Project Number:	PO 021b
Project Title:	New Poinsettia Genetics and Controlled Substrate Moisture Growing
Project Leader:	Dr Chris Bishop, University of Lincoln
Contractor:	University of Lincoln
Industry Representative:	Graeme Edwards, Woodlark Nurseries
Report:	Final 2019
Publication Date:	
Previous Report:	PO 021a 2018 Final
Date project commenced:	June 2018
Date project completed:	March 2019

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The results and conclusions in this report are based on an investigation 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.

Dr Chris Bishop, Reader of Postharvest Technology

The University of Lincoln

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[Name]

[Position]

[Organisation]

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Report authorised by:

[Name]

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GROWER SUMMARY

Project Background and Expected Deliverables

The poinsettia plant is purchased as a seasonal decoration by the domestic market, available from retail outlets from mid-November until Christmas. The market specifications are stringent, generally requiring a 1 litre potted plant, 25-30 cm high, with a foil of dark green leaves to clean red bracts; the cyathia should be prominent without pollen. The UK industry is reliant on a few varieties, of which Infinity 2.0 in previous years has accounted for up to 65% of the total market. Cutting material is sourced primarily from the EU.

Two trials are reported: the variety trial assessment and the precision and deficit irrigation assessment for plant growth control.

Variety trial

The first trial was to further develop variety trial work from previous AHDB research, where new and existing varieties were benchmarked through growth and shelf life trials, against the leading commercial variety, Infinity 2.0. Problems occurred early in the season when material from Dummen showed the presence of Bemisia, therefore the cuttings were not sent to the UK. The replacement varieties from Volmary did not include the benchmark variety Infinity 2.0. This event highlights the industry's current vulnerability, with reliance on few varieties and stock plant material sourced from abroad.

The varieties tested were:

- **Beekenkamp** – Astro Red, Lenora Red, Hera Red.
- **Volmary** – Christmas Beauty, Christmas Beauty Princess, Moijin, Crunch Red.
- **Selecta** – Christmas Break, Christmas Cracker, Christmas Sensation, SKA 159.
- **Syngenta** – Mirage Red, Sigma, Blissful Red.

The variety trial plants were grown on three nurseries across the UK (Hills Bros Chichester, Volmary Wisbech St Mary and KRN House plants Louth) to represent the different range in facilities and growing methods between industry grower sites.

Previous trials have shown varieties such as Lenora Red, Christmas Sensation and Astro Red to be promising, these varieties continued to show good results.

Details of grower's methods and procedures can be found in Appendices one and two.

At harvest, the mean score of the three nurseries showed that three varieties did not attain a saleable score of 5 or above: Christmas Break, Christmas Beauty Princess and SKA 159. The highest mean score was attained by Astro Red at 6.4. The individual nursery results showed

a range of quality scores, however no one nursery attained the highest score in all varieties, indicating that location, past knowledge and growing techniques may suit particular varieties.

The most consistent quality scores across all nurseries were for Christmas Beauty Princess, SKA 159, Christmas Sensation and Christmas Crunch. However the last two varieties however were the only ones to attain a saleable quality score in all three nurseries.

At dispatch the mean quality assessment showed that three varieties scored below five, Christmas Break (4.8), Christmas Beauty Princess (2.3) and SKA 159 (4.9). Scores of five and above are considered suitable for commercial sale. The highest mean quality score was for Astro Red (6.4) although the quality score was also the least consistent across the three grower sites (scores 7.8, 7.3 and 4.3). The varieties showing the most consistency on quality scores between growers were SKA 159 (scores 4.8, 4.8 and 5.2) and Christmas Sensation (scores 6.4, 6.2 and 6.0).

Upon arrival at the University of Lincoln, the plants from one nursery (generally the largest plants) required additional water compared to the other two nurseries. Some plants had considerable water uptake during the first couple of weeks in line with observed continued plant growth.

During the shelf life assessment, most varieties continued to grow and improve in quality score during the first few weeks; this was not seen last year in any variety. The water deficit trial plants were generally observed as wetter than variety trial plants. There was less leaf fall than last year on all plants and very few incidences of pest and disease.

On week five of shelf life, the quality scores were higher than the previous year; 4th January 2018 all plants scores 1-6, 3rd January 2019 lowest score was 2, with 45 plants scoring 7 or above.

At the end of the shelf life assessment, most plants had survived with the loss of only six plants by the second open day (17th January). Some varieties have both high and low scorers, which may be due to growers' quality specifications, however certain growers have consistently better or worse scores with certain varieties. Five of the Leona Red plants scoring 7 were from one nursery, but also five of the Christmas Beauty Princess scoring 3 were from the same nursery. Some varieties such as Christmas Sensation have few high scoring plants, but the overall score is good– indicating that the plants consistently scored better than average.

Christmas Sensation attained consistent quality scores at dispatch and end of shelf life stages.

Precision and deficit irrigation trial

This second trial was carried out due to industry concerns regarding the potential loss of chemical Plant Growth Regulators (PGRs). PGRs such as chlormequat are used to control crop size. The deficit irrigation trial was conducted by Neame Lea, Spalding.

The trial showed there was a reasonable buffer zone between the degree of substrate drying that will effectively control stem height, and what would lower plant visual quality and shelf-life potential, which should help to allay grower concerns that the reduced deficit irrigation approach is too risky.

In 2018, the varieties Astro Red, Leona Red and Aries Red were used in the precision irrigation (PI) and deficit irrigation (DI) work. Precision irrigation was used throughout the growing season to ensure that substrate volumetric moisture content (SVMC) was maintained within the optimal range, avoiding large fluctuations between too wet and too dry; this was typically 35-55%. Due to the relatively late planting date in 2018 resulting from sourcing issues, the growing team at Neame Lea focused on achieving strong growth throughout most of the season so that the minimum plant height specification could be met. Only towards the end of the growing season did the growing team feel that DI was needed to slow extension growth in each of the three varieties.

The moisture sensors, dataloggers and telemetry systems were again reliable, while remote access to real-time data through the new “Grower Dashboard” helped to inform the grower’s decision-making regarding the frequency and duration of irrigation events. Results again confirmed that rate of change in SVMC correlated with daily vapour pressure deficits (VPDs). Differences in this relationship were used to remotely detect when DI stress was sufficient to reduce plant water loss via lowered stomatal conductance.

DI was imposed successfully on three occasions during November 2018 for each variety, and resulted in slowed extension growth. Consequently, all three varieties were within height specifications by the end of the growing season, despite the fact that no PGRs were applied during the season. Residue tests confirmed that production was PGR-free, and also confirmed that the growth control was not achieved as a consequence of an earlier application of PGR applied before plants were dispatched to the UK.

Overall quality at dispatch of randomly selected, DI-treated plants was similar to that in commercial controls from the participating nurseries, and the shelf-life tests carried out by the University of Lincoln (UoL) on the DI-treated plants indicated that shelf-life potential was at least as good as commercial controls.

Additional work conducted:

Chemical residue testing

Chemical residue testing, this work was conducted in response to industry concerns regarding the chemical presence on cutting material and its potential to be systemically transferred to new plant growth. The presence of chemicals on ornamental plants at point of sale may become a public concern in the future. This work was carried out as a benchmarking exercise to ascertain the current situation.

Poinsettia nutritional monitoring work

Over the last twenty years, there has been a regular nutrient monitoring scheme of substrate and leaf tissue. Whilst there have been considerable variety changes in the poinsettia used in the market there has been a build-up of data on available nutrients in substrates during the cropping period and also a library of tissue nutrient levels.

Benefits to Industry

Approximately 8 million poinsettias were sold within the UK market per year, a popular houseplant associated with Christmas especially with red bracts on green leaves, although new coloured and glitter varieties are beginning to enter the market. Approximately 50% of the retail market has previously been supplied by UK growers with Dutch growers supplying the remaining plants. Due to “Brexit”, the coming 2019 season may bring both challenges and opportunities. New trade agreements and unknown euro exchange rates coupled with shorter UK distribution routes may help UK growers to improve plant quality in the home market and gain a competitive advantage.

Benefits of the variety trial

This project has reaffirmed previous trial data on the resilience of several new varieties, the importance of which was further highlighted by the absence this year of the known benchmark variety Infinity 2.0. The commercially grown varieties allow growers to evaluate and assess varietal resilience, performance and reliability of poinsettias at harvest, then through retail and domestic shelf life. High quality scores at harvest did not always follow through into shelf life.

Benefits of the deficit irrigation trial

Work conducted during 2017/18 showed the potential of DI within a commercial operation, using remote soil moisture sensing together with soil moisture deficit to control stem extension (plant height) during the period of rapid stem elongation, and reducing the need for PGRs. The previous trial formed a PI model to maintain “optimum” moisture content. This trial’s objective was to take the research to the next level replacing grower-led irrigation with model-led decisions. The intention is for future transferable irrigation models to other crops.

Benefits of chemical residue testing

Chemical residue testing provides the industry with current information regarding chemical residues on cutting material and saleable products, to provide a benchmark for future analysis.

Benefits of poinsettia nutritional monitoring.

Monitoring of both substrate and leaf tissue was done to ensure and predict the need for additional feeding during the production period of the crop. The overall improvement of crop quality and increase in quantity of marketable products would raise the international reputation of UK growers and their products not only in the poinsettia market but potentially for other nursery grown plants, plus increase their financial return.

Financial Benefits to the industry

Water

The three nursery locations used for the variety trial employed two irrigating plants by traditional methods on static benches and on the floor, the third location was on ebb and flow benches. The deficit irrigation trial to control the height of pot grown poinsettias to client specifications implied the use of reduced water to grow the crop by up to 20 %. The water saving could be approx. £25-30k dependent on weather and number of plants (traditional watering vs recirculating)

The automated systems installed at the deficit irrigation trail location have allowed for increased efficiency in potting, spacing and packing. Overall costs have dropped by approx. 40%. The glasshouse heating biomass boiler vs oil heating is a cost saving of approx. 0.60p/pot.

Chemical

The application of water deficit to the Poinsettia crop to control height reduced the need for chemical applications of PGRs. Therefore the success of the water deficit system to the industry and the environment is the potential reduction in water and chemical application. Dependent upon rate of application, the number of plants and issues during growing the crop an estimated saving of £3k per season.

Space

The control of plant growth allows easier maximisation of space (more pots/ m2), but choosing the best performing varieties is an important element.

Nutritional analysis

If previously growers were losing between 5-10% because of poor control of nutrition, this probably equated to their gross profit. The cost of analysis is negligible and it protects crop profit.

Varietal selection

The results of the variety trial at all stages of the production will assist growers in their selection of growing material for the coming season. An important financial consideration, especially if they are forced to change to new and for them unknown varieties due to material availability and change in purchasing trends such as coloured and glitter.

SCIENCE REPORT

Introduction

Trial one: variety trial

The UK poinsettia industry has relied heavily on relatively few genetic lines in recent years. The variety with the largest penetration over the last few years is Infinity 2.0 (circa. 65% of the UK volume in 2017/18), although this was not the case in 2018 due to disease issues. This major change in variety selection highlights the importance of awareness of varieties for the UK market, and concerns that key varieties which have been in the market for number of years are now starting to show non-typical or variable traits and habits.

In order for growers to make an informed selection choice, they require industry knowledge from other growers, breeders and research, as well as customer discussions. The process of variety selection is expensive and time consuming; poor decision-making can have significant negative commercial consequences.

Variety selection and related decision making can be assisted by grower interactions, as all varieties do not perform in a similar way in different regions.

Plant performance during the consumer stage is an important factor when selecting varieties; customer expectation is for the plant to perform well during the whole of the festive period. Shelf life trials are not always possible for growers to undertake.

Given this background, the objectives of this trial were to establish a more rigorous process to underpin the effective selection of poinsettia varieties, in particular:

- Rigorously testing 14 varieties for use by UK growers
- Testing the varieties on three different UK growers' holdings in different agro-climatic locations and using irrigation methods, to establish whether any genetic x grower interactions occurred in terms of plant responses.

Trial two: deficit irrigation control

In 2016, a “dry growing” regime developed by Neame Lea was used in combination with other strategies, such as temperature differentials and adjusting the fertiliser formulations, to achieve plant height control without reliance on plant growth regulators (PGRs). This followed earlier and more detailed work by EMR (now NIAB EMR) which showed that a Regulated Deficit Irrigation (RDI) treatment applied during the period of rapid stem extension effectively limited plant height so that retailer specifications were met at market date, despite a 90% reduction in PGR use (Else *et al*., 2008). RDI-treated plants were also more tolerant of chilling stress, and bract and leaf drop during shelf-life tests were reduced by 90% and 50% respectively, compared to well-watered control plants that received the commercial PGR programme (Else *et al*., 2008).

In this report, RDI is used to define a treatment where the water availability to the roots is purposely limited during a specific developmental stage in order to achieve optimum outcomes, whereas deficit irrigation (DI) is used to describe a more general substrate-drying treatment that is applied to a crop, irrespective of the stage of crop development.

The potential to use plant root water deficits to control stem height was tested again at Neame Lea in 2017, and this time moisture sensors were used to provide quantitative data on the rate of change of substrate drying and the degree of drying needed to achieve effective height control. Sensors were calibrated for each of the three substrates used in the experiment. Three benches were removed from the commercial irrigation system and the crops were watered by hand; the degree by which the crop was allowed to dry between irrigation events was determined by the grower. Changes in soil volumetric moisture content (SVMC) in these pots were monitored every 15 min throughout the growing season and data was uploaded to the DeltaLINK Cloud to enable “real-time” viewing of the “dry growing” regime developed by Neame Lea.

The degree of the root and shoot water deficit imposed in the “dry growing” regime was informed by identifying the SVMC at which visible wilting first occurred under a range of vapour pressure deficits (VPDs). Preliminary work was also carried out to facilitate scaling-up of the approach across the nursery for poinsettia and other crops where height control is achieved using PGRs. Preliminary shelf-life tests showed that the quality of DI-treated plants was maintained at a similar level to that of commercial controls.

The DI work in 2018 using three new varieties – “Astro Red”, “Leona Red” and “Aries Red” was repeated and extended. These varieties had not previously been worked with, therefore the lower SVMC value at which visible wilting first occurred needed to be established to guide the DI treatments. Approximately 6,000 plants were subjected to the DI treatment in 2018.

