordata* 21 is noteworthy, and might have been improved further if the frequently occurring competing maiden stem had been removed, which was not the case in this experiment, where natural growth differences needed to be assessed. Trimming would also be required to remove low laterals; height of lowest lateral varied between 17 and 38 cm above the union, but differences were not significant (Table 9).

Table 8. Number of maidens harvested (% of stocks budded) and maiden size on the basis of height, lateral production and stem diameter.

	Maidens harvested (%)	Maiden height from union (cm)	No. of laterals per tree	Stem diameter at 0.6 m (mm)
T. x *europaea* 6	88	81	1.1	6.5
T. cordata 6	100	121	3.5	9.7
T. cordata 21	96	126	6.4	10.9
T. cordata seedlings	100	132	6.5	10.2
T. platyphyllos 201	100	127	4.4	10.6
T. platyphyllos 229	100	124	3.8	9.8
T. platyphyllos 231	98	122	3.6	8.8
T. platyphyllos seedlings	94	138	6.7	11.6
Statistical probability	5%	0.1%	0.1%	0.1%
LSD	6.8	20.7	1.4	1.4

Table 9. Frequency of maiden trees producing competing main stems, and height of lowest lateral above the union (cm).

	Competing stems (%)	Height of lowest lateral (cm)
T. x *europaea* 6	0	17
T. cordata 6	6	38
T. cordata 21	43	19
T. cordata seedlings	22	19
T. platyphyllos 201	20	26
T. platyphyllos 229	17	31
T. platyphyllos 231	12	31
T. platyphyllos seedlings	15	20
Statistical probability	0.1%	NS
LSD	15.8	19.9

An estimate of maiden tree uniformity was made by counting the number of trees whose stem diameter at 0.6 m above ground fell within the range of the overall mean diameter ± 10%, or mean diameter ± 20%. In real terms this would equate approximately with a stem between 9 and 11 mm, or 8 and 12 mm respectively.

Table 10 shows that on the basis of the ± 10% range there was only a 10% chance that clones and seedlings differed, and the LSD of 19.1 would only separate the very variable *T.* x *europaea* clone 6 from all others. Using the ± 20% range, the chance of real differences in uniformity between sources increased to 99.9%. The most uniform trees were produced on *T. platyphyllos* seedlings, but those on *T. platyphyllos* clone 201 were not significantly worse. Trees on *T. cordata* clones and seedlings were equally uniform.

Budding results for 1992

The eight clones and their seedling controls were retested, with the addition of *T. cordata* clone 203, and *T. platyphyllos* 213.

In contrast to the previous year no abnormalities were observed in rootstock growth before budding, such that overall 98.8% rootstocks were suitable for budding, with no clone having less than 96% budded. It was noted, however, that other species in the same nursery suffered to varying degrees from damage by residual herbicide, especially *Robinia pseudoacacia*.

Table 10. Frequency (%) of trees falling within a band of either the mean stem diameter (at 0.6 m above ground) ± 10%, or ± 20%.

	± 10%	± 20%
T. x *europaea* 6	14	28
T. cordata 6	42	64
T. cordata 21	31	63
T. cordata seedlings	34	62
T. platyphyllos 201	38	72
T. platyphyllos 229	25	48
T. platyphyllos 231	35	56
T. platyphyllos seedlings	40	85
Statistical probability	10%	0.1%
LSD	19.1	20.4

Bud-take was generally high and statistically similar for all clones and seedlings except *T.* x *europaea* clone 6 whose bud-take was depressed (Table 11). The failure of between 2 and 18% buds in other clones suggests that latent herbicide damage may have been responsible as discussed earlier.

Bud-take was reflected in the number of good quality maiden trees harvested, although this was reduced slightly by the production of some with multiple stems giving rise to a bushy appearance of the *T.* x *euchlora* scion. *Tilia cordata* seedlings and *T. cordata* clone 21 were worst in this respect, producing 8 and 6% rejects respectively (Table 11).

