

Project title: The Bedding and Pot Plant Centre – new product opportunities for bedding and pot plant growers.

Objective 4. Adopting new responsibly sourced growing media blends

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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.

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Signature



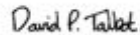
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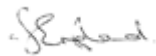
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Grower Summary

Headline

- Commercial quality plug plants were successfully produced in a range of peat-free growing media
- Marketable plants were successfully produced in hanging baskets in peat-free growing media.
- Peat-free growing media tended to exhibit higher conductivities (EC) and these may have to be accounted for in fertigation regimes
- pH tended to be higher in the peat-free mixes than targets for traditional peat-based mixes (5.5 – 6.0); this can affect plant quality as nutrients become unavailable to plants

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.

In 2011, Defra introduced a voluntary phase-out target for peat use of 2030 for professional growers of fruit, vegetables and ornamental plants. In August 2022, Defra announced plans to ban the use of peat in the amateur sector in England and Wales by 2024. Defra more recently announced a ban of peat use in the professional sector, with certain exemptions by 2026, followed by a [complete ban on the use of peat in horticulture by 2026](#) (other than non time limited conservation exemptions). The reduction of peat use in horticulture is expected to be achieved by using a blended range of materials rather than relying solely on one or two main ingredients, not least due to availability of alternative materials.

Where proprietary peat-free growing media blends have been used with some success on nurseries, the need to optimise irrigation, nutrition and mechanisation have been highlighted as areas where further support is required by the industry to get the best out of those blends and increase grower confidence.

This report covers the two final demonstration trials for this objective, both of which were hosted by Arden Lea Nurseries in 2022. These trials charted the production of a range of bedding plants from: **1. Propagation phase** to **2. Production phase** and marketing in hanging baskets; seed-raised subjects underwent an interim stage where they were transplanted into coir-filled packs to bulk them up prior to transplant into hanging baskets. These trials were not replicated, therefore statistical analysis has not been completed.

This is the Bedding and Pot Plant Centre report for:

Objective 4. Adopting new responsibly sourced growing media blends. It reports trials carried out at Arden Lea Nurseries for both propagation and production stages.

Summary

The propagation phase trial was set up at Arden Lea Nurseries, Preston on 19 May 2022 (week 21). Seeds of four plant species (*Dianthus*, *Marigold*, *Petunia* and *Verbena*), and cuttings of three plant species (*Bidens*, *Nemesia* and *Petunia*) were sown / stuck into four propagation phase peat-free substrates provided by different manufacturers plus the Nursery Standard propagation media (which contained a small proportion of peat) and grown on under glass from 23 May 2022 (**Figure 1**) until the final assessment on 7 June 2022. Tray sizes were 360 plugs (*Dianthus*, *Marigold*, *Petunia* and *Verbena*), and 50 plugs (*Bidens*, *Nemesia* and *Petunia*). Seeds were machine-sown, and cuttings were stuck by hand. Benches were open mesh and the irrigation and feeding regime followed Arden Lea's standard practice, with irrigation applied via boom and lance and no adjustment to nutrition.



Figure 1. Growing media trial: propagation phase (left) and production phase (right)

For the production phase trial, cutting-raised subjects were transplanted into hanging baskets on 13 July. The seed raised subjects underwent an interim stage where they were transplanted into coir-filled packs to bulk them up prior to transplant into hanging baskets. Plants that had been produced in the propagation phase of this trial were used in this production phase. Five plants per species were transplanted into 25 cm hanging baskets for all seven species, into nine different growing media combinations (**Figure 1**). Plants were transplanted into production phase growing media from the same manufacturer, and also into the Nursery Standard production media and grown on under glass. The irrigation and feeding regime followed Arden Lea's standard practice. Irrigation was via boom and lance.

Propagation phase outcomes

- For the cutting-raised plugs, the root quality assessment on 7 June indicated that the plugs crumbled when removed from the plug tray. However, the grower reported that the plugs held together well when transplanted in mid-July; suggesting the initial issue was linked to root development rather than plug integrity.
- The cutting-raised *Petunia* in Treatments C and D remained under mist for 4 days longer than other species / treatments before weaning.
- The high EC may have contributed to delayed rooting / low plant quality scores recorded for the cutting-raised *Petunia* in Treatments C and D. *Nemesia* had low root quality scores at the 7 June assessment, but scores improved by the July assessment.
- Results were mixed. Seed-raised plugs performed well in the Nursery Standard and Treatment A, and were all marketable (plant quality scores 3.8 to 4.8). *Dianthus* and *Petunia* performed less well in Treatment C (plant quality <3.0) and were not marketable. *Verbena*, Marigold and *Dianthus* performed less well in Treatment B for root quality <3.0, while plant quality scores ranged between 3.5 and 3.7 (marketable).

Nutrient analysis:

- Nutrient analysis indicated that Treatments C and D both had high EC (641 uS/cm and 667 uS/cm respectively). Cl and SO₄, and particularly K, contributed to the high EC. A substrate EC below 200 µS/cm is usually recommended for seedlings, above this root damage can be caused, depending on species sensitivity.
- Available N (Nitrate-N and Ammonium-N) measurements were low in Treatment B and may be linked to poor performance for some subjects.

Production phase outcomes

- The best plant quality was seen in cutting-raised *Petunia* (scores of 5.0 in Treatments B+NS and C+NS), and seed-raised *Petunia* (scores of 5.0 in six out of nine treatments).
- Root quality was poorer in the production phase than the 6 July propagation phase assessment, particularly for cutting-raised subjects (plants were transplanted 11 and 12 days prior to the final assessment).
- Rooting was generally poorest in Treatments D and D+NS
- Production in manufacturer submitted materials followed by the Nursery Standard (i.e. Treatments A+NS, B+NS, C+NS and D+NS) did not consistently improve plant performance.

