REASONS FOR LOW BUD-GRAFTING SUCCESS IN 'QUEEN COX' APPLE HIGH-WORKED ON 'M9' ROOTSTOCKS, AND METHODS FOR IMPROVING PRODUCTION (RELATING TO HDC HNS PROJECTS 7 & 7A)

B.H. HOWARD AND WENDY OAKLEY,
HRI-EAST MALLING

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ABSTRACT

Nurserymen have reported that 'Queen Cox' apple often produces poor stands of trees when summer bud-grafted on 'M9' rootstock.

In these studies it was found that the problem is not specific to fruiting apple trees, and it manifests itself by the scion bud not growing, or growing too late to produce a worthwhile tree, despite all graft-chips forming unions.

The problem was shown to occur only when the budding height was raised to 30 cm (12 in), associated with the removal of all shoots from the rootstock stem to give a 'clean leg' for budding.

Clear and unequivocal results showed that high budding, as a means of increasing the height of lateral branches, could be effective if rootstock shoots were removed only locally at the place where the scion bud was to be inserted.

There was further benefit from retaining these and new rootstock shoots until the end of May or early June of the maiden year, as long as the rootstock was headed-back in winter to the scion bud so that no 'stock shoots could develop above it. A noticeable effect of rootstock shoots in the second year was to suppress secondary scion buds, so reducing the need to 'single-up', and to suppress the early emergence of laterals, thus further raising lateral branch height.

To produce the highest percentage of good quality high-worked maiden 'Queen Cox' trees on 'M9' rootstocks nurserymen should retain rootstock shoots on the 'M9' stem during the budding year, and below the scion bud until maiden growth is well established in the following year.

The benefits are likely to be greatest in light sandy soils, where the problem is most frequent, accompanied by 'papery bark canker', which is also suppressed by these rootstock shoot treatments.

Subsidiary questions were not always answered with equal clarity. The late removal of rootstock shoots can lead to large pruning wounds, and variations on the time and extent of their removal were examined without conclusive results. Growers concerned over this aspect might prefer to remove all first year rootstock shoots at the time of heading back in January, and allow their replacement by new shoots below the scion until late May/early June of the maiden year, but by doing this there is some loss of tree quality compared to the retention of the same rootstock shoots into the second season.

There was some evidence that excessively large rootstock heads above the scion bud could depress maiden growth also, but partially reducing the rootstock head 3-4 weeks after budding gave small and inconsistent improvements, while breaking-over the head (brutting) was detrimental, so this type of rootstock manipulation should be avoided.

INTRODUCTION

Fruit trees are raised by bud-grafting a dormant scion bud onto a vegetatively propagated clonal rootstock during summer (budding). This is because scion varieties are often difficult to propagate on their own roots from cuttings, and the clonal rootstocks confer various advantages, including tree size control and resistance to soil-borne diseases. The aim is to produce orchards of uniformly growing trees to optimise ground cover and facilitate management. The most traditional and widely grown UK apple variety is 'Cox's Orange Pippin', of which 'Queen Cox' is a selection with improved red skin colour. 'M9' is the most popular dwarfing rootstock, which produces relatively small precocious trees that can be planted at high density to give economic returns of fruit early in the life of the orchard.

It was therefore of concern when, during the mid-1980's, certain nurserymen reported that their production of maiden 'Queen Cox' trees budded on 'M9' was unreliable, and that they often harvested only a small percentage of first-grade trees, making it difficult to fulfil orders from fruit growers.

A major production problem in apple tree nurseries was unexpected, partly because experience shows that fruit nurseries and fruit-related ornamentals are relatively problem-free compared to other ornamental species (Howard, 1992), and also because the production of apple trees had been put on a firm technical footing by the replacement of T-budding by chip-budding (Howard *et al.*, 1974).

Enquiries revealed that nurserymen were routinely budding higher than the conventional 10-15 cm (4-6 in). This was so that the laterals formed on the maiden tree (which would become the first orchard branches) would be elevated, thereby reducing the risk of the first crops being spoiled by contact with the soil as branches bent under the weight of fruit. Budding height was often raised to 30 cm (12 in) or more.

