AHDB HORTICULTURE

Interim 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)	Professor Keith Waldron
	(name)	Dr Andrew Watson
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**

(a) This report is intended for public consumption and as such it should be written in a clear and concise manner and represent a full account of the research project to date which someone not closely associated with the project can follow and understand.

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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 horticultural 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

11. The project summary should not ordinarily exceed 2 sides of A4 (approximately 1000 words) and should be understandable to the intelligent non-scientist i.e. growers and their advisors. Please highlight key messages as bullet points at the start of this section. It should cover progress since the last report and how this relates to the objectives. Provide information on actual results rather than just the activities. This can include a limited number of tables, charts figures etc. if deemed helpful. Description of methods and additional data etc. should be submitted in section 14

If there is something substantive to report that needs to be delivered to growers immediately then this section can be increased in size **if agreed with the project manager**

Headline

- A linear model, based on combining accurate measurements of 3 independent physical parameters, air filled porosity (AFP), available water (AW) and bulk density (D_b), has been developed in two ways. **The first approach** summarised the data in terms of a single average (centroid) point for each material and then used a geometric algorithm to populate the region described by those points with target mixtures. This is the so-called “geometric series”. Three blends were selected, based on the strategy of attempting to reproduce the peat centroid as closely as possible. These prototype mixes were tested in 2016 and used in commercial plant growth trials in 2017.
- Importantly it was not possible to recreate fine and medium grade peats that are a current significant constituent of peat-based growing media products, which dominate the professional market. To produce marketable quality plants, however, the choice of growing media appears to be confined to a precise triangulated 3D value, which is influenced by water delivery to the root-zone and plant type.
- It has been demonstrated that short cycle crops such as herbs require greater precision in terms of growing media selection and management based on physical characteristics compared with slower growing woody taxa in containerised production.
- Peat-free prototype growing media selected for their proximity to the peat centroid and which performed well in experimental trials, were shown in practice to produce marketable quality plants on grower holdings. There were however, differences in performance under protected and outside growing conditions. For example material grown under protected experimental conditions did not produce the same pattern of growth response when grown on commercial sites outdoors (e.g. apple trees). This is important, as it demonstrates the value and power of commercial testing as a necessary step for Horticulture R&D.
- **The second development** of the linear model was to replace the ‘corners’ (vertices) of the region as defined by centroid-like materials with alternative materials possessing extreme properties. This was a deliberate attempt to explore as much parameter space as possible and thereby make the relationships between plant performance and growing media parameters easier to detect. A new set of mixtures, populating that enlarged region, formed the basis of experimental trials in 2017. Data analysed so far suggest that D_b is potentially of lesser significance to plant performance compared with AFP and AW. D_b is however important in terms of transport costs and handling.
- Using the above approach, data suggest that a double plant performance peak formed, where good plant growth response was detected some distance apart in terms of physical properties. There was merit in adopting a dual linear model approach to understand the influence of targeted growing media selection on plant performance.

- The insights gained so far, are that growing media can be adequately described by three physical parameters and that the space delineated by the available materials limits the mixtures that can be created.
- CP138 is evolving a methodology for directed as opposed to random or intuitive "look see" mixing strategies. It also indicates how mainstream responsibly sourced growing media (**RSGM**) and the potential introduction of novel materials can be systematically incorporated to generate mixtures having targeted properties.
- Knowledge exchange is an important function of CP138 to ease the transition, if required, from a dependence on peat to the use of other high performing growing media products. To date over 690 Horticulture Industry professionals have attended CP138 independent on site grower workshops or heard the CP138 delivery team present at organised industry events.

Background and expected deliverables

CP138 '*Transition to responsibly sourced growing media use within UK Horticulture*' is a five year project[1] 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 then 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 switch to a dependence on a single raw material type. It is appropriate on a sustainable availability, supply, performance and cost basis to blend 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, then this 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

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[1] 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 The Institute of Food Research and Stockbridge Technology Centre.

manufacture; this is the main deliverable of CP138. If this can be achieved then it will not only increase the range of materials that can be sourced and used by the horticulture industry but expedite the uptake of alternative materials that can perform as well 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 and bulbs).

The key features of the project are summarised as follows:

- Five year co-innovation project, funded by Defra, AHDB, growing media manufacturers (GMM's) and growers to move towards 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.

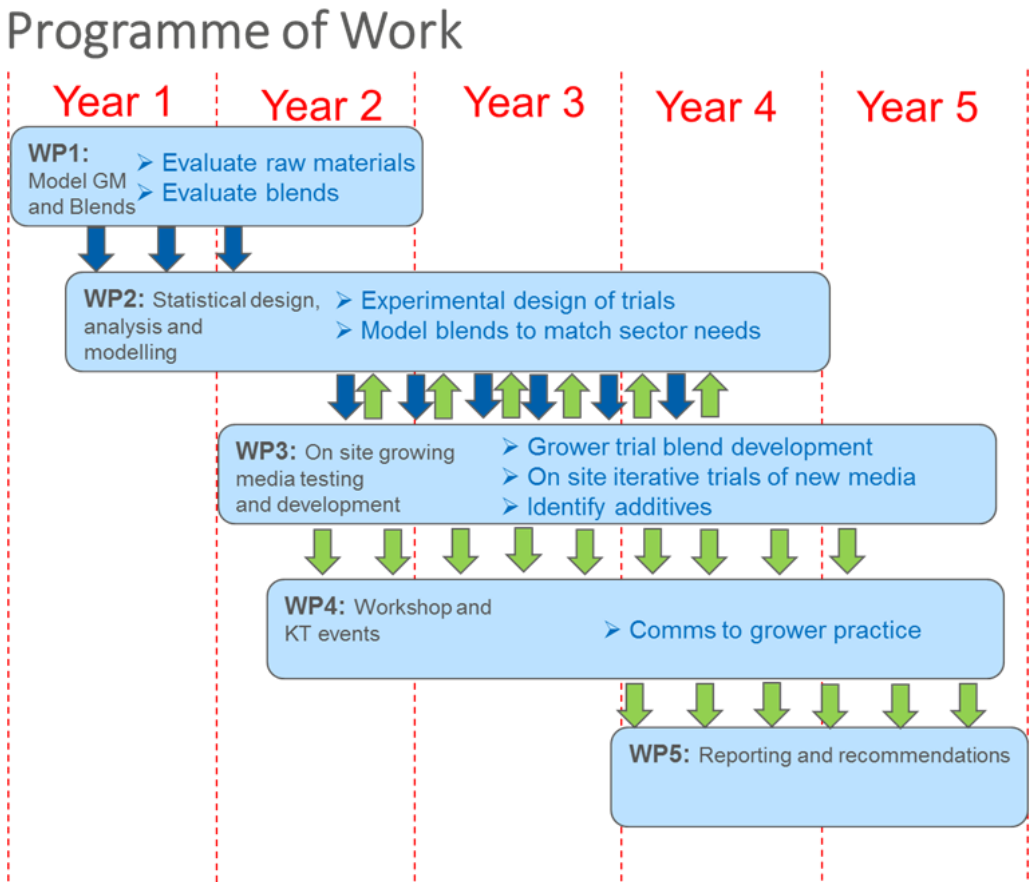


Figure i. Programme of work across the 5 year project. **WP 1** has been completed, **WP2, 3** and **4** are well underway and will run throughout the project. Each WP consists of a number of agreed specific tasks.

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. **WP1** was completed at the end of March 2017 and a synopsis is given below. The algorithms and data resulting from **WP1** activities have been developed in **WPs 2-4**. This work 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.

Progress against work plan and the completion of WP 1

In early 2017, the initial scoping and characterisation of potential RSGM materials was completed, which concluded the activities for **WP1 (**see CP138 2015 and 2016 for detailed reporting of activities and data**).** Algorithms have been produced that predict the key physical properties of the RSGM tested, either alone or in blends. **A linear model**, based on combining accurate measurements of three physical parameters, air filled porosity (AFP), available water (AW) and bulk density (Db), has been developed in **two ways**.

The first approach summarised the data in terms of a single average (centroid) point for each material and then used a geometric algorithm to populate the region described by those points with target mixtures. This is the so-called "geometric series" (see CP138 2016 annual report).

The second development of the linear model was to replace the 'corners' (vertices) of the region as defined by centroid-like materials with alternative materials possessing extreme properties. This was a deliberate attempt to explore as much parameter space as possible and thereby make the relationships between plant performance and growing media parameters easier to detect. A new set of mixtures, populating that enlarged region, formed the basis of experimental trials in 2017. Data analysed so far suggest that peat may not be the best performing material and D_b is potentially of lesser significance to plant performance compared with AFP and AW.

Using the above dual linear model approach CP138 has created the opportunity to explore other materials that go beyond initially selected and tested growing media. This is an important development as a model can now be developed that will predict plant response to a wider range of RSGM raw materials than was first envisaged within the 5 year term of CP138. This may be important for crops that have very specialised growing requirements such as vegetable propagation and mushroom production. It may also expedite the incorporation of materials that have hitherto not been so far considered and do not exist in sufficient quantities of reliable quality to be considered as commercially relevant RSGM.

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

Methodology

An important feature of this project is the hypothesis that growing media can be adequately described by three physical parameters, Air Filled Porosity (AFP), Dry Bulk Density (D_b), and Available Water (AW).For the purposes of being able to characterise growing media selections and to model / predict performance, then each growing media was described as a single point in the three-dimensional space whose axes are AFP, D_b and AW. Building on this, it was hypothesised that the properties of a mixture are a simple linear sum of the properties of the components, with if necessary appropriate correction coefficients, combined in the appropriate proportions.

An additional ingredient of the project is that four raw materials are to be considered (coir, wood fibre, green compost and bark). Explicit samples of these raw materials have particular values of (AFP, D_b, AW) and therefore each can be represented by a single point in the three dimensional space. The space is three dimensional, and a three dimensional space is said to be spanned by 3 basis vectors. For convenience we will augment this terminology and refer to the four raw materials as 'basis materials'. Strictly, one of these is not required.

A simple observation has an important outcome. Imagine that an arbitrary mixture is created using the four 'basis' materials. Then we could write:

$$mix = \lambda_1 m_1 + \lambda_2 m_2 + \lambda_3 m_3 + \lambda_4 m_4$$

where λ is the Greek letter lambda, and each λ_i value is the amount of material m_i that can be added to the mix. The 'λ_i' s are the coefficients (proportions) which control the level of the different materials in the mix: clearly they cannot be negative, none can be greater than one (it's not possible to have a mixture that is 110% coir, for example) and together they must equal 1. In symbols:

$$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1$$

This means the 'mix' above is what mathematicians call a 'convex combination'. All such combinations form a 'convex hull'. Since our 'mixture problem' turns out to be an instance of this topic from classical geometry we can freely import its result. The convex hull is a region framed by vertices – in our case the four basis materials – that encloses all possible mixes. Think of the way the corners of a square provide a framework such that, when connected up, they enclose a region. What this means in practice is that, provided the properties of a mixture are the simple linear sum of the properties of the raw (basis) materials then no combination of those four basis materials can have (AFP, D_b, AW) values outside the convex hull, the region defined by our chosen basis materials.

Put another way, if for instance a peat control has (AFP, D_b, AW) values outside of a region defined by three or more basis materials then ***no amount of testing with trial mixtures will generate a mixture with the same (AFP, D_b, AW) properties as that peat*** (provided that the assumptions of the approach hold true).

A focus in Year 2 was an attempt to create different mixtures having properties close to a preselected target value, and comparing the quality characteristics of plants grown in mixtures based on different combinations of basis materials but having similar (AFP, D_b, AW) values.

Year 3 had a complementary objective. Selecting mixtures with similar (AFP, D_b, AW) values makes it relatively difficult to reveal the dependencies on those parameters. The best way to tease out how plant quality depends on these parameters is to use mixtures having the largest possible spread in (AFP, D_b, and AW). This has been the guiding principle of the **Year 3 modelling**.

Plotting (AFP, D_b, AW) values of the coir, wood fibre, green compost and bark raw materials, along with peat samples, on three-dimensional plots and rotating those plots revealed something quite surprising: these materials lie roughly on a planar region in (AFP, D_b, AW) space. The range of (AFP, D_b, AW) values accessible by the available materials is therefore modest. A choice of four basis materials at best delineates a roughly 'flattened pyramid' shaped region.

