Project title:	The Bedding and Pot Plant Centre – new product opportunities for bedding and pot plant growers ***Objective 2****: To evaluate a range of products alone or in combination, to increase the success rate and reduce rooting time in unrooted cuttings.*
Project number:	PO 019a
Project leader:	Dr Jill England, ADAS Boxworth
Report:	Annual report, 31 March 2018
Previous report:	None
Key staff:	Dr Jill England (ADAS), Senior Horticulture Consultant Chloe Whiteside (ADAS), Horticulture Consultant David Talbot (ADAS), Horticulture Consultant
Location of project:	Baginton Nurseries, Coventry, Warwickshire
Industry Representative:	Caroline Shove, Bryants Nurseries Ltd, Water Lane, Bovingdon, Hemel Hempstead, Hertfordshire, HP3 0NA
Date project commenced:	1 April 2017
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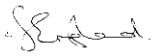
AUTHENTICATION

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 Jill England

Senior Horticulture Consultant

ADAS

Signature  Date 31 March 2018

Chloe Whiteside

Horticulture Consultant

ADAS

Signature  Date 31 March 2018

David Talbot

Horticulture Consultant

ADAS

Signature  Date 31 March 2018

Report authorised by:

Dr Barry Mulholland

Head of Horticulture

ADAS

Signature  Date 31 March 2018

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Grower Summary

Headline

- Rhizopon AA applied as a pre-sticking quick dip treatment improved rooting in both six day old and nine day old Geranium cuttings.
- A water only quick dip treatment alone can improve rooting.
- Serenade applied as a long dip can improve cutting quality.

Background

The Bedding and Pot Plant Centre (BPPC) has been established to address the needs of the industry via a programme of work to trial and demonstrate new product opportunities and practical solutions to problems encountered on nurseries. Knowledge transfer events including trial open days and study tours are also included in the programme.

The work programme is guided by a grower-led Management Group that includes members of the BPOA Technical Committee, and representatives from Baginton Nurseries, Coventry the host nursery for the BPPC, and growers representing both the bedding and pot plant sectors.

This is the Bedding and Pot Plant Centre report for:

***Objective 2**: To evaluate a range of products alone or in combination, to increase the success rate and reduce rooting time in unrooted cuttings.*

Summary

The 2015 AHDB/BPOA US study tour provided the inspiration for this trial, where Dr John Dole (Floriculture Professor, NCSU, North Carolina State University) presented a summary of trials carried out to resolve cutting quality problems that develop during delays in transit or as a result of incorrect storage, including loss of condition, dehydration and disease. In the UK, growers are increasingly taking advantage of the widening range of plant varieties available as un-rooted cuttings from an international market. This trial builds on the US work and incorporates treatments based on grower feedback and products available in the UK. The 2017 trial is a continuation of work carried out in 2016, with the most promising treatments applied both alone and in combination to cuttings of Geranium Green Leaf Series 'Bianca'.

The trial was carried out between March and April 2017. Cuttings (5000) of Geranium Green Leaf Series 'Bianca' were sourced from Newey Roundstone Nursery and dispatched from the mother stock location in Addis Ababa, Ethiopia, in week 8. On arrival at Baginton Nurseries

(28 February 2017, week 9), the packaging was opened, the cuttings agitated to release any ethylene that may have been present, and immediately refrigerated. On 3 March (week 9), 1740 cuttings were removed from the fridge and mixed up together. A sub-sample of 20 cuttings were assessed for quality and stem thickness before the treatments were applied and cuttings stuck (Sticking 1). On 6 March (week 10), a further 1740 cuttings were removed from the fridge, assessed and treated (Sticking 2).

The cuttings were treated with Omex SW7 (wetting agent), Signum (boscalid plus pyraclostrobin), Rhizopon AA tablets (rooting hormone) and Serenade ASO (*Bacillus subtilis* QST 713), either in combination or alone (**Table 1**); Signum and Serenade ASO were applied under an experimental permit. Each treatment was applied as a quick dip (prior to sticking - QD, five second, cut end of cuttings only), a long dip (prior to sticking - LD, 30 minute full submersion) and as an overhead spray (after sticking), with relevant water controls. Once stuck, the cuttings were watered in and rooted under glass (15°C, vented at 21°C, 90% RH) on a heated bench (21°C). A frame was constructed around the bench and the trial was covered with white polythene to maintain humidity. Root development was monitored weekly after sticking.

Table 1. Treatment list used for cuttings, 2017

Treatment	Product*	Application	Dose rate (ml/ L)
1	Omex SW7	Quick dip	2.5
2	Omex SW7	Long dip	2.5
3	Omex SW7	Spray	2.5
4	Signum	Quick dip	6.75
5	Signum	Long dip	6.75
6	Signum	Spray	6.75
7	Serenade ASO	Quick dip	50
8	Serenade ASO	Long dip	50
9	Serenade ASO	Spray	50
10	Omex SW7 + Signum	Quick dip	2.5 + 6.75
11	Omex SW7 + Signum	Long dip	2.5 + 6.75
12	Omex SW7 + Signum	Spray	2.5 + 6.75
13	Omex SW7 + Serenade ASO	Quick dip	2.5 + 50
14	Omex SW7 + Serenade ASO	Long dip	2.5 + 50
15	Omex SW7 + Serenade ASO	Spray	2.5 + 50

16	Rhizopon AA tablets	Quick dip	6 tablets
17	Rhizopon AA tablets	Spray	6 tablets
18	Rhizopon AA tablets + Omex SW7	Quick dip	6 tablets + 2.5
19	Rhizopon AA tablets + Omex SW7	Spray	6 tablets + 2.5
20	Rhizopon AA tablets + Signum	Quick dip	6 tablets + 6.75
21	Rhizopon AA tablets + Signum	Spray	6 tablets + 6.75
22	Rhizopon AA tablets + Serenade ASO	Quick dip	6 tablets + 50
23	Rhizopon AA tablets + Serenade ASO	Spray	6 tablets + 50
24	Rhizopon AA tablets + Omex SW7 + Signum	Quick dip	6 tablets + 2.5 + 6.75
25	Rhizopon AA tablets + Omex SW7 + Signum	Spray	6 tablets + 2.5 + 6.75
26	Water only	Quick dip	N/A
27	Water only	Long dip	N/A
28	Water only	Spray	N/A
29	Untreated control (watered in only)	N/A	N/A

*Products not currently authorised for use on protected ornamentals or for dip application were applied under experimental permit 01098/17.

Cutting and root quality, 7 DAT (days after treatment) are summarised in **Table 2** and below:

Sticking 1

- None of the treatments significantly improved cutting quality.
- Root quality was improved by QD treatments that included Rhizopon, either alone or in combination with a fungicide. Cutting quality was either unchanged or worse than the untreated control.
- Root quality was significantly improved by a water only quick dip compared with the untreated control but not by as much as the Rhizopon treatments.
- Rhizopon AA + Omex SW7 (QD) treatment did not significantly improve root quality by 7 DAT, and cutting quality was poor throughout the trial for this treatment.