Remote sensors for deficit control

A second aspect of the deficit irrigation trial was to see if DI was feasible, when not on an ebb flood bench system. Many growers grow poinsettia in facilities which are not dedicated pot plant systems, i.e. 'on the floor' systems used for multiple cropping, e.g. using capillary matting and 'lay-flat' irrigation or fertigation systems. The testing of the remote sensors was carried out at Volmary utilising wireless sensors provided by 30MHz.

Chemical residue testing

An additional piece of work carried out during the trials relates to chemical residue testing on plant leaves. This is becoming an increasing area of concern as techniques for scanning for chemical residues have improved, but it is not clear how detected levels relate to maximum residue levels (MRLs). The objective was to assess leaf chemical residues at the point of rooted cutting material arriving on nursery, and to assess whether the same chemical residues were present or not at the point of dispatch to shelf life and ultimately the customer.

Poinsettia nutritional monitoring.

The continued regular nutritional monitoring of substrate and leaf tissue was carried out as with previous growing trials for the data library.

Materials and Methods

Trial one: variety trial

Three experienced UK poinsettia growers representing a range of geographical locations agreed to participate in the variety trial. The grower's range of nursery facilities included;

- Table and floor production
- Irrigation matting and ebb and flow benches
- Different ages and height of glass.

Two nurseries have previously participated in AHDB trials in 2017/18 and 2018/2019; a new southern nursery joined the group this year:

- Volmary Ltd, Station Rd, Wisbech St. Mary, Cambridgeshire, PE13 4RY. The Volmary crop was grown in modern glass (4 m plus eaves) on the floor using matting with a capillary tubes watering system and spaced at 8.5 plants per m^2
- KRN Houseplants, Fotherby, Lincolnshire, LN11 0TG. The KRN crop was grown in a medium sized glasshouse (3.5 m eaves) on movable benches using a capillary mat irrigation system. Final spacing was 8 plants m^2.
- Hill Bros Nursery, Lagness Rd, Runcton, Chichester, W Sussex, PO20 6NL. The Hill Bros crop was grown on static benches with matting in a 3 m eave glasshouse, with a final spacing of 8 plants per m^2.

For reasons of commercial confidentiality the results from specific growers are not identified.

The trial covered 14 varieties provided by key breeders who focus on the Northern European markets;

Beekenkamp: Astro Red, Lenora Red, Hera Red, Blissful Red

Selecta: Christmas Break, Christmas Cracker, SKA159, Christmas Sensation, Christmas Beauty

Syngenta: Sigma, Mirage Red

Volmary: Christmas Crunch, Moijin, Christmas Beauty Princess

Material from Dummen was not sent to the UK due to the presence of Bemisia on the cuttings, these varieties were replaced by Volmary.

In week 31 the plants were dispatched directly to the growers with the exception of Selecta material to KRN and the Volmary Material to all growers, this arrived week 32/33. Each grower received 128 plants of each of the 14 varieties. The cuttings were potted up in industry standard poinsettia substrate, (15 mm peat plus 20% by volume medium grade perlite), into

13 cm pots and grown in a one block design under standard crop conditions, to ensure adequate guarding of the central experimental plants. The cuttings were noted to become harder into the season, the exact reason was unknown. The plants were grown to each nurseries customer specification, under the nurseries conditions of environment, irrigation, nutrition, and phytosanitary and PGR treatments. Mr Kitchener conducted regular nursery visits to oversee the trial's progress, providing agronomic advice and support.

Substrate and plant tissue analysis was undertaken to understand differences in nutritional uptake and provision between varieties and growers.

Dispatch assessment

At dispatch, plant performance was assessed on each of the nurseries (Hill Bros 19th November, Volmary 27th November and KRN 28th November). Twelve replicate plants from each variety were randomly selected and assessed against the specification. The same scorer was present for all locations ensuring standardisation of measurements between growers.

Plant performance criteria included;

- plant height (cm)
- plant width (cm)
- bract number (4 bracts plus 1, in a level arrangement)
- cyathia showing without pollen or stamens showing (on which botrytis may occur)
- 'V' shaped plant for ease of sleeving for retail
- colour typical to the variety with leaves and bracts turgid

Plant quality was scored on a scale of 1-10 where 10 was the highest value. Scores above 4 were considered marketable plants.

Open day 22nd November 2018

Each of the three trial grower nurseries supplied six plants from each variety for display at the open day located at Neame Lea Ltd. Three plants of each replicate were unwrapped and placed on show for the grower assessment. Growers were requested to assess plant quality (0-10) with 10 being the highest.

Shelf life trial

The shelf life trial was conducted at the University of Lincoln's Holbeach campus, The National Centre for Food Manufacturing (NCFM). The facilities at NCFM, Holbeach were provided with the permission of Poken and Chrysal. The plants viewed during the open day at Neame Lea, 22nd November 2018, were delivered to NCFM the following day to commence shelf life

assessment. This consisted of six replicate plants of each variety from each of the three growers.

To replicate the transportation and depot phase of commercial operations, the plants were transported in cellophane sleeves within standard transit boxes, where they remained for three days at ambient temperature.

To replicate store phase, the plants were placed randomly on the shelf life room benches and remained sleeved for five days (Figure 1). The plants were placed in pot saucers and watered with 50 ml of mains water on day one, three and five of store phase. It was noted that not all plants would have survived store phase without watering.

For the home storage phase, plants were maintained in the shelf life room until 17th January 2019 (Figure 2), the conditions followed a standard trial environment;

- Warm white LED panel lighting - 1000 lux for 12 hours per day
- Temperature maintained at 18-22^{o}C
- Relative humidity maintained at 50-65%.

The room conditions were monitored to ensure consistency.

All plants were irrigated with the same volume of mains water, 50 ml, three times per week (to maintain life in the driest plant). During week 1, the plants from one nursery (generally the largest plants), required more water than the other two nurseries, they were watered twice using double the amount of water. It was noted during the first few weeks that some plants required a considerable water uptake in line with their continued plant growth, therefore all plants were watered with double the amount. Crunch Red and Christmas Beauty Princess were generally an exception to the rule, but watered the same as other varieties. After New Year, the plants were watered on a plant requirement basis to maintain life. This was a similar procedure to the previous year when generally smaller plants where watered less.

Figure 1. Store phase in the shelf life room at NCFM, retail phase
Source; Le Grys, 26th November 2018

Figure 2. Shelf life room University of Lincoln, NCFM, 12th December 2018, home phase
Source; Le Grys, December 2018

The visual quality assessments were undertaken at weekly intervals by the same scorer to ensure consistency. Individual plants were assessed from 0-10 against a range of quality attributes;

- Overall balanced shape and colour typical to variety
- Number of bracts (4 plus 1) and level arrangement of bracts
- Cyathia present, condition of pollen on the stamen
- Presence of Bract End Burn (BEB)
- Overall leaf and bract fall
- Pest and disease presence

A score of 10 was the highest score, a score above 4 was acceptable for retail, a score of 4 represented plant deterioration, a score of 2 represented serious quality defects, a score of 1

indicated the plant break down and 0 the plant had died. Each plant, including failures, was photographed once during the shelf life period.

Trial two: deficit irrigation trial

Plants and commercial growing conditions

The DI trial was carried out in the glasshouse facilities at Neame Lea Nursery Ltd, Horseshoe Rd, Spalding PE11 3JB as in 2017. In Week 31, approximately 2,000 plants of each variety ("Astro Red", "Leona Red", Aries Red") were potted in the "Industry standard" poinsettia mix of 15 mm peat plus 20% by volume medium grade perlite. To these physical ingredients were added the following; Lime to bring the pH into a range of 5.5-6.0, base fertiliser (15-10-20 TE) at 1 g/L, wetting agent at standard rate 0.4 ml/L.

The plants were grown as a commercial crop pinched during the second week of September. Each ebb-and-flow bench initially contained approximately 550-600 pots, reduced to 300-350 at first spacing, with further reductions to 100 plants per bench at final spacing. There were 20 benches of each variety at final spacing in each irrigation block that were individually supplied by a separate solenoid valve.

Spacing was carried out on the three benches by hand (normally automated but necessary due to cable connections between the dataloggers and modems). Overhead watering was done initially by hand. The Neame Lea project team recorded the following aspects of the trial; potting date, spacing dates, plant height and plants per m^2. Environmental metrics were collated via a Hoogendoorn PC, and included glasshouse radiation, temperature and Relative Humidity (RH).

After pinching, one application of calcium nitrate was made followed by application of 11-42-11 fertiliser made weekly for 4-5 weeks. From Week 38 (approximately), the fertiliser was changed to 15-5-30 and a phosphate treatment was applied prior to flower initiation. No PGRs were applied.

Batches of the standard substrate were collected by the NIAB EMR team to calibrate the moisture sensors. Further samples of substrate and foliage were removed by the UoL project team at the start of September 2018 for analysis. All experimental plants received the same fertigation programme throughout the crop cycle as did the commercial crop.

Precision irrigation system set up

A technology package consisting of nine Delta T sensors (SM150T) connected to a GP2 Advanced Datalogger and Controller powered by a battery and solar panel, and wired to a modem, was placed on one bench in the middle of the irrigation block in each variety (Figure 3). The sensors were inserted carefully into the substrate of nine representative plant-and pots positioned across the length and breadth of each bench on 11 September 2018 (Figure 4). Individual pot SVMC values were recorded at 15 min intervals and averaged using the GP2 data logger. Telemetry enabled remote access to “real-time” (every 15 min) temperature-corrected SVMC substrate moisture data and environmental metrics including air temperature and RH from which VPD was calculated. Data was uploaded to DeltaLINK Cloud and monitored twice daily by the NIAB EMR project team; real-time data was also displayed on a “Grower Dashboard” that was made available to Neame Lea’s Production Manager throughout the trial. The absolute and relative changes in SVMC over the previous 24 h were reviewed by the NIAB EMR project team every day before 08:00 and a recommendation on whether or not to irrigate was sent to the grower via SMS message, and followed with a phone call if further discussion was needed.

Figure 3. The GP2 Advanced Datalogger and Controller on the bench in the “Astro Red” irrigation block. The SM150T sensors are hard-wired into the ports into the datalogger.
Source; Else, 2018

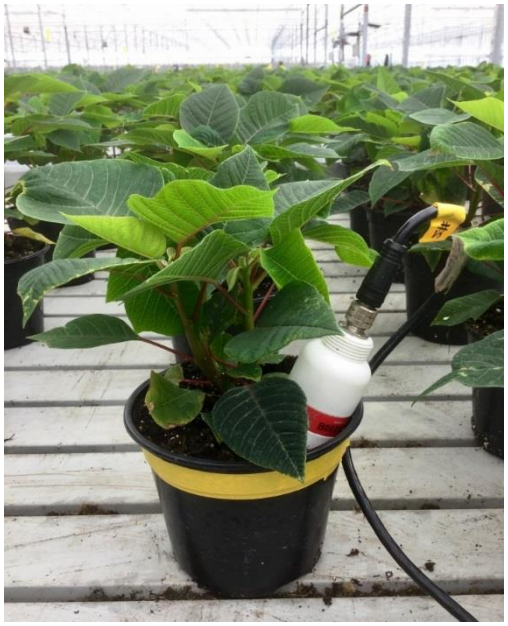

Figure 4. An SM150T sensor buried into the substrate to record changes in SVMC in an “Astro Red” plant. Source; Else, 2018

During much of the growing season, the average SVMC was maintained between 35-55% for each variety to promote strong growth and to reduce the perceived risk that the minimum height specification might not be reached by the end of the production season. Weekly plant height measurements were made for each of the three varieties by the Neame Lea team and were uploaded to an on-line tracking software package. Once the Production Manager was confident that the minimum height would be achieved, late-season DI treatments were applied to each variety during November 2018 to try to slow extension growth, so that all plants were within height specifications at dispatch (see below). The average values of SVMC at which stem extension growth was slowed in each variety, were established at different developmental stages during the season (see below).

Establishment of wilting point

Six plants of each variety were randomly selected from benches within each irrigation block and placed on upturned pots, thereby removing them from the ebb-and-flow irrigation system during October and November 2018 (Figure 5). All pots were weighed by Neame Lea staff at the same time each day using an electronic balance during the period that irrigation was withheld, and the rate of evapotranspiration over the previous 24 h was calculated. The pot weights at which visible wilting first occurred were noted (Figure 6), as was the value at which plants failed to regain turgor following a night period. All plants were then re-watered and the drying cycle was repeated.

Figure 5. Plants were removed from the flood-and-drain benches, weighed daily and monitored until visible wilting and sustained wilting were observed. All plants were then re-watered and the drying cycle was repeated.
Source; Else, 2018

Establishing the relationship between monitored plants and the crop

To determine whether the nine plants-and-pots into which the SM150T sensors had been installed continued to be representative of the rest of the crop, plant and pot weights and corresponding values of SVMC were made with an electronic balance and a Delta-T "WET" sensor on the "sensor bench" and on seven other benches in each irrigation block. Average values were calculated from five individual plants on each bench, and compared to the overall mean value to inform irrigation decision making.

Figure 6. Plant-and-pot weights were measured with an electronic balance and spot measurements of SVMC were made with a Delta-T "WET" sensor.
Source; Else, 2018

Deficit Irrigation system set up

Deficit irrigation was imposed on three occasions during November 2018. Average values of SVMC were allowed to fall to below 30% for each of the three varieties. The degree and duration of each drying episode was initially determined by the NIAB EMR team following remote analysis of the relationship between VPD and the rate of change of substrate drying. Deviations in this relationship indicated that plants were beginning to perceive a root water deficit stress which was sufficient to slow stem extension. Remote recommendations made by the NIAB EMR project team were sense-checked by the Neame Lea Production Manager who always made the final decision when to re-water following a visual inspection of the crop.

Dispatch assessment

The dispatch assessment of the deficit irrigation plants was carried out in the same manner as the variety trials at Neame Lea on the 27th November 2018.

Open day 22nd November 2018

Neame lea supplied six plants from each of the three varieties for display at the open day. Three plants of each variety were placed on show for the grower assessment. Growers were requested to assess plant quality (0-10) with 10 being the highest.