Growing media outcomes (propagation and production phases):

- There were no difficulties sowing seeds or sticking cuttings in any of the supplier mixes
- All species remained intact during transplant
- There were no issues reported with the various growing media during production
- There was a lot of weed seed in the Treatment D propagation media

Nutrient analysis:

- EC was again high for some substrates used in the production phase. A high level of K, one of the contributors to this, is often associated with coir. Cl and SO₄ also contributed to the high EC, and a particularly high level of SO₄ was measured in Treatment D. Low root quality was seen generally seen in plants produced in Treatment D and D+NA, with the lowest root quality score recorded for the cutting-raised *Petunia* (score 1.1).
- Nitrogen (ammonium-N and nitrate-N) and Mg levels were low in Treatment A but this does not appear to have overly affected plant quality scores.
- The pH of the treatment growing media mixes were higher than is usually maintained in peat-based media; nutrients, such as Mn, P and Fe can become unavailable as pH increases, and this may have contributed to some of the symptoms seen.
- There are physical benefits of using alternative substrates to peat. Materials such as bark can provide a greater buffering effect which can help to protect plants against high salt levels

Conclusions (2021 and 2022 trials)

This series of trials demonstrated that propagating and growing on pot plants and pot and bedding plants in peat free mixes is possible with appropriate adaptations in management; these include consideration of the below factors:

- Irrigation system and growing media characteristics are important as observed by growers evaluating one of three of the peat-free mixes trialled in an ebb and flood system in the 2021 pot plant trial, which had poorer draining properties that impacted root development.
- The source of growing media materials (e.g. manufacturer) and the way they are produced (e.g. size, how fibrous the final product is) can cause growing media to perform differently, particularly in terms of water holding capacity and therefore water management requirements. It is good practice to trial new mixes before widespread use.
- The EC of the peat-free mixes used in the trial tended to be higher than we would expect to see in peat-based growing media. Elevated EC can cause root damage to young plants and more sensitive species. Care should be taken when growing

sensitive species such as *Antirrhinum*, *Primula*, *Begonia* Rex and Poinsettia. Materials such as composted bark and green compost (more commonly used in retail growing media) offer a greater buffering capacity than peat which can reduce the impact of higher EC.

- In mixes where pH is higher than normal, this may lead to nutrients (e.g. iron) becoming unavailable, particularly to sensitive species such as *Calibrachoa*.
- Growers should work with their growing media manufacturer to ensure that the specification of the growing media supplied, in terms of structure and nutrition (EC and pH), is suitable for their production system and the crop(s) being produced.

Financial benefits

- A comparison of a sample of growing media products (Fargro, <https://fargro.co.uk/>) indicates that 100% peat growing media (11p/L) is usually offered at a lower price than peat-reduced (9-18% difference) and peat-free (18-73% difference). Peat has historically been the lowest cost substrate, but the price has increased in recent years because of availability and sourcing issues, and this is narrowing the price gap between peat and peat-free media.
- There are other cost implications in transitioning away from peat use. These costs include in-house trials of new substrate and blends (including nutrition / irrigation management), and new machinery (e.g. pot fillers, coir shredders) may be required.

Action points

- Trial new peat-free or peat-reduced growing media before widescale use to fully understand the best water management techniques for each substrate and performance at transplant (plug integrity).
- Select peat-free or peat-reduced growing media to suit the nursery production system, for example ebb and flood, overhead, or hand irrigation, and adjust the irrigation regime to suit the crop being produced.
- Undertake nutrient analysis of substrates before use and adjust the nutrient regime to take account of nutrient levels; irrigation water analysis should also be undertaken with nutrients accounted for within the nutrition programme.
- Encourage strong root development through careful attention to watering (not too wet), adjusting water management to suit plant species and consider allowing slightly longer for roots to develop before transplant. Remember the surface of peat-free media dries out more quickly than peat.
- The tray/pot/pack filling machine may require adjustment depending on growing media moisture level. The moisture level of the substrate can affect the speed of container filling, with a slower flow rate for moister materials, which can result in under-filled containers.
- Group plants with similar requirements
- Peat-free blends tested were suitable for use in potting machines, but flow rates may need to be adjusted to achieve the best fill
- Store all growing media in a cool, dark place and use as soon as possible
- Retain a sample of each growing media mix supplied for analysis should any issues arise

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 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

This is the Bedding and Pot Plant Centre report for Objective 4. Adopting new responsibly sourced growing media blends. It reports trials carried out at Arden Lea Nurseries for both propagation and production stages.

Background

Sectors within the horticulture industry that specialise in containerised plant production (e.g. bedding and pot plants, and hardy nursery stock) are the largest professional users by volume of peat-based growing media. Research carried out as part of CP 100 'Tracking Peat usage in Growing Media Production' showed that 60.6 % of peat sales in 2015 were in this sector. Research work on growing media amendments and alternative materials to peat (e.g. coir, bark, woodfibre and green compost) have been on-going in the horticultural industry for over 20 years, and this has led to some changes in peat use within the industry, with some businesses now offering plants grown in 100% peat-free substrates. Latest figures from the 2020 report for CP 100 and CP 203 indicated 0.72 million m³ of peat used by professional growers versus 0.44 million m³ of alternative materials. A significant number of nurseries have now reduced the amount of peat in their growing media by 10-50% (standard in bedding and hardy nursery stock is currently 70% peat, 30% alternatives), and alternative materials are used exclusively on a commercial scale in some sectors, such as coir in the soft fruit industry.

In 2011, Defra introduced a voluntary target for amateur gardeners to phase-out the use of peat by 2020, and a final voluntary phase-out target of 2030 for professional growers of fruit, vegetables and plants. In December 2021, Defra announced plans to ban the use of peat in the amateur sector in England and Wales by the end of this Parliament and has been consulting on the phasing out of peat in the professional sector. The reduction of peat use in horticulture is expected to be achieved by using a blended range of materials rather than relying solely on one or two main ingredients, not least due to availability of alternative materials.

Where proprietary peat-free growing media blends have been used with some success on nurseries, the need to optimise irrigation, nutrition and mechanisation have been highlighted as areas where further support is required by the industry to get the best out of those blends and increase grower confidence.

A series of demonstration trials has been carried out at various grower sites over two years, under the Bedding and Pot Plant Centre. This trial programme demonstrates the use of peat-free growing media in pot plants (Hills Plants), propagation (Earley Ornamentals and Arden Lea Nurseries) and bedding plants (Arden Lea). Grower inputs (standard irrigation, liquid feeding and pesticide applications) along with mechanisation considerations were monitored and adjusted as necessary to achieve a marketable crop and will help to determine the adjustments growers need to make when using peat-reduced and peat-free growing media. Workshops have been hosted at the grower sites to enable attendees to view the trials, learn about the cultural inputs and any amendments required, and ultimately increase grower confidence in the uptake of responsibly sourced growing media blends.

This report covers two trials hosted by Arden Lea Nurseries in 2022. These trials charted the production of a range of bedding plants from: **1. Propagation phase** to **2. Production phase** and marketing in hanging baskets; seed-raised subjects underwent an interim stage where they were transplanted into coir-filled packs to bulk them up prior to transplant into hanging baskets.

Project objectives

Objective 1: To evaluate need for any adjustments to Nursery Standard irrigation requirements for bedding and pot plant propagation and production using up to four proprietary peat-reduced / peat-free growing media products plus the Nursery Standard media

Objective 2: To evaluate the need for any adjustments to liquid feed applications for bedding and pot plant production using up to four proprietary peat-reduced and peat-free growing media products plus the Nursery Standard media under standard nursery irrigation.

Objective 3. To identify any adjustments required to the standard nursery machine container filling practices when using proprietary peat-reduced and peat-free growing media products.

