Project Title	Improving the quality of HNS and roses using irrigation and fertigation management techniques
Project number:	HNS 141
Project leader:	Dr Mark A Else, East Malling Research
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Previous report:	NA
Key staff:	Dr Mark A Else (Project Leader) Dr Olga M Grant (Project Manager) Mr Danny Elliott (HNS Business Consultant)
Location of project:	East Malling Research, East Malling, Kent
Project Co-ordinators:	David White (Paul Chessum Roses) David Hooker (Hillier Nurseries)
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Disclaimer:

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work, it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

Authentication

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Improving the quality of HNS and roses using irrigation and fertigation management techniques

Annual Report – March 2007

Grower Summary

Headline

Imposing Regulated Deficit Irrigation (RDI) using drip irrigation to supply 50% or 75% of plant demand for water improved several aspects of plant quality in some, but not all, of the species tested.

Background and expected deliverables

The project aims to improve plant quality of HNS species and containerised rose cultivars using both irrigation and fertigation management techniques during the production cycle. There is much interest in using water more efficiently in the production of HNS and several projects are currently making progress to this end (*e.g.* HNS 97b, HNS 122, and Defra HH3731SHN). In this project, six HNS species and four rose cultivars .are being used to determine the effects of deficit irrigation and fertigation on plant 'quality'.

Deficit irrigation techniques such as Regulated Deficit Irrigation (RDI) replace only a percentage of the water the plant loses *via* transpiration. This saves water and has the potential to modify shoot growth, plant 'robustness', plant habit and visual appeal. Research in other crops suggests that RDI can also improve shelf-life potential by bestowing an increased tolerance to the stresses encountered during distribution and retailing.

There are two aims to this project:

1. The effects of RDI on components of plant quality at the point of sale will be determined.

2. It will be determined whether plants previously exposed to RDI during the production cycle are better able to tolerate the stresses encountered during distribution and retailing. Standards of plant care can vary widely between retailers and unfavourable conditions during this period can markedly limit plant quality and subsequent garden performance. Any benefits in terms of increased tolerance to these stresses would help to reduce wastage in-store and also benefit consumers.

Expected deliverables from this work include:

- Improved crop consistency and uniformity with associated reductions in labour costs.

- Improved economic returns by reducing wastage and producing high value ‘robust’ plants.

- The delivery of efficient and sustainable production methods to improve quality and shelf-life of HNS and containerised roses.

- More efficient use of water and reduced environmental pollution.

- Potentially beneficial effects on scheduling and manipulation of flowering time.

Summary of the project and main conclusions

Quality criteria

The criteria for assessing plant quality in the HNS species and rose cultivars used in the project have been developed through consultation with Mr David White (Paul Chessum Roses), Mr David Hooker (Hillier Nurseries) and Mr Danny Elliott (HNS Business Consultant). These criteria will be developed and refined further as the project progresses by incorporating advice and suggestions from other HNS and rose growers and retailers (*e.g.* Wyevale Garden Centres).

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To date, quality criteria have been developed for roses at the dormant stage and for HNS species at the point of sale. A scoring system has been designed and scores allotted by experts (Figures GS1 and GS2). These will be compared to scores assigned by consumer groups to determine whether the perception of quality by the experts matches expectations of consumers.

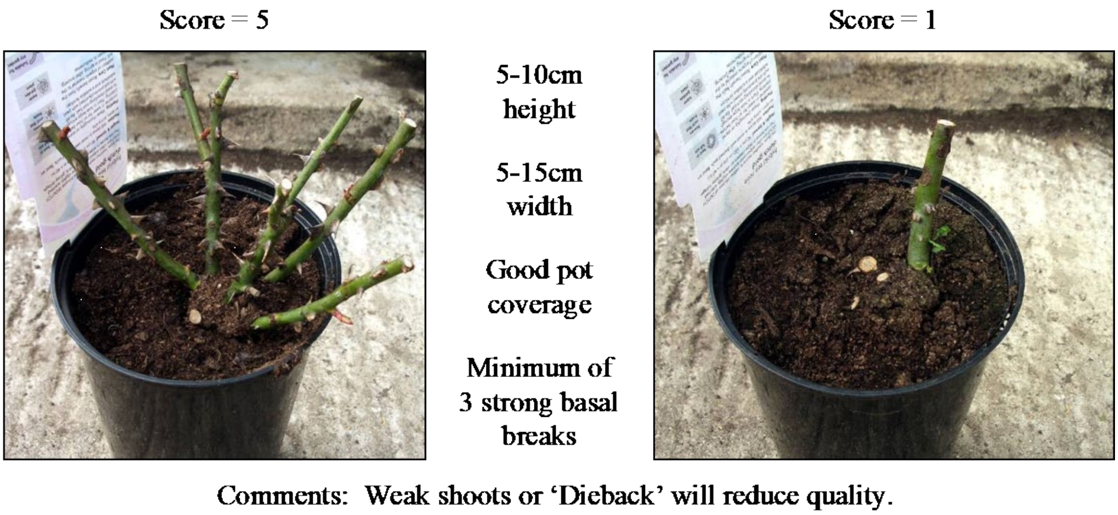

Figure GS1. Criteria used to assess the quality of *Rosa* 'Dutch Gold' at point of sale. A representative plant of excellent quality (score = 5) illustrates the key criteria; an example of a poor quality plant (score = 1) is presented for comparison.

Irrigation treatments

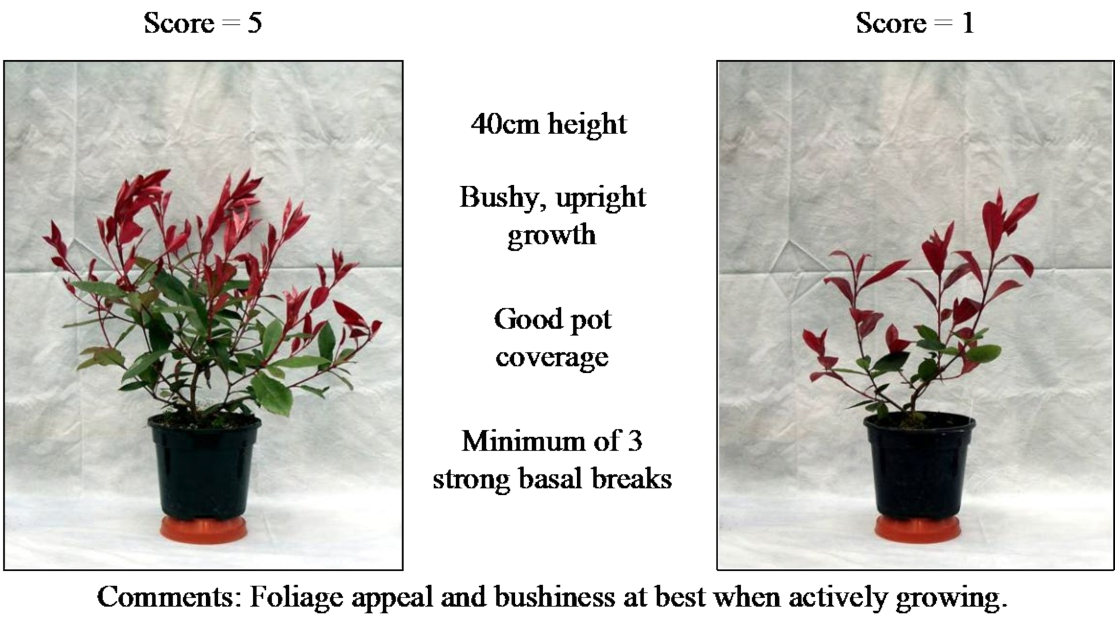

Figure GS2. Criteria used to assess the quality of *Photinia fraserii* 'Red Robin' at point of sale. A representative plant of excellent quality (score = 5) illustrates the key criteria; an example of a poor quality plant (score = 1) is presented for comparison.

Irrigation to six HNS species and four rose cultivars was scheduled using the EvapoSensor and EvapoMeter. Well-watered plants received 100% of the daily potential evapotranspiration (ET_p). RDI regimes of 75% and 50% were applied using drip irrigation during the first year of the production cycle. RDI affected several components of quality in some, but not all, of the species and cultivars tested:

- For example, plant height was reduced by RDI in *Forsythia* but not in *Photinia*.

- Stem internode length was reduced by RDI in some rose cultivars (*e.g. Rosa* 'Just Joey') but not in others.

- The total number of branches produced during the first year of production was decreased by RDI in *Forsythia x intermedia* 'Weekend'.

- In contrast, basal breaking was improved in RDI-treated *Rosa* 'Arthur Bell' and *Rosa* 'Just Joey'.

Therefore, RDI has the potential to improve the grade-out of Class 1 rose bushes where a minimum of three good strong basal breaks is required. Further work in 2007 will help determine whether these responses to deficit irrigation can be improved when RDI regimes are optimised for each species and cultivar.

The potentially beneficial effects of RDI on shelf-life potential will be determined for the different crops during March-June 2007.

Conditions during distribution and retailing

Data loggers ('TinyTag Plus 2') placed inside delivery lorries leaving Paul Chessum Roses were used to record the range of temperatures and relative humidities that dormant-stage roses were exposed to during distribution to the retailers. Conditions have been determined during the peak sales period for dormant-stage roses and these measurements will be repeated at different times during the main retailing phase. These conditions will be replicated in the store-life room to help determine the effects of RDI on shelf-life potential later in the season when conditions during distribution and retailing will have a greater impact on plant quality and shelf-life potential.

Financial benefits

Improving irrigation scheduling and imposing RDI will reduce water use and may improve plant quality, uniformity and shelf-life potential, with associated reductions in labour costs and waste. However, it is too early to identify any financial benefits associated with these treatments at this stage of the project.

Action points for growers

- Scheduling of irrigation and deficit irrigation can help to reduce water usage and improve uniformity and visual appeal in some crops.

- However, growers should also be aware that RDI can reduce the production of branches in some species by as much as 24%.

- Restricting the number of species, or grouping together species with similar water requirements under one irrigation system, will help to improve uniformity and plant quality at point-of-sale.

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Science Section

HNS 141

Improving the quality of HNS and roses using irrigation and fertigation management techniques

Annual Report – March 2007

Introduction

The project aims to improve plant quality of HNS species and containerised rose cultivars using irrigation and fertigation management techniques during the production cycle. These deliverables will assist the HDC in fulfilling the objectives outlined in the HNS Strategy document where enhancing production efficiency and improving plant quality have been identified as key targets.

There is currently much interest in using water more efficiently during the production of HNS and several key projects are making good progress towards this goal (*e.g.* HNS 97b, HNS 122, Defra HH3731SHN). HNS growers also recognise that good management of irrigation will help to reduce labour costs associated with hand-watering and those costs associated with grading of plants for marketing; work in HNS 97 identified that uneven water application was a major cause of lack of uniformity.

One of the objectives of HNS 97b (Water LINK II) is to establish whether irrigation scheduling can be implemented successfully in the commercial production of several HNS species. How this might be best achieved using the existing irrigation systems on commercial nurseries is currently being addressed on the East Malling Water Centre (EMWC) in HNS 122. In addition, the potential of deficit irrigation to deliver further water savings into the HNS sector is being determined in HNS 97b.

Deficit irrigation involves replacing only a percentage of the water the plant loses *via* transpiration. The aim is to impose a very gradual soil drying treatment to stimulate the production of root-sourced chemical signals (*e.g.* plant hormones). These signals are then exported in the transpiration stream to the shoots where they can modify shoot growth and stomatal behaviour. Many of these chemical signals are also likely to influence plant 'robustness', plant habit, time of flowering and, as a result, visual appeal.

Our work in Defra funded project HH3609TX [Partial rootzone drying (PRD): delivering water saving with sustained high quality yield into UK horticulture] suggests that Regulated Deficit Irrigation (RDI) can improve the shelf-life potential of protected crops such as poinsettia. Leaf and bract drop were reduced by 50% and 90% respectively, during a six-week home-life test. To simulate conditions encountered during distribution and retailing, plants were held at 10°C for 12 hours, returned to room temperature and left sleeved for a week without watering to simulate conditions in the retail environment. Only when the plants encounter these sorts of stresses do the benefits of deficit irrigation become apparent.