Shelf life trial

The deficit irrigation plants viewed during the open day 22nd November 2018, were delivered to NCFM to commence shelf life assessment along with the variety trial plants under the same conditions. It was noted at the start of the store phase that the plants were very dry, and therefore were watered twice with double the quantity of water (100 ml) to prevent plant loss. Initial leaf drop was higher in deficit irrigation trial plants than in plants in the variety trial (Figures 7 and 8). Thereafter, deficit irrigation plants were watered in line with the variety trial plants, although it was noted the deficit irrigation plants were generally observed to be wetter than variety trial plants.

Figure 7. Leaf drop deficit irrigation7th December 2018
Source; Le Grys December 2018

Figure 8. Leaf drop variety trial 7th December 2018
Source; Le Grys December 2018

Remote sensor testing for deficit irrigation

At Volmary, testing the remote sensors was done in partnership with 30MHz, a company based in Holland who specialise in the development of wireless enabled system for monitoring all types of sensors. 30MHz do not actually produce sensors but develop and install wireless technology. In the previous year's work, a hardwired sensor set was used. Due to those sensors being considered impractical on many nurseries, wireless-enabled sensors were used in this project. It was felt that future sensor development was much more likely to depend on wireless systems.

Six wireless enabled sensors were purchased and installed into two separate capillary floor areas at Volmary nursery, Wisbech St. Mary. The two areas initially selected considered different to each other – prior to having the capillary matting laid down, one area had been re-levelled. It was therefore anticipated that there would be a difference in the watering efficiency between the two.

30MHz kindly agreed to supply the necessary relays on the nursery to ensure even pick up of the data from the bays and the base station, plus giving access to the 'on cloud' data in real time for the period of the trial. The installation and access to the data was all completed by early August 2018. The data could be accessed in real time both by computer, tablet or mobile phones (Figures 9 and 10).

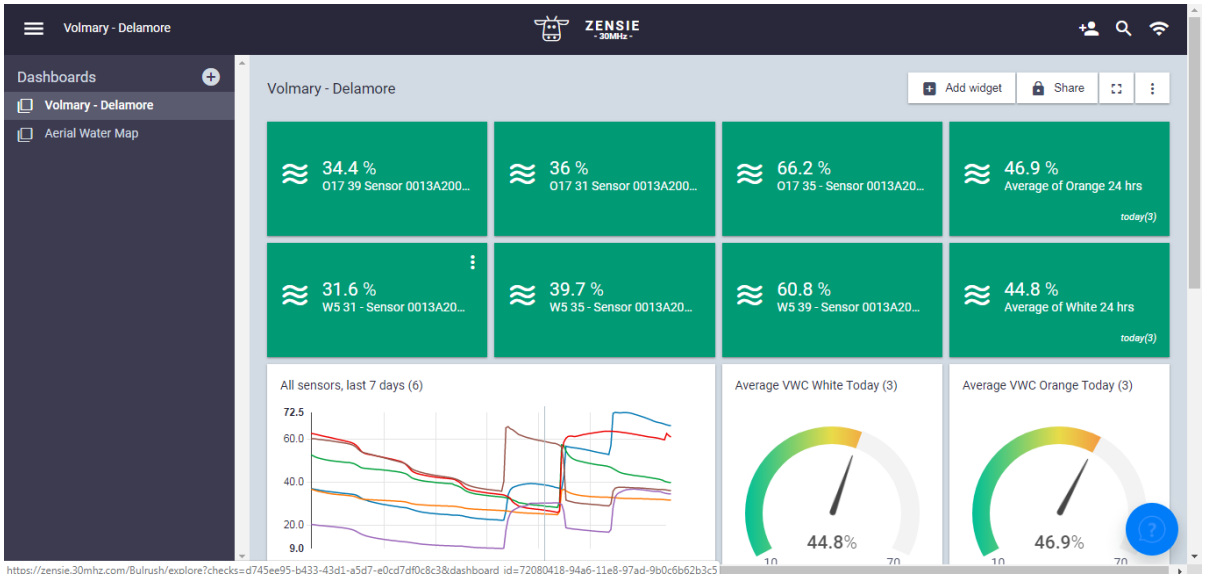

Figure 9 Dashboard of wireless sensors at Volmary nursery
Source; Bragg August 2018

Figure 10. Ariel view of water map from wireless sensor data at Volmary nursery, red indicates wetter areas.
Source; Bragg August 2018

The aerial map data in Figure 10 shows percentage water levels with red indicating wetter areas. From the outset of the data collection, there were clear differences in the apparent wetness between bays and also down the length of the bays in relation to where the headers were for the lay flat irrigation.

Chemical residue testing

Leaf samples from four different cutting suppliers were collected in July and early August 2018. The sampling of the leaves was to collect data from the older fully expanded leaves on the received cutting material. The samples were sent to the Concept Life Sciences laboratory, Bar Hill, Cambridge for scanning. The exercise was repeated 21st November 2018.

Results

Trial one: variety trial

Growers assessment

The grower assessment was carried out during the AHDB open day, 22nd November 2018. Delegates scored three plants of each variety for overall quality assessment, for both variety trial and deficit irrigation trial plants (26 data sets were received). The grower assessment results are shown in Figures 11 and 12. The location, growing facilities, irrigation systems and customer specifications are different for each of the nurseries. Some of the varieties showed a wide range of scores between growers, e.g. Crunch Red (3.5-6.9). The most consistent between grower's scores were Blissful Red (5.7-6.7) and Christmas Sensation (5.5-6.8).

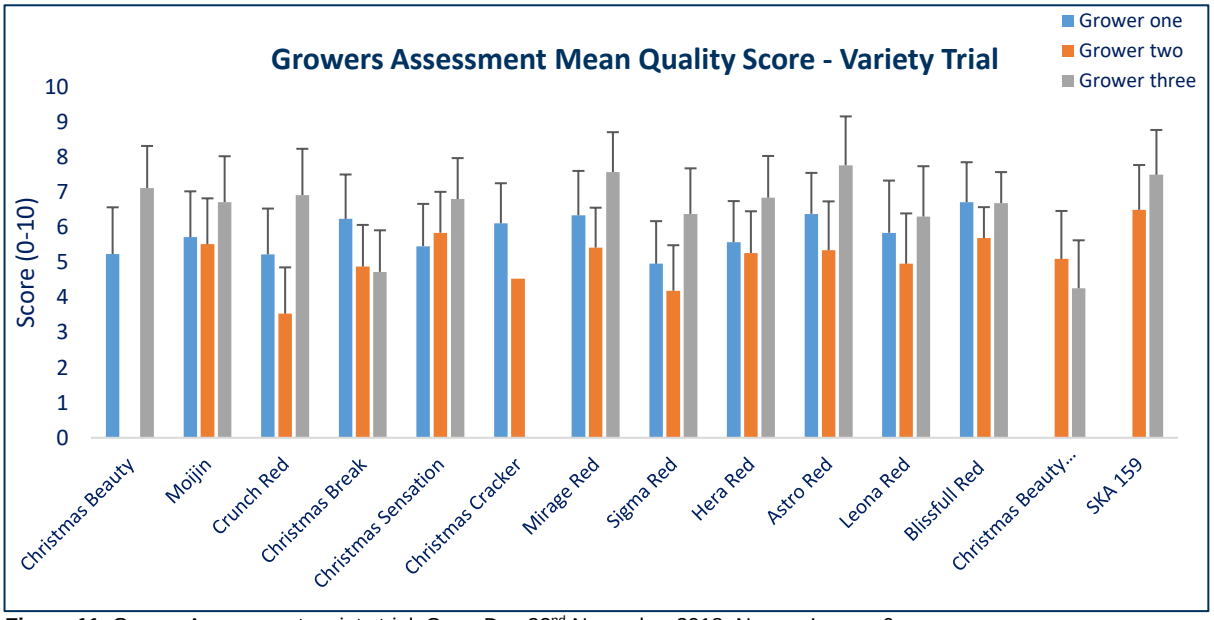

Figure 11. Grower Assessment variety trial, Open Day 22nd November 2018, Neame Lea. n=6

The combined results from the grower's assessment indicate that Christmas Beauty Princess was the least popular variety (4.7) and SKA 159 the most popular (7) (although it is worth noting that these varieties did not have plants from all growers), followed by Astro Red (6.5) and Mirage Red (6.4).

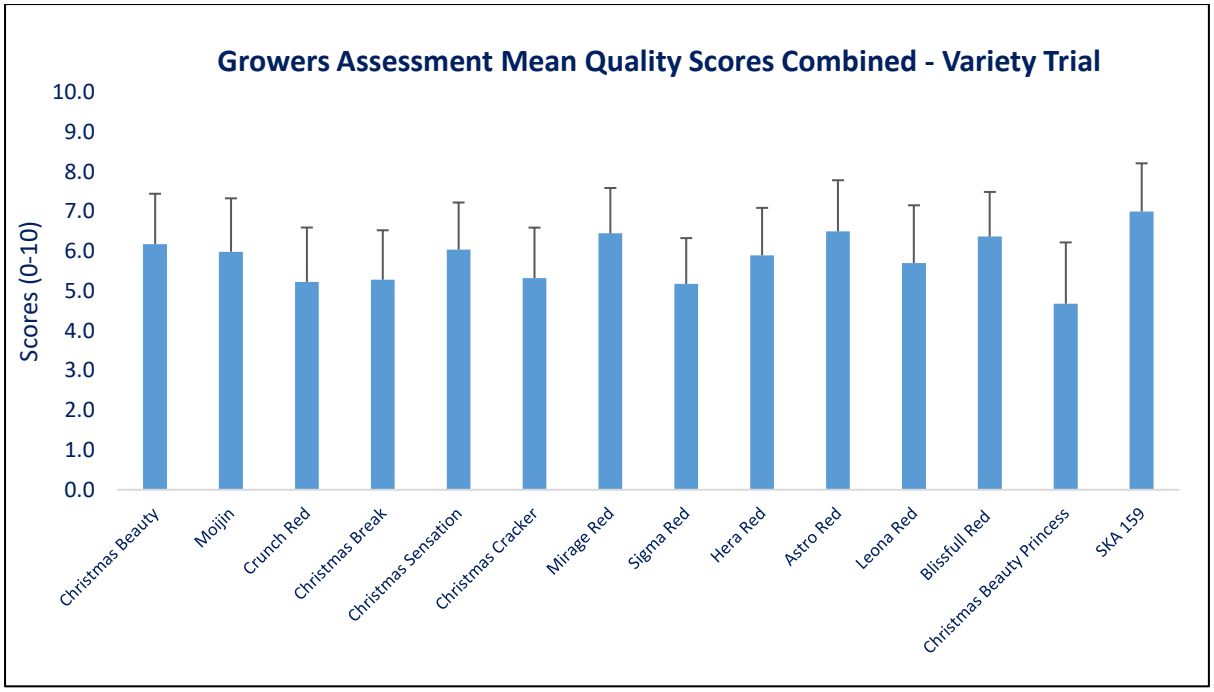

Figure 12. Combined scores by growers Grower Assessment Open Day 22nd November, Neame Lea. n= 18, except Christmas Beauty, Christmas Cracker, Christmas Beauty Princess and SKA 159 n=12

Dispatch assessment

The results of the combined nursery dispatch assessments for plant height and width are shown in Figure 13. The nurseries' height specifications range from 22-32 cm. The results show that Christmas Beauty Princess did not achieve the grower height specification and no varieties exceeded the specification.

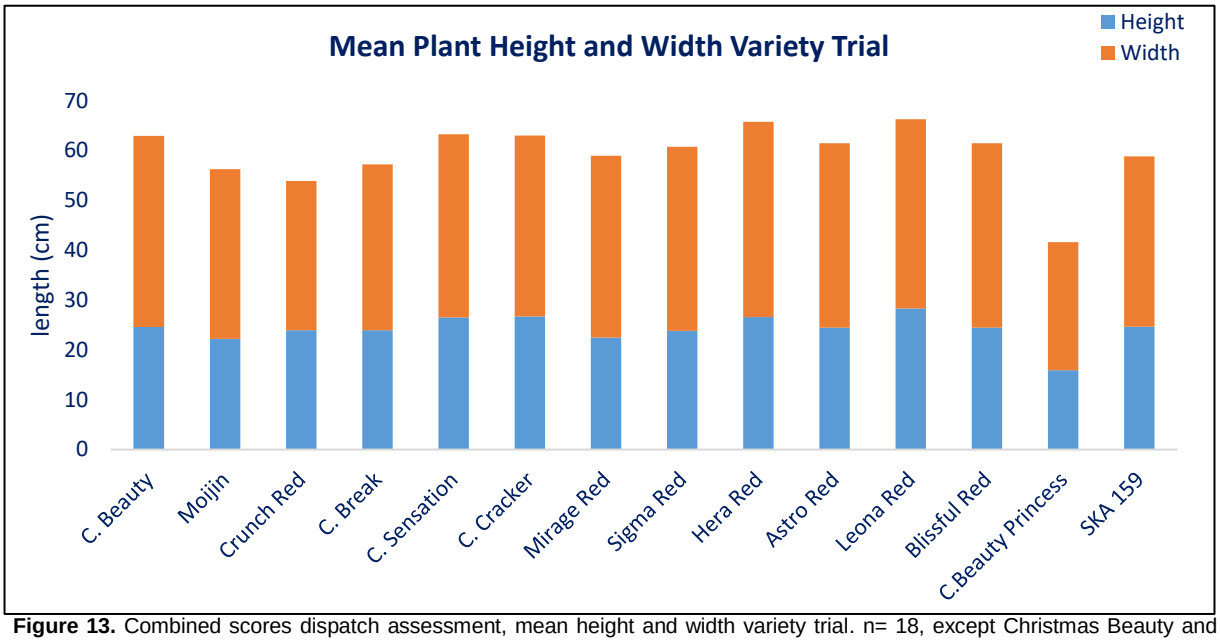

Figure 13. Combined scores dispatch assessment, mean height and width variety trial. n= 18, except Christmas Beauty and Christmas Cracker n=12.

The results of the combined nursery dispatch assessments for bracts of the variety trial are shown in Figure 14. The nursery specifications was for 4 + 1 bracts, not all plants in the variety trial attained this number, (Christmas Beauty, Christmas Break, Christmas Cracker, Christmas Beauty Princess and SKA 159). For the second year running Astro Red showed the highest number of main bracts.