Methods and materials

1. Propagation phase

Site and crop production details

This trial was set up at Arden Lea Nurseries, Preston on 19 May 2022 (week 21) in an un-replicated demonstration trial (**Figure 2**). Seeds of four plant species (*Dianthus barbatus*

'Festival Deep Red', French Marigold 'Durango Flame', *Petunia* 'Frenzy Plum Bicolour' and *Verbena* 'Quartz XP Silver'), and cuttings of three plant species (*Bidens ferulifolia* 'Golden Empire', *Nemesia* 'Burgundy' and *Petunia* 'Capella Burgundy') were sown / stuck into four propagation phase peat-free substrates provided by different manufacturers plus the Nursery Standard propagation media (which contained a small proportion of peat) and grown on under glass from 23 May 2022 until the final assessment on 7 June 2022. Tray sizes were 360 plugs (seeds-raised), and 50 plugs (cutting-raised). Seeds were machine-sown, and cuttings were stuck by hand. Benches were open mesh and the irrigation and feeding regime followed Arden Lea's standard practice, with irrigation applied via boom and lance and no adjustment to nutrition. Inspections and assessments are summarised in **Table 1**. A paclobutrazol (as Pirouette) drench was made to the Marigolds and Dianthus. No other pesticides were applied during this trial.



Figure 2. Growing media trial set up, propagation phase trial (cutting-raised subjects), Arden Lea Nurseries, 23 May 2022

Trial design and statistical analysis

This was a non-replicated, non-randomised demonstration trial, with no statistical analysis. This simple trial design allowed for ease of crop management in terms of irrigation and feeding. Plants were grouped by growing media treatment, with different coloured labels to distinguish each growing media. For each of the plant species / varieties, four peat-free blends were compared to a Nursery Standard product; this provided five demonstration plots per crop. Plots for each seed grown variety each comprised 10 trays of 360 plants (3,600 seedlings), while for cutting raised plants plots were comprised of 20 trays of 50 plants (1,000 cuttings) per variety. This provided a total of 17,400 plants per growing media blend; a total of 72,000 seed raised plants and 15,000 cutting raised plants; with an overall total of 87,000 plants for the propagation trial.

Table 1. Propagation phase: summary of trial inspections and assessments

Date	Week no.	Action	Assessment
23/05/2022	21	Cuttings and seeds planted/sown	Root development, plant quality, plant height (cm)
07/06/2022	23	Assessment	Plant height (mm), root quality, plant quality, Growing media samples for analysis. Fresh and dry weights sampled.

2. Production phase

For the production phase, cutting raised subjects were transplanted into hanging baskets on 13 July. The seed raised subjects underwent an interim stage where they were transplanted into coir-filled packs on the 27 June to bulk them up prior to transplant into hanging baskets on the 14 July (**Figure 3**). Plants that had been produced in the propagation phase of this trial were used in this production phase. Five plants per species were transplanted into 25 cm hanging baskets for all seven species, into nine different growing media combinations. Treatments involved transplanting plants into production phase growing media from the same manufacturer, and also transplanting plants into the Nursery Standard (peat-free) production media (**Table 2**) in ten hanging baskets per growing media treatment; these were grown on under glass until the final assessment on 26 July 2022. The irrigation and feeding regime followed Arden Lea's standard practice, with any effects on plant quality recorded. Irrigation was via boom and lance. Nursery standard practices were used for pest and disease control. Inspections and assessments are summarised in **Table 3**. No pesticides were applied during this trial.

Table 2. Production phase treatments. Plants were transplanted into production phase growing media from the same manufacturer (as in the propagation phase), and also into the Nursery Standard growing media

Treatment		Propagation phase media supplier / label colour	Production phase supplier / label colour
1	Nursery standard (NS)	Yellow	Yellow
2	A	Blue	Blue
3	B	Red	Red
4	C	White	White
5	D	Orange	Orange
6	A + NS	Blue	Yellow
7	B + NS	Red	Yellow
8	C + NS	White	Yellow
9	D + NS	Orange	Yellow



Figure 3. Arden Lea. Growing media production phase trial, 26 July 2022

Trial design and statistical analysis

This was a non-replicated, non-randomised demonstration trial, with no statistical analysis. This simple trial design allowed for ease of crop management in terms of irrigation and feeding, and plants were grouped by growing media treatment, with different coloured labels to distinguish each growing media.

For each plant species, eight peat-free blends were compared with the Nursery Standard product; this provided nine demonstration plots (**Table 2**). There were 70 hanging baskets per growing media treatment (total 630). Five plants were transplanted per hanging basket for each of the seven plant species, which provided a total of 3,150 plants.

Table 3. Production phase: summary of trial inspections and assessments

Date	Week no.	Action	Assessment
13/07//2022	28	Cutting-raised plants transplanted and trial set out	
14/07//2022	28	Seed-raised plants transplanted and trial set out	
26/07/22	30	Assessment	Plant height (mm), root quality, plant quality. Fresh and dry weights sampled.

Assessments

Inspections and assessments are summarised below.

- Grower comments on irrigation frequency, liquid feeding, pesticide applications and general crop husbandry were recorded.

At the end of the trial:

- Commentary on plant quality.
- Plant height. 10 plants per growing media treatment, per species, at the end of the demonstration.
- Root development. 20 plants per growing media treatment per species at the end of the demonstration on a scale of 0 – 4 (**Table 4**).
- Temperature and humidity were recorded throughout the trials.
- Fresh and dry weights.

Table 4. Root development scores

Score	Definition
0	No root development
1	Rooting in up to 25% of pot
2	Rooting in 26-50% of pot
3	Rooting in 51 – 75% of pot
4	Rooting in 100% of pot

Results

1. Propagation phase

The effect of each treatment on the height, plant and root quality, fresh and dry weights of the seven plant species produced in the peat-free growing media was compared with those produced in the Nursery Standard. Germination rates (**Table 5**), rooting rates (**Table 6**), plant height, root quality and fresh and dry weights of each species are tabulated (**Table 7**). As the seed-grown species were too small to assess by the 7 June assessment, a further assessment (height, plant quality and root quality) was carried out by Arden Lea Nurseries staff (**Table 8**). Growing media analyses are presented in **Appendix 1**, with images showing the plants in the five substrates observing plant quality at the end of the trial in **Appendix 2**. Grower

commentary on plant management and plant development are presented in **Table 9**. This was a non-replicated, non-randomised demonstration trial, and no formal statistical analysis was undertaken.

Tray fill assessment

Trays were hand-filled rather than machine-filled. Only Treatment A and B mixes were present at the site for trial set-up – other treatments were set up by the nursery on arrival. Treatment A held moisture well compared with Treatment B. Treatment B was much drier and media fell through the bottom of the 50 plug trays when filling. There were also some large woodfibre pieces present in Treatment B that caused some issues when filling trays, such as overhanging the sides of the cells and giving rise to concerns that it could catch on other plants when moved and then dislodge some of the growing media (Figure 4).