The materials selected for the 'geometric series' used in the **Year 2** Boxworth trials were shown to enclose a compact region, with a commensurate small range in accessible (AFP, D_b, AW) values. To pursue the agenda of maximising the spread of (AFP, D_b, AW) values meant selecting four basis materials in such a way as to maximise the enclosed region of the AFP, D_b, AW space (**Table 1** and **Figure 1**). In making this selection attention had to be paid to other important chemical factors such as pH and salinity. The four materials selected were (we use pressure plate data throughout, at 5 kPa suction).

Table 1. Values of the four parameters Air Filled Porosity (AFP), Dry Bulk Density (D_b) and Available Water (AW) for the four selected basis materials.

	AFP	D_b	AW
Bark	38.55	0.173	21.48
Coir	8.77	0.076	43.23
Green Compost	11.22	0.216	45.08
Wood Fibre	51.68	0.078	20.26

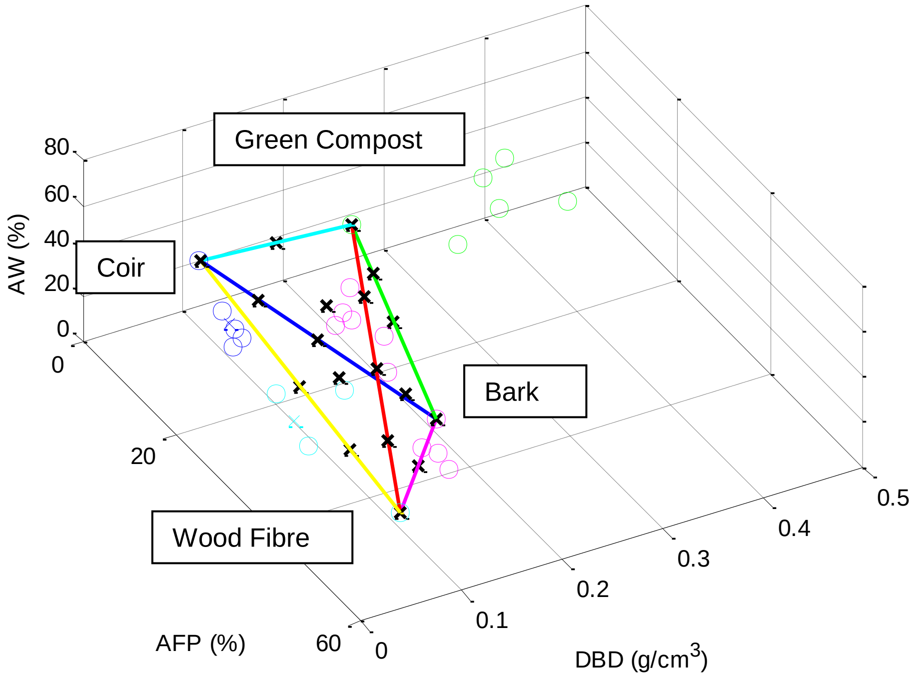


Figure 1. The four basis materials (the vertices) linked by 'edge' lines. Coloured circles show other materials from the same classes. The black crosses show target mixtures described in the text.

The pyramid-shaped region has become known as a 'samosa', which we have found is a helpful descriptor for discussing different sets of trials and showing the locations of other samples of the same material classes (**Figure 1**). In previous Annual Reports (CP138, 2015, 2016) these have been helpfully summarised by 'centroid' (mean) markers. Centroids can however, obscure some interesting features of the data. In particular, Green Compost covers a range of D_b values (a point that will be seen to be of interest below) whereas bark spans a wide range of AFP values, so these two materials might be helpful in manipulating these parameters in mixtures. Coir values form a relatively compact group, which may reflect the restricted botanical origin of the raw material.

The next step was to select combinations of the four basis materials covering as much of the (AFP, D_b, AW) space as possible with as many points as possible but constrained by the practicalities of the experimental work. The compromise is 6 points per dimension, or 18 points in all. These are to include vertices and points on edges, plus a number of interior points, the 18 points selected to give expansive but relatively even coverage. These points are marked on **Figure 1**.

The assumption that materials can be combined in such a way that the parameters (AFP, D_b, and AW) of the mixtures are a simple linear sum of the component raw materials can be tested. The computed parameter values of our mixtures, based on the mixture and the basis material values, can be compared to the actual measured mixture values. The number of mixtures available for comparison is 19 subtract 1 (the peat) and subtract 4 (the basis materials themselves) to equal 14. The calculated and measured values for the samosa series are shown in **Figure 2**.

For D_b and AW, the middle and lower panels of **Figure 2**, the agreement between measured and predicted values is acceptable. For AFP values the predicted value tends to be larger than the measured value. In some instances the values clearly do not agree with the measured values (especially mixes 7, 13 and 15). This outcome is at odds with expectation and warrants further investigation.

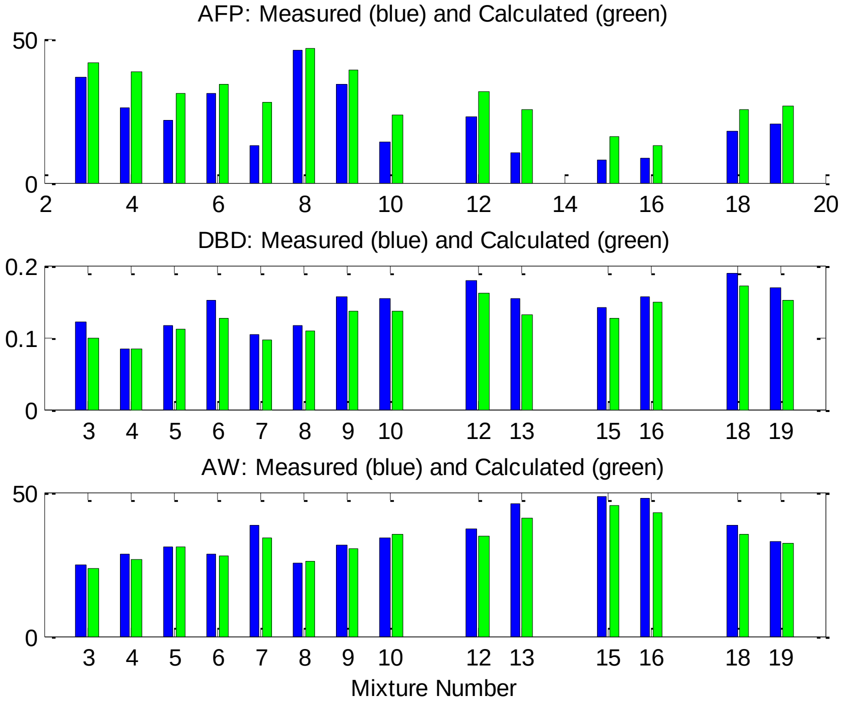


Figure 2. Measured and calculated values of the three parameters for the mixtures comprising the 'samosa' series. The gaps are due to peat (1) and the four basis materials, for which comparisons do not exist.

<u>Testing of next generation prototype mixes against pre-campaign selected plant material from commercial grower sites</u>

The Year 3 Boxworth trial crops were (**see WP3 for trial details and results**):

- Chinese cabbage, spring cabbage
- Bedding (violas)
- HNS (*Choisya*, Lavender, Vinca)

Selected plant parameters were recorded, depending to some extent on the plant type. Each plant plus compost mixture combination was replicated over an appropriate number of systematically randomised plots to avoid plot-dependent and to take into account edge effects (see **WP3** for detail). In the following section the results for Chinese Cabbage and *Choisya* are considered in detail.

Chinese Cabbage

To be submitted upon completion of the vegetable trial repeat.

Choisya

Choisya was irrigated via ebb and flood whereas the cabbage plants in trays were watered from above (see **WP3** for details). The available metrics for *Choisya* are height and quality, determined at 4, 8, 12 and 16 weeks. The correlation between height and the AFP, Db and AW parameters are shown in **Figure 3**.

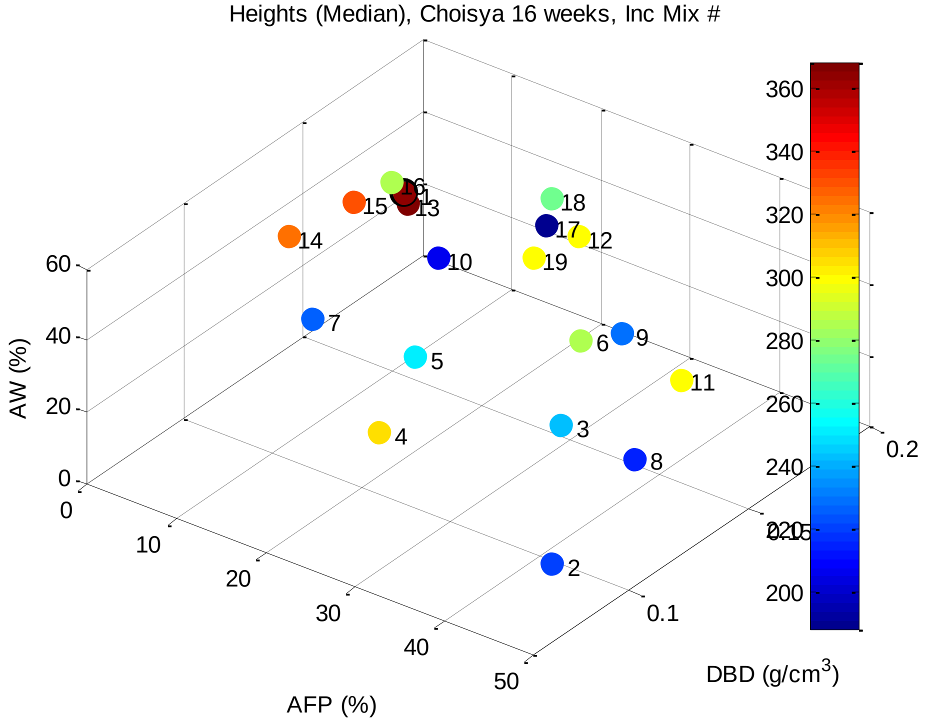


Figure 3. *Choisya*, 16 weeks, Median heights versus the parameters (AFP, D_b (DBD), AW). The coloured circles are different mixtures (as numbered) and are assigned a colour from blue to red, where red is high performing and blue is poor performing. The peat control is a black bordered open circle.

The correlation with D_b was weak (**Figure 4**) and again there is justification for visualising the plant performance data as a surface plotted against AFP and AW only (**Figure 5** and **Figure 6**).

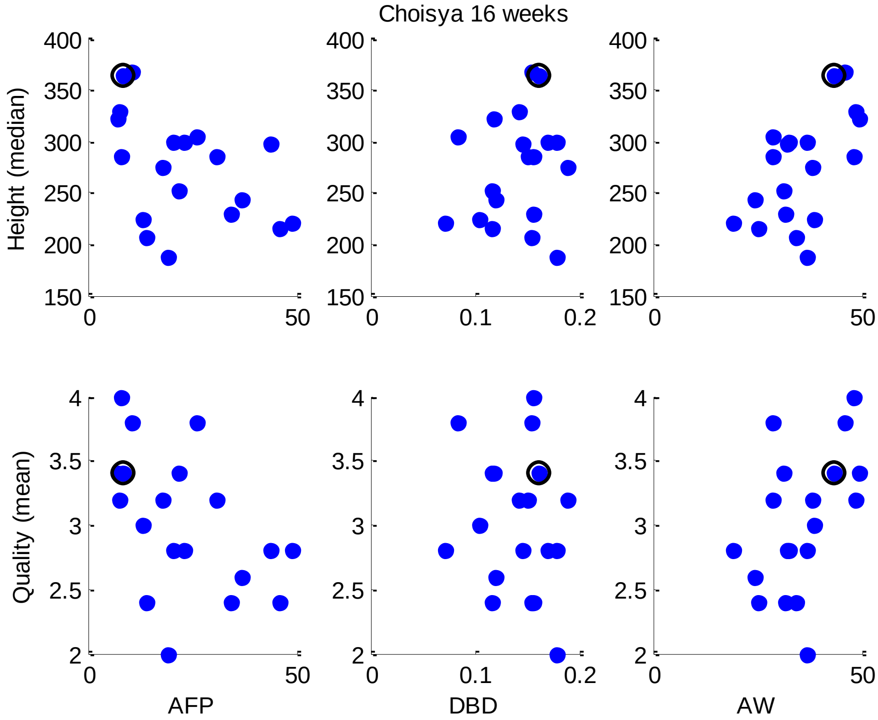


Figure 4. *Choisya*, 16 weeks, correlations between height and quality, and the parameters (AFP, D_b (DBD), AW). Peat is indicated by a hollow black circle.

