Final Project Report

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Project details

1. AHDB Horticulture Project code	CP138
2. Project title	Transition to responsibly sourced growing media use within UK Horticulture
3. Contractor organisation(s)	RSK ADAS Ltd, Quadram Institute Bioscience and Stockbridge Technology Centre
4. Project Leader	Dr Barry Mulholland
5. Key staff: (name)	Dr Barry Mulholland
(name)	Dr Andrew Watson
(name)	Click here to enter text.
6. Industry Representative	Dr Steve Carter
7. Total AHDB project costs	£ 725,000
8. Project: start date.............	01/01/2015
end date	31/12/2019

9. **Please confirm your agreement for AHDB to publish this report. YES X NO**

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Contents

Objectives

10. Please list the objectives as set out in the contract. If necessary these can be expressed in an abbreviated form, indicate where any amendments have been agreed with the AHDB project manager, with date.

Aims

1. To construct a model that will produce the desired mixes at least cost.
2. To evaluate responsibly sourced growing media blends as alternatives to peat in commercial crop production systems.
3. By on-site demonstration and effective communication of the scientific evidence base increase grower confidence to facilitate the uptake of responsibly sourced growing media for commercial horticulture.

Objectives

1. Determine the specific needs of each horticulture sector in terms of growing media requirements and match these against suitable raw materials and blends using appropriate methodology.
2. Identify and address, where practicable, any issues which may impact now and in the short to medium-term, on the suitability of the media in terms of availability, consistency and price, practical use on nurseries / farms and direct impact on production.
3. Examine the impact of the medium used throughout the whole supply chain (both retail and amenity) including, but not limited to, shelf-life and establishment after planting.
4. Formulate a programme of work via engagement with growers, growing media manufacturers (GMMs) and retailers to demonstrate the attributes of the media and to determine how they are best managed commercially.
5. Communicate any outcomes and conclusions to industry in a clear and concise way throughout the project via nursery / farm demonstrations, technical events, suitable publications, electronic media and other events as appropriate.

Project Progress Summary

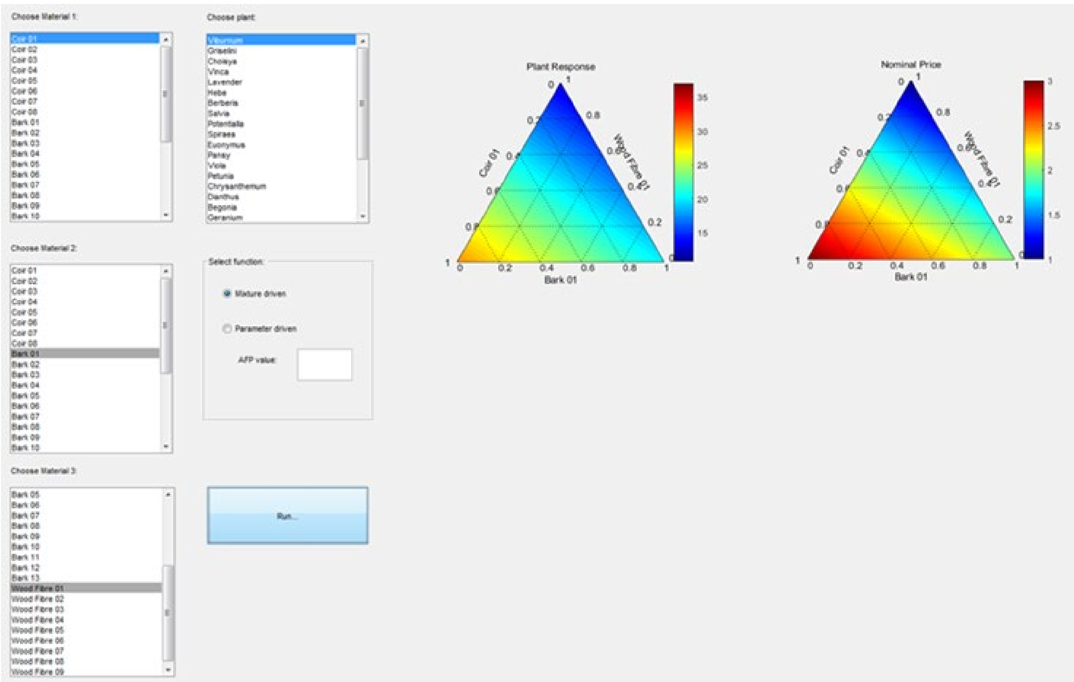
Headline

- Peat remains the dominant product that is used for commercial containerised plant raising in the UK. Replacement of peat has proved difficult because other raw materials that have been sourced and developed by the industry are either expensive or are in limited supply. To create peat replacement growing media will therefore require a solution to formulate "mixes" that are affordable and that perform as well as or better than peat.
- The project has developed a robust, tested and reliable model that will transform the speed and accuracy with which to create new blended responsibly sourced growing media products. The technique is pragmatic and will require a shift away from standard iterative biological response approaches that are expensive and inherently variable, towards the use of selected physical properties as indicators of high or poor performing mixes.
- This technological development is novel, timely and represents a significant advance for the industry to reduce the costs and increase the speed of transition towards the voluntary phase-out target of peat use by 2030.

Modelling

- Peat-free high performing growing media mixes that are compatible with a wide range of commercial water and nutrient delivery growing systems have been designed using quantitative techniques.
- This project has developed a raw material rapid screening and blending formulation technique which can be used to transition to zero peat use in commercial horticulture by 2030. At the core of the new method is the accurate measurement, using the ADAS Standard Operating Procedure (SOP[1]), of three key physical properties that functionally describe growing media; air filled porosity (AFP), available water (AW) and bulk density (D_b).
- An anonymised inventory of growing media raw materials was supplied throughout the project by companies covering >80% of the UK market. The growing media tested were representative of the current raw material supply chains. The project was therefore able to select for any material and high performing materials therein.
- Instead of calculating intuitive ratios of materials to form a growing media, the new approach uses selected physical properties that identify "high performing" mixes which in turn inform the ratios of the separate materials.
- The understanding and selection of growing media based on physical properties is important, because of the vast number of material types commercially available that constitute wood fibre, bark, coir, and green compost. The approach developed in this project is agnostic in terms of the materials available and has been developed to predict blend performance for indicator plant species from the ADAS SOP measured physical properties.
- Because the material physical parameters are measured independently of plant response, they can be determined for different materials and blends in a consistent way for the end user. This means that material data from one site can be compared to data from a different site. Plant response data can be compared knowing how any differences are partitioned between material effects and plant growing effects. In other words, results are transferable. Plant response is no longer the primary detector for measuring material properties and performance.

- This is important when selecting for and designing growing media blends as source materials can vary markedly within the supply chain; so using wood fibre “x” and combining with coir “y” and bark “z” based on mixing ratios, may give contrasting output within and between growing seasons, because the underlying physical properties of the base materials in the supply chain may have changed. Therefore to design growing media blends from ADAS SOP[1] physical properties is a much more reliable way to ensure high performing mixes. This new method moves away from intuitive mixing towards a quantitative approach for product development.
- Using a parameter-based approach also gives meaning to the idea that two mixtures could be ‘the same’, at least in terms of their physical parameters. Two mixtures are considered to be ‘the same’ if their three parameter values agree. In this sense, for example a coir:wood fibre blend can be said to be the same as a bark:green compost mix if their (AFP, D_b, AW) agree (cf. **Table i** in grower trials section).
- Plant growth variables were selected to measure performance. Plant material is however inherently variable and because of the magnitude of the variance in the data, if only a small range in parameter values had been selected for study it would have been difficult to resolve the plant response dependences on those parameters. Therefore, our strategy of selecting basis materials as widely spaced as possible in parameter space is vindicated, since this maximised the opportunity of quantifying underlying trends of plant response as a function of material parameters.
- In keeping with the project objectives, we have created a prototype of a predictive model that will act as a guide to substrate selection.
- The underlying model itself is a simple regression model that respects the variance in plant response data and is based on plant trial data versus blends characterised by their (AFP, D_b, AW) values. The coefficients appearing in the model are plant-specific. In addition, the coefficients are specific to the physical parameter ADAS SOP measurement protocol.
- The model has a user-friendly graphical interface:



[1] http://www.adas.uk/Portals/0/Documents/Technical%20Monograph%20Growing%20Media%20Laboratory%20Methods.pdf

- The model is written in the Matlab programming language. As implemented, it is focused on blends of three basis materials. The user selects these materials via the three left-most drop-down boxes, 'Choose Material 1' etc. A plant of interest is selected via a fourth drop down box, 'Choose Plant'. As currently implemented the output is via two ternary plots, one for plant response and one for blend price. All possible blends of the selected materials are present within the triangular ternary plots, with the corners corresponding to pure materials and the edges to mixes of two materials. The boxes are colour coded with red representing good performance or high cost, depending on the plot. Coordinates within the two triangle zones match, meaning that a specific composition (as given by a point in the left-hand triangle) corresponds to a cost figure given by the same coordinates but in the right-hand triangle. The space below the two triangles is allocated to future developments, including a sustainability index value.
- A triangular representation for the output allows a ready presentation of the flexible three-component blends option. In addition, the ternary plot is familiar as a soil particle size classification and group diagram. Two component blends could be represented as a colour-graded rectangle or line, but as implemented a two-component blend gives a triangle colour coded in parallel bands from one corner to the opposite side. Four component mixtures could be displayed as a tetrahedron, but this is difficult to interpret, so four component mixtures will be implemented by first combining two components.
- Existing data from CP138 provides the raw material for the drop-down materials menus. New materials must have their properties measured using the ADAS SOP. Property parameters are read in from an excel file stored on the user's computer, as are plant response data and costs, allowing for commercial confidentiality since these data files are local to the user only. Indicator plants represent classes for which plant response versus material parameters are broadly comparable, a feature that can be refined as more data is accumulated.

Grower trials and knowledge exchange

- In the 2019 grower trials, 3rd generation peat-free and coir-free growing media blends (prototypes 8-10) that were selected for their physical properties and which indicated potential to produce marketable plants from the experimental trials, were carried through to commercial testing. Of the three blends selected, all produced plants that were comparable with the nursery standard across the different crop sectors (hardy nursery stock and ornamental pot plants).
- The 3rd generation blends used a different selection approach, utilising raw materials supplied which were new to the project. With no prior experience of how these materials would perform, blending could only be based on the physical characteristics of the materials. The blends worked well on commercial grower sites, demonstrating that modelling can be used to design new growing media products that are acceptable for use in commercial UK horticulture plant production systems (see **Table i**).
- Additionally in 2019, the second stage (main growth phase) of the soft fruit trials utilising 2nd generation prototype blends (prototypes 4-7) was completed. Strawberry and raspberry plants were propagated in 2018 using 2nd generation blends and then planted out in 2019 using the same blends, to assess establishment and yield. These blends had been selected for their more 'extreme' physical properties and all but one gave promising results at both propagation and main growth phase.

- As in previous years, the 1st generation peat-free blends (prototypes 1-3) were tested again in 2019 for consistency, alongside the 2nd and 3rd generation blends (see previous project annual reports, 2017 and 2018). All proved to be high performing, which concurred with 2017 and 2018 findings, demonstrating consistency across sites, plant types and growing season.
- Experimental work at ADAS Boxworth in 2019 used fresh batches of materials tested in previous years of the project for their physical properties (i.e. from the back-catalogue of available materials) to test further peat-free and coir-free blends, to place a greater emphasis on wood fibre and bark. Again, a range of materials with different physical properties were used, resulting in good and poor results, which is important for model parameterisation and accurate performance prediction of growing media blends. Tests did show however, that it is possible to produce good quality plants in blends largely based on wood fibre and bark, as long as the physical properties of the blends are in the high performing triangulated physical property "zone" for target plant types.
- The selection of materials using a modelling approach based on physical properties allowed the project to fully explore the performance of a range of blends. The work has demonstrated that mixes of materials can be sourced to create high performing products and that there is potential to broaden the supply chain and fine tune products to meet grower needs (**Table i**).
- Physical properties have been measured for many years within the industry and as a result threshold values for individual properties such as AFP, or available water have been established for peat. Whilst this may be useful agronomic information and provides some assurances for the end user, how this relates to materials other than peat is unclear. It is also not necessarily helpful to attempt to predict performance when different raw materials are mixed to achieve a single target parameter threshold value.
- By selecting mixes of responsibly sourced growing media based on physical properties it has removed the need to select for high performing mixes by use of the standard bio-indicator or plant selected on the basis of sensitivity or not to a containerised mix. This approach is highly variable and expensive to conduct as an iterative exercise e.g. different sites, seasons and so on using the same mix and plant as standard practice. Testing of designed mixes using precise physical properties has created high performing mixes that have worked in experiments, and have been replicated on commercial holdings. This is of critical importance as not only has it helped to understand the application of the blending model and its potential value to growers and growing media manufacturers, it was also demonstration in practice. This new approach removes the need for iterative bio-indicator expensive trial work that is current standard practice to select for new growing media. The technology developed in this project is therefore not only effective in selecting for high performing products, but will, if adopted by the industry, dramatically reduce the development costs for new responsibly sourced growing media and also increase choice for the customer based on price and availability. It will also diversify a raw material supply chain for manufacturers of growing that have been traditionally conservative for constituent selection and availability.
- To embrace the technology developed in CP138 will require behaviour change throughout the industry to move swiftly and confidently towards the 2030 voluntary peat phase out target.
- Being able to blend raw materials to accurately create reliable and reproducible growing media, which is based on three key physical properties, is an "important new tool in the box" for the

growing media manufacturers and will diversify the peat-free market for affordable, high performing products used in containerised plant raising systems.

Table i. Peat-free mixes by sector that produced marketable quality plants and were comparable with the nursery standard. Mixes used host site nursery irrigation systems and had a similar starter fertiliser mix and wetter added to the mix prior to potting. GC and WF denote green compost and wood fibre respectively.

Sector	Year	Irrigation system	Physical properties (AFP, AW, D_b)*	Peat free RSGM blend raw materials⁺
Bedding and pot plants (propagation, 6-packs, 1.5 L pots)	2016 2017 2018 2019	Overhead Ebb and flood Supplementary feeding as required	17.29, 32.67, 0.13 19.67, 26.16, 0.09 20.10. 32.47, 0.12 13.12, 38.46, 0.10 10.59, 45.75, 0.15 16.23, 31.16, 0.20 13.74, 29.57, 0.19 17.47, 32.32, 0.18	66% coir, 17% bark, 17% GC 66% coir, 17% bark, 17% WF 66% coir, 17% GC, 17% WF 50% coir, 50% WF 50% coir, 50% bark 100% bark 33% bark, 66% WF 66% bark, 33% WF
Hardy Nursery Stock (liners, main crop)	2016 2017 2018 2019	Overhead Drip irrigation Sub-irrigation	17.29, 32.67, 0.13 19.67, 26.16, 0.09 20.10. 32.47, 0.12 13.12, 38.46, 0.10 10.59, 45.75, 0.15 8.13, 48.09, 0.16 16.23, 31.16, 0.20 13.74, 29.57, 0.19 17.47, 32.32, 0.18	66% coir, 17% bark, 17% GC 66% coir, 17% bark, 17% WF 66% coir, 17% GC, 17% WF 50% coir, 50% WF 50% coir, 50% bark 50% coir, 50% GC 100% bark 33% bark, 66% WF 66% bark, 33% WF
Protected edibles (pot herbs main crop)**	2016 2017	Ebb and flood	17.29, 32.67, 0.13 20.10. 32.47, 0.12	66% coir, 17% bark, 17% GC 66% coir, 17% GC, 17% WF
Top fruit (main crop)	2017-18	Drip irrigation	17.29, 32.67, 0.13 19.67, 26.16, 0.09 20.10. 32.47, 0.12	66% coir, 17% bark, 17% GC 66% coir, 17% bark, 17% WF 66% coir, 17% GC, 17% WF
Soft fruit (strawberry and raspberry propagation and main crop)	2016-17 2017 2018-19	Overhead (propagation) Drip irrigation (main crop)	17.29, 32.67, 0.13 19.67, 26.16, 0.09 20.10. 32.47, 0.12 13.12, 38.46, 0.10 10.59, 45.75, 0.15 8.13, 48.09, 0.16	66% coir, 17% bark, 17% GC 66% coir, 17% bark, 17% WF 66% coir, 17% GC, 17% WF 50% coir, 50% WF 50% coir, 50% bark 50% coir, 50% GC
Salad and vegetable propagation (modules)	2018 2019	Overhead irrigation	17.29, 32.67, 0.13 10.59, 45.75, 0.15 8.13, 48.09, 0.16	66% coir, 17% bark, 17% GC 50% coir, 50% bark 50% coir, 50% GC

*Physical properties – AFP, Air-filled porosity (%); AW, Available water (%); D_b, Dry bulk density (g cm^{-3})
⁺It is important to note that the materials used within the blends are indicative, as it is the physical properties of the mix and not the % of each material in the blend which is important.
**Trials were only completed in 2016 and 2017 for pot herbs, therefore only a small number of prototype blends were tested in this sector.

- **Knowledge Exchange:** during 2019 the project team attended six industry events and hosted four standalone workshops. The industry events were; Bedding and Pot Plant Centre (BPPC) Open Evening (bedding), III International Symposium on Growing Media, Composting and Substrate Analysis, Elsoms Open Days (veg prop), IPPS Conference (HNS), HortScience Live Midlands (HNS and bedding) and the UK and Ireland Horticulture Conference 2019. At the veg prop, HNS and bedding events, trial plants were demonstrated, along with growing media blends and raw materials, hand-outs and a project poster. Presentations were given at all events. All events were very well attended, and overall, approximately 450 growers and industry representatives were spoken to and informed of the project across the six events.

- Independent workshops were held at Hotel Colessio Stirling, New Farm Produce, Double H and James Coles and Sons Nurseries, and gave attendees the opportunity to view trials in progress. The events were well received, and attended by a total of 107 growers and industry representatives.
- An end of project conference "Growing media conference" was held in Stratford-upon-Avon on 05 February 2020. Focusing on different aspects of growing media, within which CP 138 featured and covering both the edible and ornamental sectors, this event was very well attended, with over 100 delegates.
- A knowledge exchange portfolio has been developed, which brings together summaries of all events, photographs, comments from event hosts and attendees and articles that have been published externally (i.e. Commercial Greenhouse Grower). For each workshop or industry event, an agreed KE feedback form has been developed, which provides a summary of the event, how the project was demonstrated or presented, the number of attendees and feedback from attendees and hosts. This is a working document which has been added to as the project has progressed and is an important way of encompassing the knowledge exchange component of CP138.
- In June 2016, a twitter account for CP138 was set-up (@GrowMediaADAS), and this has proved to be a very useful way in providing 'snap-shots' of the project (i.e. when a trial has been set up or an assessment completed, photographs can be added to the page for viewers to see). It has also been used to help advertise events and workshops, as well as show pictures of events taking place, which helps to generate interest in the project. As of 27 March 2020, the RSGM twitter account has 236 followers, which are a combination of growers, growing media manufacturers, horticultural companies and independents.
- Industry awareness: the workshops have been extremely well received by the industry, and by attending other industry events as well, results from the project have been communicated to over 1630 members of the horticulture sector. As the project progressed, the number of attendees at workshops grew, and the project has been viewed by many as an important step in moving towards more responsibly sourced growing media in UK horticulture.

Exploitation

- The project has completed the requirements loop to describe and design a growing media. The method and model to define and predict high performing mixes from selected physical properties needs to be tested by industry.
- The target for zero peat use is 2030 for the commercial horticulture sector. The use of a wide range of materials, in blends, will be critical to a sustainable and robust growing media supply chain.
- The use of this new growing media blending tool will require behaviour change by the industry and a move away from intuitive "look-see" testing to rapid analysis and model based screening of candidate materials either alone or in a blend of up to four types.
- The model will only provide accurate predictions by the processing of physical properties using the ADAS SOP. This also provides and impartial method to test and verify material selection before use on grower holdings.
- Using physical properties as performance indicators may also, at an early stage, aid the inclusion or not of a much wider range of candidate materials than was previously possible. The technique promotes the avoidance of expensive investment in screening or processing of materials using

plants as performance indicators to select for promising blends. This may also make the supply chain more responsive to price, sustainable sourcing, availability and will remove the reliance on one or two main materials.

- The UK move towards RSGM and "choice" is a sensible strategy as the global need for growing media use in containerised production is set to markedly increase to meet consumer demand for food and non-food fresh produce.
- The technology developed in this project is novel and is of national and global significance as countries move to address the climate emergency and within country zero carbon and environment plans.

Background and expected deliverables

CP138 '*Transition to responsibly sourced growing media use within UK Horticulture*' is a five year project[2] which will develop confidence in the use of alternative growing media materials to diversify a market that has been dominated by high performing peat products for many years. The pressure to seek other materials has come from a combination of government environmental policy and consumer preference for plant products produced in "peat alternatives". Commercially available growing media, other than peat, is grouped into four main raw material types: **coir**, **wood fibre**, **bark** and **green compost;** collectively and for the purposes of this project the four materials, plus peat, are categorised as potentially responsibly sourced growing media (**RSGM**). Over the last 20 years much progress has been made by the growing media manufacturers in the reliable sourcing and conditioning in sufficient quantities of each material. In some sectors such as soft and cane fruit, there has been a successful switch to coir from peat based growing media. Coir alone, however, is not suitable for all plant types and production systems and sufficient, high quality amounts at an affordable price could not be sourced to replace peat; furthermore, it would also again mean dependence on a single raw material type. It is appropriate on a sustainable availability, supply, performance and cost basis to mix up to four raw materials in a "blend", to produce commercially acceptable "peat alternative" plant products in containers and blocks. In sectors which are the largest users by volume of growing media and where peat dominates (hardy nursery stock and bedding), growers have found that peat-reduced growing media, typically 25% other materials, can produce reliable and consistent results. Beyond this and towards 40-50% reduction can be described as "super reduced" and at this level and up to 100% peat free, then results have been variable, or just not suitable from a practical mechanisation and growing system perspective.

As an industry, to make the cross-sector leap beyond an average inclusion rate of 25% for materials other than peat then there has to be a reliable way to predict the performance of "peat alternative" blends. To date the only way to test 100% peat-free blends has been to conduct stand-alone trials. If, however, the raw materials change between testing and manufacture for supply then there can be some discrepancy between expected and actual commercial plant performance. To develop sufficient experience, knowledge and confidence in alternative material blends, can be time consuming. There is a need therefore to short-circuit this process and be able to reliably predict the performance of blends at the point of manufacture; this is the main deliverable of CP138. If this can be achieved then it will not only increase the range of

[2] CP138 is a co-innovation project funded by Defra, AHDB Horticulture, Growing Media Manufacturers and Growers. The project is led by RSK ADAS Ltd with project partners Quadram Institute Bioscience and Stockbridge Technology Centre.

materials that can be sourced and used by the horticulture industry but expedite the uptake of alternative materials that can perform as well as, or better than, the industry standard, peat.

This will be achieved through a programme of targeted research and development, knowledge transfer, demonstration trials and dissemination of best practice throughout all the relevant horticulture sectors (**Figure i**). The project includes all commercial horticulture sectors where growing media is currently used including, but not limited to: vegetable and salad propagation, protected edible crop production, mushroom production, soft fruit propagation and production, top fruit propagation and production and ornamentals propagation and production (including container-grown plants).

The key features of the project are summarised as follows:

- Five year co-innovation project, funded by Defra, AHDB Horticulture, growing media manufacturers (GMM's) and growers to move towards an increased use of RSGM (wood fibre, bark, coir and green compost).
- The work represents commercialisation of previous Defra funded work e.g. HortLINK CP23, CP50 plus two DTI grants and numerous HDC/AHDB funded projects.
- The key deliverable is a model which will predict the performance of RSGM raw material blends.
- Data will be used to provide the evidence base to select for a range of cost effective high performing RSGM blends.
- CP138 will facilitate experimental and large-scale grower hosted trials to quantify RSGM performance for all sectors of horticulture.

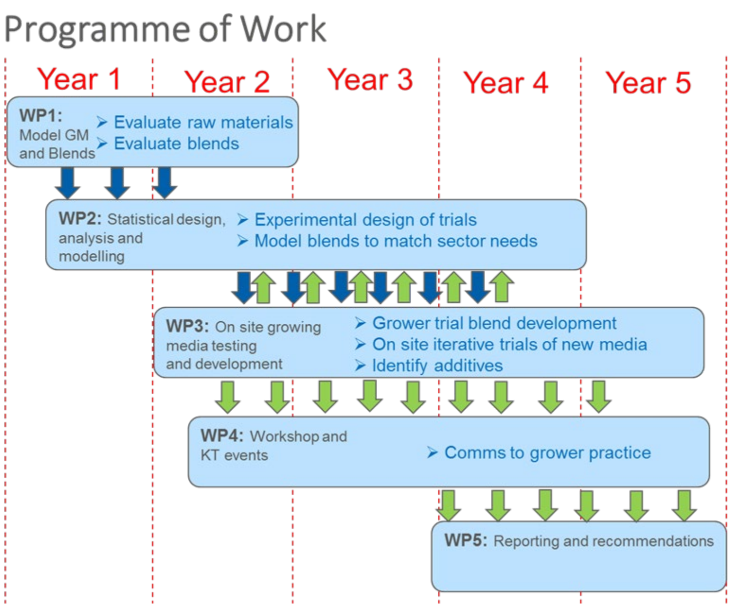


Figure i. Programme of work across the 5 year project. Each WP consists of a number of agreed specific tasks.

Summary of findings

Overarching description of work reported

The main activities and outputs for **WPs 2, 3** and **4** will be described in the following sections. **WP2** is integral to all practical work carried out in **WPs 2** and **3**, as experimental design, data analysis and modelling are core to the experimental work and the production of robust data that can be used to inform practice in the selection and use of growing media. This project is iterative, where the modelling informs experimental design and data produced informs the model. Significant and important insight has been secured for the ability of CP138 to deliver a model that can be used to design robust commercial growing media products. This will potentially create diversity in the market based on a number of key parameters (raw material availability linked to price, growing system and plant type) to mitigate risk for the Horticulture industry and avoid the reliance on a single main raw material for containerised production. The project has remained on course throughout, to meet the core Objectives. The key deliverable from the work is a new and important tool for the industry with which to respond rapidly and robustly to policy and market demands for the transition to responsible sourced growing media.

WP2: Statistical design and analysis of growing media experiments and multivariate modelling (Tasks 2.1-2.1.4).

It is important to emphasise a simple but fundamental principle which underlies the entire project, and which is particularly relevant to the modelling component. This principle represents a paradigm shift and, as the project has unfolded, we perceive that there remains space for further clarification.

A traditional way to report results of growing trials is to list trial blends by volume fraction of the component materials together with a bar chart displaying the plant response displayed against the various blends. A typical presentation might contain elements such as those shown in **Figure 1**.

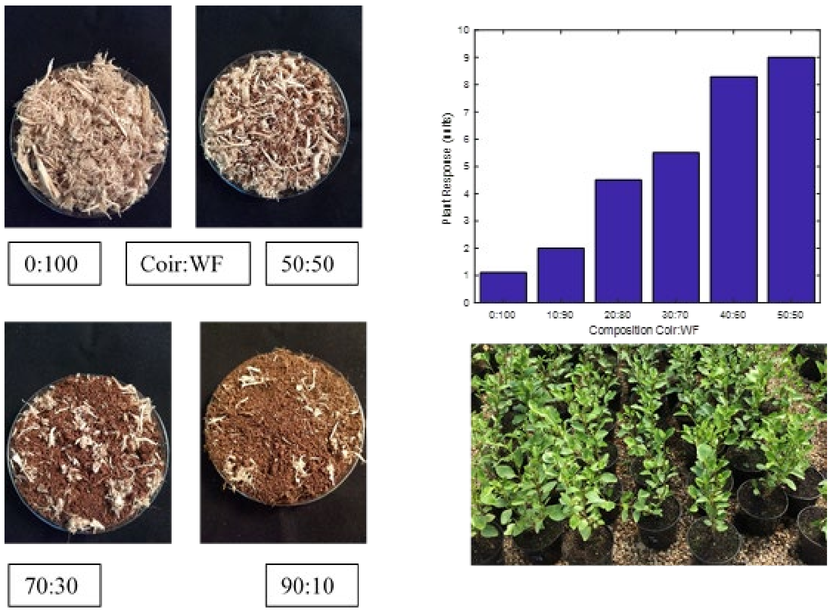


Figure 1. Mock-up of a traditional poster displaying growing trial results. The system is coir plus wood fibre with an unspecified plant and plant response.

This is not wrong, but it is a missed opportunity. The issue is that results presented in this form are stand-alone and cannot readily be transferred to other systems or used to inform other growers. For example, a different grower might use their own wood fibre in the same mix proportions but obtain very different results. This might be because the two wood fibres are different – there is no way of knowing because the original trial simply specified 'wood fibre' – or it might be down to differences in growing conditions. Given this uncertainty, how are the results of the two trials to be compared?

Alternatively the first site might use a coir:wood fibre blend in a subsequent year, hoping to compare the outcome with the original from the previous year. But again, any differences may be because of differences in substrate or differences in growing conditions. Similar considerations apply if the grower were to run a trial involving a new material, for example bark or green compost, with the intention of comparing it to the original coir:wood fibre trial.

The core of the problem is that there is no external and precisely measured universal descriptor to which all growers can refer. Firstly, plant response measurements can display a high level of variance (see below). Secondly, plant response measurements are dependent on numerous growing condition factors and are therefore not easily reproducible across different growers and different growing seasons.

A set of trials comparing two substrates conducted *with all other conditions identical* can reveal differences between those two materials and help to decide which the better substrate is; variation in measurements permitting. Subsequently, attempting to introduce a new substrate material will be problematic, as the growing conditions can no longer be considered identical. One way forward is to have a control substrate that features both in the original set of trials and in the new trials. The plant response in this control substrate can then be used to pull out differences due to growing conditions, revealing the contribution of the new substrate. However, the ultimate comparison of interest has now become a protracted process involving multiple trials and multiple comparisons of plant responses that are inherently prone to high variance, plus the new assumption that the control material is itself constant.

The problems inherent in relying only on plant response can be addressed by expressing growing media in terms of independently measurable parameters, as already outlined in previous reports. Project CP138 has used air filled porosity, dry bulk density and available water. In terms of physical properties at least, two blends can be considered equivalent if their respective values of these parameters are the same, even if the actual materials might be of different types, for example coir plus wood fibre compared to green compost with bark. In this way all materials and mixtures of those materials are unified into a single three-dimensional parameter space, replacing the stand-alone recipe descriptions and response bar charts.

Figure 2 shows the first step in establishing the relationship between the two approaches. Firstly, the bar chart information is recast into an alternative two-dimensional representation.

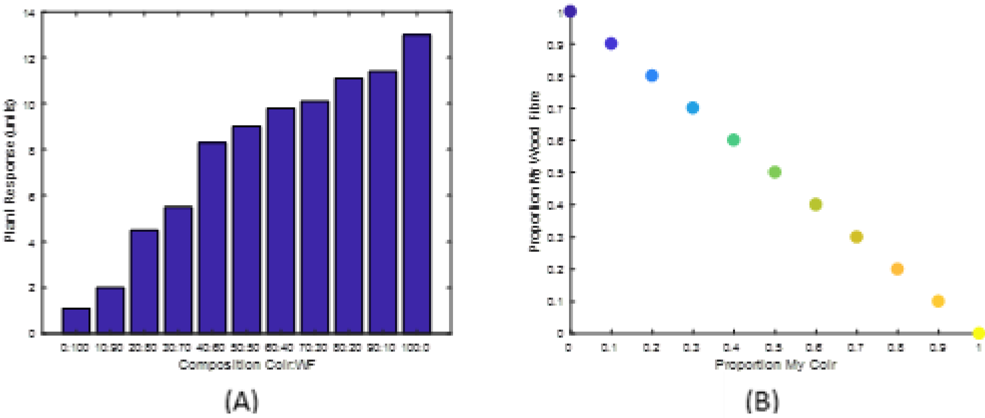


Figure 2. Panel A shows a bar chart display of plant response (vertical) against v/v of component materials (coir and wood fibre). Panel B shows the same information on orthogonal coir: wood fibre axes, with plant response indicated by colour (blue low response, yellow high response).

Each mixture composition becomes a single point on x – y axes (coir – wood fibre). Since the plane is now consumed with composition information, an additional dimension is required to denote response information. In **Figure 2** this is achieved using colour, with blue indicating poor response and yellow strong response.

Figure 3 depicts the next stage, the transformation from mixture proportions to parameter space.

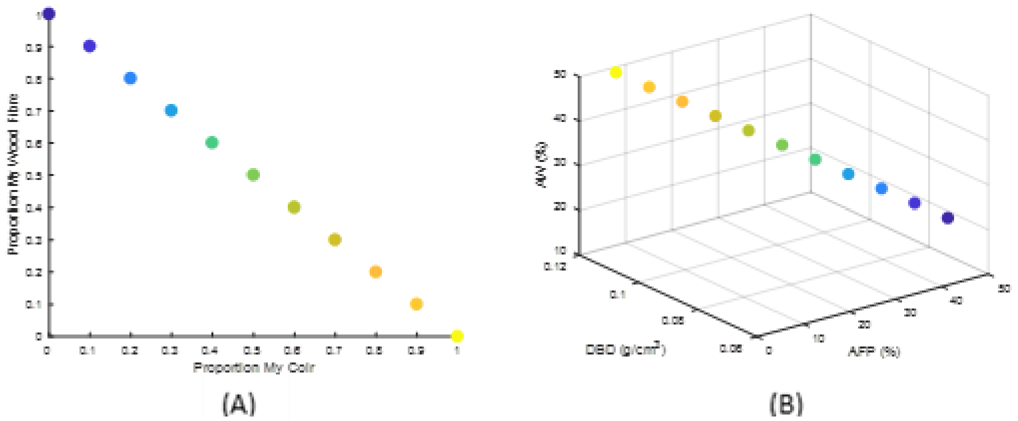


Figure 3. Panel (A) repeats the composition information, with plant response indicated by colour. Panel (B) shows the three-dimensional parameter equivalent, using the same colour scheme for response. Points having the same colour show how composition points in A map to parameter space points in B.

The right-hand panel of **Figure 2** is repeated in the left-hand panel of **Figure 3**. Each point depicted as a proportion of coir:wood fibre (panel A) maps to a corresponding point in the three-dimensional parameter space (panel B). As before, plant growth response is encoded as colour, which makes matching points easy to identify. Pure (100%) coir is shown in yellow (good plant response) and maps to an (AFP, D_b, AW) point in parameter space with coordinates (6.91, 0.12, 49.42), the measured values of these parameters for coir. Pure (100%) wood fibre is shown in dark blue (poor plant response) and maps to the point (48.90, 0.07, 19.24). In this illustrative example the intervening points in panel (B) are calculated according to the proportions of the two materials in the mix.

If a third material was to be included in the blend, for example bark, this would contribute a third axis to panel (A) in **Figure 3**, and the points indicating plant response would then inhabit a three-dimensional space. In the parameter space approach of panel (B) the bark would simply contribute a new point in the *existing* three-dimensional parameter space; idealised blends based on three materials would then correspond to a triangle with the pure materials (the so-called basis materials) located at the vertices.

A fourth material in the blend would contribute a fourth spatial axis to panel (A) – difficult to draw – and the data response points would occupy a four-dimensional space. For the parameter approach, in contrast, the fourth material simply contributes another new point to the *existing* three-dimensional space. The now four vertex points define a tetrahedron containing all the materials and blends of those materials. Comparing how new materials are to be embraced in the two approaches is perhaps the easiest way to visualise the distinction between the two.

Figure 4 (A) shows a set of real data (Chinese cabbage) in terms of three parameters (AFP, D_b, AW).

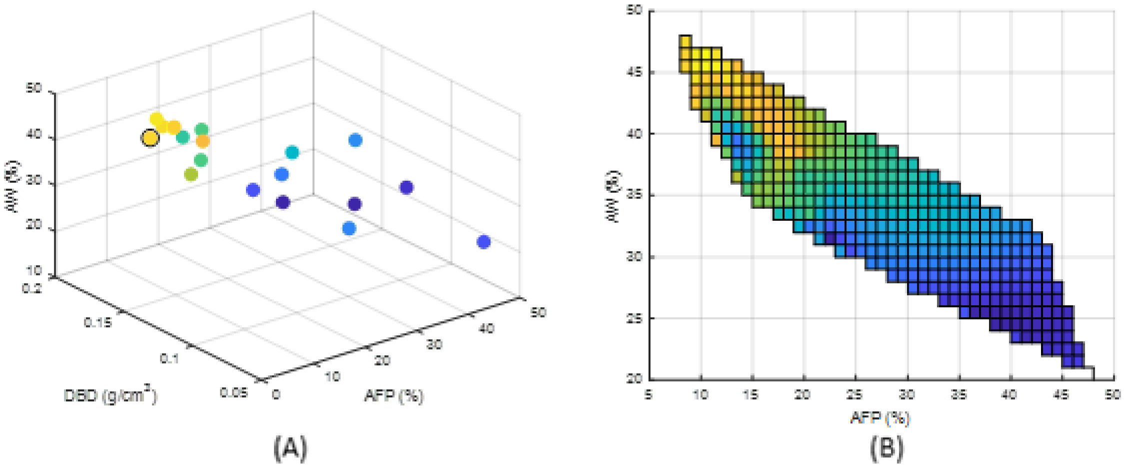


Figure 4. Panel (A) shows real data (Chinese cabbage, fresh weight) displayed on a three-dimensional plot with parameters (AFP, D_b, AW). The coloured dots depict outcomes for 4 basis materials and their blends; an additional peat result is ringed in black. Panel (B) shows the same data as an interpolated surface with the D_b axis suppressed.

The overall trend from good performance at low AFP / high AW (yellow dots) down to poorer performance (blue) parallels the trend seen previously in **Figure 3** (B). The scatter is because the current figure is real data based on blends of wood fibre, bark, coir and green compost, as opposed to calculated values used in **Figure 3** (B). To help appreciate the overall trends, the data in **Figure 4** (A) has been interpolated and redisplayed in the same colour scheme but as a surface with the D_b axis suppressed for clarity (**Figure 4** B). The overall trend from high (yellow) to low (dark blue) performance is apparent. Recall this is a unified display covering four materials and their mixtures.

Because the material physical parameters are measured independently of plant response, they can be determined for different materials and blends in a consistent way by different growers and producers. This means that material data from one site can be compared with data from a different site. Plant response data can be compared knowing how any differences are partitioned between material effects and plant growing effects. In other words, results are transferable. Plant response is no longer the primary detector for measuring material properties.

Using a parameter-based approach gives meaning to the idea that two mixtures are ‘equivalent’, at least in terms of their physical parameters. Two mixtures are considered to be ‘the same’ if their three parameter values agree. In this sense, for example a coir:wood fibre blend can be said to be the same as a bark:green compost mix if their (AFP, D_b, AW) agree, as indicated in **Figure 5** (A).

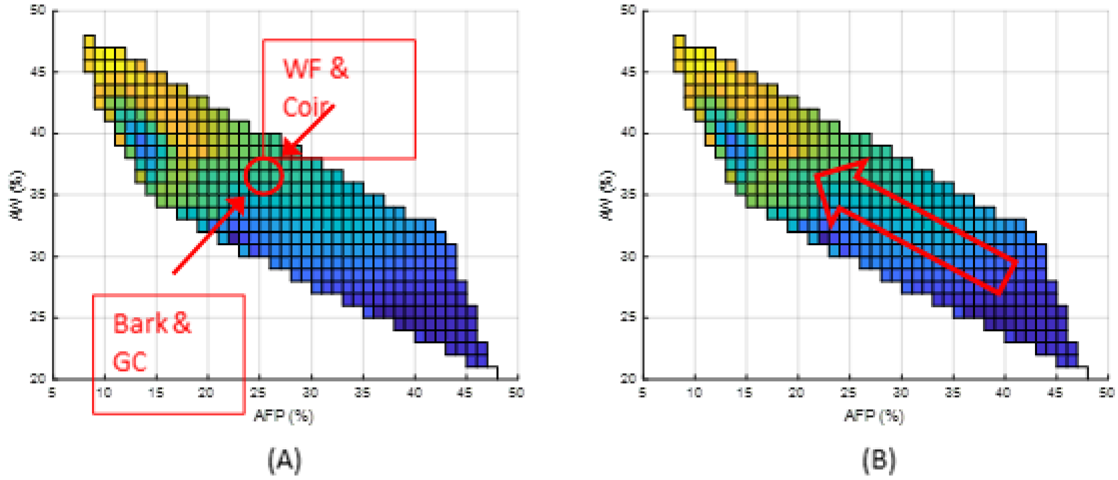


Figure 5. Chinese cabbage fresh weight data reproduced from **Figure 4** (B). Panel (A) indicates how blends of disparate materials can be considered 'the same' in a physical sense if their parameter values are the same. Panel (B) indicates a trajectory to superior blend performance, indicating how a blend can be modified for better plant response.

Using parameters also aids in the creation of new blends. **Figure 5** (B) shows the same data set but with an arrow indicating the trajectory from poorer to superior blends. Starting with a poor blend, this trajectory indicates how the blend can be modified to yield superior performance for a particular plant species.

In the early stages of the project, a group of blends using different combinations of basis materials were created with the objective of offering both good plant performance and similar (AFP, D_b, AW) values. This supported the notion that different blends can be considered 'the same' if their physical parameters agree. Subsequently, the project moved to a second stage, in which materials widely spaced in their parameter values were used as basis materials. Blends comprising up to four of these materials were then created and used in plant trials to give the greatest possible spread in parameter values. The objective was to maximise the chance of detecting the dependence of plant response on the three selected physical properties.