Maiden growth was usually in excess of 1 m from the union, except for the significantly smaller trees on *T.* x *europaea* clone 6, *T. cordata* clone 203 and *T. cordata* seedlings. Trees on seedling *T. platyphyllos* were not the largest, in contrast to the previous year, not did they have the thickest girths, being significantly thinner than trees on *T. platyphyllos* clone 229 (Table 11).

The number of laterals per tree reflected the major differences in tree height, and larger numbers of laterals were correlated with longer lengths of individual laterals (Table 12). In general, the more vigorous the rootstock, the more was the likelihood of competing maiden stems being produced which would normally necessitate singling early in the maiden year (but which were allowed to develop normally in these experiments so as to observe unmodified growth effects). Although in virtually all these respects trees on *T.* x *europaea* clone 6 were significantly smaller than trees on other rootstocks, surprisingly trees on *T. platyphyllos* seedlings were significantly smaller than trees on *T. cordata* clone 21 and *T. platyphyllos* clone 229 (in terms of numbers of laterals), and *T. platyphyllos* clones 213 and 229 in terms of lateral length (Table 12).

Table 11. Bud-take, maidens harvested and maiden size on the basis of maiden height and stem diameter

	Bud-take (%)	Maidens harvested (%)	Maiden height from union (cm)	Stem diameter at 0.5 m (mm)
T. x *europaea* 6	57	57	87.6	7.6
T. cordata 6	98	98	108.4	11.8
T. cordata 21	82	76	118.2	12.5
T. cordata 203	88	84	89.6	9.7
T. cordata seedlings	92	84	99.4	11.0
T. platyphyllos 201	92	92	105.0	12.2
T. platyphyllos 213	94	92	112.2	13.0
T. platyphyllos 229	94	94	113.2	13.6
T. platyphyllos 231	85	83	108.9	12.3
T. platyphyllos seedlings	84	84	107.1	11.8
Statistical probability	1%	1%	0.1%	0.1%
LSD	15.4	16.2	14.0	1.47

Table 12. Lateral production and frequency of maiden trees producing competing stems.

	No. of laterals per tree	Mean lateral length (cm)	Competing stems (%)
T. x *europaea* 6	5.2	18.5	21
T. cordata 6	8.6	31.4	57
T. cordata 21	10.3	30.9	68
T. cordata 203	7.8	26.6	83
T. cordata seedlings	9.5	31.4	60
T. platyphyllos 201	9.4	30.2	77
T. platyphyllos 213	9.1	35.6	89
T. platyphyllos 229	9.8	35.0	66
T. platyphyllos 231	9.1	29.6	50
T. platyphyllos seedlings	8.4	29.4	48
Statistical probability	0.1%	0.1%	5%
LSD	1.32	4.24	30.7

When the uniformity of trees was judged by those falling within a ± 20% range of the mean for a particular clone (a range of 4.6 mm over all clones) there were no significant differences, implying that all clones and seedling sources produced equally uniform trees of *T.* x *euchlora*.

When the more stringent ± 10% range was applied (overall range 2.35 mm) clones behaved significantly differently with *T. platyphyllos* seedlings and clones 213, 229, and 231 along with *T. cordata* clone 21 producing the most uniform stands (Table 13).

Table 13. Frequency (%) of trees falling within a band of either the mean stem diameter (at 0.5 m above ground) ± 10%, or ± 20%.