Observations on nurseries showed that the problem fell into one of the two categories described for ornamental trees (Howard, 1992) where either the chip fails to unite with the rootstock, or the chip forms a union but the scion bud fails to grow, or fails to grow soon enough in the maiden year to make a saleable tree.

Failures of high-worked 'Queen Cox' on 'M9' rootstocks were of the second type, where the chip healed-on but the scion bud failed to grow. In this respect it is similar to *Betula pendula* 'Dalecarlica'.

Fruit tree nurserymen are levy-paying members of the HDC HNS Sector, and so this problem with 'Queen Cox' on 'M9' rootstocks was incorporated into a series of otherwise mainly ornamental tree budding experiments.

Five experiments, each taking two years to complete, were carried out between 1987/8 and 1991/2. Although experiments overlapped, the general outcome of one experiment could be assessed in early summer before treatments for the next one were finally decided upon, thus ensuring the maximum rate of progress.

The first step was to discover the cause of 'poor bud-take', followed by the development of new nursery practices to improve tree production.

METHODOLOGY

Nursery

The fields used in these trials at East Malling were generally of a light sandy loam soil and those in the earlier experiments were particularly sandy and stony. All land was fumigated with chloropicrin in the autumn prior to planting rootstocks in the following February.

'M9' rootstocks were of virus-free (EMLA) status, planted in double rows at 0.4 m in-row spacing, with 0.8 m between rows. Shoots were encouraged to grow on the rootstock stem once it was found that their retention or removal was part of the experimental structure.

Scionwood was taken from EMLA status 'Queen Cox' mother trees.

All budding was done by the same person in early to mid-August by the chip-method, with the chip-buds covered by 25 mm wide polythene ties, which were removed after four weeks.

Rootstocks were headed-back to the scion bud during the following January. Additional treatments relating to the partial or complete removal of rootstock shoots in the budding year, and those developing below the scion bud in the maiden year, are described in the experimental results section.

Experimental layout and recording

Experimental treatments were applied along the rootstock rows in plots, usually of 10 rootstocks, which comprised the basic treatment unit in most years. These plots were replicated (usually five times) and randomised (fully randomised blocks) so as to reduce the effects of any variation inherent in the nursery.

The main records taken each year included various aspects of rootstock growth, bud-take in early summer, the percentage of maidens finally harvested, maiden growth above the union (to avoid effects of different budding heights), number and length of laterals, the height of the lowest lateral, the frequency with which secondary scion buds developed (necessitating singling the maiden stem) and the development of 'papery bark canker'. 'Papery bark canker' is a physiological disorder in which a putative hormonal imbalance stimulates callus to erupt under the bark, which then splits, allowing the internal tissues to desiccate and collapse. 'M9' rootstock is particularly prone to this disorder when the scion fails to grow vigorously.

Data were examined by the appropriate statistical analysis. In 1987-88, 1988-89 and 1991-92 the treatment replication was found to be just sufficient to accommodate the inherent

variation contributed by rootstocks, soil and management, and which masks the effects of treatments. Where treatments were significantly different the level of probability was usually between 1% and 5%. This indicates that there was only a 1% or 5% likelihood that the differences occurred by chance, and hence it is assumed that they are real differences. In 1989-90 and 1990-91 the replication was more than adequate for the conditions, and virtually all differences were at the 0.1% probability level, indicating that there was only a one per thousand possibility that treatment differences were obtained by chance, and underlining the clear effects obtained.

In the tables given in the Results section the treatment values which are significantly the best or worst are shown in bold type. However, for the purpose of this report a detailed statistical comparison between all treatments is not presented. While treatment differences may be significant because of very consistent results, the magnitude of the differences may be quite small. Production differences of 5-10%, or growth differences of 10 cm (4 in) are of little practical consequence when set against the major trends shown in these studies.

In experiments relating to tables 3 and 5 a few treatments and their results are not described in detail because they add nothing to the overall trends.

RESULTS

Experiment 1, 1987-88 : Effects of raising the budding height

The object was to see whether raising the budding height reduced the percentage of marketable trees, and whether this was a general phenomenon not specifically related to 'Queen Cox'.

