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PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

This project has identified that 'tipping back' and 'topping' cultural practices are of limited use or in some cases no benefit, for improving final grade-out of rose bushes through improving basal shoot production. However, tipping back may, in some cases, reduce 'blow out' damage in susceptible cultivars. This information should help growers save costs on a labour intensive cultural practice by not using it, or limiting its use to certain cultivars only.

Careful and timely use of a growth regulator, Ethrel C, looks very promising for improving basal shoot numbers in 'shy' basal breaking cultivars. This will be valuable for improving the grade-out and profitability of growing these cultivars.

Background and objectives

The project was aimed at increasing our understanding of the effects of 'tipping back' or pruning shoots of field roses in the maiden production year, on basal branching, flowering, 'blow-out' and final grade-out. This practice is commonly adopted in the industry to help reduce wind damage ('blow-out') to young bushes before the bud union has fully strengthened, and in the belief that basal shoot development, and hence final quality, of shy breaking cultivars will be enhanced. The application of this technique (severity, frequency and timing of the operation) vary within the industry. Some growers do not practice it at all, and some on certain cultivars only. However, there was both a limited understanding of the physiological principles involved and little previous applied research upon which to base practical recommendations.

This project studied the effects of a range of practical 'tipping back' and 'topping' treatments in the field with the aim of providing practical guidance for growers. It also investigated aspects of endogenous plant growth regulator (PGR) control, which might affect basal shoot growth differently in shy and freely basal breaking cultivars. The PGR physiology studies also provided the basis for investigating some experimental synthetic PGR treatments for improving basal break development. A commercially available growth regulator, Ethrel C, was also looked at later in the project.

Summary of results and conclusions

Field experiments on 'tipping back'

Rosa *Laxa* rootstocks were budded in summer 1998 and 1999 to provide plants for experiments in 1999 and 2000 respectively to examine tipping back and topping treatments. The 'shy' breaking cultivars Margaret Merril and Silver Wedding were compared with the cultivar Remember Me, which produces basal shoots more freely. Treatments over the two years involved tipping back primary shoots after rootstocks were headed back, at nominal stages of growth from 6 cm to 30 cm

shoot height. In the first year some were pinched back to a 4 cm 'stub' to see whether this would leave more sites for subsequent shoot development, while others were pruned back hard (nominal 1 cm). Control plots of unpinched plants were also monitored. In the second year, early and late 'topping' treatments (mid May and mid July) were also examined where the first flush of growth was topped at a height of about 350 mm simulating a mechanical hedge trimming operation. The hypothesis was that the initial flush of growth would be preserved, but that (at least with the early topping) the top heavy shoot and flower growth would be removed early enough to reduce blow out damage, and that subsequent basal shoot development would not be affected or even enhanced.

The response to tipping back treatments varied slightly between years and for cultivars. It could increase final shoot numbers slightly by up to 20%, but was not consistent. Often, this was at the expense of shoot diameter so that the number of thick shoots (over 10 mm dia.) were reduced, particularly when tipping back was done at a stage later than 200 mm shoot height. Tipping back to a 4 cm stub was no better than hard tipping back.

Tipping back could also reduce blow out damage, but, again, this was not consistent and it did not eliminate the problem. Later tipping back was more effective than earlier, as some later produced shoots on early tipped plants still suffered blow out damage. More plants of Remember Me lost shoots to blow out than the other cultivars, but this cultivar was vigorous enough to regenerate some lost shoots in the late summer growth flush, and thus tipping back did not benefit final grade-out.

Topping treatments, were not effective in either reducing blow out, or improving final plant quality over untreated plants in our one years experience with this at Efford.

A proportion of plants prematurely 'shot bud' in the summer and autumn of the budding year. These were not selected for the main experiments, but in the project's second year, shot bud plants were monitored separately. Shot bud plants produced marginally more basal shoots than non-shot bud plants, but appeared to be as susceptible to blow out.

In a separate experiment, budsticks of different stages of maturity and position (branched or basal from mother plants) were collected from each cultivar above. The buds were numbered sequentially basipetally from the first usable bud below the inflorescence and budded onto *Laxa* rootstocks in 1999. This was to test the theory that topophysic effects, that is position of buds on the parent plant, can influence subsequent growth and development after propagation, as had been suggested by some growers. Bud position and budstick origin did not have any significant effects on growth or blow-out in this experiment and thus there was no evidence to support altering current practices of budwood collection or use.

Finally, ethephon (as Ethrel C, Hortichem Ltd), was sprayed onto the cultivars Margaret Merril and Remember Me to test its potential for improving basal shoot production in field roses. Its use was originally developed in the early 1970's for glasshouse cut rose production, but there is virtually no

glasshouse cut rose production now in the UK. Ethrel C sprays were applied both to budded rootstock tops in mid October 2000 and as a directed spray to the lower 200 mm of basal scion shoots at the end of the first flush of growth in late June 2001. Concentrations of 0.75% and 1.5% product were compared with an untreated control. Agral wetter was added at 0.1%. The summer application of Ethrel C at both rates increased final basal shoot number significantly on Margaret Merril by almost 60% from 2.9 shoots per plant (≥ 6 mm thick) on the control treatment to a mean of 4.5 shoots per plant on the sprayed plants. There was also some response from autumn sprays to rootstocks with Margaret Merril, but it wasn't as effective as applications to the scion growth in the summer. The summer spray of Ethrel C also increased shoot numbers in Remember Me. As Ethrel will scorch soft tissue and causes defoliation, correct timing and targeting of sprays is important to avoid damage to flushes of primary or secondary basal shoot growth.

Physiological studies on the role of endogenous plant hormones

Basal shoots of the three cultivars growing at Efford, at different stages of growth, were sampled, and their endogenous plant growth regulators analysed at HRI East Malling. Both concentrations of auxin and ABA present in shoot tips, and the amounts diffused in the phloem sap, were extracted and diffusates collected, and analysed by gas chromatography-mass spectometry (GC-MS). Rates of auxin transport were also measured from shoot tips (where auxin production is high) towards shoot bases, in the 'polar transport stream' (i.e. from cell to cell and not via the phloem). This was to examine how auxin movement might be influencing shoot growth through 'apical dominance' effects. Auxin, ABA and cytokinins concentrations in shoot bases, near where new basal shoots are formed, were also determined at different shoot growth stages. Some synthetic PGR's were sprayed onto field grown plants of the three cultivars to test their potential for stimulating basal shoots. Finally, buds from parallel sets of budsticks as used in the position of bud experiment were also analysed for endogenous PGR's to examine possible correlations with subsequent growth.

The physiological studies did show differences between cultivars in their capacity to transport auxin, and this may influence the release of dormant buds and the emergence of basal breaks. However, more knowledge is needed about the timing of initiation and development of these buds to draw further conclusions. Results indicated that a simple 'apical dominance' model involving auxin alone was insufficient to explain how basal shoots develop, and that interactions with the other PGR's are important. There was some suggestion that externally applied BAP (a synthetic cytokinin), might stimulate shoot production, but field factors such as exposure to rain and sun at that time probably reduced its effectiveness, and the treatment did not improve basal breaks.

Action points for growers

- Do not practice tipping back or topping treatments with the primary aim of improving basal shoot production. Carefully timed tipping back (e.g. at about a 15 cm shoot growth stage), may reduce blow out damage, but possibly at the expense of thick basal shoot production. Tipping back, if done, is best targeted at blow out susceptible cultivars that are also shy to produce basal breaks. Vigorous cultivars, such as Remember Me, may cope with losing some shoots to blow out without sacrificing quality by the end of the season.

- Consider providing artificial or living windbreaks, if this can be done economically, and siting susceptible cultivars close to them to reduce blow outs.

- Use of Ethrel C sprays, at a cost of <4 p / plant, may be both a less expensive and more effective way of improving grade-out of weaker cultivars than labour intensive tipping treatments.

- Use the guidelines in this report and follow label recommendations for dose rate if wishing to trial Ethrel C. Use on outdoor bush roses is at grower's risk, and small areas should be tested first to check cultivars for possible phytotoxicity.

Anticipated practical and financial benefits

As tipping back is a labour intensive operation, the project has shown that cost savings can be made by not tipping back cultivars as a matter of course, as benefits are likely to be slight or non-existent for many of them.

The national average Class 1 rose grade-out is about 60% of rootstocks planted. If subsequent experience shows that Ethrel C works across a wide range of cultivars, then it could be of serious benefit to improving the grade-out and profitability of weaker growing cultivars, which otherwise have good agronomic characteristics.

SCIENCE SECTION

INTRODUCTION

Background

Bush roses are produced on a two-year cycle. The first year seedling rootstocks are planted in spring, followed by budding with the scion cultivars in the summer. The rootstock tops are pruned off ('headed back') the following winter, and the scion cultivar bushes develop during the second year. Plants need to have developed at least 3 strong basal shoots or 'breaks' by the autumn of that second year before they are undercut and lifted as Class 1 plants. They are then either marketed as bare root or root wrapped plants, cold stored, or containerised for selling later that autumn or the following spring / summer in flower. 'Tipping back' refers to the practice of pinching or pruning the first flush of shoot growth that develops from the scion bud after heading back the rootstocks. This is done by growers in the belief that it can help reduce these shoots from 'blowing out' i.e. breaking off at the bud union in the wind before the union has time to develop full strength. This typically happens in late May and June following vigorous spring growth, and when shoots begin to develop flowers and become top heavy. Tipping back is also done in the belief that it helps encourage more basal breaks to develop, and is therefore often practiced on 'shy to break' cultivars which otherwise tend to have a large proportion of single or twin shooted plants by the end of the year.

Tipping back is a time consuming operation and frequently fields have to be worked over several times to catch all the single shoot plants. First flush development from headed back plants is typically very variable both in timing of development, and in the number of shoots which grow most strongly in the first growth flush. Although only a single leaf axillary scion bud is inserted into rootstocks, secondary buds or bud initials are often present at budding. Frequently the following year, these develop either during the first flush or later in the season. Other new adventitous scion buds also develop from the bud shield and general callus and tissue which continues to develop as the bud union and rootstock 'trunk' swells in the summer of this second production year.

Buds which shoot prematurely in the summer and autumn of the year of budding are called 'shot buds'. These are typically pruned back to within 15 mm of the bud union at heading back.

In addition to 'tipping back', some growers have tried 'topping' bushes - ie pruning them with a mechanical trimmer, at a height of about 350 - 450 mm from the ground depending on cultivar vigour. This has been done in early summer before blow out damage becomes too serious with the aim of reducing the 'top heavy' portion of the shoot coming into flower. Some growers have reported apparently improved basal shoot production as a result, although further branching from the cut tops can occur.

There was disagreement within the industry as to the extent tipping back will improve final bush quality and basal branching, or how much it prevents blow out. There had been little research on the subject. Consequently a range of policies and practices were adopted. The primary aim, therefore, of this project was to investigate these cultural practices and give guidance to growers. There was also a need to develop our understanding of the physiological processes involved in basal shoot development, and so HRI East Malling studied the role of the naturally occurring endogenous plant growth regulators (PGR's) in the rose cultivars used. Finally, the project started to investigate some synthetic PGR's for their potential use to help stimulate basal shoot production. In addition to experimental compounds, a small trial investigated the commercially available product Ethrel C (ethephon) from Hortichem Ltd.

This final report covers the main trials undertaken in 2000 and the Ethrel C trial that concluded in October 2001. It also brings together the main findings from the first year of the project in 1999, but this is reported in more detail, together with accompanying photographs, in the previous annual report available from HDC.

Objectives

Part 1 - Field studies (HRI Efford)
The overall objective of the field studies was to examine several cultural (ie pruning and pinching), and chemical, treatments as a means of improving basal shoot growth, reducing 'blow-out' damage, and hence improving the final grade-out of field grown bush roses. Use this information to formulate some practical guidelines for the industry.

Specific objectives of field studies in 2000 - 2001:

1 Obtain a second data set on some of the 'tipping back' treatments undertaken in 1999. Also to examine 'topping' bushes slightly later in the season.

2 Monitor the growth of 'shot-bud' plants. Scion buds on these plants shoot prematurely in the summer and autumn of the budding year rather than the following spring after the rootstock tops have been pruned (ie 'headed back'). It needs to be established whether the 'shot bud' phenomenon has any beneficial effects on basal shoot production or resistance to 'blow out' damage.

3 Monitor the effects of the origin (position and maturity) of scion buds propagated onto rootstock in summer 1999 on the growth of plants in 2000.

4 Make initial observations of the effects of a range of externally applied synthetic plant growth regulators on plant growth.

5 Additional observation on the potential for using sprays of Ethrel C (ethephon, or 2-chloroethylphosphonic acid) for improving basal shoot production in outdoor bush roses.