	± 10%	± 20%
T. x *europaea* 6	25.0	60.7
T. cordata 6	36.7	71.4
T. cordata 21	57.5	82.5
T. cordata 203	32.6	65.1
T. cordata seedlings	44.2	74.4
T. platyphyllos 201	40.0	77.8
T. platyphyllos 213	66.0	83.0
T. platyphyllos 229	63.8	89.4
T. platyphyllos 231	57.5	90.0
T. platyphyllos seedlings	58.5	80.5
Statistical probability	1%	NS
LSD	21.9	-

Confirmation of early good performance

The range of rootstocks tested in early budding trials was restricted to mainly *T. cordata* clones, with seedling comparisons of *T. cordata* and *T. platyphyllos*. 1990 budding tests confirmed the promising performance of *T. cordata* clone 21, which produced significantly more vigorous trees of *T.* x *euchlora* than other clones and seedling rootstocks being tested at the time (Table 14).

Maiden tree uniformity

The uniformity of maiden *T.* x *euchlora* trees is likely to be affected by the clonal or seedling rootstock on which it is budded, but might also be influenced by the actual size of rootstocks when planted, and hence the size of the population of clonal or seedling rootstocks from which the experimental sample was taken.

Table 14. Bud-take and maiden growth of *T.* x *euchlora* on a restricted range of rootstocks.

	Maidens harvested (%)	Maiden height from union (cm)	Stem diameter (mm) at 0.5 m height
T. x *europaea* 6	98	113.8	11.3
T. cordata 6	100	105.9	10.0
T. cordata 21	98	135.2	13.3
T. cordata seedlings	100	117.2	12.0
T. platyphyllos 231	98	122.1	10.0
T. platyphyllos seedlings	98	115.6	11.0
Statistical probability	NS	1%	0.1%
LSD	-	14.7	1.3

In one of the first budding trials, conducted in 1985, sufficient established cuttings of *T. cordata* clone 21 were available to enable the relatively larger plants and the relatively smaller plants to be compared as two sub-populations of that clone. The smaller rootstocks gave a lower bud-take and smaller trees, which almost reached significance level in both cases. The smaller grade of *T. cordata* clone 21 gave a significantly lower bud-take than that on seedling *T. cordata* rootstocks, whereas bud-take on the larger *T. cordata* clone 21 rootstocks was not significantly lower than that on seedlings (Table 15).

Table 15. Effects on bud-take and maiden growth of grading *T. cordata* clone 21 rootstocks into two sizes.

	Maidens harvested (%)	Maiden height from ground (cm)
T. cordata 21 (larger rootstocks)	87	145.9
T. cordata 21 (smaller rootstocks)	74	137.8
T. cordata seedlings	94	126.3
Statistical probability	5%	0.1%
LSD	14.1	9.4

<u>Testing of older trees</u>

In most commercial nurseries trees are grown-on to about four years of age, which is not cost-effective in research. However, because of the importance to growers of being able to assess the performance of mature trees, a replicated and randomised trial is being grown-on at East Malling, comprising *T.* x *euchlora* on the following rootstocks.

T. x *europaea* 6	*T. platyphyllos* 201
	T. platyphyllos 229
T. cordata 6	*T. platyphyllos* 231
T. cordata seedlings	*T. platyphyllos* seedlings

In addition, representative sets of rootstocks were supplied on two occasions to a commercial nursery for budding and growing-on for grower-assessment.

Three-year trees of *T.* x *euchlora* on *T. cordata* 21, and *T. cordata* seedlings, and on *T. platyphyllos* 231, and *T. platyphyllos* seedlings were transplanted in late spring 1994 to investigate possible effects on mature tree establishment of clonal versus seedling rootstocks.

<u>Own-root clonal material</u>

When grown unworked and pruned hard when dormant the following clones produce attractively coloured annual shoots

T. platyphyllos 201	-	red brown
T. platyphyllos 211	-	lime green with red upper portion
T. platyphyllos 213	-	dark red orange
T. platyphyllos 228	-	yellow with red upper portion

<u>Acer platanoides</u>:

The challenge presented by this species was much greater than that of *Tilia* spp. because of the greater difficulty of propagation combined with the need to select for resistance to verticillium wilt.

The initial approach was to screen a natural seedling population as for *Tilia* spp, but it became increasingly obvious that while useful variation could be identified among individual genotypes, performance fell short of commercial acceptability.