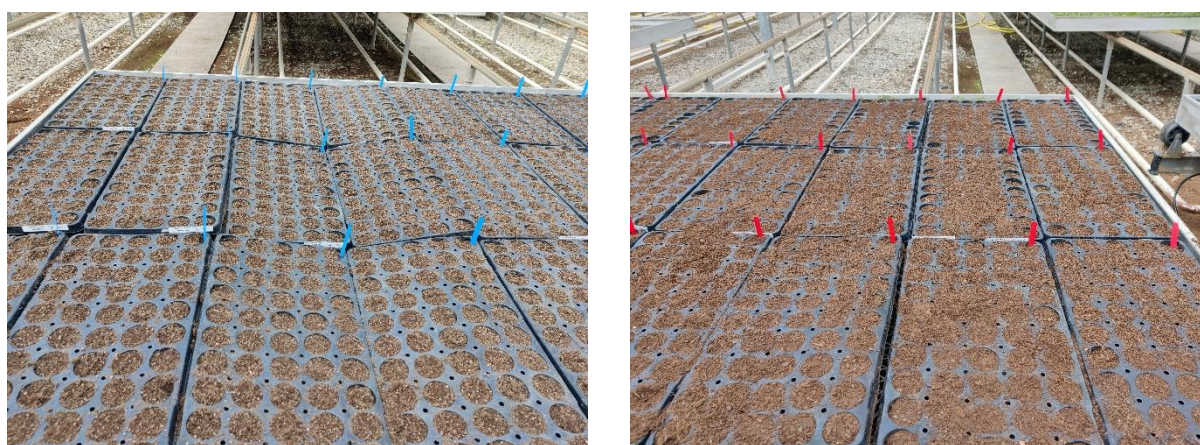


Figure 4. Growing media trial tray-fill set up, Treatment A (left) and Treatment B (right) Arden Lea Nurseries, Preston 19 May 2022

Germination assessment (nursery data)

The nursery target germination rate is 85%, and expects a germination rate of 70% for Marigolds. Germination was consistent across the species and media, except for Marigold which had lower germinations rates in all treatments. Also noteworthy, the germination rate was slightly below the target for all species in the red treatment.

Table 5. Propagation phase: germination rates. The nursery target was 85% germination, and 70% for Marigolds; cells highlighted in grey indicate species/treatment combinations where the sowing rate fell below this target

Treatment	Petunia	Verbena	Marigold	Dianthus
Nursery Standard	88%	85%	63%	85%
A	88%	87%	63%	84%
B	83%	84%	61%	83%
C	85%	87%	59%	86%
D	72%	89%	58%	89%

Cutting rooting rate (nursery data)

The nursery normally achieves a 95-98% take from cuttings, including for *Bidens*, *Nemesia* and *Petunia*. Rooting rates were fairly consistent across species and media.

Table 6. Propagation phase: rooting rates

Treatment	<i>Bidens</i>	<i>Petunia</i>	<i>Nemesia</i>
Nursery Standard	96%	94%	88%
A	96%	88%	90%
B	90%	90%	92%
C	94%	84%	84%
D	92%	90%	80%

Weaning dates for cutting-raised species (nursery data)

Weaning dates for removing plugs out of mist are listed below. The *Petunia* in Treatments C and D were slower to root compared with other species and treatments.

- 1 June – all *Bidens*
- 1 June – *Bidens*, all treatments
- 3 June – *Nemesia*, Treatment A, B and the Nursery Standard
- 6 June – *Nemesia*, Treatment C, D
- 6 June – *Petunia* in Treatments A, B and the Nursery Standard
- 10 June – *Petunia* in Treatments C and D

Plant quality.

Cutting-raised plants. All plants assessed for plant quality achieved scores of 3.0 to 5.0 by the 7 June assessment (**Table 7, Appendix 2**). A score of 5.0 (excellent quality, no damage visible) was recorded for plant quality for all species in Treatment A, for the *Bidens* and *Nemesia* in Treatment B, for the *Bidens* in Treatment C, and for the *Nemesia* and *Petunia* in the Nursery Standard. No scores of 5.0 were recorded for Treatment C. The lowest score was achieved by the *Nemesia* grown in Treatment C, scoring 3.0. By the assessment on the 6 July the plants were larger, and the highest scores were for plants in the Nursery Standard, with the *Bidens* and *Petunia* achieving scores of 5.0. The lowest score was for the *Petunia* in Treatment C (2.5) (**Table 8, Appendix 2**).

Seed-raised plants. The plants were too small to assess on the 7 June. The 6 July assessment indicated no particular trends in relation to treatments and plant quality. None of the treatments achieved a score of 5.0; the highest treatment was recorded for the *Dianthus*

in the Nursery Standard, and the lowest score for the *Dianthus* in Treatment D (**Table 8, Appendix 2**).

Plant height.

Cutting-raised plants. There was no trend to link plant height to any specific growing medium at the 7 June assessment. The Nursery Standard product produced the tallest *Bidens*, Treatment B produced the tallest *Nemesia*, and Treatment A produced the tallest *Petunia*. The shortest plants were the *Petunia* in Treatment B (17.7 mm) (**Table 7, Appendix 2**). There are no height differences to consider for the cutting-raised plants at the final assessment as they had been trimmed prior to the assessment (**Table 8, Appendix 2**).

Seed raised plants. The assessment on the 6th July did not indicate any specific trends linked to plant height, with each species performing differently in each treatment. For bedding plants height isn't the best indicator of quality; shorter plants with more flowering side shoots would be regarded as more marketable and a better quality product (**Table 7, Table 8, Appendix 2**).

Root quality

Cutting-raised plants. Root quality scores were low at the 7 June assessment, as the roots had had insufficient time to develop. There was no clear trend for root quality, and only the *Bidens* in the Nursery Standard scored as high as 4.0. The *Petunia* were slower to root in Treatment C and Treatment D, while the *Nemesia* was slower to root in Treatment C all scoring 1.0 (**Table 7, Appendix 2**). The *Petunia* cuttings grown in Treatments C and D were kept under the mist boom sprayers for longer, along with the *Petunia* and *Verbena* seedlings. By the 6 July assessment, the highest scores were 4, achieved by the *Bidens* in all treatments, the *Nemesia* in the Nursery Standard and Treatment B, and the *Petunia* in the Nursery Standard and Treatment C. The lowest score was recorded for the *Petunia* in Treatment D (2.9) (**Table 8, Appendix 2**).