Part 2 - Physiological studies on the role of endogenous plant hormones (HRI East Malling)

The overall objective of the PGR studies was to compare the hormone physiology of freely breaking and shy breaking cultivars of rose, and help explain the differences in basal shoot growth observed in the field and understand the processes involved.

1 Measure both concentrations of auxin and ABA in shoot tips, and the amounts diffused in the phloem sap stream at the different growth stages when tipping back pruning treatments were applied (1999 field experiment).

2 Determine rates of auxin transport from shoot tips in the polar transport stream (as opposed to the phloem sap stream) for vegetative and floral shoot, to assess how far the 'apical dominance' effect is involved in basal shoot production.

3 Assess auxin, ABA and cytokinin concentrations in shoot bases, near to where new basal breaks are produced, at different growth stages.

4 To analyse the hormone complement of equivalent buds used in the 'position of bud' field experiment.

PART 1 - FIELD EXPERIMENTS YEAR 2

MATERIALS AND METHODS

1 Tipping back experiment

Culture

A dressing of FYM was applied to the site in autumn 1998 followed by lime (3 tonne/ha) and a base dressing of 25 kg/ha N, 50 kg/ha P_2O_5, 50 kg/ha K_2O and 5 kg/ha Mg in mid March 1999 prior to planting. Subsequent top dressings of 40 kg/ha N were applied to rootstocks in June 1999 and 75 kg/ha N + 25 kg/ha K_2O in mid May 2000.

A standard herbicide, fungicide and insecticide programme was used throughout the trial.

Rosa Laxa rootstocks (5-8 mm grade) were planted late March 1999, and budded in mid July. Shot bud plants were recorded and tagged prior to being pruned to within 15 mm of the base when rootstock tops were headed back in mid February 2000.

Treatments

Tipping back and Topping

6/1 Primary shoots pruned at nominal 6 cm length down to 1 cm
20/1 Primary shoots pruned at nominal 20 cm length down to 1 cm
6/U Untreated - plants with primary shoots selected at 6 cm stage left unpruned
20/U Untreated - plants with primary shoots selected at 20 cm stage left unpruned
ET Early topping - shoot tops of first growth flush cut back to approx. 35 cm height from ground at early inflorescence development (mid May - early June)
LT Late topping - plants cut back to approx. 35 cm height from ground late flowering after most budwood would have been collected (mid July)

A total of 6 Tipping treatments. The Untreated control 6/U and 20/U treatments were essentially the same, but plants were selected in the untreated plots at the same time as their 6 or 20 cm tipped treatment counterparts. The doubled control treatments also improved precision for estimating treatment effects.

Cultivars

Silver Wedding (white HT)	'Shy' basal breaker
Margaret Merril (white floribunda)	'Shy' basal breaker
Remember Me (orange HT)	Easy basal breaker

A total of 3 cultivars

Shot-bud monitoring

All 6 tipping or topping treatments were applied to non-shot bud plants of Silver Wedding and Margaret Merril. Due to the high numbers of shot bud plants present in Remember Me, the 20/U and 20/1 treatments were not applied to this cultivar.

There was virtually no premature shot bud in cv. Silver Wedding. In Margaret Merril and Remember Me, while the number of shot bud plants were variable between treatment plots, there were sufficient in total in most treatments for an indication of treatment effects on shot bud plants to be made.

Trial design and layout

See Appendix 1. The experiment was laid out on the 'Laxa' rootstocks budded in 1999 with four rows of each of the above cultivars treated as separate sub-trials. Tipping back and topping treatments were arranged in a randomised block design within each cultivar. Sufficient non-shot plants were available in Silver Wedding and Margaret Merril to divide plant rows into plots of equal length and form a spatially balanced design for the 4 replicates. The distribution of shot bud plants in Remember Me, however, meant that plots were of different row length and the four replicates could not be spatially arranged as neatly.

There were nominally 200 rootstocks planted per row, giving 800 per cultivar. However, there was significant plant-to-plant variability in the start time and rate of early growth of scion shoots after heading back rootstocks. In order to deal with the variability of plant material, seven non-shot bud plants per plot were selected out of the approximate 32 total plants per plot present, and labelled for detailed monitoring throughout the experiment. Likewise, the plants that had been previously tagged as shot-bud were also selected for observation, but numbers available per plot here varied from zero to a maximum of seven selected per plot.

Application of treatments

Plots were marked out and treatments allocated to plots shortly after heading back, however individual plants were labelled and selected for monitoring at the stage when each treatment was

applied. In many cases, selected plants had one or more secondary shoots present at the time of the tipping treatments, but these were invariably significantly shorter than the first shoot arising from the bud. These secondary basal shoots were also tipped back provided they had reached at least half the 'target' height. E.g. for the 20/1 treatment, primary and secondary shoots 10 cm long or over were tipped. Tipping treatments were applied only once to individual plants. The remaining plants in the plot were given the same tipping treatment, either at the time that the selected seven were treated, or up to 2 weeks later depending on their rate of growth. This was to ensure that a broadly similar growth habit was maintained throughout the plot and selected plants were not unduly shaded or otherwise affected by adjacent un-tipped plants within the plot.

It was difficult to time the 6/1 and 20/1 tipping treatments precisely because of the variable and rapid rate of growth. As in the 1999 experiment, in practise many of the plants had shoots longer than their nominal length for tipping back, i.e. for the 6/1 treatment shoots averaged about 10 cm at tipping, and for the 20/1 treatment, they averaged 30 cm.

Treatment application dates were:

6/1	27 April 2000
20/1	9 May
ET	17 May
LT	17 July

Records and analyses

Shot bud

Shot bud plants were recorded and tagged in early January before plants were headed back in mid February.

Blow out damage

Wind damaged plants with shoots broken off at the bud union were recorded at intervals throughout the season on a whole plot basis, including non-selected and tagged plants. While blow out damage was still spatially very variable over the site, inclusion of all plants in the treated plots increased the sample size to give the best estimate of damage between different treatments.

Final growth record

Final growth was recorded in late October when shoot extension growth that would contribute to final plant quality had ceased.

Plant height was recorded from ground level to the base of the most distal flower on the longest shoot when held upright.

The same method of defining and grading basal shoots as in the Year 1 experiment in 1999 was used. Basal shoots were defined as those arising from within 50 mm of the bud union (see Fig. 1 below). Those contributing most to plant quality were classified as primary *unbranched* basal shoots with at least 200 mm of clear stem at the base. Also present were typically shorter and thinner basal shoots that had started to flower early and branched into an inflorescence while short. These basal shoot with side-shoots arising from a zone 50 – 200 mm from the bud union was classified as *branched*, and not deemed as desirable for good plant quality as un-branched shoots. A basal stem with a side-shoot within 50 mm of the bud union was considered un-branched if no further branching occurred within 200 mm of the base; both of these counting as separate basal shoots.

Basal shoots were counted for those in each of the 5 – 6 mm, 6 - 8 mm, 8 – 10 mm and > 10 mm categories. Shoots < 5 mm dia. were ignored.

As in Year 1, it was found that the treatment effects could be adequately described by summarising the numbers of basal shoot data as totals per plant ≥ 6 mm and ≥ 10 mm thick for branched and unbranched. This data was subjected to analyses of variance.

Shoot data was used to calculate two overall grade outs defined as the proportion of plants (present at the start of the season) with a minimum of 3 unbranched basal shoots ≥ 6 mm dia. and ≥ 8 mm dia., and also the proportion of single shoot waste plants.

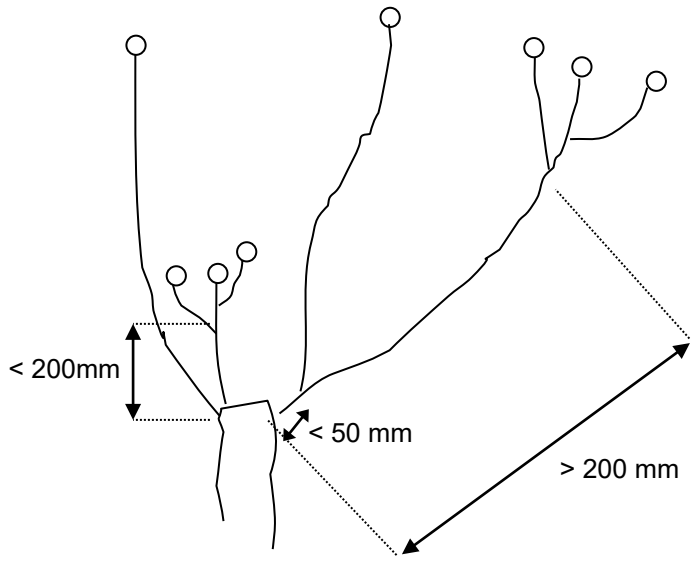


Fig 1. Diagram of plant with one branched and three un-branched basal shoots.

2 Influence of bud origin from the parent shoot on plant growth experiment

Two rows of Laxa rootstocks planted in spring 1999 were used in a 'position of bud' experiment with cvs Silver Wedding, Margaret Merril and Remember Me. Budwood collected in mid July was recorded and labelled as either 'basal', ie. growing directly from the rootstock and cut as low as possible, or cut as a 'side-shoot' budstick, ie. arising higher up the mother plant as a side-shoot from a basal shoot.

Different 'ages' of budstick were selected and defined by the number and stage of flowers in the terminal inflorescence from green buds present, to flowers where petals had started falling. The length and thickness of budsticks was recorded, and vegetative buds numbered from the top downward, starting with the first bud underneath the inflorescence. Buds from each stick were budded in order along the row of stocks, and each plant labelled so that subsequent development could be monitored. Between 120 and 140 plants of each cultivar were budded. Numbers propagated per budstick varied from about 5 to a maximum of 16.

At the same time, a parallel set of budsticks was collected and recorded, and buds collected and frozen in liquid nitrogen for plant growth regulator extraction and analysis by gas chromatography / mass spectrometry (GC-MS) (see Part 2 report).

Plants arising from the field trial were subjected to any tipping treatments in 2000, but growth was monitored to see whether scion bud position on the parent plant influenced subsequent growth.

3 Effect of Ethrel C (ethephon or 2-chloroethylphosphonic acid) sprays to increase basal shoot production experiment

The treatments and results of the small-scale field study with a range of non-commercialised synthetic plant growth regulators are presented in Part 2 - Physiological studies on the role of endogenous plant hormones.

The Hortichem product, Ethrel C, already has a label recommendation for use on glasshouse roses (for cut flower production) based on work in the early 1970's at the former Glasshouse Crops Research Institute, Littlehampton when glasshouse rose production was still important in the UK. Its potential for use on field bush roses appeared to have been overlooked both by growers and researchers until very recently, so it was decided to carry out a small field experiment towards the end of the current project.

Treatments

The original work at GCRI and on nursery trials (Deen, 1972; Anon, 1973) had looked at using ethephon as a defoliant, and had indicated that rose plants sprayed in early autumn may produce more basal breaks the following year. Sprays on current years growth also increased shoot production later on. For field bush production in this experiment, therefore, it appeared worth trying to treat both rootstocks late in the year of budding and maiden bushes during the production year. Concentrations of product above and below the label recommended rate of 10 mls/litre

Rootstocks were planted in mid March 2000, and budded in late July 2000.

Concentration of Ethrel C

L Low rate - 7.5 mls/litre product (3000 ppm active ingredient)
H High rate - 15 mls/litre product (6000 ppm ai)
U Untreated

Sprays were applied with the addition of 0.1% (1 ml/litre) Agral wetter, and sprayed to give good wetting of the target area.

Timing

Autumn	Whole of rootstock shoots to the base of the plant treated 19 October 2000
Summer	Basal 200 mm of scion growth treated as a band spray 28 June 2001

Cultivars

Margaret Merril ('shy' basal breaker)
Remember Me (produces basal breaks freely)

Design and Layout (see Appendix 2)

2 timings x 3 rates = 6 treatments
Plot size 20 plants / plot
2 replicates

Plots were arranged in a randomised block design across two adjacent rows of each cultivar.

Assessments

Simple counts of the total numbers of basal shoots present were made on two occasions. On 28 June 2001, prior to application of the summer treatments, to assess whether the autumn treatments had stimulated the production of primary basal shoots, and again near the end of the growing season on 15 October.

All basal shoots > 200 mm in length, and ≥ 6 mm diameter, and arising from within 50 mm of the bud union were counted.

RESULTS

1 Tipping back experiment

General growth

As in the 1999 trial, despite the disease spray programme with myclobutanil (as Systhane Flo), bupirimate + triforine (as Nimrod T), and dodemorph + carbendazim (as F238 + Bavistin DF), Silver Wedding suffered from rust and black spot later in the summer, resulting in early defoliation. Remember Me and Margaret Merril remained largely disease free.

Bud take and shot bud

Bud take, recorded in January 2000, was very good and exceeded 95% for all three cultivars.