Material from the HDC programme was fed, therefore, into a MAFF-funded programme which allowed more detailed testing, and the setting-up of a second phase aimed at culturing *in vitro* any promising selections from the first phase with the hope of inducing useful somaclonal variation.

Because of the shared responsibility between sponsors this section of this report will summarise the present situation by giving relevant examples.

<u>Propagation</u>

This was found to be virtually impossible by hardwood cuttings, and even the ex-Luddington selections originally screened for propagation by hardwood cuttings proved recalcitrant, suggesting that earlier results may have benefited from juvenility.

Typically, over a number of years, the following procedures were carried out and results obtained. Approximately 75 individual ex-Luddington EHS genotypes maintained at HRI Efford (Mr. C. Burgess) were assessed each year by the East Malling team and propagated by the procedure described for *Tilia* spp. Cutting production increased over the years such that in excess of 1000 cuttings were collected in 1992/93 winter. Numbers of cuttings per genotype varied, but some produced in excess of 20, and the average was 14.3 for that year. A total of 72 cuttings (6.5%) rooted from 30 genotypes (39%) and a high proportion of these failed transplanting into the raised bed. The few that have established over a number years are being grown at East Malling.

Softwood cuttings could be propagated in wet fog with moderate success, but were difficult to wean and establish, such that no shoot growth was made in the propagation year.

The method finally adopted was to collect terminal 3-4 node cuttings as growth slowed down in early September. These were treated with 1250 ppm IBA in 50% aqueous acetone for 5 sec and rooted at 20°C bottom heat under wet fog, initially directly planted into a bed of freely draining compost comprising sand, grit, peat (1:2:1 v/v).

Cuttings dropped their leaves *in situ* as the weather became colder and the fog eventually stopped in mid-November. Thus, the problem of weaning was avoided and the dormant cuttings were lifted and cold-stored in polythene bags at +2°C. The following spring they were planted into raised beds of compost as for *Tilia* spp, and grown-on for a season before being lined-out for budding tests, or passed to the pathology group (Dr. D. Harris and D. Chambers) for verticillium wilt tests.

Because very poorly rooted cuttings often failed to survive cold storage and others failed to establish in the raised beds, the most recent tests involved direct sticking cuttings in the autumn into 7.5 x 7.5 cm containers of equal parts fine bark and peat and overwintering them in a ventilated polythene house.

Table 16 shows the range of rooting among the short-listed clones when propagated by the autumn cutting method. Overall rooting levels differed between years but there was good consistency between the rooting ability of different clones in the first two years, mirrored in the third year where appropriate clones were propagated.

Although the earlier non-replicated tests carried out when fewer cuttings were available gave less reliable comparisons the consistently good and poor performing clones identified in Table 16 confirm a number of early indications of relative performance.

On the basis of experiments which showed that rooting in *Acer platanoides* 'Crimson King' summer cuttings was increased four-fold by blanching the stem with black adhesive tape prior to collection layer beds of representative *Acer* clones were established. Preliminary tests showed *Acer* to respond well to this technique, producing layers with good fibrous roots. Clones 5, 7 and 9 are retained as layer beds, and all clones are represented by short hedges.

<u>Budding</u>

Budding tests carried out over a number of years have failed to indicate superior or inferior clones. Results appear to be governed by background conditions in the budding nursery, which are being investigated in project HNS 7a (now HNS 45).