Table 2. The effect on plant quality and rooting of pre-sticking treatments applied to six day old and nine day old cuttings of Geranium 'Bianca', assessed seven days after treatment

T	Product	Method	Mean cutting quality (of 15 cuttings)		Mean root quality score (of 15 cuttings)	
			6 day old cuttings	9 day old cuttings	6 day old cuttings	9 day old cuttings
1	Untreated control	-	2.25	2.20	0.20	0.10
2	Water only	Quick dip	2.30	2.50	**0.65**	0.50
3		Long dip	2.50	2.45	0.25	0.20
4		Spray	2.30	2.35	0.20	0.30
5	Omex SW7	Quick dip	2.15	2.35	0.50	0.35
6		Long dip	1.05	1.65	0.20	0.35
7		Spray	2.30	2.30	**0.70**	0.55
8	Signum	Quick dip*	2.20	2.40	0.15	0.20
9		Long dip*	2.10	2.10	0.40	0.25
10		Spray	2.30	2.50	0.30	0.30
11	Serenade ASO	Quick dip*	2.20	2.50	0.25	0.30
12		Long dip*	2.45	**2.70**	0.30	0.20
13		Spray	2.20	2.35	0.35	0.50
14	Omex SW7 + Signum	Quick dip*	2.05	2.15	0.20	0.20
15		Long dip*†	-	-	-	-
16		Spray	2.45	2.50	0.50	**0.65**
17	Omex SW7 + Serenade ASO	Quick dip*	2.50	2.40	0.30	0.20
18		Long dip*	1.00	1.10	0.05	0.25
19		Spray	2.25	2.30	0.55	0.45
20	Rhizopon AA tablets	Quick dip	2.25	1.50	**1.15**	**0.90**
21		Spray	2.40	2.50	0.15	0.40
22	Rhizopon AA tablets + Omex SW7	Quick dip	1.30	1.65	0.25	**0.70**
23		Spray	2.20	2.30	0.50	0.25
24	Rhizopon AA tablets + Signum	Quick dip*	2.05	1.40	**1.30**	0.45
25		Spray	2.15	2.20	0.40	0.25
26	Rhizopon AA tablets + Serenade ASO	Quick dip*	2.25	1.45	**1.25**	0.45
27		Spray	2.25	2.30	0.40	0.25
28	Rhizopon AA tablets + Omex SW7 + Signum	Quick dip*	1.65	1.25	0.40	**0.75**
29		Spray	2.50	2.35	0.40	0.30

Cutting quality was assessed on a scale of 0-4 (0 = dead; 1 = very poor, yellow; 2 = green but no new growth, small; 3 = green with new leaves developing; and 4 = green with new growth). Root quality scores: 0 = dead; 1 = callous formed; 2 = finely rooted in up to 25% of cell; 3 = rooting in 25-50% of cell; 4 = Rooting in 51 = 81% of cell. Values in red are significantly better than untreated control. †Omex SW7 + Serenade ASO (LD) – all plants in this treatment died by 7 DAT. *No label recommendations.

Sticking 2

- As for sticking 1, root quality was improved by QD treatments that included Rhizopon, either alone or in combination with a fungicide. However, cutting quality was worse than the untreated control for these treatments.
- Serenade ASO (LD) was the only treatment to significantly improve cutting quality compared to the untreated control by 7 DAT.

General comments

- Omex SW7 + Signum (LD) treatment caused 100% cutting failure by 7 DAT for both sticking dates, and is not a suitable treatment for Geranium cuttings.

- Signum (LD) left a white residue on the cuttings.
- Bud development was monitored as more buds may be produced by plants under stress, however this did not appear to occur in this trial.

Conclusions

- Compared to the trial carried out in 2016, delivery of the cutting material was not delayed. The cuttings were received, any ethylene that may have been present released, and refrigerated within three days, with minimal deterioration in cutting quality, so treatments were less challenged.
- The results from this trial indicate that simple, cost effective treatments can provide the best results. For example, rooting can be improved significantly simply with a water only quick dip; this was also evident in the trial carried out in 2016. Rhizopon AA appeared to improve rooting in combination with a number of other products, it also significantly improved rooting when applied alone, and cutting quality was better than when it was mixed with other products.
- While a number of treatments improved root quality in this trial, there was little improvement in cutting quality, and some deterioration. Conversely, the Serenade ASO (LD) improved cutting quality in sticking 2, but this was not accompanied by improved root quality.
- Omex SW7 + Signum (LD) is not a suitable treatment for Geranium cuttings and neither product significantly improved cutting quality or rooting when combined with Rhizopon AA compared with Rhizopon alone.

Financial benefits

The benefits of this work are directly linked to reduced waste and quicker throughput of product. Defra Basic Horticultural Statistics indicate that in 2013 £23 million worth of cuttings and young plants were imported into the UK, so the application of this work covers a large amount of plant material. Treatments costs are provided in **Table 3**.

Cuttings that are unusable due to a delay in transit may be replaced by the supplier, which would delay the finished product, or the supplier may not be able to provide replacements. In either case it may be necessary to purchase replacement plants from an alternative supplier. The cost of plants sourced from surplus lists is likely to be 10-20% higher than the grower's sale price to his client, excluding labour, labelling, input or transport costs.

Any gaps in supply can jeopardise client relationships with the potential for penalties to be applied under some contracts. Sourcing plants from an alternative supplier's surplus list increases the risk of supplying inferior quality plants, the plants may be a different variety or quantity and there may be insufficient to fill the gap in the production programme.

Table 3. Treatment costs

Item	£/unit + VAT	Rate	**Cost / treatment (1000 cuttings) SPRAY & QUICK DIP	**Cost / treatment (1000 cuttings) LONG DIP
Geranium 'Bianca'*	0.08-0.1p each plus 0.036p royalty			
Serenade ASO	£124.74 / 10L	10L/ha	24.95ml = £0.31	1000ml = £12.47
Signum	£161.70 / 2.5 kg	1.35kg/ha	3.37g = £0.22	135g = £8.73
Fructose	£4.70 / 100 g	2L/ha	g = £0.24	200g = £9.40
Rhizopon	£21.00 / 20 tablets	0.06kg/ha	3 tablets = £3.15	120 tablets = £126
Omex SW7	£54.76 / L	0.5L / ha	1.25ml = £0.07	50ml = £2.74

*unrooted cuttings. ** excluding labour costs

Potential financial benefits will be achieved through energy savings due to faster root development and reduced crop throughput time e.g. by three days. The cost to increase the air temperature of a one acre glasshouse to 18˚C (outside temperature 5 ˚C) is estimated at £327.25 per day (air heater fuelled by gas oil). Reducing throughput time by three days will provide an estimated energy saving of £975.81. However, any savings will need to be adjusted to include the additional labour costs incurred due to applying dip treatments, for example, which are labour intensive.

Reducing throughput time will provide the added benefit of freeing up glasshouse space for other crops.

Action points

- After reviewing your rooting environment consider using Rhizopon AA, or as a minimum water only, as a pre-sticking quick dip (five seconds) treatment to improving root development in Geranium, particularly when cuttings have been delayed in transit.
- Record sticking rates with and without dipping to allow accurate estimate of labour cost of treatment and effect on sticking rates.

Science Section

Introduction

The Bedding and Pot Plant Centre (BPPC) has been established to address the needs of the industry via a programme of work to trial and demonstrate new product opportunities and practical solutions to problems encountered on nurseries. Knowledge transfer events including trial open days and study tours were also included in the programme.