Over a quarter of Remember Me plants had shot bud the previous autumn. This reflected the result in 1999 except that fewer Silver Wedding and Margaret Merril shot prematurely in the 2000 experiment:

	Shot bud as % of total plants	
Cultivar	**1999 trial**	**2000 trial**
Silver Wedding	8.5	1.8
Margaret Merril	13.2	7.9
Remember Me	26.8	26.0

There were many more shot buds in two of the four rows of Remember Me (see plan, Appendix 1). Some spatial variability in the pattern was also noted in the 1999 experiment, but this was even more marked in 2000. It appeared that these rows may have been exposed to more light at the base of the plant after budding, because of the side of the rootstock the buds were inserted and the orientation of the rootstock tops for this and adjacent rows. Extra light, combined with the horizontal orientation of the trodden down rootstock tops may have further encouraged buds to shoot prematurely in a vigorous cultivar where shot bud is more likely.

Blow out damage

Most blow out occurred from the end of May through to late June, with occasional additional shoots lost in July and August. Because of the spatial variability of blow out damage, it was not possible to statistically analyse the data, but mean treatment effects are presented in Table 1, below.

Overall, blow out damage was more severe than in 1999. No treatments eliminated blow outs. The 6/1 treatment had less damage than the untreated for Remember Me and Silver Wedding, but not

Margaret Merril. The 20/1 treatment on S. Wedding and Remember Me, appeared more effective than the 6/1 treatment.

The early and late topping treatments generally had as much damage as the untreated controls.

Although it could only be assessed for a few treatments, there was no evidence that shot bud plants were more or less susceptible to blow out than non-shot bud plants.

Table 1 Blow out. Proportion of plants losing one or more shoots as % present at the start of the season*. Most data is for non-shot bud plants, but where sufficient shot bud plants were present in a treatment, the blow-out proportion is given in brackets.

Treatment	Cultivar Silver Wedding	Margaret Merril	Remember Me
Tipping x length			
6/U	19.0	13.9 (15.4)	33.1 (41.3)
20/U	22.0	16.4	-
6/1	12.0	14.8 (6.7)	9.8 (11.8)
20/1	8.1	7.5	-
Topping			
Early top	12.9	18.7 (13.3)	30.1
Late top	16.3	30.3	41.3

* Figures include plants damaged but not necessarily totally destroyed. Also, some plants could lose more than one shoot during the season, but were counted as damaged only once.

As in 1999, Remember Me lost a large number of shoots to blow out, although provided shoot loss was not total, many plants grew to Class 1 grade by the end of the season. This cultivar has sufficient vigour to produce good numbers of shoots from the second growth flush. The blown out shoots were characterised by a browning of the freshly broken tissue at the scion / stock union. This indicated that either a fungal disease or physiological disorder in the bud union predisposed this cultivar to blow out damage. Although detailed laboratory investigation was beyond the scope of this project, no primary fungal pathogens could be isolated in some samples that were analysed. There was no evidence of poor bud take with this cultivar, which might have pointed to a wound pathogen such as black mould (*Chalaropsis thielavioides*) for example, which would have been expected to kill the scion bud at an early stage.

Plant growth by the end of the season

Plant height

Tipping treatments had no significant effect on plant height. Heights followed the same trend between cultivars as the 1999 trial with Remember Me as the tallest averaging 890 mm (s.e. 13), followed by Margaret Merril, 790 mm (s.e. 9), with Silver Wedding the shortest at 710 mm (s.e. 7).

Shoot numbers on non-shot bud plants

Tables 2 – 4 below give the mean numbers of basal shoots per plant from non-shot bud plants. Comparing cultivars for the overall treatment mean total shoot numbers ≥ 6 mm dia., Margaret Merril produced fewest shoots with 2.9 per plant, followed by Silver Wedding at 4.1 per plant and Remember Me at 4.9 per plant. The trend was the same as in 1999 with similar shoot numbers.

Silver Wedding

Overall treatment differences were only statistically significant for numbers of unbranched basal shoots ≥ 6 mm dia. and branched + unbranched shoot numbers ≥ 6 mm. Both the 6/1 and 20/1 gave an average 24% increase in shoot numbers over the untreated 6/U and 20/U treatments ($P<0.05$). The early and late topping treatments gave no increase in unbranched shoot numbers over the controls.

The number of thick unbranched shoots ≥ 10 mm dia. were slightly reduced from the 6/1 and 20/1 treatments, but this was not statistically significant.

Numbers of the less desirable 'branched' shoots ≥ 6 mm averaged less than 0.5 per plant or about 10% of the total, and were not significantly influenced by tipping or topping treatments.

Taking both unbranched and branched shoots, the 6/1 and 20/1 treatments increased numbers ≥ 6 mm dia. by almost 1 shoot per plant from 3.6 to 4.5 ($P<0.05$), and the total shoot numbers from the early topping treatment were also slightly greater. Total thick shoots ≥ 10 mm dia., however, were not increased by either tipping or topping treatments.

Table 2 **Silver Wedding - Number of basal shoots per plant late October 2000. From 'non-shot bud' plants only.**
Means of 7 plants/plot x 4 replicates

Treatment	'Un-branched' ≥6 mm ø	'Un-branched' ≥10 mm ø	'Branched' ≥6 mm ø	'Branched' ≥10 mm ø	Total ≥6 mm ø	Total ≥10 mm ø
Tipping x length						
6/U	3.57	1.46	0.25	0.11	3.82	1.57
20/U	3.07	1.43	0.32	0.11	3.39	1.54
6/1	4.11	1.32	0.29	0.07	4.39	1.39
20/1	4.12	1.07	0.44	0.04	4.55	1.11
Topping						
Early top	3.89	1.64	0.50	0.25	4.39	1.89
Late top	3.18	1.25	0.57	0.32	3.75	1.57
SED(15df)	*0.366*	*0.304*	*0.203*	*0.117*	*0.327*	*0.289*
LSD (P<5%)	*0.78*	-	-	-	*0.70*	-
Trt Significance [1]	*	*NS*	*NS*	*NS*	*	*NS*

[1] Overall treatment significance. NS - not significant, * - P<0.05, ** - P<0.01, *** - P<0.001

Margaret Merril

Table 3 **Margaret Merril - Number of basal shoots per plant late October 2000. From 'non-shot bud' plants only.**
Means of 7 plants/plot x 4 replicates

Treatment	'Un-branched' ≥6 mm ø	'Un-branched' ≥10 mm ø	'Branched' ≥6 mm ø	'Branched' ≥10 mm ø	Total ≥6 mm ø	Total ≥10 mm ø
Tipping x length						
6/U	2.14	0.79	0.64	0.29	2.79	1.07
20/U	2.29	1.21	0.39	0.25	2.68	1.46
6/1	2.64	0.61	0.75	0.25	3.39	0.85
20/1	2.54	0.57	0.68	0.14	3.21	0.71
Topping						
Early top	2.04	0.61	1.18	0.75	3.21	1.34
Late top	1.43	0.71	0.75	0.32	2.18	1.04
SED(15df)	*0.411*	*0.248*	*0.201*	*0.143*	*0.444*	*0.294*
LSD (P<5%)	-	-	*0.43*	*0.31*	-	-
Trt Significance [1]	*NS*	*NS*	*	*	*NS*	*NS*

[1] Overall treatment significance. NS - not significant, * - P<0.05, ** - P<0.01, *** - P<0.001

This cultivar was the least vigorous of the three, with the poorest grade-out from the field, and therefore would benefit most from treatments to improve basal shoot production. It produced the

highest proportion of branched basal shoots of the three cultivars, with 25% of all shoots ≥ 6 mm as an average across all treatments, even though this amounted to a mean of less than 1 shoot per plant.

Thin unbranched shoots were increased by an average of 0.5 per plant from the 6/1 and 20/1 tipping treatments over the control, but this was not significant. Thick unbranched shoots were little affected. Early topping increased numbers of branched shoots slightly in this cultivar, but not unbranched shoots. This was the only statistically significant treatment effect for M. Merril.

Remember Me

Table 4 Remember Me - Number of basal shoots per plant late October 2000. From 'non-shot bud' plants only.
Means of 7 plants/plot x 4 replicates

Treatment	'Un-branched' ≥6 mm ø	'Un-branched' ≥10 mm ø	'Branched' ≥6 mm ø	'Branched' ≥10 mm ø	Total ≥6 mm ø	Total ≥10 mm ø
Tipping x length						
6/U	5.21	2.18	0.29	0.25	5.50	2.43
6/1	5.25	0.64	0.04	0.00	5.29	0.64
Topping						
Early top	3.83	1.70	0.64	0.34	4.46	2.04
Late top	3.96	1.68	0.36	0.28	4.32	1.96
SED(9df)	*0.409*	*0.348*	*0.105*	*0.110*	*0.433*	*0.400*
LSD (P<5%)	*0.93*	*0.79*	*0.24*	*0.25*	*0.98*	*0.90*
Trt Significance [1]	**	**	**	*	*	**

[1] Overall treatment significance. NS - not significant, * - P<0.05, ** - P<0.01, *** - P<0.001

This was the most vigorous cultivar, and produced basal breaks the most freely, but was also the one most susceptible to blow out damage. There were significant effects of both tipping and topping treatments compared to the untreated control with this cultivar.

The 6/1 tipping treatment, while not affecting total shoot numbers ≥ 6 mm, clearly shifted production towards more thinner shoots with a mean of only 0.6 shoots/plant ≥ 10 mm compared to over 2 thick shoots/plant for the untreated. This reflected the trend observed in 1999. The two topping treatments did reduce the number of unbranched shoots over the untreated control both for all shoots ≥ 6 mm dia. and for just thick shoots ≥ 10 mm.

There were very few branched shoots in Remember Me, particularly for the 6/1 pinched treatment. There were as many or slightly more branched shoots because of the topping treatments.

Shoot numbers on shot bud plants

These are summarised in Tables 5 and 6 below for M. Merril and Remember Me.

Table 5 Margaret Merril - Number of basal shoots per plant late October 2000. From 'shot bud' plants only.
ANOVA carried out on means of 8-15 plants using replicates as a co-variate.

Treatment	'Un-branched' ≥6 mm ø	'Un-branched' ≥10 mm ø	'Branched' ≥6 mm ø	'Branched' ≥10 mm ø	Total ≥6 mm ø	Total ≥10 mm ø
Tipping x length						
6/U	2.31	1.11	1.35	0.63	3.66	1.75
20/U	2.87	1.16	0.62	0.28	3.49	1.44
6/1	2.52	0.56	1.11	0.52	3.62	1.08
20/1	2.72	0.93	1.25	0.12	3.96	1.05
Topping						
Early top	1.91	0.78	1.58	1.17	3.5	1.95
Late top	n.a.[2]	n.a.	n.a.	n.a.	n.a.	n.a.
SED(11df)	*0.759*	*0.26*	*0.474*	*0.212*	*0.505*	*0.269*
LSD (P<5%)	*-*	*-*	*-*	*0.47*	*-*	*0.59*
Trt Significance [1]	*NS*	*NS*	*NS*	**	*NS*	*

[1] Overall treatment significance. NS - not significant, * - P<0.05, ** - P<0.01, *** - P<0.001
[2] n.a. - Too few shot plants in this treatment to obtain reliable mean value

Table 6 Remember Me - Number of basal shoots per plant late October 2000. From 'shot bud' plants only.
ANOVA carried out on means of 10-28 plants using replicates as a co-variate.

Treatment	'Un-branched' ≥6 mm ø	'Un-branched' ≥10 mm ø	'Branched' ≥6 mm ø	'Branched' ≥10 mm ø	Total ≥6 mm ø	Total ≥10 mm ø
Tipping x length						
6/U	5.89	2.25	0.14	0.07	6.03	2.33
6/1	5.80	1.69	0.07	0.00	5.87	1.69
Topping						
Early top	4.85	2.36	0.77	0.30	5.61	2.66
Late top	6.41	1.83	0.26	0.11	6.67	1.94
SED(8df)	*0.967*	*0.723*	*0.185*	*0.121*	*0.933*	*0.725*
LSD (P<5%)	*-*	*-*	*0.43*	*-*	*-*	*-*
Trt Significance [1]	*NS*	*NS*	*	*NS*	*NS*	*NS*

[1] Overall treatment significance. NS - not significant, * - P<0.05, ** - P<0.01, *** - P<0.001

Because of the variable numbers of shot bud plants available in each plot, it was not possible to estimate treatment effects as precisely as with the non-shot bud plants, and tipping or topping treatments were not significant in most cases.