Seed-raised plants. The plants were too small to assess on the 7 June. Seed-raised species (*Dianthus*, Marigold, *Petunia*, and *Verbena*) were unable to be taken out of plug trays due to their small size and lack of developed roots (**Table 7, Appendix 2**). By the 6 July assessment the highest score was 4.0, and this was only recorded for the Marigold in the Nursery Standard. Rooting was delayed in the Marigold and *Verbena* Treatment B (2.5) compared with the other species (**Table 8, Appendix 2**).

Fresh and dry weights

Cutting-raised plants. The plants with the greatest fresh weight were the *Bidens*, and *Petunia* produced in the Nursery Standard, and the *Nemesia* produced in Treatment B. Treatment C had the largest difference in fresh weight to the Nursery Standard (**Table 7, Appendix 2**).

There was minimal difference in dry weight between treatments for the *Nemesia* (cutting-raised, 0.4g) and Marigold (seed-raised, 0.1g); slightly larger differences were found for the *Bidens* (cutting-raised, 1.5 g) and *Petunia* (cutting-raised, 0.8 g). The Nursery Standard had the highest dry weights, and Treatment B had the closest dry weight measurements to the Nursery Standard in all the cutting-raised species.

Seed-raised plants. Fresh and dry weights for the seed-raised species were unable to be assessed due to the minimal growth of the species by the date of assessment (**Appendix 2**).

Growing media analyses

Analyses of unused propagation phase growing media carried out at the start of the trial (NRM) are presented in **Appendix 1**. EC was high particularly for seed production in all treatments, with K, Cl, SO₄ and nitrates the main contributors. EC above 200 uS/cm is high for seedlings and can cause root damage. Nitrogen (ammonium-N and nitrate-N) and Mg levels were low in Treatment B.

Table 7. Propagation phase: ADAS assessment. Mean height, mean plant quality (scale of 0-5; 0=dead, 5 = excellent quality, no visible damage), mean root quality (scale of 0-4; 0 = no root development, 4 = rooting in 100% of cells), mean fresh weight (FW) and mean dry weight (DW). End of trial assessment, 7 June 2022

Format	Species	Growing Media Treatment	Height (mm)	Plant Quality	Root Quality	FW (g)	DW (g)
Cutting raised	Bidens	Nursery Standard	47.7	5.0	4.0	31.3	2.9
		A	40.5	5.0	3.0	15.6	1.8
		B	32.1	5.0	2.0	19.0	1.9
		C	27.7	4.0	2.0	13.9	1.4
		D	33.2	5.0	3.0	18.4	1.7
	Nemesia	Nursery Standard	31.4	4.0	2.0	11.3	1.2
		A	35.4	5.0	2.0	9.6	1.1
		B	41.9	5.0	2.0	11.7	1.2
		C	21.3	3.0	1.0	6.1	0.8
		D	27.7	4.0	2.0	8.1	0.9
	Petunia	Nursery Standard	28.8	5.0	2.0	26.6	2.3
		A	31.0	5.0	3.0	17.9	1.9
		B	17.7	4.0	2.0	20.3	1.9
		C	19.8	4.0	1.0	18.6	1.7
		D	26.1	4.0	1.0	17.0	1.5
Seed raised	Dianthus	Nursery Standard	*	*	*	*	*
		A	*	*	*	*	*
		B	*	*	*	*	*
		C	*	*	*	*	*
		D	*	*	*	*	*
	Marigold	Nursery Standard	*	*	*	3.0	0.3
		A	*	*	*	3.2	0.3
		B	*	*	*	2.4	0.2
		C	*	*	*	3.1	0.3
		D	*	*	*	3.1	0.3
	Petunia	Nursery Standard	*	*	*	*	*
		A	*	*	*	*	*
		B	*	*	*	*	*
		C	*	*	*	*	*
		D	*	*	*	*	*
	Verbena	Nursery Standard	*	*	*	*	*
		A	*	*	*	*	*
		B	*	*	*	*	*
		C	*	*	*	*	*
		D	*	*	*	*	*

*Note the seed raised *Dianthus*, Marigold, *Petunia* and *Verbena* were too small to assess root quality and height. Similarly the *Dianthus*, *Petunia* and *Verbena* were not assessed for fresh or dry weight.

Table 8. Propagation phase. Arden Lea Nursery assessment. Mean height, mean plant quality (scale of 0-5; 0=dead, 5 = excellent quality, no visible damage), mean root quality (scale of 0-4; 0 = no root development, 4 = rooting in 100% of cells), mean fresh weight (FW) and mean dry weight (DW). End of trial assessment, 6 July 2022

Format	Species	Growing Media Treatment	Height (mm)	Plant Quality	Root Quality
Cutting raised	Bidens	Nursery Standard	*60.0	5.0	4.0
		A	*60.0	4.2	4.0
		B	*60.0	4.2	4.0
		C	*60.0	4.6	4.0
		D	*60.0	4.7	4.0
	Nemesia	Nursery Standard	*60.0	4.7	4.0
		A	*60.0	3.9	3.0
		B	*60.0	4.3	4.0
		C	*60.0	3.4	3.0
		D	*60.0	3.6	3.0
	Petunia	Nursery Standard	*50.0	5.0	4.0
		A	*50.0	3.6	3.0
		B	*50.0	4.1	3.8
		C	*50.0	2.5	4.0
		D	*50.0	4.1	2.9
Seed raised	Dianthus	Nursery Standard	8.7	4.8	2.2
		A	8.7	4.3	3.3
		B	5.3	3.5	2.9
		C	5.8	3.7	2.9
		D	4.1	2.5	3.8
	Marigold	Nursery Standard	13.8	4.0	4.0
		A	11.6	4.2	3.8
		B	11.5	3.7	2.5
		C	8.9	2.7	3.4
		D	9.4	4.2	3.7
	Petunia	Nursery Standard	3.4	3.9	3.9
		A	3.9	3.5	3.5
		B	4.1	3.7	3.2
		C	4.7	2.8	2.6
		D	5.0	3.9	3.2
	Verbena	Nursery Standard	8.4	3.8	3.1
		A	7.0	3.5	3.1
		B	10.3	3.7	2.5
		C	7.6	4.1	3.4
		D	8.0	2.7	3.2

*Note. Cuttings were trimmed prior to the assessment

2. Production phase

The effect of each treatment on the height, plant and root quality, fresh and dry weights of the eight plant species grown on in the five peat free growing media treatments, plus four additional observations of plants grown on in the Nursery Standard after being produced in Treatment A, B, C or D. was compared with those produced in the Nursery Standard. Plant height, root quality and fresh and dry weights of each species are tabulated in **Table 10**. with plant images showing the plants in the five substrates observing plant quality at the end of the trial in **Appendix 4**. Grower commentary on plant management and plant development are presented in **Table 9**. This was a non-replicated, non-randomised demonstration trial, and no formal statistical analysis was undertaken.