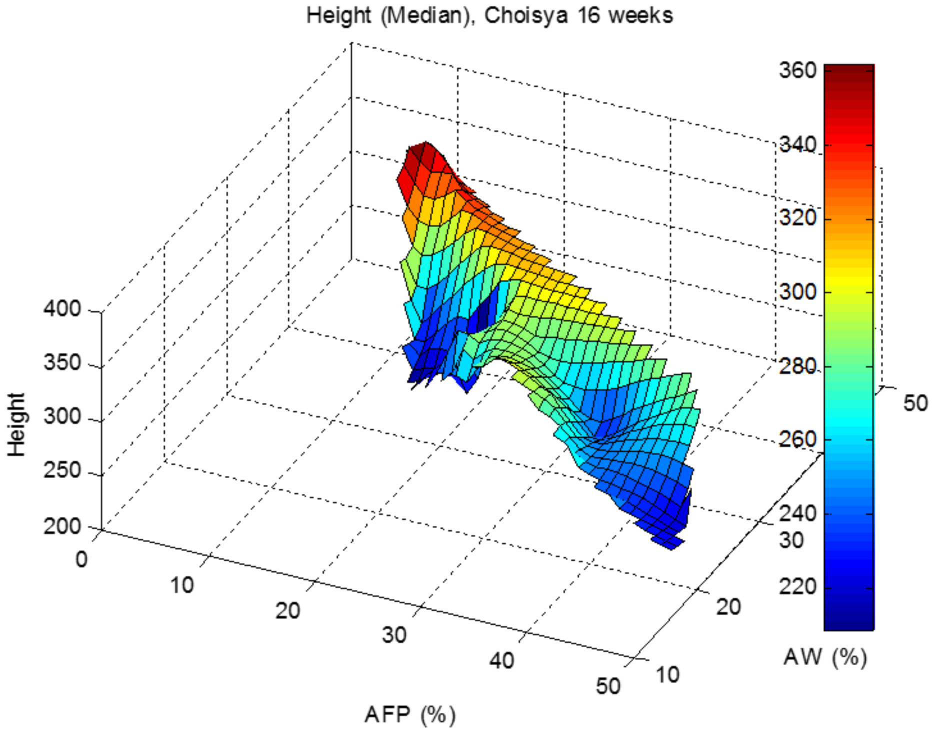


Figure 5. *Choisya*, 16 weeks, surface plot of height versus AFP and AW. The coloured response scale goes from a colour from blue to red, where red is high performing and blue is poor performing.

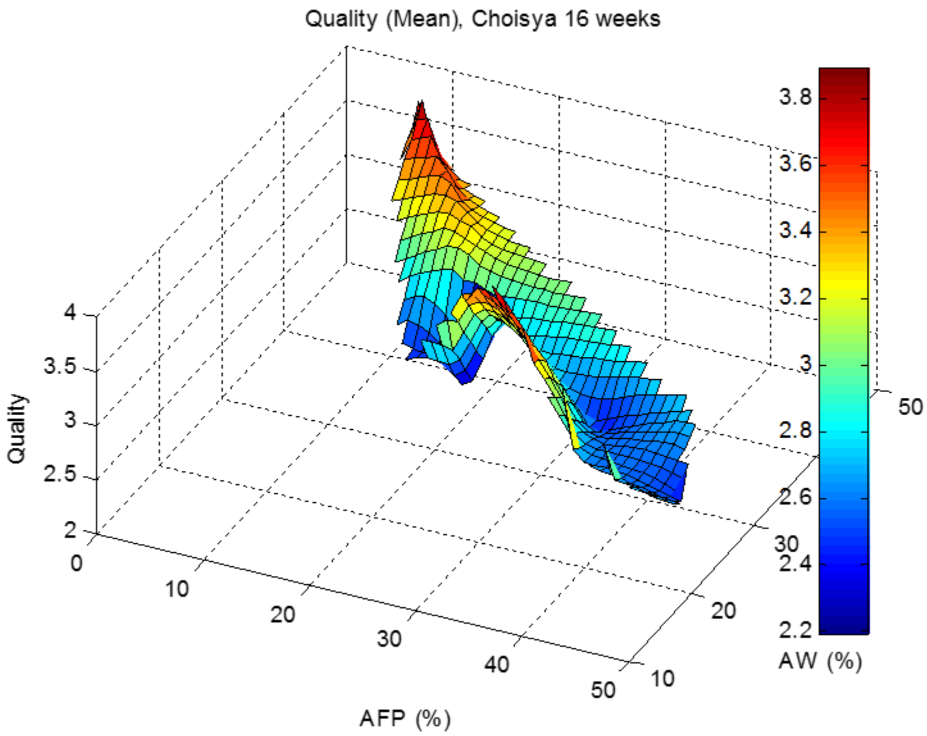


Figure 6. *Choisya*, 16 weeks, surface plot of quality versus AFP and AW. The coloured response scale goes from a colour from blue to red, where red is high performing and blue is poor performing.

Progress summary on model development

- A hypothesis of the project is that raw materials can be combined such that the three parameters (AFP, D_b and AW) of the combination is a simple linear sum of the corresponding properties of the component materials. According to the "samosa" data series there are instances where AFP values do *not* agree with this hypothesis, the measured values being smaller than the predicted values. The reason for this discrepancy is not clear and will be the subject of further investigation.
- The 'Quality' parameter is a crude device from the modelling perspective but its utility in the commercial sector is clear. Height is a useful parameter in some instances, and again is useful in the commercial sector but its applicability is compromised in plants with a spreading aspect, such as *Vinca*. Perhaps the single best parameter is plant weight, since this captures the entirety of the growth, though this may not be an adequate 'goodness' measure for some plants such as violas, which may be judged by number of flowers. The weight can be measured for the cut plant, even for systems where cutting the plant is abnormal, for example with the *Choisya*, though obviously only at the end of the trial. Growers might like to take more advantage of the opportunities offered by the experimental trials during the project, where measurements and treatments are available that would not be considered plausible in a commercial setting. Measurements at the individual plant level rather than block measurements are to be preferred since they contain more information, particularly on the variance within groups.
- From a modelling perspective, both the plant types presented above show a clear trend over AFP and AW, with a lack of dependence on D_b. This is the type of information required to move forward and was the reason for selecting the basis materials to give a wide parameter space cover. Looking ahead, the visualisations will inform a mathematical model.
- The fact that D_b seems to have little impact on plant performance has an important corollary. As is clear from **Figure 1** the different Green Compost samples have broadly similar AFP and AW values

but are spaced out along the D_b axis. This means that *all* the (tested) Green Compost materials are broadly equivalent in terms of plant performance since the parameter that most differentiates them is D_b, the factor that appears to matter least, compared with AFP and AW, in resulting plant performance.

- The surface plots hint at a possible double 'sweet spot' scenario. The *Choisya* shows a peak in plant performance at low AFP/ high AW, and a second, less pronounced peak in plant performance at mid-range AFP/ mid-range AW values. This scenario will be investigated further.
- **Commercial trial data**: the existing database generated by trials at commercial facilities will allow emerging modelling threads to be tested. This data is invaluable for comparing different performance metrics, and for understanding the natural statistical variance in the plant types of interest.

WP3: On-site growing media testing and development

Approach summary

During 2017, trials were conducted both on grower sites and at the experimental sites of ADAS Boxworth and Stockbridge Technology Centre (**WP3**, **Tasks 3.1-3.4**). 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 either Boxworth or STC and the best performing growing media were tested under commercial conditions at hosted grower sites and were termed "main campaigns".

First generation prototype blend testing – grower hosted sites

During 2017, trials were carried out on six grower sites (**Table 2**). Each trial consisted of three peat-free prototype blends which were originally tested at ADAS Boxworth in 2016, plus the nurseries standard product, resulting in four treatments per trial. Prior to the trials commencing, nutrition levels for each crop were agreed with the host grower, so that each prototype blend had the same concentration of nutrients applied at a set pH. This was to ensure that any observed differences were due to the growing media blend and not nutrient availability. The prototype blends plus the standard nursery blends were also tested for physical and chemical properties, to understand how plant performance can be related to these properties.

Table 2. Grower hosted trials in 2017.

Host	Trial	Duration
EU Plants*	Raspberry prop	Planted week 15. Overwintering into 2018
EU Plants*	Strawberry prop	Planted week 28. Overwintering into 2018
F P Matthews*	Top fruit	Planted week 12. Overwintering into 2018
G's	Mushrooms	Commenced week 29, harvested week 32
Ivan Ambrose	Pack bedding	Planted week 21, harvested week 24
Lincolnshire Herbs	Herbs Spring	Sown week 14, harvested week 19-20
Lincolnshire Herbs	Herbs Autumn	Sown week 35, harvested week 41
Lowaters*	HNS Finals	Planted week 11-22. Salvia harvested week 22. Other species overwintering into 2018

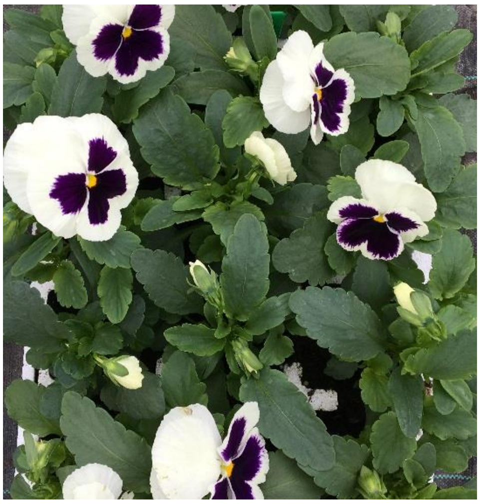
*Note that overwintering trials have not been included in this report

Protected Ornamentals – Bedding

Trials were carried out on transplanted material of Petunia Blue and Pansy Matrix White Blotch at Ivan Ambrose and Co Ltd. (Liverpool, L31 4JD), from 24 May to 16 June 2017. In each trial, four growing media treatments were used (**Appendix 1**).

Plugs were transplanted into white polystyrene jumbo 6-packs (12 plants per plot) filled with the relevant growing media, and grown on the floor under glass as per commercial practice. Irrigation was delivered via an automatic overhead boom. Plant growth and flowering was monitored by the nursery, and plants were assessed in week 24 for height (four plants per plot), quality (plot overall score, scale 0-5), root development (four plants per plot, scale 0-4) and the number of plants per plot in flower. For scoring criteria see **Appendix 1**.

For both species, there was very little difference between treatments, and all three prototypes produced plants that were of marketable quality. For both pansy and petunia, there were no significant differences between treatments for plant quality (**Figure 7** and **Figure 8**).



Nursery standard **Prototype 1**

Prototype 2 **Prototype 3**

Figure 7. Pansy white blotch grown in four growing media treatments at the final assessment date, week 24 2017.

Nursery standard **Prototype 1**

Prototype 2 **Prototype 3**

Figure 8. Petunia blue grown in four growing media treatments at the final assessment date, week 24 2017.

For plant height in the pansy crop, prototype 3 produced the shortest plants (74.9 mm average) and prototype 1 produced the tallest plants (80.4 mm average). However, this difference was not significant. The peat-reduced nursery standard produced plants with an average height of 80.0 mm. Height differences were significant in the petunia crop however ($p = 0.005$). Both prototypes 2 and 3 were significantly shorter than both the nursery standard and prototype 1 (**Figure 9**).

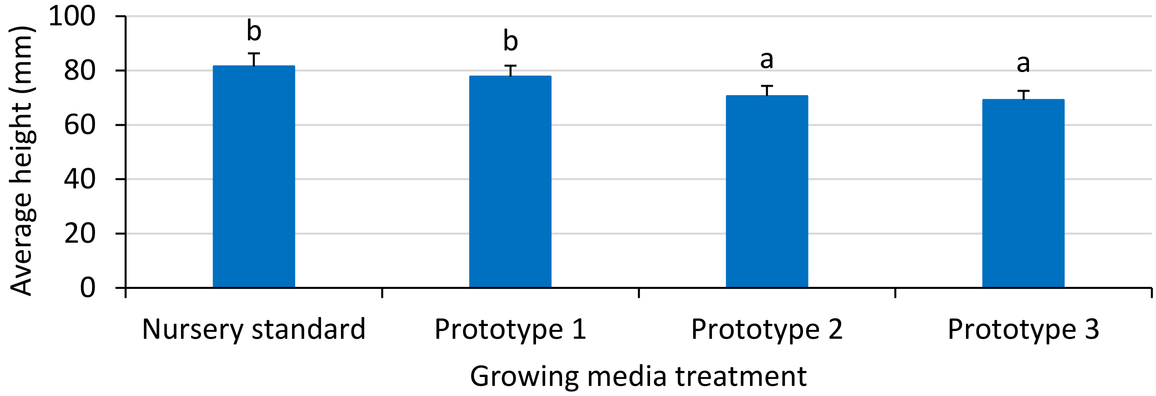


Figure 9. Petunia average height for the four growing media blends at the final assessment (week 24). Differences across treatments are statistically significant (p = 0.005). Error bars represent 1 standard error, with 3 degrees of freedom (d.f.).