Examination of the overall means for the shoot grades and comparing Tables 5 & 6 with 3 & 4, indicated that shot bud plants tended to have slightly more basal shoots than non-shot bud plants. This benefit was greatest for Remember Me, where the number of unbranched shoots ≥ 6 mm averaged across all treatments was increased from 4.8 to 5.8 per plant, and from 1.6 to 2.0 shoots ≥ 10 mm. This effects was marginal, however, with Margaret Merril, with shot bud plants giving an increase of just 0.2 unbranched shoots ≥ 6 mm.

Overall grade-out

Table 7 summarises the overall treatment effects on grade-out, derived from the shoot growth data, as the proportion of plants reaching two definitions of a commercial standard for a Class 1 rose. BS 3936: Part 2 (1990) states that a minimum *marketable* requirement is two basal shoots, with a sum of shoot diameters > 20 mm. However, three basal breaks is typically regarded as a minimum commercial requirement for Class 1 bushes and is the standard stated for 'A' quality roses in the European Nursery Stock Association standards. Stem thickness is not defined in the European standard, but the 6 mm and 8 mm dia. stem sizes were chosen in Table 7 as points that would give a minimum sum of 3 stem diameters as 18 mm and 24 mm respectively.

Table 7 Grade-out as proportion of plants with a minimum of 3 unbranched basal shoots ≥6 mm dia. and ≥8 mm dia. Non-shot bud plants only.
Expressed as % of plants present at the start of the season (including those completely lost to blow-out).

	Cultivar					
	Silver Wedding		Margaret Merril		Remember Me	
Treatment	**≥6 mm ø**	**≥8 mm ø**	**≥6 mm ø**	**≥8 mm ø**	**≥6 mm ø**	**≥8 mm ø**
Tipping x length						
6/U	75	64	21	14	93	79
20/U	71	64	50	32	-	-
6/1	86	79	50	18	96	64
20/1	89	78	46	25	-	-
Topping						
Early top	79	75	34	28	70	59
Late top	68	64	14	7	82	79

The data in Table 7 broadly reflects the results for mean shoot numbers given in Tables 2 - 4. Silver Wedding here gave an improved grade-out from both the tipping back treatments, but this was not clear-cut for Margaret Merril where the 6/U and 20/U grade-outs differed. The early topping

treatments gave better grade-outs than the late topping for these two cultivars, but no overall improvement over the untreated controls. For Remember Me, no treatments were better than the untreated controls. In 1999, overall grade-out data did not show any consistent benefits from tipping back treatments for any of the cultivars.

Table 8 Proportion of waste plants (i.e. with maximum of 1 unbranched basal shoots ≥6 mm ø. Non-shot bud plants only.
Expressed as % of plants present at the start of the season (including those completely lost to blow-out).

Treatment	Cultivar Silver Wedding	Margaret Merril	Remember Me
Tipping x length			
6/U	7	25	4
20/U	18	25	-
6/1	7	18	0
20/1	4	18	-
Topping			
Early top	14	45	15
Late top	25	57	18

The proportion of single shoot (waste) plants was slightly reduced by the tipping treatments, but was increased by the topping treatment, especially the late topping in July.

2 Influence of bud origin from the parent shoot experiment

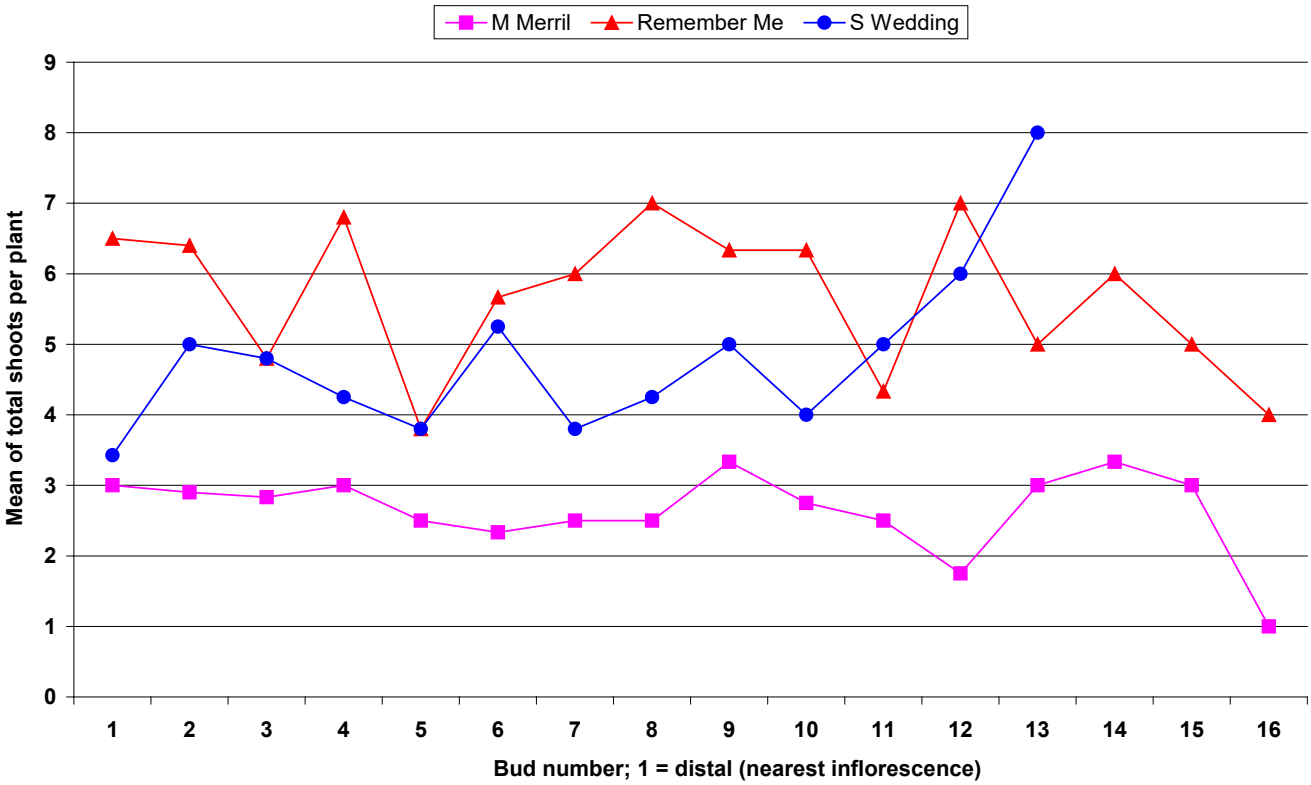
Shot buds

Some buds from shoots that had been noted as being 'dry' at budding failed to 'take', such as some of the basal buds or those from over mature shoots. Apart from this, examination of the data revealed no correlation between either bud take, or the incidence of shot bud, blow-out damage or eventual plant survival, with the position or source of buds.

Basal shoot production

There was no evidence for position of origin of buds affecting shoot production. Fig 2, below, gives the mean numbers of all shoots per plant recorded in October 2000 from non-shot bud plants present at the end of the season. Each data point is an average of up to 10 plants for the first 5 or so buds, but some of the data points from lower buds represent single plants from the few very long bud sticks that were available.

Fig. 2 Effect of scion bud position on the budstick on final numbers of basal shoots the following year.



3 Effect of Ethrel C (ethephon or 2-chloroethylphosphonic acid) sprays to increase basal shoot production experiment

Leaf drop

As expected, Ethrel C did induce leaf drop to the parts of the plant to which it was applied. Following the autumn applied spray to rootstock tops, leaves yellowed and had nearly all dropped within 2 weeks of spraying, whereas untreated plants still had a large amount of green leaf present. The summer sprays to the bottom 200 mm of the plant also caused sprayed leaves to drop, but leaves higher up the plant were unaffected. New shoot growth was unaffected so that plant bases 'leafed up' again well later in the summer. A few additional plants at the end of one row of each cultivar were sprayed overall with Ethrel to observe whether application through a conventional tractor mounted crop sprayer might be a feasible option rather than a directed spray (typically by hand) to the base of plants only. Leaves all the way up the plant were damaged by this treatment, and softer stems were scorched and died back. In some cases plants were killed out. No stem damage was seen, however, on any of the plants where Ethrel was applied to the bases only.

Basal shoot production

The assessment of shoot numbers in June showed that the autumn application of Ethrel C to the rootstocks had not increased the production of the first flush of basal shoots following heading back (Table 9). In fact, in Margaret Merril, mean numbers were slightly lower, although this was not quite significant at $P<0.05$. At this stage the summer sprays had not been applied, so these plots and the autumn untreated plots would have been expected to have similar mean shoot numbers.

By the end of the growing season, however and following the summer applied treatments, there were significant treatment differences apparent. With Margaret Merril, the summer applied Ethrel sprays had increased mean basal shoot numbers by 1.7 shoots from 2.9 to 4.5 shoots per plant, almost a 60% increase. Differences between the two rates of summer sprayed Ethrel were not significant. By this time, mean shoot numbers on the autumn Ethrel plots were higher than the control, but this was only significant for the higher application rate.

Remember Me was unusual in this experiment, in that basal shoot numbers were not generally as great as in the main trial experiments of the previous two years where they averaged some 5 shoots per plant. By October, Ethrel C had not increased shoot numbers from the autumn application to rootstocks, but had increased basal shoots from the summer treatment (significant at $P<0.05$ for the low rate only).

See Appendix 3 for photographs of treatment effects on Margaret Merril. Not all new basal shoots arose directly from the rootstock, but most that branched from the base of existing shoots occurred within 50 mm of the budding union, and therefore could be classified as basal shoots.

Table 9 Influence of Ethrel C on basal shoot production by late June and mid October 2001

Mean basal shoots per plant ≥ 6 mm dia., ≥ 200 mm long and arising within 50 mm of bud union

Treatment	Basal shoots by June	Basal shoots by October
Autumn 2000 sprays:	*Margaret Merril*	
Untreated	2.10	2.78
Low rate 7.5 ml/litre	1.70	3.39
High rate 15 ml/litre	1.79	3.70
Summer 2001 sprays:		
Untreated	2.42	2.85
Low rate 7.5 ml/litre	2.32	4.44
High rate 15 ml/litre	2.36	4.62
SED (5 d.f.) & trt. significance	*0.157 **	*0.311 ***
LSD (P<0.05)	*0.40*	*0.80*
Autumn 2000 sprays:	*Remember Me*	
Untreated	1.93	2.88
Low rate 7.5 ml/litre	2.00	2.60
High rate 15 ml/litre	1.97	2.61
Summer 2001 sprays:		
Untreated	2.04	2.79
Low rate 7.5 ml/litre	2.12	3.94
High rate 15 ml/litre	2.00	3.39
SED (5 d.f.) & trt. significance	*0.144 NS*	*0.387 **
LSD (P<0.05)	*-*	*1.00*

DISCUSSION

Reducing blow out damage

With generally more blow out in the 2000 experiment than in 1999, arguably it was a better year for testing treatment effects on reducing damage. While there was some evidence that the tipping back treatments did reduce blow out, particularly in the susceptible cultivar Remember Me, it was still not a very effective treatment. Tipping back is quite a costly operation to undertake, and requires some skill in determining the best stage to undertake it. Usually growers will have to 'work over' fields on 3 or more occasions in order to 'catch' plants which develop at varying rates, and to cope with cultivar differences in growth rates. By tipping early, this may give the best chance of stimulating more than one basal break to develop and minimise the check to growth and vigour that a very late tipping back can exhibit. However, strong shoots developing after an early tipping back are more likely to suffer blow out than those developing later, thus minimising the benefit of the treatment. The data for Silver Wedding and Margaret Merril from the 2000 trial indicated less plants were affected by blow out from the later tipping back treatment than the earlier tipping.

It was interesting that neither of the topping treatments achieved the objective of reducing blow out damage at all. Although flower buds were developing on some shoots on most plants at the time of the early topping in mid May, it is possible that the overall growth stage of the crop was not sufficiently advanced to catch all the susceptible shoots. Possibly mowing the shoot tops up to two weeks later in early June would have been more effective. However, by mid May, some shoots were already beginning to be blown out. Another disadvantage of this treatment is that it will seriously affect the availability of budwood for cutting in June and early July when demand for budwood is at its highest. The best budwood is obtained from medium to strong shoots terminating in a maturing inflorescence, and which are long enough so that when the top section is cut for budwood, there is still at least 200 mm basal shoot left to add to final bush quality. There would be few shoots for budwood that met these criteria for a month or so following topping.

Provided the grower did not still need budwood in mid July, the late topping treatment would be less problematic, but it was clearly too late to have any beneficial effect on preventing top-heavy shoots from being blown out. In fact the tendency for the topping treatments to develop some strong branch shoots from high up the cut shoot, meant that they were more likely to suffer blow out later in the season.

The evidence that shot bud plants are just as susceptible to blow out as non-shot bud plants, suggests that little useful extra strength in the bud union is developed in those plants which shoot prematurely in the autumn. Most of the strength and extra girth tissue in the bud union develops in parallel with, and in proportion to, the scion shoot growth during the summer.