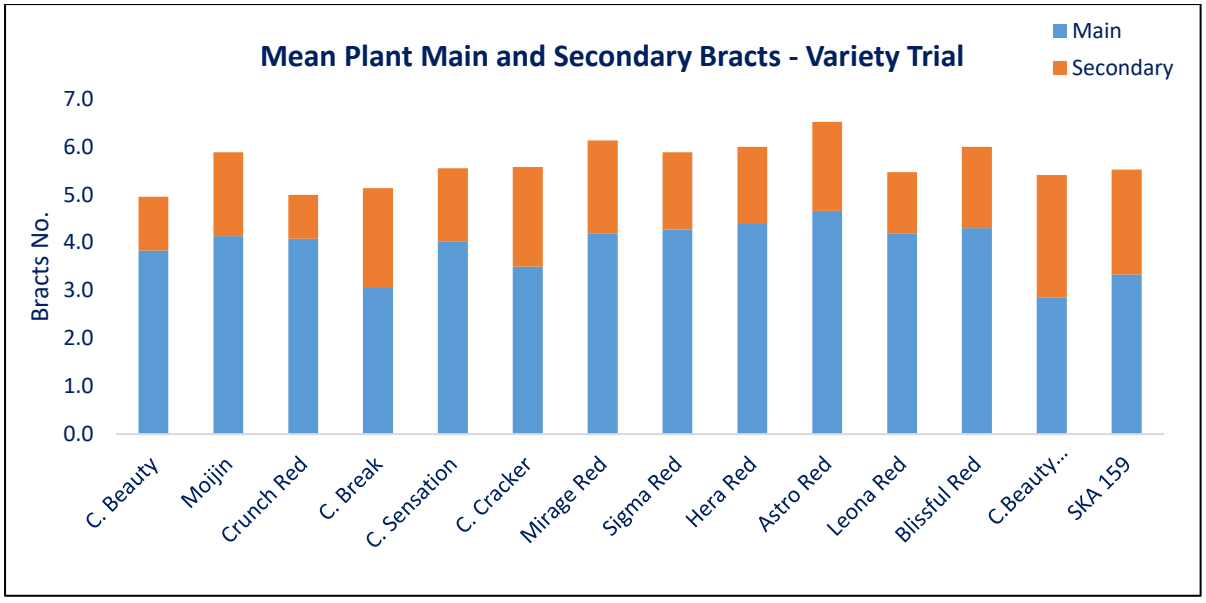

Figure 14. Combined scores dispatch assessment, mean No of bracts variety trial. n= 18, except Christmas Beauty and Christmas Cracker n=12.

The results of the combined nursery dispatch assessments for quality are shown in Figure 15. The specification was for 5 and above as a saleable product, not all varieties attained this level at dispatch: Christmas Break achieved 4.8, Christmas Beauty Princess 2.3 and SKA 159 4.9. The highest score was obtained by Astro Red at 6.4.

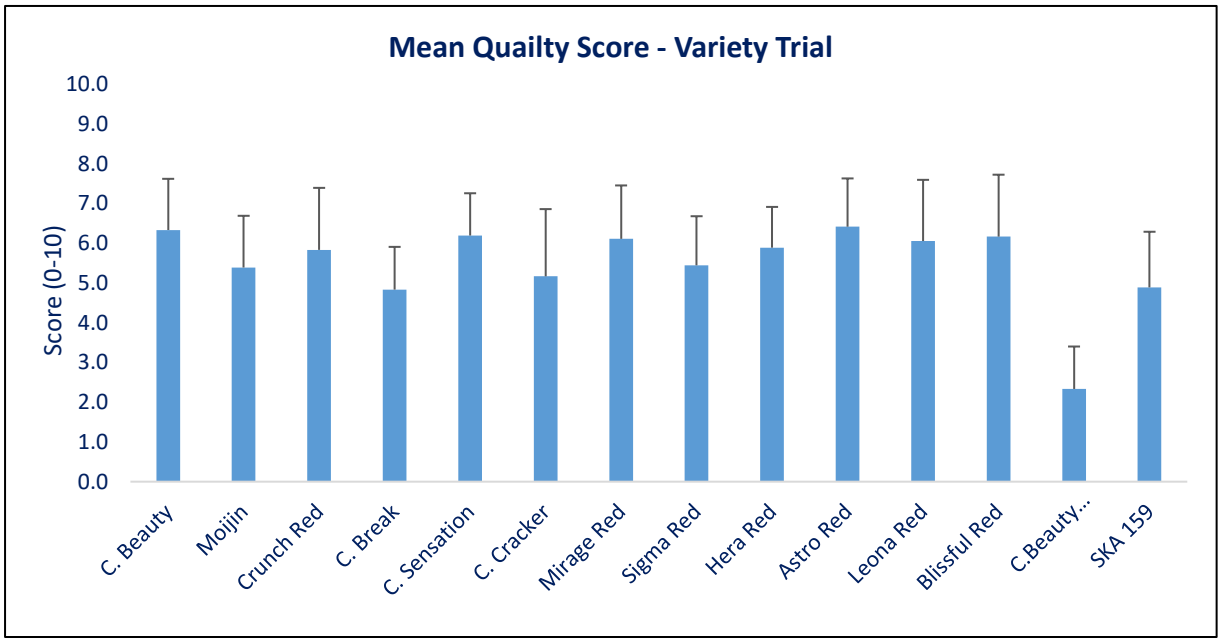

Figure 15. Combined scores dispatch assessment, mean quality score, variety trial. n=18 (Christmas Beauty and Christmas Cracker n=12.)

The comparison of quality scores between the grower's assessment and the nursery dispatch assessments is shown in Figure 16. The majority of quality scores are similar between the two assessments with Christmas Beauty (6.3, 6.2), Christmas Cracker (5.2, 5.3), Hera Red (5.9, 5.9) and Astro Red (6.5, 6.5) having the most consistent results, indicating similar opinions on quality. However there are two notable differences in Christmas Beauty Princess (2.3, 4.7) and SKA 159 (4.9, 7). A possible considered reason being the combined results for these two varieties are from only two nurseries, although this could be refuted as two of the most consistent results Christmas Beauty and Christmas Cracker also only come from two nurseries. In both assessments Christmas Beauty Princess scores the lowest. SKA 159 scores the highest in the grower's assessment at 7, but is not considered saleable in the nursery dispatch assessment at 4.9.

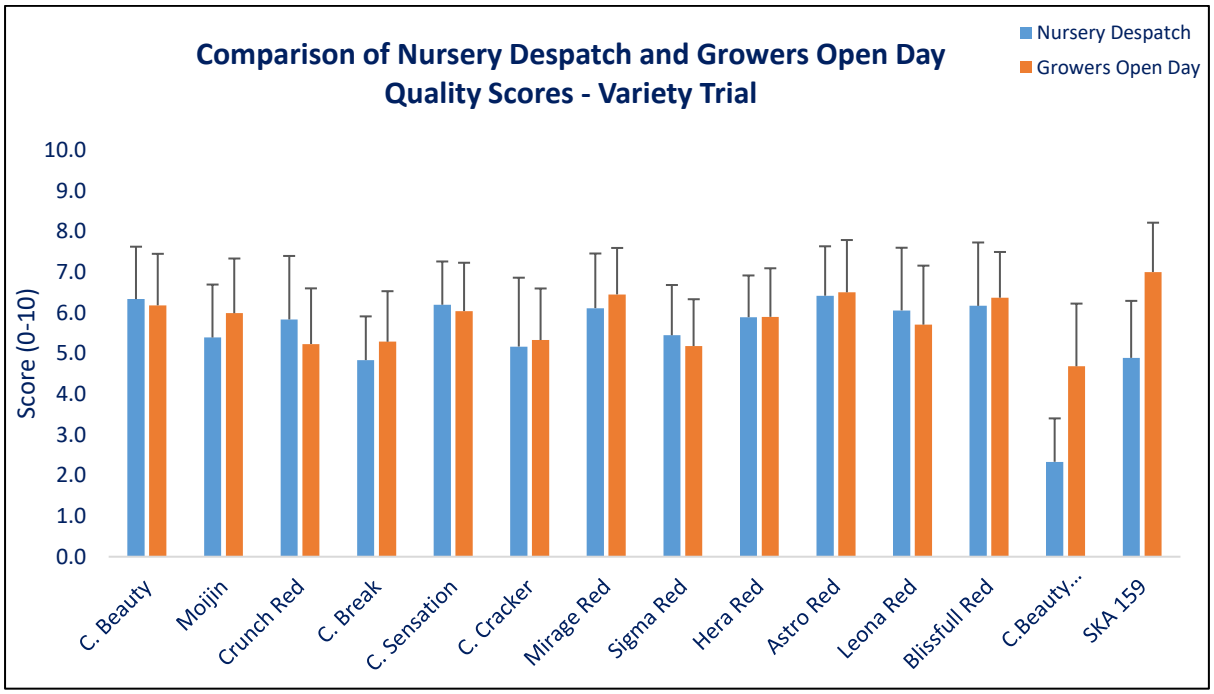

Figure 16. Comparison of combined scores dispatch assessment and growers assessment, mean quality score, variety trial n=18 except Christmas Beauty, Christmas Cracker, Christmas Beauty Princess and SKA 159 n=12 growers assessment and Christmas Beauty and Christmas Cracker n=12 dispatch assessment

Shelf life assessment

The results of the combined shelf life assessments for quality of the variety trial are shown in Figure 17. The specifications was for 5 and above as a saleable product.

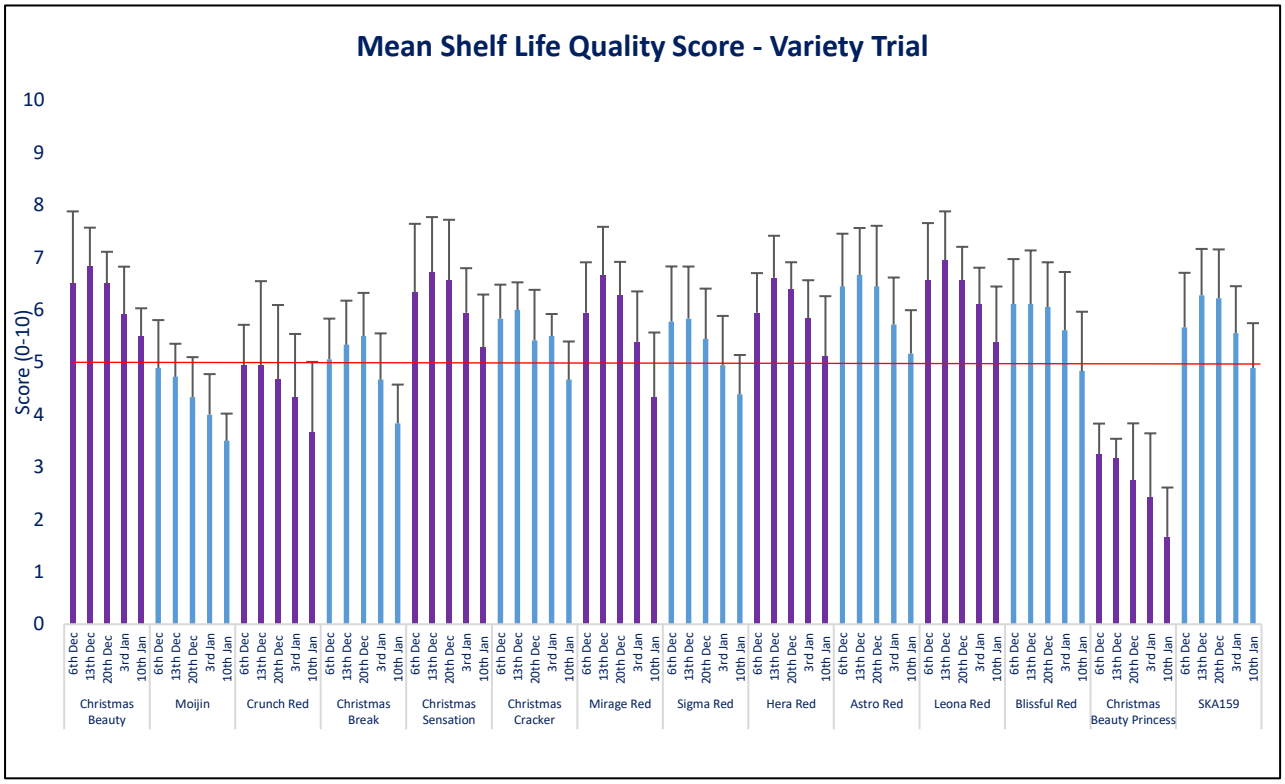

Figure 17. Combined scores shelf life assessment, mean quality score, variety trial n=18

Most varieties continued to grow and improve in quality score during the first few weeks of shelf life; the plants also grew in size though this was not measured. This improvement in plant quality was not seen last year in any variety.

The results indicate that for overall quality, Christmas Beauty Princess performed consistently the lowest throughout the assessment period on the variety trial, Moijin and Crunch Red did not score highly enough to be considered saleable.

At the closest assessment date prior to Christmas, 20th December, the four varieties which achieved the highest mean scores were Christmas Sensation, Leona Red on 6.6 and Hera Red and Astro Red on 6.4. These results were considerably higher than the previous year when Ferrera was the highest score on 5.1.

At week five, the plant quality scores on the variety trial were higher than at the same time the previous year: 4th January 2018 all plants scored 1-6, 3rd January 2019, the lowest score was 2, with 45 plants scoring 7 or above.

At the end of shelf life the highest scoring saleable varieties were Christmas Beauty (5.5), Leona Red (5.4), Christmas Sensation (5.3), Astro Red (5.2) and Hera Red (5.1). These were considerably higher than previous year's end of shelf life scores for the highest scoring: Christmas Sensation, Ferrara and Leona Red, at 3.5, 3.4 and 3.2 respectively. Two varieties scoring well across two years indicate consistent quality.

Some varieties such as Christmas Sensation had few high scoring plants, but the overall score was good, indicating that the plants were consistently better than average.