Plant quality

Cutting-raised plants. All plants assessed for plant quality were marketable, achieving scores of 3.0 to 5.0 (**Table 10, Appendix 4**), however there were no trends that linked treatment to plant performance across species. The best plant quality was observed in the *Petunia* with scores of 5.0 in Treatments B+NS and C+NS. The lowest average plant quality score was recorded for the *Bidens* in Treatment D, scoring 3.4.

Seed-raised plants. The best plant quality was observed in *Petunia*, where a score of 5.0 (excellent quality, no damage visible) was recorded for six of the nine treatments.

Plant height. There was no trend to link plant height to any specific growing medium (**Table 10, Appendix 4**). In most cases, growing on in the Nursery Standard media resulted in taller plants than those grown on in the same Treatment that they were propagated in, within the different species. Plants grown on in Treatment C had the shortest plants in several species (cutting-raised *Petunia*, Marigold and the seed-raised *Petunia*).

Root quality scores across all growing media treatments for all cutting-raised species averaged between 1.1 and 2.5. Scores were observed to be higher in the seed-raised species, averaging between 2.5 and 4.0. Scores would have improved had the plants had longer to establish before the assessment. Treatment B and Treatment B + NS produced plants with the greatest mean root quality compared with the other treatments in several species (*Bidens*, *Nemesia*, Marigold, and seed-raised *Petunia*). Delayed rooting was observed in the *Bidens* and *Nemesia* where the plants were least established (**Table 10, Appendix 4**).

Fresh and dry weights

There was no clear difference between treatments for fresh weights of species, though Treatment B+NS had the greatest fresh weights for *Nemesia*, Marigold, and seed-raised

Petunia. Treatment A had the smallest fresh weight measurements for *Bidens*, cutting-raised *Petunia*, and Marigold, and the largest difference in fresh weight compared with the Nursery Standard (**Table 9, Appendix 4**). Again, Treatment B+NS had the greatest dry weight in multiple species (*Bidens*, *Nemesia*, Marigold, and seed-raised *Petunia*), weighing more than the Nursery Standard for these species (**Table 9, Appendix 4**).

Growing media analyses

Analyses of unused production phase growing media carried out at the start of the trial (NRM) are presented in **Appendix 1**. EC was high particularly in the Nursery Standard and Treatment D. K, Cl, SO₄ and nitrates were the main contributors, with particularly high SO₄ in Treatment C; and K, Cl and SO₄ high in the Nursery Standard. Nitrogen (ammonium-N and nitrate-N) and Mg levels were low in Treatment A+A.

The pH of the treatment growing media mixes (propagation, 6.3–6.7; production pH 5.1–6.7) were higher than is usually maintained in peat-based media (5.5 to 6.0) (**Appendix 1**). Nutrients, such as Mn, P and Fe can become unavailable as pH increases, and this may have contributed to some of the symptoms seen, particularly in cutting-raised *Petunia*.

Grower commentary

Grower commentary provided throughout is presented in **Table 9**.

Table 9. Propagation and Production phases: Grower commentary.

Propagation	The target germination rate is 85%, expecting a lower germination of around 70% for Marigolds as they can be difficult
	No difficulties sowing seeds or sticking cuttings in any of the supplier mixes
	All species remained intact during transplant and did not fall apart
	Seed-raised plugs that were not marketable were the <i>Dianthus</i> in Treatments C and D; and the <i>Petunia</i> in Treatments C and D. Some of the plugs in Treatment B were just marketable. Plugs in the Nursery Standard and Treatment A were all marketable
Production	No issues reported with the various growing media during production
	There was a lot of weed seed in the Treatment D propagation media

Table 10. Production phase. Mean height, mean plant quality (scale of 0-5; 0 = dead, 5 = excellent quality, no visible damage), mean root quality (scale of 0-4; 0 = no root development, 4 = rooting in 100% of cells), mean fresh weight (FW) and mean dry weight (DW). End of trial assessment, 25 July 2022

Format	Species	Growing Media Treatment	Height (mm)	Plant Quality	Root Quality	FW (g)	DW (g)
Cutting raised	Bidens	Nursery Standard (NS)	179.7	3.6	1.9	111.7	14.7
		A + A	192.4	4.4	2	93.1	13.3
		B + B	192.8	4.2	2.5	114.3	13.1
		C + C	184.9	3.5	2.2	123.4	13.9
		D + D	203.1	3.4	1.7	100.1	13.5
		A + NS	194.9	4.6	2	105.1	14.1
		B + NS	169.2	4	2.1	117.7	15.5
		C + NS	205.2	4	1.4	111.8	14.3
		D + NS	224.4	4.1	2.4	127.8	15.2
	Nemesia	NS + NS	165.5	4.1	1.3	117.5	15.9
		A + A	186.7	4.4	1.6	105.4	14.1
		B + B	191.6	4.2	1.9	114.7	15.6
		C + C	175.8	4.1	1.4	113	14.6
		D + D	175.2	4.3	1.5	114.9	14.7
		A + NS	154.7	4.3	1.4	100.3	13.5
		B + NS	205	4.9	1.7	145.2	19.6
		C + NS	160.6	4.5	1.7	102.5	14.2
		D + NS	181.9	4.6	1.3	115.5	15.2
	Petunia	NS + NS	120.5	4.8	2.2	143	18.1
		A + A	91.2	4.5	1.4	86.5	10.3
		B + B	113.8	4.9	2	126	14.6
		C + C	88.9	4.6	1.1	87.5	11
		D + D	95.3	4.5	2	165.1	15.9
		A + NS	101.5	4.9	2.5	123	13.3
		B + NS	116.5	5	1.9	139.6	15.8
		C + NS	100.3	5	2.1	132.8	14.6
		D + NS	100.1	4.5	2	145.8	15.3
Seed raised species	Dianthus	NS + NS	85.5	4.8	3.7	79.7	9.6
		A + A	107.3	4.4	3.5	58	7.5
		B + B	95.3	4.5	3.6	56.5	7.1
		C + C	111.3	4.3	3.7	59.6	7.4
		D + D	87.4	4.5	3.6	72.3	9
		A + NS	109.3	4.7	3.2	73.1	9.4
		B + NS	103.5	4.4	3.2	65.2	8.4
		C + NS	102.7	4	2.8	61.3	8.2
		D + NS	81.8	4.5	3.6	77.6	9.1
	Marigold	Nursery Standard	121.4	4.3	3.3	85.9	7.9