In the pansy crop, differences between treatments for rooting were statistically significant (p = 0.006). Plants grown in the nursery standard had a better root system (**Figure 10**), and the poorest root system was seen in prototype 2, where roots filled approximately 25% of the cell. There was no significant difference between prototype 1 and the nursery standard. In the petunia, differences between treatments for rooting were not statistically significant. Plants grown in prototype 3 had a slightly better root system than the nursery standard, and plants grown in prototype 2 had the poorest root system. However, for all four treatments, roots filled approximately 26 - 50% of the cell.

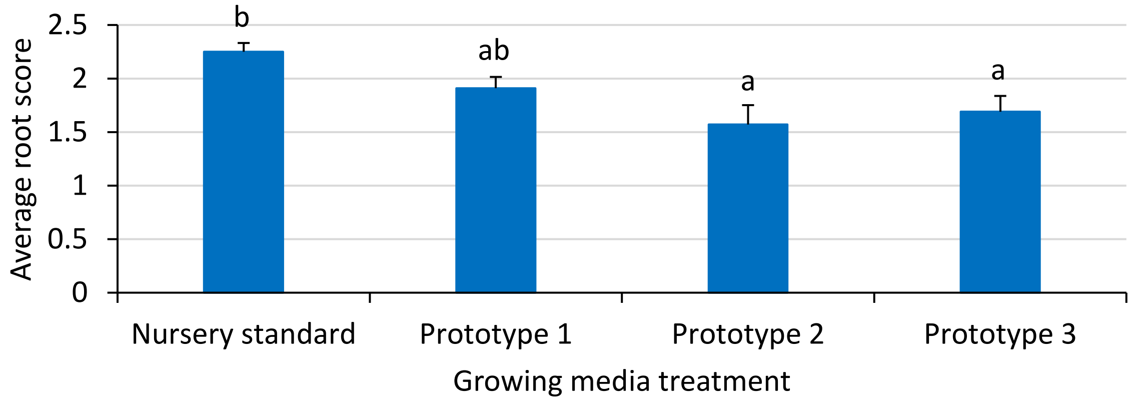


Figure 10. Average root scores for the pansy crop at the end of the trial (week 24). Differences across treatments are statistically significant (p = 0.006). Error bars represent 1 standard error, with 3 degrees of freedom (d.f.).

For both pansy and petunia, there were no significant differences between treatments for the number of plants per plot in flower at the end of the trial (**Table 3**).

Table 3. Number of plants per plot in flower for both pansy and petunia at the end of the trial (week 24).

Treatment	**No. of plants in flower (out of 12)**	
	Pansy	**Petunia**
Nursery standard	8.12	4.88
Prototype 1	7.00	3.50
Prototype 2	7.88	3.50
Prototype 3	8.00	5.00
l.s.d	2.243	1.846

Overall, all three of the prototype blends performed well in pack bedding. For the pansy crop, only the root development was significantly affected. The roots in prototypes 2 and 3 were less well developed, prototype 1 however was not significantly different to the nursery standard. In the petunia crop, only the plant height was significantly affected. The plants in prototypes 2 and 3 were significantly shorter than the nursery standard and prototype 1, which were not significantly different to each other. Of the three prototypes, prototype 1 was the strongest performing blend, and was not significantly different to the nursery standard for any of the assessment criteria for either the pansies or the petunias.

Protected edibles – herbs

Trials were carried out on basil (cv. Aroma 4), chive (cv. Polyvert) and rosemary (cv. Upright Blue) at Lincolnshire Herbs (Bourne, PE10 0AT) in spring and autumn 2017 (**Table 4**). Four growing media treatments were used for each trial, which were grown alongside a commercial crop (**Appendix 2**). Basil and chive seeds were sown into square 9 cm pots (20 pots per plot) and placed in the germination room for three days. Rosemary plugs were hand-planted into 9 cm pots and placed straight out on the nursery. Once the basil and chives had been removed from the germination room, the pots were placed on the same line as the rosemary, and all three species were kept together, although each species was a trial in its own right (**Figure 11**). Irrigation was performed mechanically via an overhead boom at the germination stage, and then via flooding of the gutter system. Germination and plant growth was monitored, and a final assessment was carried out at marketing on 10 pots per plot, for quality (scale 1-3), height, fresh and dry weight. For scoring criteria see **Appendix 2**.

Table 4. Sowing/planting and harvest dates for each species in spring and autumn 2017.

Trial	Sowing/planting date	Harvest date
Spring – basil	Week 14	Week 19
Spring - chive	Week 14	Week 20
Spring – rosemary	Week 14	Week 20
Autumn – basil	Week 35	Week 41
Autumn – chive	Week 35	Week 41
Autumn - rosemary	Week 35	Week 41

Figure 11. Basil pots set-out on the gutter system (left), and then after spacing (right).

Basil

Germination was assessed on the basil crop in spring and autumn, and in the spring, there were no significant differences between treatments, with all plots reaching the minimum requirement of at least 20 germinated seeds per pot. In the autumn however, differences between treatments were more noticeable, and germination in the nursery standard was significantly greater than prototypes 1 and 2 ($p = 0.014$). Prototype 2 did not quite reach the requirement of 20 germinated seeds per pot.

In the spring trial, the basil showed very little difference between treatments, and there were no significant differences in terms of crop quality (**Figure 12**). For height, fresh weight and dry weight, the nursery standard was significantly greater than the prototypes ($p = 0.012$, $p = 0.020$ and $p = 0.005$ respectively), although there was no significant difference between treatments. Despite this, the plants were still all deemed to be commercially acceptable.

Peat-reduced nursery standard

Prototype 1

Prototype 2

Prototype 3

Figure 12. Basil quality and root development at harvest, week 19 2017.

In the autumn basil trial, there were no significant differences between treatments for crop quality. The height of the plants was significantly greater in prototypes 1 and 3 ($p < 0.001$) compared to the nursery standard and prototype 2 (**Figure 13**). The differences in fresh and dry weight between treatments were also statistically significant ($p < 0.001$ for both criteria) with the lowest fresh and dry weight in prototype 2. Prototypes 1 and 3 were not significantly different to the nursery standard.

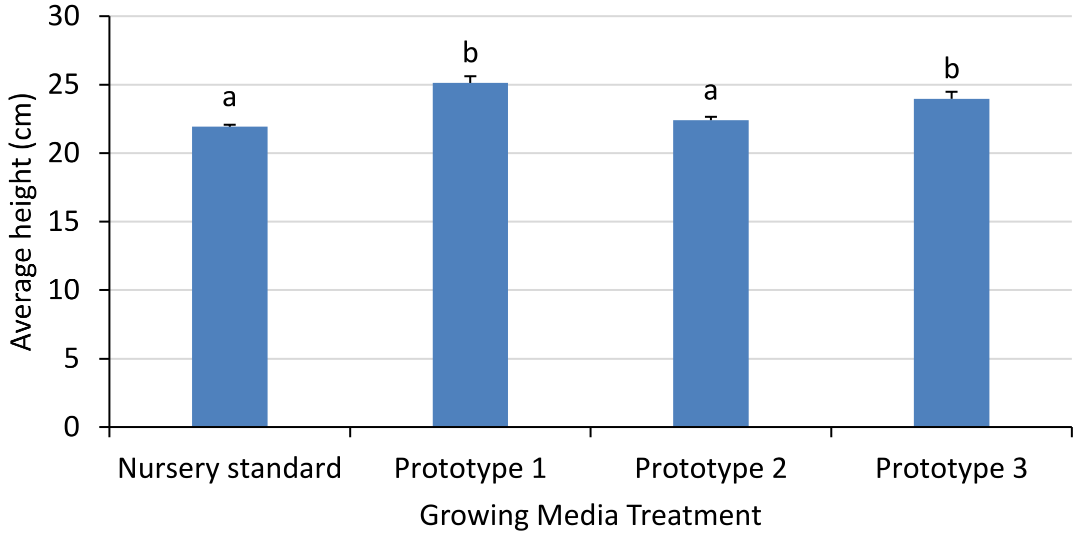


Figure 13. Basil average height (cm) for the four growing media blends in the autumn sowing at harvest (week 41). Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 3 degrees of freedom (d.f.).

Chive

Germination was assessed on the chive crop in spring and autumn, and in the spring, there were no significant differences between treatments, with all plots reaching the minimum requirement of at least 40 germinated seeds per pot. In the autumn however, differences between treatments were more noticeable, and germination in the nursery standard was significantly greater than all three prototypes (p = 0.011). However, although the number of germinated seedlings was lower in the prototypes, they still reached the minimum requirement of 40 seeds per pot.

In the spring trial, the chive crop showed very little difference between treatments. There was a significant difference in height between treatments (**Figure 14**) with the nursery standard significantly taller (p <0.001). Prototype 1 was also significantly shorter than Prototypes 2 and 3.

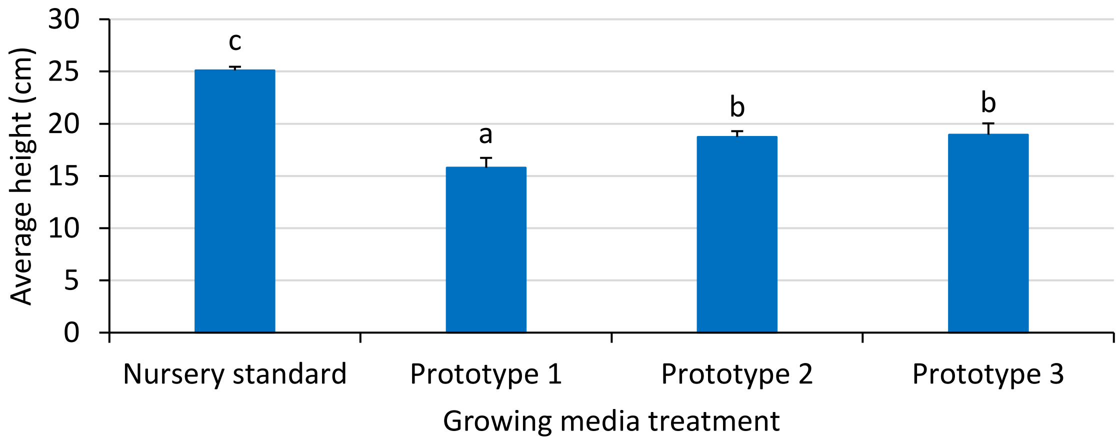


Figure 14. Chive average height (cm) for the four growing media blends in the spring sowing at harvest (week 20). Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 3 degrees of freedom (d.f.).

There was a significant difference in the fresh and dry weights in the spring (p <0.001 for both criteria), with the nursery standard greater than all three prototypes. Prototype 1 had the lowest fresh and dry weight.

In the autumn chive trial, there was a significant difference between treatments (p <0.001), with the nursery standard media producing a better quality crop (**Figure 15**). All of the prototypes were significantly different to each other, with prototype 2 producing the poorest crop, which would not have been marketable.

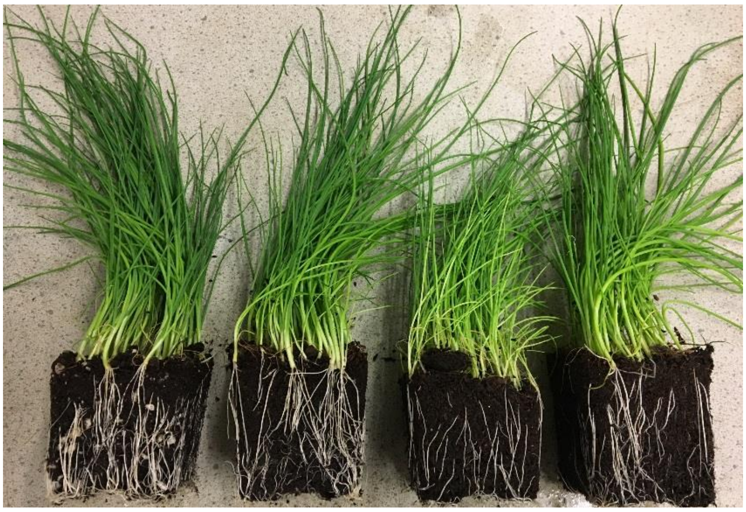


Figure 15. Chives in week 41 (l-r; nursery standard, prototype 1, prototype 2 and prototype 3).