'M9' rootstocks with all stem shoots removed to give a clean leg of 35 cm (14 in) were budded at 7.5 cm (3 in), 19 cm (7.5 in) and 30 cm (12 in), with either 'Queen Cox', or *Malus tschonoskii*. The site chosen was a particularly light sandy and stony soil, where budding problems had been experienced previously. Results for both scions are shown in table 1.

For 'Queen Cox' budding at 30 cm (treatment 3) halved the number of maiden trees produced compared to lower budding, and most rootstocks with failed buds and others with poorly growing scions, developed 'papery bark canker'. Although the intermediate budding height of 19 cm (treatment 2) gave a similar number of trees as at the lowest budding height of 7.5 cm (treatment 1), those budded at 19 cm were of a poorer quality and more developed 'papery bark canker'. With increasing budding height there was a consistent but small and non-significant reduction in maiden height, which was compensated by a small but non-significant increase in number of laterals.

Malus tschonoskii showed almost identical trends to 'Queen Cox', except that the reduction in the number of maidens harvested was relatively more serious at the intermediate budding height (treatment 5), which was almost as bad as that at the highest budding height (treatment 6). Failure of maidens to grow was associated with similar high frequency of

'papery bark canker' (treatment 6). *M. tschonoskii* is a weaker tree than 'Queen Cox' and this was reflected in a significantly reduced maiden height from the union in the highest budding treatment (6).

Interim conclusion

Increased height of budding is the cause of reduced maiden tree production on 'M9' rootstock, and is a problem of both fruiting and ornamental species. The main problem is that although the chip heals onto the rootstock the scion bud either fails to grow, or grows late and makes a weak maiden. In extreme cases the number of weak maidens depresses the average tree size at the highest budding height, but this is compensated for by the greater height of the union above the ground.

Table 1 - Effects of budding height on tree production using 'M9' rootstocks, 1987-8

	'Queen Cox'			*M. tschonoskii*		
Treatment	1	2	3	4	5	6
Budding height (cm)	7.5	19.0	30.0	7.5	19.0	30.0
Maidens harvested as % of 'stocks budded	88	88	**42**	83	59	**50**
% 'stocks with papery bark	3	18	**58**	0	23	**50**
Height of maiden growth from union (cm)	109	103	98	81	78	**52**
No. of laterals per tree	6.2	6.8	7.8	1.5	1.0	2.3

Within each measurement for each variety the value in bold type indicates that that treatment is significantly worse than one or both of the other treatments.

Experiment 2, 1988-89: Reasons for the detrimental high-budding effect

The object was to discover the reason why raising the budding height depressed the production of maiden trees by preventing scion buds from developing. It was noted that nurserymen removed shoots from the rootstock stem below the crown to give a 'clean leg', and that this extended to 35 cm (14 in) when budding was raised to 30 cm (12 in).

The possibility that this relatively long leafless stem contributed to the problem was investigated by budding 'Queen Cox' at the same three heights as in 1987 (7.5, 19.0 and 30.0 cm) on 'M9' rootstocks which either had all stem shoots removed to 35 cm as normal for high-budded trees (clean leg), or with rootstock shoots removed only at the position

where the chip-bud was to be inserted (local cleaning). Because this basic experimental structure applies with variations to later experiments the treatments are depicted in Figure 1.

Rootstocks were headed-back to the scion bud during January 1989, and rootstock shoots from the stem below the scion bud were removed in mid-May. Results are given in table 2.

Maidens grew away in greatest numbers in the high budding treatment on the locally cleaned rootstocks (treatment 6), and this was reflected in the largest percentage of maidens being harvested from this treatment, followed closely by those from the intermediate budding height, also on locally cleaned rootstocks (treatment 5).

Again, the fewest maiden trees were produced at the highest budding height on rootstocks with all stem-shoots removed to 35 cm (treatment 3), and these remaining trees were of such poor quality that maiden height, number and length of laterals were also depressed, but growth differences failed to reach significance because of limited replication of rather variable material.