Plot-Level Analysis

Several plant parameters can be measured, including root growth, plant height, fresh weight, dry weight, pot coverage and quality. In the course of CP138 we have considered all the above. Quality is subjective and lacking in resolution compared with e.g. plant weight, though quality scoring is popular with the industry. Plant height is important in some sectors (for example herbs) but is difficult to quantify and of limited use for spreading plants such as Vinca. Overall, the most useful parameter has been shown to be fresh weight. This has clear meaning, relatively well-defined means of measurement (not withstanding issues such as plant trimming during production) and gives a high resolution numerical value. CP138 has demonstrated that trends in data are best revealed using fresh weight. In addition, the sector considers this a satisfactory performance metric. However even fresh weight is not a perfect choice since it is destructive. In addition, as with any plant response measurement, the outcome is time-point specific.

Measurements are taken using randomised plots, with one or more individual plants selected per plot depending on the species. Multiple plants per plot, when available, gives improved precision for the measurement arising from that plot. The plots themselves are replicates: the number of *plots* is the sample size for statistical analysis. In CP138 we have used five or more plots. CP138 has shown that physical parameter measurements need to be performed in triplicate to calculate statistically acceptable errors. Replicates are entirely distinct assessments using distinct aliquots of bulk materials.

Figure 6 shows boxplots of the plot-by-plot breakdown for fresh weight of pansies.

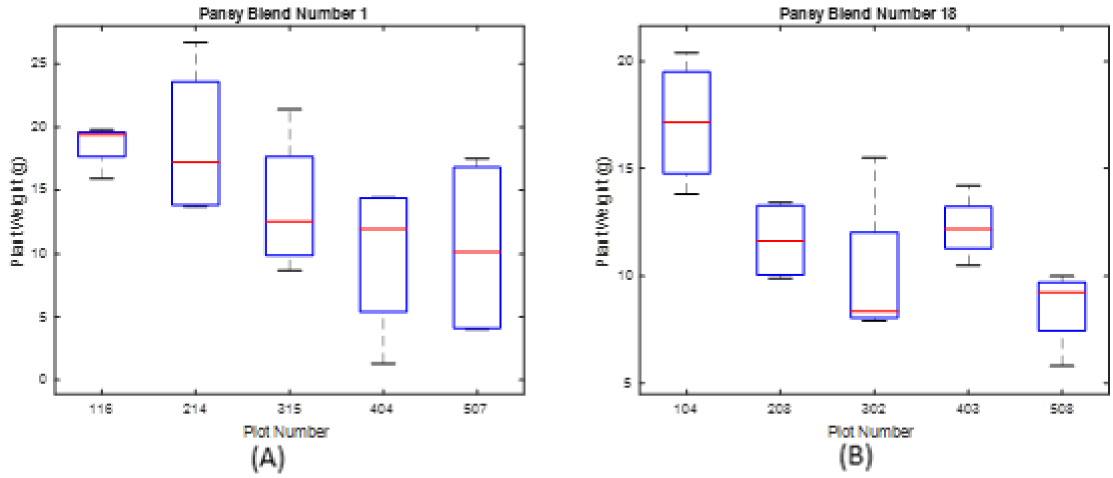
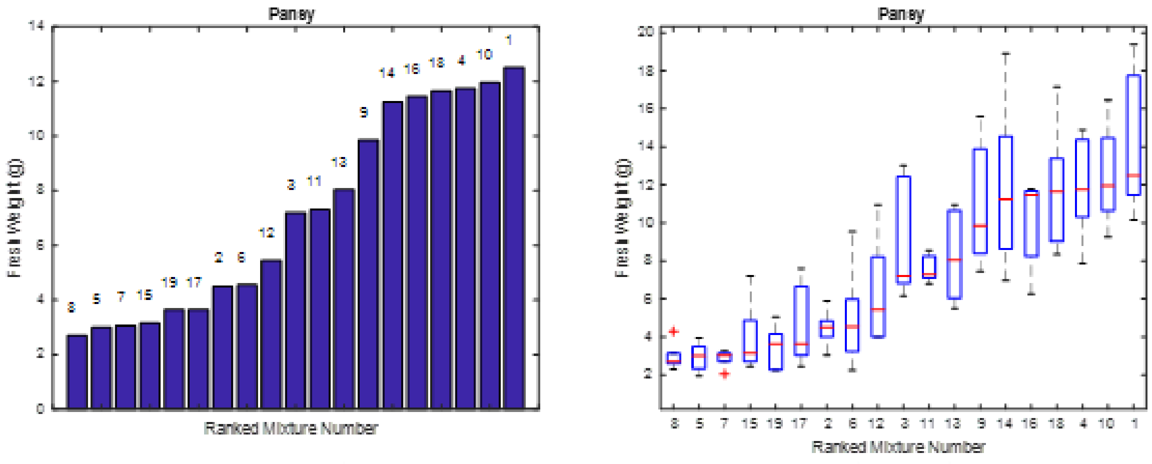


Figure 6. Boxplots depicting plant response (fresh weight, pansy) for five individual trial plots per blend. Panel (A) is peat, panel (B) is a bark, coir, wood fibre blend.

There are five plots, each with four plants randomly sampled per plot. Each plot contains the same substrate. Panel (A) is peat, used in each experimental trial at ADAS Boxworth as a local reference substrate. Panel (B) is a bark, coir, wood fibre blend. Recall that the whiskers of the box plot show maximum and minimum measurements (not error bars); the red lines are medians. The upper and lower bounds of the blue boxes denote third and first quartiles, respectively. Box plots are an attractive representation as they make very limited assumptions about the data depicted. An alternative choice for small sample sizes would be individual data points.

The most striking feature of these (and other similar) plots is the wide range in measurements both within an individual plot and also between plots. For example for pansy the measurements range from a maximum of 26.7 g (plot 214) to a minimum of 1.3 g (plot 404). The medians range from 19.4 to 10.15. There is no statistical difference between any of the five plots in panel (A). The conclusion is that the plant response data (for fresh weight at least) display a high variance. We see similar results in the geranium, coriander and thyme data acquired over the 2019 Boxworth trial season. If this is indicative of variance in growing trials more generally it underscores the inherent difficulty of using plant response for measuring material properties: uncertainty in plant response translates into uncertainty in substrates properties. In contrast, the variance in physical determination of (AFP, D_b, AW) is modest.



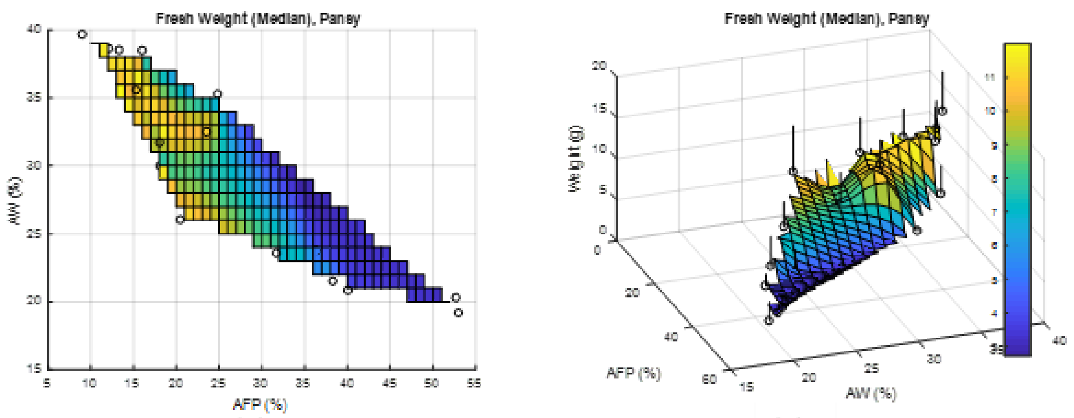
(A) (B)

Figure 7. Plant response (fresh weight, pansy) for each of 19 blends (18 trial blends plus peat local reference) ranked according to magnitude of response. Panel (A) is a simple bar chart, with blend numbers indicated above each bar. Blend 1 is peat. Blends 2, 7, 8, 15, 17 and 19 all contain at least 50% conventional wood fibre. They show poor plant response. Blend 4 is 100% coir. Panel (B) shows box plots of the same data: the red lines are median values corresponding to the bar chart values of panel (A). The medians are from the five individual plot values. Red crosses indicate outliers.

Variance in plant response is also apparent in a bar chart of plant response ranked according to increasing response, **Figure 7**. Panel (A) shows a conventional bar graph, ranked according to plant response with the value of each bar corresponding to the medians in the box plot of the same data in panel (B).

The bar chart invites interpretation regarding the relative merits of blends, for example that blend 10 (coir:novel wood fibre in 50:50 by volume) is a better performer than blend 4 (pure coir). The box plot suggests that such conclusions need to be treated with care, since the data for these two blends, for example, show considerable overlap. The 95% confidence intervals (not shown) indicate there is no significant difference between the best performing set of mixtures, numbers 13 to 1 inclusive. Crudely, the lower half of the bar chart relates to mixtures that perform significantly worse than the upper half of the bar chart.

However, there is a trend in terms of underlying parameters, as noted already in **Figure 4** for Chinese cabbage. **Figure 8** shows a plant response surface plot (pansy, median fresh weight).



(A) (B)

Figure 8. Plant response (pansy, median fresh weight) data versus AFP and AW (with D_b axis suppressed). The colour coding shows yellow (good response) through to blue (poor response) and is the same in both cases. Panel (B) shows data points as circles, with 95% confidence limits added point by point with only the upper portion displayed. The plot in panel (A) is an aerial view of (B) to emphasise the colour graduation.

Panel (A) shows the colour-coded plant response with the Db axis suppressed for clarity. There is an overall improvement in plant response from high AFP/ low AW to low AFP/high AW, as seen in the Chinese cabbage case. Panel (B) shows the same data but with fresh weight now shown on a vertical axis. Circles indicate the data points of the 19 blends in the experiment (some are obscured by the surface). In addition, vertical lines show the *upper half only* (for clarity) of 95% confidence intervals on the plant response data.

Figure 8 (B) shows graphically the high variance in the plant response data superimposed on an underlying trend revealed by the colour coding. There are two important points to note. Firstly, 'ripples' in the response surface are within the range of the confidence interval, meaning there is little evidence in the data that such ripples are real features. They are consistent with spread in the data and as such should not be modelled. This supports the use of simple modelling functions; the data is simply not refined enough to support complicated models.

Secondly, because of the magnitude of the variance in the data, if only a small range in parameter values had been selected for study it would have been difficult to resolve the plant response dependences on those parameters. Therefore, our strategy of selecting basis materials as widely spaced as possible in parameter space is vindicated, since this maximised the opportunity of quantifying underlying trends of plant response as a function of material parameters.

Modelling reveals trends and suggests a choice of material. However, the variance in the data ultimately imposes limits on any attempt to predict actual responses. The data support the case that a somewhat inferior material could in fact outperform a superior material in a given trial due simply to the spread in possible plant response.

Model Prototype

In keeping with the project objectives, we have created a prototype of a predictive model that will act as a tool for substrate selection. The model has a user-friendly graphical interface. **Figure 9** shows a screen shot of the prototype model user interface:

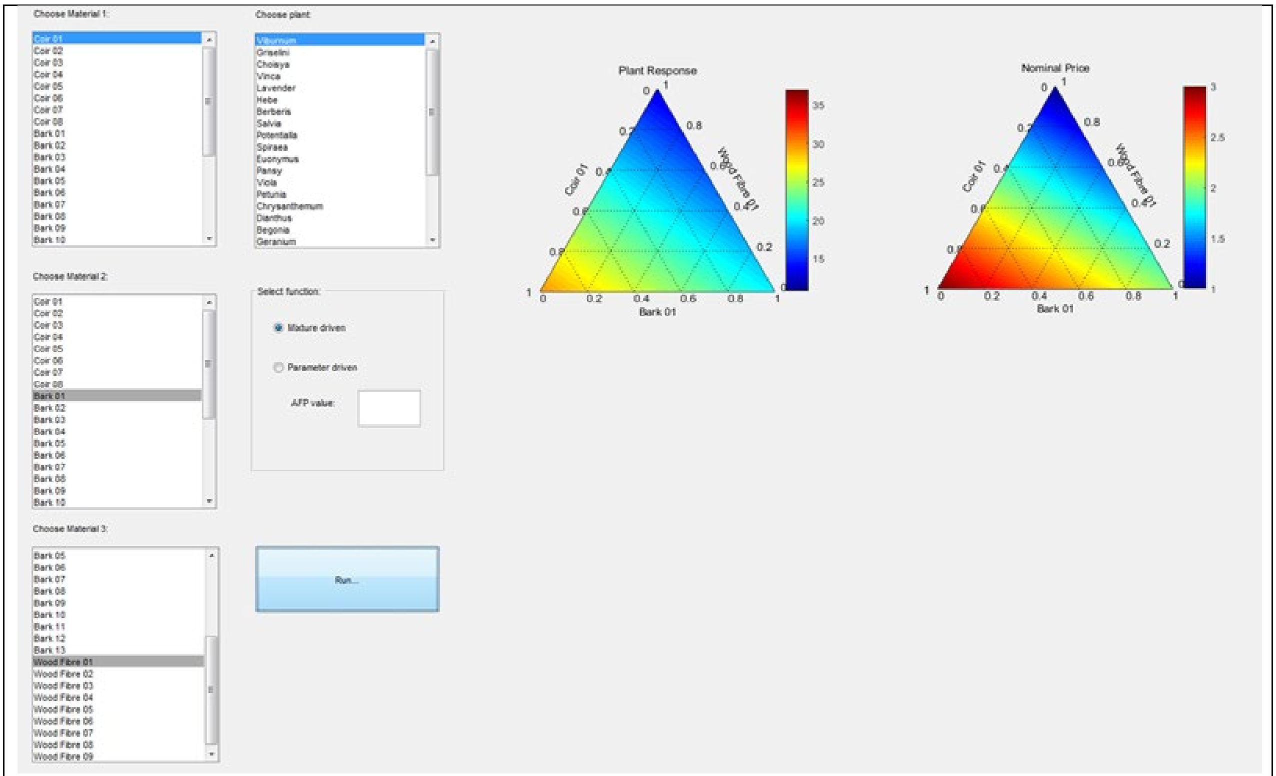


Figure 9. Screenshot of the predictive model interface.

The model is written in the Matlab programming language. As implemented, it is focused on blends of three basis materials. The user selects these materials via the three left-most drop-down boxes, 'Choose Material 1' etc. A plant of interest is selected via a fourth drop down box, 'Choose Plant'. As currently implemented the output is via two ternary plots, one for plant response and one for blend price. All possible blends of the selected materials are present within the triangular ternary plots, with the corners corresponding to pure materials and the edges to mixes of two materials. The boxes are colour coded with red representing good performance or high cost, depending on the plot. Coordinates within the two triangle zones match, meaning that a specific composition (as given by a point in the left-hand triangle) corresponds to a cost figure given by the same coordinates but in the right-hand triangle. The space below the two triangles is allocated to future developments, including a sustainability index value.

A triangular representation for the output allows a ready presentation of the flexible three-component blends option. In addition, the ternary plot is familiar as a soil particle size classification and group diagram. Two component blends could be represented as a colour-graded rectangle or line, but as formulated, a two-component blend gives a triangle coloured coded in parallel bands from one corner to the opposite side. Four component mixtures could be implemented as a tetrahedron, but this is difficult to interpret, so four component mixtures will be implemented by first combining two components.

Existing data from CP138 provides the raw material for the drop-down materials menus. New materials must have their properties measured using the ADAS Standard Operating Procedure (SOP). Property parameters are read in from an excel file stored on the user's computer, as are plant response data and costs, allowing for commercial confidentiality since these data files are local to the user only. Indicator plants represent classes for which plant response versus material parameters are broadly comparable, a feature that can be refined as more data is accumulated.

The underlying model itself is a simple regression model that respects the variance in plant response data and is based on plant trial data versus blends characterised by their (AFP, D_b, AW) values. The coefficients appearing in the model are plant-specific. In addition, the coefficients are specific to the physical parameter measurement protocol (i.e. the ADAS SOP).

WP3: On-site growing media testing and development

Approach summary

During 2019, trials were conducted both on grower sites and at the experimental site of ADAS Boxworth (**WP3**, **Tasks 3.1**-**3.4**). There were also some grower trials from 2018 which had overwintered, and were concluded in early 2019. Each trial has been summarised below, and further information can be found in the Appendices. All experimental work has been informed by the outputs of **WP2**. Plant performance in prototype growing media blends were tested in "pre-campaigns" at ADAS Boxworth and the best performing growing media were tested under commercial conditions at hosted grower sites and were termed "main campaigns". All data were analysed using Analysis of Variance (ANOVA) with use of Duncan's multiple range test to separate treatments. The test was used with a 95% confidence level, and throughout the report, mean values have been used to determine statistically significant differences, as is concurrent with previous CP138 reports.

2018 Second generation prototype blend testing – overwintered trials on grower hosted sites

During 2018, trials were carried out on four grower sites, with most of the nurseries hosting more than one trial. The completed trials were reported in the CP138 Year 4 Annual Report, however, trials on two of these sites overwintered into 2019 (**Table 1**) and therefore are reported in this Final Report. Each trial consisted of five peat-free prototype blends (four 2nd generation blends; Prototypes 4-7, plus one 1st generation blend; Prototypes 1-3), plus the nurseries' standard product, resulting in six treatments per trial. Prior to the trials commencing, the blends were analysed for their chemical properties, and then fertilisers were added as appropriate, to try to ensure that the blends were balanced nutritionally at the beginning of each trial. Nutrition levels for each crop were agreed with the host grower prior to trial commencement. This was to ensure that observed differences were not because of nutrient availability but because of growing media blend physical properties. In the soft fruit trials, no additional fertilisers were added prior to trial commencement, as the coir used as the nursery standard does not have any fertiliser added to it; all nutrients are applied through liquid feeding.

Table 1. Overwintered grower hosted trials in 2018.

Host	Trial	Duration
EU Plants	Raspberry prop	Planted week 17, 2018.
EU Plants	Strawberry prop	Planted week 28, 2018.
Darby Nursery Stock	HNS Liners and Finals	Potted week 20, 2018. Lavender finals completed week 40, 2018. All other species overwintered into 2019.

Cane fruit propagation – raspberries
Methods

The raspberry propagation trial was carried out at EU Plants Ltd (Finchampstead, RG40 3TS and Millets Farm, OX13 5PD) using propagated material of Glen Ample and Maravilla, and ran from April 2018 until

December 2018. For each trial, six growing media treatments were used, treatments were replicated six times and plots were set out in a randomised trial design (**Appendix 1**).

The raspberry cuttings were stuck into 84-cell trays (**Figure 10**) for the initial propagation stage in week 17 2018, with one tray per plot, giving a total of 3024 cuttings per treatment for each variety. Each tray was hand-filled with the relevant growing media, labelled and wet-up by sprinkler before sticking. The plant material was hand stuck by nursery staff to ensure that all trays were even and to a commercial standard. The trays were placed alongside the nurseries' commercial crop on plastic pallets to prevent them from touching the floor, and the plants were grown on within a polytunnel, with overhead irrigation.

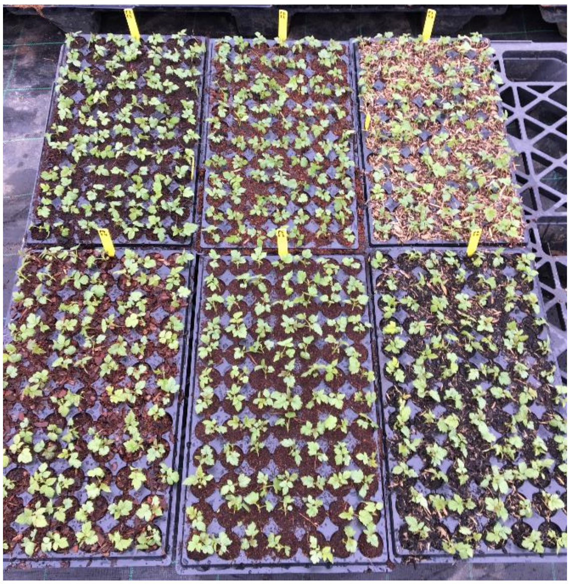


Figure 10. Trays filled with different growing media blends and raspberry cuttings stuck in week 17 2018.

Six weeks later, in week 23, the trial was assessed for the number of leaves per plant, plant height, plant quality (scale of 0-5) and root development (scale of 0-5) for four plants per plot. For scoring criteria see **Appendix 1**. A sub-sample of the raspberry plants were then transplanted into 2 L pots (two plants per pot) for growing on (**Figure 11**). The Maravilla remained at Manor Farm, whilst the Glen Ample were moved to Rectory Farm, Oxfordshire. The plants were transplanted into the same media that they had been propagated in. As before, pots were filled with the growing media blends by hand, and the plants were transplanted by nursery staff to ensure the transplanting was even and to a commercial standard. Each plot contained one pot holding two plants, with each treatment replicated six times, resulting in 12 plants per treatment, per cultivar. The plants were grown on in the field in a fully randomised trial design, with the pots set-down on one of the commercial lines, with mypex covering the soil. The trial was watered and fed via drip irrigation. Plants were treated for pest and disease as appropriate, following the standard practice of the nursery. There were no pest or disease issues during the trial.

Figure 11. Trays of raspberries ready for transplanting (left) and plants transplanted 2 L pots (right), week 23 2018.

The trial on both sites was assessed at six, 12, 19 and 24 weeks after transplant, for height, quality (scale of 0-5) and the number of nodes per cane, on one cane per plot. For scoring criteria see **Appendix 1**. Plants were tagged to ensure the same ones were assessed at each date. In week 51 2018, the long cane produced in the trial for both varieties were placed into cold storage for the winter until they were shipped to New Farm Produce for cropping production. Methods and results from the trial at New Farm Produce can be found further on in the report, in the 2019 trials section.

Results

Glen Ample propagation

Pre-transplant

At the pre-transplant assessment in week 23 2018, there were no significant differences between treatments for the number of leaves per plant. Plant quality was highest in the coir nursery standard followed by prototype 5 and 6 (4.7, 4.6 and 4.5 out of 5 respectively) and differences across the treatments were statistically significant (p <0.001). The plants grown in prototype 4 had the lowest quality at this stage (3.1) although all treatments scored greater than 3.0, the baseline for acceptable quality.

The trends for quality were reflected by plant height, with significant differences between treatments (p <0.001). The largest plants were produced by the coir nursery standard (17.9 cm), which was significantly taller than the other blends except for prototype 5. The shortest plants were produced in prototype 4 (5.9 cm), this was significantly shorter than all other treatments.

There were also significant differences between treatments for root development (p =0.007, **Figure 12**). The coir nursery standard and prototype 6 both scored over 4 for root development and neither of these were significantly better than prototype 5. Again prototype 4 had the lowest root score of all of the treatments at 3.1 out of 5.

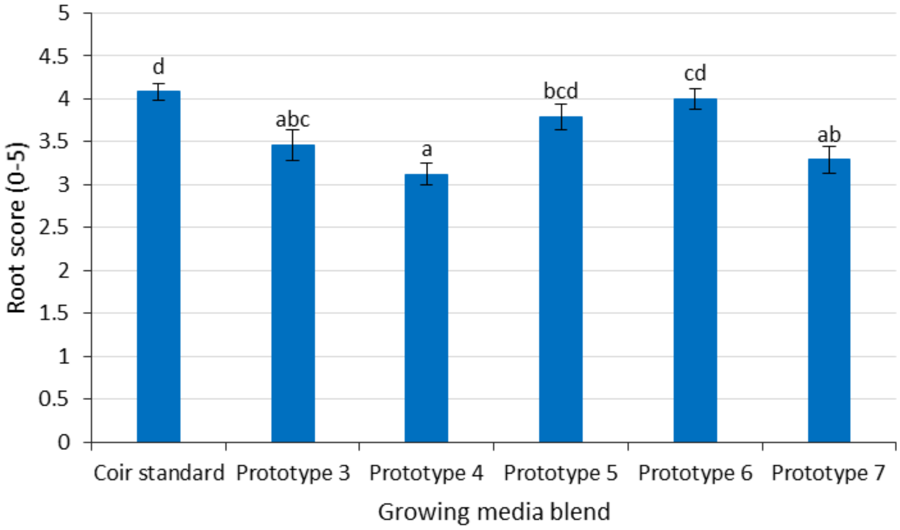


Figure 12. Average root scores for Glen Ample grown in different growing media blends at transplant, week 23, 2018. Differences across treatments are statistically significant (p = 0.007). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

Post-transplant

The canes grew well post-transplant in all of the growing media blends tested and at the six week after transplant assessment there were no differences in the height of the canes. When measured just before being put into cold storage 24 weeks after transplant, there were still no significant differences in the cane height. The mean height of the canes ranged from 155.1 cm in prototype 7 to 164.5 cm in the nursery coir standard.

The number of nodes per plant was not significantly different between treatments at any of the assessment dates (**Table 2**). Six weeks after transplant, four out of the six growing media blends trialled had an average of 17 nodes per cane, with the remaining two having 15 nodes per cane. At all of the subsequent assessment dates prototype 7 had the fewest average nodes per cane, finishing on 30 nodes. The highest number of nodes at the end of the trial period were in the nursery coir standard, prototype 3 and prototype 4, which all had an average of 32 nodes. The average distance between the nodes in the Glen Ample canes was just over 5 cm for all of the growing media blends, with just 2 mm difference between the largest and smallest.

Table 2. Average number of nodes per cane at each assessment date, Glen Ample. No significant differences between the growing media blends.

	Average number of nodes per cane				Height 24	Average distance
Treatment	**6 WAT**	**12 WAT**	**19 WAT**	**24 WAT**	**WAT (cm)**	**between nodes (cm)**
Coir standard	17	30	32	32	164.5	5.1
Prototype 3	17	30	32	32	161.5	5.0
Prototype 4	15	31	32	32	162.6	5.1
Prototype 5	17	29	31	31	161.8	5.2
Prototype 6	17	28	31	31	158.5	5.1
Prototype 7	15	28	30	30	155.1	5.1

*WAT = weeks after transplant

The rooting of the raspberry plants was significantly different at the end of the propagation trial (p = 0.016). Prototype 3 and the coir nursery standard had the highest root scores, with prototypes 6 and 7 have the lowest rooting score. Although these were significantly lower than the coir nursery standard, the root scores were still above 4, which represents excellent rooting.

Results

Maravilla propagation

Pre-transplant

At the pre-transplant assessment in week 23, there were no significant differences between treatments for the number of leaves per plant. Plant quality was highest in prototype 5 followed by the coir nursery standard (5 and 4.9 out of 5 respectively) and differences across the remaining treatments were statistically significant (p <0.001). The plants grown in prototype 7 had the lowest quality at this stage (3.1) although all treatments scored greater than 3.0, the baseline for acceptable quality.

The trends seen in the quality of the plants were reflected in the height, with significant differences between treatments (p <0.001). The largest plants were produced in the coir nursery standard (14.9 cm), followed by prototype 5 (14.4 cm) and the shortest plants were produced in prototypes 4 and 7 (8.1 cm and 8.4 cm respectively). The plants in these blends were significantly shorter compared with all other treatments.

There were significant differences between treatments for root development (p <0.001, **Figure 13**). Prototype 7 had significantly poorer rooting compared to all experimental treatments, scoring 3.3. All of the other growing media blends had roots scoring above 4, meaning that they had a well-developed rooting system.

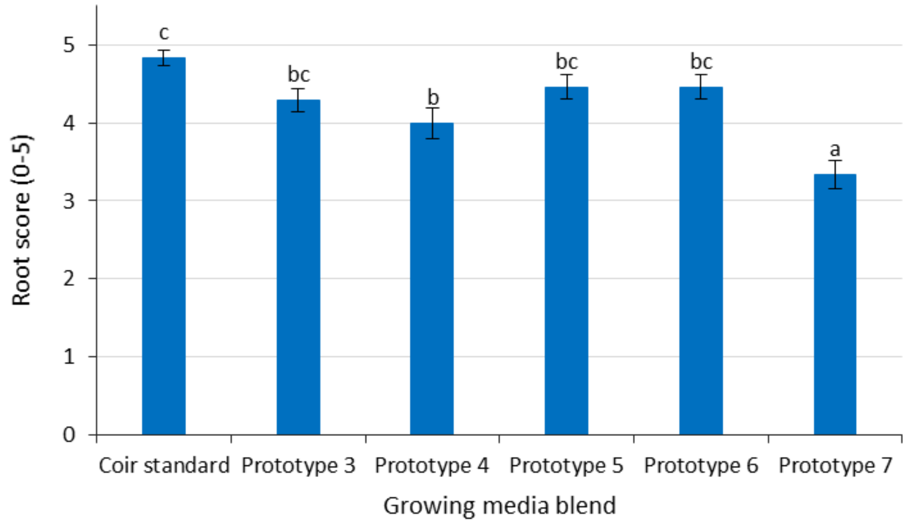


Figure 13. Average root scores for Maravilla grown in different growing media blends at transplant, week 23, 2018. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

Post-transplant

After transplant into 2 L pots all of the plants in the treatments grew well, however, prototype 7 was consistently behind the other treatments at all assessment dates. At the final assessment 24 weeks after transplant there was a significant difference in the cane height (p = 0.020), with the tallest plants produced in prototype 4 (199.6 cm) and the shortest plants in prototype 7 (159.0 cm) which was significantly shorter than the canes grown in the other growing media blends (**Figure 14**). There were no other significant differences between the other blends.

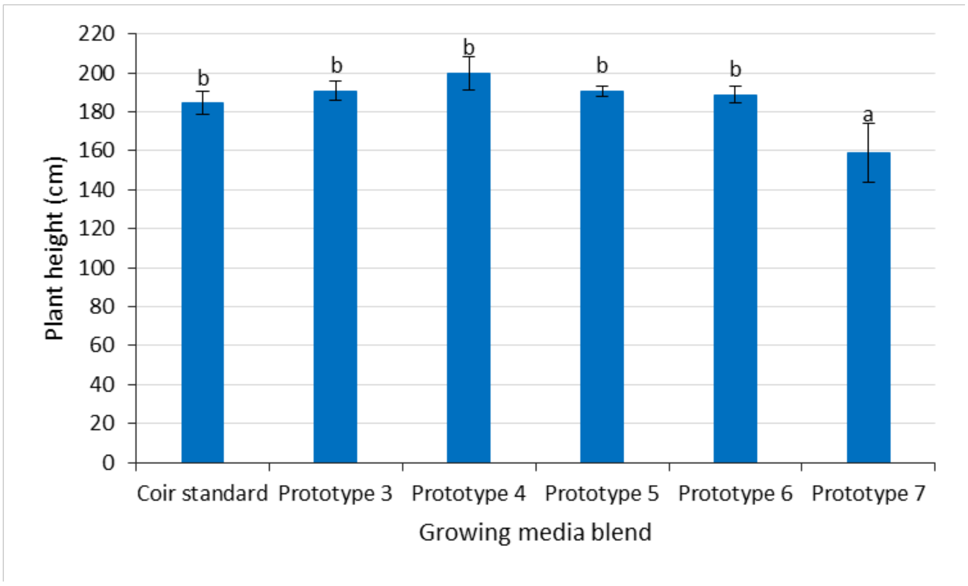


Figure 14. Average plant height for Maravilla grown in different growing media blends 24 weeks after transplant, week 49, 2018. Differences across treatments are statistically significant (p =0.020). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

The number of nodes per cane was not significantly different between treatments at the first assessment, six weeks after transplant. By the final assessment, the differences between treatments were significant (p = 0.005; **Table 3**), with prototypes 3, 4 and 6 producing the greatest number of nodes (40 nodes). The smallest number of nodes were produced in prototype 7 (30 nodes) which was significantly different to the coir nursery standard and all of the other blends.

Table 3. Average number of nodes per cane at each assessment date, Maravilla. Superscript letters [a] and [b] indicate treatments are significantly different.

	Average no. of nodes per cane				Height 24 WAT	Average distance between nodes
Treatment	**6 WAT**	**12 WAT**	**19 WAT**	**24 WAT**	**(cm)**	**(cm)**
Coir standard	13	32	38 [a]	39 [a]	184.3[a]	4.8
Prototype 3	12	33	38 [a]	40 [a]	190.7 [a]	4.8
Prototype 4	9	29	38 [a]	40 [a]	199.7 [a]	5.0
Prototype 5	12	31	37 [a]	39 [a]	190.5 [a]	4.8
Prototype 6	11	31	38 [a]	40 [a]	188.8 [a]	4.8
Prototype 7	9	28	30 [b]	31 [b]	159.0 [b]	5.1

*WAT = weeks after transplant

Discussion

In the Glen Ample trial, at the pre-transplant assessment in week 23, 2018, there were significant differences between treatments for all assessment criteria, apart from the number of leaves per plant. The coir nursery standard performed well, as did prototypes 5 and 6, producing the largest plants which were high quality, with a well-developed root system. Of the remaining prototypes only prototype 4 produced poor quality plants, which were small at the time of transplant and had a poorer root system, although the root score was still above the minimum for transplanting. At this point all of the prototype blends were performing well except for prototype 4.

At the post-transplant stage of the Glen Ample propagation trial just before cold storage, the plants had all caught up in plant height and there were no significant differences between the cane heights in any of the treatments. During this growing on stage prototype 7 had been slightly behind the other treatments and initially had the lowest number of nodes at the first assessment (six weeks after transplant) along with prototype 4. Prototype 4 caught up with the other prototype blends during the rest of the growing season and at 24 weeks after transplant the number of nodes and the height of the canes was comparable to the other prototype blends. Prototype 7 remained slightly behind the other prototypes, however the differences were not significant.

In the Maravilla trial, at the pre-transplant assessment in week 23, 2018, apart from the number of leaves per plant, there were statistically significant differences across the treatments for all assessment criteria. The coir nursery standard and prototype 5 performed well again, producing large, high quality plants with well-developed roots. Prototype 7 stood out as being poorer than the other growing media blends at this stage. This prototype along with prototype 4 produced the smallest plants, which were considerably shorter than the other prototypes and the coir nursery standard.

During the post-transplant stage of the Maravilla trial the differences seen in the height of prototype 7 continued and this remained statistically significantly shorter than the canes of any of the other growing media blends. Although prototype 4 plants at transplant were approximately the same size as those in prototype 7, these plants were able to catch up with the remaining blends and produced the tallest canes at the end of the propagation period. The number of nodes on the canes in prototype 4 were also lower than in the other growing media blends at after six weeks from transplant, however, by the time the canes were going into cold storage this had increased in line with the other treatments and these canes had some of the highest number of nodes.

Soft fruit propagation – strawberries
Methods

The strawberry propagation trial was carried out at EU Plants Ltd (Finchampstead, RG40 3TS) using propagated material of Malling Centenary, and ran from April 2018 until December 2018. Six growing media treatments were used and these were replicated six times to give a total of 36 plots per cultivar. Plots were set out in a randomised trial design within an uncovered polytunnel alongside the commercial crop and irrigated overhead (**Appendix 2**).

The strawberry runners were stuck into 84-cell trays (**Figure 15**) for the initial propagation stage in week 28 2018, with one tray per plot, giving a total of 3024 cuttings per treatment. Each tray was hand-filled with the relevant growing media, labelled and wet-up by sprinkler before sticking. The plant material was hand stuck by nursery staff to ensure that all trays were even and to a commercial standard.

Figure 15. Trays being filled with different growing media blends and strawberry runners stuck in week 28 2018.

Four weeks later, in week 32, the trial was assessed for plant height, plant quality (scale of 0-5) and root development (scale of 0-5) for four plants per plot. For scoring criteria see **Appendix 2**. A sub-sample of the strawberry plants were then transplanted into 18 cell trays for growing on (**Figure 16**).

Figure 16. Tray of strawberries ready for transplanting (left) and plants transplanted into 18 cell trays (right), week 32 2018.

The trial was assessed at five, 10 and 15 weeks after transplant, for height, quality (scale of 0-5) and root quality. At the final assessment, the crown size for each treatment was also recorded. In week 51 2018, the tray plants produced in the trial were placed into cold storage for the winter until they were shipped to New Farm Produce for cropping production.

Results

Pre-transplant

At the pre-transplant assessment in week 32, there were significant differences between treatments for plant height ($p < 0.001$). The largest plants were produced by the coir nursery standard (20.8 cm), which was significantly taller than the other blends (**Figure 17**). Prototype 7 was significantly shorter than all other treatments (12.6 cm).

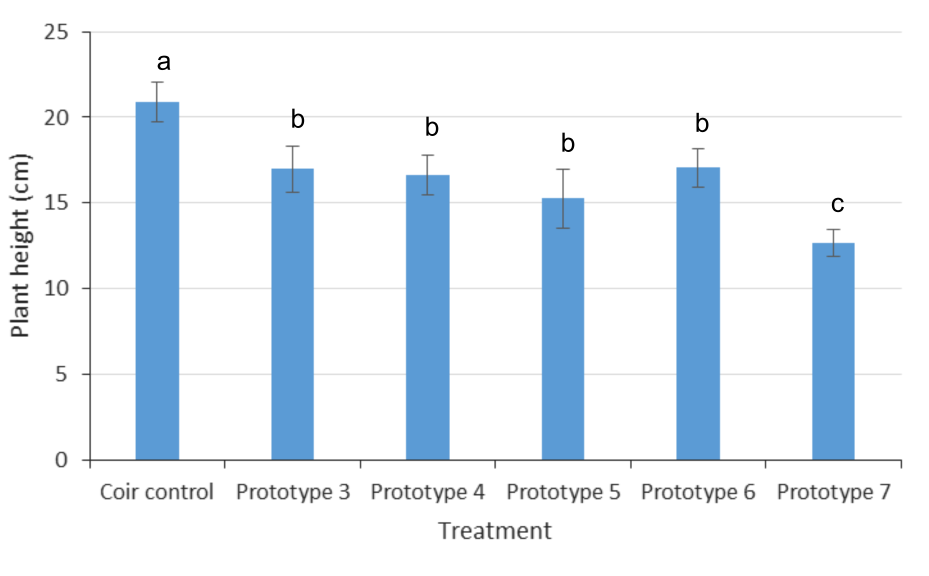


Figure 17. Average plant height of Malling Centenary grown in different growing media blends at transplant, week 23, 2018. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

The trends for height were reflected by plant quality, which was highest in the coir nursery standard followed by prototype 3 and 4 (3.7, 3.4 and 3.2 out of 5 respectively) and differences across the treatments were statistically significant (p <0.001). The plants grown in prototype 5 and 7 had the lowest quality at this stage (2.5 out of 5) and these did not meet the baseline for acceptable quality of 3.0, this was as a result of these plants being smaller than the other treatments. These plants were still transplanted to monitor development in the second phase of propagation.
There were significant differences between treatments for root development (p =0.003). The coir nursery standard and prototypes 3, 4 and 6 all scored over 4 for root development. Again, prototypes 5 and 7 had the lowest root score of all of the treatments at 3.7 out of 5.

Post-transplant
The plants generally grew well post-transplant in all of the growing media blends tested, although prototype 7 was still significantly shorter than the other blends at the five and 10 week assessments (p =0.003 and p =0.006 respectively). By the final assessment before cold storage 15 weeks after transplant, the plants in prototype 7 had caught up and there were no statistically significant differences in the plant height. At this point prototype 3 plants were the tallest (19.0 cm) and prototype 7 were still the smallest plants at 16.3 cm.

The crown size was not significantly different between treatments at the final assessment date before cold storage. The largest crowns were in prototypes 3 and 5 (21.0 mm and 21.1 mm respectively), with the smallest crowns in prototype 7 (20.0 mm). The coir nursery standard produced crowns of 20.5 mm. There were also no significant differences in the plant or root quality at the end of the propagation trial, with all treatments scoring a maximum of 5 for both.

Discussion

In the propagation trial at EU plants there were significant differences for all assessed criteria in the plants grown in the initial phase before transplant. The coir nursery standard performed well, as did prototypes 3 and 4, producing the tallest plants which were high quality, with a well-developed root system. Prototype 3 had been the best performing blend in the strawberry propagation trial in 2017. Of the remaining prototypes prototype 7 and 5 produced poor quality plants, which were small at the time of transplant and had a poorer root system.

Once transplanted into larger cell trays the plants grew well with prototype 5 catching up with the other treatments at the assessment five weeks after transplant. Prototype 7 plants remained smaller than the plants in the other blends even at the final assessment 15 weeks after transplant, however, at this stage the differences were not statistically significant. The plants were all of excellent quality before going into cold storage and all had extremely well developed rooting systems.

In strawberries, crown size is a good predictor of vigour and yield in the following year. The crown size just before cold storage was not significantly different between the treatments, however on average prototypes 3 and 5 were 0.5 mm larger than the coir nursery standard, which had the next largest crowns and were 1 mm larger than the crowns in prototype 7, which had the smallest crowns.

Hardy Nursery Stock

Methods

Trials were carried out on both potted liner material of Lavender and Vinca (finals trial), and potted plugs of Lavender, *Potentilla* and *Spirea* (liners trial) at Darby Nursery Stock (Thetford, IP26 4QU) from week 20 2018 to week 18 2019. In each trial, six growing media treatments were used, treatments were replicated six times and plots were set out in a randomised trial design (**Appendix 3** and **Figure 18**).