There was a significant difference in height between treatments with the nursery standard significantly taller than prototypes 1 and 2 (p <0.001). The three prototypes were also all significantly different to each other. There was a significant difference in fresh weight between treatments (p <0.001), with the nursery standard greater than the prototype blends. Prototype 2 had the lowest fresh weight of all the blends. This significance was also reflected in the dry weights (p <0.001).

Rosemary

In the spring trial, there was no significant difference between any of the growing media treatments for crop quality at harvest. All plots were of marketable quality and had a well-developed root system. There was a significant difference in crop height between treatments, with the nursery standard greater than the prototype blends (p <0.001). Prototype 2 was also significantly shorter than prototype 1 and 3. Differences between treatments for the fresh and dry weights were statistically significant (p <0.001 and p = 0.013 respectively). The nursery standard had the greatest fresh weight and prototype 2 was also significantly lighter than prototype 1 and 3. The nursery standard also provided the greatest dry weight and was significantly greater than prototype 2. Prototype 2 was also significantly lighter than prototype 3.

In the autumn trial, there was a significant difference in crop height between treatments (**Figure 16** and **Figure 17**), with prototype 2 significantly shorter than all other blends, including the nursery standard (p <0.001).

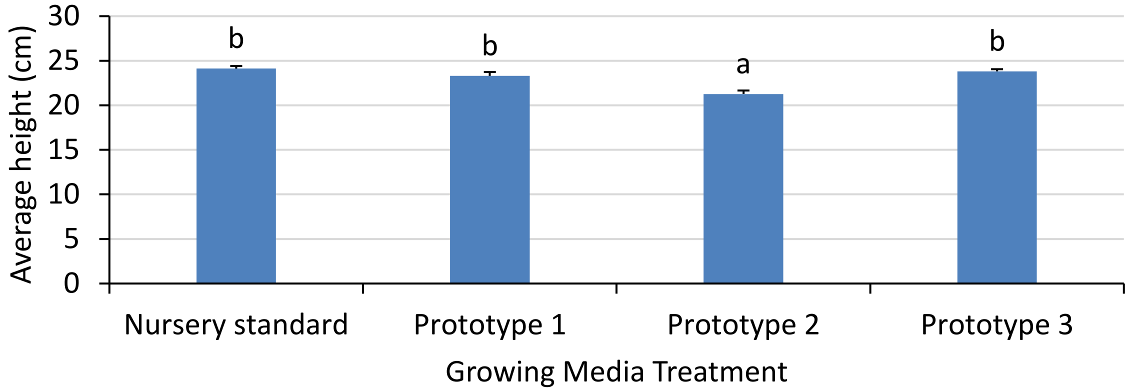


Figure 16. Rosemary average height (cm) for the four growing media blends in the autumn sowing at harvest (week 41). Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 3 degrees of freedom (d.f.).

Figure 17. Rosemary in week 41 (l-r; nursery standard, prototype 1, prototype 2 and prototype 3).

Differences between treatments for the fresh and dry weights were statistically significant (p <0.001 for each criteria). Prototype 2 was significantly lighter than the nursery standard and prototypes 1 and 3.

Generally, all three prototypes performed well in the pot herb trials, although there were differences between species and season. For basil, in the spring, although the nursery standard was significantly better for crop height, fresh weight and dry weight, the prototypes still produced a marketable crop, and there were no differences between the prototypes. In the autumn, prototype 2 did not perform particularly well, and although the crop height was similar to the nursery standard, fresh weight and dry weight was reduced. Prototypes 1 and 3 were as good as the nursery standard.

For chive in the spring, the nursery standard was significantly better than the three prototypes, although crops were still marketable in prototypes 2 and 3. Prototype 1 did not perform particularly well. In the autumn, there was a noticeable difference in quality, and the nursery standard was statistically better, with prototype 2 the poorest performing blend. Prototype 2 also produced the shortest and lightest crop. Prototype 3 was generally the better performing blend in the autumn.

For rosemary in the spring, prototype 2 produced the shortest and lightest crop, and prototype 3 was generally better performing. In the autumn, prototype 2 was significantly shorter and lighter compared to both the nursery standard, and prototypes 1 and 3.

Overall, prototype 3 was the better performing blend, showing promising results in both the spring and autumn. Prototype 1 also performed relatively well, although this blend was better in the autumn trial, particularly for chive. Results in prototype 2 were not as good, and therefore this blend may not be well suited to pot herb production.

Mushrooms

A trial was carried out at G's (Cambridgeshire, CB7 4TF) in summer 2017. Because mushroom production requires a very wet, sticky peat, a slightly different approach was taken for this trial, in order to try and produce a blend that would have similar properties to the nursery peat standard. In total, eight treatments were tested, which comprised the prototypes on their own, as well as in a blend with the nursery standard peat, a 100% peat standard and a peat/aged digestate blend (**Appendix 3**). The trial was located on a bench within a fully enclosed tunnel, and grown alongside a commercial crop (**Figure 18**). Each plot contained one crate filled with incubated mushroom compost and layered with the relevant growing media treatment. The crates were set out in a randomised design on the bench (**Appendix 3**). The crates were filled by hand in week 29, prior to filling, all blends were mixed with water to reach a consistency similar to that of the peat standard.

Figure 18. Mushrooms growing in a separate crate system, located on a bench within a fully enclosed tunnel, week 32.

The first flush was produced in week 32, with a second in week 33 and a third in week 34. The trial was picked by nursery staff, and yields were recorded. Mushrooms were also collected once per flush, and fresh and dry weights were recorded, along with yield.

The performance of the blends was generally variable, and the trial took 2-3 days longer to produce the first flush, compared to the commercial trial located in the same tunnel. Although mushroom quality was relatively good, the mushrooms were smaller than the nursery standard, and yields were reduced in all treatments compared to the nursery standard.

The most noticeable differences were seen in the percentage dry matter of the mushrooms. In flushes 2 and 3, there was a significant difference between treatments (p <0.001 and p = 0.015 respectively). In flush 2, treatments 4, 6 and 7 had a significantly lower dry matter content in comparison to the nursery standard (**Error! Reference source not found.**). In flush 3 however, treatment 6 had a significantly higher dry matter content in comparison to the nursery standard, and none of the treatments were significantly lower (**Error! Reference source not found.**).

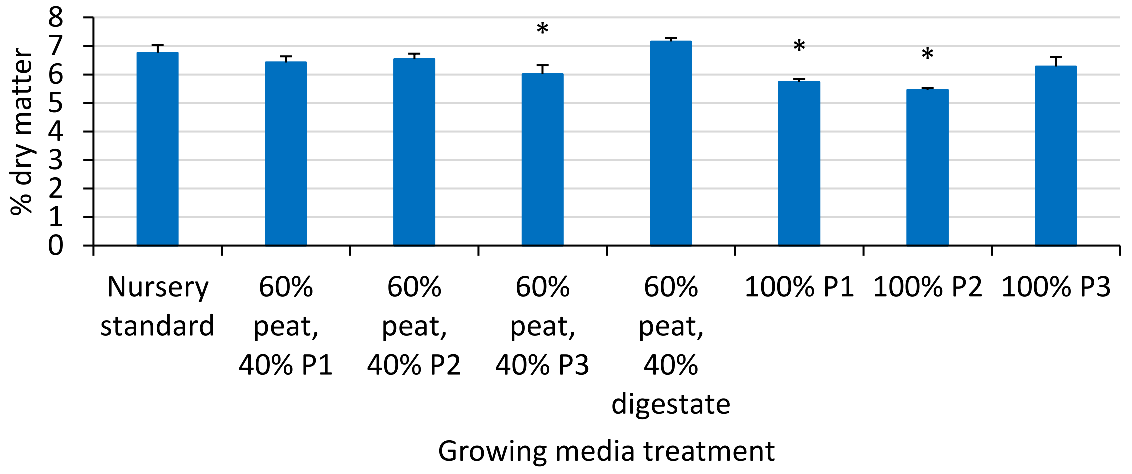


Figure 19. Percentage dry matter of the mushrooms produced in flush 2. * = significantly different to the nursery standard (p <0.001). Error bars represent 1 standard error, with 7 degrees of freedom (d.f.).

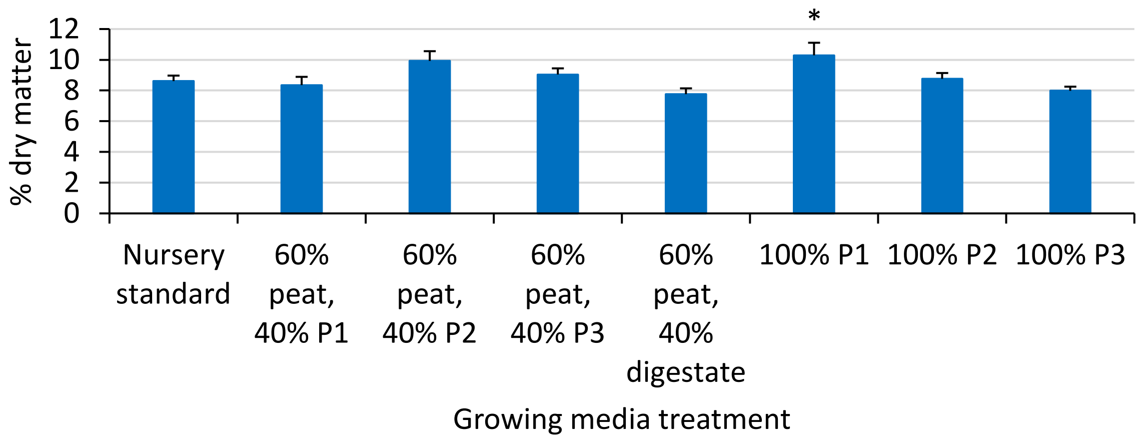


Figure 20. Percentage dry matter of the mushrooms produced in flush 3. * = significantly different to the nursery standard (p = 0.015). Error bars represent 1 standard error, with 7 degrees of freedom (d.f.).

Overall, the prototype blends did not perform particularly well in this trial, either alone or in combination with 100% peat. Mushroom production is very different to all other crop sectors, and it was clear from one trial that the first generation prototypes were simply not suited to that commercial situation. However, it is possible that some of the blends generated for the second generation prototypes may have properties that would be better suited to mushroom production, and therefore it would be practical to look at alternative blends in another trial.

Conclusions

Overall, the prototype blends performed well on commercial nurseries, and generally crops were as good as the nursery standard, although prototype 2 was not quite as good in pot herb production. There were some slight differences in performance between the prototypes, with prototypes 1 and 3 working particularly well in pack bedding production, and prototype 3 working well in pot herb production. The trials are beginning to show that the choice of growing media blends are going to be crop specific. The results shown in the experimental trials in 2016 were reflected quite nicely in the grower trials in 2017, which shows that the modelling approach taken for the first set of prototypes, to try and emulate peat, was a useful place to start. It has been shown that by taking a set of materials with a certain set of physical properties that are similar to those of peat, it is possible to grow plants in a range of crop sectors, and produce high quality plants.

Second generation prototype blend testing – "pre-campaign" selection for 2018 grower hosted trials

Following on from the prototype blend mixing experiment described in **WP2**, a greater selection of blends were selected for use in experimental trials in 2017. In total, 18 blends were tested against a 100% peat control. Blends comprised either two or three components, in selected ratios, as well as 100% of each raw material (**Appendix 4**). These blends, plus the peat control, were tested at ADAS Boxworth in 2017 on various plant subjects, to determine their suitability for use on grower holdings in the subsequent year.

The trials at ADAS Boxworth were irrigated and liquid fed using a bespoke Priva system using a range of water delivery systems. Due to the larger number of treatments, only one irrigation and feeding regime was used. Plants were irrigated as required, and a feed mix of 100 ppm nitrogen (N) was used (**Appendix 4**).

Protected Ornamentals – Bedding

The trial was conducted in the polytunnel testing facility at ADAS Boxworth using Pansy Karma Blue Sun. Plug plants were supplied by Newey Roundstone (Chichester, PO20 1LL) in week 33, and were transplanted into 10-pack bedding plant trays filled with the relevant growing media in week 34 (21 August 2017). All growing media tested in the trial had a base dressing of lime, wetter (H2Gro) and fertilizer (14:16:18 NPK) added at a rate of 0.5 g/L.