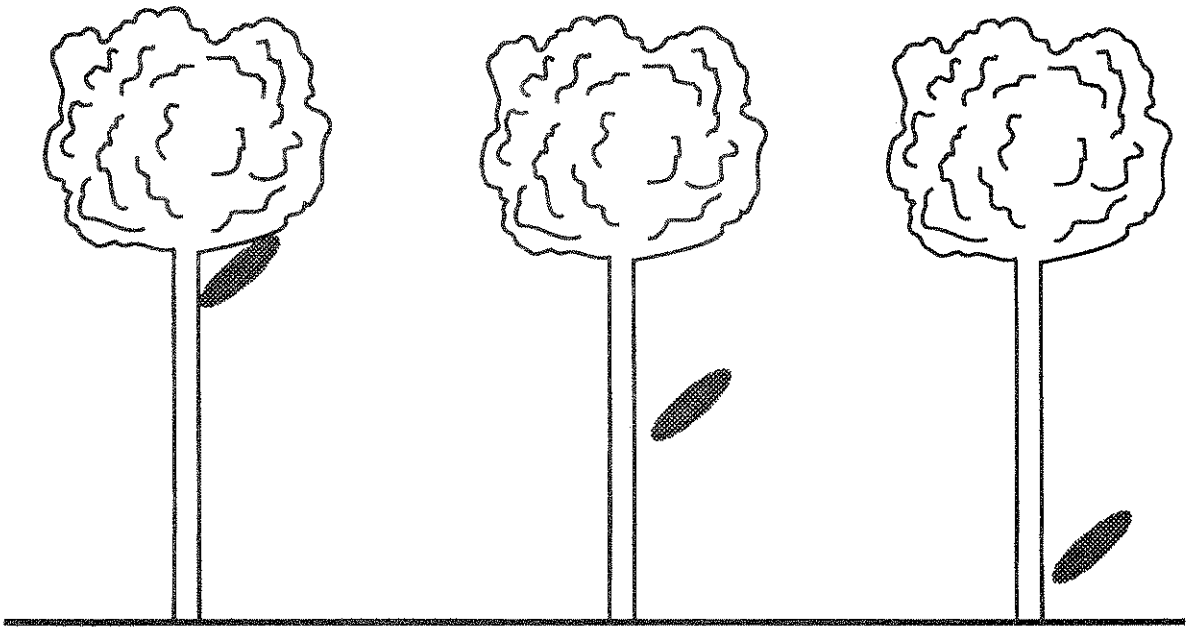
In this year low and intermediate budding of high-cleaned rootstocks (treatments 1 and 2), and low-budded locally cleaned rootstocks (treatment 4) gave poor results also, emphasising the benefits of local shoot removal for medium and high budding (treatments 5 and 6).

Table 2 - Effects of budding height and rootstock shoot removal on tree production of 'Queen Cox' on 'M9' rootstock, 1988-9.