The aims of this project are two-fold. Firstly, we will determine the effects of deficit irrigation on plant quality at simulated market date. The individual components (*e.g.* height, spread, branching framework) that determine overall plant quality will vary between different species and the perception of these attributes can also be fairly subjective. Amongst different HNS growers, the perception of quality will necessarily be influenced by individual retailers' plant specifications. The perception of plant quality by the consumer may also vary widely and may not reflect the opinions of the growers and retailers. Thus, our assessments must incorporate these different views if the effects of deficit irrigation on plant quality are to be determined accurately and reproducibly.

Secondly, we will determine whether plants previously exposed to RDI during the production cycle are better able to tolerate the stresses encountered during distribution and retailing. Conditions during distribution can have a marked effect on rose quality and susceptibility to disease during the subsequent retail phase. The on-going globalisation of the UK horticulture industry will exacerbate any existing problems associated with transportation as UK growers and retailers increasingly source plant material from overseas. Standards of plant care can vary widely between retailers and unfavourable conditions during this period can markedly limit plant quality and subsequent garden performance, as highlighted recently in the HDC training DVD on Ornamental Plant Care. Increased tolerance to these stresses as a result of deficit irrigation treatments such as Regulated Deficit Irrigation (RDI) would help to reduce wastage in-store and also benefit consumers.

Materials and Methods

Objective 1: To develop criteria for the assessment of plant quality

Criteria have been developed for six HNS species and four *Rosa* cultivars. The quality criteria for the *Rosa* cultivars have been developed by David White and his colleagues at Paul Chessum Roses. Sixteen containerised roses of varying quality of four cultivars (x2 Hybrid T's and x2 Floribunda) were scored for quality by five 'experts'. Scoring was based on a five-point scale with 1 representing very poor quality and 5 representing excellent quality. The roses are due to be transported to EMR in a delivery lorry in the last week of March. The scoring will then be repeated by a 'consumer' panel consisting of twenty individuals (horticulturists and non-horticulturists), as in HDC PC 200 for bedding plants. Scores between the two groups will be compared to determine whether the perception of plant quality at point-of-sale differs between 'experts' and 'consumers'. This system of scoring will be repeated at the half-growth stage and the bud/colour stage.

The quality criteria for HNS species have been developed after discussions with David Hooker (Hillier Nurseries) and Danny Elliott. The key quality attributes for each HNS species are presented along with examples of 'excellent' and 'very poor' quality plants (see Results). It is envisaged that these criteria will be developed further as the project progresses. Scores between 1 and 5 have been allotted by an 'expert' and these scores have been correlated with those of the ‘consumer’ group, consisting of 21 horticulturists and non-horticulturists from the EMR site. A correlation value of +1 indicates perfect agreement, 0 equals no agreement, -1 implies complete disagreement.

Objective 2: To define and duplicate conditions encountered during retail transport and shelf-life.

A data logger (‘TinyTag Plus 2’) was placed inside each one of three delivery lorries loaded with Danish Trolleys each carrying 128 containerised roses in the dormant stage of growth. The lorries were dispatched from Paul Chessum Roses on 22 February 2007 and returned to the nursery on 24 February and on 8 March after completing deliveries to retailers throughout the country. The loggers recorded the range of temperatures and relative humidity (RH) that the dormant-stage containerised roses were exposed to during transportation to the retailers. Conditions during distribution in three different types of container lorry were recorded, a ‘curtained’ container, a ‘box’ container and a ‘refrigerated’ container (cooling turned off). We propose to repeat this exercise at intervals over the coming season.

An existing fruit storage room at EMR has been modified to provide conditions that duplicate the temperature and RH fluctuations encountered during transport to retail outlets. Roses of each cultivar that were subjected to RDI in 2006 will be placed in the store-life room during May-June 2007 when conditions during distribution are most likely to affect plant quality. The roses will then be maintained outside on benches at the Plant Shelf-life Centre at East Malling and scored for overall quality in May, June and July 2007.

Objective 3: To determine the impact of irrigation and fertigation regimes on quality and shelf-life.

Plant material

Liners of *Forsythia x intermedia* 'Lynwood Gold', *Forsythia x intermedia* 'Weekend', *Cornus alba* ‘Elegantissima’, *Cornus alba* 'Ivory Halo', *Cotinus coggygria* 'Royal Purple', *Mahonia x media* ‘Winter Sun', and *Photinia fraserii* 'Red Robin' in 9cm pots were sourced from New Place Nurseries Ltd. The two *Forsythia* species were dispatched in March 2006; on arrival, all plants were immediately potted into 3L pots containing a Richmoor compost mix (peat/sphagnum, 60/40 blend), with starter feed (14.16.18), slow release fertilizer (Osmocote Plus, 4kg m^{-3}, 5:9:12), and Intercept 5GR for vine-weevil control. All other HNS species were dispatched in June 2006 and were potted on into 3L pots containing substrate sourced from New Place Nurseries Ltd. All plants were hand-watered immediately after potting and placed out on mypex-covered sand beds at EMR where they were left to establish. 'Empot carriers' were used to ensure that all plants remained upright throughout the experiments; plants were spaced at 30cm.

Maiden bushes of *Rosa* 'Remember Me', *Rosa* 'Just Joey', *Rosa* 'Arthur Bell' and *Rosa* 'Margaret Merrill' were sourced from Paul Chessum Roses and were delivered to EMR in April 2006. The bare-rooted stocks were potted into 4L pots containing the Richmoor compost mix. Again, all pots were hand-watered and maintained at pot capacity during a 6-week establishment period. Rootstock suckers were removed as and when necessary.

Irrigation application and scheduling

Each pot was irrigated using pressure-compensated, non-leakage drippers (TORO NGE 2, 3, or 4 lh^{-1}, City Irrigation Ltd, UK) each connected to a lace (PVC tubing, 4 mm i.d.) and a pot stake (Figure 5). Dripper outputs were tested prior to the experiment to ensure an accuracy of within 10%. Drippers were placed in the middle of each pot to try to ensure an even application of water. The timing and duration of irrigation events was scheduled using four Galcon DC-1S controllers (Field (GB) Ltd, UK) connected to a manifold housing four DC-1S ¾" valves.

Irrigation treatments were applied as a percentage of potential evapotranspiration (ET_p). ET_p values were obtained using an SKTS 500/PRT Evaposensor and SEM 550 Evapometer (Skye Instruments Limited, Llandrindod Wells, Powys, UK). The Evaposensor was positioned amongst the experimental plants and maintained at canopy height. The irrigation time (t) required to return the plants to pot capacity after a given period of time was calculated using the equation $t = E_{acc.} \times F$, where E_{acc} is the Evapometer output for that period. A factor (F) was recalculated regularly to adjust for changes in canopy area and environmental conditions; where W is the mean weight loss from a well-watered plant (n=6) over 24h, and E_{acc} is the Evapometer output over the same period, F was calculated as

$$F = \frac{W}{E_{acc}}$$

Irrigation was applied three times daily (08:00, 12:00 and 17:00) to minimise the risk of over-watering or run-off from the pots. Each event replaced the relevant percentage of ET_p recorded since the previous irrigation.

Experimental design and irrigation regimes

In a series of three experiments, plants were arranged on the sand beds in randomised block designs (Figures 1, 2, and 3) that were generated using Genstat. For each treatment, there were six or 12 replicates for the HNS species tested and four replicates for each rose cultivar (rose numbers for this experiment were limited in 2006 due to two large Defra trials on basal breaking). Three treatments were applied: a well-watered (WW) control given 100% ET_p, and two RDI treatments of 75% and 50% ET_p.

Experiment 1: Treatments were applied to *Forsythia x intermedia* 'Lynwood Gold', and *Forsythia x intermedia* 'Weekend' on 6 June 2006 (Day 0) until 2 November 2006 (Day 159).

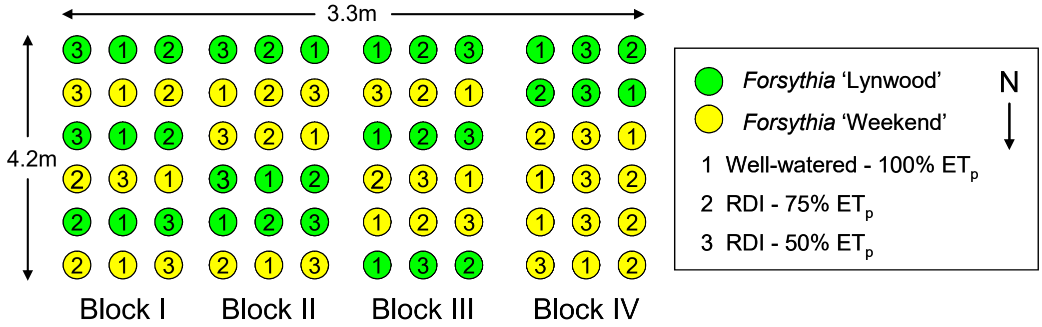
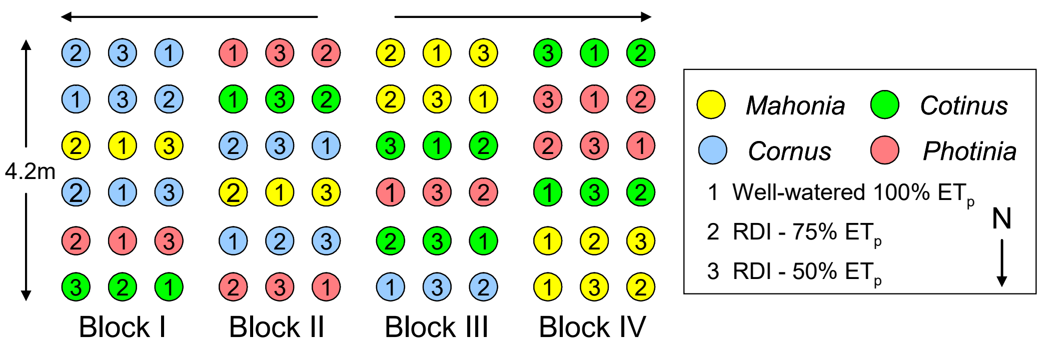


Figure 1. Plot design for Experiment 1: effects of RDI on *Forsythia* cultivars.

Experiment 2: Treatments were applied to *Cornus alba* 'Elegantissima', *Cotinus coggygria* 'Royal Purple', *Mahonia x media* 'Winter Sun' and *Photinia fraserii* 'Red Robin' from 8 August (Day 0) until 31 October 2006 (Day 84). Due to technical limitations, *Mahonia* and *Cotinus* were watered using the same irrigation line; preliminary measurements suggested that rates of water lost by these two species were similar. However, this approach made it difficult to optimise RDI regimes in both species later in the season (see Results).

Experiment 3: Treatments were applied to *Rosa* 'Remember Me', *Rosa* 'Just Joey', *Rosa* 'Arthur Bell'and *Rosa* 'Margaret Merrill' from 29 June (Day 0) until 2 November 2006 (Day 126).



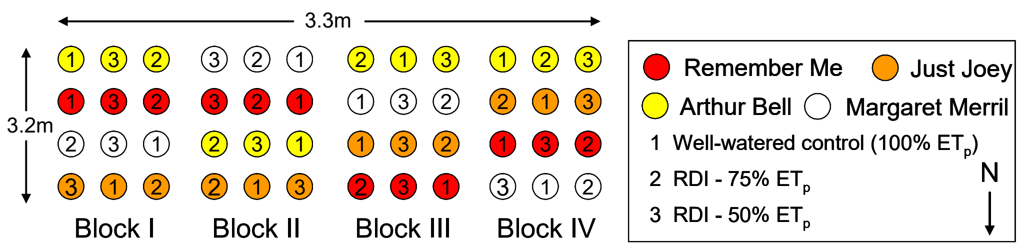


Figure 3. Plot design for Experiment 3: effects of RDI on rose cultivars.