One bench was used for this trial, which 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 other sections and the bench itself was covered in capillary matting with micro-perforated plastic film on top (**Figure 21**).

Figure 21. Polytunnel set up with pansy on one bench section separated by Perspex sheeting. Plants were watered overhead by sprinklers.

Plants were irrigated and liquid fed overhead via mist sprinkler using the Priva irrigation system. Once the plants reached maturity (week 40, 02 October) all were assessed for quality (scale of 0-5), plant height, numbers of plants in flower per pack and root quality score (scale of 0-4). For scoring criteria see **Appendix 5**.

Plants first started flowering on 15 September 2017. The peat control and treatments 4, 8, 9, 11 and 15 all started to flower at this time. By the end of the trial (02 October) there was a significant difference in the number of plants in a pack in flower (p <0.001), with the peat control and treatments 4, 7, 14 and 15 not significantly different in the number in flower (**Figure 22**). The poorest incidence of flowering were in treatments 9, 12 and 17 with three or less plants in flower per pack.

Figure 22. Peat control (left) and treatment 15 (right) in flower in the pack at the end of the trial (02 October 2017).

There was a significant difference in the height of the plants grown in the different growing media treatments (p <0.001). The peat control produced the tallest plants (**Figure 23**), however, heights of pansies grown in treatment 15 were not significantly different to the peat control, both reaching heights of over 55 mm on average. The smallest plants were in treatments 2, 4, 9, 10, 11 and 19, which were all below 35 mm on average.

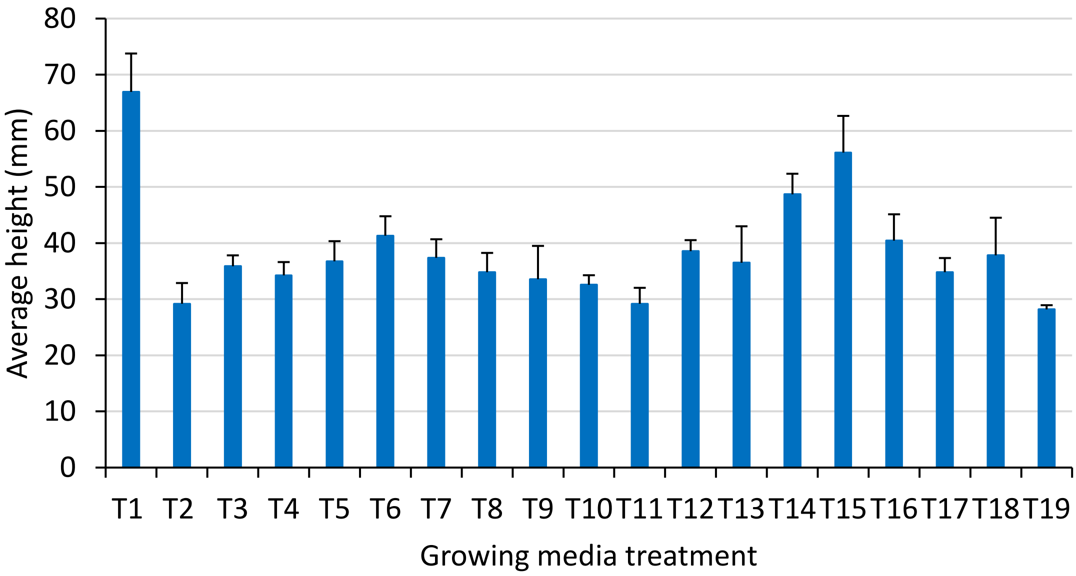


Figure 23. Average height of pansies grown in different growing media blends. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

Plant quality varied significantly across the growing media treatments (p <0.001), with treatments 2, 17 and 19 all scoring poorly at 2.5 or less. Treatments 14, 15 and the peat control all scored 4.5 or above and all produced high quality saleable plants.

The quality of the rooting in the plants was significantly different across the growing media treatments ($p < 0.001$). Treatment 15 produced the plants with the largest amount of roots, which was significantly higher than the peat control (**Figure 24**). Other treatments that also produced good rooting were 13 and 14. The poorest rooting was found in treatments 6, 17, 18 and 19.

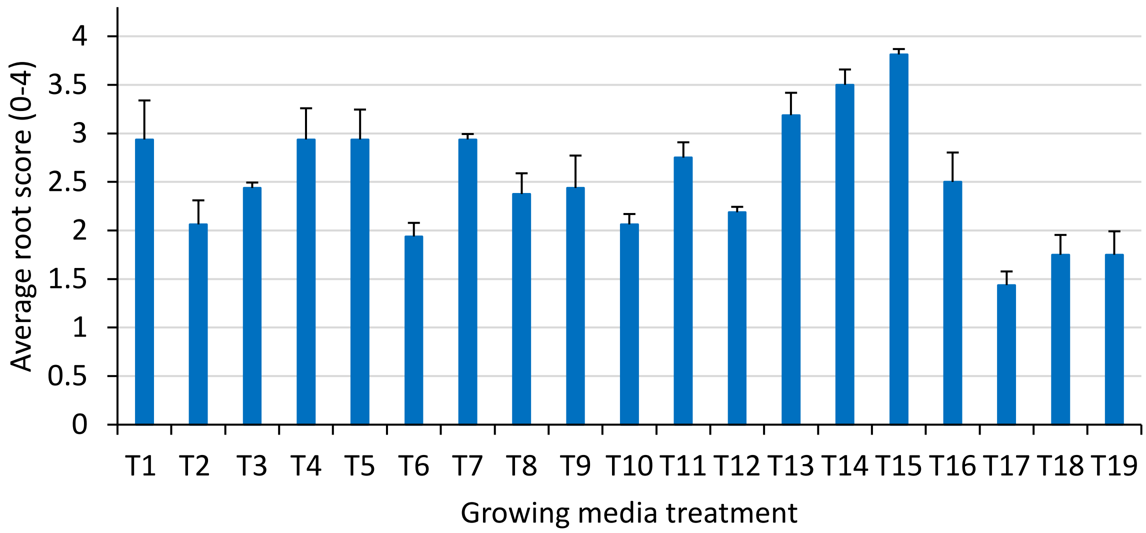


Figure 24. Average root score (0-4) of pansies grown in different growing media blends. Differences across treatments are statistically significant ($p < 0.001$). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

There were significant differences in the performance of the growing media blends tested in the bedding plant trial. The pansy performance showed that there was a large spread of growing media blends that worked equally well, with a few blends that were better.

The quality of the pansy plants was good across seven treatments, one of which was the peat control. After peat the two best performing blends were treatments 14 and 15, with treatment 15 producing the second tallest plants. The rooting in these seven well performing blends was best in treatments 13, 14 and 15.

The pansy plants tested seemed to be most sensitive to some of the blends which were 100% of a single raw material. These blends generally produced small plants with poor rooting and of unmarketable quality. It is likely that the physical characteristics of these blends are too extreme to work well for bedding plants.

The results show that no single blend outperformed the rest, but that a range of blends with different components can be used to get similar growth in the pansy species tested. All data will be fed into the growing media model to best select the blends to be taken forward into grower trials in 2018.

Hardy Nursery Stock

Liner plants of Choisya, Lavender and Vinca were supplied by Darby Nursery Stock (Thetford, IP26 4PW) in week 30 (28 July 2017), and were potted into 2 L pots filled with the relevant growing media in week 31 (31 July 2017) (**Figure 25**). All growing media tested in the trial had a base dressing of lime, wetter (H2Gro) and fertilizer (14:16:18 NPK) added at a rate of 0.5 g/L. The trial was conducted on two ebb and flood benches, and the plants were irrigated once per day to begin with, and then 2-3 times per week as the weather cooled.

Figure 25. Polytunnel set up with Lavender and *Choisya* on one bench section separated by Perspex sheeting. Plants were watered overhead by ebb and flood.

The HNS plants were monitored for pest, disease and nutritional issues during the trial. The plants were assessed at four week intervals during the trial, with a final assessment in week 47 once the plants reached marketable size.

The *Choisya* and Lavender plants were assessed for quality (scale of 0-5), plant height and root quality score (scale of 0-4). The Vinca were assessed for pot cover rather than height, however the quality and root assessments remained the same as for the other species. For scoring criteria see **Appendix 6**.

Choisya

The height of the *Choisya* was significantly different at the 4 week assessment date (p= 0.009), with plants grown in treatments 2 and 17 being significantly smaller than the peat control (T1), 4, 15, 18 and 19. Throughout the trial treatment 17 remained the smallest plants, with the differences across all treatments becoming more pronounced at the 16 week assessment (p <0.001; **Figure 26**). The tallest plants were those grown in the peat control (T1), 13 and 15 and a further six treatments produced plants that were not significantly different in height to these (4, 6, 11, 12, 18 and 19).

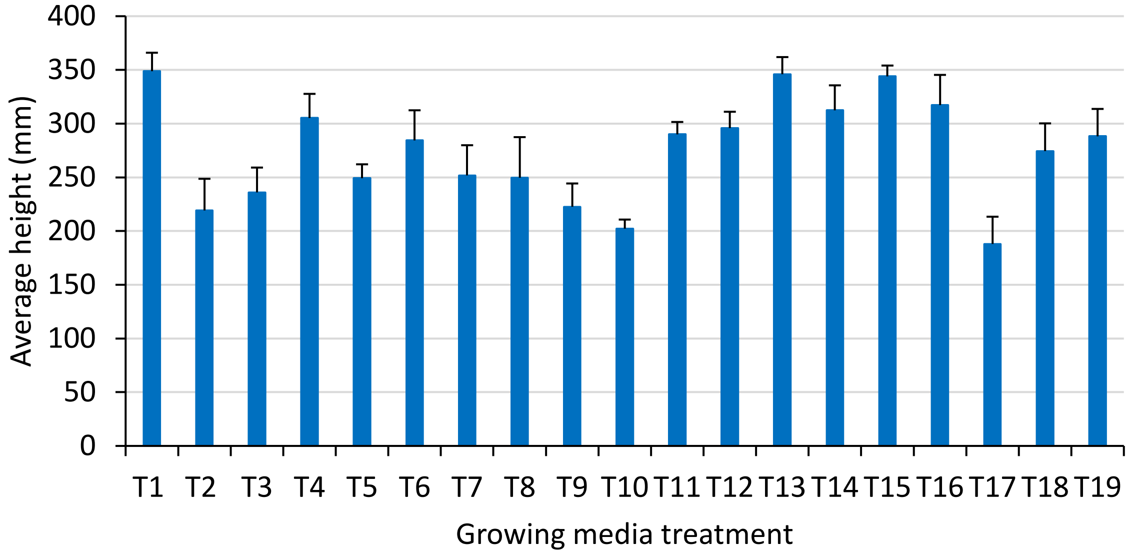


Figure 26. Average height of *Choisya* grown in different growing media blends 16 weeks after potting. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

Choisya quality was not initially different across the treatments, however, by the 16 week assessment there were significant differences in quality (p = 0.009). Treatments 8, 9, 10 and 17 all performed poorly with scores of less than 2.5 on average. Treatment 16 performed the best with an average score of 4. This treatment was not significantly different to the peat control or treatments 4, 5, 13 or 14.

The quality of the rooting in the plants was significantly different across the growing media treatments 16 weeks after potting (p <0.001; **Figure 27**). Treatments 7 and 14 produced the plants with the largest amount of roots, with up to 75% root coverage. Other treatments that also produced good rooting were the peat control, 4 and 13. The poorest rooting was found in treatments 9 and 17, which had almost no rooting in the pot at the final assessment.