For the finals trial, liners were potted into black 2 L pots (five plants per plot) filled with the relevant growing media, and grown on mypex under polythene (Lavender) and on mypex outside (Vinca) as per commercial practice. Irrigation was delivered via sub-irrigation for the Lavender, and overhead for the Vinca. As Lavender is a relatively quick growing crop, this trial was assessed at 4, 8, 12, 16 and 20 weeks after potting, and was completed in week 40 2018. The Vinca was assessed at 4, 8, 12, 16, 20, 28 and 49 weeks after potting, finishing in week 18 2019. At each assessment date, plots were assessed for plant quality (5 plants per plot, scale 0-5), plant height (3 plants per plot) and root development (3 plants per plot, scale 0-4). At the end of the trial, fresh and dry weight was recorded for three plants per plot. For scoring criteria see **Appendix 3**.

For the liners trial, plugs were potted into 9 cm liners (five plants per plot) filled with the relevant growing media, and grown on sand under polythene as per commercial practice. Irrigation was delivered via sub-irrigation. Assessment dates and criteria were the same as for the finals trial, finishing in week 18 2019, with fresh and dry weights completed on three plants per plot.

Figure 18. Vinca finals trial set out on mypex outside in a randomised trial design, week 28 2018.

Results

Lavender finals

At the first assessment, four weeks after transplant, there were no significant quality differences between treatments. However, by the eight week assessment, differences were noticeable, with prototype 7 significantly poorer than all other treatments ($p<0.001$). These plants were just starting to look paler than the other treatments, and were not putting on quite as much growth. The differences in quality remained the same throughout the trial, although at the final two assessments (16 and 20 weeks after potting), quality had reduced across the trial in all treatments. However, the trend was still the same with both prototype 7 and prototype 5 poorer quality.

Height differences were significant throughout the whole trial period. Prototype 7 was significantly shorter than the nursery standard at four and eight weeks after potting ($p =0.018$ and $p<0.001$ respectively). It then continued to be significantly shorter, and by the time of the final assessment prototypes 4, 5 and 7 were all significantly shorter than the nursery standard ($p =0.091$). The nursery standard measured 47.9 cm, and the shortest plants in prototype 7 measured 38.6 cm.

Plant fresh weight was significantly lighter ($p =0.138$; **Figure 19**) in prototypes 2 and 5 (53.1 g and 52.6 g respectively) compared to the nursery standard (67.3 g). This was also reflected in the dry weight, although prototypes 4 and 7 (22.9 g and 22.0 g respectively) were also significantly lighter than the nursery standard ($p =0.014$). The dry weight of the nursery standard was 27.0 g.

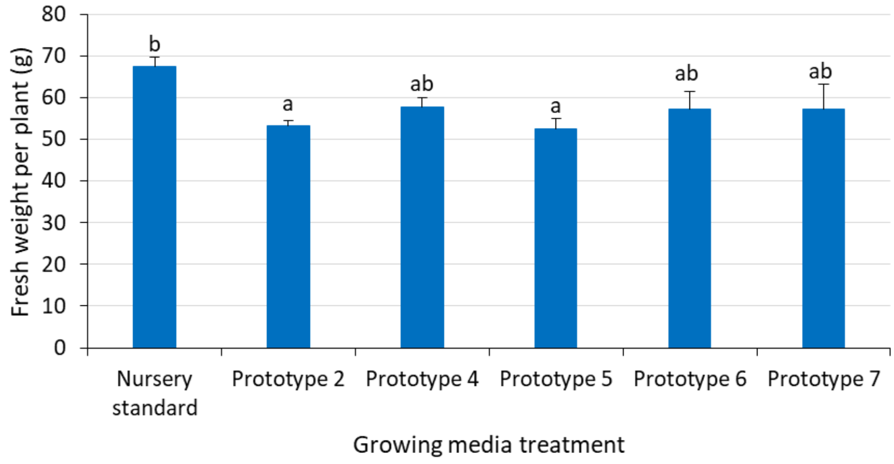


Figure 19. Average Lavender fresh weight (g) in different growing media blends 20 weeks after potting, week 40, 2018. Differences across treatments are statistically significant (p =0.138). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

Vinca finals

At the first assessment four weeks after potting, there were no significant differences between treatments for plant quality. There were significant differences however at the next four assessments (8, 12, 16 and 20 weeks after potting), with prototypes 4 and 5 significantly different to the nursery standard ($p < 0.01$, $p < 0.01$, $p < 0.05$ and $p < 0.001$ respectively). These prototypes were smaller than the others, and the foliage was slightly paler. However, by the time of the final assessment 49 weeks after potting, differences between treatments were no longer significant. Prototype 4 was still the lowest scoring (3.7 out of 5) but was above the acceptable score of 3.0. The nursery standard scored 3.9 and prototype 7 received the highest score of 4.1. The plants had overwintered outside and all were of good quality, with no sign of frost damage or root disease.

Because Vinca spreads out across the pot, rather than growing upwards, percentage pot cover was assessed, rather than height. Throughout the course of the trial, there were no significant differences between treatments for percentage pot cover. By the end of the trial, all plants had filled out nicely, with the nursery standard at approximately 88% pot cover, and prototype 5 at approximately 83% pot cover (lowest of the six treatments).

For root development, there were differences early on, with prototype 7 showing significantly less root than all other treatments ($p < 0.001$), but by the end of the trial, all treatments had fully rooted, with plenty of white healthy root, and there was no evidence of root disease.

Fresh and dry weight was assessed at the end of the trial, and there were no significant differences for either criteria. The nursery standard had an average fresh weight per plant of 178 g, and prototype 2 had the highest fresh weight of 180 g on average. The lowest fresh weight of 160 g was observed in prototype 5, which correlates with the lower % pot cover seen in this treatment.

Lavender liners

Throughout the Lavender liners trial there were significant differences between treatments with the nursery standard scoring higher than the prototype blends. Only prototypes 4 and 7 scored below 3.0 at the 8, 12, 16 and 20 week assessment, these plants were smaller than the others and were also paler in colour. However, the quality did improve as the trial went on, and by the time of the final assessment 49 weeks after potting, all treatments scored greater than 3.0 (**Figure 20**), meaning that they were all of good quality and foliage colour was even across the treatments. Despite this, there were still significant differences between treatments, with prototypes 2, 4, 5 and 7 scoring significantly lower than the nursery standard and prototype 6 (p <0.001).

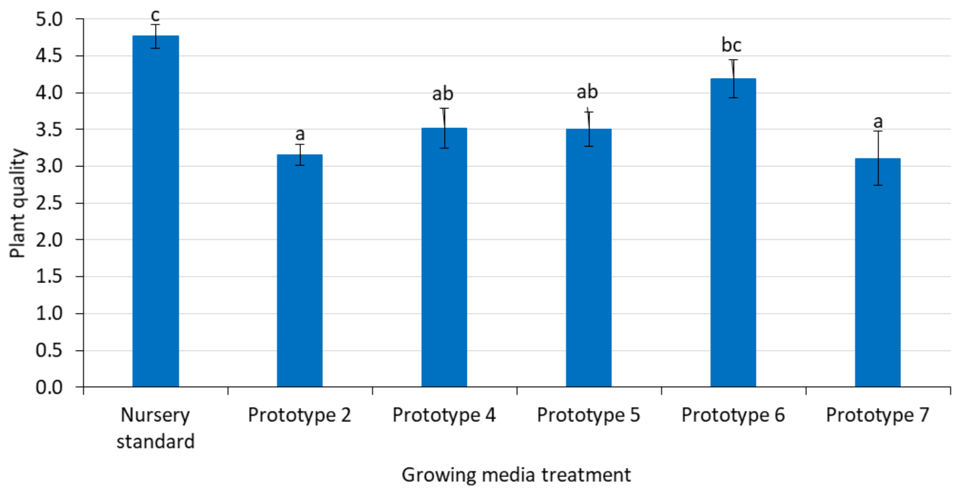


Figure 20. Average Lavender liner quality (scored 0-5) in different growing media blends 49 weeks after potting. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

Plant height was significantly different throughout the trial period, with the nursery standard consistently taller than the prototype blends. At the final assessment, the nursery standard measured 20.1 cm on average and prototype 7 measured 14.5 cm on average, which was the smallest of the prototype blends (p <0.05).

Root development was significantly different four weeks after potting (p =0.008), with less root development in prototypes 6 and 7, but by the end of the trial, all treatments had fully rooted.

There was a significant difference in fresh and dry weight of the plants, which mirrored plant height. The nursery standard had the greatest fresh weight (40.1 g) and prototype 4 has the lowest fresh weight (17.8 g; p<0.001).

Potentilla liners

The quality of the *Potentilla* liners was significantly different throughout the trial period (p <0.001 at all assessment dates). Whilst prototypes 4 and 6 scored just below 3.0 during the summer and autumn assessments, by the time of the final assessment, all treatments scored above the acceptable score of 3.0. Prototype 4 was the lowest scoring treatment with 3.1 and the nursery standard scored 4.0.

Plant height was not significantly different at the first assessment four weeks after potting, but once the plants had established and started to put on more growth, differences were significant, with the nursery standard taller than all prototypes at the final assessment (p <0.001). The nursery standard measured 26.1 cm on average and the smallest plants were seen in prototype 4, with an average plant height of 19.2 cm.

This was reflected in the plant fresh and dry weight, where the nursery standard was significantly heavier than all prototype blends (p <0.001). The nursery standard had an average fresh weight of 16.8 g and the lowest fresh weight was seen in prototype 4 with an average weight of 4.6 g.

Spirea liners

In terms of plant quality, there were significant differences between treatments at all assessment dates, however none of the treatments scored less than 3.0 at any point. Prototypes 6 and 7 scored significantly lower earlier on in the trial, but by the time of the final assessment, the quality of these plants had improved, and only prototype 4 scored significantly lower than the nursery standard (p =0.005; **Figure 21**). As seen in the lavender liners trial, prototype 7 was slightly paler earlier on in the trial, but this was not apparent at the final assessment 49 weeks after potting.

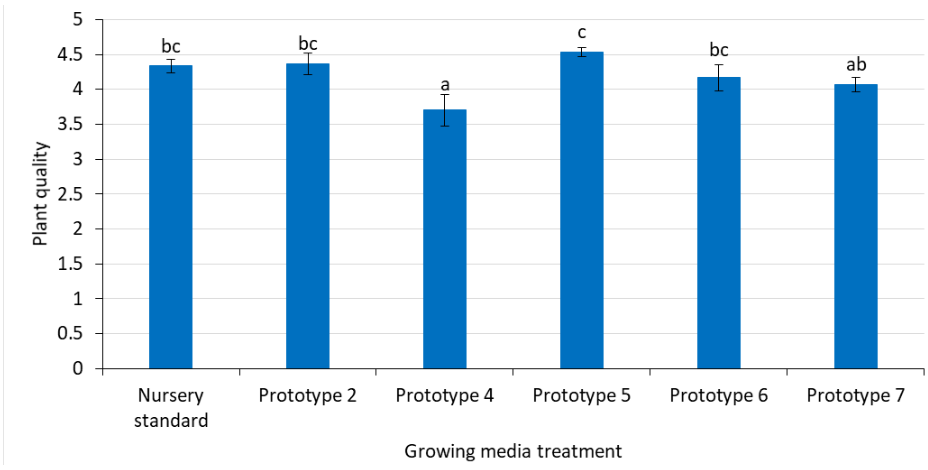


Figure 21. Average *Spirea* liner quality (scored 0-5) in different growing media blends 49 weeks after potting. Differences across treatments are statistically significant (p =0.005). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

Plant height was also significantly different throughout the trial period, with the nursery standard taller than the prototypes. By the end of the trial, only prototypes 4, 6 and 7 were significantly shorter than the nursery standard (p =0.002). The nursery standard measured 42.6 cm and the shortest plants were grown in prototype 6 with an average plant height of 35.6 cm. All other prototypes measured between 35.9 cm and 41.2 cm.

Differences in plant height were reflected in the fresh and dry weight, with the nursery standard significantly greater than all prototypes (p <0.001). The nursery standard had a fresh weight of 20.8 g and the lightest plants were grown in prototype 7 with an average fresh weight of 9.8 g.

Discussion

In the finals trial, generally all prototypes were successful, particularly in the Vinca trial. By the time of the final assessment, all plants had covered more than 80% of the pot and there were no significant differences between treatments for plant quality. The plants had also fully rooted. The blends used in these HNS trials were a mixture of quite light, open blends with coarser or fibrous material (prototypes 2, 4 and 5) and heavier, finer grade materials (prototypes 6 and 7). Whilst all blends worked well in the Vinca trial, there was more of a difference in plant quality and height in the Lavender trial, with a reduction in plant quality for all prototype blends, although these were still marketable. Species such as Lavender which are more sensitive to growing media composition require more careful management of irrigation and nutrition in order to produce a high quality plant, whereas more robust species such as Vinca are more tolerant of different growing media, and a range of physical properties.

There appeared to be greater differences in the liners trial compared to the finals, and the trends were similar for each of the liner species. Generally the nursery standard performed better, although plants grown in the prototype blends were good at the end of the trial. As with the Lavender finals, it is likely that for younger plant production, to get the most out of the growing media blend, greater management of irrigation and nutrition is required. However, these trials were grown on a nursery where the growing system is optimised for peat-reduced growing media, and results were encouraging. Therefore the trial has demonstrated that a range of materials with different physical properties can be used for HNS production. Ideally, better results will be achieved if a blend contains a mix of materials which will provide adequate AFP for rooting and aeration, and suitable AW to retain moisture over a long period of time.

2019 Third generation prototype blend testing – "main-campaign" grower hosted trials

During 2019, trials were carried out on four grower sites (**Table 4**). Five experimental prototype blends were tested against the nurseries standard product, resulting in six growing media treatments per trial. Three of these blends were '3rd generation' peat-free and coir-free prototype blends (Prototypes 8-10) which were originally tested at ADAS Boxworth in 2018. These blends were designed to really test the model, by taking a set of materials which were new to the project ('novel' materials) and create blends purely based on their physical characteristics. This was the start of putting the model into practice. In addition to the 3rd generation blends, there was also one 2nd generation blend (Prototypes 4-7) and one 1st generation blend (Prototypes 1-3) in each trial. This would allow the project team to gather year-on-year data and see whether the results generated in previous years would be replicated. For each sector, the best performing 1st and 2nd generation prototype blends were selected to carry forward, therefore the blends used on the individual nurseries were likely to be different. It is important to note that the source of the coir, bark and wood fibre used in the 2nd generation blends is different to the 1st generation blends. The green compost source remains the same. Because the materials used in the 3rd generation blends are relatively new to the growing media manufacturers, and are not yet commercially available, these have been kept anonymous throughout the report to maintain commercial confidentiality. Prior to the trials commencing, the blends were analysed for their chemical properties, and then fertilisers were added as appropriate, to try to ensure that the blends were balanced nutritionally at the beginning of each trial. Nutrition levels for each crop were agreed with the host grower prior to trial commencement. This was to ensure that observed differences were not because of nutrient availability but because of growing media blend physical properties. The prototype blends plus the standard nursery blends were also tested for physical properties. All data were analysed using Analysis of Variance (ANOVA) with use of Duncan's multiple range test to separate treatments. The test was used with a 95% confidence level, and throughout the report, mean values have been used to determine statistically significant differences, as is concurrent with previous CP138 reports.

Table 4. Grower hosted trials in 2019.

Host	Trial	Duration
James Coles and Sons Ltd	HNS Finals	Potted week 19. Trials completed week 42. Sub-sample planted into the field to assess establishment in 2020.
Double H	Pot chrysanthemum	Set-up week 20. Completed week 30.
New Farm Produce	Raspberry	Planted week 15. Completed week 26.
New Farm Produce	Strawberry	Planted week 15. Completed week 30.
Delfland Nurseries	Veg prop	Sown week 28, planted out week 34. Not yet complete.

Hardy Nursery Stock
Methods

Trials were carried out on potted liner material of *Cistus corbariensis*, *Griselinia littoralis* and *Viburnum tinus* at James Coles and Sons Nurseries (Leicester, LE7 9QB) from week 19, 2019 to week 42, 2019. In each trial, six growing media treatments were used, treatments were replicated 10 times and plots were set out in a randomised trial design (**Appendix 4**).

Liners were potted into black 2 L pots (5 plants per plot) filled with the relevant growing media, and grown on gravel under polythene (*Griselinia* and *Viburnum*) and on mypex outside (*Cistus*) as per commercial practice. Irrigation was delivered overhead (automatic and manual). All plants were assessed at 4, 8, 12, 17 and 23 weeks after potting. At each assessment date, plots were assessed for plant quality (5 plants per plot, scale 0-5) and plant height (3 plants per plot). At the final assessment in week 42, plants were assessed for quality, height, root development (3 plants per plot, scale 0-4) and fresh and dry weight (3 plants per plot). None of the species were trimmed as a total plant weight was required at the end of the trial. For scoring criteria see **Appendix 4**.

Results

Cistus

There was very little difference between treatments for plant quality throughout the Cistus trial, with only the second assessment, eight weeks after potting, showing significant differences ($p < 0.001$). Prototypes 2, 6 and 9 all scored significantly lower than the nursery standard, which scored 4.6. However, these three prototypes were still above the commercially acceptable score of 3.0 (4.0, 3.9 and 3.9 respectively). Prototypes 8 and 10 scored 4.6 and 4.7. These plants, along with the nursery standard, had slightly more growth to them. However, this was not noticeable at the later assessments, and by the end of the trial, all the Cistus were of marketable quality (**Figure 22**), with scores between 4.2 (prototypes 9 and 10) and 4.4 (prototypes 6 and 8).

Figure 22. Cistus grown in different growing media blends at the final assessment, 23 weeks after potting, week 42, 2019. L-R: nursery standard, prototype 2, prototype 6, prototype 8, prototype 9, prototype 10.

There were no significant differences between treatments for plant height until the final assessment in week 42 (p =0.038). At the very first assessment, the nursery standard was marginally shorter than all other treatments, but by the second assessment it was similar to the prototype blends. At the final assessment, the nursery standard was the tallest of the treatments (33.4 cm), with only prototype 6 significantly shorter (29.6 cm; **Figure 23**).

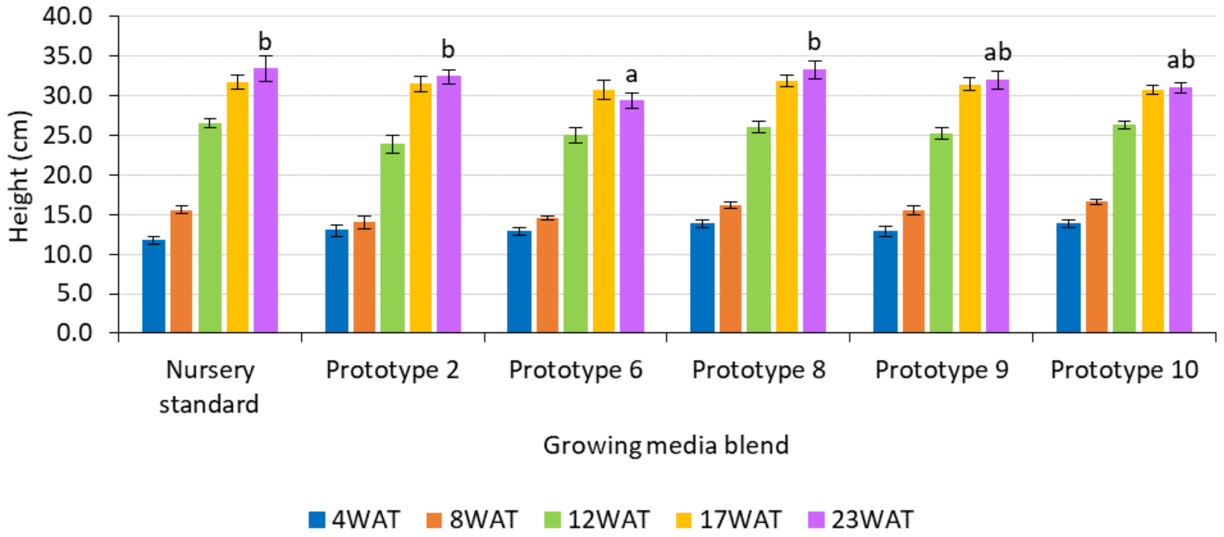


Figure 23. Average *Cistus* height (cm) in different growing media blends throughout the trial period. Differences across treatments are statistically significant 23WAT (p =0.038). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance at the 23WAT assessment.

Throughout the trial period, root development was similar across the six treatments, and by the time of the final assessment 23 weeks after potting, root development remained insignificant. Scores ranged from 3.3 (prototype 6) to 3.8 (prototype 8; rooting in 51 – 75% of pot).

When fresh weight was completed at the end of the trial, differences between treatments were statistically significant (p <0.001; **Figure 24**). Prototype 8 had the greatest fresh weight (87.1 g) and this was significantly greater than the nursery standard (74.4 g). Although prototypes 2 and 10 were also heavier than the nursery standard, this was not significant. Prototype 9 was the only treatment to have a fresh weight which was significantly lighter (61.5 g) than the nursery standard.

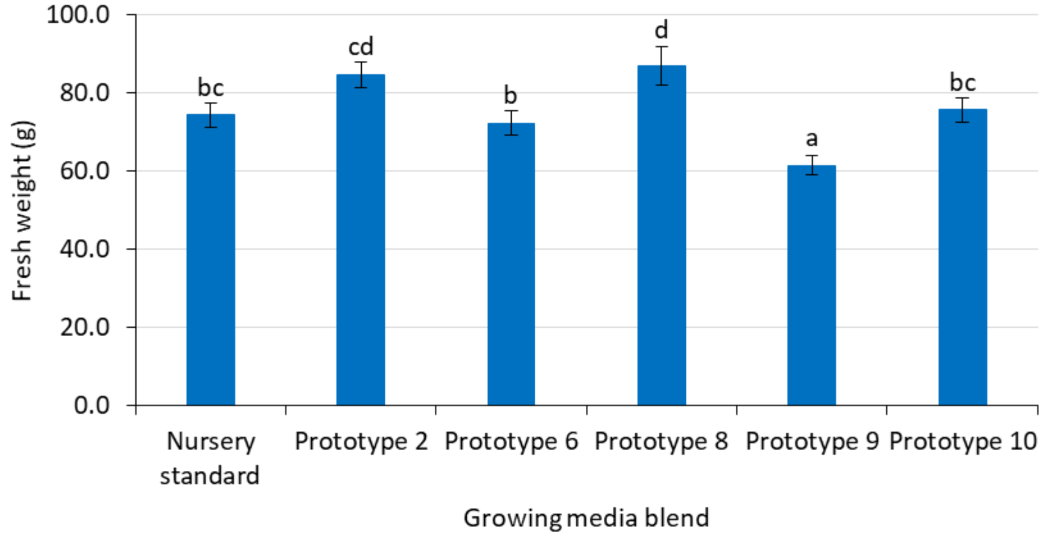


Figure 24. Average *Cistus* fresh weight (g) in different growing media blends 23 weeks after potting, week 42, 2019. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance.

The dry weight generally reflected the fresh weight, with prototype 8 significantly greater than the nursery standard, and prototype 9 significantly lower (p <0.001).

Griselinia

The quality of the *Griselinia* plants was consistently high, and throughout the trial period, there were no significant differences between treatments for plant quality until the final assessment, 23 weeks after potting (p =0.042). At the end of the trial, prototype 10 scored 4.5 which was significantly higher than the nursery standard, which scored 4.1. None of the other treatments were significantly different to the nursery standard, scoring between 4.1 and 4.4. All plants had grown extremely well, with plenty of new growth, and there were no signs of any discolouration or nutritional issues (**Figure 25**).

Figure 25. *Griselinia* grown in different growing media blends at the final assessment, 23 weeks after potting, week 42, 2019. L-R: nursery standard, prototype 2, prototype 6, prototype 8, prototype 9, prototype 10.

In the early stages of the trial, height was significantly different between treatments, but over time the height evened out across the trial and differences were no longer significant (**Figure 26**). Four weeks after potting, prototype 8 was the tallest (31.4 cm) and prototype 2 was significantly shorter (27.6 cm; p =0.006) than all other treatments. The nursery standard measured 29.8 cm. By the end of the trial, although prototype 8 was still the tallest (78.1 cm) and prototype 2 still the shortest (73.9 cm), these results were no longer significant. The nursery standard measured 76.0 cm.

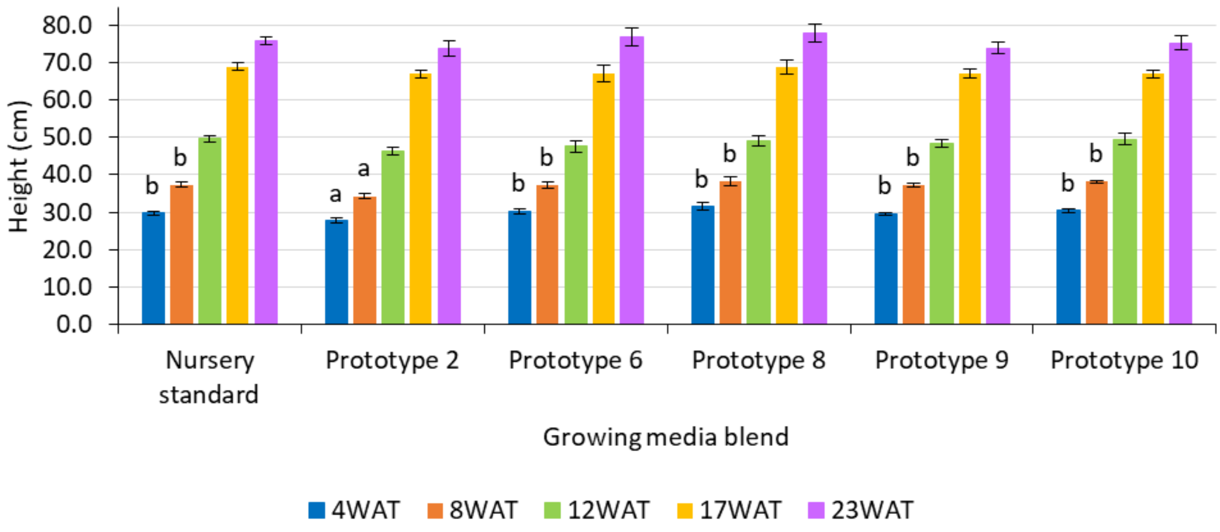


Figure 26. Average *Griselinia* height (cm) in different growing media blends throughout the trial period. Differences across treatments are statistically significant 4WAT (p =0.006) and 8WAT (p =0.010). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance at the 4WAT and 8WAT assessment.

There was some variability in root development across the treatments, and at the end of the trial, differences were significant (p <0.001) with prototype 6 scoring lower than all other treatments (score of 1.7 - rooting in up to 25% of pot). The nursery standard scored 2.3 and the highest level of rooting was seen in prototype 8, which scored 2.7.

At the end of the trial period, there was no significant difference between treatments for plant fresh weight. The greatest fresh weight was seen in prototype 10 (114 g) and the lowest fresh weight was seen in both the nursery standard and prototype 2 (99.5 g). Dry weight showed a similar trend to fresh weight, and differences were not significant. Prototype 10 had the greatest dry weight (34.1 g), however prototype 6 had the lowest dry weight (29.2 g). The nursery standard had a dry weight of 30.4 g.

Viburnum

At the first assessment, four weeks after potting, there were no significant differences between treatments for *Viburnum* plant quality, with all treatments scoring between 4.8 and 5.0. The plants had begun to grow really well, and were putting on plenty of new growth. However, by eight weeks after potting, there was a significant difference between treatments (p <0.001), and plant quality had reduced across the trial. The temperatures did start to get warm from mid-June onwards (six weeks after potting onwards), and it would seem that this did impact on the quality of the *Viburnum* in all treatments, including the nursery standard (**Figure 27**). However, by the end of the trial, all treatments, apart from prototype 6, scored above 3.0, meaning they were of acceptable quality (**Figure 28**). Prototype 6 scored 2.8, so was almost acceptable, this treatment just hadn't put on as much growth as the other treatments.

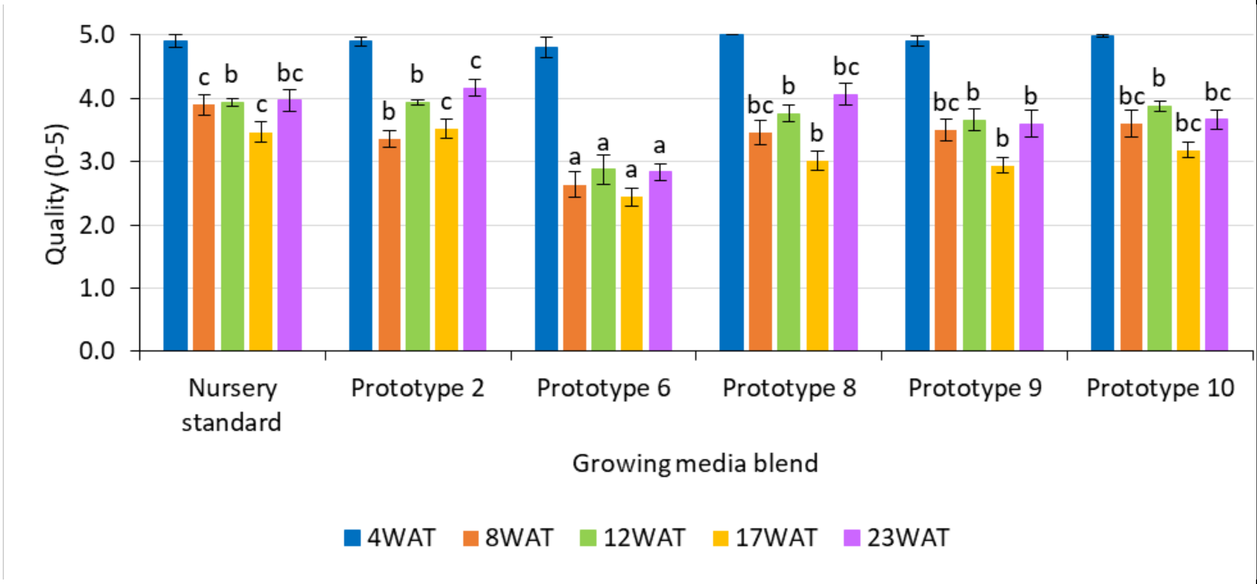


Figure 27. Average *Viburnum* quality (scored 0-5) in different growing media blends throughout the trial period. Differences across treatments are statistically significant 8WAT, 12WAT, 17WAT and 23WAT (p <0.001 for all). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance at the 8WAT, 12WAT, 17WAT and 23WAT assessment.

Figure 28. *Viburnum* grown in different growing media blends at the final assessment, 23 weeks after potting, week 42, 2019. L-R: nursery standard, prototype 2, prototype 6, prototype 8, prototype 9, prototype 10.

Differences in height across the six treatments was significant at each assessment date (**Figure 29**). After four weeks, prototype 2 (14.9 cm) was significantly taller than the nursery standard (13.5 cm). None of the treatments were significantly shorter, although prototype 6 (12.8 cm) was just shorter than the nursery standard.

Eight weeks after potting, prototype 6 had not really grown anymore (12.8 cm) and was now significantly shorter than the nursery standard (14.4 cm; p =0.008). None of the treatments were significantly taller than the nursery standard, although prototype 10 was now the tallest (15.1 cm).

After 12 weeks, the nursery standard measured 18.8 cm, the tallest of all the treatments. This was significantly taller than prototype 6 only (14.3 cm; p =0.006).

Height differences became more pronounced at the fourth assessment, 17 weeks after potting. The nursery standard was still the tallest (25.8 cm) and this was significantly taller than prototypes 10, 9 and 6 (21.3 cm, 19.5 cm and 15.5 cm respectively; p <0.001). Prototype 6 was significantly shorter than all other treatments.

There was a similar trend at the end of the trial, 23 weeks after potting, with prototype 6 still significantly shorter than all other treatments (18.5 cm) and the nursery standard (27.5 cm) significantly taller than prototypes 10 and 9 (23.4 cm and 23.0 cm respectively; p <0.001). Prototype 2 (27.9 cm) was marginally taller than the nursery standard.

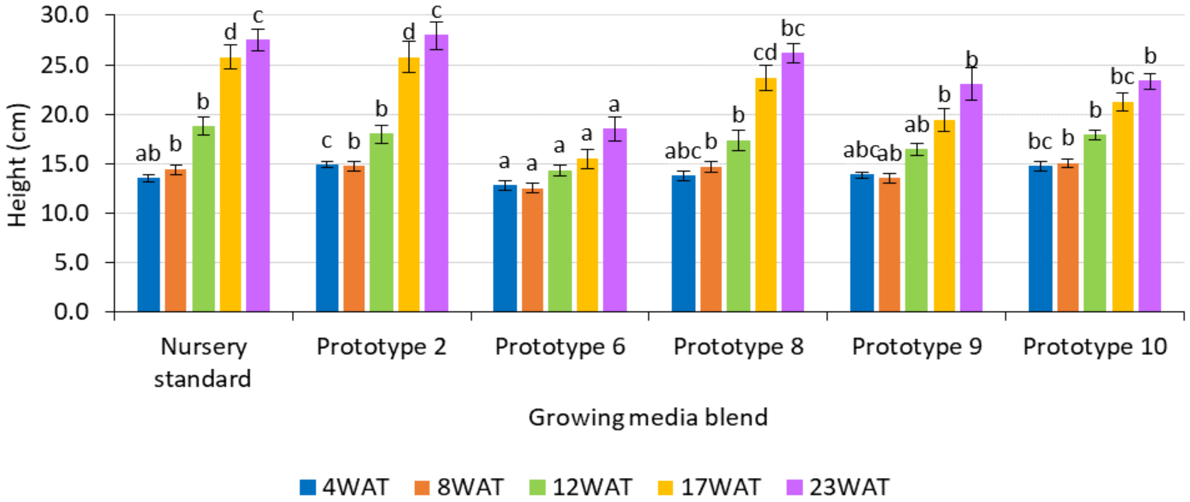


Figure 29. Average *Viburnum* height (cm) in different growing media blends throughout the trial period. Differences across treatments are statistically significant at all assessments (p =0.009; p =0.008; p =0.006; p <0.001; p <0.001). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance at all assessment dates.

Root development was variable across the treatments, and at the final assessment, results were significantly different (p <0.001). The greatest level of root development was seen in prototype 2 and the nursery standard (scores of 2.9). This was significantly better than prototypes 6, 9 and 10, with prototype 6 receiving the lowest root score (1.7). Prototype 8 scored 2.7 and was similar to prototype 2 and the nursery standard.

When fresh weight was assessed at the end of the trial, differences across treatments were statistically significant (p <0.001; **Figure 30**). Prototypes 6 (22.0 g) and 9 (33.7 g) were significantly lighter than the nursery standard (45.9 g). All other treatments were not significantly different to the nursery standard, although the greatest fresh weight was seen in prototype 2 (46.8 g).

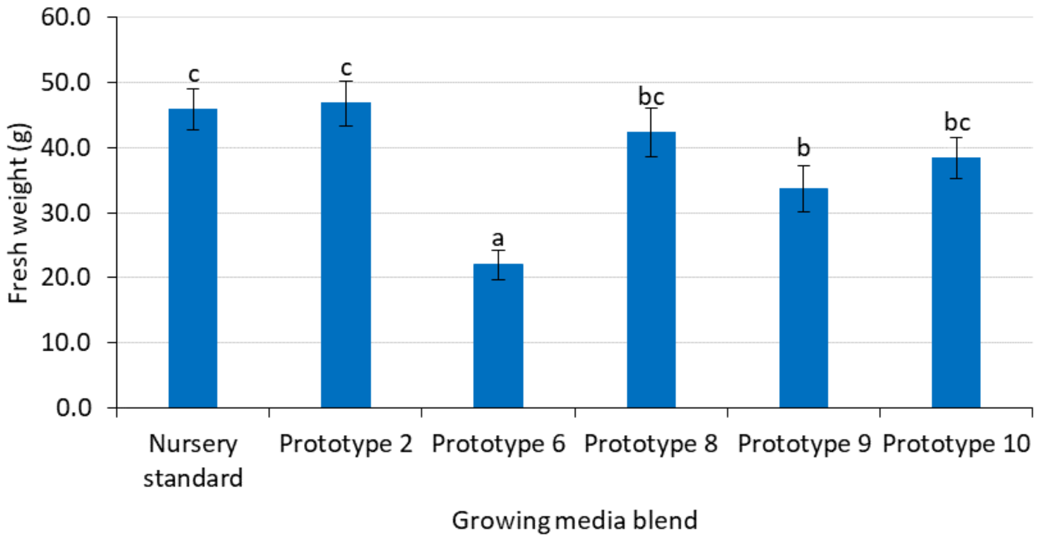


Figure 30. Average *Viburnum* fresh weight (g) in different growing media blends 23 weeks after potting, week 42, 2019. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance.

The dry weight showed a similar trend, with prototypes 6 (8.1 g) and 9 (13.8 g) significantly lighter than the nursery standard ($p < 0.001$). All other treatments were not significantly different to the nursery standard, which had the greatest dry weight (19.4 g).

Discussion

Generally, all prototypes worked very well in the *Cistus* and *Griselinia* trial, with more observable differences in the *Viburnum* trial. Prototype 2 worked well in the *Cistus* trial, and in the *Viburnum* trial it produced the tallest plants, with the highest fresh weight and a good root system. However, in the *Griselinia* trial, these plants were the shortest and lightest. Prototype 2 has both good air-filled porosity and available water, so you would expect this to work well for hardy nursery stock species.

Prototype 6 was the weakest of the experimental treatments. In the *Cistus* trial it produced the shortest plants, in the *Griselinia* trial these plants had the lowest dry weight and in the *Viburnum* trial it was the poorest blend for all assessment criteria. In addition, root development across the three species was also weakest in this blend. Prototype 6 contained quite a heavy, dense material. It is possible that this reduced the air-filled porosity which would impact on root development, and in turn, plant establishment and growth.

Prototype 8 worked very well for all three species, producing the tallest plants in the *Griselinia* trial and the greatest fresh weight and quality in the *Cistus* trial. Root development was also greatest in the *Cistus* and *Griselinia* trials, and very good in the *Viburnum* trial. This blend contains 100% of one of the new anonymous materials (M1), which is a very fine-grade material, with high water holding capacity and adequate air-filled porosity, which suits hardy nursery stock species.

There were mixed results for prototype 9, which performed well in the *Griselinia* trial, and resulted in good height and root development in the *Cistus* trial. However, fresh weight was reduced in the *Cistus*, and in the *Viburnum* trial, height, fresh weight and root development were all lower. Prototype 9 contains 33% M1 and 66% M2. M2 is a very light, fibrous material, and whilst it would have increased the air-filled porosity within this blend, perhaps this was too much for hardy nursery stock production.

Conversely, prototype 10 contains 66% M1 and 33% M2, and this worked very well in the *Cistus* trial, produced good quality *Griselinia* plants with the greatest fresh weight, and performed well in the *Viburnum* trial, although here plants were shorter than the nursery standard. Within prototype 10, the high proportion of M1 brings high water holding capacity to the mix, and the inclusion of M2 helps to increase the air-filled porosity, but not so much to the extent that it has a negative impact on plant growth.

Protected ornamentals – Pot Chrysanthemum
Methods

The trial was carried out at Double H Nurseries Ltd (New Milton, BH25 5NG) from May to July 2019, using cuttings of Mount Aubisque Pink in 1.5 L pots. A total of six growing media treatments were used (**Appendix 5**) and these were replicated 10 times, to give a total of 60 plots. Each plot contained five 1.5 L pots, giving a total of 300 plants.

The pots were filled with the relevant growing media using the nurseries own potting machine, and the cuttings were stuck by hand, with four cuttings per pot, in week 20, 2019. The pots were placed on ebb and flood benches within a glasshouse, watered, and covered with white polythene, which remained in place for two weeks. After two weeks, when the cuttings had started rooting, the polythene was removed and the plants were spaced. The trial was set out in a fully randomised trial design (**Appendix 5**), and the plants were watered and fed via ebb and flood. The plants were pinched three weeks after sticking, as per commercial practice.

The trial was placed alongside the nurseries commercial crop, and was treated for pest and disease as appropriate, following the standard practice of the nursery. Fortunately there were no pest or disease issues during the trial. The trial was treated with plant growth regulators by the nursery, as the aim was to produce a marketable crop, and Mount Aubisque is a vigorous variety. Daminozide (as B-Nine) was applied at a rate of 3 g/L using an overhead boom, twice in week 25, and once in weeks 26, 28 and 29. The plants were grown on until week 30 (24 July 2019), and were assessed at 2, 4 and 10 weeks after sticking. At each assessment date, plots were assessed for height and width (three plants per plot), plant quality (five plants per plot, scale 0-5) and root development (three plants per plot, scale 0-4). At the final assessment in week 30, plants were assessed for height and width, quality, root development and fresh and dry weight (three plants per plot). For scoring criteria see **Appendix 5**. A sub-sample of plants were returned to ADAS Boxworth, Cambridgeshire, for shelf-life testing. Three plants of each treatment were watered to full capacity, allowed to drain, and then placed within a shelf life room for 14 days. The plants were monitored daily, and the day of plant wilting recorded. The shelf life room was set to 18°C, 12 hours light/dark.