The work programme is guided by a grower-led Management Group that includes members of the BPOA Technical Committee and representatives from Baginton Nurseries, Coventry the central host nursery for the BPPC. The agreed objectives for the Bedding and Pot Plant Centre, 2017-18 were:

Objective 1: To evaluate a range of plant growth regulators (PGRs) either approved in the UK or in other European Countries for use on bedding and pot plants (spray and drench application).

Objective 2: To evaluate a range of products alone or in combination, to increase the success rate and reduce rooting time when striking un-rooted cuttings. This is a continuation of work carried out in 2016.

Objective 3: To investigate plant nutrition, water quality and environment as possible causes of necrotic spotting and associated symptoms in susceptible *Verbena* varieties. This is a continuation of work carried out in 2016.

Objective 4: To extend the marketing season for coloured varieties of pot-grown Hellebore to include the months prior to the New Year through cool treatments.

Objective 5: To evaluate the shelf life performance of micro-propagated Hellebores produced as pot plants for pre-Christmas marketing.

Objective 6: To evaluate a range of plant growth regulators (PGRs) and fungicides either approved in the UK or in other European countries for spray application on Poinsettia.

This is the Bedding and Pot Plant Centre report for Objective 2.

Background

During the 2015 AHDB/BPOA US study tour, Dr John Dole presented the summary of a project carried out at the North Carolina State University Extension Cooperative (NCSU). The US work was developed to resolve cutting quality problems that developed when material was delayed in transit or stored incorrectly, resulting in a loss of cutting turgidity. Various products

were tested (**Table 4**) that were expected to improve cutting recovery through a number of different processes. Parameters for consideration included:

- There are dual effects of water on cutting quality. Cuttings rapidly lose water post-harvest, resulting in desiccation and defoliation. However, although dry when dispatched, temperature fluctuations and cutting transpiration during transport can cause condensation, providing favourable conditions for fungal and bacterial disease development.
- Whilst ethylene used during stock plant production can promote branching and root development, it can cause chlorosis, defoliation and epinasty in cuttings, resulting in leaf senescence and abscission. The adverse effects of ethylene can be counteracted by application of gibberellin.
- Carbohydrate levels in Geranium cuttings can be affected by nitrogen levels during stock plant production, with increased nitrogen supply resulting in reduced carbohydrate levels in cuttings. There is an interaction between ethylene and carbohydrate levels, as stored Geranium cuttings (with depleted carbohydrate levels) are sensitive to exogenous ethylene, while freshly harvested cuttings do not appear to be similarly affected.

In addition to this, cuttings continue to respire once harvested. To maintain cutting quality, respiration should be reduced as soon as possible after harvest, and this is achieved by reducing the storage temperature (but avoiding chilling/freezing injury). Geranium cuttings can be stored for up to five days at 4˚C without any detrimental effect compared with un-stored cuttings (Faust *et al.,* 2017).

Table 4. Products tested by NCSU, USA and their expected effects

US product	Active ingredient(s)	Expected effect
CapSil (Aquatrols) -	Blend of polyether-polymethylsiloxanecopolymer and non-ionic surfactant	Wetting agent, improves uptake of water
Pageant (BASF)	Boscalid plus pyraclostrobin	Fungicide - disease control
Daconil (Syngenta) -	Chlorothalonil	Fungicide - disease control
Plant hormones	K-IBA	IBA products promote rooting
Configure	Benxyladenine (cytokinin)	Promotes cell division and axillary bud development.
Sucrose, glucose, fructose	Carbohydrates	Restores depleted carbohydrates. Low carbohydrates limit rooting in Geranium.
Urea solution	Nitrogen	Increased nitrogen in feed results in reduced carbohydrate levels in cuttings for Geranium.
Fascination (Valent)	Gibberellin	Counteracts the effect of exogenous ethylene
Distilled water	Water	Restores turgidity

In the recent USA work, the most promising treatments for Geranium were the 30 minute dip in the plant growth regulator K-IBA (400ppm) plus either fructose or Pageant. For most treatments, water plus CapSil dipping into solutions had a positive effect on rooting even when applied to un-stored cuttings (Personal communication, 2016).

In the UK, growers are increasingly taking advantage of the growing range of plant species available as unrooted cuttings. However, plant material can suffer from loss of turgor, dehydration and potentially disease in transit from suppliers. Treatments to counteract these effects would be beneficial. Growers are also keen to find treatments that reduce rooting time and increase throughput. In spring 2016, work was carried out at the Bedding and Pot Plant Centre, drawing on the work carried out by John Dole, and using cuttings of Geranium Green Leaf Series 'Bianca'. The cuttings, supplied from Ethiopia, were six days in transit. Treatments were Omex SW7 (silicon-based wetter), Signum (fungicide boscalid plus pyraclostrobin); Fructose; Rhizopon AA tablets (IBA, 3-Indolebuteric acid, plant rooting hormone); Serenade A.S.O (*Bacillus subtilis* QST 713) and untreated controls (including water only applied as dips and sprays). Cuttings were subjected to a quick dip (five seconds, cut end only), long dip (30 minute total immersion) and spray application in two batches, either one (T1) or five days (T2) after delivery.

Preliminary results from the first assessment of root development and plant quality, 11 and 14 days after treatment (Application 1 and Application 2 respectively) indicated that rooting was advanced by some of the treatments. For Application 1, the most promising treatments in terms of root development were the Rhizopon (quick dip), Omex (long dip) and Serenade ASO (long dip); however, whilst the quality scores for the majority of treatments were generally similar to the control, cutting quality was poor for Rhizopon (long and quick dips) and Signum (long dip) at this point. For Application 2, Signum (quick dip), Serenade ASO (long dip) and Omex (quick and long dips) were the most promising treatments as far as the root development was concerned; the quality of Rhizopon (long and quick dips) was significantly worse than the control. Other than for Rhizopon, root development and plant quality scores were lower for spray application rather than dips (long and quick) for both treatment dates.

For the 2017 trial, the most promising treatments were applied both alone and in combination to cuttings of Geranium Green Leaf Series 'Bianca', using the same application methods as in 2016.

Project objectives

Objective: To evaluate a range of products alone or in combination, to increase the success rate and reduce rooting time when striking unrooted cuttings.

Specific objectives:

Objective1. To evaluate fungicide (Signum, Serenade ASO), wetter (silicon-based non-ionic wetter, Omex SW7) and rooting hormone (Rhizopon) products, alone or in combination to increase cutting success rate and reduce rooting time when striking un-rooted cuttings.

Objective 2. To evaluate application method (quick dip, long dip and spray) of a range of products to increase cutting success rate and reduce rooting time when striking un-rooted cuttings.

Objective 3. To carry out a financial impact assessment for the most promising treatments.

Methods and materials

Site and crop production details

The trial was carried out between March and April 2017. Cuttings (5000) of Geranium Green Leaf Series 'Bianca' were sourced from Newey Roundstone Nursery and dispatched from the mother stock location in Addis Ababa, Ethiopia, in week 8. The cuttings arrived at Baginton Nurseries in small polythene bags (100 cuttings per bag) within a cardboard box on 28 February (week 9), having been in transit for three days. The packaging was opened and cuttings agitated to release any ethylene that may have built up during transit, and were immediately refrigerated. On 3 March (week 9), 1740 cuttings were removed from the fridge and mixed together. A sub-sample of 20 cuttings were assessed for quality and stem thickness before the treatments (**Table 5**) were applied and cuttings stuck (Sticking 1). On 6 March (week 10), a further 1740 cuttings were removed from the fridge and treated, following the same assessment and treatment process (Sticking 2).