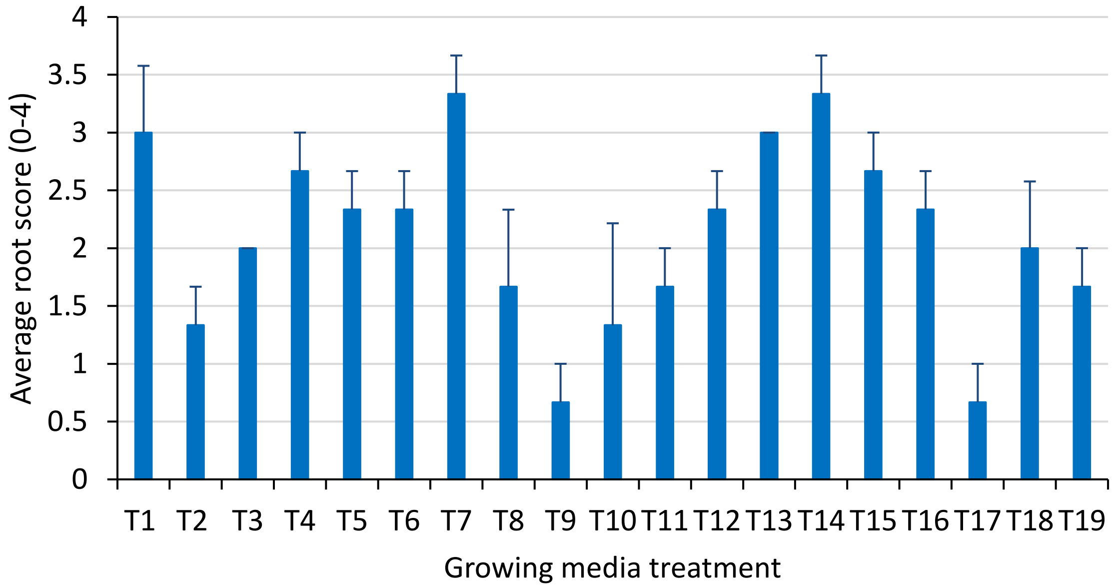


Figure 27. Average root score (0-4) of Choisya grown in different growing media blends at 16 weeks after potting. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

Vinca

The pot cover of the *Vinca* was significantly different at the 4 week assessment date (p = 0.003), with plants grown in treatment 7, 8 and 11 covering less than 50% of the pot. This is in contrast to the peat control (T1), 12, 13, 15 and 16, which had all achieved over 65 % coverage after 4 weeks.

During the trial treatments 7 and 8 remained the plants with the lowest pot coverage and this did not increase across the 16 weeks. There was a significant difference across all treatments at the final assessment (p <0.001). The plants that reached an average cover of 70% or over were those grown in the peat control (T1), 12, 14, 15 and 19.

The quality of the *Vinca* was significantly different at each of the assessment dates and by week 16 weeks after initial potting the differences had become most pronounced (p <0.001). At the 16 week assessment treatments 7 and 8 had performed poorly with scores of less than 2.5 on average (**Figure 28**). The peat control had the highest quality score with an average of 4, however, this treatment was not significantly different to six other treatments (12, 13, 14, 15, 17 and 19) which all scored over 3.5 on average.

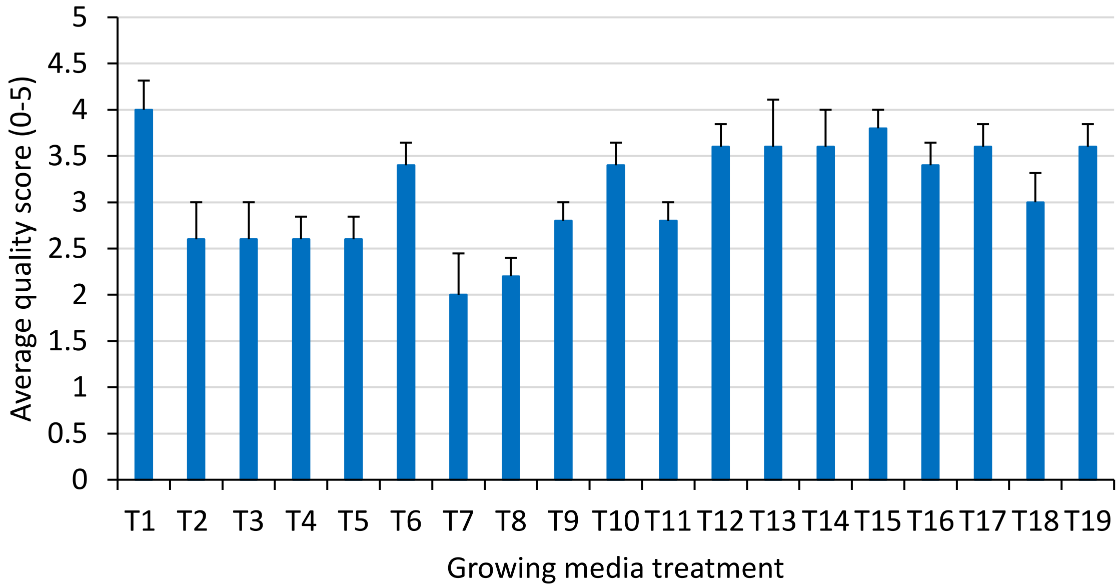


Figure 28. Average *Vinca* quality (scored 0-5) in different growing media blends 16 weeks after potting. Differences across treatments are statistically significant (p =.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

The quality of the rooting in the plants was significantly different across the growing media treatments 16 weeks after potting (p = 0.023). The majority of treatments had good rooting, however treatments 8 and 11 had significantly poorer rooting compared to the best rooting plants. Seven treatments (5, 6, 9, 10, 13, 14 and 16) scored the highest possible rooting score of 4, meaning that there was 76 to 100% coverage in these treatments.

Lavender

There was no significant difference in the quality of the Lavender plants throughout the trial. There were plant deaths noted at the later assessment dates which were not a reflection of the growing media performance. It is likely that some of the blends remained too wet, and due to the cooling temperatures, were not able to dry back enough. The height data from the initial assessments is presented below to give a fairer indication of plant performance in the growing media blends.

The height of the Lavender was significantly different at both the 4 and 8 week assessments (p = 0.001 and p= 0.041 respectively). The plants grew better in the peat control (T1), 2 and 7 (**Figure 29**). The smallest plants were in treatments 11 and 17, with plants struggling particularly in the latter growing media.

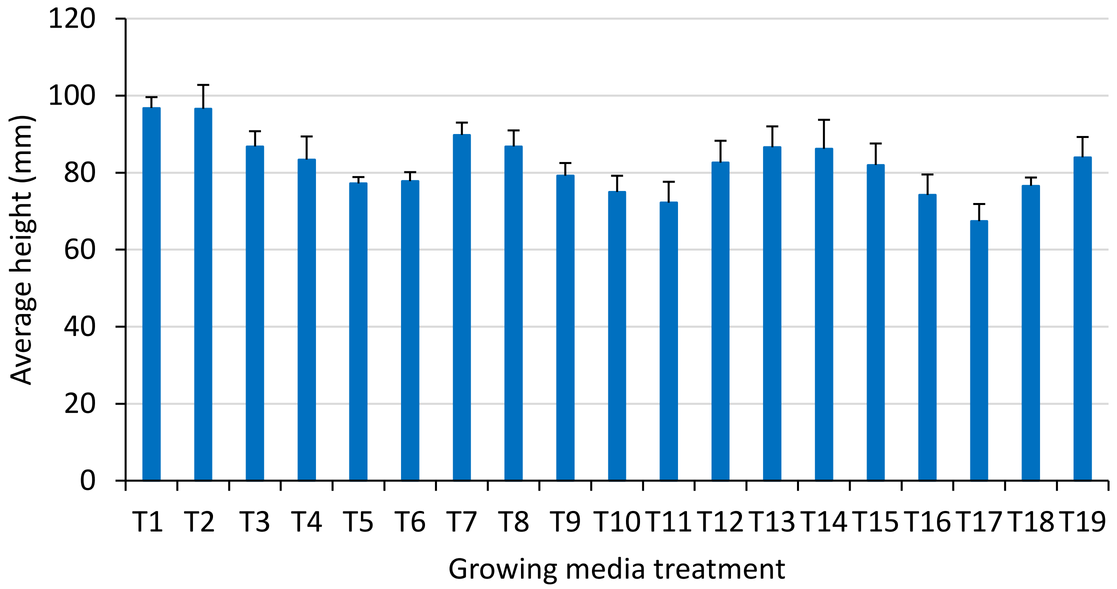


Figure 29. Average plant height of Lavender grown in different growing media blends 8 weeks after potting. Differences across treatments are statistically significant (p = 0.041). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

The hardy nursery stock species tested in this trial reacted differently to the growing media blends that were used. There was some overlap in the best performing blends between the *Choisya* and the *Vinca*, though the poorest performing blends were different for the two species.

In the *Choisya*, there were six blends that significantly outperformed the poorest mixes in terms of quality. Treatment 15 produced the tallest plants, however this did not lead to the highest quality plants. The highest quality plants were grown in treatment 16, although these were not significantly better than the other five treatments (1, 4, 5, 13 and 14). Of these blends the highest rooting scores were given to treatments 4, 13 and 14. Overall the consistently poorest quality *Choisya* plants were those grown in treatment 17, producing the smallest plants, with the lowest quality and poorest rooting. It is likely that a high water holding capacity and low air filled porosity in this blend would be unfavourable to the *Choisya* plants.

Treatment 17 performed better in the Vinca plants than in the *Choisya*, which is likely to be due to this species being more tolerant of a range of conditions. In these plants, the poorest performing growing media blends were treatments 7 and 8. The latter having the lowest pot cover, low pot rooting and overall poor quality. At the 16 week assessment there were six blends that performed well (1, 12, 13, 14, 15 and 19).

As with the *Choisya*, treatment 13 performed well in all of the assessments, producing good quality plants, with one of the best pot coverages and rooting.

The results show that no single blend outperformed the rest, but that a range of blends with different components can be used to get similar growth in the hardy nursery stock species tested. Although there were similarities at the high performance end for the species there were difference at the poor end due to the different tolerances of the plants tested. All data will be fed into the growing media model to best select the blends to be taken forward into grower trials in 2018.

Vegetable propagation

The conditions required to germinate and grow cabbage seed are tightly defined in commercial practice. The trial was therefore carried out at Delfland Nurseries Limited (Cambridgeshire, PE15 0TU) in early 2018. Two species of cabbage were used for this trial; Spring cabbage 'Caraflex' and Chinese cabbage 'Kaboko', which were sown into 345 trays. The trays were split into quarters and each quarter was filled with a different growing media. A total of 40 trays (20 per species) were filled with growing media by hand in week 5 (01 February 2018) and sown by machine at the nursery in week 6 (06 February 2018). The trays were covered with vermiculite, placed in the germination room and covered with plastic for two days. The trays were removed on 08 February 2018 and set down in separate areas of the nursery, with the Chinese cabbage under warmer glass and the Spring cabbage under cooler glass. The trays were set down on pots to allow for aeration of the roots, and to prevent rooting through, which would result in a loss of growth control (**Figure 30**). The trial was watered overhead by hand, as and when required.

Figure 30. Chinese cabbage set out on concrete (left) and Spring cabbage set out on mypex matting (right), both under glass, at Delfland Nursery, February 2018.

Chinese Cabbage

Germination occurred one week after the seeds were sown, and the plots were assessed in week 7 when the plants were at cotyledon stage. There was no significant difference in the percentage of germination across the plots. Germination in the peat control was 97%, and the lowest germination was seen in T17, with 90% germination.

Marketability assessments were carried out in week 10 when the plants were at the transplanting stage. Plant quality was significantly different across treatments ($p < 0.001$), with treatments 3, 5, 6, 7, 8 and 11 all significantly different to the control, which scored 3.0. However, these treatments all scored between 2.0 and 2.25, which meant they were still suitable for transplant. Treatments 12-18 inclusive all scored 3.0, along with the peat control.

The height of the Chinese cabbage was significantly different across the treatments (p = <.001). The smallest plants were produced in treatment 5 (37.45 mm) and the largest plants were produced in the peat control (64.65 mm) (**Figure 31**). Treatments 13-16 inclusive were a similar height to the control, all other treatments were significantly smaller.