Remember Me was most susceptible to blow-out damage with 33 % of affected plants in the untreated control, which was reduced to less than 10% affected from the 6/1 tipping treatment. However, it is interesting that while tipping may have saved a number of shoots, it gave no improvement to the final shoot numbers or grade-out by the end of the season. It would appear that, provided all shoots are not blown out, plants are either vigorous enough to regenerate some lost shoots from the late summer growth flush, or that shoot numbers are sufficient to bear the loss of one or two without downgrading. This indicates that blow out damage will be more serious with cultivars that may be tall growing but have weak stems or bud unions, and that are not vigorous shoot producers. The cultivar L'Aimant falls into this category, and suffered serious plant losses to blow out in both project years where it was grown on the same site as the cultivars used in the project.

The observation of internal browning on freshly broken internal tissues of Remember Me does indicate that cultivar susceptibility to blow out may be more complex than just a relationship to shoot height or weight of top growth. It would be interesting to see whether cultivars like Remember Me were as susceptible to blow out when budded onto other rootstocks such as *Rosa canina* Inermis or *R. multiflora*. This might help determine how far incompatibility with rootstocks or a pathogen was involved.

Making use of existing shelter belts around fields, or provision of natural or artificial windbreaks may be the most effective answer to preventing blow out damage if it can be done economically. Finally, while not examined in this project, the time at which rootstocks are headed back may be another factor to consider. Anecdotal evidence from one grower suggests that very early heading back, even into late autumn of the budding year, and well before buds on rootstock shoots begin to swell again in the new year, may result in slower and more even scion bud development in the spring. Late heading back, once sap is moving up into rootstock tops again, may encourage the primary scion shoots to grow too tall too quickly.

Improving basal shoot development

In the first year, it was shown that numbers of shoots in the initial flush after heading back were not necessarily greater from the 'freely' branching cultivar Remember Me, but that the vigour in this cv. was expressed through a greater number of shoots developing later in the season. If this later growth flush is so important for final plant quality, it partly explains why the tipping back treatments can only have a limited influence on final branch numbers, as tipping mainly impacts on the first growth flush.

In 1999, it was also found that tipping back to leave a 40 mm stub did not benefit shoot production, and that a late tipping (nominally at 300 mm length) generally produced weaker shoots than tipping earlier. These treatments were therefore dropped from the 2000 trial.

The conclusion from the 1999 trial was that tipping back had not given any worthwhile increase in shoot numbers, and that final grade-out was not improved. The effect of tipping back treatments in 2000 broadly ratified the results obtained in 1999, but with some differences. In 2000, both the tipping treatments did give a slight improvement in both shoot numbers and grade-out with Silver Wedding, but this was not so clear cut for Margaret Merril. The effect of tipping back in reducing vigour, with a shift towards thinner shoot production, was most apparent for the most vigorous cultivar, Remember Me in both years. This effect was less apparent for Silver Wedding and Margaret Merril in 2000 than in 1999. Also, the later tipping back treatments in 1999 did increase the production of weaker branched basal shoots, particularly for Silver Wedding and Margaret Merril. This was not so obvious in 2000, but there was still evidence of it. For the weakest cultivars like Margaret Merril, cultural practices which increase the proportion of weak branched shoots will be deleterious, as these shoots do not contribute to final plant quality.

The topping treatments did not show any real benefits on basal shoot production. Although it did not form part of the formal record, strong branch shoots did develop later in the season from buds just below the point of topping rather than as basal breaks, on a large number of the topped plants. It is likely, therefore, that plants that just had a single primary shoot at the time of topping may have been encouraged to divert energy into strong branches from the top of the cut shoot, whereas leaving the primary shoot intact with its inflorescence, was better for encouraging later basal breaks.

Effect of bud position

It was clear from this experiment that if the origin of buds does have any influence on subsequent growth in roses, it is not an overriding factor in field bush rose production. Some workers have investigated the phenomenon known as topophysis in glasshouse roses, where the influence of axillary bud position along a shoot can influence subsequent growth and differentiation. Also, that these differences can result from plants propagated by budding or single node cuttings from these buds.

This finding was supported by the analysis of endogenous PGRs did not reveal significant differences due to bud position or shoot type (see Part 2). From the evidence from this project, therefore, there are no grounds to change current cultural practices of collecting and using budwood in field rose propagation.

The potential for the use of Ethrel C

Although this was intended to be a minor observation at the end of the project, it yielded some of the most positive and potentially valuable information from the work. Ethlyene, as a growth regulator, has several commercial applications including enhancing fruit ripening, causing more compact growth in some subjects, stimulating flowering in bromediads (but inhibiting it in other species), and improving branching in roses, geraniums and azaleas. For field rose production, applying a single

directed spray of Ethrel C should be a much less expensive option than the labour required for repeated tipping operations, and potentially more effective. It must be stressed that these findings were from a relatively small area, in a single year, and only two cultivars were involved. However, the very favourable response from Margaret Merril, make it worth testing further with other cultivars.

Growers wishing to try the technique should consider the following:

- The spray will be at growers' own risk. Ethrel C will cause leaf drop and will scorch or kill soft growth. While no adverse effects were observed when spraying the 200 mm basal portion of stems of M. Merril and Remember Me in this trial, other cultivars may be more susceptible. In the early 1970's work, the bush rose cultivars Blue Moon and Queen Elizabeth showed a good response.

- Sprays should be applied as a directed band application to the base of bushes only. Ethrel C could cause serious damage to plants if used overall. Do not exceed the label concentration of 10 mls product / litre recommended for glasshouse roses, and add a suitable wetter such as Agral at 1 ml/litre. The product label rate was in between the two rates used in our experiment, where there appeared little extra benefit from the higher rate trialled.

- Correct spray timing will be important to achieve a good response and minimise scorch to new basal shoots. In the absence of further experimental evidence, the best time would appear to be after the first flush of shoot growth has finished and flowers have developed on these shoots, but before a significant second flush of basal shoot growth has started. There will thus be sufficient well-lignified target area at the base of the plant to absorb the spray safely, and sufficient time to influence the development of new growth. This stage was in late June at Efford in 2001.

- Ethephon, the active ingredient in Ethrel C, breaks down in the plant to release ethylene. This works best at warmer temperatures, and it is recommended that spraying be carried out at temperatures above 10 °C. Spraying of dormant plants is not recommended, nor sprays to plants that are weak or stressed (e.g. by drought). Overall spraying of budded rootstocks in October, however, did give some benefit in final shoot numbers the following year in Margaret Merril (but not Remember Me). This effect was not as great as that for the summer spray on scion growth but this may be worth further trialling as there is little risk of crop damage, and the treatment can be applied easily overall from a tractor mounted sprayer. It is not clear why this treatment had some effect on final shoot numbers but did not increase initial basal breaks.

- Ethrel C costs approximately £130 / 500 ml (November 2001). Volume used in the experiment was not recorded, but at the label rate for glasshouse roses of 560 ml of 1% spray / 40 plants, this works out at approximately 3.6 p / plant.

CONCLUSIONS

The objectives of the project were to investigate whether cultural 'tipping back' and pruning treatments give any improvement to basal shoot production in field grown roses, and how far they reduced plant damage from 'blow out' in the summer.

Also to investigate further the plant growth regulator physiology behind basal shoot development, and see if some experimental synthetic PGR's had potential uses for enhancing basal shoot development.

- Much basal shoot production occurs in the second flush of growth in late summer. Tipping back treatments on the primary flush after heading back therefore has a limited effect on final shoot number.

- Tipping back may increase mean final shoot numbers slightly (eg by up to 20%), but effects have not been consistent across years or cultivars. Also, tipping back, especially when done at a late stage (e.g. later than 200 mm shoot height), will reduce vigour and tend to encourage more thin, rather than thick, basal shoots. Also, late tipping back will stimulate and a higher proportion of weaker 'branched' basal shoots that terminate in a flower while still short, and do not give the 200 mm length of clear basal shoot which contributes to final quality.

- Tipping back can help reduce blow outs, but will not eliminate them. Late tipping back is more effective for blow out control than early tipping back, even though late tipping back is more detrimental to plant vigour. Subjects such as Remember Me, while they may be more susceptible to blow out, have sufficient vigour to regenerate some lost shoots without losing final grade-out, provided the whole plant is not blown out.

- 'Topping', or pruning back bushes to about 350 mm height in mid May or mid July, was not effective in reducing either blow out or improving plant quality in the one years experience at Efford. Although some grower's have reported benefits on some cultivars, correct timing of the treatment is likely to be critical. Pruned shoots may branch from near their tops in preference to new basal shoot production.

- Use of natural or artificial windbreaks should be considered as a better method of reducing blow out damage than cultural pruning treatments where this can be done cost effectively.

- Both tipping back and topping practices will affect the quantity available and delay the production of budwood for propagation. This needs to be borne in mind when considering cultivars for treating.

- Ethephon, as Ethrel C, applied as a summer spray to the lower 200 mm of shoots at the end of the first flush of growth, looks very promising for improve basal shoot development and improving grade-out of weak cultivars such as Margaret Merril, Blue Moon and Queen Elizabeth. Further trialling is recommended, but use on rose cultivars will be at grower's own risk, and it may be worth testing on small numbers of plants first.

- As tipping back is labour intensive, its use may be best directed towards weak but tall growing cultivars that are susceptible to blow out damage. Use of Ethrel C sprays may well be a more effective and less expensive method of improving grade-out.

- Shot bud plants may give a marginally better grade-out than non-shot bud plants, but appear to be as susceptible to blow out. Cultivars vary in their tendency to premature shot bud. Other factors, such as amount of light reaching the base of the plant after budding, also appear to affect it.

- The age of the scion budstick or position of the bud on the budstick appeared not to have a large effect on either susceptibility to blow out or subsequent basal shoot development in this experiment. Thus, there is no evidence to support altering current practices of budwood collection or use.

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PART 2 - PHYSIOLOGICAL STUDIES ON THE ROLE OF ENDOGENOUS PLANT HORMONES (HRI EAST MALLING)

MATERIALS AND METHODS

IAA transport experiments

Shoots were harvested, immediately placed in water and the bases of shoots were re-cut under water. Shoots were deemed vegetative while they were less than 90mm long and floral shoots were between 150 and 200mm long and contained a small, developing flower bud. In the laboratory, the shoot tip to below the last rolled leaf was removed or the flower bud and first node were removed from each shoot and then a 10mm segment was excised. The segments were placed, in the correct orientation, in 400µl of agar blocks (0.85% Gelrite in 10mM MES buffer pH 5.2), there were 10 explants for each cultivar and each growth stage. A 1.0µl droplet containing 3,333Bq of [^{3}H]-IAA (indole-3-acetic acid) and 333Bq of [^{14}C]-BA (benzoic acid) was applied directly to the cut, apical surface of each explant. Then, 5mins later the explants were transferred to fresh agar blocks to allow for any 'drainage' that occurred directly through open vessels. After the initial transfer, segments were transferred to fresh agar every 30mins over a 3 hour period. Then explants were removed from the agar, their diameters recorded and they were divided into 3 segments, 2mm apical, 4mm middle and 4mm basal segments. Each agar block and the stem segments were extracted in 2ml of methanol overnight, then 15ml of 'Ultima Gold' scintillant were added and the amount of radioactivity in each sample counted. Results are presented in graphical form (Figs 1 and 2) and as derived data (Table 1), the 'velocity' (how fast IAA is transported) and 'intensity' (how much IAA is transported in a given time) of IAA transport.

Hormone extraction, purification and analysis

i) IAA and ABA from phloem exudates.