Results

Early on in the trial, at both the two weeks and four weeks after sticking assessments, there were no observed differences between treatments. All plants were growing nicely, the foliage was healthy and green and all treatments scored 5 for quality. However, by the time of the final assessment 10 weeks after sticking (WAS), there was a significant difference between treatments ($p < 0.001$), with prototypes 3 and 9 significantly poorer than all other treatments. Prototype 9 still scored 4.7, so was still of acceptable quality, the plants just didn't look as full and well developed as the other treatments and the nursery standard. Prototype 3 however had much paler foliage in comparison to the other treatments (**Figure 31**), and whilst this made it score 2.0 and was unmarketable due to the colour, it is likely this was a nutritional issue rather than a direct effect of the growing media blend. The nursery standard and prototypes 5, 8 and 10 all scored 5.0.

Figure 31. Pot Chrysanthemum grown in the nursery standard (left), prototype 3 (centre) and prototype 8 (right), 10 weeks after sticking, week 30 2019.

Height specification for marketable chrysanthemums at Double H is 18 – 24 cm. At the first assessment two weeks after sticking, there was a significant difference in plant height ($p = 0.018$) with prototype 5 significantly taller (6.3 cm) than the nursery standard (5.5 cm). The nursery standard was actually one of the shortest of the six treatments, along with prototypes 9 and 10.

However, by the time of the next assessment four weeks after sticking, treatment differences were still significant (p <0.001) but the nursery standard was now the tallest (12.5 cm), and prototype 9 was significantly shorter (11.4 cm) than all the other treatments. There was only 0.2 cm difference in height between prototypes 3, 5, 8 and 10.

By the time of the final assessment 10 weeks after sticking, there were no significant differences between treatments. Prototype 10 (19.6 cm) was marginally taller than the nursery standard (18.9 cm), and the shortest plants were in prototype 9 (18.5 cm). All plants were within the marketable range of 18 – 24 cm. **Figure 32** shows the height differences between treatments at the three assessment dates.

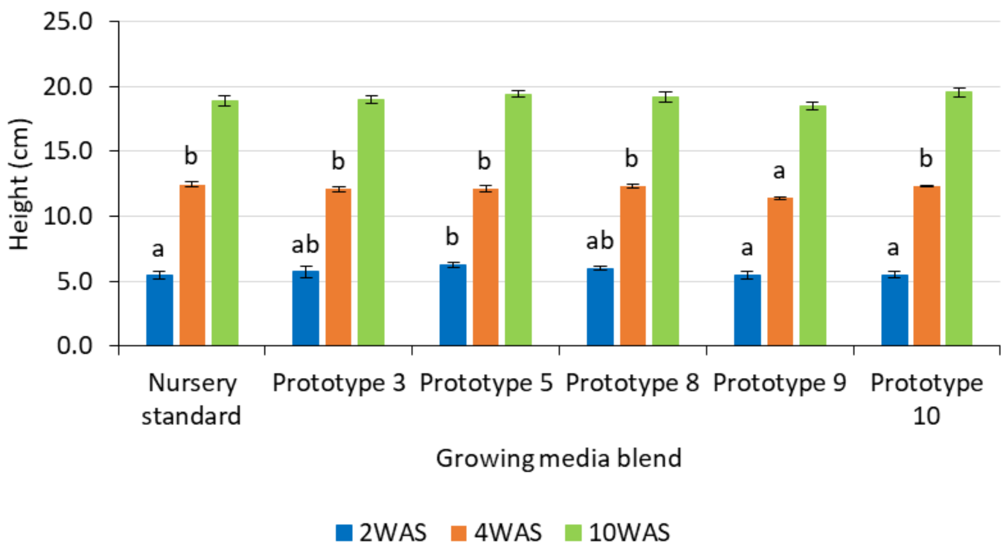


Figure 32. Average height (cm) of Chrysanthemum grown in different growing media blends across the trial period. Differences across treatments are statistically significant 2WAS (p =0.018) and 4WAS (p <0.001). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance at the 2WAS and 4WAS assessments.

Width specification (top of pot) for chrysanthemums at Double H is 25 – 30 cm. Early on in the trial at the first assessment two weeks after sticking, prototype 8 was significantly larger than the nursery standard (p =0.092), but none of the treatments were significantly smaller. There were no significant differences at the mid-way assessment, and at the end of the trial, 10 weeks after sticking, prototypes 3 and 9 were significantly smaller (p <0.001) than all other treatments (28.9 cm and 29.6 cm respectively). However they were still within nursery specification. The nursery standard was the largest with a width of 31.2 cm, which was just larger than the specification. **Figure 33** shows the width differences between treatments at the three assessment dates.

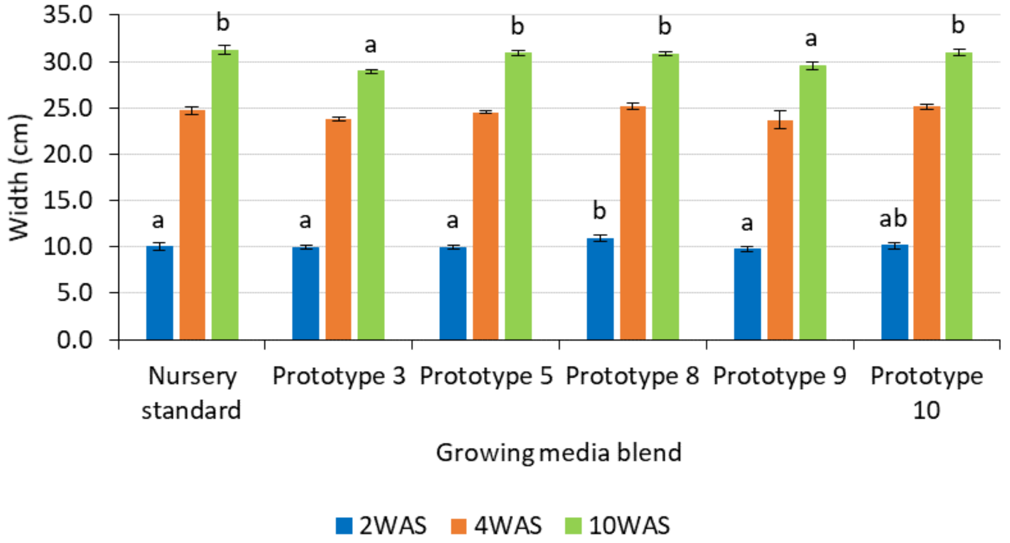


Figure 33. Average width (cm) of Chrysanthemum grown in different growing media blends across the trial period. Differences across treatments are statistically significant 2WAS (p =0.092) and 10WAS (p <0.001). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance at the 2WAS and 10WAS assessments.

There were no significant differences between treatments for root development at any of the assessment dates. The cuttings rooted out quickly and at the first assessment, two weeks after sticking, all treatments scored 2.0, with visible roots in 26 – 50% of the pot. After four weeks, this had improved to 51 – 75% of the pot, and at the final assessment 10 weeks after sticking, the plants were fully rooted in all treatments, with healthy roots visible in 76 – 100% of the pot.

When fresh weight was assessed at the end of the trial, there was a significant difference between treatments (p <0.001) with the nursery standard significantly heavier than all other treatments (189.5 g; **Figure 34**). Prototypes 3 and 9 were significantly lighter than all other treatments (146.1 g and 153.3 g respectively), and there was little difference between prototypes 5, 8 and 10.

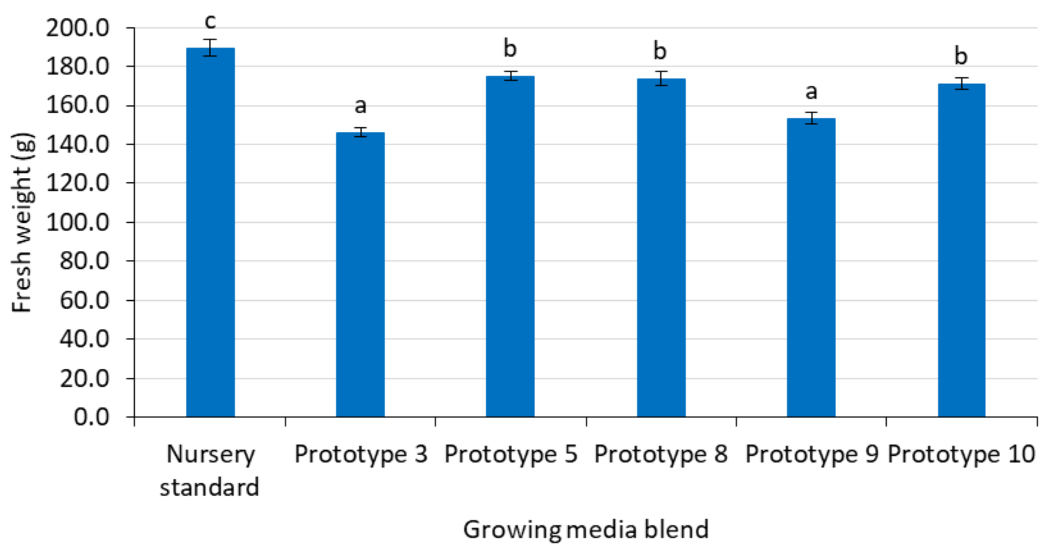


Figure 34. Average fresh weight (g) of Chrysanthemum grown in different growing media blends at the end of the trial period. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 45 degrees of freedom (d.f.). Letters denote level of significance.

The dry weight was similar to the fresh weight, with the nursery standard significantly greater than all other treatments ($p < 0.001$; 19.4 g). Prototype 3 was significantly lighter than all other treatments (15.1 g), followed by prototype 9 (16.3 g). Again, prototypes 5, 8 and 10 were very similar to each other.

Shelf life

All plants were irrigated once to container capacity before entering shelf life. The plants remained in the shelf life room for 14 days and were checked daily for signs of wilting and / or plant death. After 10 days, all plants were starting to show some slight signs of wilting, but by the end of the shelf life period, there were no differences between treatments. Plants had wilted some more but had not reached a critical stage where they would not recover.

Discussion

Overall, prototypes 5, 8 and 10 all worked extremely well during the trial. Prototype 5 has both good air-filled porosity and available water. Prototype 8 is 100% M1. This is a very fine-grade material, with high water holding capacity and adequate air-filled porosity. Prototype 10 is 67% M1, 33% M2. This high proportion of M1 brings high water holding capacity to the mix, and the inclusion of M2 helps to increase the air-filled porosity.

Prototypes 3 and 9 did not work quite as well as the other experimental prototypes. The issues with prototype 3 are related to the nutritional content of the materials within the blend, rather than the physical properties of the blend. Prototype 9 however is 33% M1, 67% M2, and converse to prototype 10. M2 is a very light, fibrous material, and whilst it would have increased the air-filled porosity within this blend, perhaps this was too much for pot chrysanthemum production on an ebb and flood system.

Soft fruit production - raspberries
Methods

The long cane produced at EU Plants were transported to New Farm Produce (NFP - Lichfield, WS13 8EX) in week 15 2019. The canes were taken out of cold store and allowed to fully thaw before planting on to reduce the risk of transplant shock. The 2 L potted twin canes were transplanted into 7 L pots containing the same growing media blend they were propagated in (**Figure 35**). The pots were laid out alongside the commercial crop in a fully randomised plot design (**Appendix 6**).

Figure 35. Transplanted canes into 7 L pots week 15 (left) and just before harvest in week 26 (right).

The growth of the canes were monitored by ADAS and NFP staff up to fruiting, with any issues noted. From the onset of fruiting (week 26 onwards) staff at NFP picked and assessed the fruit twice per week until fruiting had finished. The fruit were assessed for number of fruit, total weight and Brix (°) at each assessment.

Results

Glen Ample - cropping

The raspberry canes grew well when transplanted into larger pots. A few buds did not break on some of the canes, however, it was the same across all of the treatments and was not attributable to the growing media blends. Spawn production was consistent across all of the treatments, with no differences seen between any of the blends.

Berry production commenced from the 24 June 2019, with picking occurring approximately every four days. The final pick was 46 days after the first on 9 August 2019. There were no significant differences in the number of berries produced between any of the growing media blends per raspberry cane (**Figure 36**).

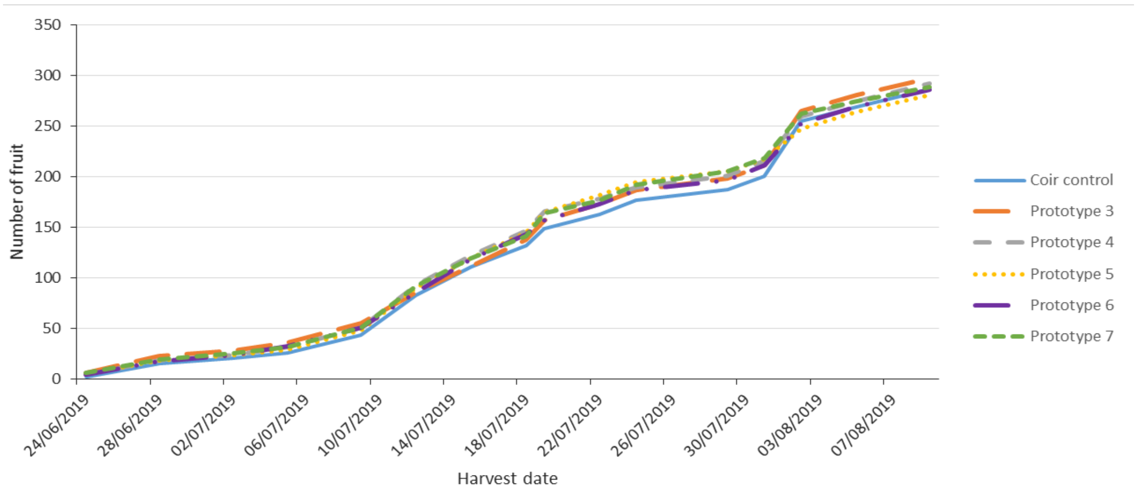


Figure 36. Cumulative number of Glen Ample fruit per cane over harvest period from 24 June to 09 August. No significant differences in total berry number at the end of the trial.

There was also no significant difference in the yield for any of the growing media blends (**Figure 37**). Prototype 3 had the highest yield (1926 g per cane) of the treatments, with prototypes 5 and 6 having the lowest total yield across the season (1828 g and 1813 g per cane respectively). The coir nursery standard produced a total yield of 1868 g per cane. There was an increase in fruit production in all growing media blends towards the end of July, which corresponded to a period of cool weather followed by high temperatures immediately afterwards. This change in weather was likely to have caused this fruit to ripen together. The average berry weight for all treatments except for prototype 6 was the same at 6.5 g per berry. Prototype 6 had an average berry weight of 6.3 g, but this was not significantly different to the other growing media blends.

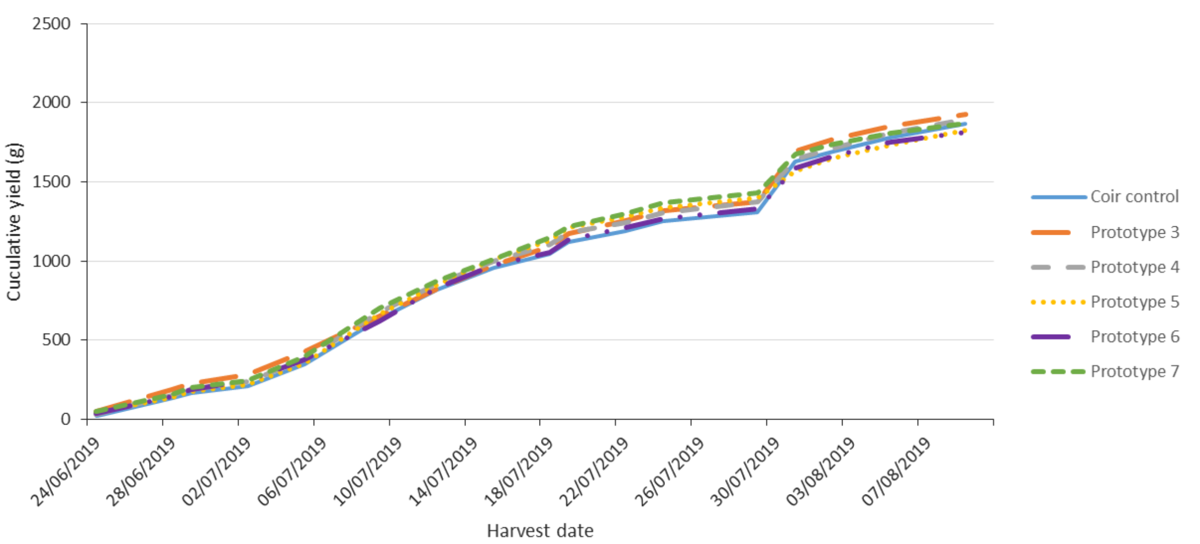


Figure 37. Cumulative fruit yield per Glen Ample cane over harvest period from 24 June to 09 August. No significant differences in total berry number at the end of the trial.

The Brix across the whole of the picking season was not significantly different for any of the growing media blends (**Figure 38**). The highest average Brix was 11.2° in prototype 6 and the lowest was 10.0° in prototype 4. The coir nursery standard had the joint second highest Brix at 10.24°.

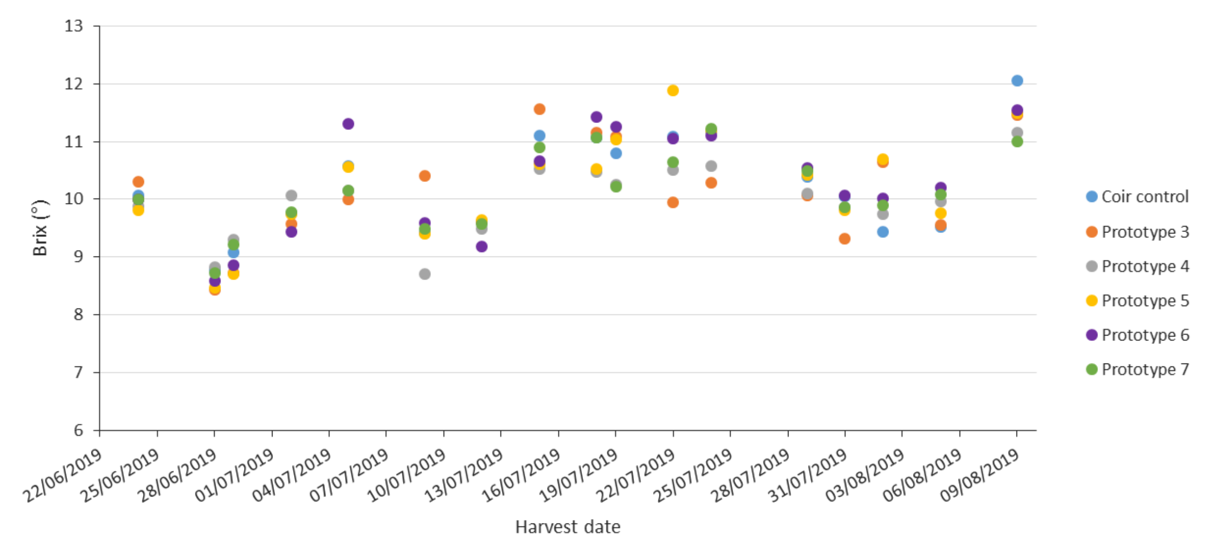


Figure 38. Average Brix (°) at each picking date for Glen Ample from 24 June to 9 August 2019.

Visual inspections of the roots at the end of the trial showed some differences between the treatments. The coir nursery standard, prototypes 3, 4 and 5 all had good rooting with white roots from the top to bottom of the pot (**Figure 39**). Prototypes 6 and 7 had poorer rooting with some patchy brown areas indicating dead roots towards the bottom of the pots.

Figure 39. Roots of Glen Ample plants after cropping finished 09 August 2019. Photos L-R are: Coir nursery standard, prototype 3 and prototype 7.

Maravilla - cropping

The raspberry canes grew well when transplanted into larger pots. Spawn production was consistent across all of the treatments, with no differences seen between any of the blends.

Berry picking commenced on the 24 June 2019, with a pick approximately every four days. The final pick was 46 days after the first on 9 August 2019. There were no significant differences in the number of berries produced between any of the growing media blends (**Figure 40**). Prototypes 5 and 6 produced the highest number of berries (316 per cane for both), whilst the coir nursery standard produced the lowest at 298 berries per cane.

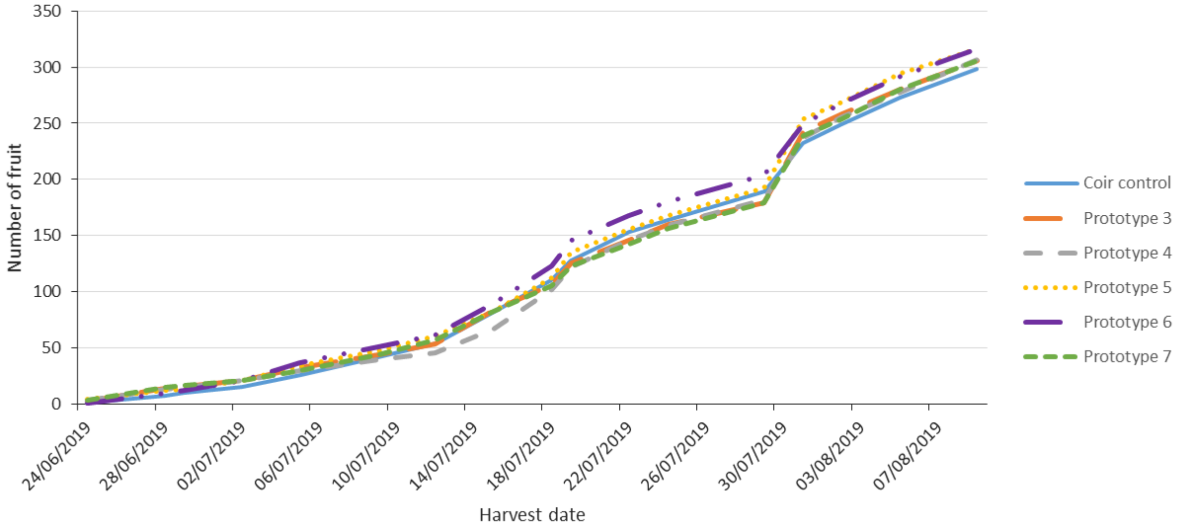


Figure 40. Cumulative number of Maravilla fruit per cane over harvest period from 24 June to 09 August. No significant differences in total berry number at the end of the trial.

There was also no significant difference in the yield for any of the growing media blends (**Figure 41**). Prototype 5 had the highest yield (1906 g per cane) of the treatments, with the coir nursery standard having the lowest total yield across the season (1787 g per cane). There was an increase in fruit production in all growing media blends towards the end of July, which corresponded to a period of cool weather followed by high temperatures immediately afterwards. This change in weather was likely to have caused this fruit to ripen together. The average berry weight for all treatments was the same at 6 g per berry.

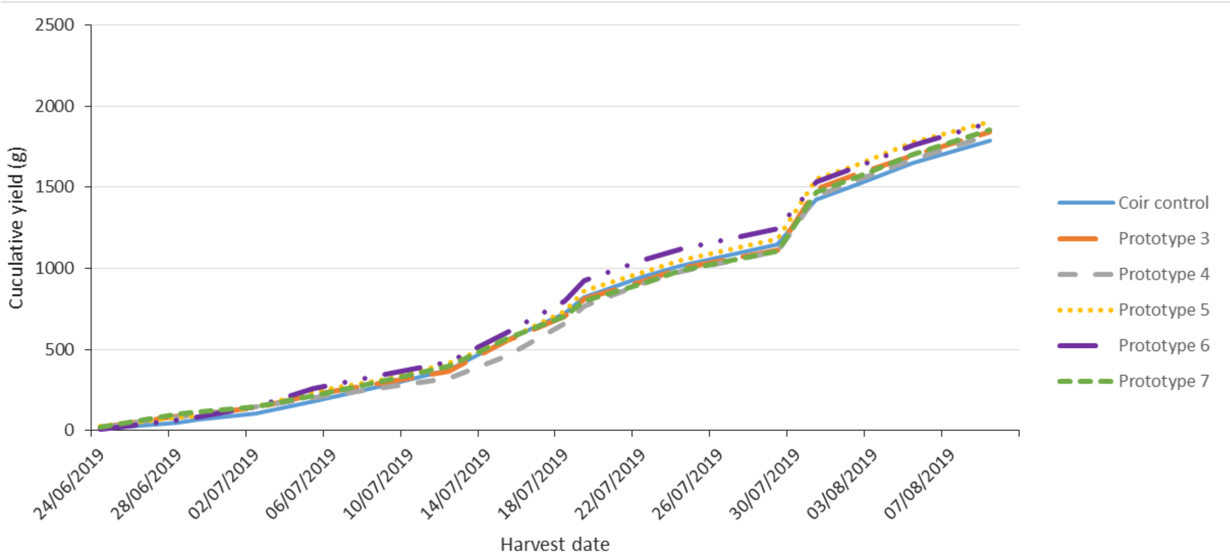


Figure 41. Cumulative fruit yield per Maravilla cane over harvest period from 24 June to 09 August. No significant differences in total berry number at the end of the trial.

The Brix across the whole of the picking season was not significantly different for any of the growing media blends (**Figure 42**). The highest average Brix was 11.2° in prototype 6 and the lowest was 10.0° in prototype 4. The coir standard had the joint second highest Brix at 10.24°.

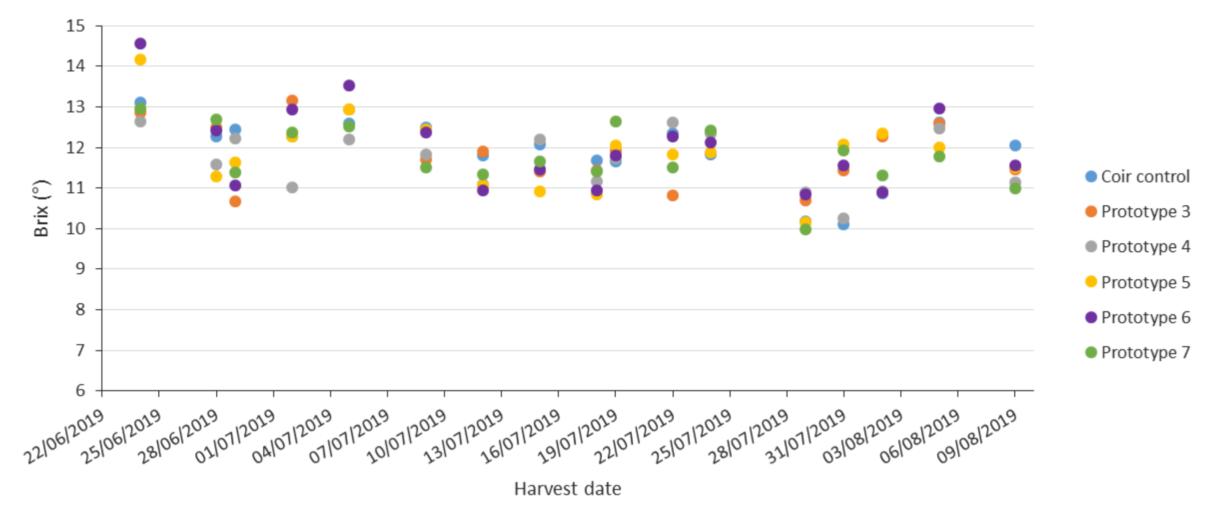


Figure 42. Average Brix (°) at each picking date for Maravilla from 24 June to 9 August 2019.

Visual inspections of the roots at the end of the trial showed some differences between the blends (**Figure 43**). The coir nursery standard, prototypes 3, 4 and 5 all had good rooting with white roots from the top to bottom of the pot. Prototypes 6 and 7 had poorer rooting with some patchy brown areas indicating dead roots.

Figure 43. Roots of Maravilla plants after cropping finished 09/08/2019. Photos L-R are: Coir standard, prototype 5 and prototype 7.

Discussion

During cropping the Glen Ample plants performed well, producing good yields with relatively large berries across all prototype blends. There were no statistically significant differences between the yields of the plants in the growing media blends, however, the highest and lowest total yielding blends differed by 113 g per cane (difference between prototype 3 and prototype 6). In a commercial system this could equate to a large loss in production across a whole production area of several thousand canes.

At the end of the trial, prototype 7 had a poor root system, so although the yield production in the first year was good, these plants would be likely to suffer from root death or disease, such as *Phytophthora*, if kept for cropping in a second or third year. Prototype 3 in particular had a good root system at the end of the trial, with a good proportion of healthy white roots across the profile of the whole pot. This means that the Glen Ample grown in prototype 3 not only produced an excellent yield, but also has the potential for the plants to be carried on for further cropping.

In the Maravilla trial, there were no statistically significant differences between the yields of the plants in the growing media blends, however, the highest and lowest total yielding blends differed by 119 g per cane (difference between prototype 5 and the coir nursery standard). The coir nursery standard had the lowest yield and number of fruit in this trial, which is unexpected as the plant in this treatment had been some of the best along with prototype 5 during the propagation phase. The canes grown in the coir nursery standard were on average slightly shorter than those in some of the other blends, however, the number of nodes were comparable. As in the Glen Ample a few of the buds (nodes) at the top of the canes did not break, however this was spread across the treatments, so should not have had an impact on yields of any particular treatment.

At the end of the trial, prototype 7 had a poor root system, so although the yield production in the first year was good, these plants would be more likely to suffer from root death or disease if kept for cropping in a second or third year due to its physical properties. This particular prototype had a high dry bulk density and low AFP, which would provide favourable conditions for root diseases such as *Phytophthora*. The other prototypes had a good root system at the end of the trial, with a good proportion of healthy white roots across the profile of the whole pot.

Overall the prototype blends worked well in propagation and cropping with both raspberry varieties. Prototypes 5 and 6 performed particularly well in propagation, and in the case of prototype 5 this also translated into the best cropping plants in the Maravilla trial in a commercial setting. Prototypes 4 and 7 resulted in small plants at the initial stage of propagation, however those in prototype 4 were able to catch up with the other treatments and produced good long cane plants. Prototype 7 was generally the poorest performing blend and although it was not the lowest yielding blend during either trial, the root zone created by the blend would not be suitable for cropping in multiple years.

Soft fruit production - strawberries
Methods

The tray plants produced at EU Plants were transported to New Farm Produce (NFP - Lichfield, WS13 8EX) in week 15 2019. The plants were taken out of cold store and allowed to thaw before planting on to reduce the risk of transplant shock.

The tray plants in each growing media treatment were split into two batches, with half being transplanted into troughs containing the NFP coir nursery standard and the other half transplanted into troughs containing the same growing media blend they were propagated in (**Figure 44**). These were treated as separate trials and each one had its own separate irrigation system to allow for any differences in management that may have been required.

A total of six growing media treatments were used in the reciprocal blend trial and these were replicated 12 times, to give a total of 72 plots. Each plot contained two troughs, giving a total of 144 troughs. The coir trial also had 72 plots, with 12 plots of plants propagated in each of the six growing media treatments. Each trial was arranged in a fully randomised design (**Appendix 7**).

Figure 44. Transplanted tray plants into troughs week 15 (left) and just before harvest at the end of week 25 (right)

The plants were watered and fed by a dripper system, with two dripper heads per trough. All troughs had the same feed and nutrient regime. The growth of the plants were monitored by ADAS and NFP staff up to fruiting, with any issues noted. From the onset of fruiting (week 25 onwards) staff at NFP picked and assessed the fruit twice per week until fruiting had finished. The fruit were assessed for number of fruit, total weight and Brix (°) at each assessment.

Results

Coir transplant trial

The strawberry plants propagated in the different growing media blends grew well when transplanted into troughs containing the coir nursery standard. Berry production commenced from the 22 June 2019, with picking occurring approximately every four days. The final pick was 30 days after the first. There were significant differences in the number of berries produced between the growing media blends per strawberry plant (p =0.007; **Figure 45**). Prototypes 3, 4, 5 and the propagator coir nursery standard all produced significantly more berries per plant than prototype 7 (18.8, 18.8, 18.9 and 18.2 fruit respectively vs. 15.1 for prototype 7).

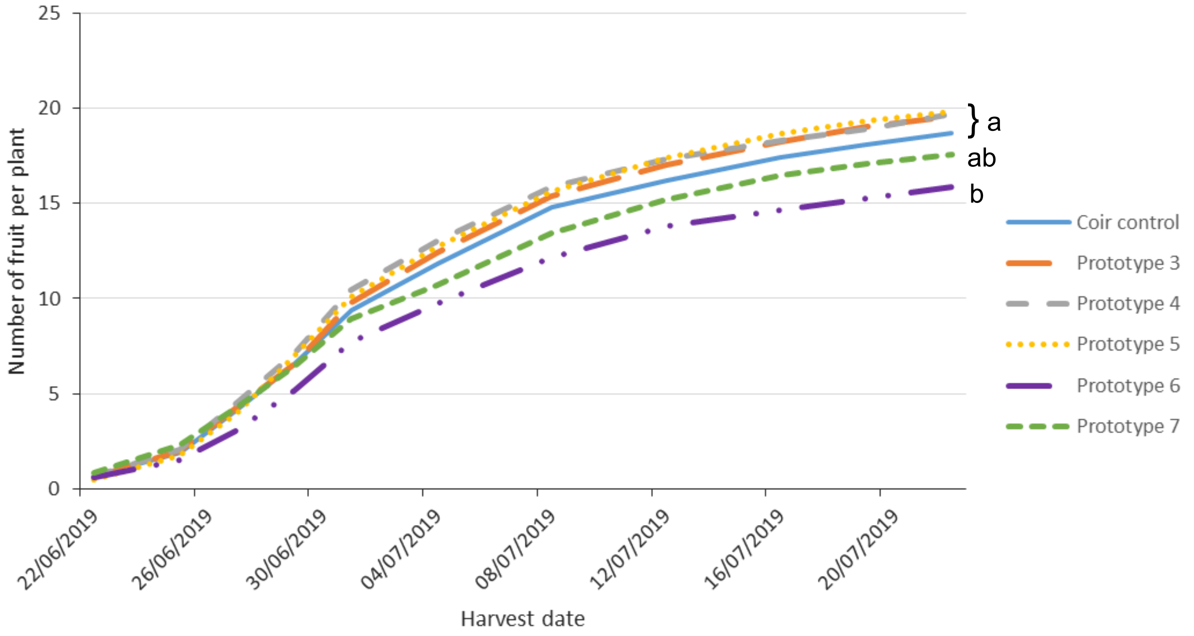


Figure 45. Cumulative number of Malling Centenary fruit over harvest period from 22 June to 22 July 2019. Differences are significant (p =0.007, d.f. = 5). Letters denote level of significance.

The difference in fruit number led to a significant difference in the yield for the plants propagated in the different growing media blends (**Figure 46**). Prototype 5 had the highest yield (331 g per plant) of the treatments, with prototypes 6 and 7 having the lowest total yield across the season (272 g and 293 g per plant respectively). The propagator coir nursery standard produced a total yield of 315 g per plant.

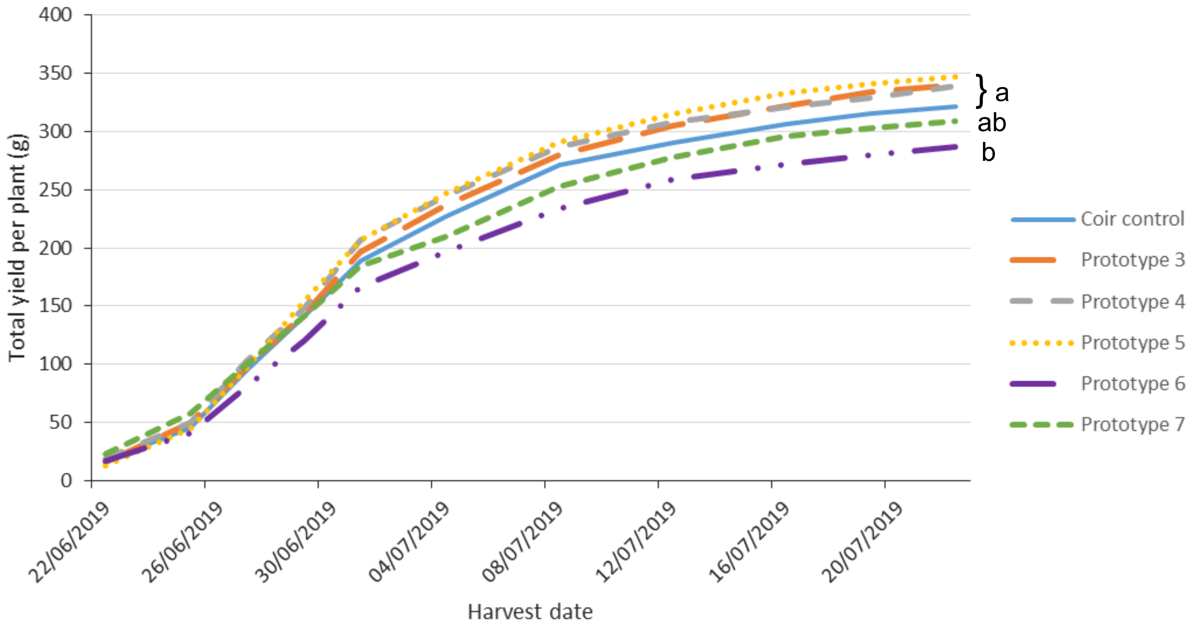


Figure 46. Cumulative total fruit yield per Malling Centenary plant over harvest period from 22 June to 22 July 2019. Differences are significant (p = 0.010, d.f. = 5). Letters denote level of significance.

The Class 1 yield mirrored the pattern seen in the fruit number and total yield, with significant differences between the different propagation growing media treatments (**Figure 47**). Again prototype 5 had the highest Class 1 yield (299 g per plant) of the treatments, with prototypes 6 and 7 having the lowest total yield across the season (250 g and 267 g per plant respectively). The propagator coir nursery standard produced a Class 1 yield of 289 g per plant.

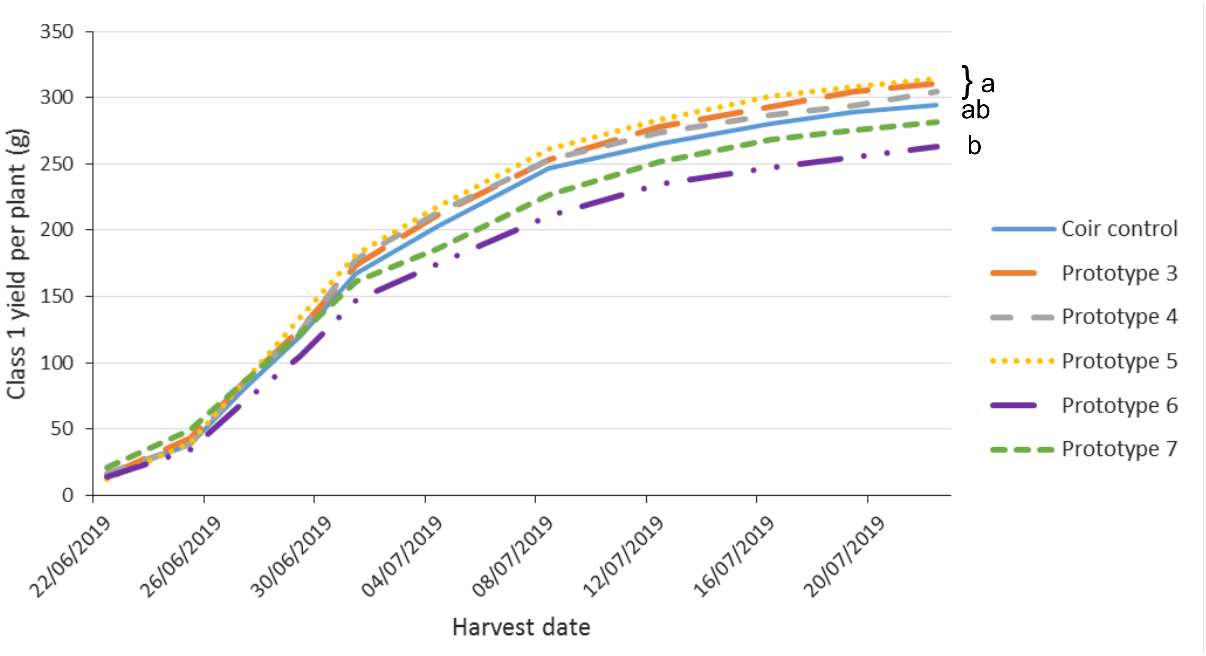


Figure 47. Cumulative Class I yield per Malling Centenary plant over harvest period from 22 June to 22 July 2019. Differences are significant (p = 0.026, d.f. = 5). Letters denote level of significance.

There was no significant difference in the Class 2 yield between the propagator treatments when planted into coir (p =0.104). Prototype 4 had the highest Class 2 yield, followed by prototypes 5 and 3 (34 g, 32 g and 28 g respectively). Prototype 6 had the lowest Class 2 yield at 24 g. There was also no significant difference in the percentage Class 1 yield in the treatments. The propagator coir nursery standard had the highest percentage, with prototype 4 having the lowest percentage Class 1 (91.7 % and 89.6 % respectively).

The Brix across the whole of the picking season was not significantly different for any of the growing media blends (p =0.534, d.f. =5). The highest average Brix was 10.4° in prototype 4 and the lowest was 8.3° in the plants raised in the propagator coir nursery standard.

Visual inspections of the roots at the end of the coir planting trial showed very little differences between the treatments (**Figure 48**).

Figure 48. Roots of coir planted Malling Centenary plants propagated in different growing media blends after cropping finished 22/07/2019. Photo L-R: Propagator coir nursery standard, prototypes 3, 4, 5, 6 and 7.