Trial two: deficit irrigation trial

Growers assessment

The deficit irrigation plants Astro Red and Leona Red achieved similar quality scores from the grower's assessment as plants of the same variety in the variety trial, indicating no potential negative impact of using deficit irrigation as growth control. Figure 18.

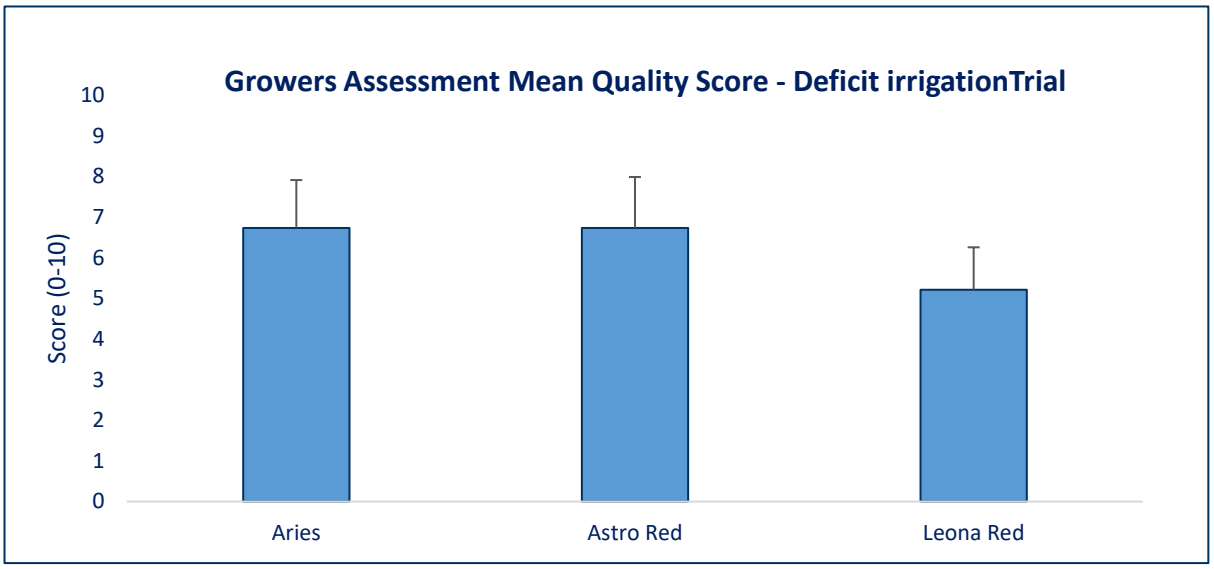

Figure 18. Grower Assessment deficit irrigation trial, Open Day 22nd November 2018, Neame Lea. n=6

Dispatch assessment

The plants of all three varieties in deficit irrigation trial are taller than plants in the variety trial at Aries 27 cm, Astro Red 30 cm and Leona Red 32 cm. Figure 19. This could be due to an aspect of the growth control or nursery specification. All three varieties where within the nurseries' height specifications range 22-32 cm.

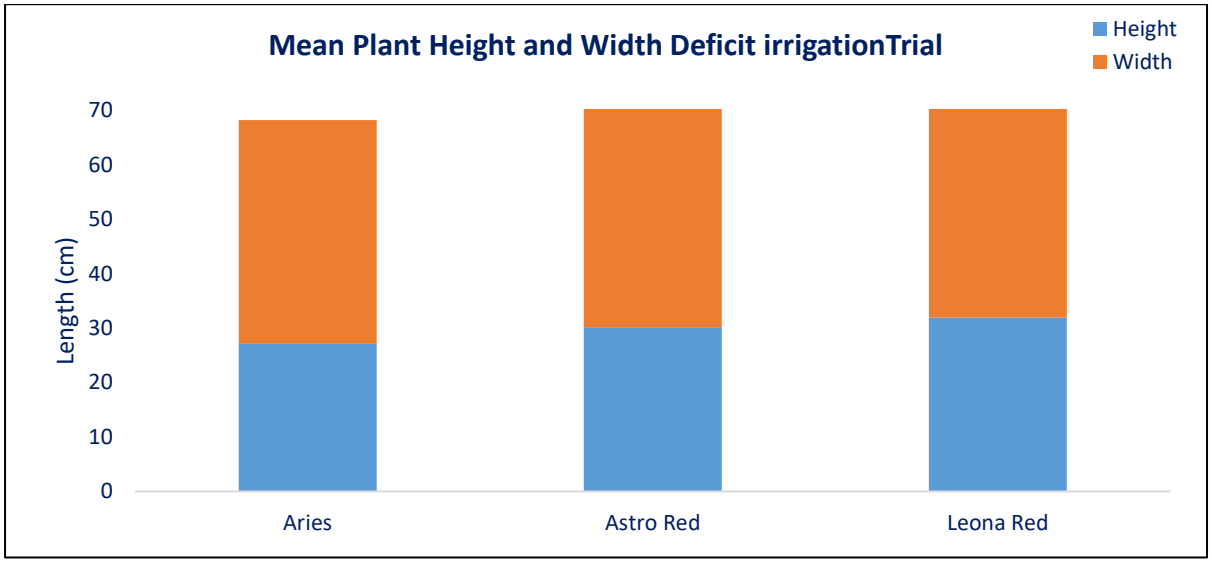

Figure 19. Combined scores dispatch assessment, mean height and width deficit irrigation trial n= 6

The results of the combined nursery dispatch assessments for bracts of the deficit irrigation trial are shown in Figure 20. The nursery specifications was for 4 + 1 bracts, all plants attained this number. Astro Red showed the highest number of main bracts.

Plants of all three varieties in deficit irrigation trial have more main bracts and less secondary bracts than plants in the variety trial. This could be due to an aspect of the growth control or nursery specification.

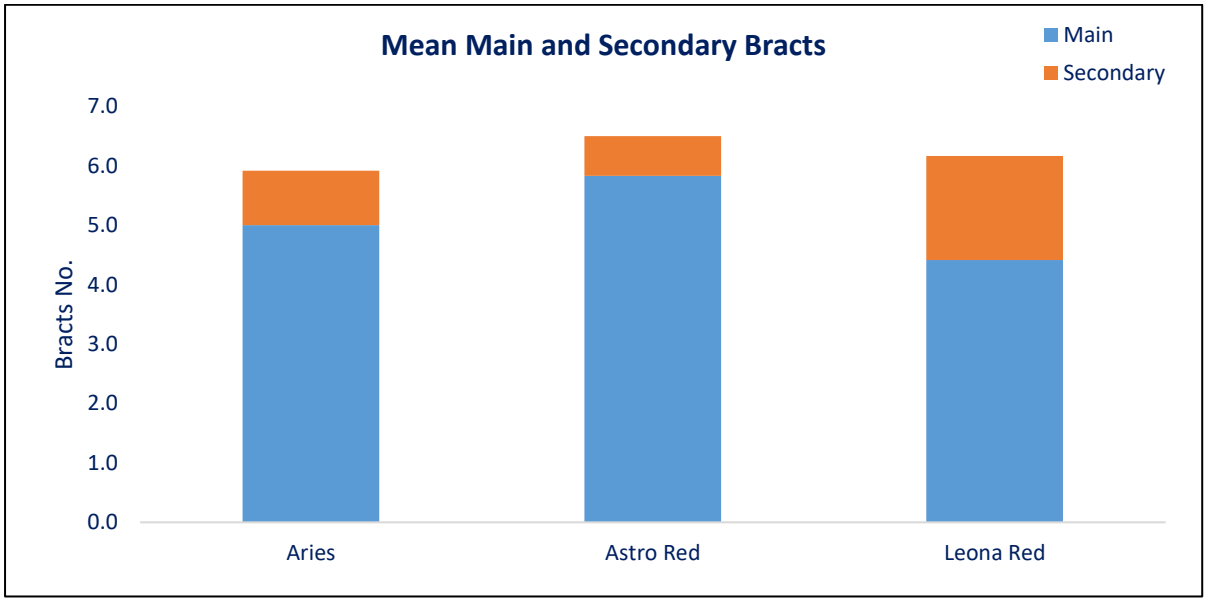

Figure 20. Combined scores dispatch assessment, mean No of bracts deficit irrigation trial n= 6

The results of the combined nursery dispatch assessments for quality of the deficit irrigation trial are shown in Figure 21. The specification was for 5 and above as a saleable product, all varieties attained this level at dispatch.

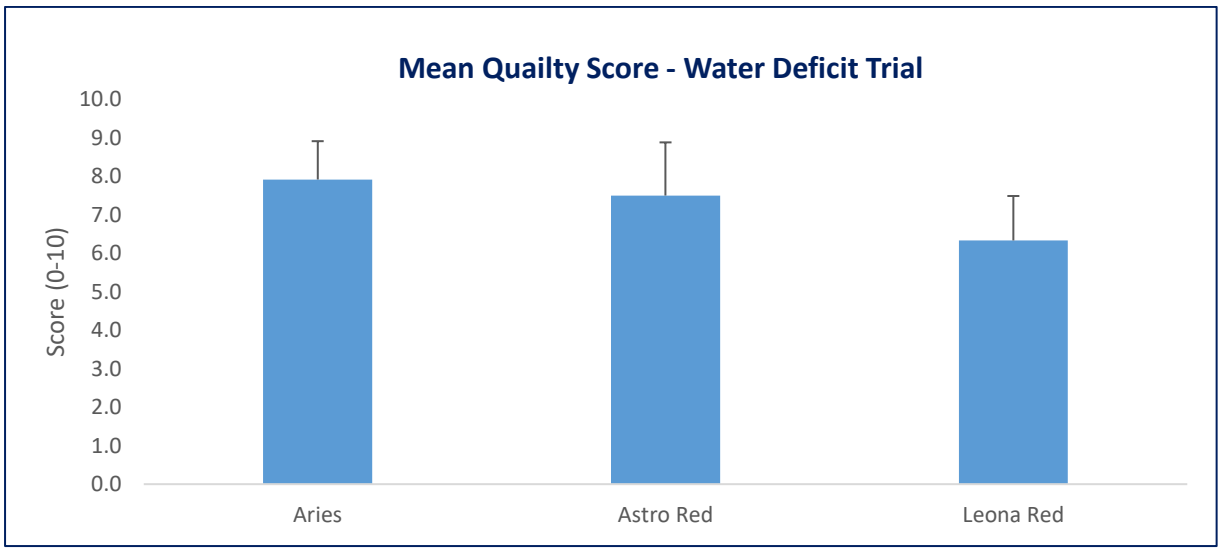

Figure 21. Combined scores dispatch assessment, mean quality score, deficit irrigation trial n=6

The deficit irrigation plants Astro Red and Leona Red achieved higher quality scores at dispatch as plants of the same variety in the variety trial, indicating no negative impact of using deficit irrigation as growth control.

The comparison of quality score results for the deficit irrigation trial between the grower assessments and dispatch assessment showed the growers scored slightly lower on all varieties.

Shelf life assessment

The results of the combined shelf life assessments for quality of the deficit water trial are shown in Figure 22. The specifications was for 5 and above as a saleable product. This was maintained by all varieties throughout shelf life

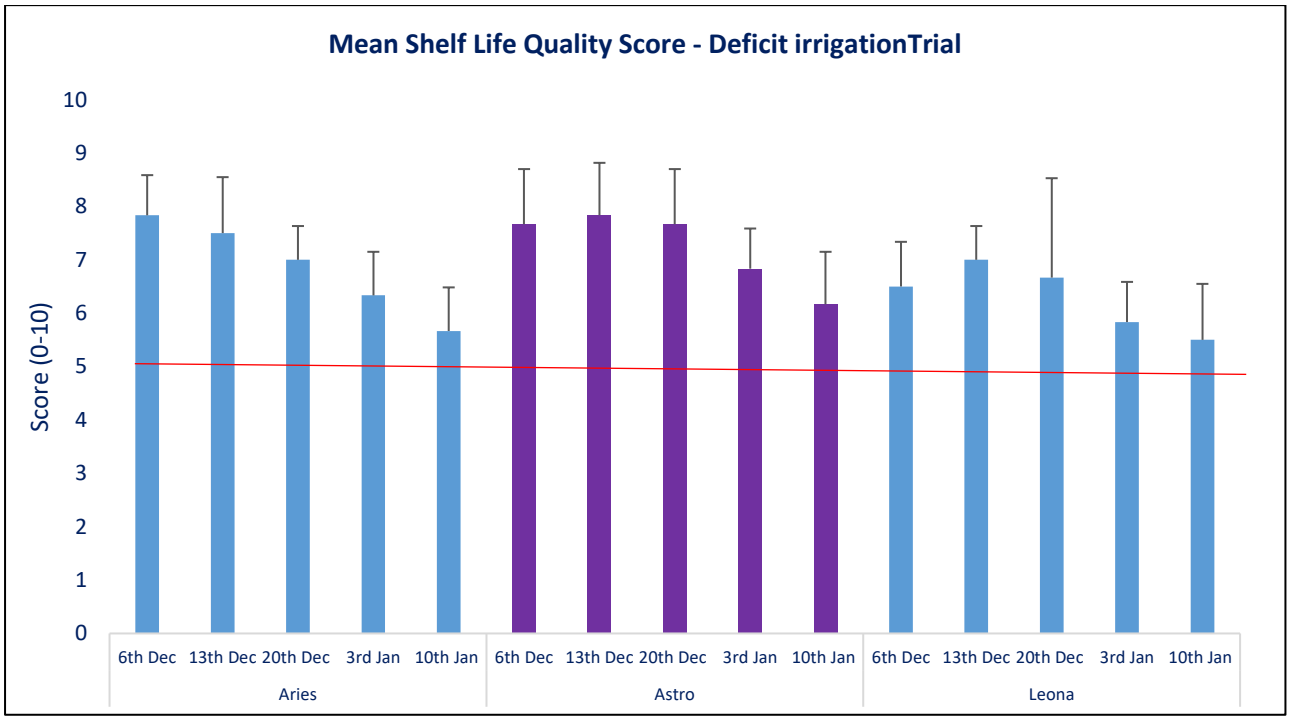

Figure 22. Combined scores shelf life assessment, mean quality score, deficit irrigation trial, n=6

Astro Red and Leona Red continued to grow in size (though this was not measured) and improve in quality score during the first few weeks of shelf life. The deficit irrigation trial plants Astro Red and Leona Red achieved higher quality scores during shelf life compared to plants of the same variety in the variety trial, indicating a potentially positive impact of using deficit irrigation as growth control on some varieties.