Table 16. Rooting (%) of *Acer platanoides* cuttings (best five clones are identified*)

Clone	1991	1992	1993 (selected clones only)
1	51	32	-
2	10	0	8
3	52	18	-
5	81*	52*	-
6	92*	30	-
7	94*	58*	80
8	15	13	27
9	82*	65*	62
10	73	43*	-
11	67	38	-
12	80*	58*	50
13	43	8	32
14	62	37	63
15	70	13	-
'Crimson King'	75	12	37
Statistical probability	0.1%	0.1%	0.1%
LSD	22.1	15.8	24.5

Verticillium wilt resistance

The clones raised by cuttings as described above were subjected to assessment for verticillium wilt resistance by planting the one-year-old plants lifted from the raised bed into soil inoculated with *Verticillium dahliae*. This work was done at East Malling by Dr. D. Harris and D. Chambers and will be reported by them in the Final Report for their project HNS 29.

So that progress towards selecting a useful clonal rootstock of *Acer platanoides* can be judged in this respect for project HNS 6a, the following table illustrates progress made by Harris and Chambers in identifying relative resistance to verticillium wilt among a sample of clonal rootstocks produced in this project (Table 17).

Table 17. Level of external wilt symptoms (%) following inoculation, given as a range over two separate assessments carried out in 1991 and 1992, arranged in increasing order of susceptibility.

Clone	External symptoms %	
9	14-21	Relatively resistant
7	19-23	
5	16-57	
8	29-52	
10	53-63	
2	63-75	
15	78-100	
'Crimson King'	84-97	Highly susceptible

Comparison of Tables 16 and 17 show that clones 5, 7 and 9 propagate relatively easily and are relatively resistant to verticillium wilt. They have also been established as layer beds in the process of seeking a more commercially relevant propagation method than that offered by the late summer cutting technique.

Sorbus x *intermedia*

Following a Project Review on 25th November, 1991, industry co-ordinators proposed that the principles of selecting clonal rootstocks from among seedling populations should be tested for *S.* x *intermedia*, with the aim of seeking wide compatibility with *Sorbus* varieties, including those with compound leaves.

Accordingly, in late winters 1992 and 1993 a total of 1350 cuttings was collected from the tops of budded rootstocks on a large commercial nursery.

Growth had been relatively poor, necessitating cutting into two-year-old wood, resulting in a decision to split-wound all cuttings prior to their treatment with 2500 mg l^{-1} IBA and rooting at 20°C bottom heat as described for *Tilia* hardwood cuttings.

A number of cuttings rooted and established in the raised bed, providing a total over the two years of 94 which are now planted-out in the field to form single-genotype stockplants for further cutting tests, representing a success rate at the initial screening stage of 6.7%. These plants are being maintained under project HNS 6b.

Screening other species

As a guide to the general feasibility of screening ornamental genera for rootability as a preliminary step towards developing clonal rootstocks, seedling sources of various species were tested, showing a wide rooting response, with some equal or better than *Tilia* spp. (Table 18).

Table 18. Best rooting (%) of hardwood cuttings taken from three- to five-year-old seedling-derived stockplants.

Species	No. of sources	Highest rooting (%)
Acer negundo	2	88
Acer platanoides	11	25
Acer pseudoplatanus	21	22
Ailanthus altissima	6	100
Laburnum anagroides	7	84
Nothofagus procera	150 (3 provenances)	14
Prunus padus	5	100
Tilia cordata	32	91
Tilia platyphyllos	31	62

Rootstocks for use under ornamental trees derived from fruit rootstock research

From the same Project Review in November 1991 came the suggestion that fruit rootstock breeding and introduction programmes should be accessed to search for rootstocks of potential value in raising ornamental trees, given the success of using *Prunus avium* x *P. pseudocerasus* 'Colt' for all but the most vigorous species of ornamental cherry.

<u>*Pyrus calleryana* 'Chanticleer'</u>

A rootstock was required for *P. calleryana* 'Chanticleer' providing a more fibrous and less 'fangy' root system than that obtained on *Pyrus* seedling rootstocks, with the expectation that this will lead to improved transplanting and establishment.