Reciprocal blend transplant trial

The strawberry plants propagated in the different growing media blends grew well when transplanted into the same blends they were propagated in (referred to as reciprocal blends in text). Berry production commenced from the 22 June 2019, with picking occurring approximately every four days. The final pick was 30 days after the first. There were significant differences in the number of berries produced between the growing media blends per strawberry plant (p =0.010; **Figure 49**). Prototypes 4 and 5 produced significantly more berries per plant than prototypes 6 and 7 (21.4 and 21.5 fruit vs. 18.4 and 17.7 fruit respectively).

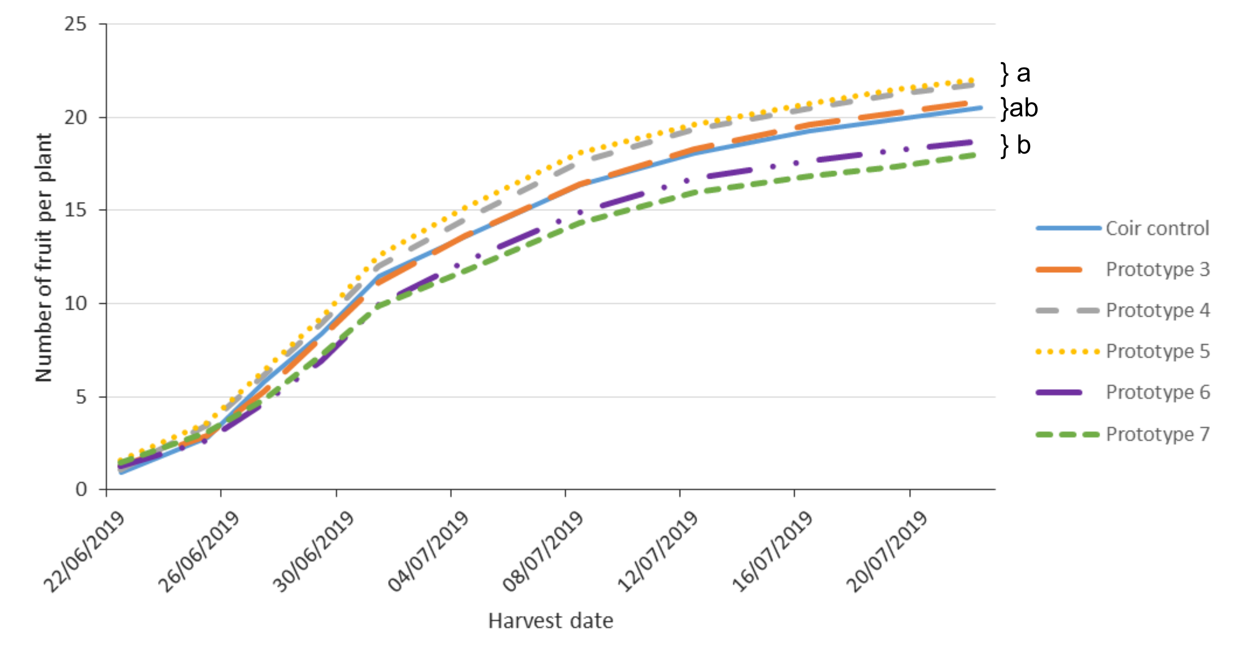


Figure 49. Cumulative number of Malling Centenary fruit over harvest period from 22 June to 22 July 2019 in reciprocal blends. Differences are significant (p = 0.010, d.f. = 5). Letters denote level of significance.

The difference in fruit number led to a significant difference in the yield for the plants propagated in the different growing media blends (p <0.001; **Figure 50**). There was just under 100 g per plant difference between the highest and the lowest yields. Prototype 5 had the highest yield (376 g per plant) of the treatments, with prototypes 6 and 7 having the lowest total yield across the season (279 g and 296 g per plant respectively). The grower coir nursery standard produced a total yield of 358 g per plant and this was significantly different to the yield in prototype 5.

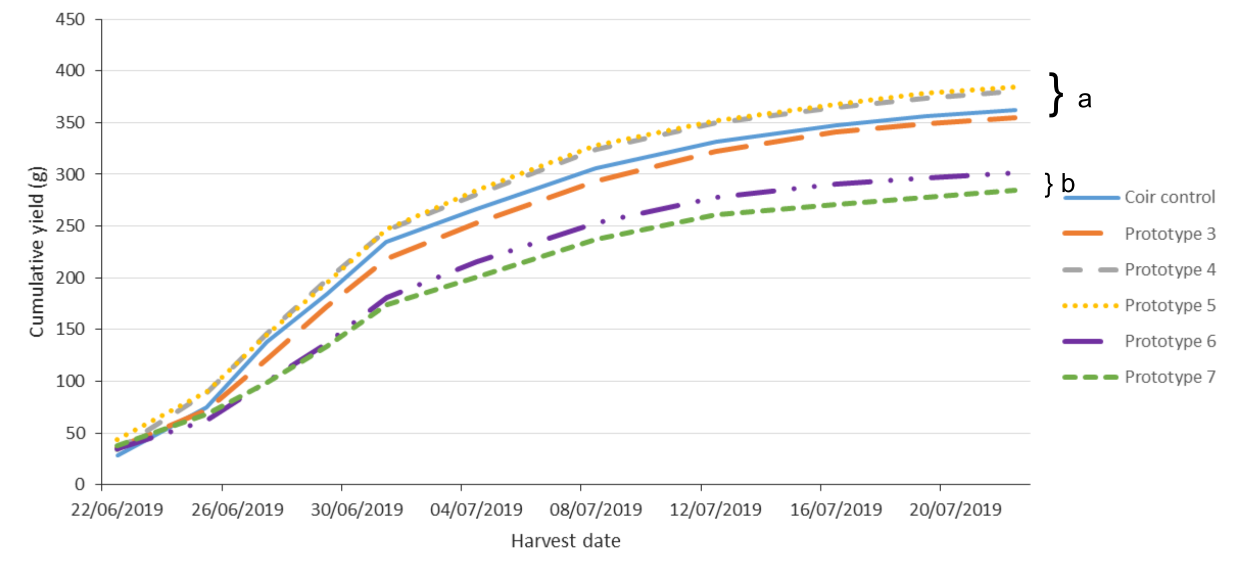


Figure 50. Cumulative total fruit yield per Malling Centenary plant over harvest period from 22 June to 22 July 2019 in reciprocal blends. Differences are significant (p < 0.001, d.f. = 5). Letters denote level of significance.

The Class 1 yield mirrored the pattern seen in the fruit number and total yield, with significant differences between the different growing media blends (p <0.001; **Figure 51**). Again prototype 5 had the highest Class 1 yield (352 g per plant) of the treatments, with prototypes 6 and 7 having the lowest total yield across the season (260 g and 278 g per plant respectively). The propagator coir nursery standard produced a Class 1 yield of 338 g per plant.

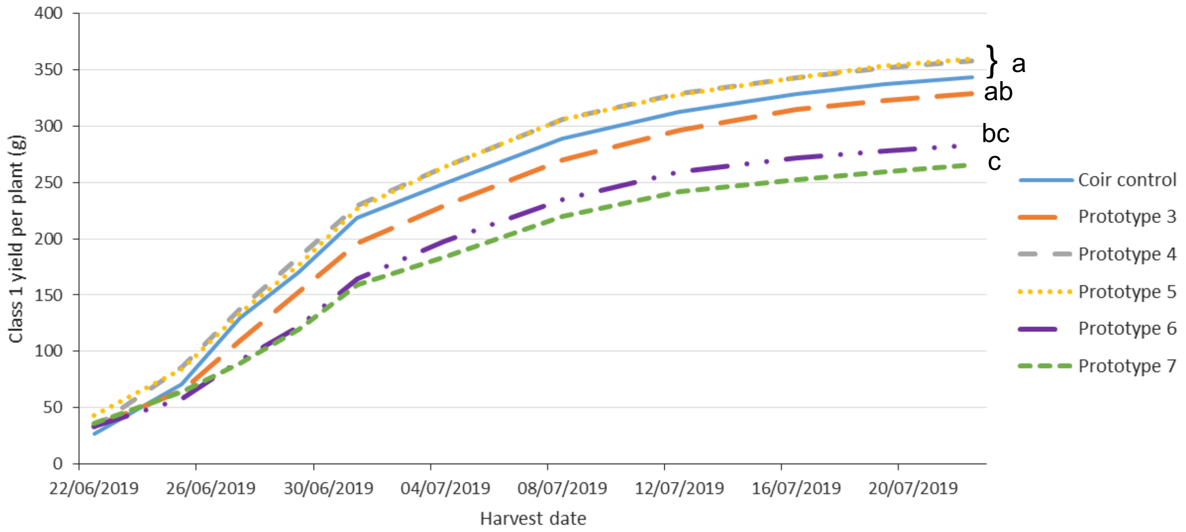


Figure 51. Cumulative Class I yield per Malling Centenary plant over harvest period from 22 June to 22 July 2019 in reciprocal blends. Differences are significant (p < 0.001, d.f. = 5). Letters denote level of significance.

There was no significant difference in the Class 2 yield between the growing media treatments (p =0.182). Prototype 3 had the highest Class 2 yield per plant, followed by prototypes 5 and 4 (25.7 g, 24.7 g and 21.8 g respectively). Prototype 6 had the lowest Class 2 yield at 18.5 g. The percentage Class 1 yield for all of the treatments was excellent and there was no significant difference between the treatments. The grower coir nursery standard had the highest percentage, with prototype 3 having the lowest percentage Class 1 (94.6 % and 92.4 % respectively).

The Brix across the whole of the picking season was not significantly different for any of the growing media blends (p =0.725, d.f. =5). The highest average Brix was 10.2° in prototype 4 and the lowest was 8.3° in the plants in prototype 3.

Visual inspections of the roots at the end of the coir planting trial showed some differences between the treatments (**Figure 52**). Prototype 5 had the best roots across all of the treatments, with large areas of white roots visible; this was also true of the coir nursery standard. Prototype 6 had the poorest roots and although there were areas of white root visible, large patches of dead roots were also present.

Figure 52. Roots of Malling Centenary plants grown in different growing media blends after cropping finished 22/07/2019. Photo L-R: coir nursery standard, prototypes 5 and prototype 6.

Discussion

When the plants propagated in the different growing media blends were planted into the commercial grower's coir nursery standard for cropping, the plants all grew away well and there were no visual differences between the treatments. Prototypes 3 and 5 had the highest number of berries, Class 1 yield and total yield in the coir trial. These were statistically significantly more than prototype 6, but not the other treatments. The difference in Class 1 yield between prototype 5, which was the highest yielding blend, and the grower coir nursery standard was 10 g per plant. Prototype 5 did have a higher Class 2 yield than the coir nursery standard of 5 g per plant, which impacted the percentage of Class 1 yield, although the differences were not statistically significant. The propagator coir nursery standard had the highest at 91.7%, whilst prototype 5 was 90.7% Class 1. Prototype 6 produced tray plants that performed the poorest when transplanted into the coir troughs, followed by prototype 7. Prototype 6 produced the fewest berries and consequently had the lowest total yield and Class 1 yields.

The second set of plants that were planted into the same blends that they were propagated in showed a similar pattern to those planted into the commercial grower's coir. Prototype 5 was the best performing blend in this trial in terms of number of berries and total and Class 1 yield, but was not significantly different to the coir nursery standard. The second best performing blend was prototype 4 and was very similar to prototype 5 in the number of berries and yield. The poorest performing blends were prototypes 6 and 7, producing significantly lower total yields compared with the other growing media blends. The coir nursery standard produced the highest percentage Class 1 yield, however all of the blends performed well in this trial, with the lowest Class 1 of 92.4%. At the end of the trial the roots in all of the prototype blends were good except for the poorest performing prototypes 6 and 7. The roots in these troughs had large dark patches of dead roots and the growing media had lost some structure during the trial. These blends would not be suitable for using for multiple years of cropping as is standard in the industry due to this loss of structure.

The coir planting trial demonstrated how strawberry plants propagated in different growing media blends perform when planted into the same standard coir. Although runners propagated in prototype 5 had initially been slow to get away, they had caught up at the end of the propagation period and produced the highest yielding strawberry plants. Prototype 7 produced small plants that did not catch up with the other treatments, had the smallest crown size and one of the lowest yields in the coir planting trial. This blend had a high bulk density and lower AFP than the other trial blends, which may account for its poorer performance during propagation.

The reciprocal blend trial demonstrated the ability of the blends to be used from propagation all the way through to cropping. Again in this trial prototype 5 performed well and produced substantial numbers of high quality fruit. The poorer performance of prototype 7 indicated that this type of blend with a high bulk density and lower AFP is not necessarily suited to strawberry cropping. The root death noted at the end of the trial would likely result in a drop off in yield were they to be kept for a second cropping season.

Vegetable propagation
Methods

Trials were carried out on Spring cabbage 'Caraflex' at Delfland Nurseries Limited (Cambridgeshire, PE15 0TU) from week 28 (11 July 2019). A total of four growing media treatments were used (**Appendix 8**), with one 1st generation blend, two 2nd generation blends and the nursery standard product. There were no 3rd generation blends 'novels' in this trial.

Trays were filled with growing media by hand in week 27 and sown by machine at the nursery in week 28 (11 July 2019). The trays were covered with vermiculite, placed in the germination room and covered with plastic for two days. They were then set down under glass, in a randomised trial design (**Appendix 8**) with the trays set down on pots to allow for aeration and air pruning of the root system for growth control (**Figure 53**). The trial was watered overhead by hand, as and when required.

Figure 53. Spring cabbage set out on concrete under glass at Delfland Nursery, week 28.

Germination was monitored by nursery operatives who informed ADAS staff when the seeds had germinated. The trials were assessed in week 33 for percentage germination of each tray, plant quality (plot overall, scale of 1-3), plant height (10 plants per plot), fresh and dry weight (10 plants per plot), and root quality (10 plants per plot, scale of 0-4). For scoring criteria see **Appendix 8**. A sub-sample of plants were then planted by hand at Elsoms trial ground, Spalding, in week 34 (21 August). Each treatment was replicated three times, giving a total of 12 plots, and each plot contained 120 plants. The aim was to grow these plants on to harvest. However, due to the extremely wet conditions experienced towards the end of 2019, these plants struggled to grow, and the trial had to be abandoned.

Results

Propagation

Germination occurred one week after the seeds were sown, and there were no differences between treatments in terms of germination timing. There were also no significant differences between treatments for percentage germination, with the highest level of germination in the nursery standard (97.6%) and the lowest in prototype 5 (96.2%) (**Table 5**). This is almost identical to what was seen in the 2018 trial, with 97.6 % germination in the nursery standard, and 95.9% germination in prototype 5.

Table 5. Percentage germination for spring cabbage sown week 28, 2019.

Treatment	% germination
Nursery standard	97.6
Prototype 1 (1st Gen)	96.4
Prototype 5 (2nd Gen)	96.2
Prototype 6 (2nd Gen)	96.4
l.s.d = 1.745 F pr. = 0.324	

Interestingly, there was a significant difference in plant quality, with all three experimental blends scoring higher than the nursery standard (p <0.001). Plant quality was reduced in the nursery standard by the presence of downy mildew, which was much less prevalent in the prototype blends (**Figure 54**). However, the nursery standard still scored 2.0 which was of acceptable quality. Prototype 1 scored 2.8 and prototypes 5 and 6 both received the highest score of 3.0. These plants were well developed, with full leaves, and good foliage colour

Figure 54. Spring cabbage grown in the nursery standard (left), prototype 1 (middle), and prototype 6 (right), week 34 2019.

There was a significant difference between treatments for plant height (p =0.003), with the nursery standard greater than all the other treatments (127.6 mm, **Figure 55**). This was followed by prototype 5 (114.2 mm) and prototype 1 (111.4 mm). The shortest plants were grown in prototype 6 (107.2 mm).

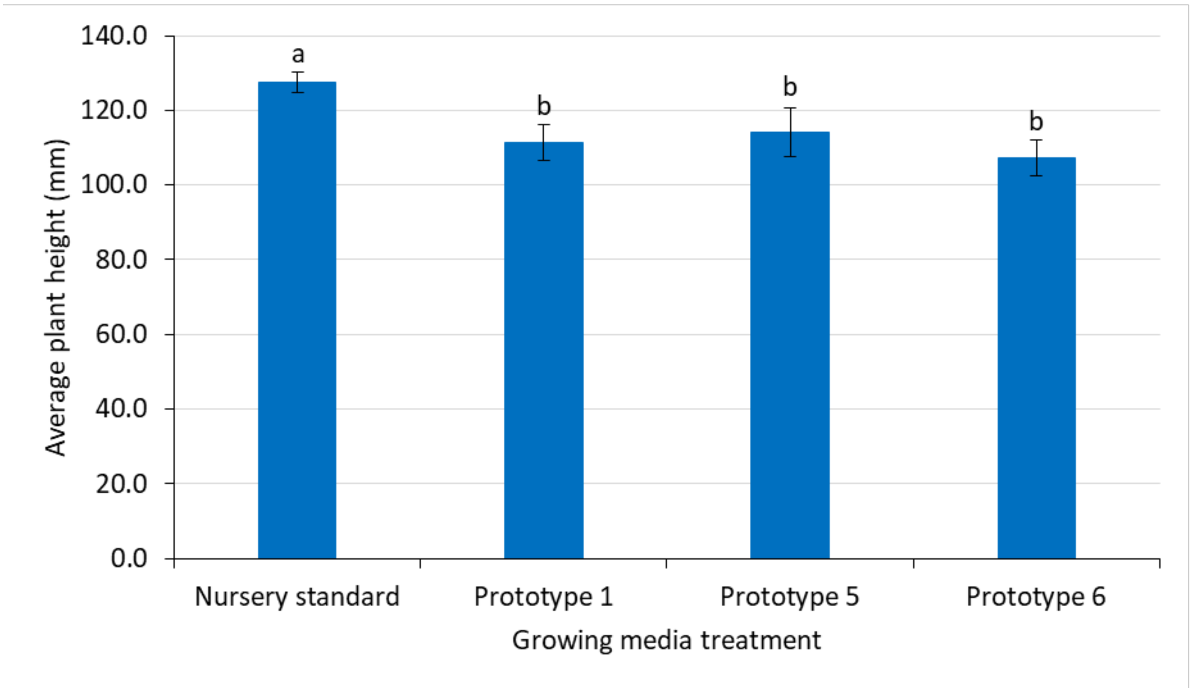


Figure 55. Average height (mm) of spring Cabbage plants grown in different growing media blends. Differences across treatments are statistically significant (p =0.003). Error bars represent 1 standard error, with 5 degrees of freedom (d.f.). Letters denote level of significance.

There were no significant differences between treatments for either the fresh or dry weight of individual plants. Prototype 5 produced the largest plant fresh weight (1.57 g). This was closely followed by prototype 1 (1.44 g), and the plants with least biomass were produced in the nursery standard (1.19 g). The dry weight results were similar, with prototype 5 greater than all other treatments (0.18 g). However, the lowest dry weight was recorded in prototype 6 (0.16 g), with both the nursery standard and prototype 1 weighing 0.17 g.

There was also no significant difference between treatments for root development. Plants in all treatments had produced a healthy white root system, which filled the plug from top to bottom, and all treatments scored just below the top score of 4.0 (**Figure 56**).

Figure 56. Plant growth and root development for spring cabbage in each of the growing media prototype blends, week 34 2019. (L-R; nursery standard, prototype 1, prototype 5, prototype 6).

Discussion

Propagation

With the spring cabbage, germination was excellent in all treatments, with all prototypes achieving over 96% germination in the tray. It was very difficult to determine much difference between the three prototypes for plant growth and root development, they all performed very well.

In terms of plant height, the nursery standard was taller than the prototypes, indicating that these plants had probably had a boost of growth early on from the nutrition held within the growing media. However, the prototype blend plants were still of an acceptable size, none of them were stunted. There was some downy mildew present in the trial, which impacted slightly on plant quality, more so in the nursery standard treatment. It may be that because these plants grew quicker and were taller, that this made for a damper, humid environment within the tray, which would have increased the incidence of downy mildew within those trays. In the prototype blend trays, where the plants were a bit smaller, there was more air movement throughout the tray, and so less chance of downy mildew developing.

Overall, there was very little variability between treatments. Prototype 5 was slightly better than the other two prototypes in terms of plant growth, although germination was lowest in this treatment. The materials within prototype 5 provide good AFP and available water for both plant and root development. However, it is likely that one of the materials was probably too coarse for use in small cell plug trays, which is likely to have affected the germination. At the time of sowing, seeds may not have sat well in all cells, because of the size of the material. However, if a finer material could be used, that brought similar physical properties to the blend, it is likely germination would improve, and there would be minimal impact on plant and root development.

Fourth generation prototype blend testing – 2019 experimental trials

The final stage of experimental testing in 2019 was to aid further development of the model. Four materials were selected from the back-catalogue of materials tested over the last four years, based on their physical properties. All four materials were very different in terms of their physical properties, which allowed for wider-scale testing of a range of physical properties. A total of 18 blends were created, these blends comprised single component media as well as mixtures of the materials. The blends were tested against a peat standard with plant material at ADAS Boxworth. All data were analysed using Analysis of Variance (ANOVA) with use of Duncan's multiple range test to separate treatments. The test was used with a 95% confidence level, and throughout the report, mean values have been used to determine statistically significant differences, as is concurrent with previous CP138 reports.

The trials at ADAS Boxworth used a bespoke Priva single line irrigation and feed delivery system. Because of the number of growing media blends identified for testing a single irrigation and feeding regime was used. Plants were irrigated as required, and a feed mix with a target concentration of 100 ppm nitrogen (N) was used (**Appendix 9**).

Protected Ornamentals

Methods

Plugs of Pansy Matrix Orange Blotch and Geranium Horizon Red were supplied in 288-cell trays by Bryants Nursery on 29 July 2019, and were transplanted by hand into standard 6-packs filled with the relevant growing media on 30 July (week 31). For each species there were 19 treatments replicated 5 times, with a total of 95 plots. The packs were spaced out evenly on the benches to ensure even watering (**Appendix 10**). Two benches were used for this trial, one for each plant species. The benches were split into four sections, with each section measuring 1200 mm by 1900 mm. These sections were separated by perspex to avoid any splash from adjacent sections and the bench itself was covered in capillary matting with micro-perforated plastic film on top (**Figure 57**). The plants were irrigated overhead using automatic sprinklers, which was set to irrigate three times per day for two minutes, and adjusted as necessary throughout the trial period.

Figure 57. Polytunnel test facility with Pansy and Geranium on separate benches, with each bench divided into four sections. Plants were watered overhead by sprinklers.

The plants were monitored for pest, disease and nutritional issues during the trial and biocontrols (*Aphidius colemani*) were introduced on a fortnightly basis for aphid control. Plugs were assessed for height, quality and root development just prior to transplant. An interim assessment took place on 19 August (week 34) and the final assessment was completed on 04 September (week 36) for pansy, and 14 October (week 42) for geranium. Plants were assessed for quality (scale of 0-5, plot overall), plant height (two plants per plot), root development (scale of 0-4, two plants per plot), number of plants per plot in bud or flower and fresh and dry weight (four plants per plot). For scoring criteria see **Appendix 10**. Plants were oven dried at 80 ˚C for 48 hours to obtain dry weights.

Results

Pansy

The quality of the pansy plants was significantly different at the interim assessment, three weeks after transplant ($p < 0.001$) with the majority of the treatments scoring lower than the peat control (which scored 4.8). Only T10, T18 and T14 were not significantly different to the peat control. The poorest plants were in T7 (score of 2.0) with a further six treatments scoring below the acceptable score of 3.0 (T5, T6, T8, T15, T17 and T19).

At the final assessment five weeks after transplant, the best quality score was seen in T10 (score of 4.7) and this was not significantly different to the peat control or a number of other treatments (**Figure 58**). The plants in these treatments had all filled out nicely, with good foliage and flower colour, and had reached pack-cover meaning they would be marketable. The poorest plants were seen in T2, T5, T7 and T8 (all scoring 2.7; $p < 0.001$). These plants were smaller and had not filled out enough to reach pack-cover.

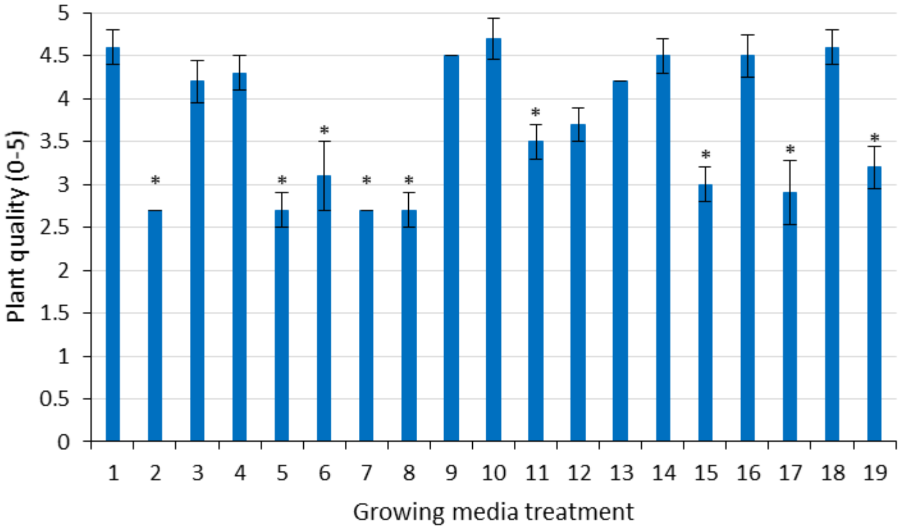


Figure 58. Average Pansy quality (scored 0-5) in different growing media blends, week 36. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

At the interim assessment, there was a significant difference between treatments (p <0.001) with the tallest plants grown in the peat control (6.58 cm), followed by T18, T14, T9, T10, T13, T4 and T11. All other treatments were significantly shorter than the peat control, with the shortest plants produced in T8 (3.4 cm).

At the final assessment five weeks after transplant, only T5, T7, T8 and T19 were significantly shorter than the peat control (p <0.001; **Figure 59**), with T8 still producing the shortest plants (8.7 cm). Plants produced in the peat control were 14.1 cm tall on average, and the largest plants were produced in T10 (14.9 cm).

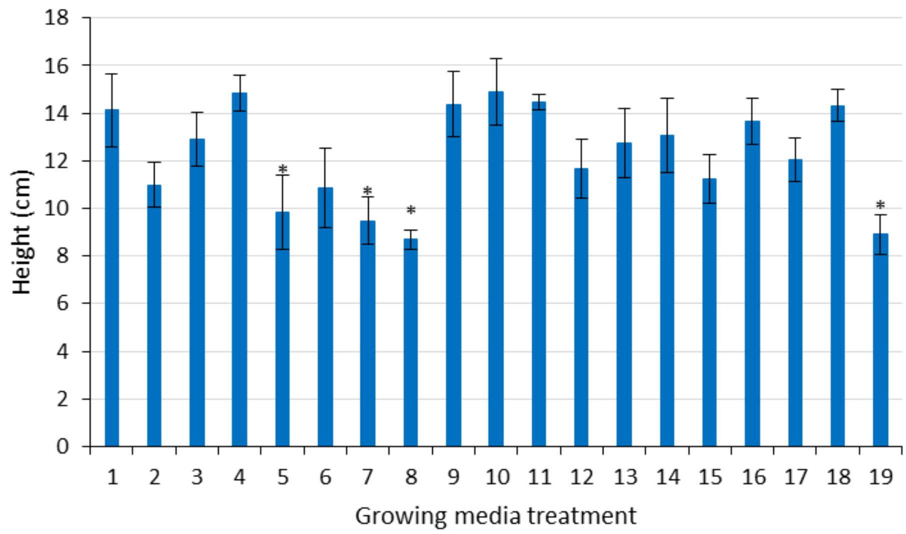


Figure 59. Average height (cm) of Pansy grown in different growing media blends, week 36. Differences across treatments are statistically significant (p =<0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

Root development was assessed once at the end of the trial, five weeks after transplant (week 36). The differences between treatments were significantly different (p <0.001) with the greatest root development in T10 (score of 3.6), however this was not significantly better than the peat control which scored 3.3. Only T3, T5, T8 and T19 scored significantly lower than the peat control, with the lowest score in T8 (1.9).

The fresh weight of the plants was rather variable across the treatments, although generally related to plant height, with the greatest fresh weight in the peat control (14.3 g). All other treatments apart from T10, T18, T14 and T4 produced significantly less biomass (p <0.001; **Figure 60**). The lowest fresh weight was observed for T7 (2.9 g), followed by T8 (3.0 g) and T5 (3.1 g).

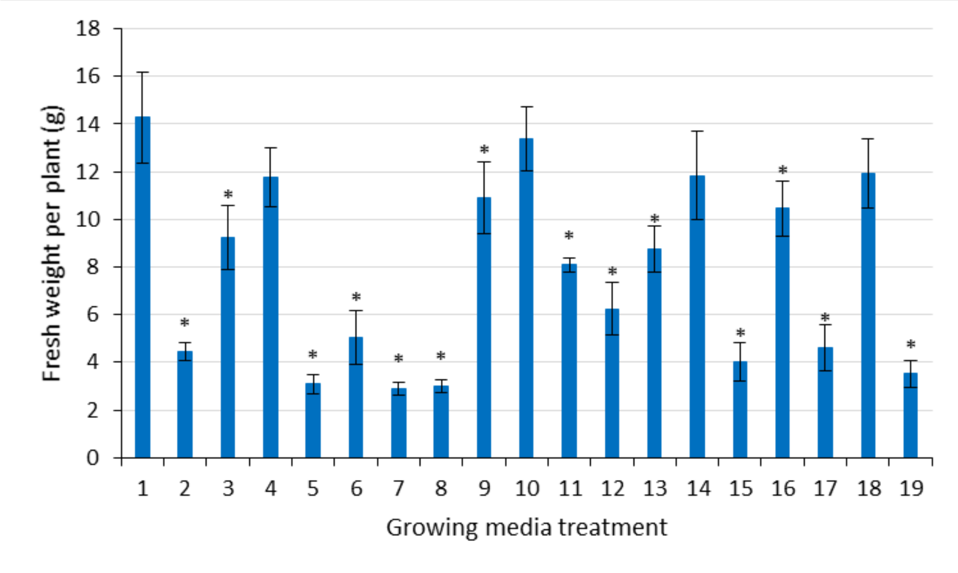


Figure 60. Average fresh weight (g) of pansy grown in different growing media blends, week 36. Differences across treatments are statistically significant (p =<0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

As expected, the dry weights mirrored the fresh weight, with the greatest dry weight in the peat control (1.96 g). This was significantly greater than all other treatments (p <0.001) apart from T10, T18, T14, T9 and T4. The lowest fresh weight was recorded in T7 (0.46 g).

At the interim assessment, only a small number of plants were in flower, and there were no significant differences between treatments. There were however significant differences in the number of plants per plot in bud in week 34 (p <0.05; **Table 6**). All treatments had some plants in bud, with T10 and T12 showing significantly more plants in bud compared to the peat control (2.2 and 2.8 plants per plot respectively). The peat control and T9 had the lowest number of plants per plot in bud (0.4).

At the final assessment in week 36, all plots were in flower, and only T5 had significantly lower plants per plot in flower than the peat control (p <0.01; 3.1 plants). The peat control had an average of five plants per plot in flower, and all six plants per plot were flowering in T10 and T18.

Table 6. Number of Pansy plants per plot which were either in flower or in bud, week 34 and week 36 2019. Figures in red are significantly different to the peat control.

	Week 34		**Week 36**
Treatment	**No. in flower (out of 6)**	**No. in bud (out of 6)**	**No. in flower (out of 6)**
1	0.0	0.4	5.0
2	0.0	0.6	4.4
3	0.0	0.8	5.6
4	0.0	2.0	5.6
5	0.2	0.6	3.1
6	0.0	0.8	4.8

7	0.0	1.0	4.0
8	0.0	0.8	4.6
9	0.0	0.4	5.6
10	0.4	2.2	6.0
11	0.4	1.6	5.8
12	0.2	2.8	5.4
13	0.4	2.0	5.4
14	0.0	1.6	5.8
15	0.2	1.4	5.4
16	0.2	1.8	5.4
17	0.2	0.8	4.8
18	0.0	2.0	6.0
19	0.0	1.4	5.2
F pr.	0.470	<0.05	<0.01
l.s.d.	0.4333	1.382	1.288

Geranium

The quality of the geranium plants was significantly different at the interim assessment, three weeks after transplant ($p < 0.001$) with a number of treatments scoring lower than the peat control (which scored 4.6 on average). Although not significant, T18 showed the best quality early on in the trial, with a score of 4.8. T3 and T10 scored the same as the peat control. The lowest scoring treatments were T5 and T15, both of which scored 3.0. However, this was just within the range of acceptable quality, there were no treatments which scored lower than this.

At the final assessment on 14 October, 11 weeks after transplant, there were a number of treatments which scored higher than the peat control (score of 4.2), although they were not significantly better. Six of the experimental treatments scored significantly lower than the peat control ($p < 0.001$; **Figure 61**). T16 scored the highest for quality (4.6), followed by T10 and T3 (both 4.4). The lowest scoring treatment was T2 with a score of 3.0, again there were no treatments which scored below the acceptable level of 3.0. Those treatments which scored significantly lower than the peat control had simply not filled out as much, and had not reached pack-cover, unlike the other treatments. **Figure 62** shows a comparison between the peat control, the highest performing treatments, and the lowest.

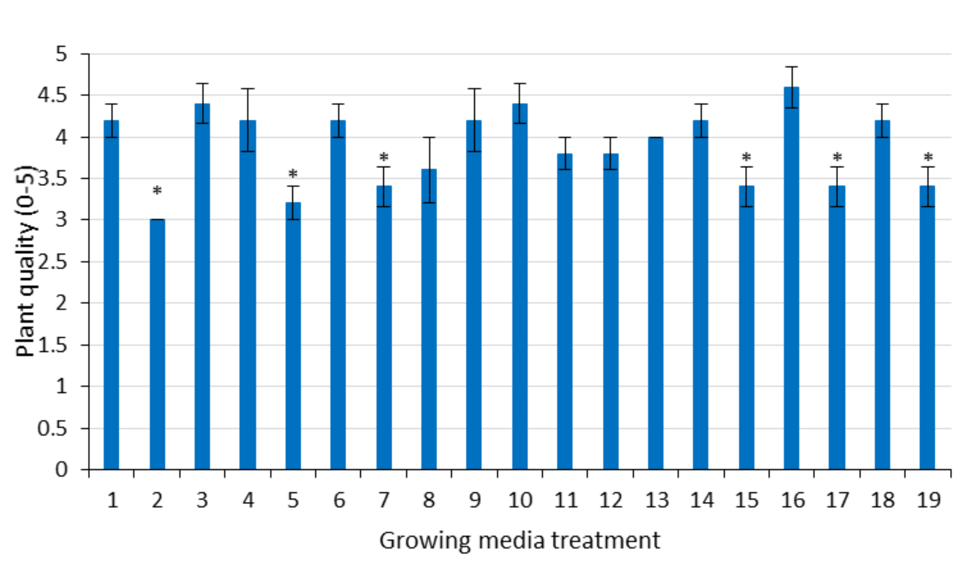


Figure 61. Average Geranium quality (scored 0-5) in different growing media blends, week 42. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

Figure 62. Geranium grown in T16, T10, T5 and T2, at the final assessment, 11 weeks after transplant, week 42. Peat control is on the left of each image.

At the interim assessment, there was a significant difference between treatments (p <0.001) with the tallest plants grown in the peat control (8.19 cm), followed by T10, T18, T4 and T3. All other treatments were significantly shorter than the peat control, with the shortest plants produced in T15 (5.1 cm).

At the final assessment 11 weeks after transplant, only T8, T2, T5 and T15 were significantly shorter than the peat control (p <0.001; **Figure 63**), with T8 producing the shortest plants (16.7 cm). Plants produced in the peat control were 22.6 cm tall on average, and the largest plants were produced in T13 (24.0 cm).

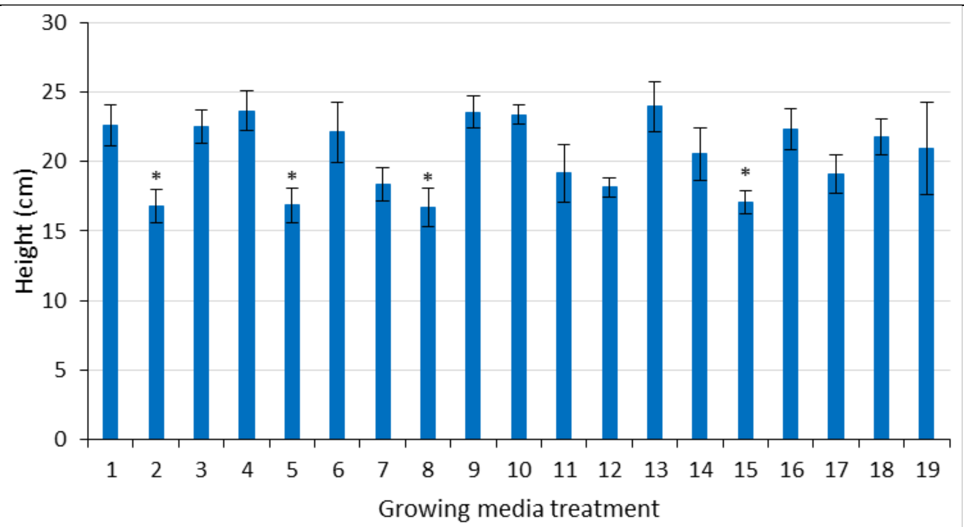


Figure 63. Average height of Geranium grown in different growing media blends, week 42. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

Root development was assessed once at the end of the trial, 11 weeks after transplant (week 42). The differences between treatments were significantly different (p <0.001) with the greatest root development in T4 (score of 3.5); significantly better than the peat control which scored 2.1. T3, T9, T10 and T18 also had visibly better developed root systems compared with the peat control. Only T2, T5, T7 and T11 scored lower than the peat control, with the lowest score in T5 (1.9), although this was not significant.

Similar to the pansy trial, the fresh weight of the geranium plants was rather variable across the treatments, although generally related to plant height. The greatest fresh weight was in T9 (79.8 g), compared to 67.3 g in the peat control. A number of treatments were significantly lighter than the peat control (p <0.001; **Figure 64**). The lowest fresh weight was seen in T5 (29.3 g), followed by T7 (30.6 g) and T8 (31.6 g).

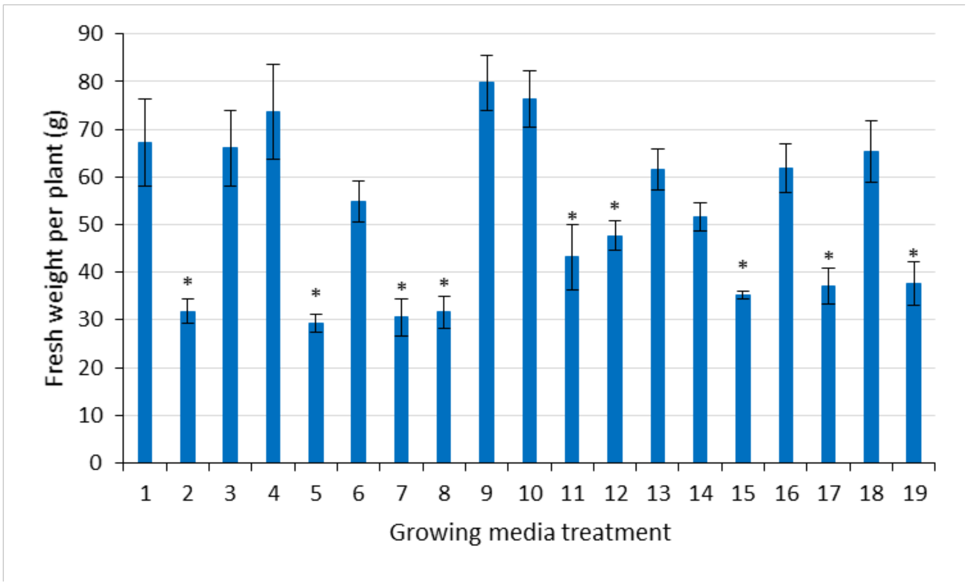


Figure 64. Average fresh weight (g) of geranium grown in different growing media blends, week 42. Differences across treatments are statistically significant (p =<0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

Plant dry weight performance was reflected by the fresh weight, although the greatest dry weight was in the peat control (7.7 g), followed by T9 (7.6 g). This was significantly greater than all other treatments (p <0.001) apart from T4, T10, T3, T18, T16 and T13. The lowest fresh weight was recorded in T5 (3.1 g).

When the interim assessment was completed on 19 August, there were no flowers or buds on the Geranium plants. Flowering was assessed at the end of the trial in week 42, results can be seen in **Table 7**. The peat control had an average of 2.8 plants per plot in flower, and only T18 had more than this (3.4 plants per plot), although this was not significant. There were a number of treatments that had significantly less flowers per plot than the peat control, and T5 was the only treatment which had no open flowers.

Table 7. Number of Geranium plants per plot in flower, week 42 2019. Figures in red are significantly different to the peat control.