Table 5. Treatment list used for cuttings, 2017

Treatment	Product*	Application	Dose rate (ml/ L)
1	Omex SW7	Quick dip	2.5
2	Omex SW7	Long dip	2.5
3	Omex SW7	Spray	2.5
4	Signum	Quick dip	6.75
5	Signum	Long dip	6.75
6	Signum	Spray	6.75

7	Serenade ASO	Quick dip	50
8	Serenade ASO	Long dip	50
9	Serenade ASO	Spray	50
10	Omex SW7 + Signum	Quick dip	2.5 + 6.75
11	Omex SW7 + Signum	Long dip	2.5 + 6.75
12	Omex SW7 + Signum	Spray	2.5 + 6.75
13	Omex SW7 + Serenade ASO	Quick dip	2.5 + 50
14	Omex SW7 + Serenade ASO	Long dip	2.5 + 50
15	Omex SW7 + Serenade ASO	Spray	2.5 + 50
16	Rhizopon AA tablets	Quick dip	6 tablets
17	Rhizopon AA tablets	Spray	6 tablets
18	Rhizopon AA tablets + Omex SW7	Quick dip	6 tablets + 2.5
19	Rhizopon AA tablets + Omex SW7	Spray	6 tablets + 2.5
20	Rhizopon AA tablets + Signum	Quick dip	6 tablets + 6.75
21	Rhizopon AA tablets + Signum	Spray	6 tablets + 6.75
22	Rhizopon AA tablets + Serenade ASO	Quick dip	6 tablets + 50
23	Rhizopon AA tablets + Serenade ASO	Spray	6 tablets + 50
24	Rhizopon AA tablets + Omex SW7 + Signum	Quick dip	6 tablets + 2.5 + 6.75
25	Rhizopon AA tablets + Omex SW7 + Signum	Spray	6 tablets + 2.5 + 6.75
26	Water only	Quick dip	N/A
27	Water only	Long dip	N/A
28	Water only	Spray	N/A
29	Untreated control (watered in only)	N/A	N/A

Products not currently authorised for use on protected ornamentals or for dip application were applied under experimental permit 01098/17.

Each plot consisted of half of a 72-cell plug tray (Pöpplemann, cell – 3.6 x 3.4cm, 41ml cell volume). 15 cuttings were stuck into each tray; 15 cells were filled with growing medium, with the remaining cells left empty. Cells were filled with growing medium (Peat + 20% perlite propagation medium (Tref), pH 5.8-6.2) and watered in before the cuttings were stuck.

Each treatment was applied as an overhead spray (S), a five second quick dip (QD) and a 30 minute long dip (LD). For the spray treatments, cuttings were stuck into the trays, and the treatments were sprayed overhead using a knapsack sprayer and single nozzle lance with an 02f110 nozzle, at a rate of 200L/ha. For the dip treatments, two 1L solutions were made up, one for the QD and one for the LD. For the QD, the bases of the cuttings only were agitated in the solution for five seconds (five cuttings were treated at a time) before being stuck into the growing medium. For the LD, cuttings for all replicate trays (60 cuttings in total) were fully submerged in the 1L solution for 30 minutes, before being removed and stuck into the growing medium. There were four controls: untreated control (cuttings were watered in only), and water only sprays, quick dips and long dip control treatments. Once the treatments had been applied, the trays of cuttings were placed on a heated bench (21°C) within the propagation house (heated to 15°C, vented at 21°C, 90% relative humidity) and once the cuttings had dried, they were watered in. A frame was constructed around the bench and the trial was covered with white polythene. Temperature and humidity was monitored throughout the trial using Tinytag data loggers.

The trial was monitored for pests and disease throughout, and treated once with Amistar (1ml/L) on 31 March to control *Botrytis*.

Trial design and statistical analysis

For each sticking date, treatments were arranged in a fully randomised plot design with 29 treatments (product x application method), with four replicate blocks and a total of 1740 cuttings per sticking date (60 per treatment). Each plot consisted of half of a 72-cell plug tray (Pöpplemann, cell – 3.6 x 3.4cm, 41ml cell volume). 15 cuttings were stuck into each tray; 15 cells were filled with growing medium, with the remaining cells left empty.

Results were examined by ANOVA with use of Duncan's multiple range test to separate treatments.

Assessments

The trial was monitored for root development and growth of foliage and assessed approximately every seven days from sticking, until 4 April (**Table 6**). The trial was assessed for cutting quality and root quality from a sub-sample of five cuttings per plot, the total number with buds and the total number that had died, per plot. Assessments were carried out as outlined in **Table 7**, **Table 8**, **Table 9** and **Figure 1**.

Table 6. Assessment times for both sticking dates

Date	Action
Week 8	Cuttings dispatched
28 Feb (wk 9)	Cuttings arrived
03 Mar (wk 9)	Sticking 1 set up
06 Mar (wk 10)	Sticking 2 set up
10 Mar (wk 10)	1st assessment – Sticking 1 (7 DAT*)
13 Mar (wk 11)	1st assessment – Sticking 2 (7 DAT)
16 Mar (wk 11)	2nd assessment – Sticking 1 (13 DAT)
21 Mar (wk 12)	2nd assessment – Sticking 2 (15 DAT)
24 Mar (wk 12)	3rd assessment – Sticking 1 (21 DAT)
28 Mar (wk 13)	3rd assessment – Sticking 2 (22 DAT)
31 Mar (wk 13)	4th assessment – Sticking 1 (28 DAT)
04 Apr (wk 14)	4th assessment – Sticking 1 (29 DAT)

*DAT = days after treatment

Table 7. Pre-sticking quality assessment scores

Score	Definition
0	Dead
1	Very poor quality
2	Poor quality
3	Good quality, some damage visible
4	Very good quality, very little damage
5	Excellent quality, no damage visible

Table 8. Cutting quality assessment scores

Score	Definition
0	Dead
1	Very poor, yellow
2	Green but no new growth, small
3	Green with new leaves developing
4	Green with new growth

Figure 1. Plant quality scores; l-r, 0 = Dead; 1 = Very poor, pale, no new growth; 2 = Green but no new growth, small; 3 = Green with new leaves developing; 4 = Green with new growth

Table 9. Root assessment scores

Score	Definition
0	No change/dead
1	Callus formed
2	Finely rooted in up to 25% of cell
3	Rooting in 25 - 50% of cell
4	Rooting in 51 - 85% of cell
5	Fully rooted and ready for transplanting

Results

Pre-sticking

On arrival at Bagintons, the cuttings were healthy and green, with no signs of wilting. They were refrigerated for three days, and a sub-sample was assessed for quality and stem thickness prior to sticking on 3 March. The average quality score for the first batch of cuttings (Sticking 1) was 3.9 - very good quality, with minimal damage. The average stem thickness was 6mm.

The second batch of cuttings (Sticking 2) was assessed just prior to sticking on 6 March, after a further three days cool storage. The cuttings were still green and healthy, although there were early signs of wilting (**Figure 2**). However, there was no discolouration or yellowing to the leaves. The average quality score for the second batch of cuttings was 3.85 and the average stem thickness was 6mm.