Monitoring RDI regimes

In each of the three experiments, plant-and-pot weights were determined each week throughout the experiment using a portable balance (ScoutPro 4000, Ohaus UK Ltd, UK). The substrate volumetric moisture content (SMC), in each pot was determined using a Delta T Theta probe ML2x and Delta T HH2 Moisture meter (Delta T Devices, UK), which was calibrated for the compost used. Measurements were made through holes drilled mid-way up both sides of the pots. These measurements helped to determine whether the RDI regimes were being applied effectively in each species or cultivar tested.

Following significant rainfall events during the season, irrigation was suspended until the pot weights had returned to the values recorded at the last measurement date. At the end of each experiment (Nov 2006), all RDI-treated plants were gradually re-watered to pot capacity and plants were left to over-winter on the sand beds.

Measurements of components of plant quality

In experiments 1 and 2, plant heights and spreads, and the numbers of new branches produced were measured at intervals throughout the growing season (July-September 2006) and again at the end of the dormant season (March 2007). In experiment 3, the numbers of basal breaks were recorded in July and August 2006 after the second growth flush and again at the end of the dormant season (March 2007). Since roses are routinely dead-headed, measuring the effects of RDI on stem height would not be instructive. Instead, the lengths of the internodes on each stem were measured below 15cm stem height and the average internode length per rose bush calculated.

More complete assessments of plant quality will be made immediately prior to the simulated market date using the criteria developed under Objective 1.

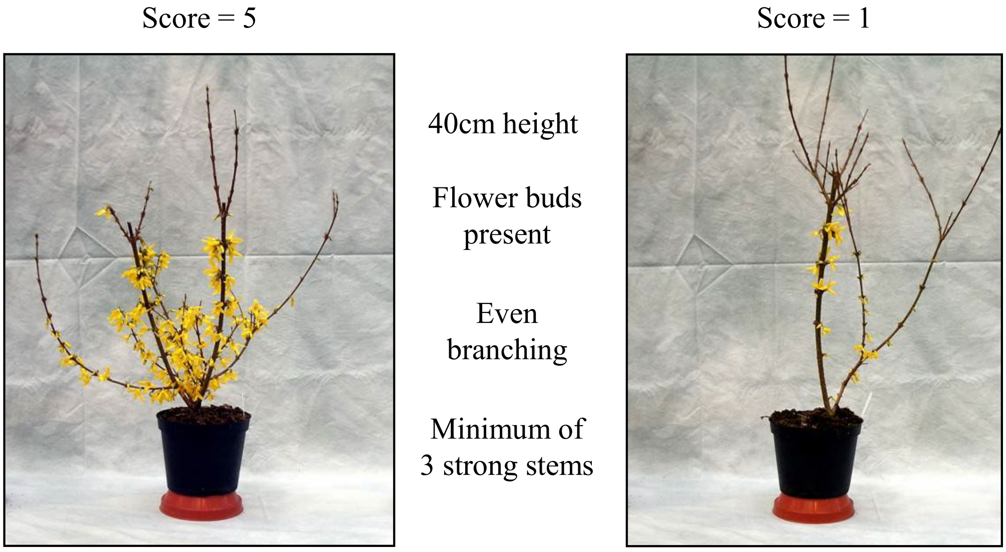
Results and Discussion

Objective 1

Quality criteria for Rosa cultivars

The most important factor determining the quality of dormant-stage roses is the number of basal breaks; a minimum of 3 strong basal breaks are required for a Class I rose bush (Figure 4). Therefore, any treatment that can improve basal breaking will increase the grade-out of Class I bushes, currently estimated at only 60%. Retailers also require good pot coverage; the height and width restrictions can be readily achieved through careful pruning. Weak shoots or 'dieback' in pruned shoots will reduce the overall quality.

*Quality criteria for HNS species*For many HNS species, one of the most important quality



Comments: Flower appeal, bushiness, flowers on previous season's growth.

Figure 5. Criteria used to assess the quality of *Forsythia x intermedia* 'Lynwood Gold' at market date. A representative plant of excellent quality (score = 5) illustrates the key criteria; an example of a poor quality plant (score = 1) is presented for comparison.
poor quality plant (score = 1) is presented for comparison.

criteria is a minimum of three good, strong branches at the base of the plant, giving rise to a uniform framework of upright branches. The key criteria for assessing plant quality for *Forsythia x intermedia* 'Lynwood Gold', *Cotinus coggygria* 'Royal Purple', *Mahonia x media* 'Winter Sun' and *Photinia fraserii* 'Red Robin' are presented in Figures 5, 6, 7 and 8. Examples of plants

scoring 5 (excellent quality) and 1 (very poor quality) are also presented, along with more general comments on plant quality for each species.

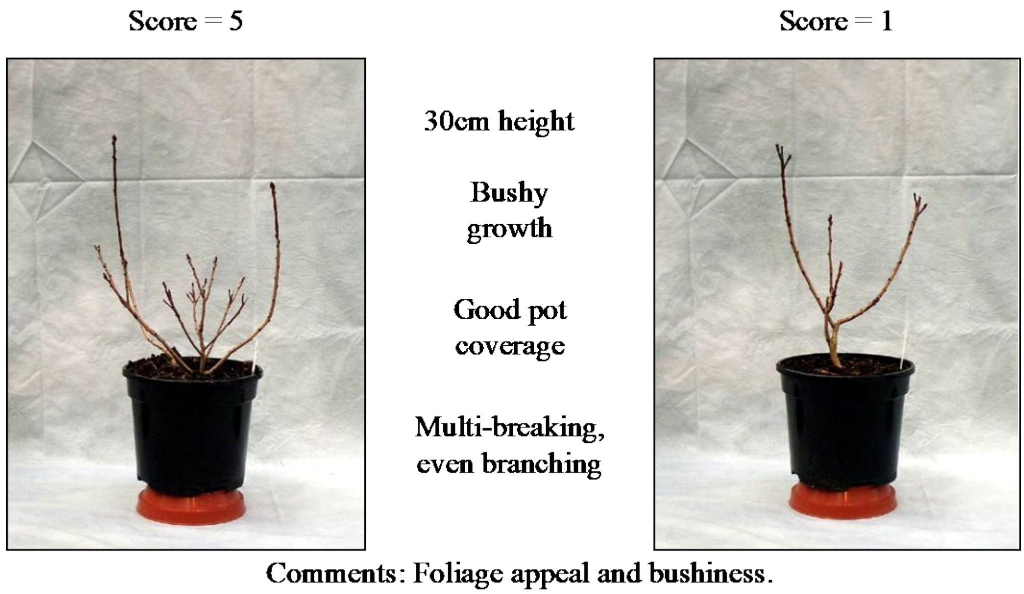


Figure 6. Criteria used to assess the quality of *Cotinus coggygria* 'Royal Purple'. A representative plant of excellent quality (score = 5) illustrates the key criteria; an example of a poor quality plant (score = 1) is presented for comparison.

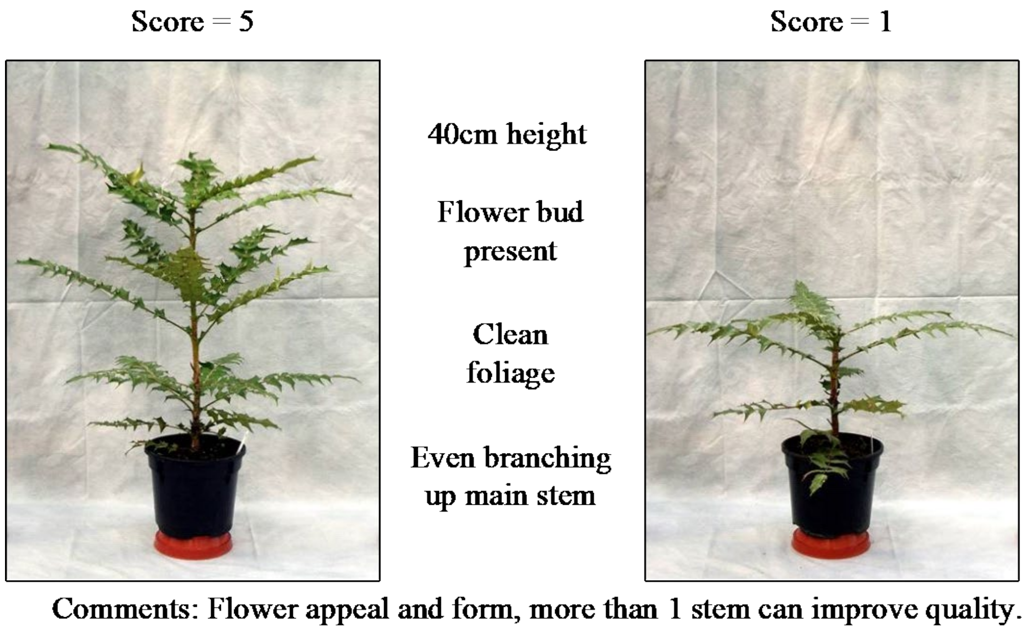


Figure 7. Criteria used to assess the quality of Mahonia x media 'Winter Sun'. A representative plant of excellent quality (score = 5) illustrates the key criteria; an example of a poor quality plant (score = 1) is presented for comparison.

Perception of quality: 'Expert' versus 'Consumer'

Correlation analysis was used to compare the 'expert' score to scores given by a 'consumer' group, consisting of 21 horticulturists and non-horticulturists from the EMR site. A correlation value of +1 indicates perfect agreement, 0 equals no agreement, -1 implies complete disagreement between the 'expert' and 'consumer' scores. The correlation between 'expert' and 'consumer' was generally very good for *Forsythia* (Figure 9), the mean correlation value was 0.88 (± 0.04) indicating that consumers sought the same quality attributes as the expert. The key quality attribute in *Forsythia* at point-of-sale is the number and quality of the flowers; this is a very visible and easily quantifiable trait which presumably explains the close similarity between the 'expert' and 'consumer' scores.

For *Cotinus coggygria* 'Royal Purple', the mean correlation value was 0.35 (± 0.12) indicating only a fair correlation between the 'expert' and 'consumer' scores. The majority of consumers agreed to some extent with the 'expert' score, with obvious exceptions (Figure 10). The fairly weak overall correlation may be due to the fact that

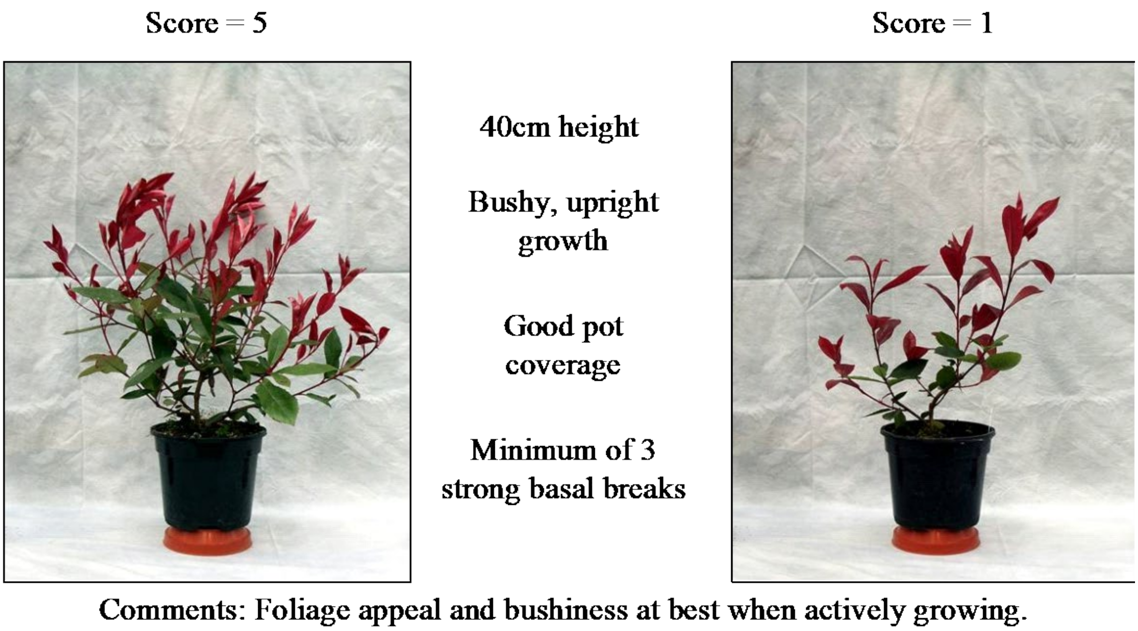


Figure 8. Criteria used to assess the quality of *Photinia fraserii* 'Red Robin' at market date. A representative plant of excellent quality (score = 5) illustrates the key criteria; an example of a poor quality plant (score = 1) is presented for comparison.

the plants were not yet in leaf at our simulated market date; many 'consumers' then somewhat reluctantly scored the plants based on their overall 'shape'.