At the closest assessment date prior to Christmas, 20th December, the deficit irrigation trial plants scored higher than the same variety in the variety trial with Aries (7), Astro Red (7.7) and Leona Red (6.7).

Generally the cyathia abscessed over the Christmas period in both trials; the abscission on variety trial plants was more than on deficit irrigation trial plants, with exception of Aries. It was noted that there was less leaf fall than the previous year from all plants in both trials. There was very little bract end blackening on any plants or pests and disease on either trial.

Deficit irrigation to limit stem height, effects of substrate drying on stem extension

Precision irrigation to optimise substrate water availability

The range of SVMC was maintained between the pre-determined values in each variety throughout September and October 2018 (Figure 23 A-C). The “stepping” during the drying phases shown in the insert reflects differences in the rate of plant water use between day and night. The aim was to avoid large fluctuations in SVMC as previous work shows that these can reduce plant quality, uniformity and robustness. Seventeen 20 minute irrigation events were applied from 11th September to 31st October 2018, although some of these were drenches applied as part of the routine P&D programme at Neame Lea.

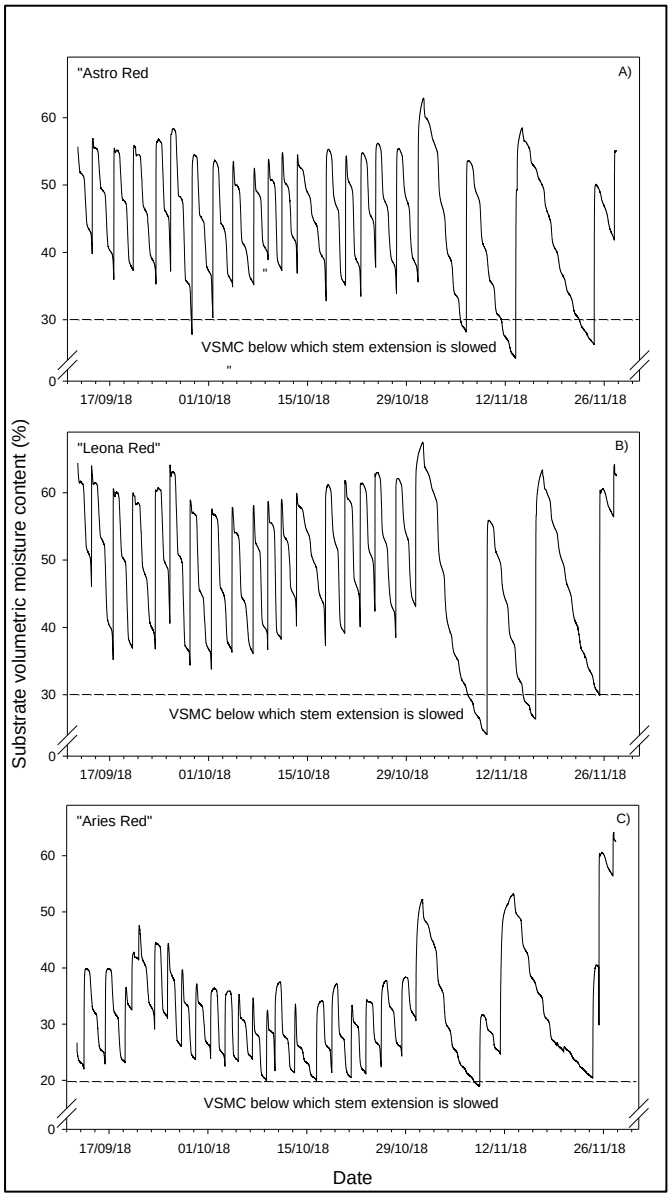

Figure 23 A-C. Changes in average substrate volumetric substrate moisture content (SVMC) in “Astro Red” throughout the PI/DI trial. The minimum SVMC value for effective height control is shown as a dashed line.
Source; Else, March 2019

Our original intention was to begin to impose the DI treatments in the last week of September (week 39) and the average SVMC in “Astro Red” was allowed to fall to 28% before re-watering to assess the impact on stem extension rate (Figure 23 A). Analysis of the stem height data the following week (Week 40) showed that this treatment did reduce the rate of stem extension (Figure 24 A, D), but the Neame Lea Production Manager took the decision to delay the DI treatment to ensure that sufficient plant height was achieved. Consequently, the average SVMC in each of the three varieties was maintained between 35-55% throughout October 2019 (Figure 23 A-C).

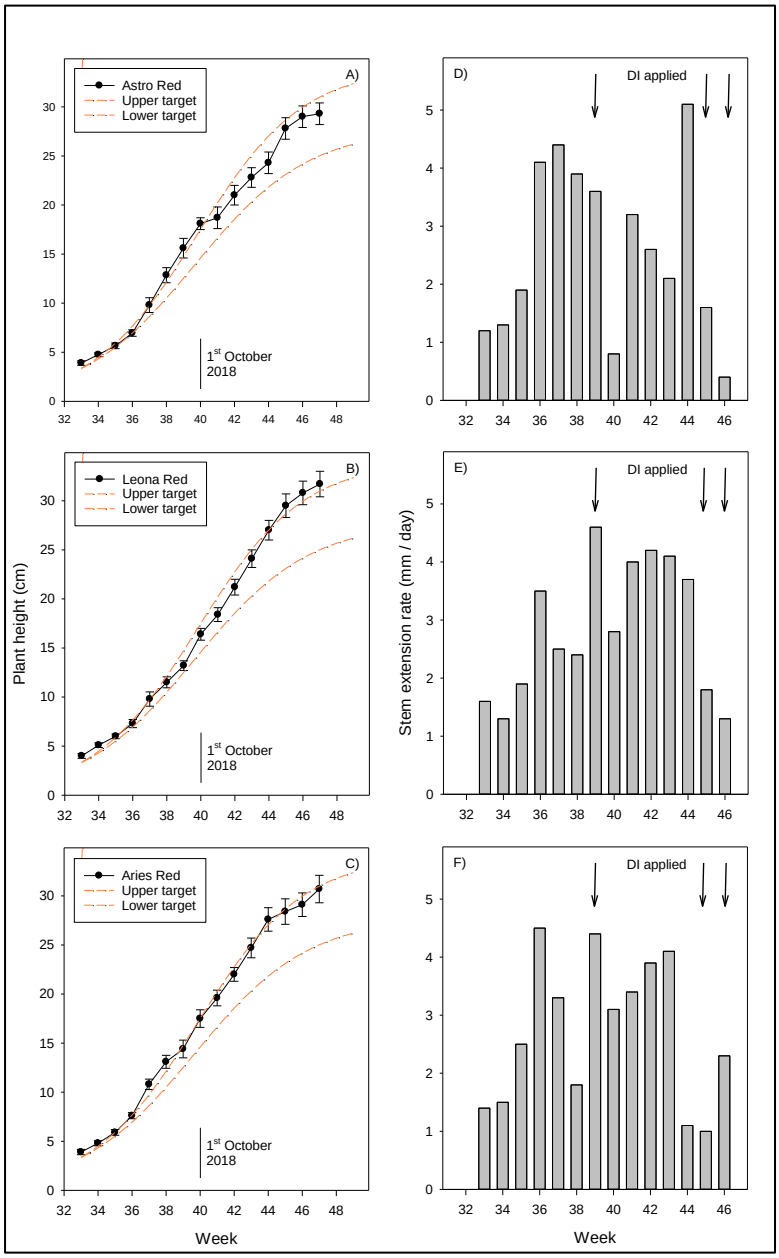

Figure 24 A-F. Changes in A-C) average stem height and B-F) stem extension rate of “Astro Red”, “Leona Red” and “Aries Red” plants under precision irrigation and deficit irrigation at different times of the season. The upper and lower ranges of stem height needed to ensure that height specs are met at market date are also shown. Vertical arrows indicate when DI was imposed. Source; Else, March 2019

On the afternoon of 27th October 2018, VPD had already begun to fall from its peak by the time irrigation was applied (15:00) (Figure 25 A&B), and so any wilting plants would have quickly recovered during the late afternoon and early evening. The irrigation event could then perhaps have been applied at 08:00 the following morning to allow some degree of substrate drying overnight

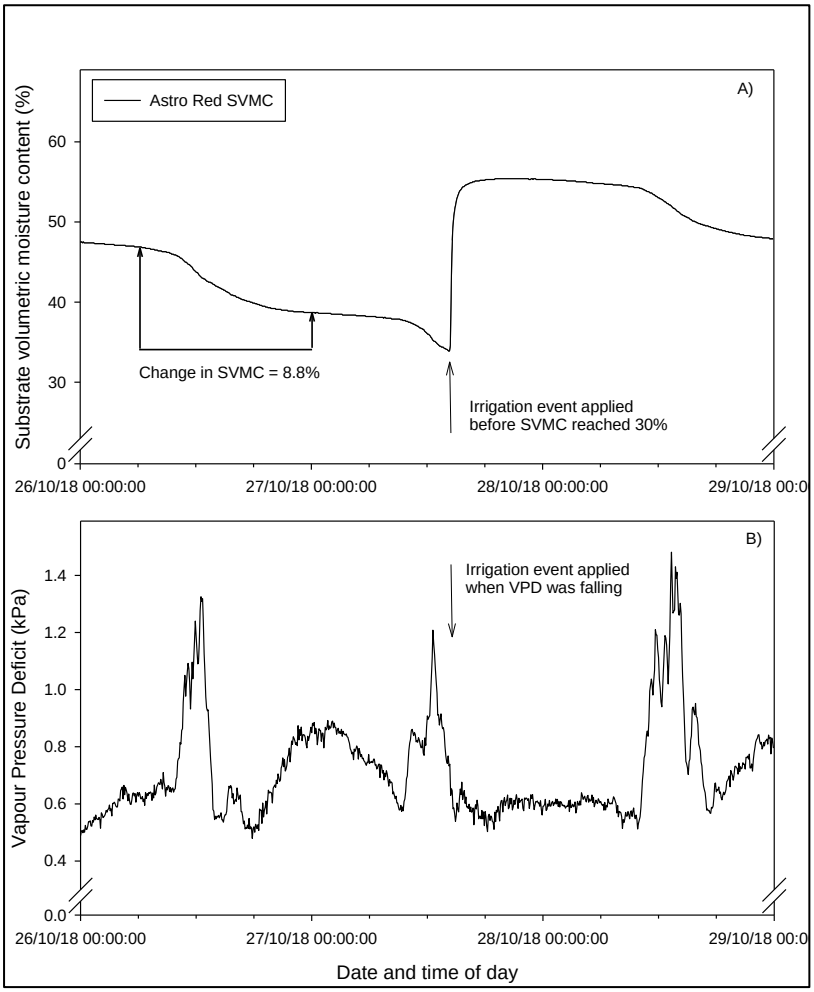

Figure 25. A, B Changes in A) substrate volumetric moisture content in "Astro Red" plants and B) glasshouse VPD before and after an irrigation event.
Source; Else, March 2019

Using Deficit Irrigation as a non-chemical means of growth control

In plants from which irrigation was withheld, visible wilting of the leaf tips first occurred at an average plant-and-pot weight of c. 265 g, and an associated SVMC of 15%. Sustained wilting occurred at average plant-and-pot weights of 248, 243 and 235 g (Figure 26 A-C), and c. 7% SVMC (data not shown) during three separate drying cycles and different levels of VPD.

Deficit irrigation was imposed on the three varieties during the first week in November 2018 (week 44), and average values of SVMC were allowed to fall below 30%. This was not the ideal developmental stage to impose DI because the effects of transient shoot water deficits on bract quality are not well known and so caution was needed. To inform our decision making, we monitored the relationship between the daily percentage change in substrate SVMC and changes in daily evaporative demand i.e. VPD measured in the trial area (Figure 27 A&B). In well-watered plants, higher VPDs resulted in a greater rate of water plant loss, reflected in the steepness of the stepping shown in Figure 27 A, for example 9% on the 2nd November 2018. However when the degree of DI imposed was sufficient to trigger stomatal closure in the leaves, an adaptive response to root water deficits, the percentage change in substrate drying became uncoupled from VPD – see 5th November 2019 in Figure 27 A. At this point, we hypothesised that the plants were experiencing sufficient root and shoot water deficit stress to impact on shoot extension. A further two DI events were applied during the remainder of November, and again extension rate was slowed in Weeks 45 and 46.