Figure 2. Geranium cuttings prior to sticking on 6 March 2017.

Cutting quality - sticking 1

It was observed that the cuttings treated with Omex SW7 (LD, long dip) had brighter green foliage immediately after treatment compared with the other treatments and the untreated control, and the cuttings also appeared more turgid (**Figure 3**).

Figure 3. Sticking 1: untreated (left) and Omex SW7, LD (right) treatments directly after application. LD = long dip.

The first assessment was completed seven days after treatment (DAT) and all cuttings in the Omex SW7 + Signum (LD) plots had died, therefore these trays were removed from the trial. In terms of cutting quality, none of the treatments had significantly improved quality 7 DAT compared to the untreated control. However, quality was significantly reduced ($p < .001$) in a number of treatments with Omex SW7: Rhizopon AA + Omex SW7 + Signum (QD, quick dip), Rhizopon AA + Omex SW7 (QD), Omex SW7 (LD) and Omex SW7 + Serenade (LD) compared to the untreated control.

At the second assessment 13 DAT, cutting quality had not significantly improved in any of the treatments compared to the untreated control. Quality was significantly reduced in the treatments that had shown poorer quality at the 7 DAT assessment, compared with all control treatments. In addition, cutting quality was significantly poorer than the untreated control (but not the QD control) ($p < .001$) in three additional treatments: Rhizopon AA + Signum (QD), Signum (S, spray) and Rhizopon AA + Serenade ASO (QD).

By the third assessment, 21 DAT, plant quality was significantly poorer than the untreated control in only the Rhizopon AA + Omex SW7 (QD) and Rhizopon AA + Omex SW7 + Signum (QD) treatments. At the final assessment, 28 DAT, plant quality was significantly poorer than the untreated control only in the Rhizopon AA + Omex SW7 (QD) treatment (**Figure 4**); plant quality was similar to the untreated control in all other treatments.

Figure 4. Sticking 1: untreated (left) and Rhizopon AA + Omex SW7, QD (right) 28DAT (31 March 2017). QD = quick dip.

Cuttings failed in a number of treatments. Significantly more cuttings died in the Rhizopon AA + Omex SW7 + Signum (QD) treatment (average 4.25 dead cuttings/15 cuttings per tray) and the Rhizopon AA + Omex SW7 (QD) treatment (average 11.25 dead cuttings/15 cuttings per

tray) than all control treatments by 21 DAT. All cuttings treated with Omex SW7 + Signum (LD) had died by 7 DAT, therefore these trays were removed from the trial, and the results were not included with the statistical analysis.

Cutting quality - sticking 2

As with Sticking 1, the cuttings treated with Omex SW7 (LD) had greener, brighter foliage immediately after treatment compared with the other treatments and the untreated control. A small amount of residue was noted on the foliage of cuttings treated with Signum (LD). By 7 DAT, all cuttings in the Omex SW7 + Signum (LD) plots had died, as with Sticking 1, and these trays were removed from the trial.

In terms of cutting quality, the Serenade ASO (LD) treatment significantly improved quality ($p<.001$) compared with the untreated control, but not the QD, LD or S controls (7 DAT). Quality was significantly reduced in a number of treatments (**Figure 5**), with the lowest quality score in the Omex SW7 + Serenade ASO (LD) treatment (score of 1.1 compared to 2.2 for the untreated control).

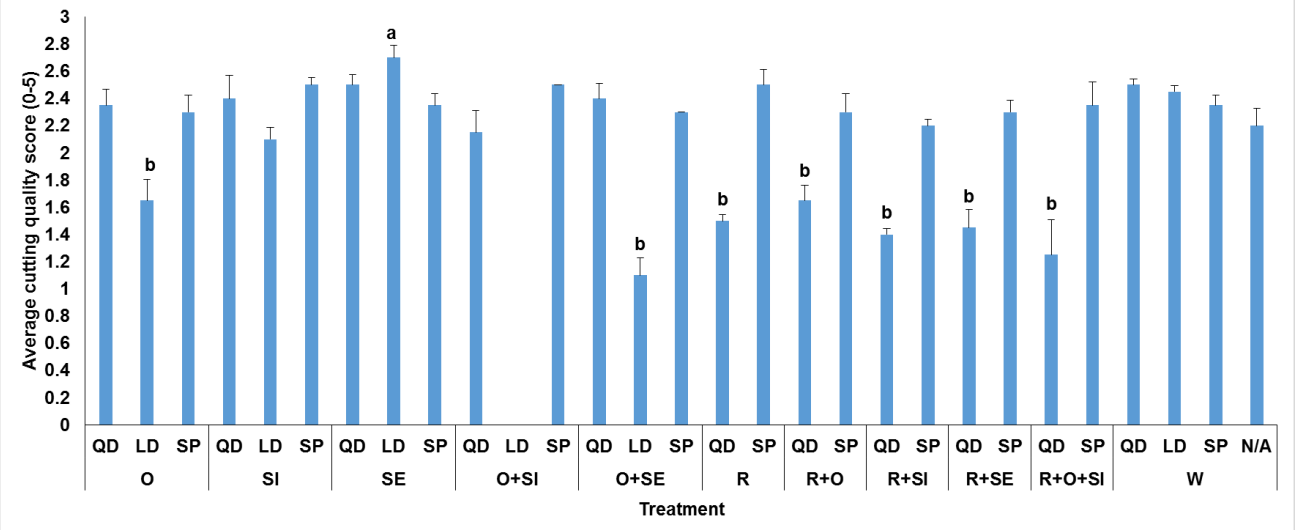

Figure 5. Average cutting quality scores, sticking 2, 7 DAT (13 March 2017)

Assessed on a scale of 0-4 (0 = dead; 1 = very poor, yellow; 2 = green but no new growth, small; 3 = green with new leaves developing; and 4 = green with new growth). O = Omex SW7; SI = Signum; SE = Serenade ASO; R = Rhizopon AA; W = water. QD = quick dip; LD = long dip; SP = spray. a = sig better than untreated control; b = significantly worse than untreated control.

Plant quality improved over time in some of the treatments. At the final assessment 29 DAT (4 April 2017), plant quality was significantly better in the Omex SW7 (spray) treatment than the untreated control (scores of 3.85 and 3.2 respectively) (**Figure 6**). Quality was significantly reduced in the Rhizopon AA + Omex SW7 + Signum (QD) treatment (score of 2.6).

Figure 6. Sticking 2: untreated control (left) and Omex SW7, spray (right) 29DAT (4 April 2017).

The number of cuttings that died (**Figure 7**) was significantly greater in the Rhizopon AA + Signum (QD) treatment (average 3.5 cutting dead/15 cuttings per tray), Rhizopon AA + Omex SW7 + Signum (QD) treatment (average 5 cuttings dead/15 cuttings per tray), Rhizopon AA (QD) treatment (average 5.5 cuttings dead/15 cuttings per tray), Rhizopon AA + Serenade ASO (QD) treatment (average 6.25 cuttings dead/15 cuttings per tray) and the Rhizopon AA + Omex SW7 (QD) treatment (average 7 cuttings dead/15 cuttings per tray) than in all control treatments. All cuttings treated with Omex SW7 + Signum (LD) died by 7 DAT, therefore these trays were removed from the trial, and were not included with the statistical analysis.