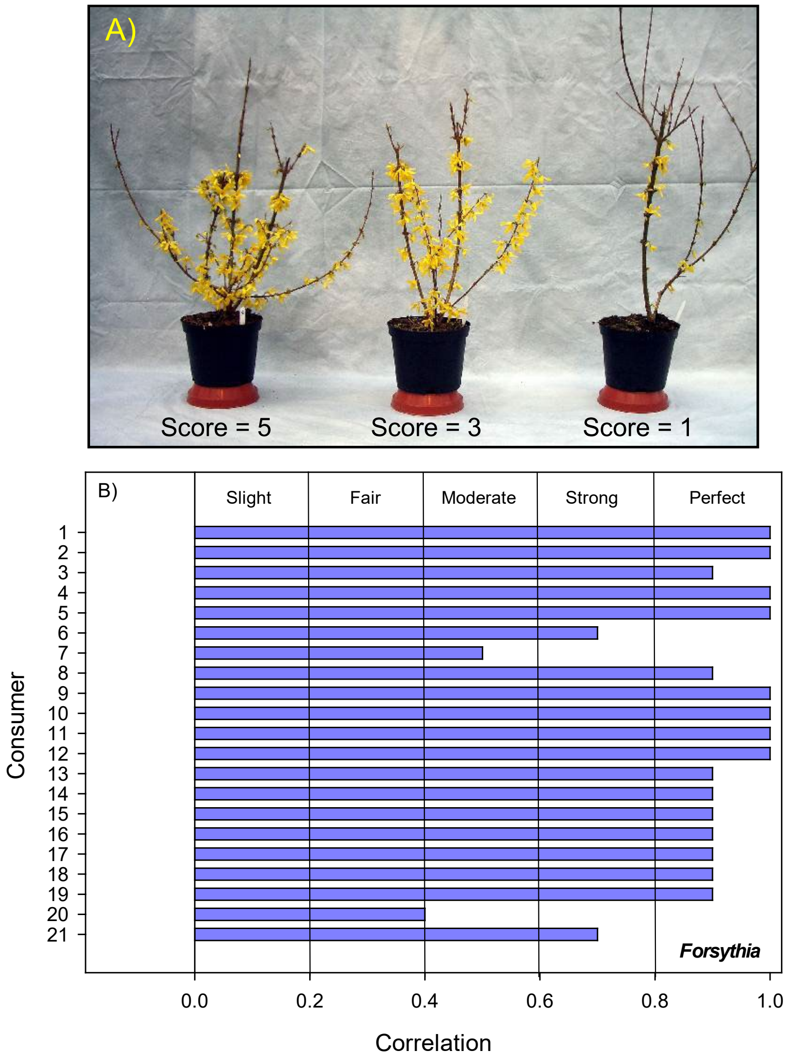


Figure 9. A) Representative plants (***Forsythia x intermedia*** 'Lynwood Gold') of decreasing quality from left to right, as determined by an HNS 'expert'. B) Correlation between 'expert' score and individual 'consumer' scores for plants of quality 1 to 5 (correlation of +1 indicates perfect agreement, 0 = no agreement, -1 = complete disagreement).

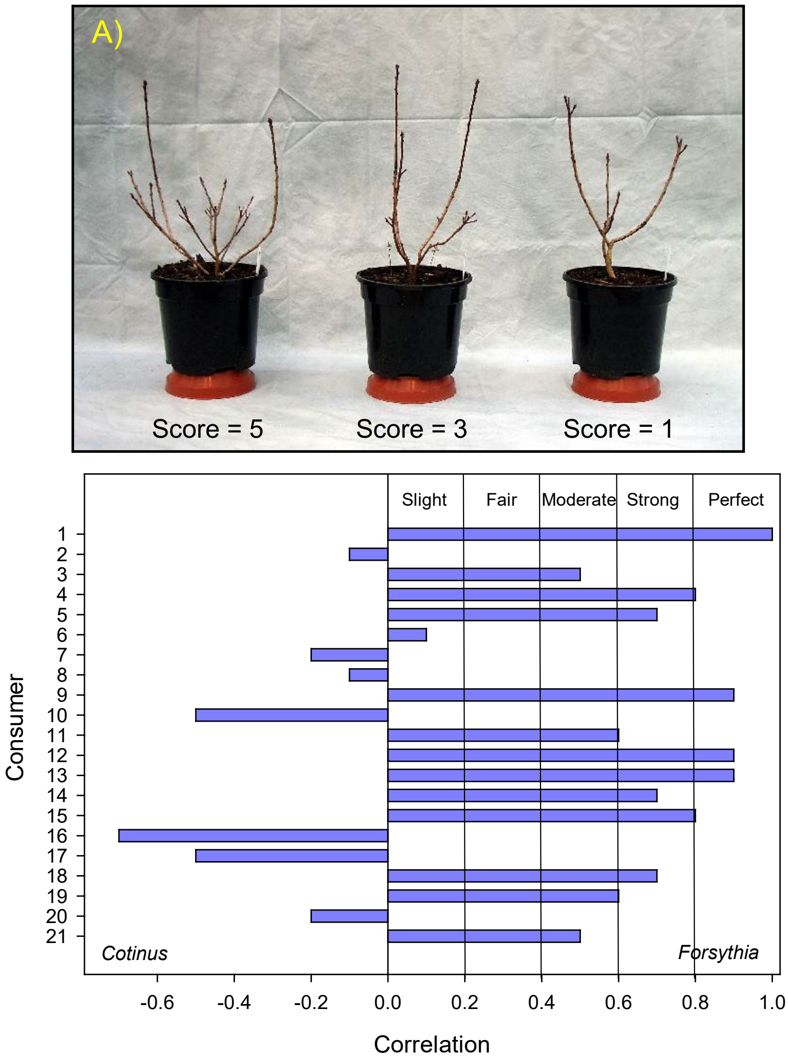


Figure 10. A) Representative plants (*Cotinus coggygria* 'Royal Purple') of decreasing quality from left to right, as determined by an HNS 'expert'. B) Correlation between 'expert' score and individual 'consumer' scores for plants of quality 1 to 5 (correlation of +1 indicates perfect agreement, 0 = no agreement, -1 = complete disagreement).

The mean value of the correlation between 'consumer' and 'expert' scores for *Mahonia x media* 'Winter Sun' was 0.35 (± 0.13), again indicating only a fair agreement between the two groups (Figure 11). Some 'consumers' scored plants that were the tallest as the best quality, while several preferred the very 'compact' plant that had been pruned at the nursery and was allocated a score of 1 by the 'expert'. The majority preferred an intermediate height, with shorter internodes and even branching up the main stem (for example, the plant with a quality score of 5). Treatments such as RDI that have the potential to limit stem elongation, thereby producing more compact plants, may help to increase the visual appeal of *Mahonia* at point-of-sale.

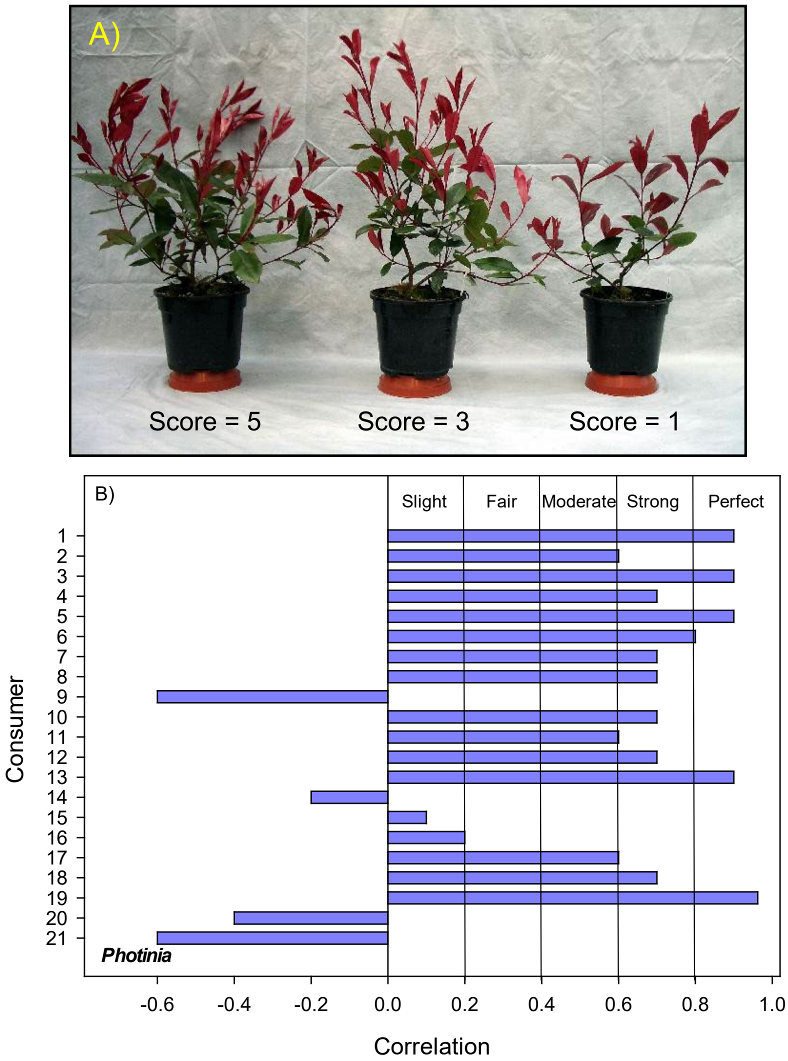


Figure 12. A) Representative plants (***Photinia fraserii*** 'Red Robin') of decreasing quality from left to right, as determined by an HNS 'expert'. B) Correlation between 'expert' score and individual 'consumer' score for plants of quality 1 to 5 (correlation of +1 indicates perfect agreement, 0 = no agreement, -1 = complete disagreement).

For ***Photinia fraserii*** 'Red Robin', over 50% of the 'consumers' agreed strongly with the quality assessments made by the 'expert' (Figure 12); the mean correlation value was 0.47 (± 0.13). The generally positive correlations indicated that the 'consumer' group often agreed with the 'expert'. A good, balanced overall shape was the key quality attribute that the majority of the 'consumers' sought.

The consistency with which the 'consumers' scored each HNS species on consecutive days was also assessed, these results are currently being processed and will be reported in the next annual report. The 'expert' versus 'consumer' scores for the rose cultivars will also be determined in early April 2007. The 'consumer' group will also score quality before, during and after the shelf-life tests to be carried out later in 2007.

Objective 2

Conditions encountered during distribution

The conditions encountered during distribution differed depending on the type of container lorry used. In the ‘curtained’ container, air temperatures were similar to ambient values and ranged from 0-26°C. Relative humidities reached 100% during the evening, night and early morning (Figure 13), but fell to between 35-80% during the day; the lower relative humidities coincided with higher daytime temperatures.