In summer 1992 available rootstocks of Quince A and Quince C were test-budded with 'Chanticleer'. Although virtually all buds grew out the following spring after heading-back, there was progressive union failure through the summer, such that only 41% of trees on Quince C and 5% on Quince A were standing at the end of the maiden year. Although these surviving trees had grown well, making in excess of 1 m growth on both rootstocks, the combinations must be considered incompatible.

In parallel, during winters 1992/93 and 1993/94 a number of newly introduced or newly bred quinces were propagated by hardwood cuttings.

Of even greater relevance is that a number of clonal pear rootstocks were identified with the ability to root well from hardwood cuttings, although they have the disadvantage of producing many spines on their annual shoots which must be removed before propagation.

These quince and pear clonal rootstocks are being propagated as hardwood cuttings, established for one year on raised beds, and then lined-out for budding.

The first budding tests were done in summer 1993, and will be assessed within the maintenance project HNS 6b.

The following clones are under hardwood cutting and budding tests and have been established as stoolbeds.

Quince	**Pears**
QC	B661
QA	QR 107-2
C51	QR 517-9
C84	QR 708-2
QR 193-16	QR 708-36
QR 196-8	QR 708-63
QR 447-54	
QR 530-11	

Prunus tenella 'Fire Hill'

Some nurserymen prefer to bud this shrubby tree, so in summer 1992 existing plum rootstocks 'Pixy', 'St. Julien A' and 'Myrobalan B' were test-budded with 'Fire Hill'.

'St. Julian A' gave the highest bud-take leading to most trees being harvested, although the early bud-take on 'Pixy' appeared better, before trees failed during the summer.

Despite 'Myrobalan B' being a more vigorous rootstock trees on 'St. Julien A' grew more vigorously, (Table 19), possibly implying better compatibility with *P. insititia* ('St. Julien A') than with *P. cerasifera* ('Myrobalan B').

Table 19. Maiden growth of *P. tenella* 'Fire Hill' on clonal rootstocks.

Rootstock	Height from union (cm)	Laterals per tree	Scion diameter at 10 cm above the union
'Pixy'	59.5	0.5	7.8
'Myrobalan B'	92.5	7.8	10.5
'St. Julien A'	97.4	14.4	13.7

Bearing in mind the possibility of incompatibility, potential new rootstocks derived from 'Marianna' were tested for propagation by hardwood cuttings and are now lined-out for test-budding with 'Fire Hill', being maintained under project HNS 6b. The clone numbers are E613, E631, E632, E633.

Prunus mume

Budding tests of the *P. mume* varieties 'Albaplena', 'Alphandii' and 'Beni-shidon' on the *Prunus avium* clones F12/1 and 'Charger', and on *P. avium* x *P. pseudocerasus* 'Colt' showed *P. mume* to be completely incompatible on cherry.

Tests on the plum rootstocks 'Pixy' (*P. insititia*), 'St. Julien A' (*P. insititia*), 'Brompton' (*P. domestica*) and 'Myrobalan' (*P. ceracifera*) gave results similar to those described above for *P. tenella* 'Fire Hill'.

'St. Julien A' rootstocks, despite not being considered vigorous, were superior for all *P. mume* varieties, producing the tallest trees and fewest root suckers (Table 20).

Table 20. Maiden growth of *P. mume* (average of three varieties) on clonal rootstocks (arranged in ascending order of vigour for fruiting plums).

Rootstock	Scion growth from union (cm)	Suckers per tree
'Pixy'	160	1.3
'St. Julien A'	202	0
'Brompton'	167	0.3
'Myrobalan B'	154	3.1

Malus tschonoskii

The traditional use of *Malus* seedlings to raise ornamental crabs such as *M. tschonoskii* is declining. From time-to-time, both within and before the period of this project, small lots of apple rootstocks have been budded with *M. tschonoskii*, as a species which is often difficult to bud because it produces very thin budwood, particularly unsuitable for chip-budding. All existing clonal apple rootstocks are capable of giving 100% bud-take with *M. tschonoskii* provided they are virus-free, although when growing vigorously it is difficult to match stock and scion, and inverted T-budding should be used.