Shoots were collected from the field-grown plants and placed directly into water. The tips were then excised just below the first fully unrolled leaf, while the shoots were under water. The excised tips were placed in vials containing 4 ml of 10mM tris/edta buffer pH6.5. There were 3 replicates of 5 tips per sample on each occasion. The tips were maintained in humid conditions in growth room at 20ºC under continuous light. After 24 hours the tips were removed from the vials and the diameter of the base of each tip was recorded and the weight of each tip was recorded. The buffer remaining in the vials was combined and 50.0ng of hexadeuteroabscisic acid and 50.0ng of [$^{13}C_6$]-IAA added, then the pH was adjusted to 8.0 with 0.1M potassium hydroxide. It was passed through a 5.0ml bed volume column of QAE Sephadex A-25 (formate form), the column was washed with water adjusted to pH 8.0 with potassium hydroxide and ABA was recovered by eluting with 0.2M formic acid and IAA recovered by eluting with 0.5M formic acid. Then each of the formic acid solutions was passed through a prepared (5 ml methanol and

5 ml 5% acetic acid) C18 Sep-Pak cartridges (Waters Corporation, Welwyn Garden City, UK) each cartridge was washed with 2 ml 10% methanol. Then ABA was recovered by eluting the cartridge (initially loaded with 0.2 M formic acid) with 70% methanol and the IAA was recovered by eluting the cartridge (initially loaded with 0.5M formic acid) with 30% ethanol. The eluants were evaporated to dryness and redissolved in 100µl of methanol and methylated with ethereal diazomethane. The excess diazomethane and ether were evaporated under a stream of dry nitrogen gas and the ABA samples dissolved in 20µl of pyridine and IAA samples dissolved in 20µl of Tri-Sil BSA (Pierce and Warriner, Chester, UK) for analysis by gas chromatography-mass spectrometry (GC-MS).

ii) IAA, ABA, zeatin and zeatin riboside from shoot tips, stem bases and vegetative buds.
Shoot tips were collected as described above and were immediately frozen in liquid nitrogen. While shoot 'bases' were collected as 1.0cm segments from the area of stem in which 'basal breaks' were expected to form, i.e. within 2 - 3 cm of the graft union. Vegetative buds were collected from equivalent shoots used in the 'bud position' experiment. Buds were excised from bud sticks and immediately frozen in liquid nitrogen and the position of the bud on the bud stick noted. Buds were grouped as apical, middle or basal for extraction of hormones.

Samples were weighed, then homogenised in cold 80% methanol (containing 20mg.l^{-1} BHT) at rate of 1 g tissue to 20 ml solvent. After homogenisation 1µg of hexadeuteroabscisic acid and 100ng of [$^{13}C_6$]-IAA were added to extracts of shoot tips and in addition 50ng each of trideuterozeatin and hexadeuterozeatin riboside were added to extracts of buds and shoot bases, they were then gently shaken overnight at 4ºC. Samples were filtered and the solid residue was washed on the filter with methanol. The extracts were evaporated to aqueous under reduced pressure and an equal volume of pH 3.0 phosphate buffer added. Each extract was then partitioned twice against equal volumes of diethylether. The aqueous phase was retained at -20ºC for extraction of cytokinins. The organic phase was washed with a 10 ml of water adjusted to pH3 with hydrochloric acid, then evaporated to near dryness under reduced pressure and 10ml of water added and the remaining ether removed. The pH was adjusted to 8.0 with potassium hydroxide and purification was continued as was described for recovery of ABA and IAA from phloem exudates as described above.

Cytokinins were extracted from the stored aqueous phase by adjusting the pH to 8.0, then extracting three times with equal volumes of water saturated n-butanol. The butanol extract was washed twice with small volumes of water adjusted to pH 8.0. The butanol was removed under reduced pressure and the sample redissolved in water and the pH adjusted to 3.0 with acetic acid. The samples were passed through a column of PVPP (PVPP was slurried with water allowed to settle and the fines decanted, this was repeated three times). The PVPP column was washed with water acidified to pH 3 with acetic acid and the washings and sample combined and loaded on to an SP Sephadex column (acetate form). The column was washed with water adjusted to pH3 with acetic acid and the cytokinins recovered with 0.2M ammonia. The cytokinins were extracted

from the ammonia by passage through a prepared (5ml methanol and 5 ml 0.2M ammonia) C18 Sep-Pak cartridge. The cartridge washed with water and eluted with methanol. The methanol was evaporated to dryness under a stream of dry nitrogen gas and redissolved in 20µl Meth-Elute reagent (Pierce and Warriner, Chester, UK) for analysis by GC-MS.

GC-MS Analysis of IAA, ABA, Zeatin and Zeatin riboside

i) Capillary column GC-MS

Extracts were analysed using a VG TRIO-1 MS coupled to a HP 5890 GC equipped with a split/splitless injector and electronic pressure control. The CP-SIL 5 CB-MS (Chrompack, London, UK) capillary column (25 m long x 0.25 mm i.d., 0.25 µm film thickness) was coupled directly to the ion source with an interface temperature of 275ºC and the He carrier gas inlet was programmed to maintain a linear velocity of 40 cm sec^{-1}.

ii) Analysis of ABA and IAA,

Samples (1 µl) were injected (injector temperature 250ºC) at an oven temperature of 60ºC with the injection splitter (50:1) closed. After 1.0 min the splitter was opened, then 1.0 min later the oven temperature was increased to 170ºC at 20ºC min^{-1} and finally to 290ºC at 4ºC min^{-1}. Detection was by selected ion recording mass spectrometry, monitoring ions m/z 190 and 162; 261 and 202 for endogenous ABA and IAA respectively and m/z 194 and 166; 167 and 202 for the internal standard compounds.

The endogenous hormones were quantified by comparing the ratio of the peak areas 190:194 and 261:266 in each sample with calibration curves constructed for known molar ratios of standard ABA and IAA respectively with their isotope labelled analogoues.

iii) Analysis of cytokinins

Samples (1 µl) were injected (injector temperature 310ºC) at an oven temperature of 50ºC with the injection splitter (50:1) closed. After 1.0 min the splitter was opened, then the oven temperature was increased to 230ºC at 35ºC min^{-1} and finally to 280ºC at 3ºC min^{-1}. Detection was by selected ion recording mass spectrometry, monitoring ions m/z 261 and 230; 421 and 390 for endogenous zeatin and zeatin riboside respectively and m/z 266 and 235; 427 and 395 for the internal standard compounds. The endogenous hormones were quantified by comparing the ratio of the peak areas 230:235 and 390 and 395 for zeatin and zeatin riboside respectively with calibration curves constructed from known molar ratios of standard compounds with their deuteriated analogoues.

Plant Growth Regulator Applications

The plant growth regulators (PGRs) ABA, benzylaminopurine (BAP) and Trinexepac ethyl (TE) were applied as foliar sprays to field raised rose bushes as the primary shoots were extending rapidly. The first application was made on 16th May and repeats applications were made 2 and 4

weeks later. 2,3,5 tri-iodobenzoic acid (TIBA) was applied by painting the main stem, between 5 and 15 cm above the graft union, with an aqueous solution of the PGR.

RESULTS

Tables of data and figures are presented at the end of this section.

The IAA transport assay showed little difference between the intensities of IAA transport in floral and vegetative shoots of the freely breaking cv Remember Me and the shy breaking cv. Margaret Merril. In both cases, the intensity was slightly greater in vegetative shoots than in those that had become floral (Table 1). However, the velocity of IAA transport did change, in vegetative shoots of cv. Margaret Merril the velocity was over twice that observed in floral shoots, while the velocity increased slightly as shoots of cv. Remember Me progressed from vegetative to floral. This is evident in the graphs presented (Figs 1 & 2).

The results of analysis of phloem diffusates (Table 2) demonstrates clearly the consistency of the IAA flow from shoot tips of Remember Me in comparison with tips from cvs. Silver Wedding and Margaret Merril. While the levels of ABA in diffusates of cv. Remember Me were generally greater than in diffusates from cvs. Silver Wedding and Margaret Merril (Table 3), with the exception of the values obtained at the 30cm shoot stage and in September, where levels in cv. Remember Me were lowest. This is further demonstrated by the lower ratio of ABA:IAA detected in the diffusate collected from cv. Remember Me at the 30cm stage and in September (Table 4). In all cultivars the ratio of ABA:IAA peaks during late June and had declined by September.

The concentrations of IAA and ABA in shoot tips of the three cultivars were also measured (Tables 5 & 6) in samples collected at the time when 'tipping back' treatments were applied (6cm, 15 cm and 30 cm shoot length). The levels of IAA detected in each cultivar were similar at the 6cm growth stage and were greatest in the tips of the 30cm shoots. However, large differences in levels between the cultivars were apparent, with the level in cv. Remember Me being three times that of cv. Silver Wedding. The lowest levels were in the tips of 15cm shoots, with the exception of cv. Margaret Merril where levels were slightly higher than the initial value. ABA levels were generally very high (ca.100 times the IAA levels), but were lowest in the 6cm sample and greatest in the 15cm sample.

Concentrations of IAA and ABA were found to be lower in the 'bases' of shoots than in the tips (Tables 7 & 8). However, the highest concentrations of auxin were found in bases of shoots at the 15cm stage. This is in contrast to the tips of 15cm shoots in which the lowest levels of IAA were detected. With the exception of bases of 6cm shoots from cv Silver Wedding the levels of ABA were lowest in bases of shoots from cv Remember Me at each growth stage. We also measured the concentrations of the cytokinins zeatin and zeatin riboside in shoot bases (Table 9).

In each cultivar the concentrations of the cytokinins was lowest at the 15cm growth stage and tended to be greatest at the 30cm growth stage.

Bud position did not appear to effect the concentrations of IAA, ABA or cytokinin in a consistent manner (Tables 10 &11) and no clear patterns were apparent. This was reflected in the results of budding from defined bud positions, where differences appeared to be between bud-sticks than individual buds.

Shoot numbers were not consistently increased by any of the synthetic PGR treatments we applied (Table 12). While, one or more of the concentrations of growth regulator applied tended to result in very small increases in the numbers of shoots produced per bush, none of the treatments increased basal shoot numbers significantly on all three cultivars. Some effects of treatments, particularly TE, were visible on shoot growth and leaf colour as a general yellowing. None of the treatments decreased basal shoot numbers significantly.

Table 1 Transport of [3H]-IAA in vegetative and floral shoots

	Intensity dpm min^{-1}		Velocity mm hr^{-1}	
	Vegetative	Floral	Vegetative	Floral
Margaret Merril	99.90	93.89	21.46	9.21
Remember Me	87.04	85.22	9.04	10.21

Table 2 Concentration of IAA in Rose phloem diffusates (means of 3 replicates).

	Variety					
	Silver Wedding		Margaret Merril		Remember Me	
Length of shoot	ng $shoot^{-1}$	ng mm^{-2}	ng $shoot^{-1}$	ng mm^{-2}	ng $shoot^{-1}$	ng mm^{-2}
6 cm	4.1 (1.6)	5.7 (2.2)	2.3 (0.6)	4.4 (1.1)	2.8 (0.4)	4.6 (0.6)
15 cm	1.5 (0.1)	4.0 (0.2)	2.0 (0.1)	5.4 (0.3)	2.4 (0.1)	4.6 (0.5)
30 cm	1.8 (0.1)	2.6 (0.1)	1.8 (0.2)	3.3 (0.5)	4.1 (0.7)	4.3 (0.6)
Time of budding	2.0 (0.1)	3.7 (0.3)	2.2 (0.1)	4.2 (0.2)	4.6 (0.4)	5.8 (0.3)
September 1998	1.3 (0.2)	4.5 (0.7)	1.9 (0.1)	4.7 (0.4)	1.9 (0.1)	5.9 (0.2)

Figures in brackets denote standard error of the mean.