In the ‘box’ container, temperatures were similar to those encountered in the ‘curtained’ container but RH quickly rose to 100% and was maintained at this level for the duration of the, albeit shorter, transport period (Figure 14). This effect may have been due to the limited air movement in the ‘box’ container compared to the ‘curtained’

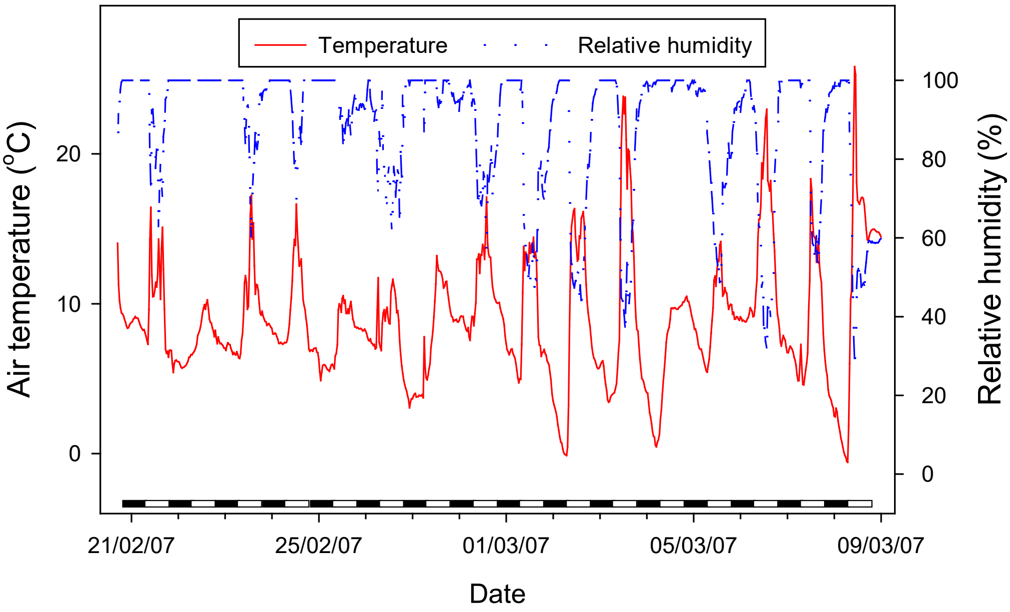


Figure 13. Air temperature and relative humidity inside a 'curtained' container lorry during the distribution of dormant-stage roses in February-March 2007.

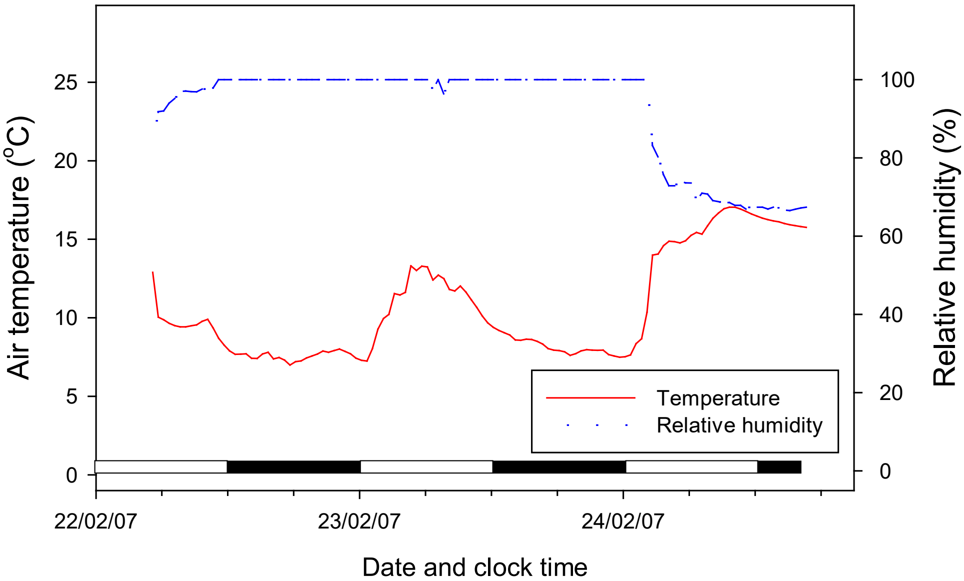


Figure 14. Air temperature and relative humidity inside a 'box' container lorry during the distribution of dormant-stage roses in February 2007.

container. At the time of writing, the data logger in the 'refrigerated' lorry had not yet been returned and so could not be downloaded. More comparisons of the conditions encountered during the different types of container lorries will be made later in the season. The effects of these conditions on the shelf-life potential of different rose cultivars will be determined in Spring/Summer 2007.

Objective 3

Experiment 1

Imposition of RDI

The RDI regimes were first imposed on 6 June 2006. The plant-and-pot weights of the 75% and 50% RDI-treated ***Forsythia x intermedia*** 'Lynwood Gold' plants decreased gradually over the following 3 weeks and were then only 83% and 69%, respectively, of the well-watered controls (Figure 15A). These differences were maintained for a further two weeks until bouts of heavy rain in the second half of August temporarily increased plant-and-pot weights in all treatments.

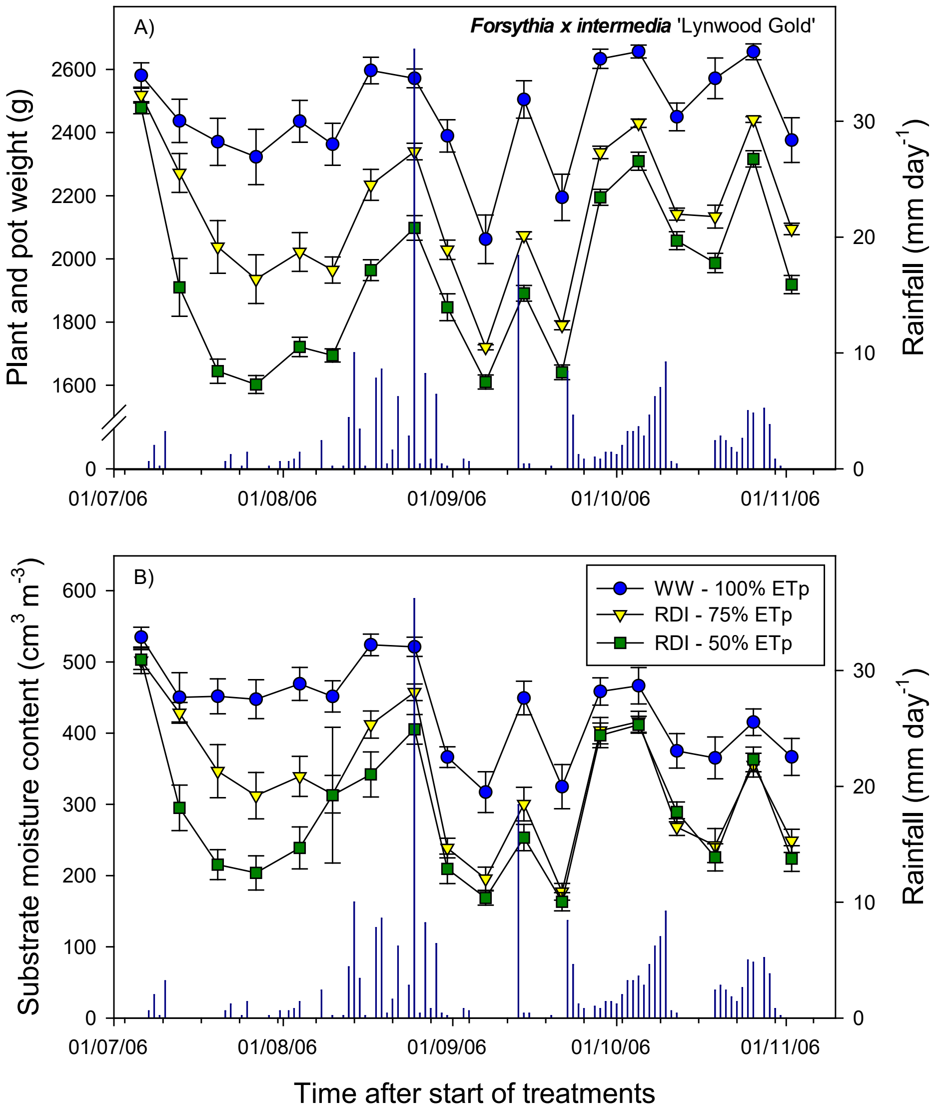


Figure 15. The effects of two RDI regimes imposed on ***Forsythia x intermedia*** 'Lynwood Gold' during July to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Irrigation was scheduled using the Evaposensor; well-watered plants received 100% of the daily potential evapotranspiration (ET_p); RDI-treated plants received 75% or 50% of that volume. Daily rainfall throughout this period is also presented. Results are means of 12 replicate plants, with associated standard error bars.

Despite further periods of rainfall, differences between well-watered and RDI-treated plants were maintained for much of the 4-month experiment. The SMC's confirmed that deficit treatments were being applied effectively over the experiment; transient increases in SMC were also evident following significant rainfall (Figure 15B). As the season progressed, the two *Forsythia* species began to differ in their water use and, therefore, irrigation requirements. Since the two species were watered using the same irrigation line, it was not possible to schedule the irrigation effectively for both RDI regimes in both species. Consequently, the SMC's in the 75% and 50% RDI-treated *Forsythia x intermedia* 'Lynwood Gold' were not significantly different from September onwards (Figure 15B). The effects of RDI on patterns of plant-and-pot weight loss and SMC over the experiment in *Forsythia x intermedia* 'Weekend' were similar to those described above for *Forsythia x intermedia* 'Lynwood Gold' except that both the 75% and 50% RDI regimes were imposed effectively throughout much of the experiment (Figure 16 A&B).

Effects of RDI on plant height and spread

The 50% RDI regime decreased plant height of *Forsythia x intermedia* 'Lynwood Gold' by 35% within 6 weeks, compared to well-watered controls. This reduction in height was maintained throughout the autumn and at simulated market date (February 2007), 50% RDI-treated plants were 13cm shorter than their well-watered counterparts (Figure 17A). In contrast, plant heights were not reduced by the 75% RDI regime in August or the following February, when compared to well-watered values. Plant heights were reduced by 50% and 75% RDI regimes in *Forsythia* 'Weekend' on both measurement dates, compared to well-watered controls. At simulated market date, 50% and 75% RDI-treated plants were 6.5cm and 9cm shorter, respectively, than plants that had received 100% of ET_p. As expected, heights of *Forsythia* 'Weekend' were lower than those of *Forsythia* 'Lynwood Gold' at simulated market date (Figure 17A&B).

In both *Forsythia* cultivars, plant spreads were significantly reduced by 50% RDI within 6 weeks of the start of the experiment and at simulated market date (Figure 18 A&B).