		A + A	119.1	4	3.8	72.4	8.6
		B + B	121.7	3.9	3.7	101.7	10.5
		C + C	104.3	4	3.5	91	8.7
		D + D	110.7	3.8	3.7	93.9	9.3
		A + NS	125.4	4.5	3.6	107.2	10.5
		B + NS	129.5	4.1	4	141	12.3
		C + NS	121	4.1	3.1	103.4	9.7
		D + NS	114.5	4.3	3.8	76.5	7.8
	Petunia	NS + NS	146.9	5	3.2	224.9	14.2
		A + A	129.6	5	3.2	153.9	11.5
		B + B	128.9	5	3.6	176.6	13.1
		C + C	110.2	5	3	151.1	11.2
		D + D	133.5	4.8	2.5	140.1	10.5
		A + NS	121.8	4.9	3.3	198.1	12.3
		B + NS	142.1	5	3.6	246.6	15.4
		C + NS	135.3	4.8	2.8	214.9	14.5
		D + NS	136.3	5	2.7	230.8	14.1
	Verbena	NS + NS	154.6	4.5	2.9	92.2	14.9
		A + A	159.5	4.4	3.9	83.2	14.2
		B + B	118.4	4	3.4	89.1	14.6
		C + C	143.7	4.3	3.5	69.1	10.7
		D + D	160	4.3	3	86.8	12.8
		A + NS	151.3	4.4	N/A	N/A	N/A
		B + NS	124.9	4	2.6	73.6	11.8
		C + NS	145.3	4.6	2.7	69.2	11.3
		D + NS	132.3	4	3	74.5	11.5

Discussion and conclusions

1. Propagation phase

The root quality assessment on 7 June indicated that the plugs crumbled when removed from the plug tray. However, the grower reported that by the time the plants were transplanted in mid-July the plugs held together well, suggesting that the initial issue was linked to root development rather than plug integrity.

The cutting-raised *Petunia* in Treatments C and D remained under mist for 4 days longer than other species / treatments before weaning. Nutrient analysis indicated that Treatments C and D both had high EC (641 uS/cm and 667 uS/cm respectively). Cl and SO₄, and particularly K, contributed to the high EC and may have contributed to the delayed rooting / low plant quality scores recorded for the *Petunia*. The *Nemesia* also had low root quality scores at the 7 June assessment, but scores improved by the July assessment. A substrate EC below 200 µS/cm

is usually recommended for seedlings, above this root damage can be caused, depending on species sensitivity.

Seed-raised plugs performed well in the Nursery Standard (contained a small amount of peat) and Treatment A, and were all marketable (plant quality scores 3.8 to 4.8). The *Dianthus* and *Petunia* did not perform well in Treatments C (plant quality <3), and were not marketable. The *Verbena*, Marigold and *Dianthus* performed less well in Treatment B (root quality <3), and may be related to the low N (Nitrate-N and Ammonium-N).

2. Production phase

There were no clear trends to link plant quality across plant species and treatment. The best quality was seen in cutting-raised *Petunia* (scores of 5.0 in Treatments B+NS and C+NS), and seed-raised *Petunia* (scores of 5.0 in six out of nine treatments).

Root quality was poorer in the production phase than the 6 July propagation phase assessment, particularly for cutting-raised subjects. It should be noted that the plants had been transplanted into the hanging baskets 11 (seed-raised species) and 12 (cutting-raised species) days prior to the final assessment on 25 July 2022. Rooting was generally poorest in Treatments D and D+NS

Production in manufacturer submitted materials followed by the Nursery Standard (i.e. Treatments A+NS, B+NS, C+NS and D+NS) did not consistently improve plant performance. There was no clear correlation between EC and plant quality or root quality, although for cutting-raised species treatments where growing media A, C or D was followed with the Nursery Standard plant quality (but not root quality) was often improved, particularly for *Bidens* (all treatments), *Nemesia* (all treatments except for A+NS) and *Petunia* (all treatments except for D+NS); however plants grown in the nursery standard alone (NS+NS) did not perform better than when following Treatment A, B, C or D; these trends were not evident for the seed-raised species.

EC was again high for some peat-free substrates used in the production phase. High levels of K are often associated when coir is present, but for the Nursery Standard, and particularly Treatment D levels of SO₄ were particularly high. Low root quality was seen generally seen in plants produced in Treatment D and D+NA, with the lowest root quality score recorded for the cutting-raised *Petunia* (1.1). Nitrogen (ammonium-N and nitrate-N) and Mg levels were low in Treatment A but this does not appear to have affected plant quality scores. The pH of the treatment growing media mixes were higher than is usually maintained in peat-based media; nutrients, such as Mn, P and Fe can become unavailable as pH increases, and this may have contributed to some of the symptoms seen.

There are physical benefits of using alternative substrates to peat. Materials such as bark can provide a greater buffering effect which can help to protect plants against high pH and salt levels. It is also worth noting that the source of materials (e.g. manufacturer) and the way they are produced (e.g. size, how fibrous the final product is) can cause the growing media to behave differently, particularly in terms of water holding capacity and this will affect water management requirements.

Notwithstanding the financial implications of growing in peat-free growing media compared with 100% peat, many growers, have transitioned, or have started to transition, to substantially peat-reduced or peat-free substrates. Growers that haven't made this change have voiced that they often lack the confidence and require further support to achieve this transition.

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- Sarah Fairhurst and the team at Arden Lea
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- The Scientific Support team at ADAS.
- The BPPC Management Group for steering the project.

Appendix 1

Propagation phase: unused growing media analyses (2022)