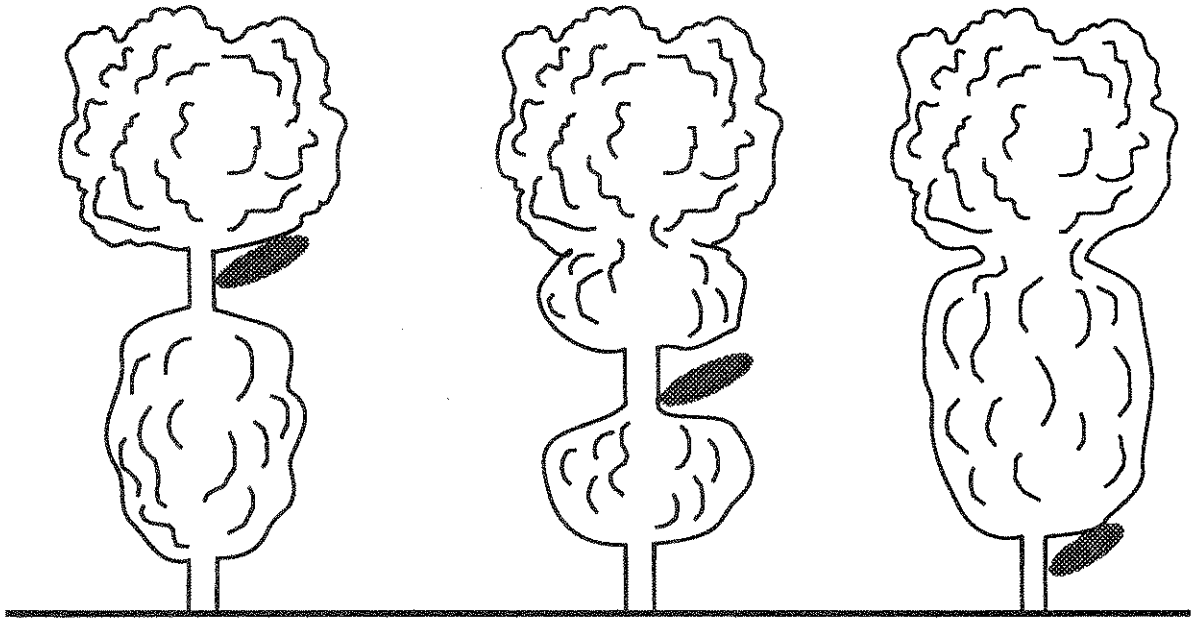
Treatment	1	2	3	4	5	6
Rootstock shoots on stem:	Removed to 35 cm			Removed locally at budding height		
Budding height (cm):	7.5	19.0	30.0	7.5	19.0	30.0
Maidens growing in mid-May as % 'stocks budded	42	24	3	34	48	**61**
Maidens harvested as % 'stocks budded	48	48	33	39	82	**84**
Height of maiden growth from union (cm)	96	97	85	100	95	95
Number of laterals per tree	12.0	11.6	5.4	13.3	11.9	13.1
Length of lateral (cm)	30.3	26.7	19.6	28.6	29.5	28.8

Within each measurement the value in bold type is significantly better than one or more of the other values.

Figure 1. Diagram of treatments in experiment 2



High, medium or low budding on rootstocks with all shoots removed on the stem to give a clean leg.



High, medium or low budding on rootstocks with stem shoots removed only at the position of budding

Interim conclusion

Failure of 'Queen Cox' to grow in the maiden year is because nurserymen remove all shoots from the stem of the rootstock when raising the budding height. If shoots are retained on the rootstock stem and removed only at the budding location a good production of high quality trees results from high budding. Trees in this experiment budded at 30 cm on locally cleaned stems gave 84% success, with a mean tree height above ground of 1.25 m, and 13 laterals per tree, each with an average length of 29 cm.

Experiment 3, 1989-90: Further investigations of the benefits of retaining rootstock shoots

The objective was to confirm the results of the previous year in a very highly replicated experiment.

The following treatments were applied to 45 single-plant replicates of each treatment in randomised blocks, which enabled treatment differences to be further accentuated by selecting rootstocks with well-furnished stems for local shoot removal, and sparsely furnished stems for total rootstock shoot removal up to 35 cm.

1. Rootstock shoots removed to 35 cm, with budding at 7.5 cm.

2. Rootstock shoots removed to 35 cm, with budding at 30 cm.

3. Rootstock shoots removed locally at the height of budding, with budding at 7.5 cm.

4. Rootstock shoots removed locally at the height of budding, with budding at 30 cm.

All rootstock shoots were finally removed in the following June and results are given in table 3.

Maiden trees grew away slowly in treatments 1 and 2, where rootstock shoots were removed to 35 cm regardless of budding height, and this was reflected in a reduced harvest, especially of the higher budded trees.

Both treatments where shoots on the rootstock stem were removed only at the height of budding gave good stands of equally good quality trees, with the high-budded ones (treatment 4) growing over 1.5 m tall (above ground level) with 14 laterals, 44 cm long on average. Again, so many of the high-budded trees with rootstock shoots removed to 35 cm to give a clean leg were of such poor quality that their average height, and number and length of laterals, were significantly depressed.