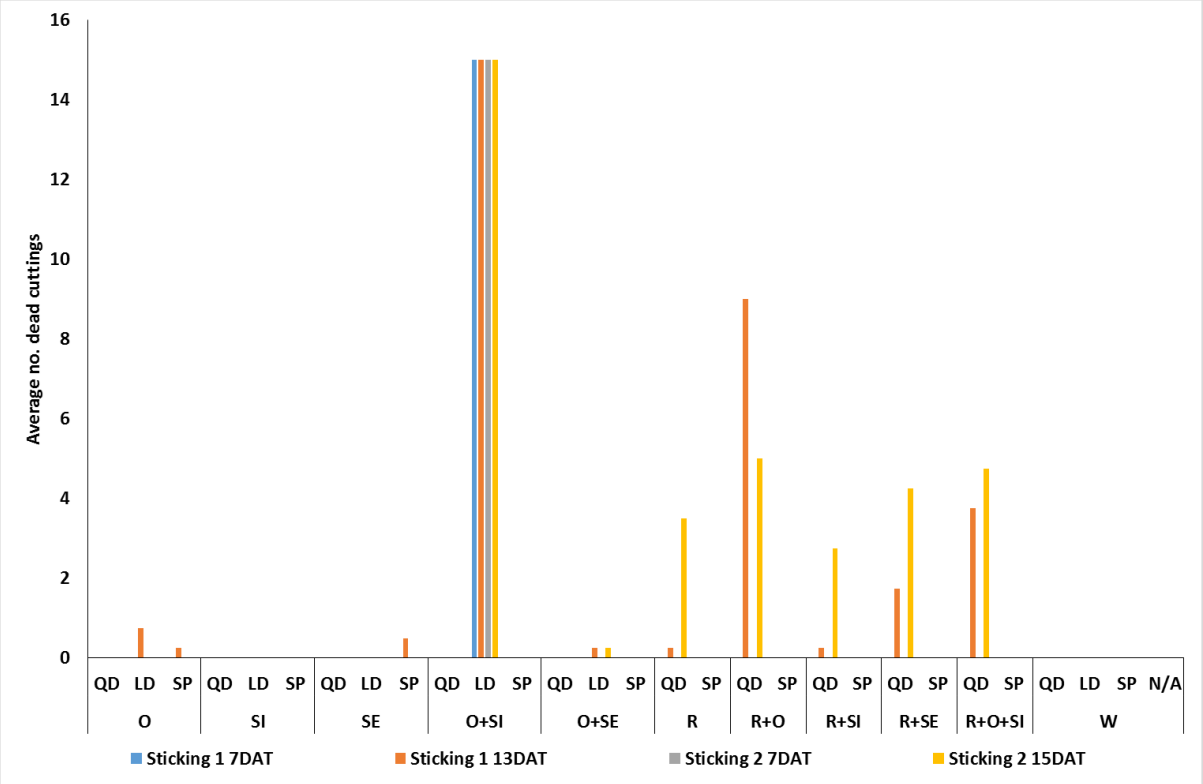

Figure 7. Average number of dead cuttings, sticking 1 (7 and13 DAT) and sticking 2, 7 and 15 DAT. O = Omex SW7; SI = Signum; SE = Serenade ASO; R = Rhizopon AA; W = water. QD = quick dip; LD = long dip; SP = spray. a = sig better than untreated control.

Root quality - sticking 1

As with cutting quality, the differences in root quality between treatments were more noticeable in the first 13 days of the trial. At the first assessment, 7 DAT, rooting was significantly improved ($p < .001$) in cuttings treated with Rhizopon AA (QD), Rhizopon AA + Serenade ASO (QD) and Rhizopon AA + Signum (QD) than all control treatments (**Figure 8**). In addition, rooting was significantly better in the water control (QD) and Omex SW7 (S) treatments than the untreated control. No treatments were significantly worse than the untreated control.

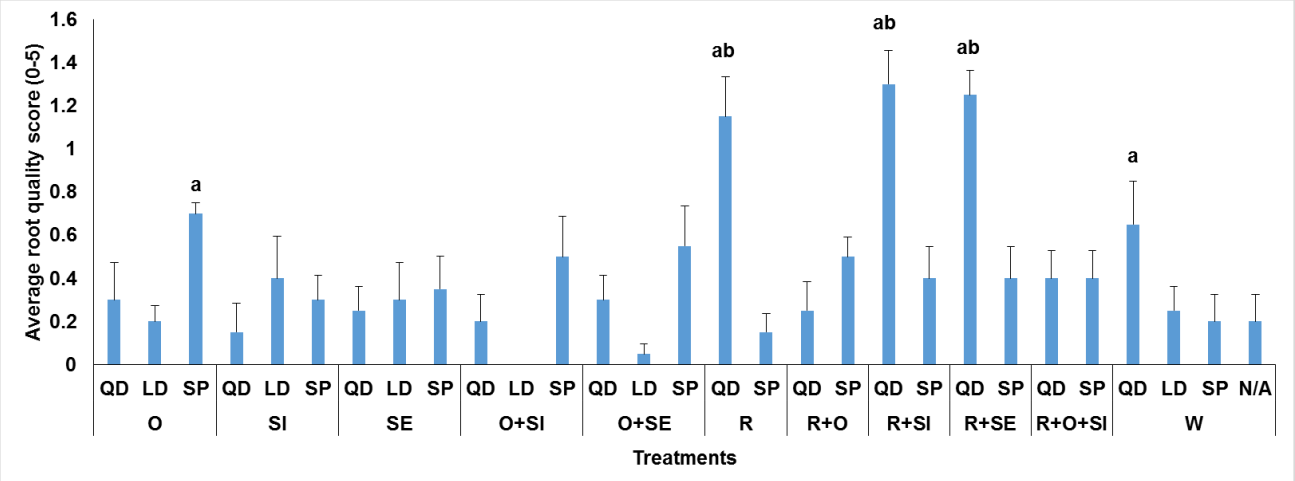

Figure 8. Average root quality scores, sticking 1, 7 DAT (10 March 2017)

Root quality scores: 0 = dead; 1 = callous formed; 2 = finely rooted in up to 25% of cell; 3 = rooting in 25-50% of cell; 4 = Rooting in 51 = 81% of cell. O = Omex SW7; SI = Signum; SE = Serenade ASO; R = Rhizopon AA; W = water. QD = quick dip; LD = long dip; SP = spray. a = sig. diff. to untreated control; b = significantly different to QD control.

By 13 DAT, root quality was no longer significantly improved by the water (QD) or Omex SW7 (S) treatments compared with the untreated control. However, root quality was significantly improved by the Rhizopon AA + Omex SW7 + Signum (QD) in addition to the Rhizopon AA (QD), Rhizopon AA + Serenade ASO (QD) and Rhizopon AA + Signum (QD) compared with all control treatments (**Figure 9**). Root quality was significantly worse compared to the untreated control in the Rhizopon AA + Omex SW7 (QD) treatment.