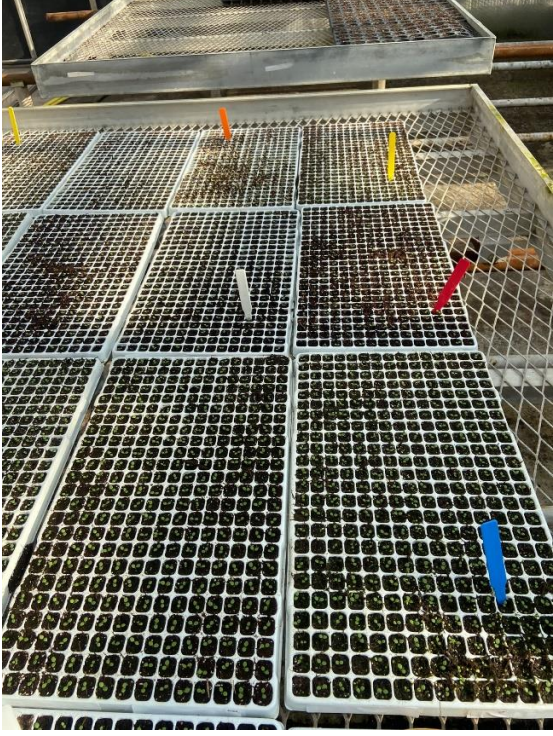

Treatment	pH	EC	NH ₄ -N	NO ₃ -N	Total Soluble N	P	K	Mg	Ca	Na	Mn	Zn	Fe	Cl	SO ₄	B	Cu	Density	Dry Matter	Dry Density
		uS/cm	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Kg/m ₃	%	Kg/m ₃
Standard	6.5	319	48.2	64.8	113	31.1	87.1	42.1	31.3	24.2	0.10	0.28	1.36	18.6	267.5	0.13	0.07	397	40.8	162
Blue (A)	6.6	480	35.7	132.4	168.1	33.7	397.4	39.8	75.1	52.2	2.15	3.73	120.63	237.7	253.2	1.09	0.62	504	35.1	176.9
Red (B)	6.7	290	<0.6	<0.6	<0.6	40.1	250	2.9	4.7	41.6	0.15	0.57	4.45	109.9	190.9	0.08	0.04	355	63.3	224.7
Orange (C)	6.6	641	92.3	139.0	231.3	93.7	528.0	7.9	7.7	81.6	<0.01	1.18	0.80	114.1	324.5	0.28	0.12	385	21.9	84.3
White (D)	6.3	667	1.9	199.8	201.7	24.7	624.6	25.1	52.5	117.9	0.05	0.94	0.99	221.6	121.8	0.70	0.04	437	150.3	150.3

Production phase: unused growing media analyses (2022)






Treatment	pH	EC	NH ₄ -N	NO ₃ -N	Total Soluble N	P	K	Mg	Ca	Na	Mn	Zn	Fe	Cl	SO ₄	B	Cu	Density	Dry Matter	Dry Density
		uS/cm	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Kg/m ₃	%	Kg/m ₃
Standard	5.8	910	46.4	231.8	278.1	26.4	725.3	58.7	141.0	87.6	0.87	0.44	2.00	120.2	709.8	0.30	0.18	235	50.0	117.5
Blue (A)	6.7	210	3.3	<0.06	3.7	14.2	201.8	4.0	12.2	44.8	0.10	2.92	11.36	89.2	199.6	0.93	0.34	428	42.7	182.8
Red (B)	6.3	697	33.2	67.9	101.1	60.1	621.2	20.2	23.7	130.7	0.38	2.13	1.16	311.5	440.3	0.41	0.35	310	45.9	311.5
Orange (C)	6.1	609	89.6	119.7	207.3	50.4	450.7	8.7	11.5	74.6	0.08	1.00	1.62	120.5	355.7	0.23	0.08	380	32.4	123.1
White (D)	5.1	825	21.0	81.9	102.9	42.8	377.5	203.9	176.5	102.2	7.42	5.41	4.03	81.8	1565.6	2.26	2.77	392	38.3	150.1

Appendix 2





- a. Arden Lea. Plant quality. Peat-based Nursery sStandard growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels) Seed raised species: Sown 23 May 2022

	
<p><i>Dianthus</i></p>	<p><i>Marigold</i></p>
	
<p><i>Petunia</i></p>	<p><i>Verbena</i></p>






- a. Arden Lea. Plant quality. Peat-based Nursery Standard growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels) Cutting raised Bidens: Transplanted 23 May 2022

	
<p>Nursery Standard</p>	<p>Treatment A</p>
	
<p>Treatment B</p>	<p>Treatment C</p>
	
<p>Treatment D</p>	

- b. Arden Lea. Plant quality. Peat-based Nursery Standard growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels) Cutting raised Nemesia: Transplanted 23 May 2022










	
<p><i>Nursery Standard</i></p>	<p><i>Treatment A</i></p>
	
<p>Treatment C</p>	<p>Treatment D</p>

- c. Arden Lea. Plant quality. Peat-based Nursery Standard growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels) Cutting raised Petunia: Transplanted 23 May 2022

	
<p>Nursery Standard</p>	<p>Treatment A</p>
	
<p>Treatment B</p>	<p>Treatment C</p>
	
<p>Treatment D</p>	









Appendix 3











Arden Lea production trial. Peat-free growing media samples: Nursery standard control product (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), treatment D (white labels).

		
Nursery Standard Control Product	Product A	Product B
		
Product C	Product D	Product A + Control
		
Product B + Control	Product C + Control	Product D + Control







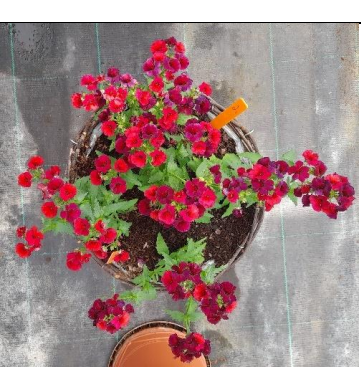

Appendix 4











- a. Arden Lea production trial. *Bidens*. Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard Control		
A		
B		
C		









D		
A + Control		
B + Control		
C + Control		
D + Control		










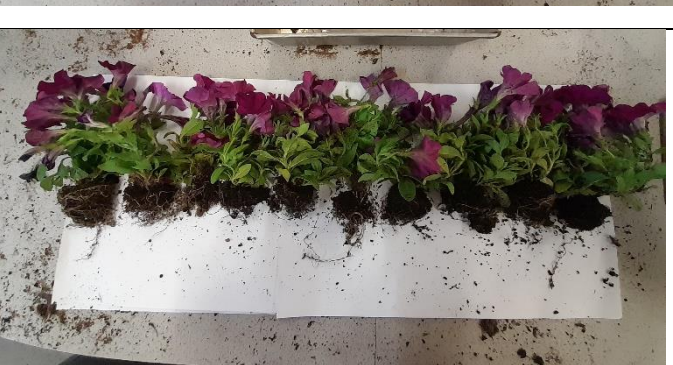
b. Arden Lea production trial. *Nemesia*. Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard		
A		
B		
C		








D		
A + Control		
B + Control		
C + Control		
D + Control		











- c. Arden Lea production trial. *Petunia*. Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard Control		
A		
B		
C		

D		
A + Control		
B + Control		
C + Control		
D + Control		









- d. Arden Lea production trial. *Dianthus*. Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard		Missing Photograph
A		
B		
C		









D		
A + Control		
B + Control		
C + Control		
D + Control		











- e. Arden Lea production trial. *Marigold*. Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard Control		
A		
B		
C		
D		









A + Control		
B + Control		
C + Control		
D + Control		







- f. Arden Lea production trial. *Petunia* (seed). Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard control		
A		
B		
C		

D		
A + Control		
B + Control		
C + Control		
D + Control		

g. Arden Lea production trial. *Verbena*. Plant quality (left) and root quality (right). Peat-based growing media (yellow labels), treatment A (blue labels), treatment B (red labels), treatment C (orange labels), and treatment D (white labels), July 2022

Nursery Standard		
A		
B		
C		

D		
A + Control		
B + Control		
C + Control		
D + Control	