On balance, weaker rootstocks such as M.9 and M.26 give less reliable results from year to year, and the more vigorous rootstocks such as MM.106, MM.111 and M.25 are most reliable. Of these, only MM.106 is available now in commercial quantities and this should be the nurserymen's preferred rootstock. Its rapid establishment and good growth in the nursery is likely to make it suitable for most *Malus* spp, while its free rooting habit and medium vigour enables it to transplant and grow well.

Conclusions

There is sufficient natural variation in relatively small samples of tree seedlings raised routinely for the production of seedling rootstocks, to select individual genotypes with the potential to be developed as clonal rootstocks. In this respect this programme mirrors what was arguably the most important contribution to fruit production in the first part of this century, when the first clonal rootstocks were selected from naturally occurring seedlings, giving rise to many years of formalised breeding and further improvement. In the studies reported here this opportunity was demonstrated clearly for *Tilia* spp. and *Acer platanoides* although neither have yet received extensive commercial testing, and for *Acer* the challenge is greater owing to the need to combine both effective propagation and increased resistance to the soil-borne disease verticillium wilt.

The cost-effectiveness of this process must be assessed by the industry for two reasons. Firstly, different nurserymen have different attitudes towards the possible benefits of trying to emulate the advantages that clonal rootstocks have brought to fruit growing. Large businesses producing trees for the public amenity sector are likely to be most positive, because they sell by tender to specification, which requires all trees to meet the stated size and quality. Although not yet proven, there are likely to be other benefits at the interface of the HNS industry and its customers, in that relatively more fibrous root systems of clonal stocks may transplant and establish more readily than those more fangy root systems of some seedling rootstocks. In this study the search for improved pear rootstocks for *Pyrus calleryana* 'Chanticleer' is a case in point.

The second consideration relates to timescale and the extent to which the most useful natural variation has been located. Typically, a breeding programme for improved fruit rootstocks takes about 20 years, and this would appear to be the time required to select useful HONS material from natural sources. As already set out, this is because of the need to find suitable propagation techniques, improving them as required, especially for attractive but recalcitrant individual genotypes. It will be a number of years before adequate plants are available from the original single individual for replicated tests, and for moving into second phases, such as budding tests and screening for verticillium wilt, which require even more plants for sensible assessment.

The third phase requires a measure of nursery performance beyond the maiden tree year, and of establishment and longer-term growing trials equivalent to orchard performance trials in fruit, involving more than one site, and preferably commercial participation. *Tilia* was originally chosen for this investigation because in the early 1970s it was impossible to obtain sources of seed with reliable germination, and commercial rootstock production fluctuated from year to year. Improved techniques for germinating *Tilia* and other seeds have developed during the course of this research programme, reducing the general justification for seeking clonal rootstocks, but not negating the value of targeting specific deficiencies such as incompatibility with the ornamental scion, or resistance to soil-borne diseases.

This heavy commitment of resources and time needs to be seen also against the concern that in sampling relatively small sub-populations, even more valuable genetic variation is likely to have been missed. In the case of *Tilia* spp. it is therefore perhaps surprising that a relatively large number of clones, especially of the more difficult to propagate *T. platyphyllos*, are capable of propagation by hardwood cuttings (and with reasonable expectation for effective stooling). Their performance in the budding nursery is also very promising, although when attempting to assess the effect of clonal rootstocks on uniformity of maiden tree stands, it must be remembered that virtually all available clonal stocks must be used in the trials, with the inclusion of considerable variation in plant size and root systems, in comparison with commercial rootstocks produced now in very large numbers and to high quality standards, giving rise to very uniform grading. In these trials variation in size of clonal rootstocks was found to have an effect on maiden tree size, but even so some clones produced stands of equal uniformity to those on well-graded seedling rootstocks.