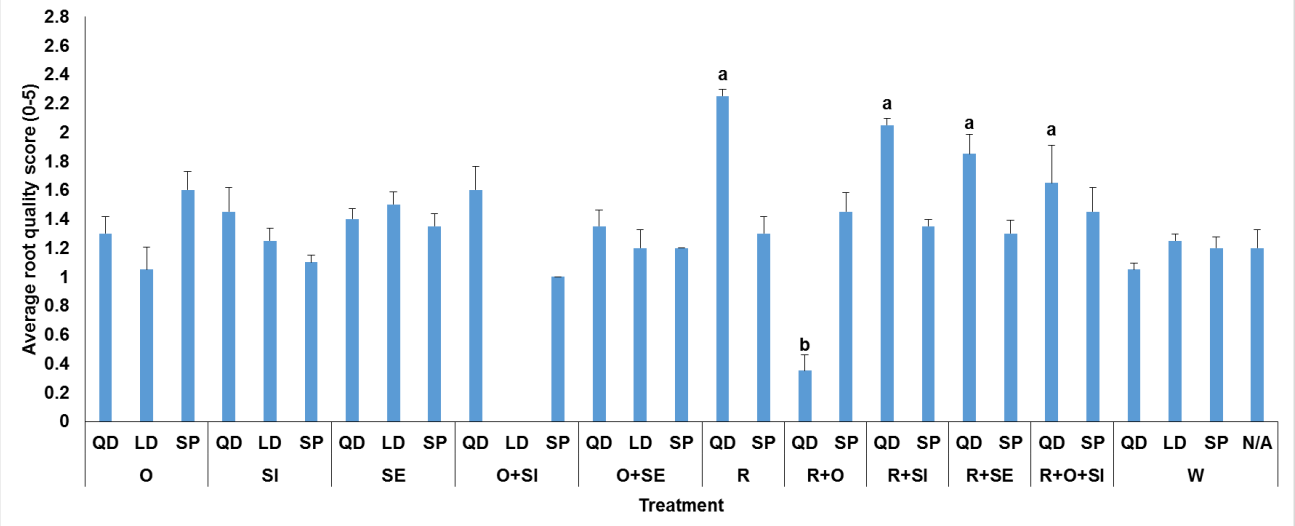

Figure 9. Average root quality scores, sticking 1, 13 DAT (16 March 2017)

Root quality scores: 0 = dead; 1 = callous formed; 2 = finely rooted in up to 25% of cell; 3 = rooting in 25-50% of cell; 4 = Rooting in 51 = 81% of cell. O = Omex SW7; SI = Signum; SE = Serenade ASO; R = Rhizopon AA; W = water. QD = quick dip; LD = long dip; SP = spray. a = sig better than untreated control; b = significantly worse than untreated control.

Root quality scores ranged between 2.25 (finely rooted in 25-50% of the cell; Omex SW7 + Signum, QD; Rhizopon AA, QD; and Rhizopon AA + Signum, QD treatments) and 1.4 (Rhizopon AA + Omex SW7, QD). Root quality of the untreated control was 2.0 (finely rooted in up to 25% of the cell).

Root quality - sticking 2

As with cutting quality, the differences in root quality between treatments were more noticeable earlier in the trial. At the first assessment 7 DAT, root quality was significantly improved compared with all control treatments ($p = 0.006$) in cuttings treated with Omex SW7 + Signum (spray), Rhizopon AA + Omex SW7 (QD), Rhizopon AA + Omex SW7 + Signum (QD) and Rhizopon AA (QD). No treatments were significantly worse than the control.

At 15 DAT there were no significant differences between treatments.

At the third assessment, 22 DAT, root quality was significantly improved by the Rhizopon AA + Omex SW7 + Signum (QD) treatment than all control treatments. Root quality was significantly greater than the untreated control in the Omex SW7 (spray), Omex SW7 + Signum (QD) and Rhizopon AA + Omex SW7 + Signum (QD) treatments.

At the final assessment, 29 DAT, only one treatment had significantly greater root quality than the untreated control; Rhizopon AA + Serenade ASO (QD) scored 2.5 compared with 2.0. No treatments were significantly worse than the control (**Figure 10**).

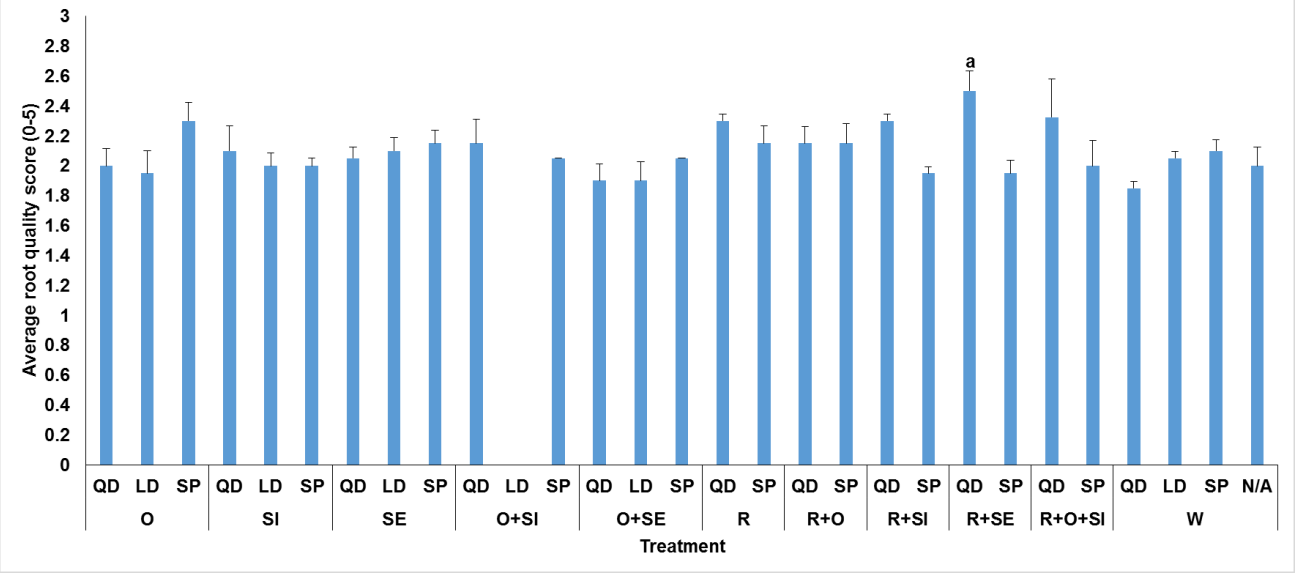

Figure 10. Average root quality scores, sticking 2, 29 DAT (4 April 2017)

Root quality scores: 0 = dead; 1 = callous formed; 2 = finely rooted in up to 25% of cell; 3 = rooting in 25-50% of cell; 4 = Rooting in 51 = 81% of cell. O = Omex SW7; SI = Signum; SE = Serenade ASO; R = Rhizopon AA; W = water. QD = quick dip; LD = long dip; SP = spray. a = sig better than untreated control.

Bud development

Sticking 1

The number of cuttings that developed buds was monitored throughout the trial. At the final assessment 28 DAT, cuttings treated with Rhizopon AA + Omex SW7 (QD) had significantly fewer buds than the untreated control ($p < .001$).

Sticking 2

At the final assessment 29 DAT, cuttings treated with Signum (spray) had significantly more buds than the untreated control ($p < .001$). No treatments had significantly fewer buds than the untreated control.