Effects of RDI on branch production

Although branch production in *Forsythia* 'Lynwood Gold' was reduced slightly by both RDI regimes, these differences were not statistically significant (Figure 19A). However,

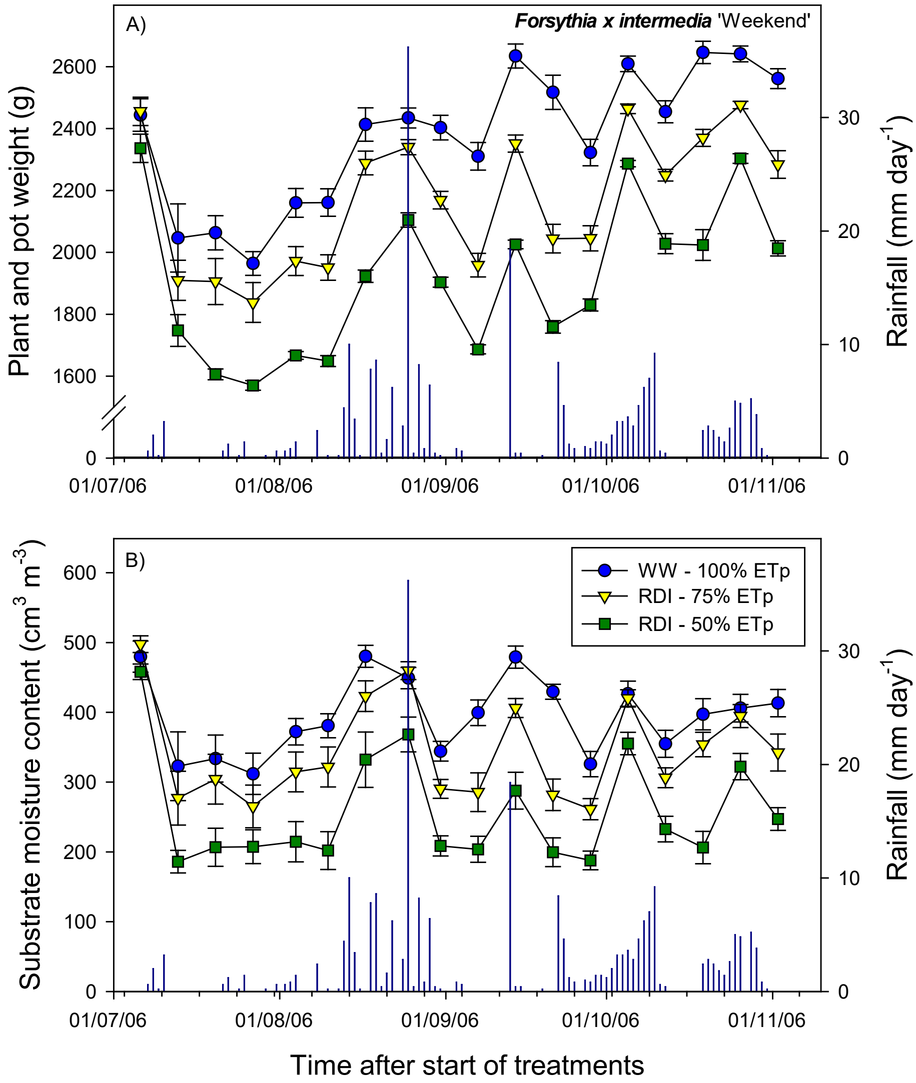


Figure 16. The effects of two RDI regimes imposed on ***Forsythia x intermedia*** 'Weekend' during July to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Daily rainfall throughout this period is also presented. Results are means of 12 replicate plants, with associated standard error bars.

the total number of branches was reduced by both RDI treatments in ***Forsythia*** 'Weekend'; at simulated market date, there were 25% fewer branches on the RDI-treated plants than on the well-watered controls. As expected, the more compact, 'bushier' cultivar of ***Forsythia*** ('Weekend') had 33% more branches than the more traditional 'upright' cultivar 'Lynwood Gold' (Figure 19B).

Effects of RDI on overall plant 'quality' and shelf-life potential

The effects of RDI on plant quality will be determined during March 2007, using the quality criteria developed under Objective 1. The plants will then be transferred to the PSLC where they will be exposed to conditions similar to those encountered during

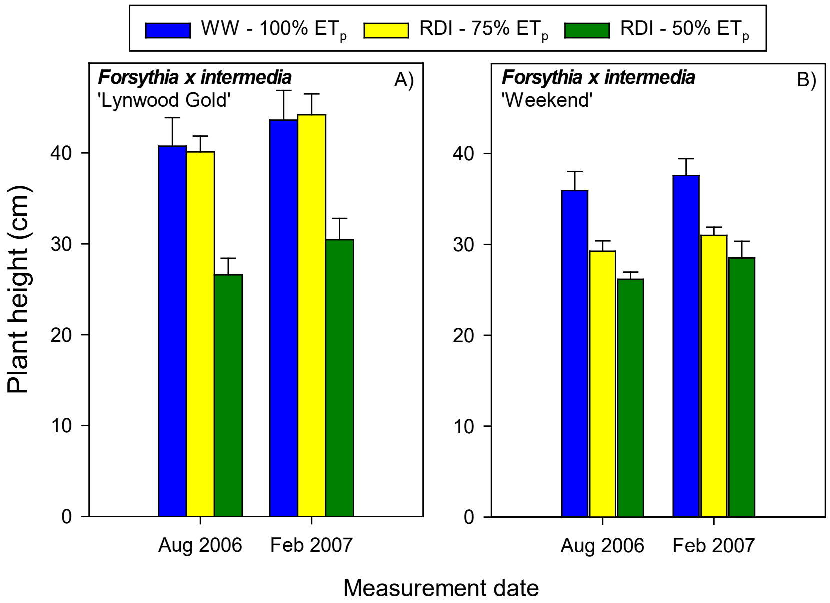


Figure 17. Effects of RDI on plant heights in A) ***Forsythia x intermedia*** 'Lynwood Gold' and B) ***Forsythia x intermedia*** 'Weekend'. Results are means of 12 replicate plants, with associated standard error bars.

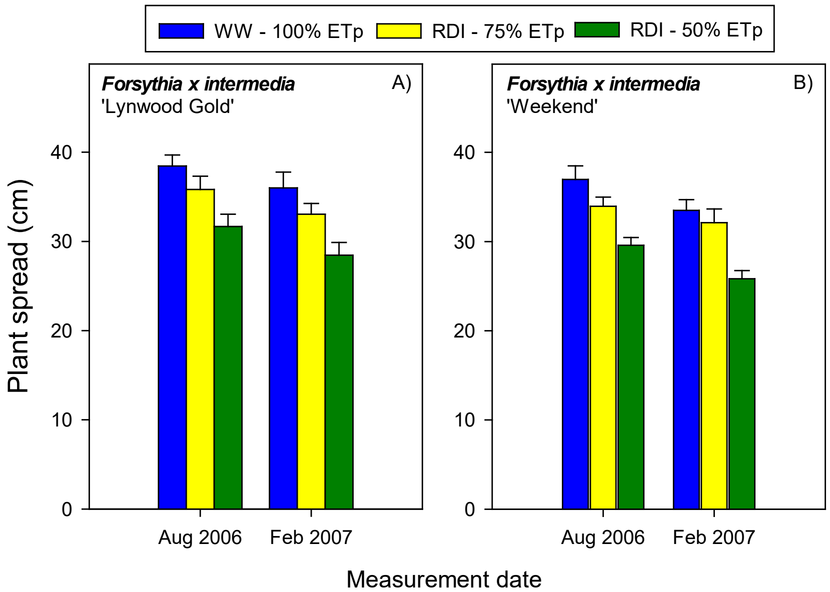


Figure 18. Effects of RDI on plant spreads in A) ***Forsythia x intermedia*** 'Lynwood Gold' and B) ***Forsythia x intermedia*** 'Weekend'. Results are means of 12 replicate plants, with associated standard error bars.

retailing to determine whether RDI enhances shelf-life potential of ***Forsythia*** 'Lynwood Gold' and. ***Forsythia*** 'Weekend.'

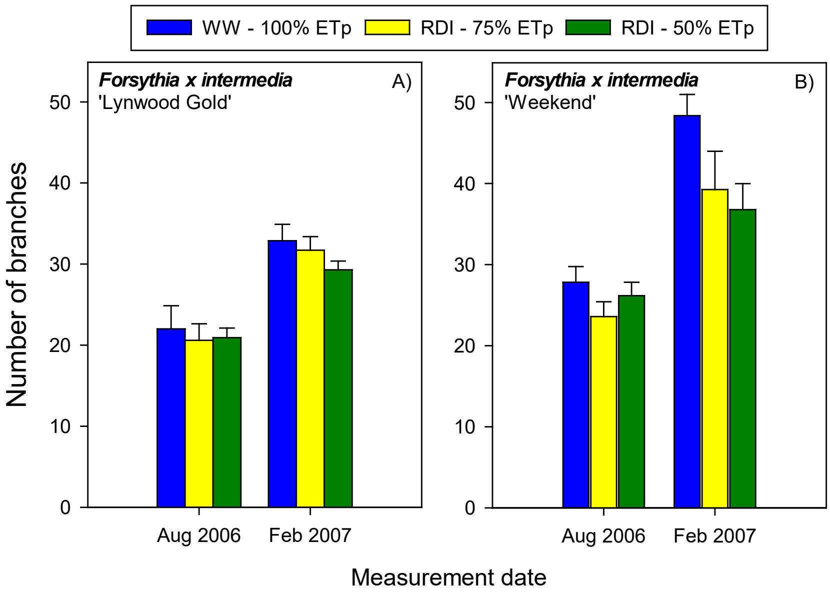


Figure 19. Effects of RDI on the number of branches produced in A) ***Forsythia x intermedia*** 'Lynwood Gold' and B) ***Forsythia x intermedia*** 'Weekend'. Results are means of 12 replicate plants, with associated standard error bars.

Experiment 2

Imposition of RDI

The deficit irrigation treatments were imposed on 8 August 2006. However, plant-and-pot weights of ***Mahonia*** were similar over the first 3 weeks of the experiment; persistent and heavy rainfall during this time prevented the RDI-treated pots from drying down (Figure 20A). At the beginning of September, pot weights of the RDI-treated plants began to diverge from WW values and remained lower for 5 weeks until significant rainfall at the beginning of October (Figure 20A). RDI was again imposed effectively during the middle of October after which further rainfall minimised any treatment effects. As expected, patterns of SMC mirrored those of plant-and-pot weights. For the first three weeks of the experiment, SMC's were not significantly lowered by the RDI regimes, despite the plants receiving only 75% and 50% of the daily ET_p; this was again due to significant rainfall during this time (Figure 20B). SMC's of both the 75% and 50% RDI-treated plants were then maintained at lower values throughout most of October, except during the heavy rain at the beginning of the month (Figure 20B).

Cotinus plants were watered using the same irrigation line as that used for ***Mahonia*** and this prevented RDI being optimised in both species. Consequently, only the 50% RDI regime resulted in any significant substrate drying in ***Cotinus***; SMC's of the 50% RDI-treated plants were maintained significantly lower than WW values from the beginning of September (Figure 21 A&B).

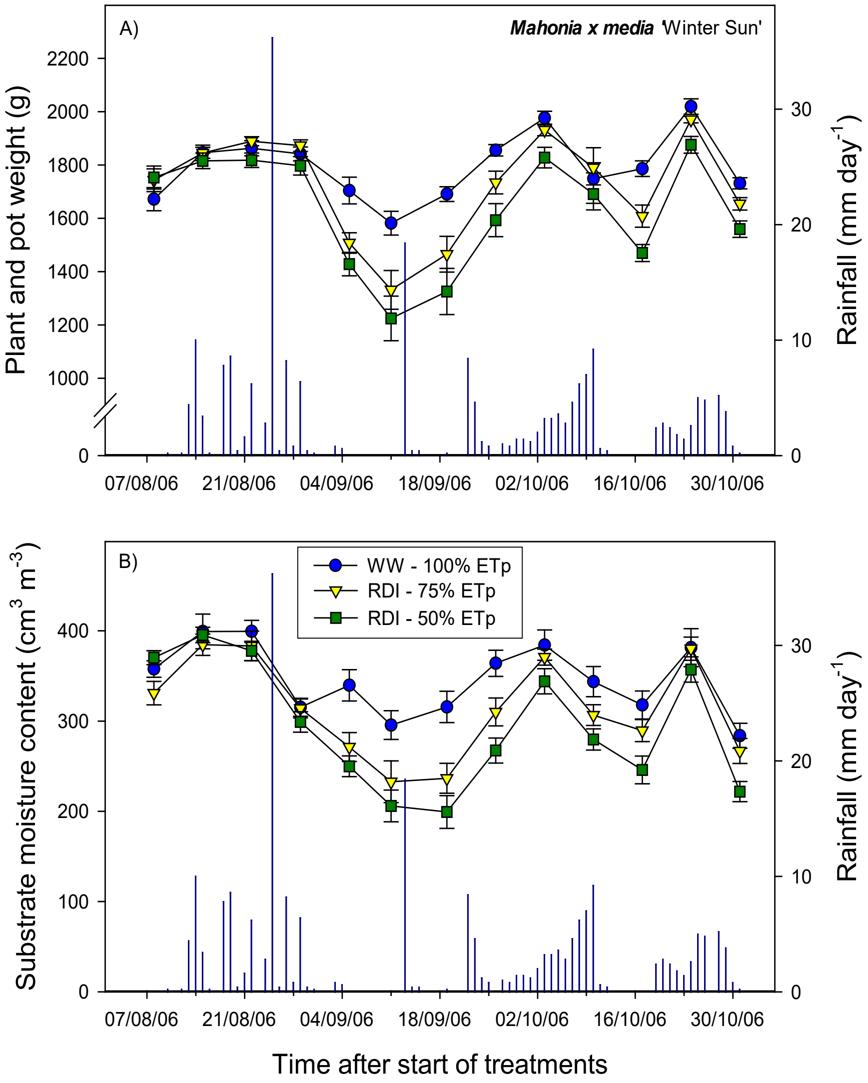


Figure 20. The effects of two RDI regimes imposed on ***Mahonia x media*** 'Winter Sun' during August to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Daily rainfall throughout this period is also presented. Results are means of six replicate plants, with associated standard error bars.