Fig. 1 - Transport of [3H]-IAA in vegetative shoots

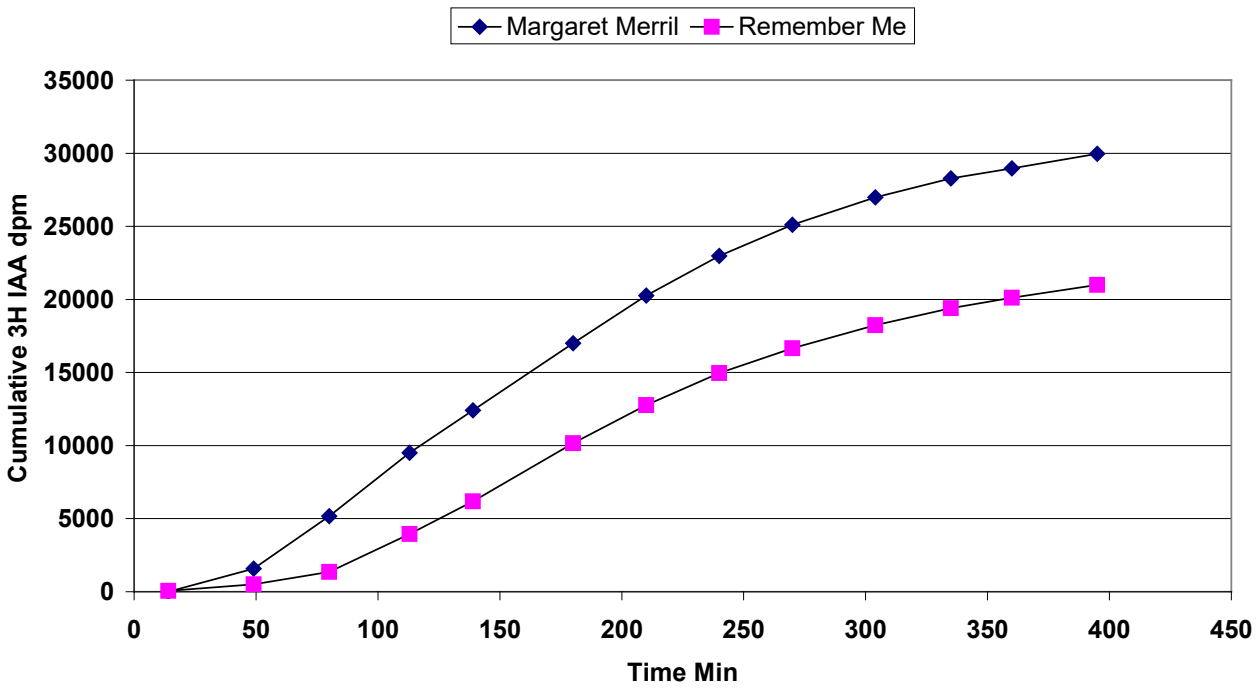


Fig. 2 - Transport of [3H]-IAA in floral shoots

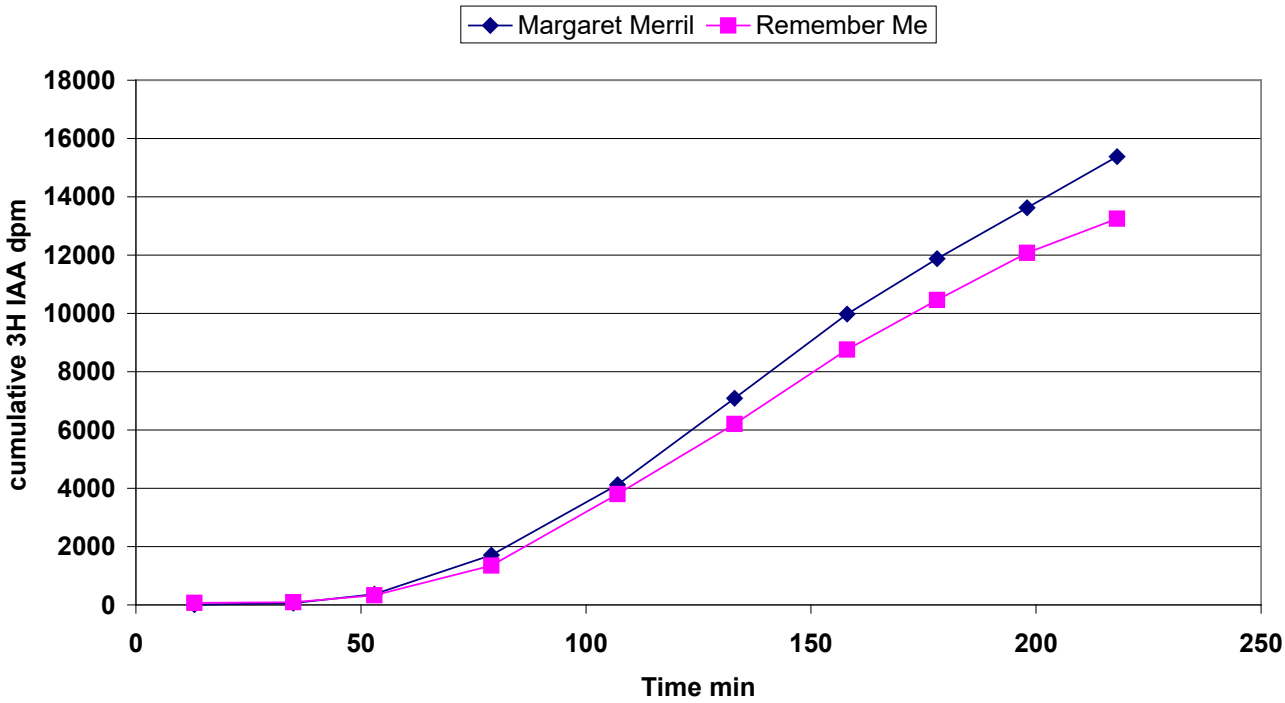


Table 3 Concentration of ABA in Rose phloem diffusates (means of 3 replicates).

	Variety					
	Silver Wedding		Margaret Merril		Remember Me	
Length of shoot	ng shoot^{-1}	ng mm^{-2}	ng shoot^{-1}	ng mm^{-2}	ng shoot^{-1}	ng mm^{-2}
6 cm	27.7 (2.2)	38.3 (1.2)	26.2 (5.1)	50.4 (13.2)	41.8 (5.9)	68.3 (3.0)
15 cm	17.3 (2.1)	46.8 (4.9)	22.6 (0.8)	59.5 (0.9)	45.7 (9.7)	84.9 (12.2)
30 cm	65.5 (4.8)	94.6 (11.4)	45.3 (8.3)	80.3 (14.4)	72.5 (10.1)	77.2 (9.9)
Time of budding	53.1 (4.9)	95.4 (6.0)	44.4 (2.1)	84.9 (2.5)	97.5 (17.9)	121.7 (16.2)
September 1998	33.1 (7.5)	113.1 (30.5)	34.8 (8.2)	84.1 (15.5)	18.8 (4.2)	58.4 (14.3)

Figures in brackets denote standard error of the mean.

Table 4 Ratio of ABA : IAA in Rose phloem diffusates (means of 3 replicates).

	Variety		
	Silver Wedding	Margaret Merril	Remember Me
Length of shoot			
6 cm	11.7 (0.6)	11.8 (2.3)	15.3 (1.8)
15 cm	11.7 (1.7)	11.2 (0.5)	19.2 (4.1)
30 cm	36.8 (2.5)	25.6 (6.6)	18.8 (4.3)
Time of budding	26.4 (3.1)	20.1 (0.4)	21.3 (3.4)
September 1998	24.3 (3.4)	18.6 (4.3)	10.1 (2.8)

Figures in brackets denote standard error of the mean.

Table 5 Concentration of IAA in Rose shoot tips (means of 3 replicates).

	Variety		
	Silver Wedding	Margaret Merril	Remember Me
Length of shoot	ng shoot^{-5}	ng shoot^{-5}	ng shoot^{-5}
6 cm	85.8 (4.7)	85.2 (3.3)	85.8 (4.7)
15 cm	56.6 (0.2)	86.4 (0.5)	33.7 (0.7)
30 cm	121.4 (5.8)	248.1 (4.1)	350.0 (9.2)

Figures in brackets denote standard error of the mean.

Table 6 Concentration of ABA in Rose shoot tips (means of 3 replicates).

	Variety		
	Silver Wedding	Margaret Merril	Remember Me
Length of shoot	μg shoot^{-5}	μg shoot^{-5}	μg shoot^{-5}
6 cm	2.7 (0.1)	5.0 (0.2)	7.5 (0.0)
15 cm	14.5 (0.2)	8.1 (0.3)	16.2 (0.5)
30 cm	7.1 (0.1)	6.0 (0.1)	11.4 (0.1)

Figures in brackets denote standard error of the mean.

Table 7 Concentration of IAA in Rose shoot bases (means of 3 replicates).

	Variety		
	Silver Wedding	Margaret Merril	Remember Me
Length of shoot	ng base^{-5}	ng base^{-5}	ng base^{-5}
6 cm	45.7 (3.2)	68.8 (2.5)	73.4 (3.0)
15 cm	97.7 (1.2)	99.3 (2.3)	95.8 (1.8)
30 cm	72.7 (2.2)	57.7 (3.1)	36.1 (1.3)

Figures in brackets denote standard error of the mean.

Table 8 Concentration of ABA in Rose shoot bases (means of 3 replicates).

	Variety		
	Silver Wedding	Margaret Merril	Remember Me
Length of shoot	µg base^{-5}	µg base^{-5}	µg base^{-5}
6 cm	0.6 (0.1)	4.0 (0.6)	2.6 (0.0)
15 cm	4.1 (0.2)	6.8 (1.1)	3.4 (0.4)
30 cm	4.6 (0.1)	3.7 (0.5)	2.9 (0.2)

Figures in brackets denote standard error of the mean.

Table 9 Concentration of Cytokinins in shoot bases. (means of 3 replicates)

	Zeatin ng $^{-5}$ shoot bases			Zeatin Riboside ng $^{-5}$ shoot bases		
Cultivar	22 April 6cm	6 May 15cm	20 May 30 cm	22 April 6cm	6 May 15cm	20 May 30 cm
Silver Wedding	15.4 (3.1)	7.5 (0.9)	10.8 (1.3)	51.3 (19.6)	20.4 (3.5)	48.5 (6.8)
Margaret Merril	13.3 (2.9)	7.4 (0.9)	10.0 (1.7)	45.6 (12.0)	18.9 (3.0)	48.4 (5.4)
Remember Me	6.7 (0.4)	5.3 (0.9)	11.1 (0.6)	25.6 (1.9)	16.4 (3.3)	41.2 (6.3)

Figures in brackets denote standard error of the mean.

Table 10 Effect of position on the bud stick on the concentrations of IAA and ABA in buds

	Variety					
	Silver Wedding ($ng.bud^{-1}$)		Margaret Merril ($ng.bud^{-1}$)		Remember Me ($ng.bud^{-1}$)	
Bud position	IAA	ABA	IAA	ABA	IAA	ABA
Apical	0.25	105	0.51	131	0.39	129
Middle	0.48	163	0.38	159	0.48	147
Basal	0.40	183	0.31	152	1.29	130

Table 11 Effect of position on the bud stick on the concentrations of zeatin (Z) and zeatin riboside (ZR) in buds

	Variety					
Bud position	Silver Wedding ($ng.bud^{-1}$)		Margaret Merril ($ng.bud^{-1}$)		Remember Me ($ng.bud^{-1}$)	
	Z	ZR	Z	ZR	Z	ZR
Apical	0.24	0.88	0.61	2.86	0.67	1.59
Middle	0.28	1.17	LS	LS	0.85	2.33
Basal	0.24	1.87	LS	LS	0.44	1.81

Table 12 Effect of growth regulator sprays on basal shoot number

Treatment / spray concentration		Silver Wedding	Margaret Merril	Remember Me
Control		3.1 (0.2)	2.3 (0.3)	3.9 (0.4)
ABA	1000mgl^{-1}	3.2 (0.5)	2.7 (0.3)	4.2 (0.3)
	50mgl^{-1}	3.8 (0.4)	3.1 (0.2)	5.3 (0.6)
	5mgl^{-1}	4.6 (0.6)	2.6 (0.3)	4.0 (0.4)
TIBA	1000mgl^{-1}	3.1 (0.5)	2.6 (0.5)	4.3 (0.7)
	100mgl^{-1}	3.5 (0.4)	2.1 (0.2)	4.3 (0.5)
	10mgl^{-1}	3.6 (0.4)	2.3 (0.3)	4.6 (0.6)
BAP	1000mgl^{-1}	3.5 (0.4)	2.1 (0.4)	4.4 (0.3)
	100mgl^{-1}	4.2 (0.6)	2.3 (0.2)	5.4 (0.5)
	10mgl^{-1}	2.4 (0.3)	2.4 (0.3)	5.2 (0.5)
TE	2000mgl^{-1}	3.0 (0.3)	2.3 (0.2)	4.6 (0.4)
	1000mgl^{-1}	3.2 (0.3)	2.9 (0.3)	4.6 (0.4)
	10mgl^{-1}	4.0 (0.4)	2.0 (0.3)	4.6 (0.6)

Figures in brackets denote standard error of the mean.

DISCUSSION

The velocity of transport of IAA was different in the two cultivars tested. Rate of transport in the freely breaking cv. Remember Me was uniform from vegetative through to floral shoots, also the intensity (the quantity of auxin moved) was not affected by the transition. While, the shy breaking cv. Margaret Merril also maintained a similar intensity in vegetative and floral shoots, the velocity of the transport system decreased markedly.

Transport of auxin is strongly associated with 'apical-dominance' the phenomenon that prevents axillary buds from breaking into growth while a dominant apex is growing strongly. However, this would tend to allow the growth of buds nearer to the shoot apex initially. Although, basal breaks tend to occur just after the flowers have senesced at a time when auxin transport would be expected to decline. This perhaps suggests that there is some involvement of apical dominance in the control of emergence of basal breaks, but it is probably not the overriding factor in determining the number of basal breaks that are produced.

While differences in hormone concentrations were apparent between the cultivars as they developed, further correlative work comparing other shy and freely- breaking cultivars is needed to draw firm conclusions. At present, it would appear that the IAA physiology of the freely breaking cultivar is different to that of the shy breaking cultivars. IAA is recognised as an important signal that moves between shoot and roots and the IAA signal is thought to control production of cytokinins and possibly ABA by the roots. ABA levels and cytokinin levels also show differences between shy and freely breaking cultivars. However, concentrations of ABA in rose tissues are noteworthy, in that they are extremely high in comparison with other species. (In ca. 20 years of analysing ABA in a number of different species, I have never before detected such high levels, even in stressed tissues). However, the difference in concentrations of hormones between shy and freely breaking cultivars are not generally large or consistent. To progress this work it is important to identify the 'timing' of the critical events such as when the buds that give rise to basal breaks are initiated, when do they develop and for how long are they dormant.