	Week 42
Treatment	**No. in flower (out of 6)**
1	2.8
2	1.0
3	1.6
4	2.2
5	0.0
6	1.8
7	0.6
8	1.4
9	2.0
10	2.8
11	1.8
12	0.4
13	1.0
14	1.2
15	0.4
16	2.0
17	1.4
18	3.4
19	0.6
F pr.	<0.001
l.s.d.	1.353

Discussion

In terms of plant quality and height, geranium appeared to be broadly compliant with a range of growing media blends compared with pansy. Selected treatments stood out as high performing blends for both plant species, producing plants of marketable quality, these were T4, T9, T10 and T18.

T4 consists of 100% of one material, which is well known in the industry as a good peat replacement, and it is reassuring to see it working well in the experimental trials at ADAS Boxworth, as that shows the trials are robust and reliable. This particular material has relatively low AFP and high available water, so is a good alternative. However, simply switching from peat to 100% of another raw material retains an over-reliance on a single product. Incorporating other raw material streams creates new products and a range of growing media options for end users.

T10 stood out as the best all round performer for both the pansy and the geraniums and consists of a 50:50 split of two materials. This blend has both very good AFP and available water. Throughput time of bedding species can be very quick, just a matter of weeks in the height of summer, and so the growing media used needs to have both good available water, so that the plant can take up water and nutrients and grow quickly, but also a good AFP to allow for quick rooting. This blend produced plants that were of marketable quality, with well-developed root systems, and in the case of pansies, had significantly more buds in week 34, and were fully in flower by week 36.

T18 was the only blend containing three components to give very good results in both trials (containing one third of each raw material). Not only was plant growth and root development very good, but this blend produced more flowers in the geranium trial than any other blend, including the peat control. One of the materials used in these trials has a much higher AFP than the other two materials, but it is clear from the results that for these particular species of plant, using a material with a much higher AFP has been beneficial.

The blends that stood out as poor performers for both pansy and geranium were T5, T8 and T19. T5 contained 100% of a material which was very chunky, with very high AFP, and generally this would not be considered a suitable material for growing in on its own, especially pack bedding where the cells are quite small. The treatments were selected however to parameterise the blending model and to establish the "boundaries" of plant growth and growing media physical properties.

Hardy Nursery Stock - Choisya
Methods

Liners of *Choisya ternata* were supplied by Kernock Park Plants Ltd in week 29 (17 July 2019), and were potted by hand into 2 L pots filled with the relevant growing media on the 19 July. There were 19 treatments replicated 5 times, with a total of 95 plots. The pots were spaced out evenly on the benches to ensure even watering (**Appendix 11**). One bench was used for this trial, and the bench was split into four sections, with each section measuring 1200 mm by 1900 mm. These sections were separated by perspex to avoid any splash from adjacent sections and the bench itself was covered in capillary matting with micro-perforated plastic film on top (**Figure 65**). The plants were irrigated overhead to start with using automatic sprinklers, which irrigated for four minutes every day over the first weekend. Irrigation then switched to drip irrigation on 22 July. This was set to irrigate two times per day for two minutes, and adjusted as necessary throughout the trial period.

Figure 65. Polytunnel test facility with *Choisya* set-up with drip irrigation.

The *Choisya* plants were monitored for pest, disease and nutritional issues during the trial, and biocontrols were introduced on a fortnightly basis for aphid and spidermite control (*Aphidius colemani* and *Phytoseiulus persimilis* respectively). The plants were assessed at four week intervals during the trial, with a final assessment in week 41 (11 October). At each assessment date, plants were assessed for quality (scale of 0-5) and plant height. At the final assessment in week 41, plants were also assessed for root development (scale of 0-4) and fresh and dry weight. For scoring criteria see **Appendix 11**. Plants were oven dried at 80 ˚C for 48 hours to obtain dry weights.

Results

At the first assessment, four weeks after potting, there were no significant differences between treatments for plant quality. The peat control scored 3.0, and the highest scoring treatment was T7 with a score of 4.0. The lowest scoring treatments were T10 (2.6) and T15 (2.8). These were the only treatments to score less than 3.0. The plants in T10 and T15 were just a bit behind the other treatments and had not put on as much new growth.

At the next assessment, eight weeks after potting, there were significant differences between treatments ($p < 0.05$), with the lowest scoring plants in the peat control (1.4). T13 was the highest scoring treatment (4.0). There had been some plant death in the peat control, as well as in T6, T10, T11, T12, T15 and T18, which contributed to the lower quality scores. It would appear that these liners had struggled to root-out sufficiently, and with the hot summer temperatures, the plants had struggled to take-up enough water to thrive. Because not all the plants in any one treatment had died, plant death did not appear to be treatment related, instead it is likely that these were simply weaker liners.

At the final assessment in week 41, 12 weeks after potting, quality differences between treatments remained significant ($p < 0.05$). The peat control was still the lowest scoring treatment (1.4) and T13 was the highest scoring (4.0). A number of treatments were significantly better than the peat control; T2, T4, T5, T7, T13, T14 and T19 (**Figure 66**). These all scored greater than 3.0. There was some variability in plant quality within treatments. *Choisya* can be quite a tricky plant to grow and they are very slow to root so again it is unlikely that these differences were treatment related. **Figure 67** shows a comparison between the peat control, the highest performing treatments, and the lowest.

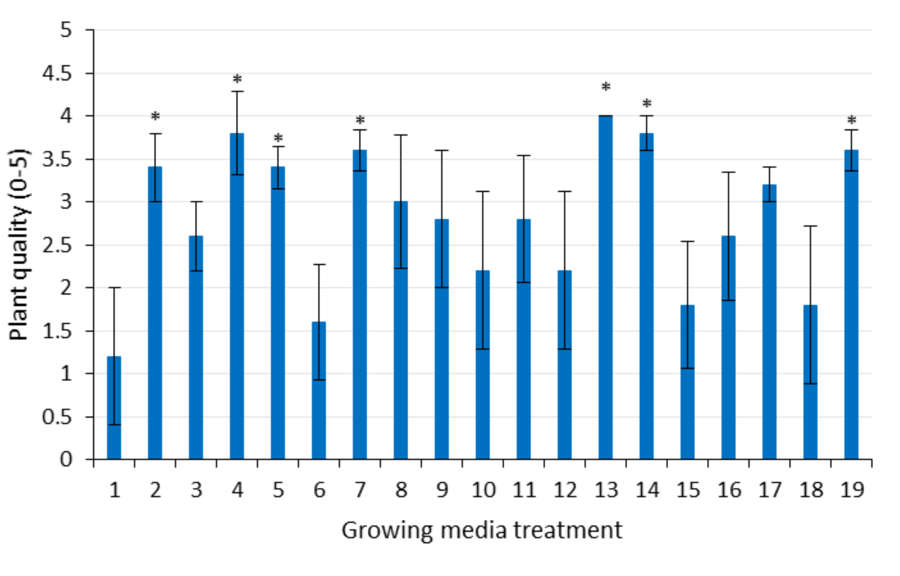


Figure 66. Average *Choisya* quality (scored 0-5) in different growing media blends 12 weeks after potting. Differences across treatments are statistically significant ($p < 0.05$). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

Figure 67. *Choisya* grown in T1, T6, T14 and T13 at the final assessment, 12 weeks after potting.

There were no significant differences between any of the treatments in the first two assessments for plant height. At the final assessment, the tallest plants had been produced in T13, with an average plant height of 35.2 cm. The smallest plants were produced in T6 (17.0 cm), closely followed by the peat control (17.2 cm). The peat control was significantly shorter than T5, T7, T13, T14, T17 and T19 (p =0.020; **Figure 68**).

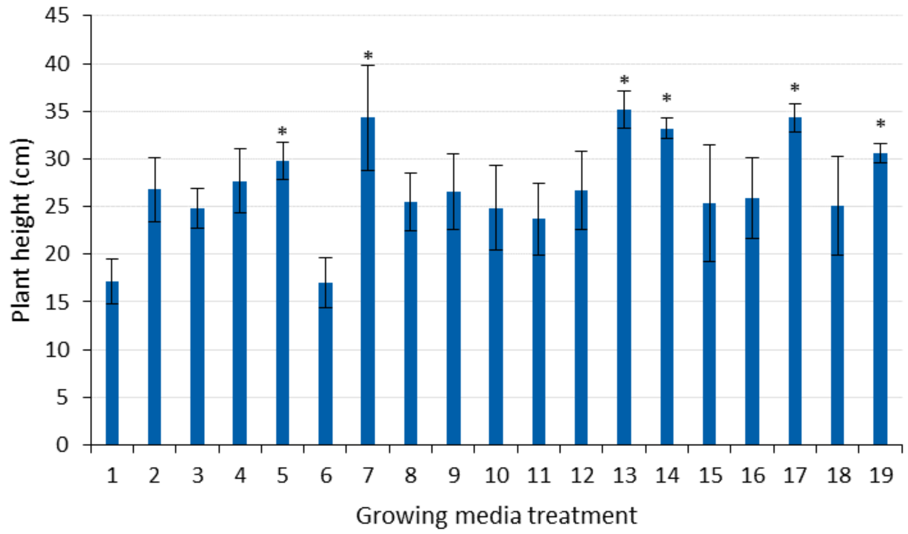


Figure 68. Average height of *Choisya* grown in different growing media blends 12 weeks after potting. Differences across treatments are statistically significant (p =0.020). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

At the final assessment 12 weeks after potting, there was a significant difference in root development between treatments (p =0.050). *Choisya* are slow rooting, so the amount of root in all treatments was not huge, however T7 had the highest root development score (2.2). The lowest amount of root development was observed in the peat control (0.2). These liners had simply failed to root out sufficiently. Overall, root development was significantly greater in T4, T7, T8, T9, T13 and T14 compared with the peat control.

At the end of the trial, there was no significant difference between treatments for fresh weight. The lowest fresh weight was recorded in the peat control (16.5 g) and the highest fresh weight was recorded in T12 (48.0 g).

There was a significant difference however in the dry weight (p =0.023; **Figure 69**) with the greatest dry weight recorded in T12 (14.9 g) and the lowest dry weight recorded in the peat control (4.5 g).

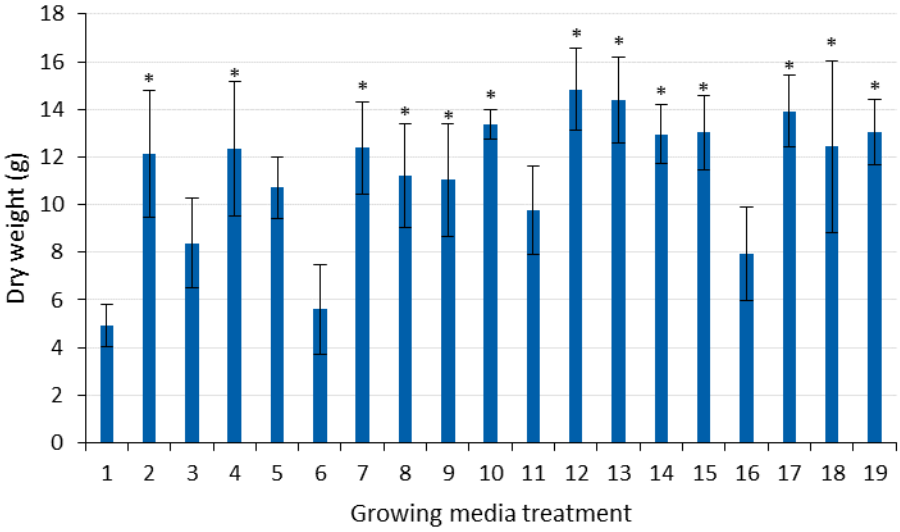


Figure 69. Average dry weight of Choisya grown in different growing media blends 12 weeks after potting. Differences across the treatments are statistically significant (p =0.023). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

Discussion

Plant height was not significantly affected by any of the treatments until the final assessment in week 41. All plants started growing well initially, but growth slowed down in some treatments later on in the trial, whereas other treatments continued to flourish. Treatments 5, 7, 13, 14, 17 and 19 were particularly promising for plant height; these treatments were all significantly taller than the peat control at the end of the trial.

Similarly to plant height, there were no significant differences in plant quality early on in the trial, but differences did become apparent at the second assessment. Whilst the peat control was good quality initially, the plants did become poorer as the trial went on, with some plant death occurring. This was also noted in some other treatments (T6, T8, T9, T10, T11, T12, T15, T16 and T18). However, not all plants within each treatment were affected, and so it seems unlikely to be treatment related and more of an unfortunate combination of hot summer temperatures and some liners simply struggling to establish.

Root development was slow within the trial, as is normal for *Choisya,* although the treatments with the better root system seemed to be those where plant quality was also better. This would make sense as you would generally expect a plant with a good root system to be able to take-up water and nutrients, hence a better quality plant. It is encouraging to see that in these treatments, both top growth and growth within the root zone was decent.

Although there was no significant difference in fresh weight, the dry weight was significant, with the peat control the lightest of the treatments, and this can be attributed to the lower plant height within this treatment. Interestingly, T12 had the greatest biomass, and yet this treatment was not one of the best performing for quality or plant height, and the root development was one of the lowest scoring in the trial.

Overall, the most promising treatments in the *Choisya* trial were T5, T7, T13, T14, T17 and T19. T5 contained 100% of a chunky material, whilst this may seem an unusual choice for a growing media, *Choisya* like free-draining compost with a good AFP. This material had a particularly high AFP and was clearly suited to *Choisya* production.

T13 and T14 contained two of the same materials, but in different quantities (50:50 and 25:75 respectively). One of these materials was the same as in T5 (large component parts creating large pore spaces and high AFP) and the other material had a much lower AFP, with a higher available water content. Combining these materials in various combinations clearly works well, with the coarse material helping to increase the amount of air spaces available for root development and drainage.

Protected edibles – Pot herbs
Methods

Seeds of thyme and coriander were supplied by Moles seeds in July 2019, and these were sown into square 9 cm pots on 01 August (week 31). The pots were filled with the relevant growing media blend, and 40 seeds were added to each pot, and then lightly covered with growing media. For each herb species there were 19 treatments replicated eight times, with a total of 152 plots.

Once the pots were sown they were irrigated overhead, placed into plastic trays, and then stacked-up in a cool dark shed and covered with white polythene for four days, to encourage germination and prevent the pots from drying out. The trays were removed on 05 August and placed within a glasshouse where they were watered overhead by hand three times a day. Finally, on 08 August the trays were moved into the polytunnel testing facility and placed on an ebb and flood bench. Green shade netting was placed over the top of the bench to help prevent the pots from drying out completely in the hot weather, and the pots continued to be watered overhead by hand, until 16 August when germination was complete. The pots were then set-out on the bench in a randomised trial design (two bench sections per herb species). Each bench section measured 1200 mm by 1900 mm and contained one ebb and flood tray unit. The pots were irrigated once per day using the ebb and flood system, which delivered water to a depth of 15 mm across each bench section for a total flooding time of 3.5 minutes. The pots were spaced out evenly on the benches to ensure even watering (**Figure 70** and **Appendix 12**).


Figure 70. Thyme and coriander plants set out on the bench in a randomised design, the bench was covered with green shade netting. Plants were watered once per day via ebb and flood.

The coriander and thyme were assessed in week 36 (02 September) and week 40 (01 October) respectively. For each plot, the plants were assessed for quality (scale of 0-3), plant height and the number of germinated seeds per pot. Fresh and dry weight was recorded for the first six replicates (114 plots). For scoring criteria see **Appendix 12**. Plants were oven dried at 80 ˚C for 48 hours to obtain dry weights. The remaining two replicates, two plants of each treatment, were placed into shelf life for 14 days. The plants were only watered once to capacity before entering shelf life. The plants were then monitored daily, and the day of plant wilting recorded. The shelf life room was set to 18°C, 12 hours light/dark.

Results

Coriander

When germination was assessed, there were no significant differences between treatments. The highest level of germination was observed in T12 (91.9%) and the lowest germination was in the peat control (65%).

The quality of the coriander plants was broadly similar across the treatments, with almost all plants scoring 2.0 or above, meaning they were of marketable quality (**Figure 71**). Only T5 scored just below 2.0 (score of 1.9), and this was significantly lower than the peat control which scored 2.3 ($p < 0.001$). T5 was just on the smaller side, and not as well developed as the other treatments. Two of the treatments scored significantly higher than the peat control; T9 and T18 (both scoring 2.7). These pots were nice and full, and the coriander foliage was green and healthy. **Figure 72** shows a comparison between the peat control, the highest performing treatments, and the lowest.

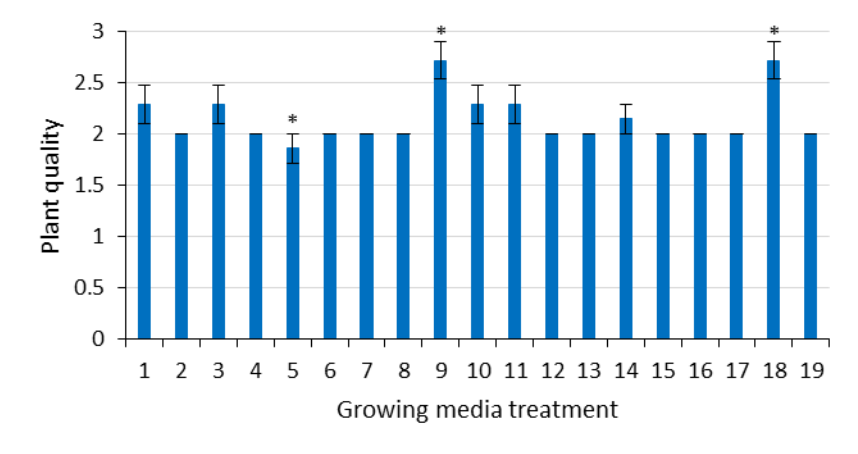


Figure 71. Average coriander quality (scored 0-3) in different growing media blends, week 36. Differences across treatments are statistically significant ($p < 0.001$). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

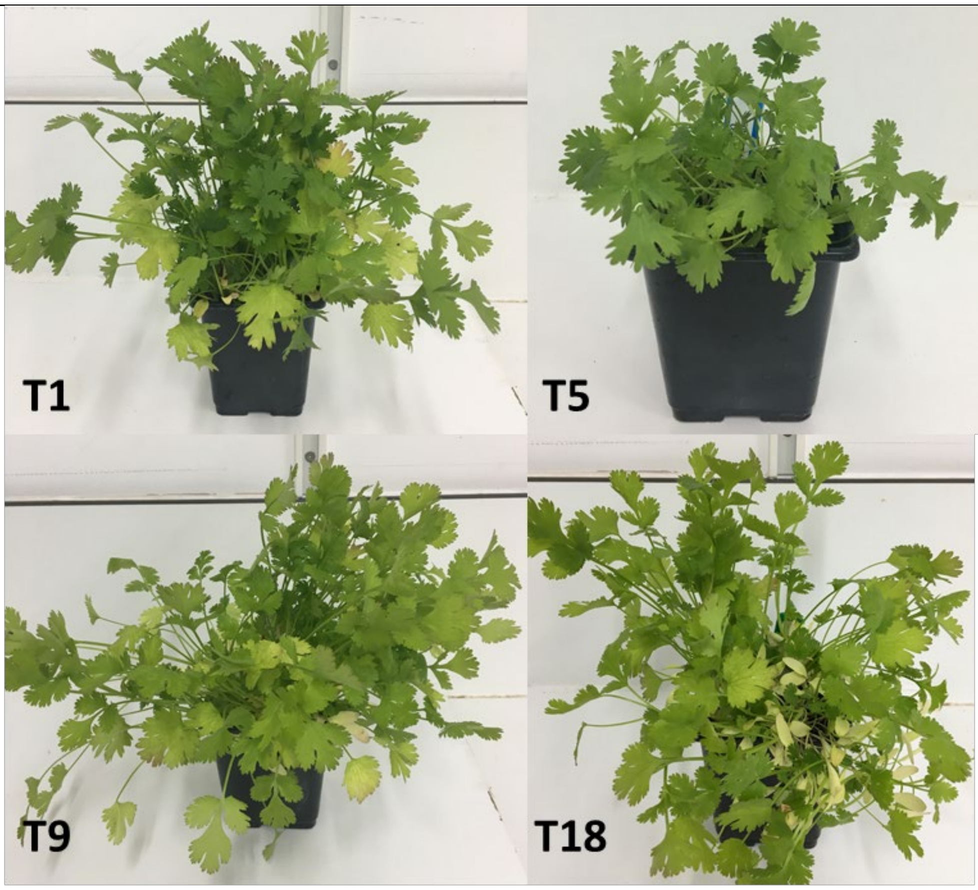


Figure 72. Coriander grown in T1, T5, T9 and T18 at the final assessment, 02 September 2019, week 36.

The general height specification for coriander is 17 cm. The tallest plants were produced in T3 and the peat control (20.1 cm). The shortest plants were produced in T5 (13.0 cm), and in total eight of the treatments were significantly shorter than the peat control (p <0.001; **Figure 73**). Aside from T5 and T6, all other treatments reached, or were very close to, the target height of 17 cm.

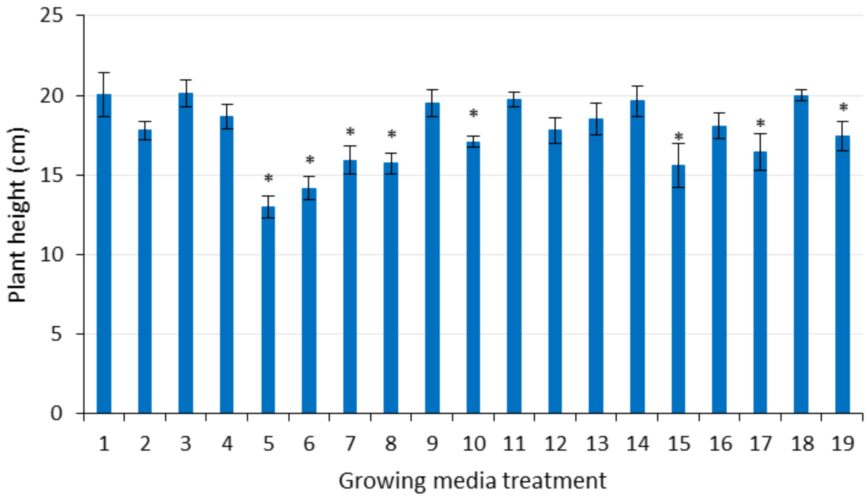


Figure 73. Average height of coriander grown in different growing media blends, week 36. Differences across treatments are statistically significant (p =<0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatment is significantly different to the peat control (T1).

There were significant differences between treatments for fresh weight (p <0.001) with both T9 (29.2 g) and T18 (25.6g) producing a yield that was significantly greater than the peat control (20.7 g; **Figure 74**). The lowest fresh weight was recorded in T5 (9.5 g) and this was significantly lower than all other treatments. In total there were seven treatments which produced significantly lower yield than the peat control.

The dry weight results followed the same trend, with the greatest dry weight in T9 (3.9 g), followed by T3 (3.4 g). Both these results were significantly greater than the nursery standard (2.9 g). T5 gave the lowest dry weight (0.87 g), and nine treatments were significantly lower than the peat control.

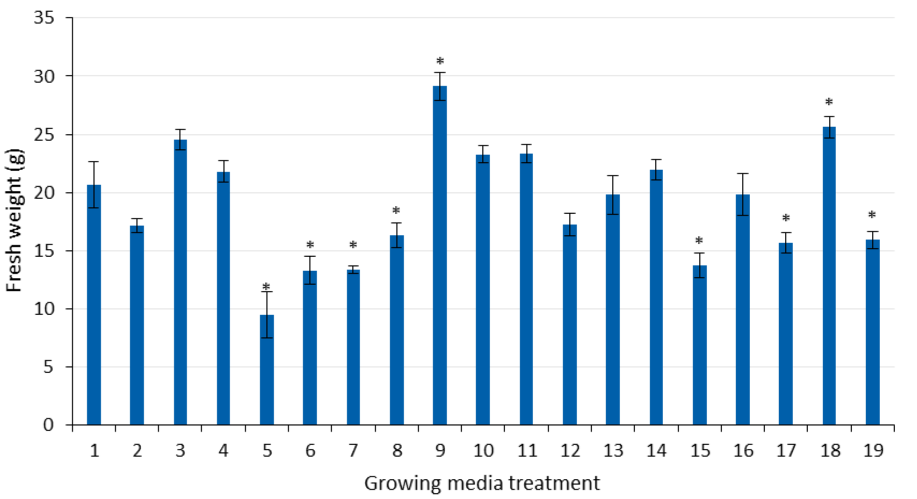


Figure 74. Average fresh weight of coriander grown in different growing media blends, week 36. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

All treatments entered shelf life for 14 days. Both T3 and T15 started to wilt after only three days, followed by T12, T13, T14 and T19 after four days (**Table 8**). T5, T7, T8, T9 and T11 did very well, lasting for at least 11 days before starting to wilt, and T6 was the only treatment which hadn't shown any signs of wilting after the 14 day assessment period.

Table 8. The number of days before plant wilting and plant death occurred in the coriander shelf life trial.

Treatment No.	No. of days before wilting occurred
1	6
2	6
3	3
4	8
5	11
6	-
7	13
8	11
9	11
10	8
11	11
12	4
13	4
14	4
15	3
16	7
17	5
18	6
19	4

Thyme

When germination was assessed, T9 had the greatest level of germination (76.3%), although this was not significantly greater than the peat control (59.6%). Only one treatment had significantly lower germination than the peat control (p <0.001) and this was T5 (28.3%).

The quality of the thyme plants was significantly different across the treatments (p <0.001; **Figure 75**), with the lowest quality seen in T5 and T6, with an unmarketable score of 1.8. These pots were small, they hadn't filled out within the pot and they didn't look very strong compared to the other treatments. The peat control scored 3.0, and there were a number of other treatments which also received this score. These plants grew strongly and at harvest were of marketable quality. **Figure 76** shows a comparison between the peat control, the highest performing treatments, and the lowest.

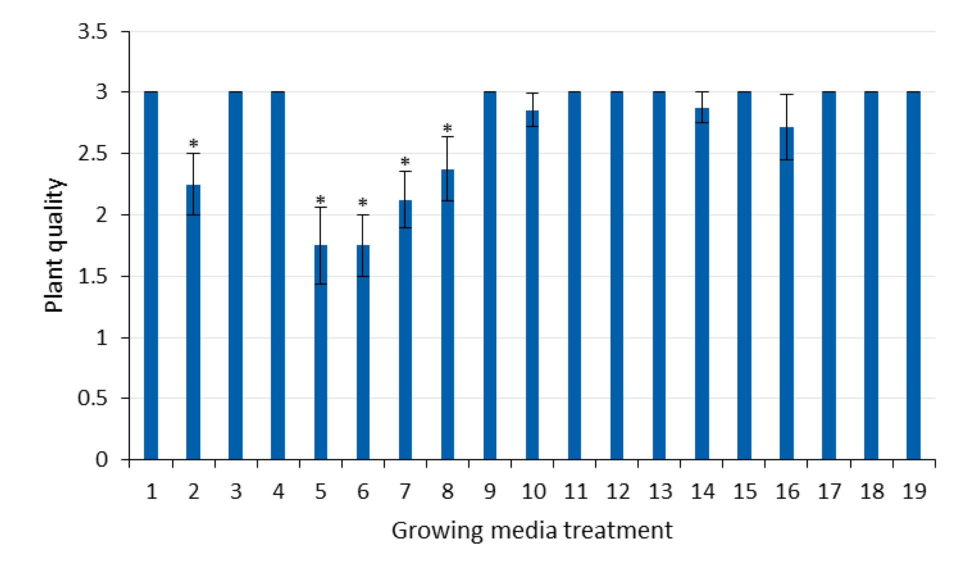


Figure 75. Average thyme quality (scored 0-3) in different growing media blends, week 40. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

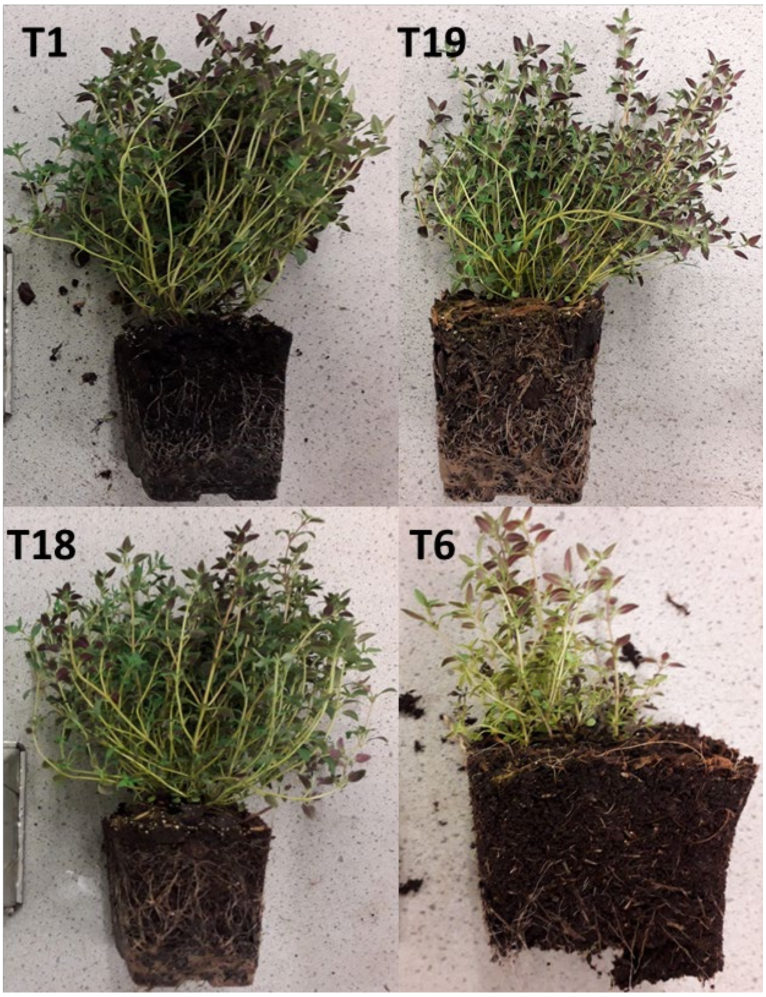


Figure 76. Thyme grown in T1, T19, T18 and T6 at the final assessment, 01 October 2019, week 40.

The general height specification for thyme is 17 cm. The tallest plants were produced in the peat control (21.0 cm), followed by T3 (20.4 cm) and T14 (19.8 cm) which was not significantly different to the peat control (**Figure 77**). All other treatments were significantly shorter than T1 (p <0.001). The shortest plants were produced in T6 (12.1 cm), T7 (13.0 cm) and T5 (13.9 cm). There were however a number of treatments which reached, or were very close to, the target of 17 cm.

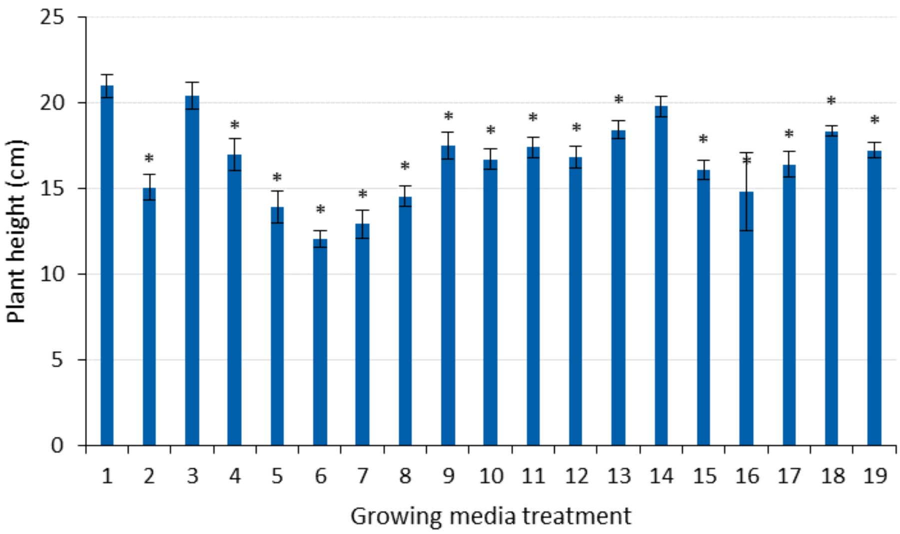


Figure 77. Average height of thyme grown in different growing media blends, week 40. Differences across treatments are statistically significant (p =<0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatment is significantly different to the peat control (T1).

The fresh weight of the thyme was generally similar to the height, with T1 producing the greatest fresh weight (27.8 g). T18, T13, T3 and T14 were slightly lighter than the peat control (26.6 g, 24.7 g, 24.0 g and 22.9 g respectively), but not significantly so. All other treatments were significantly lighter than the peat control (p <0.001; **Figure 78**) with the lightest grown in T5 (5.6 g).

The dry weight of the thyme was generally reflected by the fresh weight, although this time the greatest dry weight was in T18 (4.3 g), followed by T1 (4.2 g). Only T13, T3, T9, T11 and T14 were not significantly different to the peat control; all other treatments were significantly lighter (p <0.001). The lightest dry weight was T6 (0.78 g) followed by T5 (0.82).

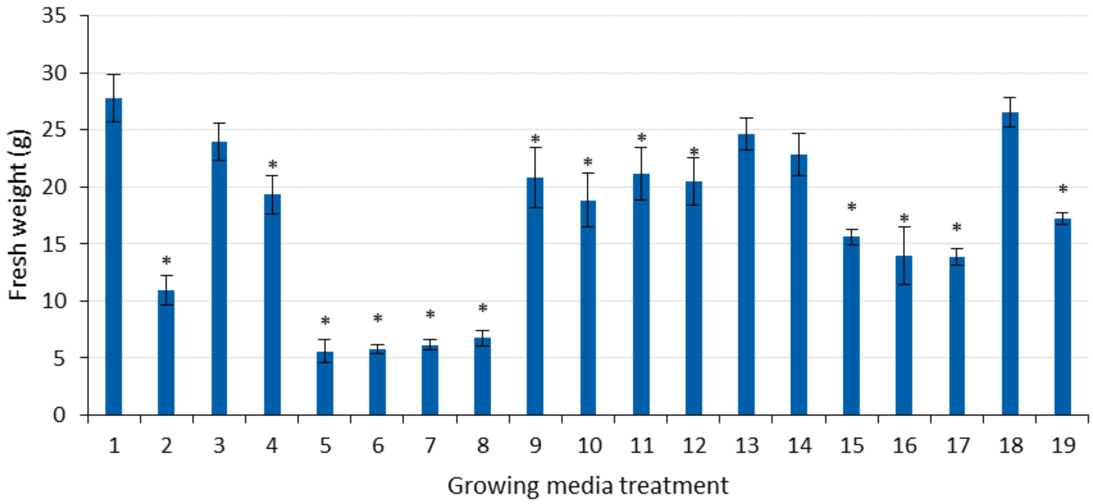


Figure 78. Average fresh weight of thyme grown in different growing media blends, week 40. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.). * = treatments are significantly different to the peat control (T1).

All treatments entered shelf life for 14 days. The first plants to show signs of wilting were in T12, four days after the start of the shelf life test. A number of treatments then started to wilt after five days (**Table 9**), with some plant death occurring after eight days in the following treatments; T1, T2, T3, T5, T13, T15 and T18. Both T4 and T7 did very well in the shelf life test, lasting at least 10 days before showing any signs of wilting.

Table 9. The number of days before plant wilting and plant death occurred in the thyme shelf life trial.

Treatment No.	No. of days before wilting occurred	No. of days until plant death
1	5	8
2	6	8
3	5	8
4	11	-
5	6	8
6	8	-
7	10	-
8	8	-
9	6	-
10	5	-
11	8	-
12	4	-

13	5	8
14	6	-
15	5	8
16	9	-
17	6	-
18	5	8
19	5	-

Discussion

Across the two trials, T3, T9, T14 and T18 all stood out as high performing blends, producing plants of a good quality which would be marketable. There were a couple of treatments which worked better for certain criteria for one species. For example, T18 was very promising in the coriander trial, producing plants that had significantly better quality and fresh weight, but in the thyme trial, although it was reasonable for most assessment criteria, the plants died after eight days in the shelf life test. Therefore, some growing media blends may be well suited to certain herb species, but not all.

Interestingly, T3 is 100% of a rather light, fibrous material, which you may not expect to be particularly successful on its own. However, this particular material has both AFP and available water values which fall within the suitable range for plant growing, and so it would seem this material is well suited to herb growing in an ebb and flood production system.

The most unsuccessful blend was T5, which is 100% of a chunky material with very high AFP. Generally this would not be considered a suitable material for growing in on its own. However, it needed to be tested to help see where the boundaries lie in terms of plant growth and growing media physical properties. Seed germination was also significantly lower in this blend in the thyme trial. Thyme seeds, in comparison with other herb seed types, are small and it is likely that the seeds migrate through the pore space continuum to a depth at which germination failed. However, as demonstrated in the trials, incorporating this material in relatively small amounts (25% - 33%) into a blend was successful, as the material helps to increase the AFP of the blend, without overly large pore spaces.

When it came to shelf life testing, generally the treatments which had produced the tallest plants, with the largest fresh weight, were the first to start wilting. These plants would have used up their water reserves by transpiration and water extraction from the root-zone more rapidly compared with other treatments, and so in shelf life may require top up watering.

Mechanisation

In August 2019, all of the prototypes which have been used on grower holdings (Prototypes 1-10, not the Boxworth experimental blends), were tested at the Mechanical Botanical machinery depot to see how well they would flow through different types of machinery (**Figure 79**). 300 L of each prototype were mixed at STC and delivered to the depot and a pot filling machine and a tray filling machine were tested. The machines were set-up by Mike Berry (Mechanical Botanical) ensuring that the machinery settings were suited to the material. Work was also overseen by John Adlam (Dove Associates).

Figure 79. Testing prototype blends on a pot filling machine (2 L pots) and a tray-filling machine (345-cell trays).

All blends were run through the pot filling machine first and the number of 2 L pots filled using 300 L of each blend was recorded. Observations were also made on how easily the material flowed, how well the pots filled, how well a crown was formed on the surface of the pot, and whether there were any issues with material slumping in the pots, or clogging the machine.

All blends were then run through the tray filling machine, using 345-cell trays. In 2018, 84-cell trays were tested. **Table 10** shows how many pots and trays were filled when the blends were run through the machines.

Table 10. Blend performance in a potting machine and a tray filling machine using 300 L of each blend.

Prototype	No. of 2 L pots filled	No. of 345-cell trays filled
1	135	51
2	143	57
3	149	54
4	154	55
5	139	47
6	138	52
7	137	53
8	142	53
9	141	53
10	138	55

There were no issues with the pot filling machine when testing the 10 prototypes. All blends flowed through well, none of the material caused any blockages, and the pots were well filled with an even crown to the pots. The dibbed holes also held well and there were no issues with material slumping.

With the tray-filling machine, the only blends to cause any issues were prototypes 4 and 7. Prototype 4 was particularly fibrous compared to the other blends, and there were some issues with the material clogging up the recycling section of the machine. The machine had to be stopped and the blockage cleared before tray-filling could continue. This slowed down the tray-filling process quite considerably. There was also an issue with some of the material catching on the brush which evens out the material over the tray. Eventually, this resulted in some of the material being pulled back out of the tray, so the machine had to be turned off and the brush cleaned. Overall this prototype was not suitable for use with a tray-filling machine, due to the material being too fibrous. Prototype 7 was a very heavy, dense blend, and this also caused some issues with the recycling section of the tray-filling machine. Over time, the material started to build-up, meaning that eventually the machine had to be turned off and the material cleared. Therefore, this material was not particularly well suited to use with a tray-filling machine either. However, there were no issues with any of the other eight prototypes when using the tray-filling machine.

In addition, the trial at Double H on pot chrysanthemum was set-up using the nurseries own potting machine. Again, there were no issues with pot filling, and throughout the life of the trial, no slumping was observed in any of the treatments.

Conclusions by sector

The following conclusions are based on the commercial grower trials carried out over the last four years, rather than the experimental trials carried out at ADAS Boxworth (see previous project annual reports, 2016, 2017 and 2018). The experiments at ADAS Boxworth served the dual purpose of screening and testing of candidate materials for commercial trials and the blending model development. As such, both predicted high and low performing blends were utilised to parameterise the model. The commercial grower trials used selected high performing blends identified by the experimental work. To provide a robust test of the selected materials based on physical properties and the acid test of the predictive model, the same growing media treatments were applied to a range of different nurseries, with different crops and growing systems. Therefore, the results and conclusions from these trials are of commercial significance and interest as the industry moves toward the 2030 voluntary peat use phase-out target and embraces responsibly sourced growing media.

Hardy Nursery Stock

Hardy nursery stock trials were carried out at Wyevale Nurseries in 2016, Lowaters Nursery in 2017, Darby Nursery Stock in 2018 and James Coles and Sons in 2019. The trials at Wyevale tested peat-reduced and peat-free commercially available blends on a range of species for propagation, liner production and final production. Across all of the trials, there were barely any differences between any of the treatments for any of the species, at all stages of HNS production. All of the plants were of marketable quality at the end of the trial. This showed that the growing media industry has made great progress in creating successful peat-reduced and peat-free blends, however these blends would have required significant investment in time and money to ensure the blends were effective. The model developed in this project would accelerate that process, broaden the range of materials that could be used and significantly reduce development costs for the growing media manufacturer and grower.