Similar trends in plant-and-pot weights and SMC's were noted for ***Cornus***

(Figure 22 A&B), except that values for the 75% RDI-treated plants were often significantly lower than WW controls. For ***Photinia***, plant-and-pot weights were reduced in RDI-treated plants for only four weeks during September; at all other times, there were no significant differences between well-watered plants and plants supposedly receiving 75% and 50% of ET_p (Figure 23).

Effects of RDI on plant height and branch production

Plant heights of ***Cornus***, ***Cotinus*** and ***Photinia*** were not significantly affected by any of the RDI regimes (Table 1) and there were no treatment effects on plant spread (data not

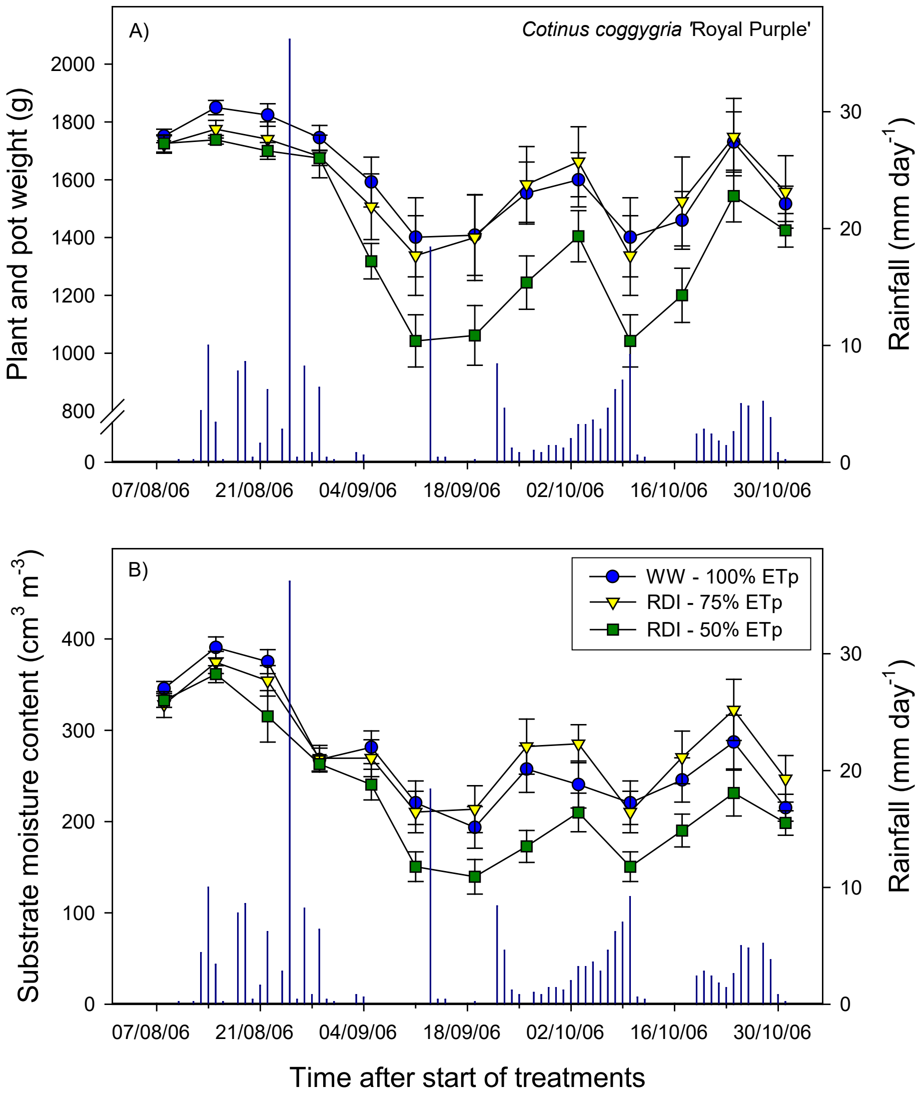


Figure 21. The effects of two RDI regimes imposed on *Cotinus coggygria* 'Royal Purple' during August to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Daily rainfall throughout this period is also presented. Results are means of six replicate plants, with associated standard error bars.

shown). Although RDI regimes were not optimised in all species, RDI was imposed effectively during the time that shoots were actively growing (*e.g.* 50% RDI-treated *Cotinus*). Either these species do not respond to RDI or the regimes imposed were not severe enough. This experiment will be repeated and extended in 2007 to ensure that the different RDI regimes are imposed effectively in all species.

Measurements of *Mahonia* plant heights taken in September did indicate small but statistically significant reductions in RDI-treated plants (Table 2), even though the

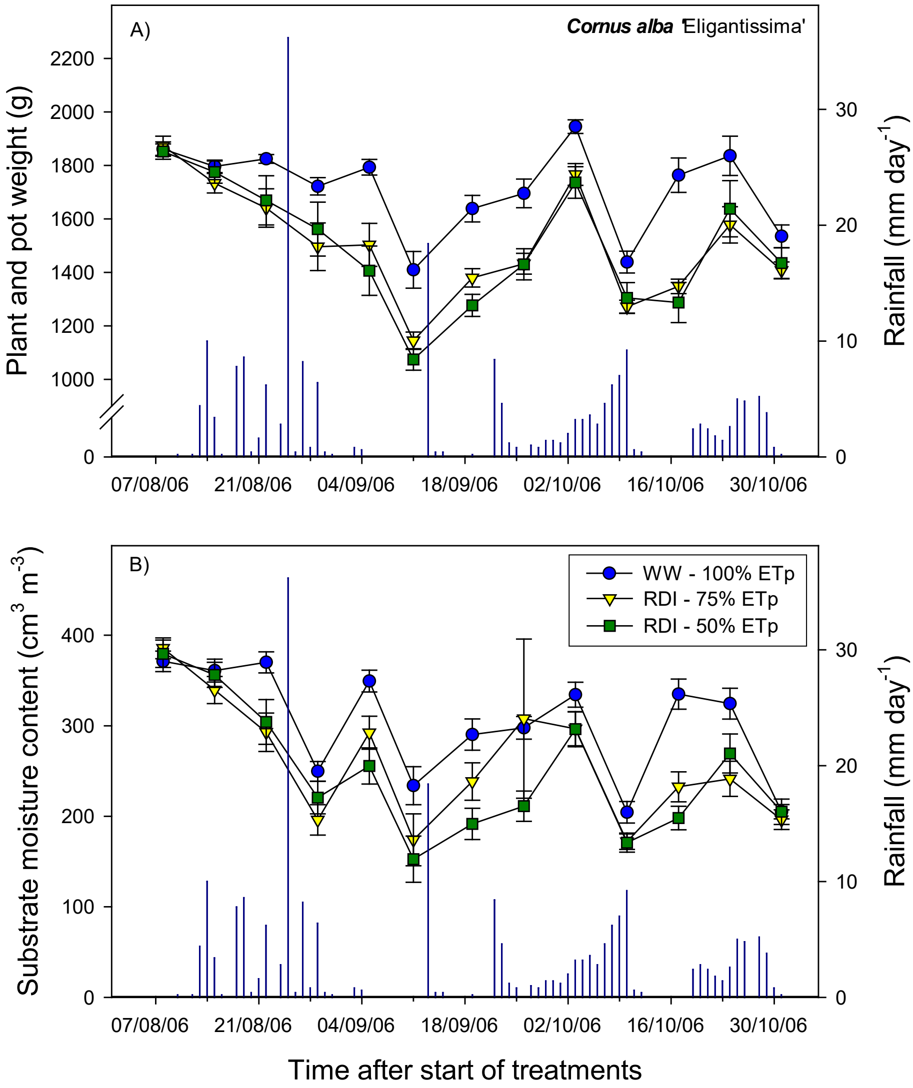


Figure 22. The effects of two RDI regimes imposed on ***Cornus alba*** 'Eligantissima' during August to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Daily rainfall throughout this period is also presented. Results are means of six replicate plants, with associated standard error bars.

SMC's had only recently fell below WW values. However, this effect was only transient and no significant reductions in plant height were recorded in February 2007 (Table 2).

Table 1. Effects of RDI on ***Cornus***, ***Cotinus*** and ***Photinia*** heights and branch production measured during February 2007. Results are means of 6 replicate plants with associated standard errors.

HNS species	Plant height (cm) Irrigation regime (% of ET_p)			Number of branches Irrigation regime (% of ET_p)		
	100%	75%	50%	100%	75%	50%
Cornus	57.7±4.4	60.7±1.2	56.7±2.8	30.7±1.8	33.5±2.2	29.2±3.2

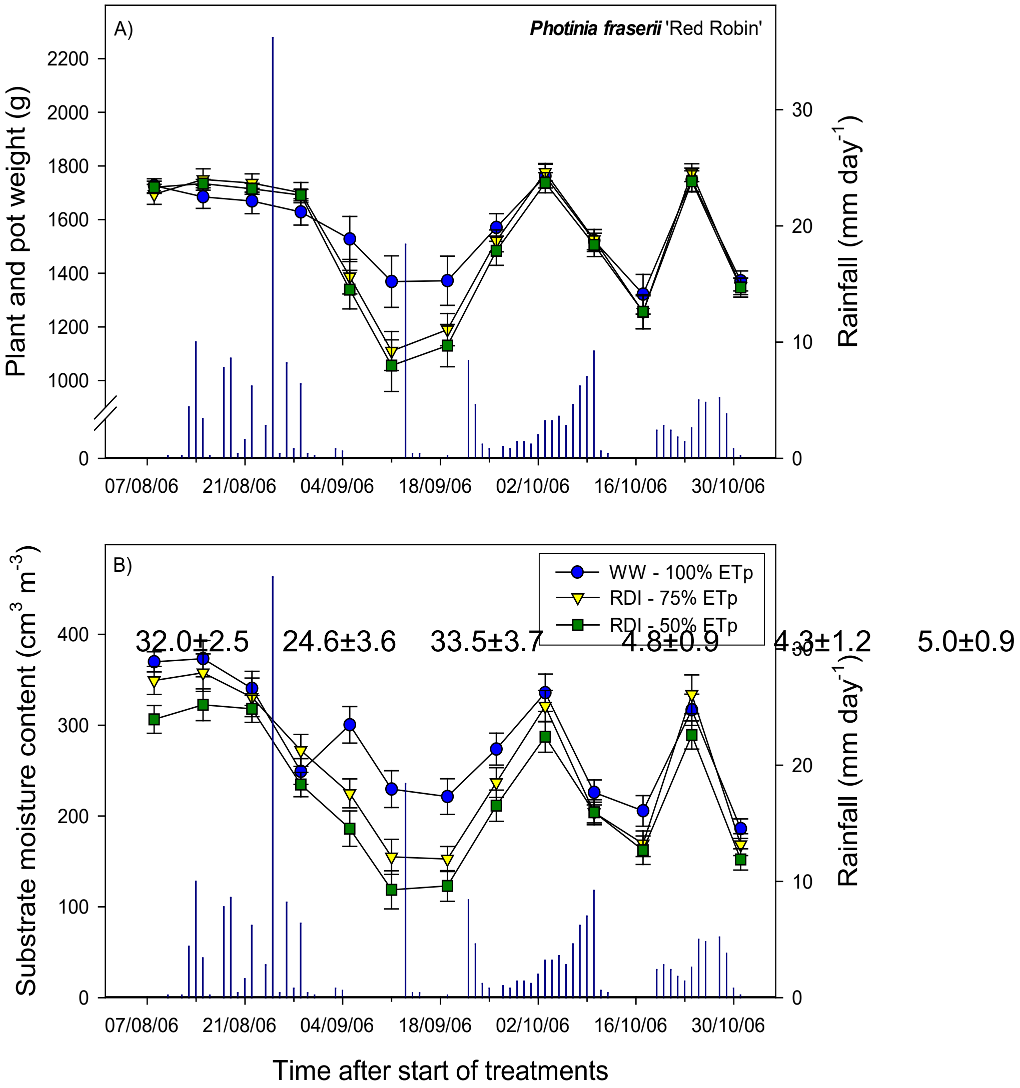


Figure 23. The effects of two RDI regimes imposed on ***Photinia fraserii*** 'Red Robin' during August to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Daily rainfall throughout this period is also presented. Results are means of six replicate plants, with associated standard error bars.