Table 3 - Effects of budding height and rootstock shoot removal on tree production of 'Queen Cox' on 'M9' rootstock, 1989-90

Treatment	1	2	3	4
Rootstock shoots on stem:	Removed to 35 cm		Removed locally at budding height	
Budding height (cm):	7.5	30.0	7.5	30.0
Maidens growing in mid-June as % 'stocks budded	**56**	**47**	80	82
Maidens harvested as % 'stocks budded	**61**	**42**	78	88
Height of maiden growth from union (cm)	127	**114**	134	133
Number of laterals per tree	12.2	**8.7**	16.1	14.1
Length of lateral (cm)	40.3	**36.4**	44.0	44.4

For each type of measurement the value(s) in heavy type is significantly worse than others

By this time there was slight evidence that apical dominance might suppress the scion bud after low budding beneath a rootstock top increased in size by shoots on the stem. This was tested by reducing the size of the rootstock top four weeks after budding in additional treatments, but results were virtually identical to those in treatments 3 and 4.

In an ancillary trial the possibility of assisting maiden growth the following year by breaking (but not totally removing) the rootstock head above the scion bud in autumn (brutting) was investigated as a drastic way of removing apical dominance. A high proportion of scion buds began to grow after brutting, but many failed to continue to grow the following year and production was seriously depressed, so this is not recommended.

Interim conclusion

The detrimental effect of removing all shoots from the stem of the rootstock was confirmed at two budding heights, underlining rootstock shoot removal as the cause of poor production of 'Queen Cox' high-worked on 'M9'.

Good stands of excellent quality trees were produced by budding at 30 cm with rootstock shoots removed only at that location on the stem.

Experiment 4, 1990-91: Retaining rootstock shoots in the maiden year

The value of retaining shoots on the stem of the rootstock during the budding year has been shown clearly. The question now arises as to whether their presence is of any benefit during the early part of the maiden year. In experiments described so far the rootstock top was headed-back in January to the scion bud, and existing and new rootstock shoots developing below the scion were finally removed in May or early June, once maiden growth was well-established. The late removal of these woody rootstock shoots carried over from the previous year caused between five and seven noticeable pruning wounds, underlining the need to identify the best time for their removal. The possibility that earlier reduction of the rootstock head after budding would promote earlier maiden growth was re-examined by reducing crown shoots by a third in length three weeks after budding.

In this experiment all budding of 'Queen Cox' on 'M9' was done at a height of 30 cm. Rootstocks were treated as follows:-

1. All stem shoots were removed to 35 cm in the budding year and shoots in the crown of the rootstock were reduced in length by one third three weeks after budding. In the maiden year all shoots were removed regularly.

2. Rootstock shoots were removed only locally at 30 cm height in the budding year, and shoots in the crown of the rootstock were reduced in length by one third three weeks after budding. Shoots were then retained until early June in the maiden year.

3. All stem-shoots were removed to 35 cm in the budding year, and continually removed in the maiden year.

4. Rootstock shoots were removed only locally at 30 cm. After heading-back existing and new shoots were retained until mid-June of the maiden year.

5. Rootstock shoots were removed only at 30 cm height in the budding year, and continually removed in the maiden year.

6. Rootstock shoots were removed only at 30 cm height in the budding year, and retained until mid-June of the maiden year, but the tips of these and most new rootstock shoots were removed as scion growth started.

Results are shown in table 4.

There were no tree losses in treatments 2, 4, 5 and 6, where rootstock shoots were retained in the budding year and removed only where the chip-bud was inserted. Losses associated with removing all shoots from the stems of rootstocks during the budding year (treatment 3) were reduced if the shoots in the crown were pruned after budding (treatment 1) and this treatment was not significantly poorer than treatments 2, 4, 5 and 6.