Discussion

Sticking 1

- In sticking 1, none of the treatments significantly improved cutting quality over the course of the trial.
- By 7 DAT root quality was significantly improved by a water only quick dip compared with the untreated control.
- Root quality was significantly improved by QD treatments that included Rhizopon, either alone or in combination with a fungicide by 13 DAT; however the addition of Omex SW7 (wetter) to Rhizopon appeared to have a negative effect on cutting quality.
- The quality of cuttings treated with Rhizopon AA + Omex SW7 (QD) was poor throughout the trial. By the final assessment, 28 DAT, this was the only treatment with significantly worse root quality than the control, and the majority of the cuttings had failed.
- Although Rhizopon AA + Omex SW7 + Signum (QD), Rhizopon AA + Serenade ASO (QD) and Rhizopon AA + Signum (QD) significantly improved rooting 13 DAT, cutting quality was significantly worse in these treatments.
- Significantly more cuttings failed in the Rhizopon AA + Omex SW7 + Signum (QD), Rhizopon AA + Omex SW7 (QD) and Omex SW7 + Signum (LD) treatments than all control treatments by the end of the trial.

Sticking 2

- At the final assessment, 29 DAT, Rhizopon AA + Serenade ASO (QD) had significantly improved rooting. However, cutting quality was reduced in this treatment.
- Root quality was significantly improved by three QD treatments that included Rhizopon, either alone or in combination with a fungicide by 7 DAT, and the Omex SW7 + Signum (S) treatment.
- Cutting quality was significantly improved by the Serenade ASO (LD) treatment by 7 DAT; no other treatments significantly improved cutting quality compared with the untreated control.
- Cutting quality was significantly worse than the untreated control throughout the trial in the Rhizopon AA + Omex SW7 + Signum (QD) treatment.
- Root quality was not reduced in any of the treatments throughout the trial, compared with the untreated control.
- A number of cuttings died in the QD treatments containing Rhizopon AA either alone, or in combination with Omex SW7, Signum and Serenade ASO.

Overall

- Omex SW7 + Signum (LD) treatment caused 100% cutting failure by 7 DAT for both sticking dates, and is not a suitable treatment for Geranium cuttings. Omex SW7 generally gave poorer results where it was added to treatments.
- For both sticking 1 and 2, Omex SW7 + Signum (LD), Rhizopon AA + Omex SW7 + Signum (QD), Rhizopon AA + Omex SW7 (QD), Rhizopon AA + Signum (QD) and Rhizopon AA (QD) treatments significantly worsened quality in >50% of assessments.
- Signum (LD) left a white residue on the cuttings.
- Bud development was monitored as more buds may be produced by plants under stress, however this did not appear to occur in this trial.

Conclusions

- The cuttings used in this trial were in transit for three days, in 2016 however, the cuttings were in transit for six days before receipt, so the treatments were more challenged.
- The results from this trial indicate that simple, cost effective treatments can provide the best results. For example, rooting can be improved significantly simply with a water only quick dip; this was also evident in the trial carried out in 2016. Similarly, while

Rhizopon AA appeared to improve rooting in combination with a number of other products, it also significantly improved rooting when applied alone and cutting quality was better than when it was mixed with other products.

- While a number of treatments improved root quality in this trial, there was little improvement in cutting quality, and some deterioration. Conversely, the Serenade ASO (LD) improved cutting quality in sticking 2, but was not accompanied by improved root quality.
- Omex SW7 + Signum (LD) is not a suitable treatment for Geranium cuttings.

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Appendix 1. To improve cutting success.

Appendix 1.1 Glasshouse temperature and humidity

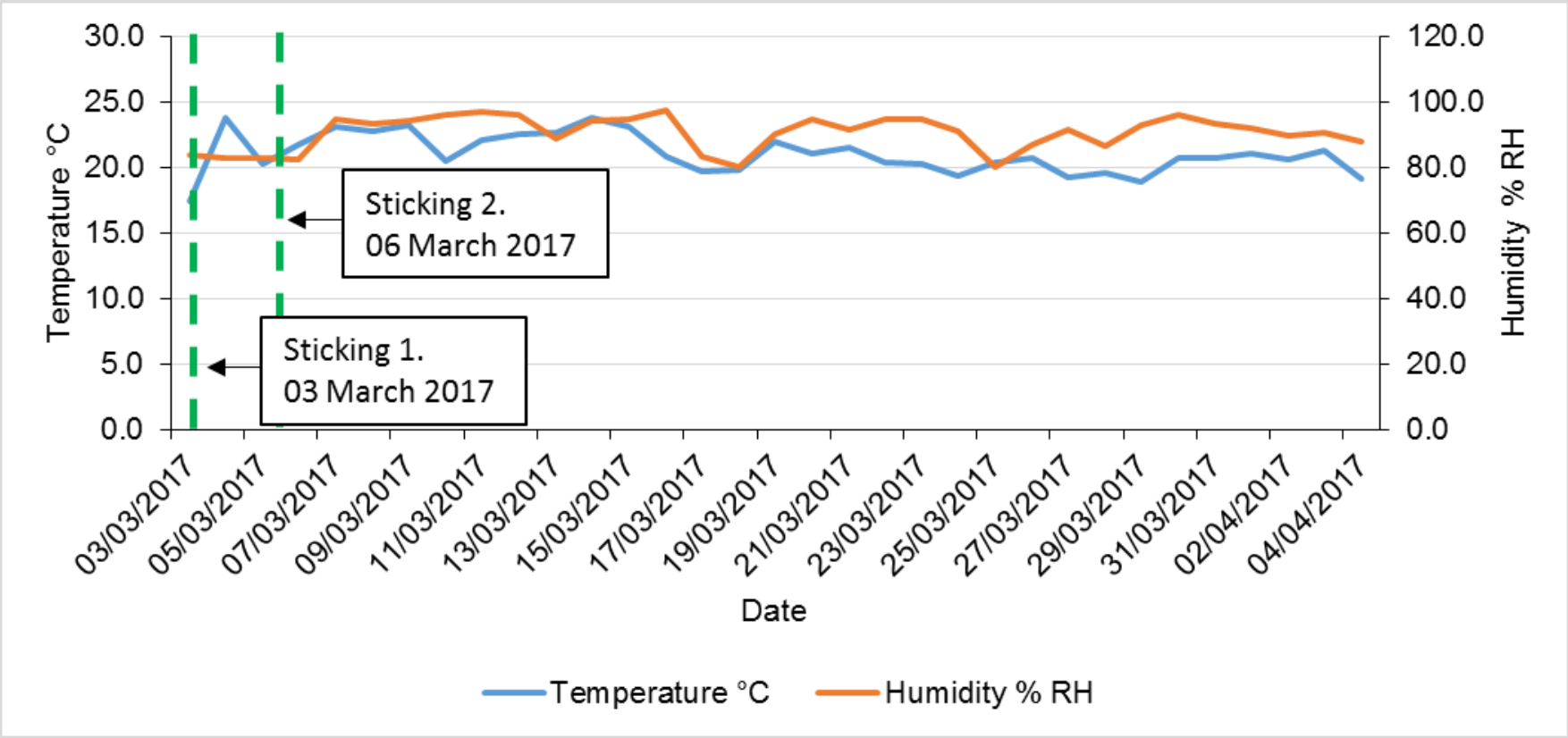

Figure i. Temperature and humidity. 24-hour average.