The first stage of prototype testing was completed at Lowaters Nursery in 2017, using prototypes 1-3 on *Choisya, Hebe* and *Salvia* finals. These blends were used as their physical characteristics came closest to peat in terms of their triangulated physical properties, and therefore the blends should perform well. Whilst the *Salvia* trial was completed quite quickly, due to it being a fast growing crop, the *Hebe* and *Choisya* overwintered to spring 2018. In summary, all three prototype blends worked well, none failed, and all plants were of marketable height and quality. Variation in root development was observed, with prototype 2 (AFP 19.7%; AW 26.2%, D_b 0.09) performing slightly better, which was a more open mix compared with prototypes 1 and 3 (**Figure 80**). Both prototype 1 (AFP 17.3%; AW 32.7%; D_b 0.13) and prototype 3 (AFP 20.1%, AW 32.5%, D_b 0.12) were slightly heavier and denser, and would have held on to the water more. For overwintering plants like *Choisya* and *Hebe*, this can cause performance issues. It was clear from these trials that a more open mix was better for longer term crops, especially those which were to overwinter.

Figure 80. *Salvia* root development in different growing media blends seven weeks after potting, week 18, 2017. L-R: nursery standard, prototype 1, prototype 2, prototype 3

The 2018 trial at Darby Nursery Stock used prototypes 2 and 4-7 on liners of Lavender, *Potentilla* and *Spirea*, and finals of Lavender and Vinca. Prototypes 4-7 were designed to be more 'extreme' in terms of their physical properties, and test where the boundaries were in terms of physical properties and plant performance. In the finals trial, generally all prototypes were successful, particularly in the Vinca trial. By the time of the final assessment, all plants had covered more than 80% of the pot and there were no significant differences between treatments for plant quality. The plants had also fully rooted. The blends used in these HNS trials were a mixture of quite light, open blends with coarser or fibrous material (prototypes 2, 4 and 5) and heavier, finer grade materials (prototypes 6 and 7). Whilst all blends worked well in the Vinca trial, there was more of a difference in plant quality and height in the Lavender trial, with a reduction in plant quality for all prototype blends, although these were still marketable. Species such as Lavender which are more sensitive to growing media composition require more careful management of irrigation and nutrition in order to produce a high quality plant, whereas more robust species such as Vinca are more tolerant of different growing media, and a range of physical properties.

There appeared to be greater differences in the liners trial compared with the finals, and the trends were similar for each of the liner species. Generally the nursery standard performed better, although plants grown in the prototype blends were good at the end of the trial. As with the Lavender finals, it is likely that for younger plant production, to get the most out of the growing media blend, greater management of irrigation and nutrition is required. However, these trials were grown on a nursery where the growing system is optimised for peat-reduced growing media, and results were encouraging. Therefore this trial demonstrated that a range of materials with different physical properties can be used for HNS production.

The 2019 trial at James Coles and Sons used prototype 2, 6 and 8-10 on finals of *Cistus, Griselinia* and *Viburnum*. Prototypes 8-10 were designed using materials which were new to the project team, and therefore were included simply because of their physical properties. In summary, all prototypes worked very well in the *Cistus* and *Griselinia* trial, with more observable differences in the *Viburnum* trial. Prototype 2 worked well in the *Cistus* trial, and in the *Viburnum* trial it produced the tallest plants, with the highest fresh weight and a good root system. However, for *Griselinia*, plants were shorter and had a lower biomass, but were of marketable quality. Prototype 2 was consistently good throughout the HNS trials, showing that blends with materials that provide a suitably open structure, with adequate available water, are well suited to HNS production. Prototypes 8 and 10 also worked very well in the 2019 trial. Both contained a very fine material with a high AW, and prototype 10 also contained a material which was light and fibrous, therefore increasing the AFP which is required for long term crops. Whilst prototype 9 was reasonable, this blend was probably too open, and not particularly well suited to long term containerised production because of potential slumping and the contraction of the growing media root zone volume.

Bedding and Pot Plants

Trials on bedding and pot plants were completed at Bordon Hill and Baginton Nurseries in 2016, Ivan Ambrose in 2017, Newey Roundstone in 2018 and Double H in 2019. The trials at Bordon Hill used commercially available peat-reduced and peat-free media to propagate Pansy and *Begonia* in 230-cell trays. These were then transplanted into 6-packs at Baginton Nurseries using peat-reduced and peat-free media, and grown on to pack-cover. During the propagation stage, germination of both the Pansy and *Begonia* was relatively even, and with the Pansy, there was little difference in the size of the young plants. Differences were more noticeable in the *Begonia,* where plants grown in one of the peat-free blends appeared to stop growing soon after germination, and were still small at transplant. Generally, the peat-reduced treatments were better during propagation, and produced plants that were even in size.

For plant quality at transplant, and final marketability, the majority of the growing media treatments performed as well as the nursery standard. The plants in one of the peat-free treatments performed poorly at the transplant stage for both Pansy and *Begonia*, producing *Begonia* plants that would not have been suitable for transplant. However, once plants had been transplanted into 6-packs, the growth and development began to even out, and by the target market week, the Pansy plants were of marketable quality, and all of the treatments were in flower. *Begonia* grown in one of the peat-free blends remained small and there were less plants in flower by the target marketing week, although they had started flowering. It is interesting to note that when the transplanted Pansy and *Begonia* were grown on to full pack cover in the same growing media the differences in quality and height were no longer significant when compared with the nursery standard at the final assessment. This trial showed that, similar to the HNS trial at Wyevale in 2016, commercially available peat-reduced and peat-free media work effectively.

The trial at Ivan Ambrose in 2017 tested prototypes 1-3 on packs of Petunia and Pansy. Overall, all three of the prototype blends performed well in pack bedding, and all plants were marketable. For the pansy crop, all plants were of very good quality, and there were no significant differences in plant height or the number of plants per plot in flower. Only the root development was significantly affected, with better rooting in prototype 1. It is possible that the addition of a chunky material in prototype 1 helped to create a more open texture, aiding root development. Prototype 1 also performed slightly better in the Petunia trial, producing plants that were a similar height to the nursery standard. This trial was showing that a range of peat-free materials will work well in pack bedding production, but the inclusion of a slightly chunkier material will help to open up the blend and improve rooting, which is important for pack bedding production.

In the 2018 trial at Newey Roundstone, trials were completed on Pansy and Geranium in packs, and Geranium and *Fuchsia* in pots in the summer, and on Pansy in packs in the autumn. Within each trial, prototypes 3 and 4-7 were tested. Overall, all prototypes, with the exception of prototype 7 worked very well and produced plants that were comparable to the nursery standard, and of high quality. Differences were more noticeable in the summer pack trials, which suggests that under extreme conditions such as those experienced in the summer of 2018, management of the prototype blends may need to be refined, in order to get the desired growth response.

Prototypes 3, 4 and 5 (**Figure 81**) were all promising, with some good results within each trial. These blends all contain woody materials, which would open up the growing media structure, creating plenty of air spaces and allowing for good root development. Prototypes 6 and 7 on the other hand both contained a material which was heavier and denser, and this may have proved problematic for bedding plant production (prototype 6, AFP 8.13%; AW 48.09%; D_b 0.16 and prototype 7, AFP 16.4%; AW 40.8%, D_b 0.27). However, this material can be useful in a blend if it is added in a smaller amount, as seen with prototype 3, as it will help to retain moisture. Generally, no single prototype stood out as a better performer in the 2018 trials, which indicated that a range of materials blended in different ways can all be suitable for pot and pack bedding plant production, as long as there is adequate AFP to allow for good root development, and the AW is not too high.

Figure 81. Pansy 'Inspire' grown in different growing media blends at the final assessment, week 44. Left: nursery standard (top) and prototype 3 (bottom). Middle: nursery standard (top) and prototype 4 (bottom). Right: nursery standard (top) and prototype 5 (bottom).

At Double H in 2019, prototypes 3, 5 and 8-10 were tested on pot chrysanthemum. The plant quality was extremely good, and all plants reached the target market height on time. There were no delays in flowering and root development was very good across the treatments. Prototypes 5, 8 and 10 all worked extremely well during the trial. Prototype 5 has both good air-filled porosity and available water as it contains both a fine grade material, similar to peat, along with a coarser, chunkier material. Prototype 8 is a very fine-grade material, with high water holding capacity and adequate air-filled porosity. Prototype 10 also contains a fine-grade material, along with a fibrous material, which brings high water holding capacity to the mix, as well as an increased air-filled porosity.

Generally, the trials on bedding and pot plants with the prototype blends were very successful, and even those which appeared to not be quite as good, could be improved with some careful management of irrigation and nutrition. It is important to use materials which provide a nice open structure to allow for root development, along with materials with a good AW which will help aid water retention, which is particularly important in relatively small packs during the hot summer months.

Potted herbs

Trials on potted herbs were completed at Vitacress in 2016 and Lincolnshire Herbs in 2017 using sub-irrigation systems which is standard for herb production. Trials were completed on a number of species, including seed-raised (basil, coriander, parsley etc.) and plug-raised (rosemary), in spring, summer and autumn.

The trials at Vitacress in 2016 were the first year of grower trials, and therefore tested peat-reduced and peat-free blends which had been created by the growing media manufacturers and were commercially available. Basil, coriander and parsley were tested in spring, summer and autumn on an ebb and flood system. Pots were monitored for germination, and for each species at each sowing date, there was very little difference between treatments for both germination time and the number of seeds that germinated within each pot. During the main growth phase, the roots were examined and there was also little difference in root development between any of the growing media treatments. Each species exhibited strong white

root growth, the tips of which were visible through the bottom of the pot. It was noted during all trials at Vitacress that some of the commercial peat-free treatments were slower to grow, and were shorter than the other plants. However, once the trial reached harvest, these plants had generally caught up and reached the specified height. Quality did not generally appear to be affected by any of the treatments, apart from one peat-free treatment in the summer and autumn, which may have benefitted from extra water.
The pots had been grouped on benches by treatment type (i.e. peat-reduced or peat-free) to allow for different watering needs, however, overall, the water requirement of the various blends was not as different as was originally expected, with the exception of the peat-free blend mentioned above. Therefore, the treatment plots were watered the same as the nursery standard. When these blends were tested for their physical properties, it was noted that they were all rather similar in terms of AFP and AW, and their triangulated physical property values were in relatively close proximity to peat. This helps to understand why these blends were successful in practice, as a reasonable AFP would help with the root development, and the AW ensures that the pots do not dry out too quickly.

In the 2017 trial at Lincolnshire Herbs, prototypes 1-3 were tested on basil, chive and rosemary in spring and autumn on a sub-irrigation gutter system. Whilst there were some differences in crop height and fresh weight for prototype 2, prototypes 1 and 3 gave promising results, and produced good quality marketable plants (**Figure 82**). Both prototypes 1 and 3 contained a material with a slightly higher bulk density and available water, along with materials that have a good AFP. This meant that for these prototypes, the AFP allowed for improved rooting, and the AW prevented the plants from getting too dry. Prototype 2 did not have any material with a higher AW, and instead consisted of materials which had a higher AFP. Whilst these values were not too high for other longer term crops, it is likely the for pot herb production on a sub-irrigation system the AFP was too high, and the pots dried out too quickly. Therefore in pot herb production, it is important to use materials which have a reasonable AW as well as AFP so that the herbs can root, but do not dry out too quickly.

Figure 82. Basil grown in different growing media blends at the final assessment, week 41, 2017. L:R - Nursery standard, Prototype 1, Prototype 2, Prototype 3.

Soft fruit

In the soft fruit sector, coir is now the most commonly used growing media, with crops grown in troughs, pots and bags. Although coir can take on many forms, and comes in various grades, the physical properties of coir are not too dissimilar to those of peat, and so it is easy to understand why growers have been able to make the transition from peat to coir relatively easily. However, in the long-term, this may not be a viable option, as the demand for coir will increase as other sectors look to move away from peat and the global demand for growing media is set to increase. Therefore, it is just as important to explore the use of alternative materials in the soft fruit sector, as it is in other sectors of horticulture where peat is still heavily used.

Throughout the project, trials have been completed on strawberries and raspberries both in propagation at EU Plants in 2017 and 2018, and as a main crop at New Farm Produce (NFP) in 2016-2017 and 2019. The first trial at NFP in 2016-2017 used commercially available coir-reduced and coir-free blends from the growing media manufacturers, with bare root plants and tray plants. Strawberries were planted in 2016, and yields were recorded in 2016 and 2017. In 2016, the different growing media treatments had more of an effect on the tray plants than the bare root plants. Whilst there were no significant differences in the total yield of the bare root plants, there were differences in the tray plants, with all but one of the coir-free treatments producing lower yields than the coir nursery standard. In 2017, there was no significant difference between treatments for the total yield of either the bare root plants or the tray plants. Generally, the differences between treatments were less pronounced in the second year of the trial. For bare root plants, the coir nursery standard was still the highest yielding, with a significantly greater percentage of Class I fruit compared to the coir-free blends, but the coir-reduced blends performed well. For tray plants, the greatest yield was produced in one of the coir-free blends, however this treatment also produced the greatest Class II yield, so although the yield was greater, the quality of the fruit was not quite as good. All of the blends performed reasonably well compared to the coir nursery standard for the tray plants. This trial demonstrated that it was possible to move away from coir in soft fruit production, and through experience, with optimised irrigation and nutrition, to achieve maximum marketable yields.

The propagation trials at EU Plants in 2017 and 2018 with raspberries and strawberries also appeared to echo the results seen at NFP in 2016. This time, further coir-reduced blends were used, which were mixed based on their physical properties and results were very encouraging. There was little observed difference in the strawberry trial, with some growth effects in the early stages of the raspberry propagation trial. However, when the raspberry plugs were transplanted into 2 L pots of the same prototype blends, they caught up with the coir standard plants, and there were no significant differences in cane height by the time the plants were ready for cold storage. The strawberry plants were incredibly even in terms of size and quality in the 2018 trial at EU Plants, with virtually no difference in crown size, which was promising for yields the following year.

When the propagated material was planted on in 2019 and grown at NFP, there were some yield differences between treatments for both raspberries and strawberries, but again, results were promising. There was one exception with prototype 7 which was a heavy, dense blend with low AFP. In soft fruit production, where growing media is generally kept on for at least two years, this blend may not be suitable, as the media had become more compacted when compared to the other blends, which was starting to impact on root health. However, the trials have demonstrated that it is possible to reduce the amount of coir used in soft fruit propagation and achieve good quality plants and high yields, as long as the structure is maintained over the growing period to allow for effective root development.

Top fruit

Top fruit trials were carried out at F P Matthews from 2017-2018 on apple and cherry using prototypes 1-3. The trial took young fruit trees which were potted into 12 L pots and grown on for 18 months. Whilst this nursery already grows some of its crop in 100% peat-free, it was important to look at the use of other materials, and use blends which had been created based on their physical properties, rather than through trial and error.

The results for top fruit production were very encouraging. For both apple and cherry performance there were almost no significant differences in any of the variables measured throughout the trial period. The cherry trees in particular were very uniform across all of the treatments (**Figure 83**). The quality of the final trees was very high and all of the treatments had produced good root growth, all filling up to 75% of visible pot volume. There were differences in the regrowth of the apple trees after pruning, with prototypes 1 and 2 having the largest regrowth after 16 weeks. The increase in the girth of the apple trees in the growing media treatments followed a similar trend, with both prototypes 1 and 2 having the largest increase in tree girth. These differences did not affect the overall quality scores at the end of the trial and although there were very minor differences in the root scores by growing media type, these were not significant. Both prototypes 1 and 2 contained a coarse, overtly fibrous material as part of the blend, and this opened up the structure of the root-zone which was maintained for the duration of the crop cycle. This may explain to some extent these blends performing better than prototype 3. Prototype 3 did not contain this material, but did contain a heavier material and a fibrous material which could degrade over time leading to a more consolidated growing media. For long term containerised top fruit tree production, using materials which give a more open structure, with a higher AFP, would be beneficial to rooting and plant growth.

Figure 83. Cherry trees at the final assessment date, week 19 2018. L:R - Prototype 3, Prototype 2, Prototype 1, Nursery standard.

Salad and Vegetable propagation

Throughout the course of the project, trials work on salad and vegetable propagation was carried out for both blocking and modules. Blocking compost has unique physical properties, with a very low AFP, high AW and high D_b (average blocking peat values for G's Fresh Ltd in 2016 were 8.0% AFP, 52.5% AW and 0.16 D_b). The material is also very sticky, and holds together very well when going through the blocking machinery. Previous experience with alternative materials at G's Fresh Ltd outside of CP138 indicated that simply switching to peat-free would not be possible, due to a lack of alternative materials currently available which have a similar set of physical properties to the peat used for blocking. Therefore, an approach looking at peat-reduced blends incorporating materials such as coir and bark, at 20% and 40% were agreed as an appropriate way to start reducing the peat content of the blocks.

Lettuce trials propagated in blocks and taken through to harvest were completed in 2016 at G's Fresh Ltd, in spring, early summer and late summer, with a smaller demo trial completed in summer 2017. One area of concern was how well the blends would pass through the blocking machine, and form the blocks, due to reduction of peat and therefore a reduced water content. However, this proved not to be an issue when it came to trial set-up. The trial blends had to be mixed with water, but once enough water had been added to the blend, it was possible to send peat-reduced blends (up to 40% peat-reduced) through the machine, and produce blocks which seeds could then be sown into. These blocks also maintained their integrity throughout the propagation phase, and when it came to planting the blocks out into the field, they held together well, and did not crumble or cause issues for planting.

Generally, in terms of lettuce germination and initial growth, there was very little difference with all treatments germinating at the same time. When it came to harvest, there were some differences in yield, with the 40% peat-reduced having a slightly lower yield, but this was only seen in the spring trial, not the summer trials. Overall for blocking production, fine-grade material as the peat alternative worked better, and it was possible to go as low as 40% peat-reduced and still get comparable yields. It is not currently possible to go lower than 40% peat-reduced with the range of materials that are commercially available. However, if a material could be found that was similar in its properties to the current blocking peat, then it is likely that this could be incorporated into the mix at a higher percentage.

For vegetable propagation in modules, trials were carried out at Delflands Nurseries in 2018 and 2019, and this time peat-free blends were tested for both Chinese and Spring cabbage. In 2018, five peat-free blends were tested, and germination was excellent for both cabbage types, with 96-98% germination. The young plants grew very well, and all plants were fully rooted as well, which meant that the plugs held together well and did not fall apart when removed from the cell tray. Results were very similar in 2019, when three peat-free blends were tested. As with the blocking trial, finer materials worked better, as they sat in the module trays better, and allowed for a more even sowing (i.e. seed sat in the centre of the module rather than at the edge). All of the young plants produced were suitable for planting, and in summer 2019, spring cabbage was planted out into the field so that yield could be assessed. Unfortunately, due to extremely wet weather in autumn and winter of 2019, the crop failed and the trial was abandoned.

It was observed in 2018 and 2019 that the plants propagated in the prototype blends were slightly slower to grow than the nursery peat-reduced plants. This could be useful for plant scheduling, if for one reason or another plants need to be held onto for longer prior to planting. However, it was also possible to speed up their growth just by feeding the plants once to give them a boost. Overall, the trials showed that it is possible to propagate cabbage in modules using peat-free growing media, and with a more tailored approach to irrigation and feeding, results could be improved even further.

Mushrooms

The peat used in mushroom production is very similar to the peat used in salad blocks, being very wet and sticky, with a high AW and low AFP. As such, trying to find alternative blends is difficult, as there are currently no other materials commercially available that have comparable physical properties with peat.

Trials work was carried out for mushrooms at G's Fresh Ltd in 2017, using both peat-reduced and peat-free blends. Again, the blends needed to be mixed with water in order to achieve a consistency that was similar to that of the casing material. This was placed on top of incubated mushroom compost, to create a layer approximately 5 cm thick, and the mushroom mycelium was then incorporated into this top layer.

There were three flushes of mushrooms, with yield and number of mushrooms produced at each flush recorded. Overall, the performance of each blend throughout the trial was not consistent, and generally, the prototype blends either on their own, or mixed with peat, did not perform as well as the peat nursery standard. Currently, there are no viable alternatives for mushroom production, as even the peat-reduced blends did not work particularly well.

In 2019, a different approach to mushroom production was considered. Rather than carrying out further trials work with materials that would not be suitable, or in the absence of any suitable alternative being provided at this time by the industry, it was agreed that testing using mushroom casing of different ages for its physical properties, would be beneficial to the industry. If the industry could find a way to recycle spent mushroom compost, then this would be a suitable alternative to simply reducing the amount of peat used in the production.

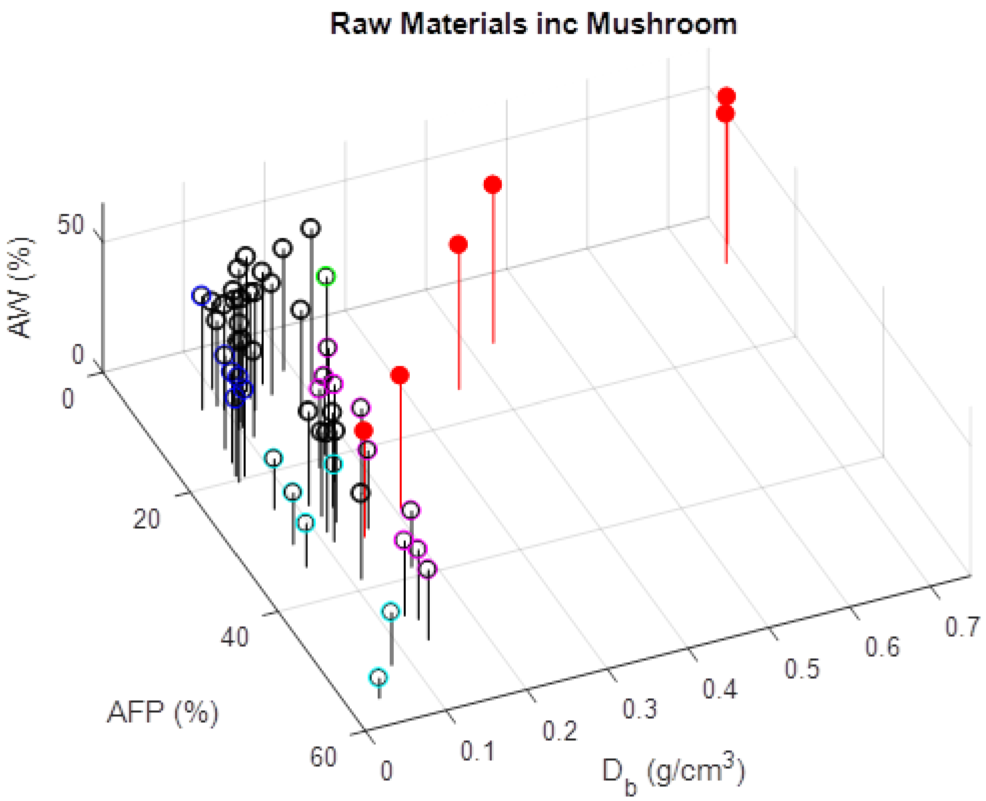


Figure 84. Mushroom compost material (red symbols) versus peat, wood fibre, bark and green compost materials for comparison. Increase in D_b follows period of composting. Period of composting will be critical to mass per unit volume and mushroom yield. AFP and AW appear to be broadly comparable with fresh peat casing materials for moderately composted "spent" material. There could be an opportunity to blend the spent casing with other materials using the CP138 blending model.

Overall

- In the 2019 grower trials, 3rd generation peat-free and coir-free growing media blends (prototypes 8-10) which were selected for their physical properties and which performed well in the Boxworth experimental trials were carried through to commercial trial assessment. Of the three blends selected, all produced plants that were comparable with the nursery standard across the different crop sectors (hardy nursery stock and ornamental pot plants).
- The 3rd generation blends used a different selection approach, utilising raw materials supplied by the GMM's which were new to the project. With no prior experience of how these materials would

perform, blending could only be based on the physical characteristics of the materials. The blends worked well on commercial grower sites, demonstrating that modelling can be used to design new growing media products that are acceptable for use in commercial UK horticulture plant production systems.

- Additionally in 2019, the second stage (main growth phase) of the soft fruit trials utilising 2nd generation prototype blends (prototypes 4-7) was completed. Strawberry and raspberry plants were propagated in 2018 using 2nd generation blends and then planted out in 2019 using the same blends, to assess establishment and yield. These blends had been selected for their more 'extreme' physical properties, and all apart from prototype 7 gave promising results at both propagation and main growth phase.
- As in previous years, the 1st generation peat-free blends (prototypes 1-3) were tested again in 2019 for consistency, alongside the 2nd and 3rd generation blends. Again, all performed well, with results similar to those seen in 2017 and 2018, demonstrating consistency across sites, plant types and growing season.
- Experimental trials at ADAS Boxworth in 2019 used the back-catalogue of available materials to test further peat-free and coir-free blends, making greater use of wood fibre and bark. Again, a range of materials with different physical properties were used, resulting in good and poor results, which is important for model development. However, the trials did show that it is possible to produce good quality plants in wood fibre and bark based blends, as long as the physical properties of the blends are selected for a triangulated value in the high performing zone.

WP4: Workshop and knowledge exchange events

Knowledge exchange has been an integral part of CP138, as important messages from the project have been communicated to growers and the industry. Throughout 2019 the outputs and progress of CP138 were communicated to the industry through independent workshops, as well as continuing to attend and present at additional industry events. This allowed attendees to not only learn about the project and results gathered to-date, but to also view trials in-situ or be "shown in practice". Knowledge Exchange has not, however, been limited to workshops and industry events. It can also take the form of magazine articles (i.e. AHDB Grower, Commercial Greenhouse Grower), technical documents and social media updates (**Tasks 4.1-4.1.2**). Knowledge Exchange activities completed to-date are detailed in **Table 11**.

Table 11. Knowledge Exchange completed to-date.

Date	KE type	Description
21/01/2015	Conference	**BPOA conference** – Oxford. Overview of project given by Barry Mulholland.
07/02/2015	Magazine	**HDC News article** general piece about the project (Claire Shaddick, issue 210, page 5).
03/06/2016	Document	**Technical Monograph** of methods for analysing growing media and raw materials. Published on ADAS website (http://www.adas.uk/Portals/0/Documents/Technical%20Monograph%20Growing%20Media%20Laboratory%20Methods.pdf).
06/06/2016	Twitter	**Twitter** account launched - @GrowMediaADAS.
08/06/2016	Magazine	**AHDB grower magazine article** general piece about the project (Spence Gunn, issue 224, page 5).
21/06/2016	Event	**Bedding and Pot Plant Centre Open Evening.** Demonstration and discussion of project and bedding trials hosted at Bordon Hill Nurseries and Baginton Nurseries.
25/08/2016	Event	**British Herbs Field Day.** Demonstration stand with herbs. Outlining project and progress, discussing current and future trials.
Sept 2016	Magazine	**Commercial Greenhouse Grower article** covering the bedding trial at the Bedding and Pot Plant Centre Open Evening in June (September 2016 edition, page 10).
12-13/10/2016	Event	**Elsoms Open Days.** Demonstration stand with lettuce. Outlining project and progress, discussing current and future trials.
25/10/2016	Online magazine	**Mini article in Horti Daily** advertising the 2016 workshops at Wyevale and Vitacress (http://www.hortidaily.com/article/29740/UK-Developing-new-blends-of-growing-media-for-horticulture).
15/11/2016	Workshop	**Wyevale Nurseries workshop (HNS).** Overview of project and view of trials. Talks from Susie Holmes and David Talbot and machinery demo from Mechanical Botanical.
07-08/12/2016	Event	**HNS Substrate and Nutrition Workshops (Oxford and N. Yorkshire).** Overview of project given by Neil Bragg.
Feb 2017	Magazine	**AHDB Grower magazine article** written by project team (Issue 230, page 16).
08/02/2017	Event	**Herbaceous Perennial Technical Discussion Group meeting.** Overview of project given by Barry Mulholland.
25/04/2017	Workshop	**New Farm Produce workshop (Strawberries).** Overview of project and view of trials. Talks from Janet Allen, Jude Bennison and Sam Brown (ADAS). Machinery demo from Mechanical Botanical and Farm Tour from Stephen McGuffie.
15/05/2017	Online magazine	**Mini article in Horti Daily** summarising the strawberry workshop (http://www.hortidaily.com/article/34533/UK-New-growing-media-blends-to-reduce-reliance-on-coir).
07/06/2017	Workshop	**Vitacress workshop (Herbs).** Overview of project and view of trials. Talks from Susie Holmes and Chloe Whiteside. Machinery demo from Mechanical Botanical and nursery tour from Simon Budge.
20/06/2017	Event	**Bedding and Pot Plant Centre Open Evening.** Overview of project and trials completed so far on protected ornamentals (bedding). Demonstration of bedding trials hosted at Ivan Ambrose (trials relocated to BPPC for Open Evening).

22/06/2017	Event	**G's NIAB Leafy Salads Open Day.** Overview of project and trials work completed on salad propagation given by Chloe Whiteside and Sonia Newman. Demonstration of young lettuce in trays and crop grown on out in the field, propagated in various blends.
July 2017	Magazine	**AHDB Grower magazine article** covering the workshop at Vitacress Herbs (Spence Gunn, issue 235, page 20-21).
July 2017	Magazine	**Commercial Greenhouse Grower article** covering the potted herbs trial at the Vitacress workshop in June (July 2017 edition, page 4).
July 2017	Magazine	**Commercial Greenhouse Grower article** covering the soft fruit trial at the New Farm Produce workshop in April (July 2017 edition, page 11-13).
23-28/08/2017	Event	**Portland Oregon ISHS symposium.** Scientific paper delivered on the CP138 approach and outputs, by Dr Barry Mulholland.
14/09/2017	Event	**British Herbs Field Day.** Demonstration stand with herbs. Outlining project and progress, discussing current and future trials.
19/09/2017	Workshop	**F P Matthews workshop (fruit trees).** Overview of project and view of trials. Talks from Dr Brian Jackson (NCSU), John Adlam and Chris Nicholson. Machinery demo from Mechanical Botanical and nursery tour from Andrew Wright and Dale Swash.
01/11/2017	Event	**Total Food Norwich.** Overview of project given by Barry Mulholland.
07/12/2017	Workshop	**Lowaters workshop (HNS).** Overview of project and view of trials. Talks from Dr Gracie Barrett (Walberton Nursery) and Jude Bennison (ADAS). Machinery demo from Mechanical Botanical and nursery tour from Stephen Carr.
15/02/2018	Conference	**Fruit Technical Seminar, Dundee.** Overview of project and soft fruit trials given by Chloe Whiteside.
19/06/2018	Event	**Bedding and Pot Plant Centre Open Evening.** Overview of project and trials completed so far on protected ornamentals (bedding). Demonstration of bedding trials hosted at Newey Roundstone (trials relocated to BPPC for Open Evening).
03/07/2018	Meeting	**Growing Media Association meeting** hosted at Darby Nursery Stock. Led by Neil Bragg and Steve Carter.
19/09/2018	Workshop	**EU Plants workshop (soft fruit propagation),** in association with FARMA/FRA. Overview of project and view of raspberry and strawberry trials. Presentation from Ruth D'urban-Jackson (ADAS) and nursery tour from Slavey Slavchev and Janet Allan (ADAS).
04/10/2018	Event	**HortScience Live (South).** Palmstead Nursery, Kent. Demonstration stand with HNS plants from the Boxworth trial. Outlining project and progress, discussing current and future trials and results in HNS.
09/10/2018	Workshop	**Delflands Nursery workshop (veg propagation).** Overview of project and view of cabbage prop trials. Presentations from Kirsty Wright (STC), and Andrew Taylor and Rosemary Collier (Warwick Crop Centre). Machinery demo from Mechanical Botanical and nursery tour from John Overvoorde.
15/10/2018	Magazine	**AHDB Grower magazine article** written by project team (Issue 242, page 20-21).
17/10/2018	Event	**HortScience Live (North).** Stockbridge Technology Centre. Demonstration stand with HNS plants from the Boxworth trial. Outlining project and progress, discussing current and future trials and results in HNS.
31/10/2018	Event	**Alternative growing media for the production of ornamental crops. Newey Roundstone, Chichester**. Pre-GroSouth event. Overview of project. Demonstration of autumn bedding trial at Newey Roundstone, along with physical properties of different blends and an update on bedding and HNS trials completed so far.
06/12/2018	Workshop	**Wyevale Nursery workshop (hardy nursery stock).** Overview of project and trials completed so far on HNS. Presentations from Jude Bennison, David Talbot, Dave Kaye and Ruth D'Urban Jackson (ADAS). Demonstration of RSGM HNS trials hosted at Darby Nursery Stock (some plants relocated to Wyevale for the workshop), as well as SceptrePlus trials and herbicide trials. Nursery tour from Steve Reed.
13/02/2019	Workshop	**Hardy nursery stock research and development update,** Stirling. This was a repeat of the event held at Wyevale Nursery on 06.12.18.

18/06/2019	Event	**Bedding and Pot Plant Centre Open Evening.** Overview of project and trials completed so far on protected ornamentals (bedding). Demonstration of pot Chrysanthemum trial hosted at Double H (sample of plants taken to BPPC for Open Evening).
25/06/2019	Event	**III International Symposium on Growing Media, Composting and Substrate Analysis, Milan.** 'Designing Rockets and Growing Media'. Scientific paper delivered on the CP138 approach and outputs, by Dr Andrew Watson (QIB).
26/06/2019	Workshop	**New Farm Produce workshop (Strawberries and raspberries).** Overview of project and view of trials. Talks from Erika Wedgwood (ADAS) and Scott Raffle (AHDB). Farm Tour from Stephen McGuffie.
10/07/2019	Workshop	**Double H workshop (ornamentals).** Overview of project and trials completed so far on protected ornamentals (bedding). Talks from Hilary Papworth (NIAB) and Neil Bragg (Bulrush Horticulture). View of pot Chrysanthemum trial and machinery demo using Double H potting machine. Tour of nursery from Howard Braime and Ben Shaw.
12/09/2019	Workshop	**James Coles & Sons Nurseries Ltd workshop (HNS).** Overview of project and trials completed so far on HNS. Presentations from Jill England (ADAS) and Neil Bragg (Bulrush Horticulture). View of HNS trials (CP 138 and HNS 200) and nursery tour from James Moffatt.
09-10/10/2019	Event	**Elsoms Open Days.** Demonstration trial of spring cabbage in the field. Outlining project and progress in veg propagation.
10/10/2019	Conference	**International Plant Propagators Society Conference, Stratford-upon-Avon.** Overview of project and HNS trials given by Chloe Whiteside.
16/10/2019	Event	**HortScience Live (Midlands).** New Leaf Plants. Demonstration stand with HNS plants from the Boxworth and Coles trials. Outlining project and progress, discussing current trials and results in HNS.
03/12/2019	Event	**UK and Ireland Horticulture Conference 2019.** Project overview and progress given by Neil Bragg.
05/02/2020	Conference	**The transition towards responsibly sourced growing media conference (Stratford-upon-Avon).** Output from CP138 and other related projects, along with industry best practice, to provide practical guidance on moving from peat-based to peat-free growing media for many horticultural sectors.

In 2019 the project team attended six industry events and hosted four standalone workshops. The industry events were; Bedding and Pot Plant Centre (BPPC) Open Evening (bedding), III International Symposium on Growing Media, Composting and Substrate Analysis, Elsoms Open Days (veg prop), IPPS Conference (HNS), HortScience Live Midlands (HNS and bedding) and the UK and Ireland Horticulture Conference 2019. At the veg prop, HNS and bedding events, trial plants were demonstrated, along with growing media blends and raw materials, hand-outs and a project poster. Presentations were given at all events. All events were very well attended, and overall, approximately 450 growers and industry representatives were spoken to and informed of the project across the six events.

Independent workshops were held at Hotel Colessio Stirling, New Farm Produce, Double H and James Coles and Sons Nurseries, and gave attendees the opportunity to view trials in progress. The events were well received, and attended by a total of 107 growers and industry representatives.

A knowledge exchange portfolio has been developed, which brings together summaries of all events, photographs, comments from event hosts and attendees and articles that have been published externally (i.e. Commercial Greenhouse Grower). For each workshop or industry event, an agreed KE feedback form has been developed, which provides a summary of the event, how the project was demonstrated or presented, the number of attendees and feedback from attendees and hosts. This is a working document which has been added to as the project has progressed and is an important way of encompassing the knowledge exchange component of CP138.

In June 2016, a twitter account for CP138 was set-up (@GrowMediaADAS), and this has proved to be a very useful way in providing ‘snap-shots’ of the project (i.e. when a trial has been set up or an assessment completed, photographs can be added to the page for viewers to see). It has also been used to help advertise events and workshops, as well as show pictures of events taking place, which helps to generate interest in the project. As of 16 December 2019, the RSGM twitter account has 222 followers, which are a combination of growers, growing media manufacturers, horticultural companies and independents.

Industry awareness
The workshops have been extremely well received by the industry, and by attending other industry events as well, results from the project have been communicated to over **1530** members of the horticulture sector. As the project progressed, the number of attendees at workshops grew, and the project has been viewed by many as an important step in moving towards more responsibly sourced growing media in UK horticulture.

Financial benefits

- Growing media use for the industry are not available, so to measure the gross impact of CP138 on growing media use by type is not possible at the time of reporting. In 2016 the predominant raw material for containerised production was peat versus peat free (0.69 and 0.41 million m^3 respectively), out of a total growing media use of 1.1 million m^3. The usage reflects the peat reduced and coir only products that are widely used in the nursery stock and soft fruit sectors respectively. There is clearly opportunity to diversify the growing media market and transition to zero peat use by 2030 using a range of suitable raw materials, either existing or yet to be identified.
- Whilst this project has produced a new and robust technique to develop existing and new responsibly sourced growing media (RSGM) the technique remains untested by the primary customer, the growing media manufacturers and end user, the grower. To achieve market penetration and meet the UK targets for commercial Horticulture then there is a need to continue to use the physical testing SOP and growing media model. This will be an important industry tool to underpin and de-risk the UKs transition to RSGM.

Action points

- Peat alternative products have been selected and blends designed that are high performing. The project had access to an anonymised inventory of raw materials from 4 growing media manufacturers that supply >80% of the UK market.
- As more raw materials are selected for and tested then bespoke products can be designed that will meet end user needs and retail specification.
- The approach developed in this project will expedite the move to RSGM, but will require behaviour change by the supply chain to test and accept the methodology for a much wider range of product availability than is currently available for commercial plant raising.
- The model is only constrained by the materials made available to test. If for example there is no affordable alternative to “sticky peat” then that is a supply chain issue to resolve to either source

an affordable model designed blend, or to change the production system to accommodate a range of growing media.

Exploitation

- The project has completed the requirements loop to describe and design a growing media. The method and model to define and predict high performing mixes from selected physical properties needs to be tested by industry.
- The target for zero peat use is 2030 for the commercial horticulture sector. The use of a wide range of materials, in blends, will be critical to a sustainable and robust growing media supply chain.
- The use of this new growing media blending tool will require behaviour change by the industry and a move away from intuitive “look-see” testing to rapid analysis and model based screening of candidate materials either alone or in a blend of up to four types.
- The model will only provide accurate predictions by the processing of physical properties using the ADAS SOP. This also provides and impartial method to test and verify material selection before use on grower holdings.
- Using physical properties as performance indicators may also, at an early stage, aid the inclusion or not of a much wider range of candidate materials than was previously possible. The technique promotes the avoidance of expensive investment in screening or processing of materials using plants as performance indicators to select for promising blends. This may also make the supply chain more responsive to price, sustainable sourcing, availability and will remove the reliance on one or two main materials.
- The UK move towards RSGM and “choice” is a sensible strategy as the global need for growing media use in containerised production is set to markedly increase to meet consumer demand for food and non-food fresh produce.
- The technology developed in this project is novel and is of national and global significance as countries move to address the climate emergency and within country zero carbon and environment plans.

Changes to the project

1. Are the current objectives still appropriate for the remainder of the project? **Yes** X **No** ☐

If **No**, please explain the reasons for any change and the implications for finances and staff time.

(**Any changes must be agreed with the AHDB project manager and the Industry Representative**)

Click here to enter text.

Progress in relation to targets

2. List the agreed milestones for the report period as set out in the contract (or any variation thereof) and when they have been reached. If milestones have not been achieved a full explanation for the reasons why not should be provided.

Milestone		Target Date	Milestone met	
Number	Title		In full	On time
1	**Tasks 1.1-1.1.1.3** Milestone **(M)1** Identified and sourced raw materials and proprietary growing media including peat-free blends and model plant species for sector specific experimental (Boxworth, STC) and on site grower holding trials (year 1, 2016 season).	01/04/2015	Yes	No, two months late. Growing media testing system installation completed – delayed because contract was not signed until late June 2015 and expenditure could not be actioned (until a contract was in place).
2	**Tasks 1.1.2-1.1.4** **M2** Physical properties measured; variation in raw materials quantified	01/10/2015	Yes	No, delay of D1 will cause a concurrent delay to D2. Completed by 30/11/15.
3	**Tasks 1.1.5** **M3** 35-40 blends created	01/11/2015	Yes	No, delay of D1 and D2 will cause a delay in D3. D3 completed on 30/11/15. The numbers of combinations have been worked out (8/9/15) but the precise blend combinations can be worked out once D2 is complete.
4	**Tasks 1.1.6-1.1.6.2** **M4** Modelling of media blending in relation to physical property prediction	01/12/2015	Yes	Delay of D3 pushed milestone completion to 18/12/15.
5	Tasks **1.2-1.2.1** **M5** Commercial media obtained	01/02/2016	Yes	Completed in full and on time
6	Tasks **1.2.2** **M6** Data on commercial media collated and analysed	01/02/2016	Yes	Completed in full and on time
7	Tasks **1.2.3-1.2.3.2** **M7** Initial designs of blends and mixes completed for scoping studies	01/02/2016	Yes	Completed in full and on time

8	Tasks **1.2.4** **M8** Database of raw material and media properties completed	01/02/2016	Yes	Completed in full and on time
9	Tasks **1.3-1.3.2** **M9** Media available for scoping study	01/06/2016	Yes	Completed in full and on time
10	Tasks **1.3.3** **M10** Scoping trials completed	01/10/2016	Yes	Completed in full and on time
11	Task 1.3.4 **M11** Conclusions	31/03/2017	Yes	Completed in full and on time
12	Tasks 1.1-1.3 **M12** Create database of growing media	31/03/2017	Yes	Completed in full and on time
13-29	**M13** All tasks on schedule to complete	30/10/2019	Yes	Completed in full and on time
30	**M14** All tasks on schedule to complete (Final report)	31/12/2019	Yes	Completed in full and on time

Additional supporting material

3. This section should be used to include relevant supporting material such as statistical analyses, tables, graphs, data and additional narrative etc. that are required to demonstrate that the research was conducted and analysed in an appropriate and scientifically defensible manner. If no substantive results are available at this stage the provision of supporting material is not required in an interim report

   This section will not be published on the AHDB website but will be available on request.