Table 4 - Effects of rootstock shoot treatments on tree production of 'Queen Cox' budded on 'M9' rootstocks at 30 cm height, 1990-91

Rootstock treatments	1	2	3	4	5	6
Before budding:	Removed to 35 cm	Removed locally at 30 cm	Removed to 35 cm	Removed locally at 30 cm	Removed locally at 30 cm	Removed locally at 30 cm
After budding:	Crown shoots tipped back	Crown shoots tipped back	-	-	-	-
In maiden year:	All shoots removed regularly	Shoots retained until June	All shoots removed regularly	Shoots retained until June	All shoots removed regularly	Shoot tips only removed regularly
Maidens harvested as % of 'stocks budded	95	100	**86**	100	100	100
Maidens needing scion buds to be singled as % of 'stocks budded	12.5	0	**23.9**	2.5	7.5	12.5
Maiden height from union in June (cm)	**16.6**	38.6	**10.1**	36.6	32.9	33.1
Maiden height from union when harvested (cm)	**128**	156	**121**	158	154	155
No. of laterals per tree	13.1	14.8	**8.7**	16.4	19.4	16.4
Length of lateral (cm)	22.7	26.3	**15.4**	27.3	30.8	28.5
Height of lowest lateral from union (cm)	**11.4**	27.0	16.4	18.8	**10.1**	16.6

For each type of measurement the value(s) in heavy type denotes the treatment(s) which is significantly worse than others

Maiden height was depressed by total removal of 'stock shoots to a height of 35 cm in the budding year, but slightly less so if shoots in the crown were reduced in length after budding. There was little to choose in terms of maiden height among treatments which had rootstock shoots removed only locally at the budding location, irrespective of whether they were retained or removed during the early period of maiden growth the following year.

The most noticeable effect of retaining rootstock shoots below the scion bud in the early months of the maiden year was that the first laterals on the scion itself were suppressed, and so when these eventually emerged they were higher above ground than normal.

A new phenomenon was noted this year. Where the treatment encouraged vigorous scion growth from the main bud on the chip few, if any, subordinate scion shoots needed to be removed. Where scion growth was weaker these secondary buds developed, necessitating their removal in 'singling-up' the maiden. Twenty four percent of scions required singling-up where rootstock shoots were removed to 35 cm, and not allowed to re-grow in the maiden year (3).

Interim summary

The main value of retaining rootstock shoots in the budding year is to allow more scion buds to grow into good quality maiden trees. Their presence in the early months of the maiden year appears to prevent the scion from producing multiple scion shoots and laterals low down on the stem.

Experiment 5, 1991-92: Alternative strategies for managing rootstock shoots

Further variations in the way that shoots on the stem of the rootstock could be managed were tested, especially with a view to avoiding the carry-over of large shoots from the budding year leading to large pruning wounds when they were finally removed at the end of May in the maiden year.

Treatments were as follows, with all rootstocks budded at 30 cm.

1. Rootstock shoots were removed only locally at 30 cm in the budding year, those below the scion bud were retained at heading back in early February, and both old and new rootstock shoots were retained below the scion bud until late May (= maximum benefit from rootstock shoots, but large pruning wounds).

2. Rootstock shoots were removed only locally at 30 cm in the budding year. All existing ones were removed at deheading, but new ones were allowed to grow in the maiden year until the end of May (= maximum benefit of rootstock shoots during budding, and some benefit in the maiden year, but no large pruning wounds).

3. Rootstock shoots were removed to 35 cm in the budding year, and regularly in the maiden year (= no benefit from rootstock shoots in either year, and no pruning wounds).

For the first time in this series of experiments a few chips failed to take and treatment differences were not as large as previously. These effects may have resulted from the repeated use of herbicides to control a weed problem exacerbated by the mild winter. Results are shown in table 5.

Tree production was close to 90% for all treatments when assessed on the basis of the number of stocks budded and in excess of 90% on the basis of chips that formed unions, with 95% in treatment 1.

The largest maiden trees were produced in treatment 1., where all rootstock shoots were present in both years, and the smallest trees were produced in treatment 3., where they were absent in both years. Intermediate values were obtained where rootstock shoots present in the budding year were replaced by new ones in the maiden year (treatment 2). There were few outstandingly poor trees, so differences are due to overall effects on the majority of trees in each treatment.

The most laterals were produced in treatment 1., and in particular, they began to emerge at the greatest height above ground in this treatment also. Treatments in which rootstock shoots were present only in the budding year, or only in the first part of the maiden year in limited numbers, gave results similar to treatment 2, and are not shown.

The frequency of 'papery bark canker' and multiple scion shoots was least in treatment 1., but in no case did either problem exceed 9%.