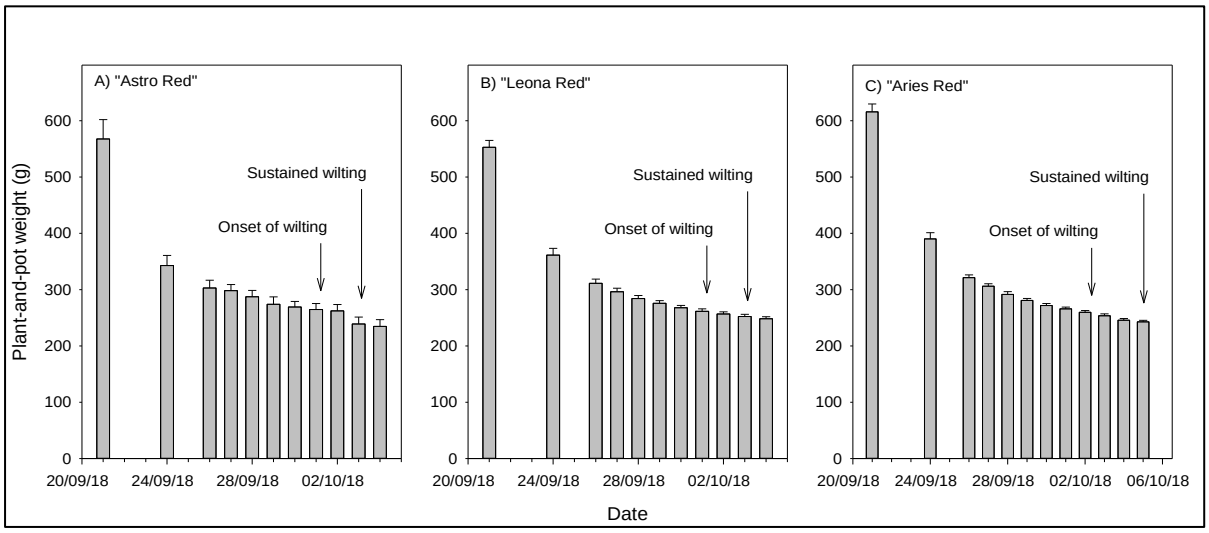

Figure 26 A-C. Changes in plant-and-pot weights in A) “Astro Red”, B) “Leona Red” and C) “Aries Red” plants from which irrigation was withheld. Values are means of six replicates with associated SEs.
Source; Else, March 2019

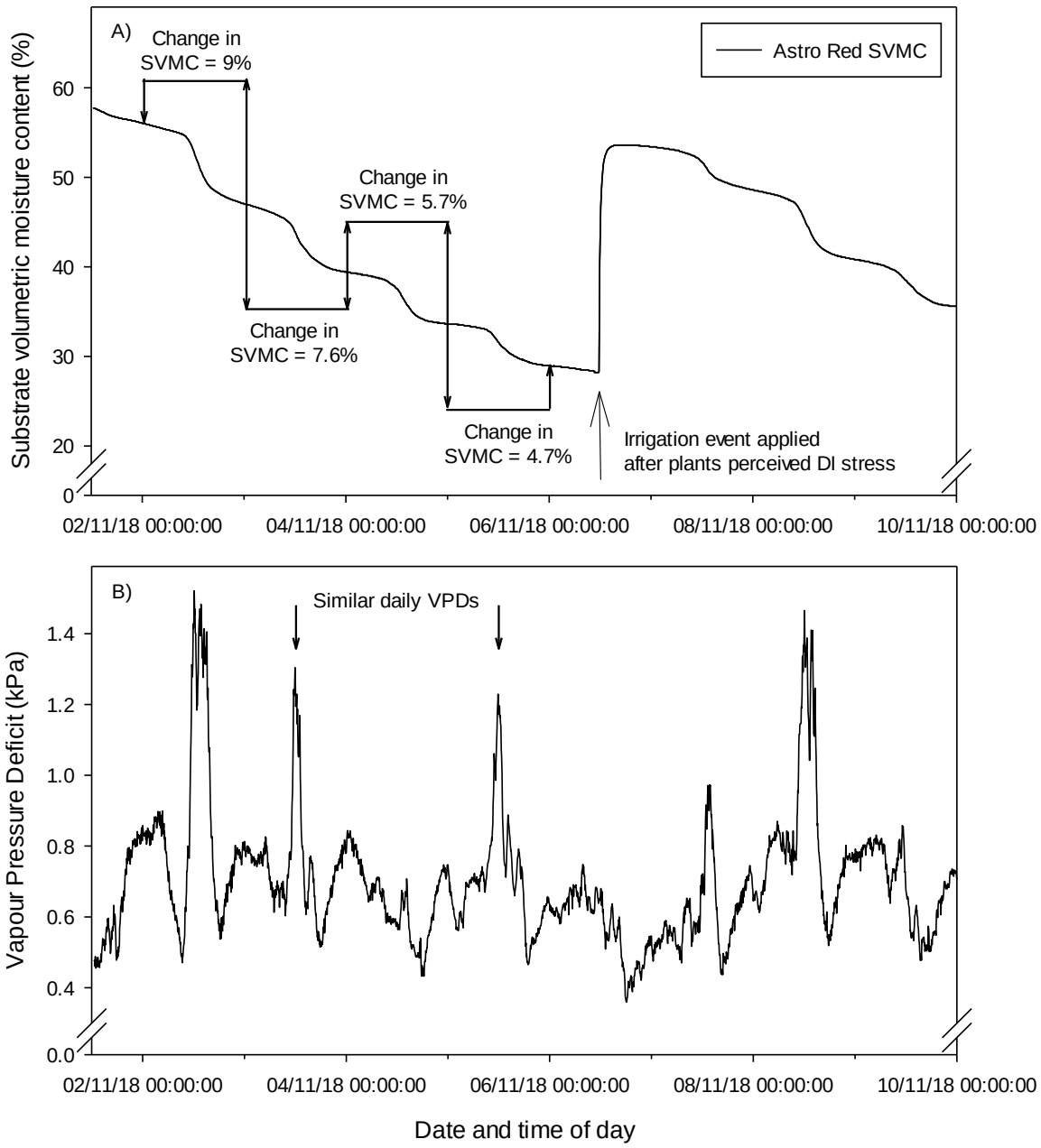

Figure 27 A-B. Changes in A) substrate volumetric moisture content in "Astro Red" plants and B) glasshouse VPD over several days during the 2018 growing season. In A), the percentage daily change in SVMC is given on consecutive days; DI was being applied from 2nd to 6th November 2018.
Source; Else, March 2019

Stem extension

Increases in stem height were tracked and plotted weekly by Neame Lea staff, and compared to upper and lower “target” values of stem heights that are used by growers to inform decisions about the frequency of PGR applications throughout a typical season. A significant slowing of stem extension in “Astro Red” was detected in Weeks 39-40, and again in Weeks 45-46, coinciding with values of SVMC below 30%. Similar results were obtained with “Leona Red” and “Aries Red”. These results confirm those reported by Else *at al.* (2008), namely that a targeted RDI treatment over the period of rapid stem extension effectively reduced stem extension so that plants were within the height specification at simulated market date. Taken together, results from the “dry growing work in 2016 and 2017, and from the DI work in 2018 suggest that DI is a reliable non-chemical method of growth control for poinsettia, provided that water deficits are applied judiciously.

Estimating plant water loss

Daily changes in substrate drying

When plants were removed from the benches to identify the SVMC values at which temporary and sustained wilting occurred, measurements of plant water loss over 24 h were used to calculate rates of evapotranspiration (*E*). At the outset in well-watered plants, calculated values of *E* across the three varieties ranged from 65-75 g per 24 h. The potential to use the daily percentage of substrate drying to estimate plant water loss was also tested. The average weight (mass) of well-watered plant-and–pots on 21 September 2018 was *c.* 600 g. Between 21 and 24 September, the average daily decrease in SVMC was c. 12.6%; therefore, the calculated weight loss, or estimated value of *E*, over 24 h was 69-76 g. The potential of this approach to inform growers’ irrigation scheduling decision making is discussed below.

Wireless sensors at Volmary

From the readings recorded by the 30MHz wireless sensors over this first season, there seemed to be serious issues regarding the total number of sensors needed to achieve a reasonable picture of the variation and evenness in moisture in pots across the nursery. Towards the end of the monitoring period it was felt that the variations being seen could in part be related to sensor variation as much as pot moisture variation. In order to test this a study was undertaken over the Christmas period to 'ground-truth' the sensors. Pots were filled to set weight of substrate per pot and then fully saturated and allowed to start to dry back. The results indicated clearly that 4 out of the 6 sensors were very close but two sensors were constantly outliers.

Chemical residue testing

The leaf cuttings were scanned for up to 180 residues. The results of the first scans (as received from cutting suppliers) are illustrated in Table 1. The table the common name for any residues and whether the residue identified relates to an approved EU chemical where possible. As can be seen, there are a number of apparent residues which relate to chemicals not approved or known in the EU or UK. The different colours relate to different cutting suppliers. The names of the suppliers have been withheld for reasons of confidentiality.

Table 1. Showing scanned results of chemical residues of leaf cuttings material from four suppliers Shown as different coloured typeface, August 2018.

Chemical	Level mg/kg	LOD	Generic name	UK Approval
Boscalid	**0.02**	0.01	Fulmar	Yes
Chlorothalonil	**0.64**	0.01	Bravo	Yes
cis-1,2,3,6-Tetrahydrophthalimide	**0.02**	0.01	Not Known	No
Diphenylamine	**0.03**	0.01	Not Known	No
Fenamidone	**1.4**	0.01	Not Known	No
Iprodione	**24**	0.01	Rovral	Yes
Metalaxyl	**0.5**	0.01	Subdue	yes
Trifloxystrobin	**0.02**	0.01	Swift SC	Yes, on cereals
Carbendazim	**4.1**	0.01	Not Known	No
Cyromazine	**0.02**	0.01	Not Known	No
Flonicamid	**0.01**	0.01	Mainman	Yes
Propamcarb	**0.11**	0.01	Proplant	Yes
Thiophanate Methyl	**13**	0.01	Cercobin	Yes
Boscalid	**0.02**	0.01	Fulmar	Yes
Deltamthrin	**0.01**	0.01	Decis	Yes
Diphenylamine	**0.03**	0.01	Not Known	No

Iprodione	**0.05**	0.01	Rovral	Yes
Flonicamid	**0.02**	0.01	Mainman	Yes
Nicotine	**0.01**	0.01	Nicotine	No
Propamcarb	**0.02**	0.01	Proplant	Yes
Pyraclostrobin	**0.02**	0.01	vanguard	Yes, on cereals
Buprofezine	**0.04**	0.01	Not Known	No
Iprodione	**0.03**	0.01	Rovral	Yes
Lambda Cyhalothrin	**2.7**	0.01	Karate	Yes
Paclobutrazol	**0.03**	0.01	Bonzi	Yes
Propiconazole	**0.03**	0.01	Bumper	yes
Pyriproxyfen	**1.2**	0.01	Not Known	No
Nicotine	**0.03**	0.01	Not Known	No
Propamcarb	**3.5**	0.01	Proplant	Yes
Pymetrozine	**0.43**	0.01	Chess	Yes
SpiNosad	**4.5**	0.01	Conserve	Yes
Boscalid	**0.02**	0.01	Fulmar	yes
Chlorothalonil	**0.03**	0.01	Bravo	Yes
Cyprodinil	**0.01**	0.01	Kyack	Yes, on cereals
Fenhexamid	**0.13**	0.01	Teldor	Yes, on berries
Fludioxonil	**0.1**	0.01	medillion	Yes, on seed treatment
Iprodione	**0.02**	0.01	Rovral	Yes
Metalaxyl	**0.05**	0.01	Subdue	Yes
Propiconazole	**0.02**	0.01	Bumper	Yes
Cyromazine	**7.2**	0.01	Not Known	No
Flonicamid	**0.22**	0.01	Mainman	Yes
Propamcarb	**4.5**	0.01	Proplant	Yes
Pyraclostrobin	**0.01**	0.01	Not Known	No
Teflubenzuron	**0.09**	0.01	Not Known	No
Thiacloprid	**0.12**	0.01	Exemptor	Yes

Table 2 shows the results for the test repeated on 21st November for chemical residue on leaf cuttings.

Table 2 Showing scanned results of chemical residues of new leaf cuttings from plants grown during a normal season, the four suppliers are shown as different coloured typeface, 21st November 2018.

Chemical	Level mg/kg	LOD	Generic name	UK Approval
Boscalid	**0.04**	0.01	Fulmar	Yes
Deltamthrin	**0.02**	0.01	Decis	Yes
Pyraclostobin	**0.01**	0.01	vanguard	Yes, on cereals
Boscalid	**2**	0.01	Fulmar	Yes
Pymetrozine	**0.02**	0.01	Chess	Yes
Pyraclostrobin	**0.37**	0.01	Decis	Yes
Pirimicarb	**0.06**	0.01	Proplant	Yes
Chlorothalonil	**0.02**	0.01	Bravo	Yes
Thiacloprid	**0.06**	0.01	Exemptor	Yes

The most important point from the second leaf sampling is that none of the chemical residues found on the original scans appear to have transferred to the newer leaves, suggesting that the residues found were on the leaf surfaces and were not systemically transferable. Also, at the end of the observation, the chemicals recorded were either fungicides or insecticides and interestingly there were no residues of PGR's detected.

Poinsettia nutritional monitoring work.

In the 2018 season, whilst there were some minor drops in specific phosphorous (P) levels, these were quickly corrected by the change in fertigation to meet the plant needs.

Infinity as a variety has always been prone to visual symptoms of remobilisation of nutrients from the lower, older leaves. The newer introductions, e.g. Christmas Feeling etc. show fewer visual symptoms, but they are still remobilising the elements. These, such as P, remain mobile, and are picked up by leaf analysis in the absence of visual clues.

Figure 28. Illustrates the type of lower leaf marking seen when remobilisation of phosphorous occurs, this type of symptom was very limited during 2018.

Figure 28. Lower leaf markings as a result of remobilisation of phosphorous
Source; Bragg August 2018

The levels of P were monitored over 30 samples during the season, these are illustrated in Figure 29. The results indicate there were some dips in leaf tissue P levels, but reporting of such levels by the poinsettia monitoring scheme (since 1998) helps to avoid issues occurring in the plants.

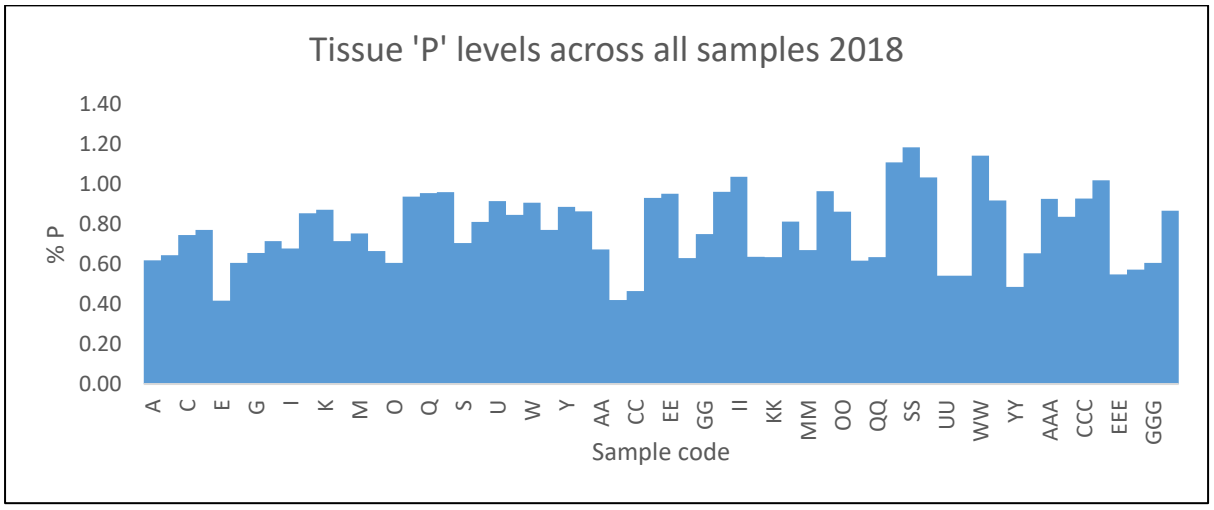

Figure 29. The overall levels of leaf tissue 'P' recorded during the season.