Cotinus	32.0±2.5	24.6±3.6	33.5±3.7	4.8±0.9	4.3±1.2	5.0±0.9
Photinia	45.2±3.6	50.0±1.6	40.2±3.3	9.3±1.5	9.2±1.5	11.5±1.1

Table 2. Effects of RDI on ***Mahonia*** height and spread at two stages during the growing season. Results are means of 6 replicate plants with associated standard errors.

Measurement date	Plant height (cm) Irrigation regime (% of ET_p)			Plant spread (cm) Irrigation regime (% of ET_p)		
	100%	75%	50%	100%	75%	50%
September 2006	25.5±0.6	21.8±1.7	21.7±1.2	53.9±1.8	48.9±1.4	47.6±2.6
February 2007	31.2±1.0	28.3±0.9	30.5±1.7	55.3±1.4	53.3±0.9	51.9±2.1

The production of branches in ***Cornus, Cotinus*** and ***Photinia*** was not reduced by either of the RDI regimes (Table 1).

Effects of RDI on overall plant 'quality' and shelf-life potential

The effects of RDI on plant quality will be determined during Spring 2007, using the quality criteria developed under Objective 1. The effects of RDI on shelf-life potential will then be determined.

Experiment 3

Imposition of RDI

RDI treatments were initiated on 29 June 2006, to coincide with the beginning of the second growth flush. Pot weights and SMC's within the different treatments did not differ significantly between rose cultivars and so values were averaged for presentation. SMC's of the 75% RDI-treated plants were maintained significantly lower than WW values from early July until the heavy rainfall at the beginning of September (Figure 24), thereafter, SMC values in the WW and 75% RDI-treated plants were similar. In contrast, plant-and pot weights and SMC of 50% RDI-treated plants were maintained significantly lower than WW values from the beginning of July until the end of the experiment in November (Figure 24).

Effects of RDI on stem internode length and basal breaking

The average internode length of cultivar 'Just Joey' was significantly reduced by both RDI regimes (Table 3). There were no statistically significant effects of RDI on internode length in any other *Rosa* cultivar (Table 3).

RDI increased basal breaking in *Rosa* cultivars 'Arthur Bell' and 'Just Joey' with the most significant increases occurring in the 50% RDI-treated plants (Table 3). The number of basal breaks in *Rosa* cultivar 'Remember Me' was not affected by either RDI regime but the number of basal shoots in 'Margaret Merril' was significantly reduced by both 75% and 50% RDI treatments (Table 3).

Effects of RDI on overall plant 'quality' and shelf-life potential

The effects of RDI on plant quality will be determined during March 2007, using the quality criteria developed under Objective 1. The effects of RDI on shelf-life potential will then be determined.

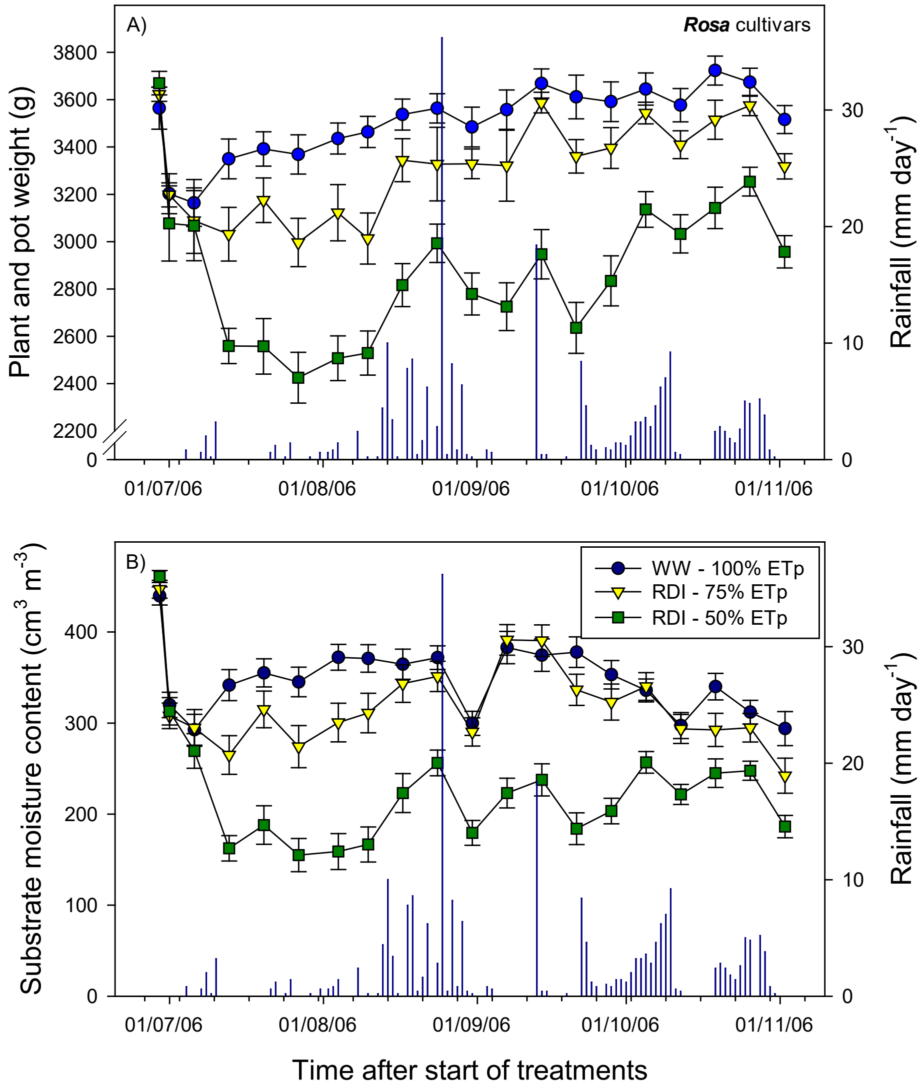


Figure 24. The effects of two RDI regimes imposed on ***Rosa*** cultivars during June to November 2006 on A) plant-and-pot weights and B) substrate moisture content. Daily rainfall throughout this period is also presented. Results are means of 16 replicate plants, with associated standard error bars.

Table 3. Effects of RDI on stem internode length and the production of basal breaks in four ***Rosa*** cultivars. Results are means of 4 replicate plants with associated standard errors.

Rosa cultivar	Stem internode length (cm) Irrigation regime (% of ET_p)			Number of basal breaks Irrigation regime (% of ET_p)		
	100%	75%	50%	100%	75%	50%
'Just Joey'	4.3 ± 0.3	3.7 ± 0.1	3.2 ± 0.2	2.0 ± 0.6	2.5 ± 0.3	2.8 ± 0.2
'Remember Me'	2.5 ± 0.2	2.4 ± 0.1	2.5 ± 0.1	2.3 ± 0.2	3.0 ± 0.4	2.5 ± 0.4
'Arthur Bell'	3.4 ± 0.2	3.0 ± 0.1	3.3 ± 0.3	3.5 ± 0.4	4.5 ± 0.4	4.3 ± 0.4
'Margaret Merril'	3.0 ± 0.2	3.7 ± 0.3	3.2 ± 0.3	4.8 ± 0.7	1.5 ± 0.3	2.8 ± 0.7

Conclusions

Rainfall throughout the season affected the effectiveness with which RDI was imposed. An associated issue was judging when to re-apply irrigation following bouts of heavy rain. In our experiments, pots were weighed regularly and irrigation was suspended until pot weights had returned to values measured before the rainfall. Work in 2007 on the EMWC will aim to develop an alternative strategy to schedule the resumption of irrigation. The amount of rainfall will measured by a rain gauge and converted to an ET_p equivalent; this value will then be subtracted from the ET_p used to determine the duration of irrigation on the following day. If successful, this approach could be incorporated into work where the irrigation of commercial crops is being scheduled using the Evaposensor (e.g. HNS 97b).

Despite frequent and heavy rainfall, significant reductions in plant height and spread were achieved in both species of *Forsythia* and internode lengths were reduced by RDI in *Rosa* 'Just Joey.' While branch production was decreased in *Forsythia* 'Weekend', basal breaking in *Rosa* 'Just Joey and 'Arthur Bell' was improved by RDI. Despite being imposed effectively throughout some or all of the growing season, RDI did not affect plant heights of *Cornus, Cotinus, Mahonia* and *Photinia*, and average internode lengths in *Rosa* cultivars 'Remember Me, Arthur Bell and 'Margaret Merril' were not reduced by the RDI regimes. To determine whether these plants do respond to deficit irrigation, RDI regimes will need to be optimised for each species in 2007. All species will be irrigated using separate lines and estimates of F will be made more frequently throughout the season.

The potential benefits of RDI on shelf-life potential will be determined in Spring/Summer 2007.

Technology Transfer

1) 'How irrigation affects plant quality'. HDC News article (April 2006).
2) 'Improving the quality of Rose and Hardy Nursery Stock at East Malling Research'. Article in British Rose Growers' Association Newsletter (Summer 2006).
3) 'Improving the quality of Rose and Hardy Nursery Stock'. Project summary supplied to representatives of Homebase, B&Q, Wyevale Garden Centres, Harkness Roses, Burston Nurseries, David Austin Roses and Paul Chessum Roses.

4) Overview of project presented to the members of the Horticultural Trade Association (February 2007).
5) Several meetings and discussions with Mr David White (Paul Chessum Roses) and Mr David Hooker (Hillier Nurseries).

Glossary

EvapoSensor – an instrument developed at HRI East Malling and now available from Skye Instruments that provides an electrical signal approximately proportional to potential transpiration from a model leaf. It integrates the effects of humidity, radiation, temperature, wind, and leaf wetting.

ET_p – potential evapotranspiration – the rate at which a crop would lose water under prevailing environmental conditions if water supply was non-limiting. It includes evaporation from the plants *i.e.* transpiration and from the growing medium in the container.

Volumetric substrate moisture content – water content of the soil or growing medium expressed as a fraction or percentage of the total volume occupied by water. Its maximum value, when the soil is saturated, depends on the percentage of pore space in the soil, which in peat-based media is generally about 90%.

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Defra HH3731SHN: Manipulation of branch production in woody perennials. First Year Report 2006.

Defra HH3609TX: Partial rootzone drying: Delivering water savings and sustained high quality yield into horticulture. Third Year Report 2007.

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HDC HNS 122: Container nursery stock irrigation: demonstration and promotion of best practice. Second Year Report 2006.

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