CONCLUSIONS

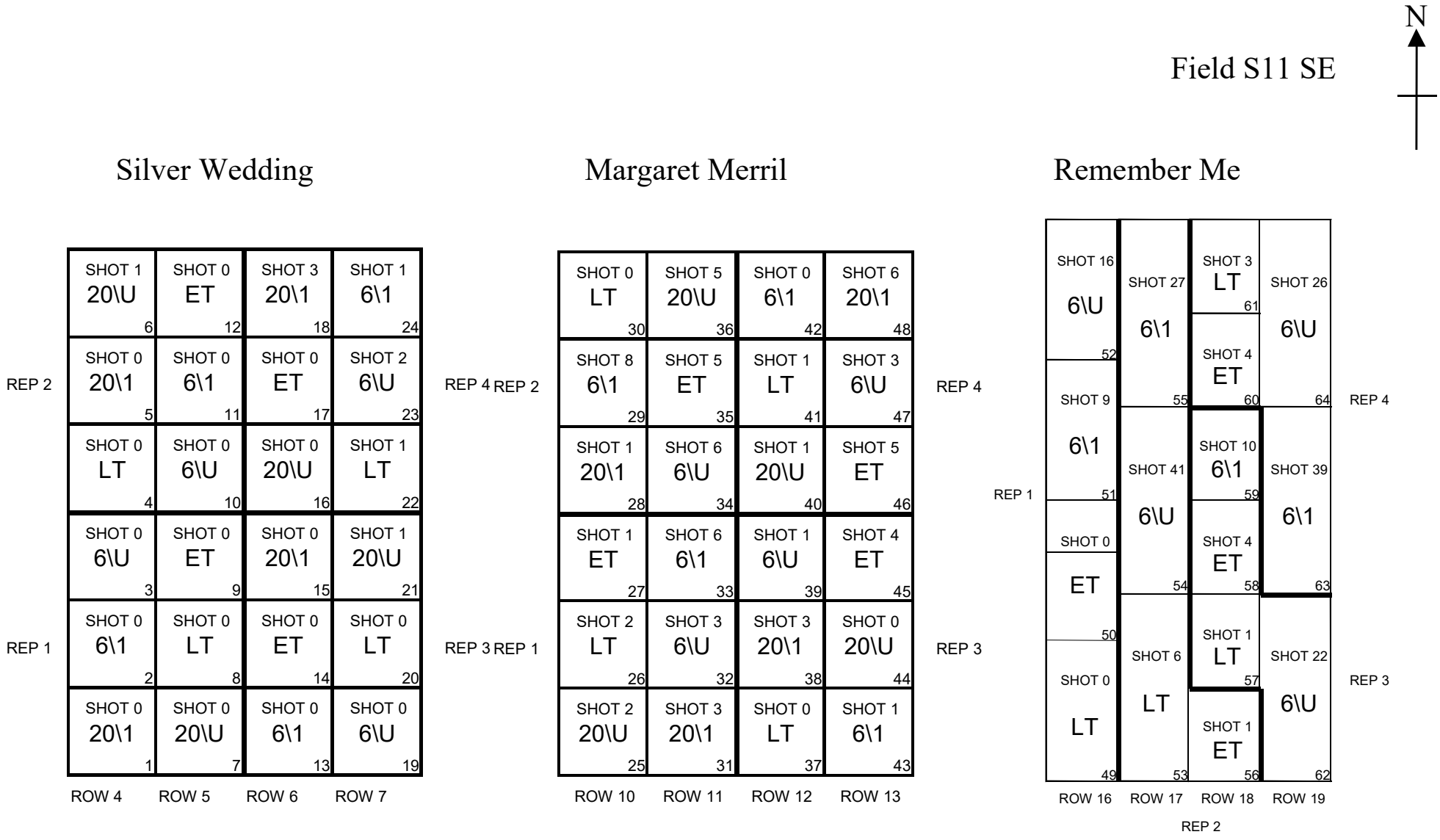
Overall, the physiological study has indicated that there are differences between the cultivars particularly in terms of their capacity to transport auxin and this may influence the release of dormant buds and the emergence of basal breaks. However, without clear knowledge of the timing of intiation and development of these buds it is difficult to draw firm conclusions from the physiological studies. Basal breaks are produced from buds that occur close to the graft union, often emerging from the mass of tissue that forms the union. This tends to suggest that these buds are adventitious, i.e. a 'new meristem' is formed that develops into a bud and then, after release from dormancy, into a shoot. Further work should investigate the time these buds are initiated and the hormone physiology during this critical period. It may also be necessary to investigate the development of these buds that form basal breaks. It may be that equal numbers of buds are initiated in shy and freely breaking cultivars, but the development of some buds may be arrested in the shy-breakers.

While there is a slight suggestion that BAP (the synthetic cytokinin we applied) may have stimulated shoot production when applied as a spray, synthetic cytokinins are used routinely in *in vitro* tissue culture to induce adventitious shoot formation. However, *in vitro* cultures are placed on a medium containing the cytokinin for considerable periods. In the field surface deposits from sprays are subjected to rain, sun and other factors that may degrade the active ingredient, also uptake through mature leaves and stems may be poor, while that which is taken up by the plant will be metabolised away. A slow release formulation of cytokinin applied to newly emerging shoots, or directly to the bud early in the season might be a more effective treatment.

Basal breaks tend to be vigorously growing and very spiny, suggesting that they may be 'juvenile' shoots and this would support the adventitious bud theory. Also, the gibberellin group of plant hormones have been implicated in the control of juvenility in other rosaceous species and suggest additional chemical treatments that could be tested. Some gibberellins are already cleared for commercial use in fruit and other crops.

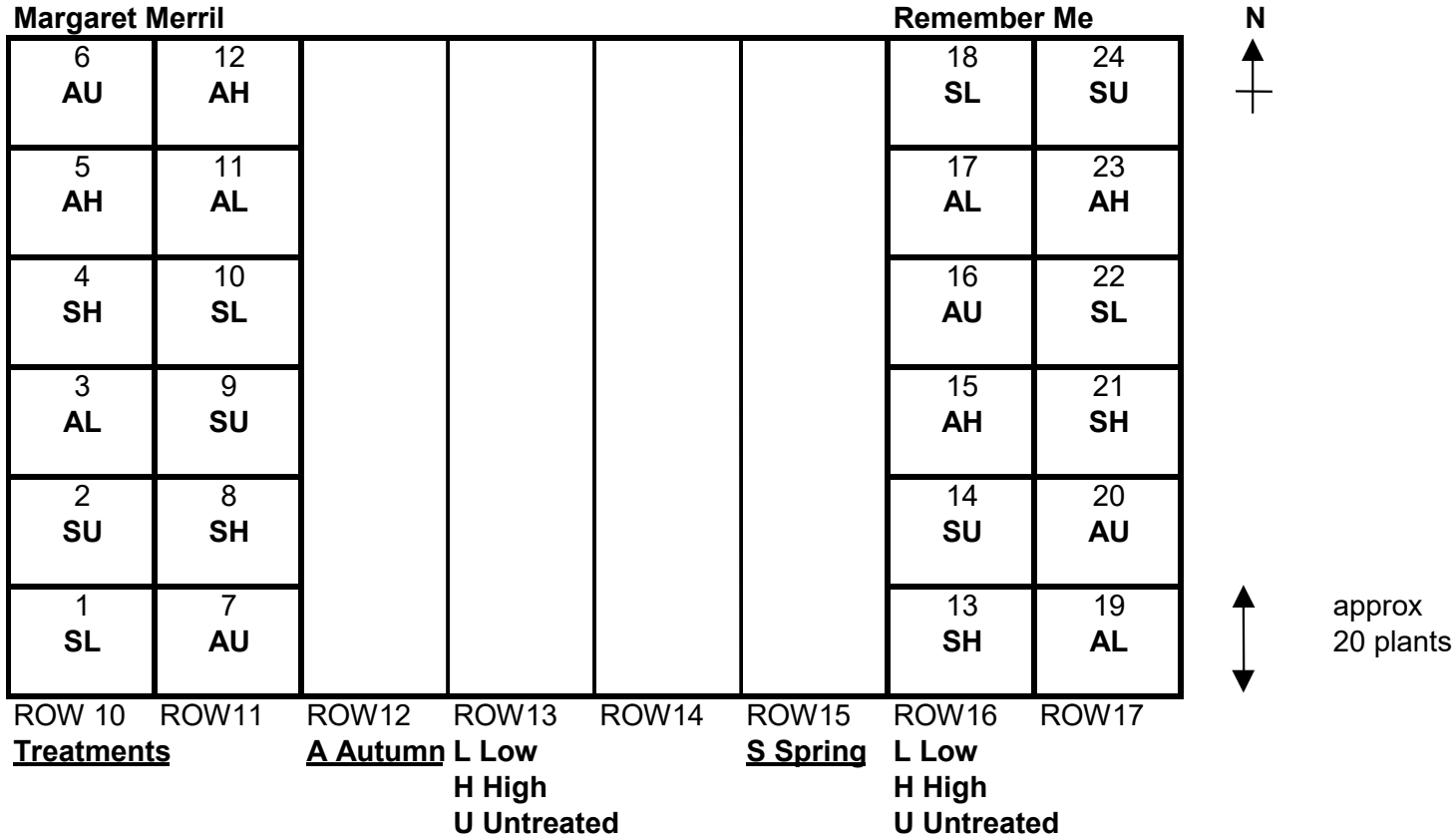
Appendices

Appendix 1 - Field Tipping back experiment layout 2000



Appendix 2 - Use of Ethrel C experiment layout 2000 / 2001

Field S6 south central. Budded July 2000



Ethrel C Low = 0.75% Product = 7.5 mls/litre (3000ppm ai)
High=1.55 Product=15mls/litre (6000pm ai)
plus 0.1% (1ml/litre) Agral wetter.

Autumn Whole rootstock top and base of plant treated 19 October 2000.

Spring Bottom 20cm of scion growth treated 28 June 2001.

Appendix 3 - Photographs of Ethrel C experiment

Plate 1 - Margaret Merril - Untreated plants October 2001

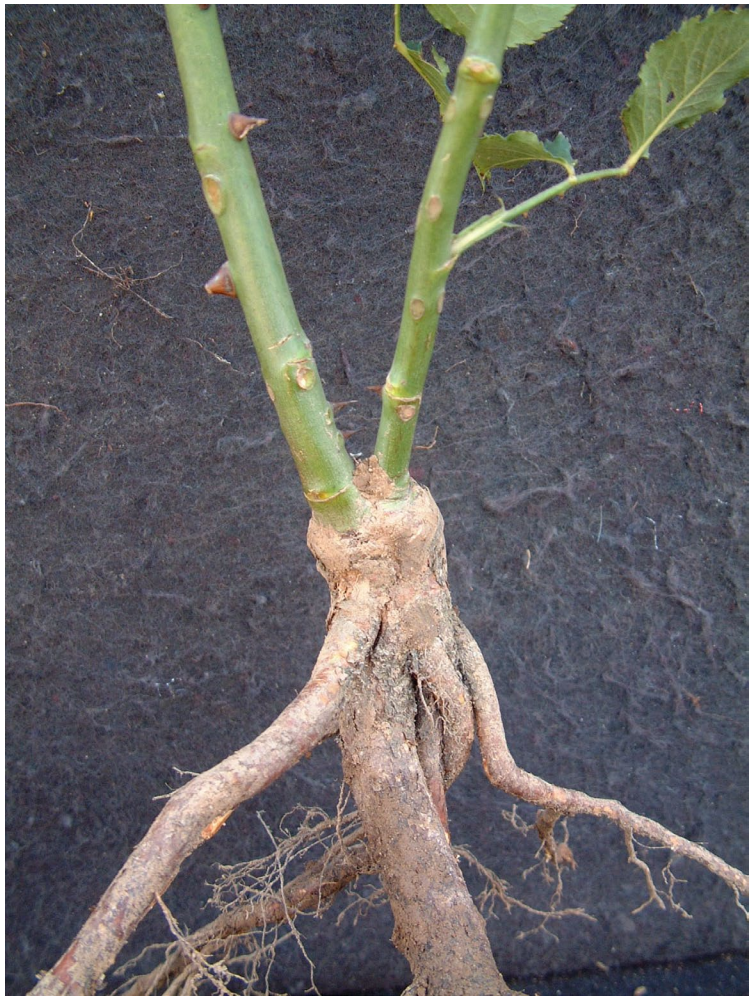


Plate 2 - Margaret Merril - Ethrel C (high rate) sprayed late June 2001 to base of plants - photographed at lifting October 2001