Adequate time must be allowed to ensure that the juvenile characteristics of seedling rootstocks do not influence clonal rootstock performance. Although phase change from juvenile to adult (mature) tree is difficult to measure, especially when severe hedge pruning removes the opportunity for flowering, 15 years would be regarded generally as adequate. Of possible greater significance is to realise that the seedling controls in these experiments had the benefit of juvenile vigour and free-rooting, and that for adult clonal material to equal them in rooting and tree growth implies that the clonal genotypes have enhanced propagation characteristics.

The long-term opportunities offered by work of this type indicate the need for a reappraisal of the role of HDC, with the implication of a long-term commitment. This might be more cost-effective if research were to carry-out the initial search for individual genotypes, encompassing more than one provenance where possible, and to develop the initial propagation method and early bulking-up. Promising material would then be transferred to the nurseries of those commercial growers interested in developing clonal stocks, so that the ongoing testing and selection was done under the conditions relevant to those interests. It is reasonable to suppose that for reasons of soil type, husbandry methods and market objectives, different initial selections might be preferred by different producers. Such a two-stage development would not only focus industry needs sharply, but also reduce R&D costs, which escalate with increasingly large trials and extensive stockplant holdings in the later stages of this type of work.

For a significant range of important HONS species which derive from fruit genera, there is the opportunity to exploit more than at present rootstocks being developed for fruit growing, especially if breeding programmes can be accessed as in this study, at a relatively early stage when genotypes with characteristics more appropriate to ornamental than fruit trees still remain among the selections. There will need to be an element of expediency in this approach, in that improvements offered via this route may not meet all requirements, but gains are nevertheless of great commercial importance.

An example is the development of the cherry rootstock *Prunus avium* x *P. pseudocerasus* 'Colt'. At the time 'Colt' was being selected parallel trials within an early stage of this HONS programme had identified a different selection 'Cob' which produced ornamental cherry trees of greater vigour and which was more suitable for stronger scion varieties such as *P. avium* 'Plena', which on 'Colt' produces an overgrowth at the union. 'Colt', however, has been widely accepted by growers because it propagates more readily than other selections, including 'Cob', and because large numbers of rootstocks became available quickly via fruit nurserymen.

In the case of the clonal pear rootstocks which are likely to be suitable for *Prunus calleryana* 'Chanticleer' their value to HONS producers may be decided ahead of any uptake for fruiting pears, and ornamental tree producers will need to make their own arrangements for propagating these novel clones.

In conclusion, unique material comprising 12 potential *Tilia* rootstocks, 26 clones of *Acer platanoides*, and a total of 19 various pear, quince and plum selections is being maintained under the small new project HNS 6b until a decision is made on the future of this type of work. In addition 94 individual genotypes of *Sorbus* x *intermedia* have also been established for easy screening. On-going budding, growing-on, and transplanting trials will be carried out under HNS 6b also.

It seems highly likely that useful new rootstocks for *Pyrus calleryana* 'Chanticleer' and *Prunus tenella* 'Fire Hill' will be developed, along with identifying existing rootstocks suitable for ornamental cherries, crabs and special trees such as *Prunus mume*. Without doubt some clonal rootstocks of *Tilia*, such as *T. cordata* clone 21, and *T. platyphyllos* clones 213, 229 and 231 are worth commercial testing, with clone 213 among four clones providing interest from coloured annual shoots when unworked.

Given an acceptable method of propagation, possibly by the layering/stooling technique currently being assessed, there is likely also to be considerable practical benefit from the relatively verticillium wilt-resistant clones no. 5, 7 and 9 of *Acer platanoides*.

References

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Within the U.K. new quince and pear clonal rootstocks (p 26) are owned by HRI and will be commercialised via the HRI Apple and Pear Breeding Club.

New 'Marianna'-related plum rootstocks E631, E632 and E633 (p 27) were bred in South Africa and the variety rights do not belong to HRI.