In the 1990s one issue which occurred frequently was the depletion of specific nutrients around the flower initiation period; this could be anytime from the end of August until the end of September and very much reflected the specific climatic conditions and the response group of the cultivars. P levels were often significantly lower in the substrate, falling to less than 10

mg/l rather than the desired range of 30-40 mg/l. In the leaf tissue, levels of P often fell below the 0.5% dry matter level where 0.6-1% dry matter was needed to maintain sufficient P, avoiding remobilisation from older leaves to the apical growth points where flower initiation was taking place.

Discussion and Conclusions

Trial one: variety trial

As stated previously, the objective of the variety trial was to establish which varieties are suitable for cropping across a range of growers locations and facilities. The five highest performing varieties during growing and shelf life stages are shown in Table 3.

Table 3. Comparison of the five highest quality scores at dispatch and end of shelf life phases.

dispatch quality score	End of Shelf Life quality score
Astro Red 6.4	Christmas Beauty 5.5
Christmas Beauty 6.3	Leona Red 5.4
Christmas Sensation	Christmas Sensation 5.3
Blissful Red 6.1	Astro Red 5.2
Mirage Red 6.1	Hera Red 5.1

The varieties Astro Red, Christmas Beauty and Christmas Sensation appeared in both lists. For the growers' assessments the best performer was SKA 159 and followed by Blissful Red and Astro Red. The quality scores for the varieties grown under the water deficit trial achieved higher quality scores at dispatch and had no negative results during the shelf life phase (Aries, Astro Red, and Leona Red).

As was expected there were some differences between growers, plus their different customer specifications.

The plants of all three varieties of the water deficit trial were taller than plants in the variety trial, but just within the specification limit, possibly due to the method of growth control or nursery specification. A repeat of the deficit trial by an alternative grower or the selection of known, shorter varieties for the deficit irrigation trial, such as SKA159 and Christmas Break, may provide more clarity. The success of both Astro Red and Leona Red (shown in the variety trial to be tall varieties), to be grown to 32 cm or below, indicates the effectiveness of deficit irrigation.

Not all varieties satisfied the specification of four or more bracts in the variety trial. Christmas Break was the most disappointing, Astro Red has been shown in both the 2017 and 2018 variety trials to have the highest number of main bracts. Plants of all three varieties in the deficit irrigation trial gave more main bracts and less secondary bracts compared to the same varieties in the variety trial. The nursery specification of 4+1 indicates this is preferable. This

higher number of main bracts on deficit irrigation plants could be due to growth control or nursery specification. A repeat of the deficit trial by an alternative grower or the selection of varieties shown to have fewer main bracts for the deficit irrigation trial such as SKA159 and Christmas Break may provide more clarity.

Unlike the previous year, most varieties continued to grow and improve in quality score during the first few weeks of shelf life in both trials. This could be caused by the slightly later planting of cuttings due to issues obtaining material, and indicates that plants may have benefitted from a few more weeks on the nursery before dispatch, flexibility which is not available to the grower. This is in line with findings noted in the 2017 trial, where the plants from the more northern nursey would have benefitted from an extra week of nursery growth. It should be a high priority for the industry to secure future cutting material on time, especially if sourced from abroad. The date the plant is dispatches is fixed, meaning the grower has to achieve a balancing act to achieve market readiness.

The results indicate that for overall quality Christmas Beauty Princess performed consistently the lowest throughout the assessment period of the variety trial with Moijin and Crunch Red also not scoring above saleable grade. All three varieties where new to the variety trial in 2018. The performance of varieties will assist growers in their selection for the coming season an important financial consideration.

Trial two: deficit irrigation trial

The aim of the DI trial was to demonstrate that poinsettia plant height could be controlled without PGRs by imposing substrate drying at key phases during the growing season. Our results from earlier research funded by DEFRA *and* the AHDB-funded work in 2017 trial imply that DI can be an effective and reliable means of non-chemical growth control. A similar conclusion can be drawn from the current work, even though DI was applied relatively late during the season in 2018. At dispatch, the overall plant quality scores allocated to the DI-treated varieties were similar to those grown on other nurseries which used PGRs throughout the season.

Effective DI control was achieved in 2018 through daily communication between the Neame Lea Production Manager and NIAB EMR Project Lead. Ideally, DI should be imposed during the developmental stage that is least risky in terms of inadvertent effects on leaf and bract quality, and our previous work has shown that the beginning of the period of rapid stem elongation is the optimum time, although it can be applied later in the season as demonstrated here.

Two important decisions when using DI as a non-chemical method of growth control are 1) whether the fall in SVMC after withholding irrigation is sufficient to slow stem extension rate, and 2) when to re-water to avoid potentially damaging effects of prolonged shoot water deficits on leaf and bract quality. In the current work, we have developed systems and approaches to help inform both of these decisions.

Firstly, the accumulated percentage change in SVMC over several days may be a useful tool to help growers to manage the application of DI treatments. The change in the relationship between rate of change of substrate drying and VPD marks the SVMC value at which stress-induced partial stomatal closure is triggered, and at this point the plant is experiencing the root water deficit stress that is needed to limit stem extension. Further work is needed to establish how long DI stress should be imposed after this point is reached to achieve effective height control.

Secondly, real-time access to changes in daily VPD, SVMC and other important parameters via the grower dashboard will help to inform growers' decision making on when to re-water. On one or two occasions, for example, 27th October 2018, the Production Manager chose to irrigate the crops in the afternoon, sooner than advised by the NIAB EMR Team who wished to continue substrate drying throughout the night in order to achieve effective height control. However, the primary aim of the grower was to reduce the risk of inadvertent losses in plant quality due to shoot water deficits developing during periods of high evaporative demand, and the onset of wilting at these times understandably prompted the reaction. The decision to re-water or to leave the crop to dry further is a challenging one and more information is needed to help to guide the growers at these times. The pattern of diurnal changes in VPD could be used to help to inform these decisions.

Due to both trials running in the shelf life room at the same time, only six randomly selected DI-treated plants were shelf-life tested and overall quality scores were at least as high as the other varieties. More detailed and statistically robust research is needed to properly quantify the impact of DI on shelf-life potential and on plant resilience to abiotic and biotic stresses. In previous Defra-funded work, the quality of RDI-treated plants at simulated market date (scored by staff at Staplehurst Nursery) was higher than the commercial crop, and quality during distribution and shelf life testing was also improved, suggesting that judicious application of RDI can improve plant quality and shelf-life potential.

Wireless sensor work

The overall observations from the wireless sensor work are that it is possible to have wireless enabled sensors deployed around a nursery and to receive in real time data from the selected sensors, accessible from a range of mobile devices.

The variation across a capillary water system of pot plants on the floor raises the question of how many sensors would be needed to achieve confidence in the average values being monitored. In terms of using deficit irrigation across such systems, it appears that this type of monitoring would probably not be practically useful. However if the uniformity of irrigation could be significantly improved across such application systems, then it would prove the sensors are able to give real time recordings. There remains the need to do more to 'ground-truth' the sensors employed and the issues surrounding evenness of pot fill using such systems of monitoring do need addressing.

Chemical residue testing

The conclusion was that chemicals applied to mother stock and hence cutting material supplied to growers did not persist to the finished plant stage being supplied to 'retailers'. Importantly there was no evidence of PGR's being carried forward to end users.

However the general consensus was that whilst this was a very useful first indication of monitoring of residues, the exercise should be repeated in 2019 to give further confidence. Also the late application of fungicides and insecticides should be considered in relation to the harvest interval so as to reduce further any possible carry over to shelf life of residues.

Poinsettia nutritional monitoring work.

The conclusion from this work is that if regular substrate and leaf tissue monitoring are undertaken, then nutritional deficiency type symptoms can be avoided and or corrected before any last damage is observed on plants.

Knowledge and Technology Transfer

AHDB Poinsettia Open Day 22nd November, Neame Lea Nursery,

The open day itinerary included;

- A display of plant samples from the four nurseries grown for both trials, the plants were coded for anonymity, assessed by growers for quality prior to shelf life trial.
- The work on deficit irrigation trial at Neame Lea
- The work on moisture level monitoring using wireless sensors at Volmary including a live demonstration by 30MHz
- The poinsettia PGR product evaluation and plant display
- The grower assessments and work on the variety trial and future shelf life objectives
- Initial results of plant residue testing
- A variety plant display from growers

AHDB Poinsettia Open Day 17th January 2019, NCFM Campus University of Lincoln,

The open day itinerary included;

- The final review on the deficit irrigation trial conducted at Neame Lea
- The findings of work carried out on wireless enabled sensors on floor matting at Volmary
- A final resume of PGR work undertaken by ADAS
- The results of residue testing on plant material
- A review of the shelf life study on plants of both trials at NCFM and a display of the plants
- Lighting and other European work
- Presentation on the American poinsettia variety trial
- Presentation on Poinsettia study tour, Latina, Italy.

The well attended grower open day discussions raised issues relating to relevance and feasibility of “dry growing” on non-ebb and flow bench operations and the need for mobile wireless sensors to allow for bench movement within a commercial operation. The discussions also raised the concerned relating to the number of sensors required to provide an accurate overview of the real life commercial scenario and the economics.

The trial results and open days provide growers with informative guidance on varietal selection and growing regimes from a selection of UK nurseries and industry bodies.

Recommended follow-up activities

- Future security of cutting material procurement
- Variety testing both in growing under different agro-climates and irrigation systems should be undertaken
- Further research regarding potential varietal options, especially into Non-red varieties and glitter
- Use the precision irrigation technology developed at NIAB EMR to schedule irrigation automatically to a glasshouse compartment (40,000+ plants)
- Determine the timing and frequency of RDI events needed to control stem height effectively in key varieties
- Implement PI and RDI automatically using the precision irrigation technology
- Quantify the impact of RDI on plant quality, shelf-life potential and stress resilience
- Derive crop co-efficient for three key varieties to enable scaling-up
- Carry out a small-scale experiment on implementing precision irrigation control in plants grown on capillary matting at a commercial nursery
- To determine whether imposing RDI on a commercial scale can deliver added value in terms of plant quality at dispatch, after transport and during shelf-life
- Understand how these approaches can be deployed across nurseries that use capillary matting and/or irrigation. Much work has been done on optimising irrigation scheduling in HNS crops using capillary matting in the past, but PO-specific research is needed

Acknowledgments

The authors would wish to thank the AHDB Horticulture team for funding the project work. The authors wish to express gratitude to the four nursery teams for their support and dedication with growing the crops for both trials and to thank Mr Kitchener for his support and guidance throughout the trials. Acknowledgement for the teams at Bulrush and NIAB EMR for their technical assistance and knowledge and to the technical team at NCFM, University of Lincoln for their work during the shelf life trials. The author's acknowledgment of the use of the Pokon and Chrysal shelf life room at NCFM.

We wish thank all those associated with the organisation of the two open days, and the representatives from industry for their attendance and support of this research, whom we hope will benefit from the findings.

Thank you to Volmary for sourcing the plant material.

Key Staff

Harry Kitchener, HMK Ltd.

Neil Bragg, Bulrush Horticulture Ltd

Wayne Brough, AHDB horticulture

Martin Squire, Pokon Chrysal

Andrew Fuller, Vasile Agache and the team at Neame Lea Nursery

Francis Mizuro, Martin King and the team at Volmary Ltd

Paul Firth and the team at KRN Plants Ltd

Greg Hill, Luke Lloyd and the team at Hill Bros

Mark Else and Mike Davies, NIAB EMR

Chris Bishop, Nicole Le Grys and Technicians, University of Lincoln

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APPENDICES

Appendix one. Variety Trial Growers Information - Volmary

Production:

- Potted date: week 31 1/08/2018
- Pinched date: week 33 14/08/2018
- Spacing first: week 38
- Final spacing: week 42

Growth regulator application:

- C.C.C. 20/08/2018, 2/08/2018

Sprays:

- Mycotal + Addit: 3/08/2018, 16/08/2018, 31/08/2018, 7/09/2018
- Naturalis: 10/08/2018
- Botanigard: 13/09/2018

Temperatures:

- Ambient unit (Week 37 - 14/09/2018) 20.C vent
- Then night temp of 16.C and venting at 20.C all day
- (Week 39 - 24/09/2018) air temp at day and 18 at night and venting at 22.C
- (Week 44) negative diff down 12.C air and 14.C vent and 18.C day and 16.C night with 20.C vent

Feed application:

- 15-7-20: two weeks after potting at 1.4 E.C
- Calcium nitrate applying every other feed to 1.4 E.C
- 10-52-10 for weeks 38-39 1.6 E.C
- 15-3-20 finishing feed from week 40 at 1.8- 2.0 E.C

Week 40

- Naturalis
- Subdue drench on hole house root diseases Pythium/ Phytophthora

Week 41 and 42

- Mycotal with addit

Week 43

- Naturalis

Appendix two. Variety Trial Growers Information - Hills Bros

Production:

- Planted week 30/31 (under fleece for the first 7 days)
- Pinched week 33
- Half Spaced week 35
- Final Spaced week 40

Growth regulator application:

- Week 34 0.5ml Stabilan
- Week 38 0.5ml CC + 0.2ml Bonzi

Feed application:

- Feeding between 1.6 to 1.8 ec (incoming ec 0.5)
- N 200ppm, P 75ppm, K 225ppm.

Pest and Disease:

- Higher levels of Scarid fly this year, the crop was treated twice with Nematodes.
- White Fly levels No higher than usual, control programme followed as Normal (only native glasshouse whitefly identified).
- Higher levels of Thrips present in the crop at planting causing initial grazing issues, but Not persistent.

Information from KRN was not available at time of publication.