Interim conclusion

In this year treatment differences were small, but where trends existed they were in favour of the previous best treatment of retaining shoots on the stem of the rootstock in both the budding year, and early in the maiden year. It was again clear that the rootstock shoots present at the beginning of the maiden year depressed the emergence of low laterals on the scion, thus raising the height of laterals without any reduction in numbers of laterals per tree.

Table 5 - Effects on tree production of season of shoot removal from the stems of 'M9' rootstocks, budded at 30 cm with 'Queen Cox'

Rootstock treatments	1.	2.	3.
Before budding:	Removed locally at 30 cm	Removed locally at 30 cm	Removed to 35 cm
At deheading:	Retained	Removed	-
In maiden year:	Old & new shoots retained until end of May	New shoots allowed to grow until end of May	New shoots removed regularly
Maidens harvested as % of 'stocks budded	87	88	90
Height of maiden growth from union (cm)	**128**	120	118
No. of laterals per tree	16.1	13.2	14.2
Length of lateral (cm)	33.3	32.7	29.8
Height of lowest lateral from union (cm)	**16.9**	12.2	7.4

Within each measurement the value in bold type is significantly better than one or more of the other values.

OVERALL CONCLUSIONS

In reaching these conclusions the favourable experiences of nurserymen who tested these treatments in conjunction with the East Malling trials are also taken into account.

There is a problem in nurseries on light sandy soils in which the production of 'Queen Cox' is depressed when budded on the popular 'M9' rootstock.

Usually, all chips form unions, but scion buds fail to grow, or they grow late and fail to make useful maidens. This is associated generally with high working at 30 cm (12 in) above ground, and specifically with the removal of rootstock shoots to a height of 35 cm to give a clean leg for budding.

The problem can be overcome by only removing shoots from the stem of the rootstock locally at the place of budding, and further benefits arise from retaining rootstock shoots **below** the scion bud until the end of May/early June of the maiden year.

Responses to improved management of rootstock shoots are varied between years. In some cases significant increases were obtained in the percentage of trees harvested

(e.g. 1988-89 - table 2, and 1989-90 - table 3), whereas in years when overall maiden tree production approached 100% of rootstocks budded, the benefits were seen in terms of tree quality (e.g. 1990-91 - table 4, and 1991-92 - table 5). Sometimes these improvements from retaining rootstock shoots were small for any one feature of the tree, but often combined so that the largest trees with highest laterals were produced when rootstock shoots were retained in both years. Treatments that benefitted tree production reduced the frequency and severity of 'papery bark canker'.

Some, but not all, nurserymen are concerned at the relatively large pruning wounds made when removing two-year woody shoots below the union in early June of the maiden year. These are unavoidable if the maximum benefit of retaining rootstock shoots is to be obtained, but the second best approach is to remove the budding-year shoots at the time of winter heading-back, and allow new ones to develop during the spring and early summer. Under no account should rootstock shoots be allowed to develop above the developing maiden tree, otherwise the scion will be forced away from the vertical, and its growth will be depressed.

Nurserymen producing trees on light sandy soil, who experience tree losses and 'papery bark canker' on 'M9' rootstocks high budded at 30 cm, should not remove rootstock shoots from the entire stem, but only at the budding position. The best quality trees in terms of maiden height and the height of laterals, result from retaining these and new rootstock shoots below the scion-bud until late May/early June of the maiden year.

Work with *Malus tschonoskii* shows that these results apply beyond 'Queen Cox', although it is accepted that nurserymen will not normally high-work ornamental species.

The practical value of these findings is underlined by the fact that these clear and consistent effects were obtained despite typical variation among rootstocks in terms of number and position of shoots on the stems when setting-up treatments in the budding year, and their variable and continuing emergence in the maiden year, making it difficult to ensure their permanent removal in relevant treatments.

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References

Howard, B.H., Skene, D.S., and Coles, J.S. (1974). The effects of different grafting methods upon the development of one-year-old nursery apple trees. *Journal of Horticultural Science*, **49**, 287-95.

Howard, B.H. (1992). An analysis of why bud-grafting gives poor and inconsistent results for many ornamental trees. *HDC Report*, pp. 24.