Appendix 1
EU Plants Raspberries

Table 1a. The six treatments used in the raspberry propagation trial.

Trt no.	Growing media blend
1	Nursery 100% Coir standard
2	Prototype 3 (1st Gen)
3	Prototype 4 (2nd Gen)
4	Prototype 5 (2nd Gen)
5	Prototype 6 (2nd Gen)
6	Prototype 7 (2nd Gen)

Table 1b. List of scores and definitions used to assess overall plant quality at transplanting.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Green but no new growth, small
3	Green with new leaves developing
4	Green with new growth
5	Good quality, plenty of new growth, marketable

Table 1c. List of scores and definitions used to assess plant rooting in the cell at transplanting.

Score	Definition
0	No change / dead
1	Callous 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

Maravilla

Block	1	1	1	2	2	2	3	3	3
Plot	1	2	3	7	8	9	13	14	15
Treatment	5	6	3	5	2	3	3	4	5
Variety	1	1	1	1	1	1	1	1	1
	1	1	1	2	2	2	3	3	3
	4	5	6	10	11	12	16	17	18
	1	4	2	1	4	6	1	2	6
	1	1	1	1	1	1	1	1	1

Block	4	4	4	5	5	5	6	6	6
Plot	19	20	21	25	26	27	31	32	33
Treatment	5	2	6	1	6	3	3	6	5
Variety	1	1	1	1	1	1	1	1	1
	4	4	4	5	5	5	6	6	6
	22	23	24	28	29	30	34	35	36
	4	1	3	4	5	2	2	4	1
	1	1	1	1	1	1	1	1	1

Glen Ample

Block	1	1	1	2	2	2	3	3	3
Plot	1	2	3	7	8	9	13	14	15
Treatment	5	2	3	1	4	3	1	5	2
Variety	2	2	2	2	2	2	2	2	2
	1	1	1	2	2	2	3	3	3
	4	5	6	10	11	12	16	17	18
	4	1	6	2	5	6	3	6	4
	2	2	2	2	2	2	2	2	2

Block	4	4	4	5	5	5	6	6	6
Plot	19	20	21	25	26	27	31	32	33
Treatment	5	2	4	5	2	6	3	5	6
Variety	2	2	2	2	2	2	2	2	2
	4	4	4	5	5	5	6	6	6
	22	23	24	28	29	30	34	35	36
	3	1	6	1	3	4	4	2	1
	2	2	2	2	2	2	2	2	2

Figure 1a. Trial plan for the raspberry propagation trial set-out within a covered polytunnel. Each plot contains 1 x 84-cell tray.

Block	1	4
Plot	1	19
Treatment	5	5
Block	1	4
Plot	2	20
Treatment	6	2
Block	1	4
Plot	3	21
Treatment	3	6
Block	1	4
Plot	4	22
Treatment	1	4
Block	1	4
Plot	5	23
Treatment	4	1
Block	1	4
Plot	6	24
Treatment	2	3
Block	2	5
Plot	7	25
Treatment	5	1
Block	2	5
Plot	8	26
Treatment	2	6
Block	2	5
Plot	9	27
Treatment	3	3
Block	2	5
Plot	10	28
Treatment	1	4
Block	2	5
Plot	11	29
Treatment	4	5
Block	2	5
Plot	12	30
Treatment	6	2
Block	3	6
Plot	13	31
Treatment	3	3
Block	3	6
Plot	14	32
Treatment	4	6
Block	3	6
Plot	15	33
Treatment	5	5
Block	3	6
Plot	16	34
Treatment	1	2
Block	3	6
Plot	17	35
Treatment	2	4
Block	3	6
Plot	18	36
Treatment	6	1

Treatment No.	Growing media blend
1	Nursery control
2	Prototype 3
3	Prototype 4
4	Prototype 5
5	Prototype 6
6	Prototype 7

Figure 1b. Trial plan for the raspberry propagation trial set-out in rows within the field after transplant. Each plot contains 1 x 2 L pot holding two canes.

Appendix 2
EU Plants Strawberries

Table 2a. The six treatments used in the strawberry propagation trial.

Trt no.	Growing media blend
1	Nursery 100% Coir standard
2	Prototype 3 (1st Gen)
3	Prototype 4 (2nd Gen)
4	Prototype 5 (2nd Gen)
5	Prototype 6 (2nd Gen)
6	Prototype 7 (2nd Gen)

Table 2b. List of scores and definitions used to assess overall plant quality at transplanting.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Green but no new growth, small
3	Green with new leaves developing
4	Green with new growth
5	Good quality, plenty of new growth, marketable

Table 2c. List of scores and definitions used to assess plant rooting in the cell at transplanting.

Score	Definition
0	No change / dead
1	Callous 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

Block	1	1	1	2	2	2	3	3	3
Plot	1	2	3	7	8	9	13	14	15
Treatment	**4**	**1**	**2**	**3**	**1**	**2**	**1**	**6**	**5**
Block	1	1	1	2	2	2	3	3	3
Plot	4	5	6	10	11	12	16	17	18
Treatment	**6**	**5**	**3**	**5**	**6**	**4**	**3**	**2**	**4**
Block	4	4	4	5	5	5	6	6	6
Plot	19	20	21	25	26	27	31	32	33
Treatment	**1**	**5**	**6**	**6**	**2**	**5**	**5**	**3**	**6**
Block	4	4	4	5	5	5	6	6	6
Plot	22	23	24	28	29	30	34	35	36
Treatment	**2**	**3**	**4**	**4**	**1**	**3**	**4**	**1**	**2**

Figure 2a. Trial plan for the strawberry propagation trial set-out within an uncovered polytunnel. Each plot contains 1 x 84-cell tray.

Block	1	2	3	4	5	6	7
Plot	1	7	13	19	25	31	37
Treatment	**6**	**4**	**5**	**1**	**5**	**3**	**2**
Block	1	2	3	4	5	6	7
Plot	2	8	14	20	26	32	38
Treatment	**1**	**3**	**6**	**5**	**2**	**2**	**3**
Block	1	2	3	4	5	6	7
Plot	3	9	15	21	27	33	39
Treatment	**2**	**5**	**1**	**3**	**4**	**6**	**5**
Block	1	2	3	4	5	6	7
Plot	4	10	16	22	28	34	40
Treatment	**3**	**2**	**2**	**6**	**1**	**5**	**4**
Block	1	2	3	4	5	6	7
Plot	5	11	17	23	29	35	41
Treatment	**4**	**1**	**4**	**2**	**3**	**1**	**6**
Block	1	2	3	4	5	6	7
Plot	6	12	18	24	30	36	42
Treatment	**5**	**6**	**3**	**4**	**6**	**4**	**1**

Figure 2b. Trial plan for the strawberry propagation trial set-out within an uncovered polytunnel after transplant. Each plot contains 1 x 18-cell tray.

Appendix 3
Darby Nursery Hardy Nursery Stock

Table 3a. The six treatments used in the hardy nursery stock trial.

Trt no.	Growing media blend
1	Nursery peat-reduced standard
2	Prototype 2 (1st Gen)
3	Prototype 4 (2nd Gen)
4	Prototype 5 (2nd Gen)
5	Prototype 6 (2nd Gen)
6	Prototype 7 (2nd Gen)

Table 3b. List of scores and definitions used to assess overall plant quality.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Poor quality, small
3	Good quality, healthy foliage
4	Very good quality, healthy foliage, some new growth
5	Excellent quality, healthy foliage, plenty of new growth

Table 3c. List of scores and definitions used to assess plant rooting in the pot.

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 76 – 100% of pot

Lavender

Block	1	1	1	1	1	1	2	2	2	2	2	2
Plot	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	1	2	3	5	6	4	4	2	1	5	3	6
Variety	1	1	1	1	1	1	1	1	1	1	1	1
Block	3	3	3	3	3	3	4	4	4	4	4	4
Plot	13	14	15	16	17	18	19	20	21	22	23	24
Treatment	6	5	1	3	4	2	2	4	3	6	5	1
Variety	1	1	1	1	1	1	1	1	1	1	1	1
Block	5	5	5	5	5	5	6	6	6	6	6	6
Plot	25	26	27	28	29	30	31	32	33	34	35	36
Treatment	3	4	6	1	2	5	4	5	2	1	3	6
Variety	1	1	1	1	1	1	1	1	1	1	1	1

Vinca

Block	1	1	1	1	1	1	2	2	2	2	2	2
Plot	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	2	4	1	5	6	3	4	3	5	1	6	2
Variety	3	3	3	3	3	3	3	3	3	3	3	3
Block	3	3	3	3	3	3	4	4	4	4	4	4
Plot	13	14	15	16	17	18	19	20	21	22	23	24
Treatment	1	5	2	6	3	4	1	2	5	6	3	4
Variety	3	3	3	3	3	3	3	3	3	3	3	3
Block	5	5	5	5	5	5	6	6	6	6	6	6
Plot	25	26	27	28	29	30	31	32	33	34	35	36
Treatment	2	1	6	5	4	3	6	5	4	1	2	3
Variety	3	3	3	3	3	3	3	3	3	3	3	3

Treatment no.	Growing media blend
1	Nursery Control
2	Prototype 2
3	Prototype 4
4	Prototype 5
5	Prototype 6
6	Prototype 7

Figure 3a. Trial plan for HNS plants (finals) set out on mypex under polythene (Lavender) and on mypex outside (Vinca) (Darby Nursery Stock). Each plot contains 5 x 2 L pots.

Lavender

Block	1	1	1	1	1	1	2	2	2	2	2	2
Plot	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	2	6	5	4	3	1	1	5	4	2	6	3
Variety	1	1	1	1	1	1	1	1	1	1	1	1
Block	3	3	3	3	3	3	4	4	4	4	4	4
Plot	13	14	15	16	17	18	19	20	21	22	23	24
Treatment	6	5	2	3	1	4	2	1	3	6	4	5
Variety	1	1	1	1	1	1	1	1	1	1	1	1
Block	5	5	5	5	5	5	6	6	6	6	6	6
Plot	25	26	27	28	29	30	31	32	33	34	35	36
Treatment	2	6	3	1	4	5	1	5	3	2	6	4
Variety	1	1	1	1	1	1	1	1	1	1	1	1

Potentilla

Block	1	1	1	1	1	1	2	2	2	2	2	2
Plot	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	1	3	2	5	4	6	4	3	5	1	6	2
Variety	2	2	2	2	2	2	2	2	2	2	2	2
Block	3	3	3	3	3	3	4	4	4	4	4	4
Plot	13	14	15	16	17	18	19	20	21	22	23	24
Treatment	2	6	1	3	5	4	3	4	6	5	2	1
Variety	2	2	2	2	2	2	2	2	2	2	2	2
Block	5	5	5	5	5	5	6	6	6	6	6	6
Plot	25	26	27	28	29	30	31	32	33	34	35	36
Treatment	3	5	2	6	4	1	6	1	2	4	5	3
Variety	2	2	2	2	2	2	2	2	2	2	2	2

Spiraea

Block	1	1	1	1	1	1	2	2	2	2	2	2
Plot	1	2	3	4	5	6	7	8	9	10	11	12
Treatment	2	6	4	1	5	3	1	6	2	3	5	4
Variety	3	3	3	3	3	3	3	3	3	3	3	3
Block	3	3	3	3	3	3	4	4	4	4	4	4
Plot	13	14	15	16	17	18	19	20	21	22	23	24
Treatment	5	1	2	3	4	6	4	3	6	1	5	2
Variety	3	3	3	3	3	3	3	3	3	3	3	3
Block	5	5	5	5	5	5	6	6	6	6	6	6
Plot	25	26	27	28	29	30	31	32	33	34	35	36
Treatment	2	3	4	6	5	1	3	4	6	5	1	2
Variety	3	3	3	3	3	3	3	3	3	3	3	3

Treatment no.	Growing media blend
1	Nursery Control
2	Prototype 2
3	Prototype 4
4	Prototype 5
5	Prototype 6
6	Prototype 7

Figure 3b. Trial plan for HNS plants (liners) set out on sand under polythene (Darby Nursery Stock). Each plot contains 5 x 9 cm pots.

Appendix 4
James Coles and Sons Hardy Nursery Stock

Table 4a. The six treatments used in the hardy nursery stock trials.

Trt no.	Growing media blend
1	Nursery peat-reduced standard
2	Prototype 2 (1st Gen)
3	Prototype 6 (2nd Gen)
4	Prototype 8 (3rd Gen)
5	Prototype 9 (3rd Gen)
6	Prototype 10 (3rd Gen)

Table 4b. List of scores and definitions used to assess overall plant quality.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Poor quality, small
3	Good quality, healthy foliage
4	Very good quality, healthy foliage, some new growth
5	Excellent quality, healthy foliage, plenty of new growth

Table 4c. List of scores and definitions used to assess plant rooting in the pot.

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 76 – 100% of pot

Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment
101	5	201	3	301	3	401	2	501	1	601	5	701	3	801	6	901	4	1001	2
102	4	202	1	302	1	402	1	502	6	602	6	702	1	802	3	902	3	1002	5
103	2	203	4	303	6	403	4	503	3	603	1	703	2	803	1	903	5	1003	6
105	6	204	6	304	2	404	3	504	5	604	3	704	5	804	2	904	1	1004	4
106	1	205	5	305	4	405	6	505	4	605	2	705	4	805	4	905	2	1005	3
104	3	206	2	306	5	406	5	506	2	606	4	706	6	806	5	906	6	1006	1

Treatment No.	Growing media blend
1	Nursery standard peat-reduced
2	Prototype 2
3	Prototype 6
4	Prototype 8
5	Prototype 9
6	Prototype 10

Figure 4a. Trial plan for HNS plants set out on the floor under polythene and on mypex outside (James Coles and Sons). Each plot contains 5 x 2 L pots.

Appendix 5
Double H Pot Chrysanthemum

Table 5a. The six treatments used in the pot chrysanthemum trial.

Trt no.	Growing media blend
1	Nursery Peat-reduced standard
2	Prototype 3 (1st Gen)
3	Prototype 5 (2nd Gen)
4	Prototype 8 (3rd Gen)
5	Prototype 9 (3rd Gen)
6	Prototype 10 (3rd Gen)

Table 5b. List of scores and definitions used to assess overall plant quality for marketability.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Poor quality, small
3	Good quality, healthy foliage
4	Very good quality, healthy foliage, some new growth
5	Excellent quality, healthy foliage, plenty of new growth

Table 5c. List of scores and definitions used to assess plant rooting in the pot.

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 76 – 100% of pot

BENCH 1

Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment
101	3	201	6	301	5	401	3	501	2
102	2	202	1	302	1	402	4	502	4
103	1	203	3	303	2	403	1	503	6
104	6	204	5	304	3	404	6	504	1
105	5	205	4	305	4	405	2	505	5
106	4	206	2	306	6	406	5	506	3

BENCH 2

Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment	Plot	Treatment
601	1	701	1	801	4	901	5	1001	4
602	6	702	5	802	5	902	6	1002	5
603	2	703	4	803	2	903	1	1003	2
604	3	704	3	804	3	904	3	1004	6
605	4	705	2	805	6	905	2	1005	1
606	5	706	6	806	1	906	4	1006	3

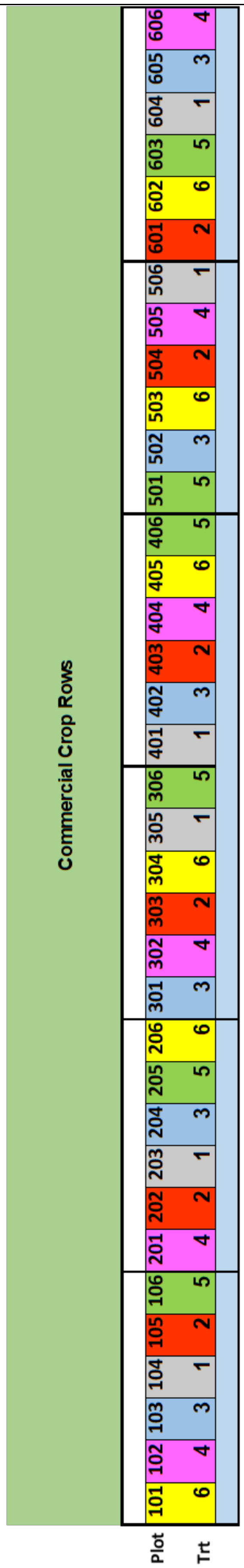
Treatment No.	Growing media blend
1	Nusery standard peat-reduced
2	Prototype 3
3	Prototype 5
4	Prototype 8
5	Prototype 9
6	Prototype 10

Figure 5a. Trial plan for the pot chrysanthemum plants set out on ebb and flood benches under glass at Double H. Each plot consists of 5 x 1.5 L pots.

Appendix 6
New Farm Produce Raspberries

Table 6a. The six treatments used in the raspberry main cane trial.

Trt no.	Growing media blend
1	Nursery 100% Coir standard
2	Prototype 3 (1st Gen)
3	Prototype 4 (2nd Gen)
4	Prototype 5 (2nd Gen)
5	Prototype 6 (2nd Gen)
6	Prototype 7 (2nd Gen)



No.	Treatment
1	Coir control
2	Prototype 3
3	Prototype 4
4	Prototype 5
5	Prototype 6
6	Prototype 7

Figure 6a. Trial plan for the raspberry cane trial set-out in rows under polythene. Each plot contains 1 x 7 L pot holding two canes.

Appendix 7
New Farm Produce Strawberries

Table 7a. The six treatments used in the strawberry trial.

Trt no.	Growing media blend
1	Nursery 100% Coir standard
2	Prototype 3 (1st Gen)
3	Prototype 4 (2nd Gen)
4	Prototype 5 (2nd Gen)
5	Prototype 6 (2nd Gen)
6	Prototype 7 (2nd Gen)

Prototype planting — **Troughs filled with prototype blends** (Rows 1–4)

Coir planting — **Troughs filled with nursery standard coir** (Rows 5–8)

Trough	Row 1	Row 2	Row 3	Row 4	Trough	Row 5	Row 6	Row 7	Row 8
1	P1	P19	P37	P55	1	P1	P19	P37	P55
2	**T3**	**T1**	**T5**	**T4**	2	**T4**	**T1**	**T2**	**T6**
3	P2	P20	P38	P56	3	P2	P20	P38	P56
4	**T5**	**T4**	**T2**	**T6**	4	**T6**	**T3**	**T1**	**T5**
5	P3	P21	P39	P57	5	P3	P21	P39	P57
6	**T2**	**T3**	**T6**	**T5**	6	**T3**	**T6**	**T5**	**T4**
7	P4	P22	P40	P58	7	P4	P22	P40	P58
8	**T4**	**T6**	**T1**	**T1**	8	**T5**	**T2**	**T6**	**T1**
9	P5	P23	P41	P59	9	P5	P23	P41	P59
10	**T6**	**T2**	**T4**	**T3**	10	**T1**	**T4**	**T3**	**T2**
11	P6	P24	P42	P60	11	P6	P24	P42	P60
12	**T1**	**T5**	**T3**	**T2**	12	**T2**	**T5**	**T4**	**T3**
13					13				
14	P7	P25	P43	P61	14	P7	P25	P43	P61
15	**T5**	**T4**	**T3**	**T1**	15	**T1**	**T3**	**T2**	**T1**
16	P8	P26	P44	P62	16	P8	P26	P44	P62
17	**T1**	**T6**	**T4**	**T5**	17	**T2**	**T1**	**T3**	**T5**
18	P9	P27	P45	P63	18	P9	P27	P45	P63
19	**T6**	**T2**	**T1**	**T4**	19	**T4**	**T4**	**T1**	**T2**
20	P10	P28	P46	P64	20	P10	P28	P46	P64
21	**T2**	**T3**	**T5**	**T6**	21	**T5**	**T6**	**T5**	**T3**
22	P11	P29	P47	P65	22	P11	P29	P47	P65
23	**T4**	**T5**	**T2**	**T3**	23	**T6**	**T5**	**T6**	**T4**
24	P12	P30	P48	P66	24	P12	P30	P48	P66
25	**T3**	**T1**	**T6**	**T2**	25	**T3**	**T2**	**T4**	**T6**
26					26				
27	P13	P31	P49	P67	27	P13	P31	P49	P67
28	**T3**	**T6**	**T4**	**T2**	28	**T6**	**T3**	**T2**	**T1**
29	P14	P32	P50	P68	29	P14	P32	P50	P68
30	**T2**	**T4**	**T5**	**T1**	30	**T4**	**T1**	**T1**	**T2**
31	P15	P33	P51	P69	31	P15	P33	P51	P69
32	**T1**	**T3**	**T6**	**T3**	32	**T2**	**T5**	**T4**	**T5**
33	P16	P34	P52	P70	33	P16	P34	P52	P70
34	**T6**	**T5**	**T2**	**T6**	34	**T1**	**T6**	**T5**	**T3**
35	P17	P35	P53	P71	35	P17	P35	P53	P71
36	**T5**	**T1**	**T3**	**T5**	36	**T3**	**T2**	**T3**	**T6**
37	P18	P36	P54	P72	37	P18	P36	P54	P72
38	**T4**	**T2**	**T1**	**T4**	38	**T5**	**T4**	**T6**	**T4**
39					39				
40					40				
41					41				
42					42				
43					43				

NFP plots   **NFP plots**

Figure 7a. Trial plan for the strawberry trial set-out in troughs under polythene. Each plot contains 2 x troughs planted with five plants.

Appendix 8
Delfland Nurseries Vegetable propagation

Table 8a. The four treatments used in the vegetable propagation trial.

Trt no.	Growing media blend
1	Nursery Peat-reduced standard
2	Prototype 1 (1st Gen)
3	Prototype 5 (2nd Gen)
4	Prototype 6 (2nd Gen)

Table 8b. List of scores and definitions used to assess overall plant quality.

Score	Definition
1	Obvious quality issues, not suitable for transplant
2	Very minor quality issues, ok to transplant
3	Perfect, no quality issues

Table 8c. List of scores and definitions used to assess plant rooting in the cell.

Score	Definition
0	No root development
1	Rooting in up to 25% of cell
2	Rooting in 26 – 50% of cell
3	Rooting in 51 – 75% of cell
4	Rooting in 76 – 100% of cell

TREATMENT	**4**	**4**	**4**	**4**
BLOCK	**1**	**2**	**3**	**4**
PLOT	**104**	**204**	**304**	**404**
TREATMENT	**3**	**3**	**3**	**3**
BLOCK	**1**	**2**	**3**	**4**
PLOT	**103**	**203**	**303**	**403**
TREATMENT	**2**	**2**	**2**	**2**
BLOCK	**1**	**2**	**3**	**4**
PLOT	**102**	**202**	**302**	**402**
TREATMENT	**1**	**1**	**1**	**1**
BLOCK	**1**	**2**	**3**	**4**
PLOT	**101**	**201**	**301**	**401**

Trt No	Treatment
1	Nursery control
2	Prototype 1
3	Prototype 5
4	Prototype 6

Figure 8. Trial plan for Spring cabbage plants set out under glass at Delflands Nursery. Each plot contains 1 x 345-cell tray. Note the treatments have not been randomised for ease of watering, at the request of the grower.

Appendix 9
Experimental trials

Table 9a. Measured physical properties for the experimental prototype blends.

Growing media blend	AFP	D_b	AW
Blend 1 - Peat standard	9.05	0.17	39.64
Blend 2	52.74	0.08	20.28
Blend 3	23.40	0.14	29.32
Blend 4	13.36	0.11	38.49
Blend 5	49.87	0.15	20.33
Blend 6	16.05	0.11	38.46
Blend 7	24.89	0.11	35.25
Blend 8	34.02	0.10	27.90
Blend 9	12.13	0.13	38.60
Blend 10	15.34	0.13	35.56
Blend 11	18.13	0.13	29.96
Blend 12	38.34	0.16	21.49
Blend 13	31.74	0.16	23.56
Blend 14	20.50	0.15	26.00
Blend 15	53.03	0.11	19.15
Blend 16	23.59	0.12	32.47
Blend 17	36.37	0.11	23.75
Blend 18	18.09	0.15	31.70
Blend 19	40.13	0.12	20.82

Table 9b. Levels of nutrients delivered to the trial when fertilisers were diluted to 1:100 (i.e. 1% solution).

NO_3-N mg/l	NH_4-N mg/l	P_2O5 mg/l	K_2O mg/l	MgO mg/l	Ca mg/l	B mg/l	Cu mg/l	Fe mg/l	Mn mg/l	Mo mg/l	Zn mg/l	EC (mS)
95.9	1.3	79.3	200.7	30.5	150.7	0.23	0.09	1.62	0.54	0.05	0.69	1.47

Appendix 10
Experimental ornamental bedding trial

Table 10a. List of scores and definitions used to assess overall plant quality for marketability.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Poor quality, small
3	Good quality, healthy foliage
4	Very good quality, healthy foliage, some new growth
5	Excellent quality, healthy foliage, plenty of new growth

Table 10b. List of scores and definitions used to assess plant rooting in the pack.

Score	Definition
0	No root development
1	Rooting in up to 25% of pack
2	Rooting in 26 – 50% of pack
3	Rooting in 51 – 75% of pack
4	Rooting in 76 – 100% of pack

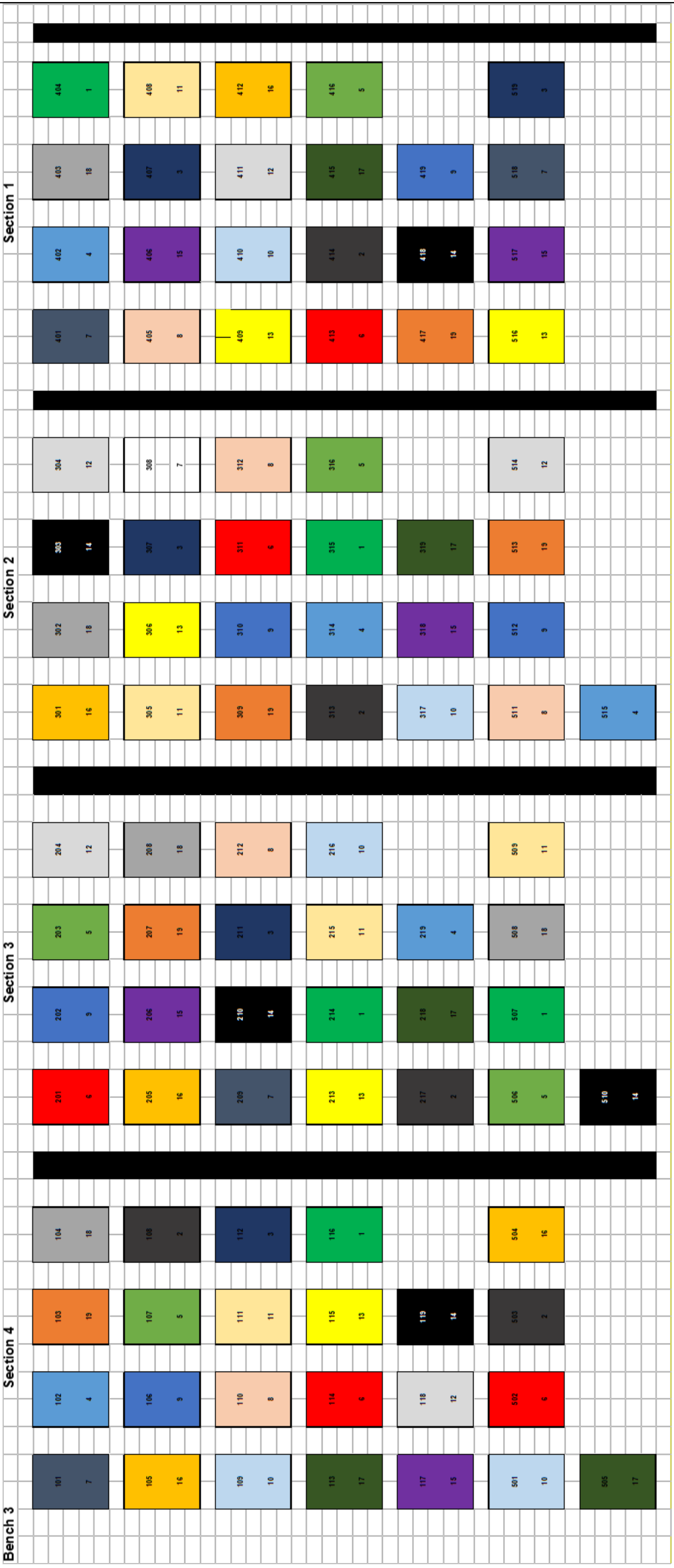


Figure 10a. Trial plan for Pansy packs set out on an overhead sprinkler bench split into four sections separated by Perspex sheeting.

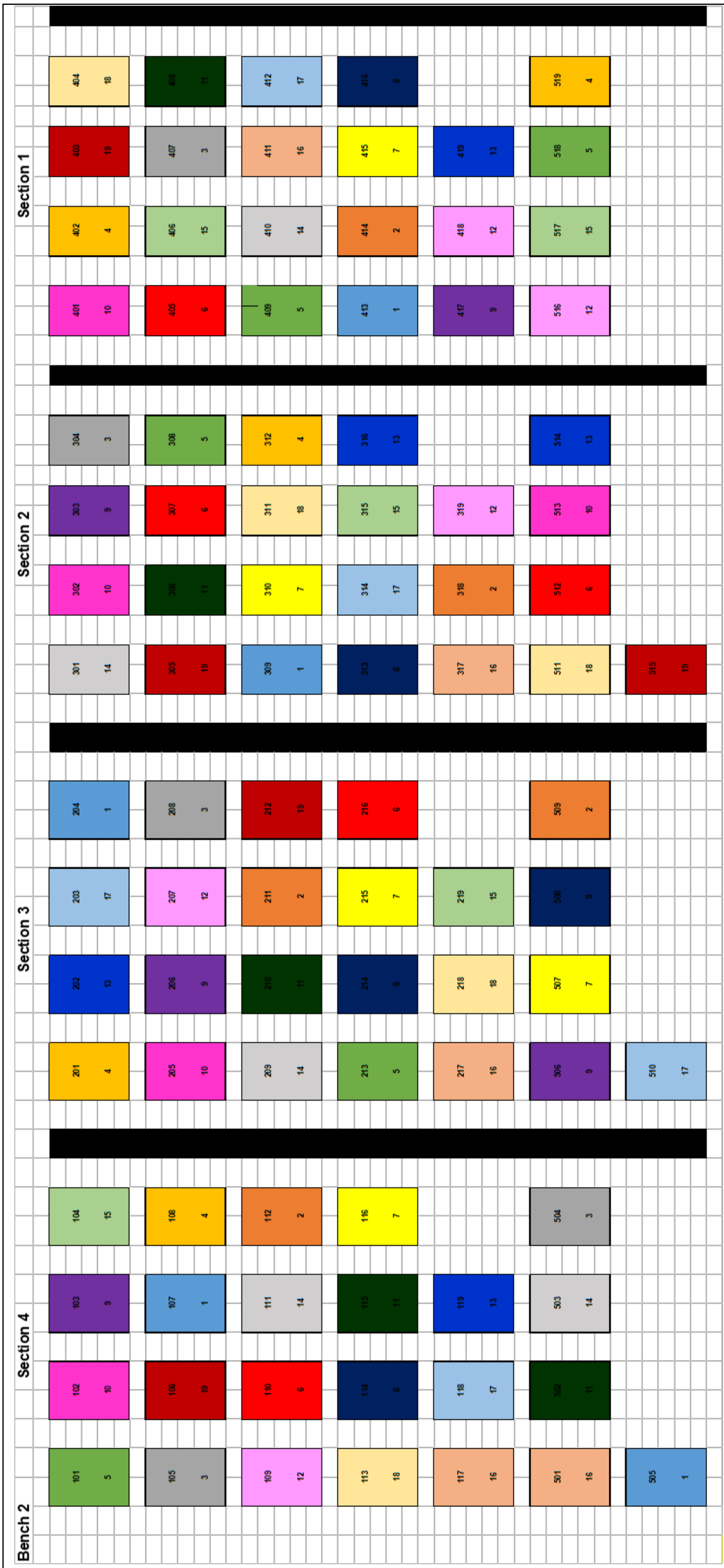


Figure 10b. Trial plan for Geranium packs set out on an overhead sprinkler bench split into four sections separated by Perspex sheeting.

Appendix 11
Experimental HNS trial

Table 11a. List of scores and definitions used to assess overall plant quality during the trial.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Poor quality, small
3	Good quality, healthy foliage
4	Very good quality, healthy foliage, some new growth
5	Excellent quality, healthy foliage, plenty of new growth

Table 11b. List of scores and definitions used to assess plant rooting at the end of the trial.

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 76 – 100% of pot

Bench 5	Section 1				Section 2				Section 3				Section 4			
Plot	101	102	103	104	201	202	203	204	301	302	303	304	401	402	403	404
Trt	4	19	15	3	9	14	1	2	18	3	2	13	8	17	1	19
Plot	105	106	107	108	205	206	207	208	305	306	307	308	405	406	407	408
Trt	1	8	9	5	4	15	12	17	11	10	6	16	18	5	16	4
Plot	109	110	111	112	209	210	211	212	309	310	311	312	409	410	411	412
Trt	7	17	16	18	10	11	8	3	17	7	12	14	13	15	14	6
Plot	113	114	115	116	213	214	215	216	313	314	315	316	413	414	415	416
Trt	10	12	14	13	5	16	6	18	1	9	4	19	3	9	7	2
Plot	117	118	119		217	218	219		317	318	319		417	418	419	
Trt	11	2	6		7	13	19		5	8	15		12	11	10	
Plot	501	502	503		506	507	508		511	512	513		516	517	518	
Trt	16	13	7		17	10	11		1	6	18		8	12	5	
Plot	504	505			509	510			514	515			519			
Trt	15	4			14	2			9	3			19			

Figure 11a. Trial plan for *Choisya* set out on a bench split into four sections separated by Perspex sheeting with drip irrigation.

Appendix 12

Experimental Herbs trial

Table 12a. List of scores and definitions used to assess overall plant quality during the trial.

Score	Definition
0	Dead
1	Obvious quality issues not suitable for dispatch
2	Very minor quality issues ok to dispatch
3	Perfect no quality issues

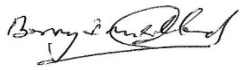
	Thyme trial							
	Section 1				Section 2			
Plot	1	20	39	58	77	96	115	134
Block	1	2	3	4	5	6	7	8
Treatment	13	8	13	2	12	12	10	4
Plot	2	21	40	59	78	97	116	135
Block	1	2	3	4	5	6	7	8
Treatment	2	10	12	9	17	13	17	8
Plot	3	22	41	60	79	98	117	136
Block	1	2	3	4	5	6	7	8
Treatment	19	15	2	7	7	4	15	7
Plot	4	23	42	61	80	99	118	137
Block	1	2	3	4	5	6	7	8
Treatment	12	17	6	14	3	1	12	15
Plot	5	24	43	62	81	100	119	138
Block	1	2	3	4	5	6	7	8
Treatment	15	9	14	5	9	19	16	17
Plot	6	25	44	63	82	101	120	139
Block	1	2	3	4	5	6	7	8
Treatment	4	13	11	3	1	3	7	3
Plot	7	26	45	64	83	102	121	140
Block	1	2	3	4	5	6	7	8
Treatment	14	3	8	16	15	15	1	9
Plot	8	27	46	65	84	103	122	141
Block	1	2	3	4	5	6	7	8
Treatment	5	5	15	17	8	17	9	13
Plot	9	28	47	66	85	104	123	142
Block	1	2	3	4	5	6	7	8
Treatment	3	11	19	15	14	18	2	16
Plot	10	29	48	67	86	105	124	143
Block	1	2	3	4	5	6	7	8
Treatment	9	2	5	1	13	2	4	6
Plot	11	30	49	68	87	106	125	144
Block	1	2	3	4	5	6	7	8
Treatment	16	12	4	18	19	10	14	19
Plot	12	31	50	69	88	107	126	145
Block	1	2	3	4	5	6	7	8
Treatment	1	1	3	13	5	11	3	10
Plot	13	32	51	70	89	108	127	146
Block	1	2	3	4	5	6	7	8
Treatment	8	19	1	11	2	5	11	14
Plot	14	33	52	71	90	109	128	147
Block	1	2	3	4	5	6	7	8
Treatment	17	18	18	8	18	14	19	12
Plot	15	34	53	72	91	110	129	148
Block	1	2	3	4	5	6	7	8
Treatment	18	4	10	12	16	9	5	1
Plot	16	35	54	73	92	111	130	149
Block	1	2	3	4	5	6	7	8
Treatment	7	7	16	6	6	8	6	2
Plot	17	36	55	74	93	112	131	150
Block	1	2	3	4	5	6	7	8
Treatment	10	14	17	4	11	16	18	5
Plot	18	37	56	75	94	113	132	151
Block	1	2	3	4	5	6	7	8
Treatment	11	16	9	19	4	6	13	11
Plot	19	38	57	76	95	114	133	152
Block	1	2	3	4	5	6	7	8
Treatment	6	6	7	10	10	7	8	18

	Coriander trial						
	Section 3				Section 4		
Plot	1	20	39	58	77	96	115
Block	1	2	3	4	5	6	7
Treatment	12	16	14	10	14	16	6
Plot	2	21	40	59	78	97	116
Block	1	2	3	4	5	6	7
Treatment	6	12	16	11	6	12	12
Plot	3	22	41	60	79	98	117
Block	1	2	3	4	5	6	7
Treatment	19	3	3	12	18	18	16
Plot	4	23	42	61	80	99	118
Block	1	2	3	4	5	6	7
Treatment	9	11	5	4	2	19	13
Plot	5	24	43	62	81	100	119
Block	1	2	3	4	5	6	7
Treatment	3	5	7	8	17	10	18
Plot	6	25	44	63	82	101	120
Block	1	2	3	4	5	6	7
Treatment	5	8	9	3	7	5	10
Plot	7	26	45	64	83	102	121
Block	1	2	3	4	5	6	7
Treatment	17	19	4	16	3	2	2
Plot	8	27	46	65	84	103	122
Block	1	2	3	4	5	6	7
Treatment	18	18	13	6	5	3	5
Plot	9	28	47	66	85	104	123
Block	1	2	3	4	5	6	7
Treatment	11	15	2	2	12	7	14
Plot	10	29	48	67	86	105	124
Block	1	2	3	4	5	6	7
Treatment	4	14	12	13	8	15	1
Plot	11	30	49	68	87	106	125
Block	1	2	3	4	5	6	7
Treatment	7	9	11	19	1	13	9
Plot	12	31	50	69	88	107	126
Block	1	2	3	4	5	6	7
Treatment	10	7	18	14	16	11	11
Plot	13	32	51	70	89	108	127
Block	1	2	3	4	5	6	7
Treatment	14	17	17	15	15	4	8
Plot	14	33	52	71	90	109	128
Block	1	2	3	4	5	6	7
Treatment	8	1	15	18	13	17	19
Plot	15	34	53	72	91	110	129
Block	1	2	3	4	5	6	7
Treatment	2	4	1	9	19	8	7
Plot	16	35	54	73	92	111	130
Block	1	2	3	4	5	6	7
Treatment	1	13	19	7	9	14	17
Plot	17	36	55	74	93	112	131
Block	1	2	3	4	5	6	7
Treatment	15	2	8	17	11	1	4
Plot	18	37	56	75	94	113	132
Block	1	2	3	4	5	6	7
Treatment	16	10	10	5	4	6	3
Plot	19	38	57	76	95	114	133
Block	1	2	3	4	5	6	7
Treatment	13	6	6	1	10	9	15

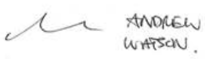
Figure 12a. Trial plan for thyme (left) and coriander (right) set out on an ebb and flood bench split into four sections.

Declaration

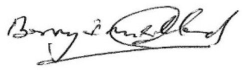
4. We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Name	Dr Barry Mulholland
Position	Project Lead and Director of Horticulture
Organisation	RSK ADAS Ltd
Signature	
Date	27.03.2020

Statistical analyses authorised by:

Name	Andrew Watson
Position	Institute Statistician
Organisation	Quadram Institute Bioscience
Signature	
Date	27.03.2020

Report authorised by:

Name	Dr Barry Mulholland
Position	Director of Horticulture
Organisation	RSK ADAS Ltd.
Signature	
Date	27.03.2020

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