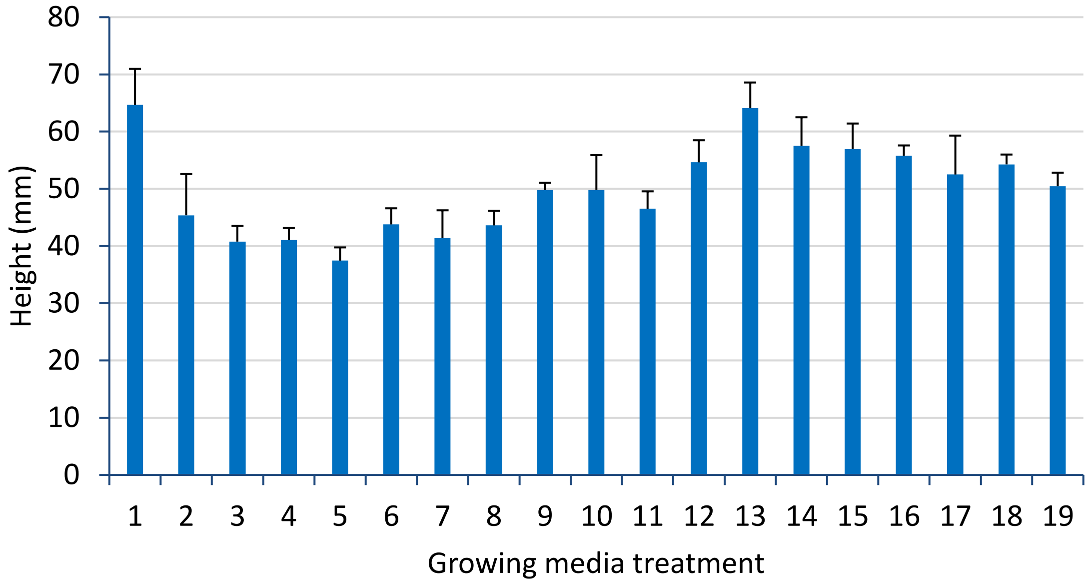


Figure 31. Average height (mm) of Chinese cabbage grown in different growing media blends. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

The fresh and dry weights of the plants were significantly different across the growing media treatments (p = <0.001 for both measurements). The patterns in the plant weight reflect those seen in the height of the plants. The lightest plants were produced in treatment 3 (0.5 g per plant), whilst the heaviest plants were produced in treatment 13 (1.15 g per plant) (**Figure 32**). Treatments 10, 13, 14, 15, 16 and 18 were all similar to the control, all other treatments were significantly lighter than the peat control. The differences in overall plant growth between treatments 5, 13 and the control can be seen in **Figure 33**.

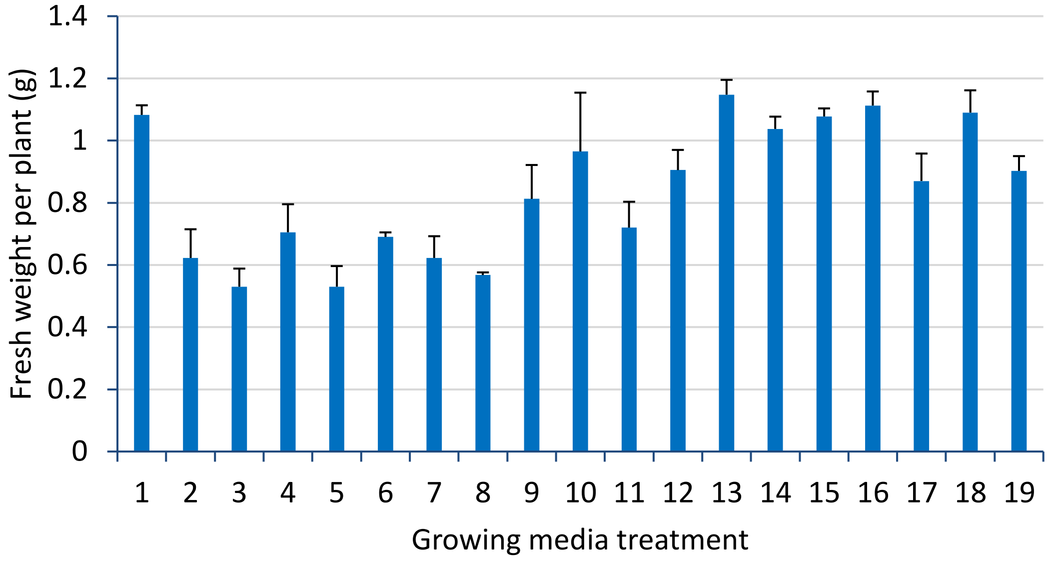


Figure 32. Average fresh weight (g) of Chinese cabbage grown in different growing media blends. Differences across treatments are statistically significant (p <.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

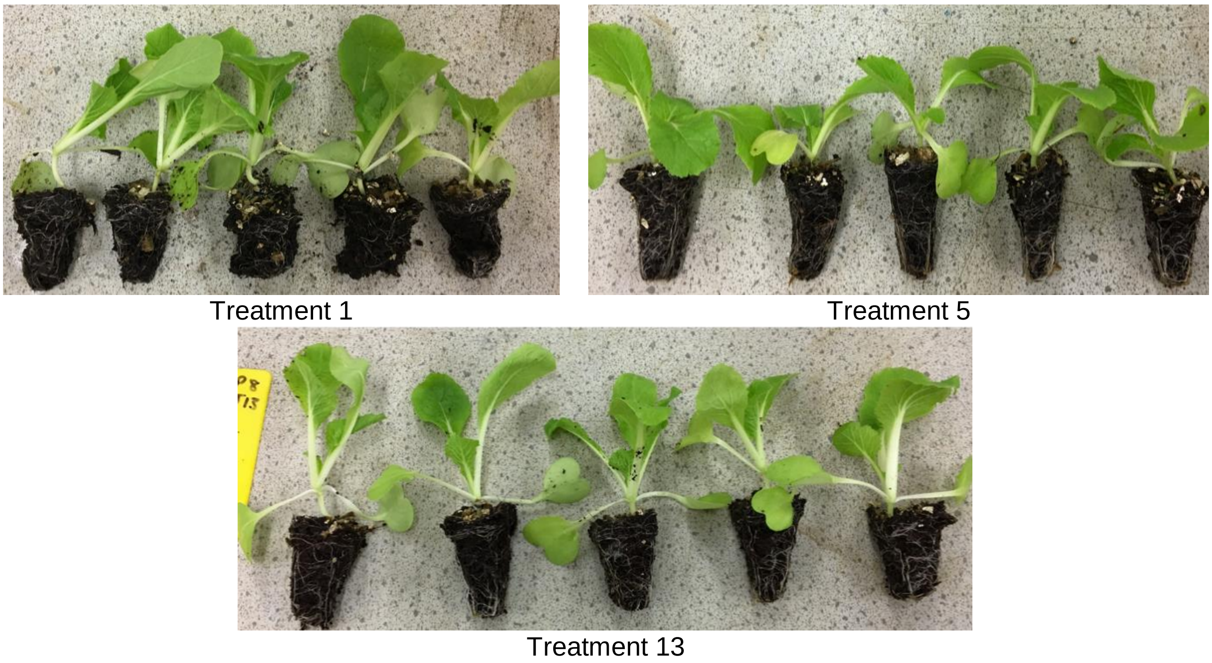


Figure 33. Differences in growth of Chinese cabbage seen in week 10, 2018, in treatment 1 (top left), treatment 5 (top right) and treatment 13 (bottom).

Spring Cabbage

Germination occurred two weeks after the seeds were sown, and the plots were assessed in week 10 when the plants were at cotyledon stage. There was a significant difference in the percentage of germination across the plots (p <0.001), with T17 significantly lower than the peat control and all other treatments. Germination for this treatment was 83% compared to 94% for the control.

Marketability assessments were carried out in week 15 when the plants were at the transplanting stage. Plant quality was significantly different across treatments (p <.001), with the majority of treatments scoring lower than the peat control, which scored 3.0. However, 12 of these treatments scored above 2.0, which meant they were still suitable for transplant (T7, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18, and

T19). The lowest scoring treatment was T2, which scored 1.0. Treatments 12, 14 and 16 were not significantly different to the peat control.

Plant height was significantly different across treatments (p <.001). The tallest plants were seen in T16 (78.42 mm), this was not significantly different to the control (73.30 mm) or blends 12 or 14. The smallest plants were seen in treatments 2 and 4 (**Figure 34**).

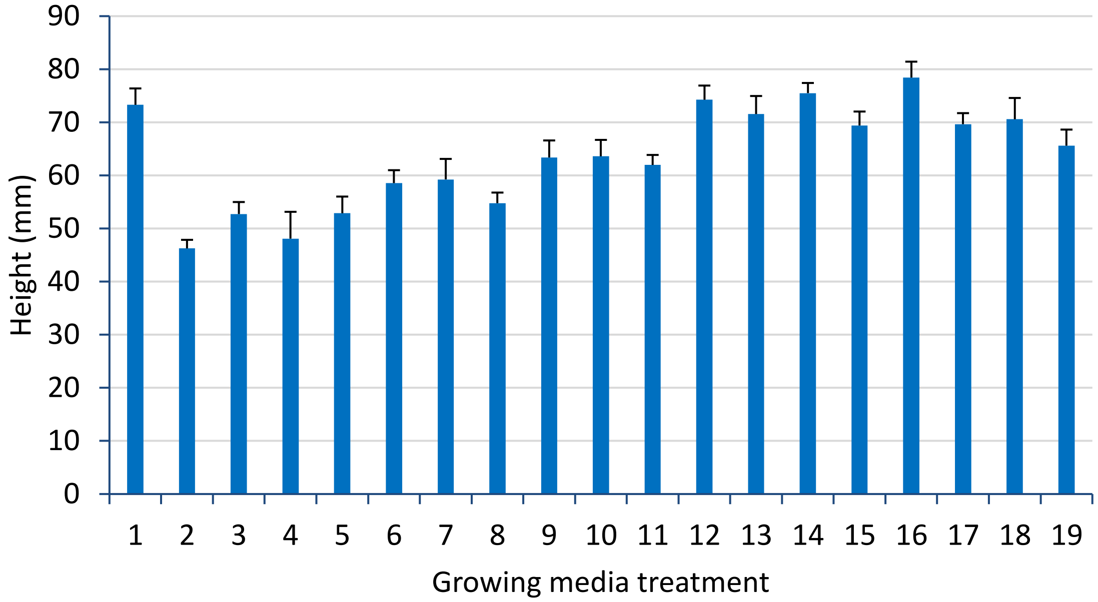


Figure 34. Average height (mm) of Spring cabbage plants grown in different growing media blends. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

There were significant differences in the fresh (p <0.001) and dry weight (p <0.001) of the Spring cabbage plants. The highest fresh weight was seen in treatment 16 (0.62 g per plant), this was significantly greater than the control (0.53 g per plant). Treatments 12, 14, 17 and 18 were also greater than the control, although not significantly. The lowest fresh weight was seen in T2 (0.19 g per plant). Treatments 2-11 inclusive and T19 were all significantly lighter than the control (**Figure 35**).

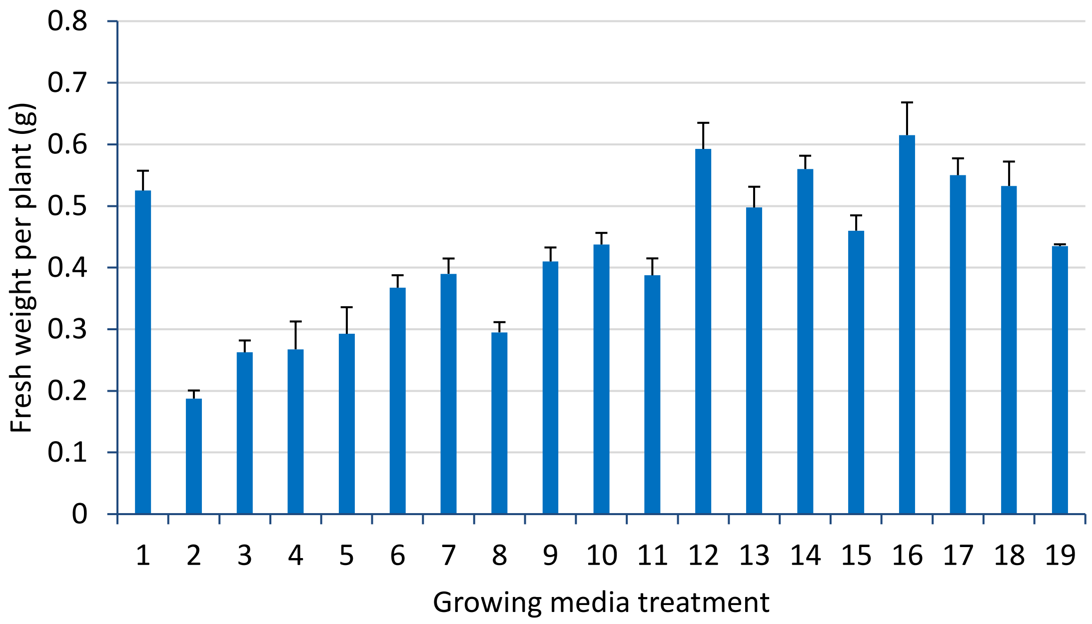


Figure 35. Average fresh weight (g) of Spring cabbage plants grown in different growing media blends. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).

The dry weight of the Spring cabbage showed a similar pattern in the most and least successful treatments. Treatment 16 had the highest dry weight of any treatment, and treatment 2 was still the lowest (**Figure 36**). The differences in overall plant growth between treatments 2, 16 and the control can be seen in **Figure 37**.

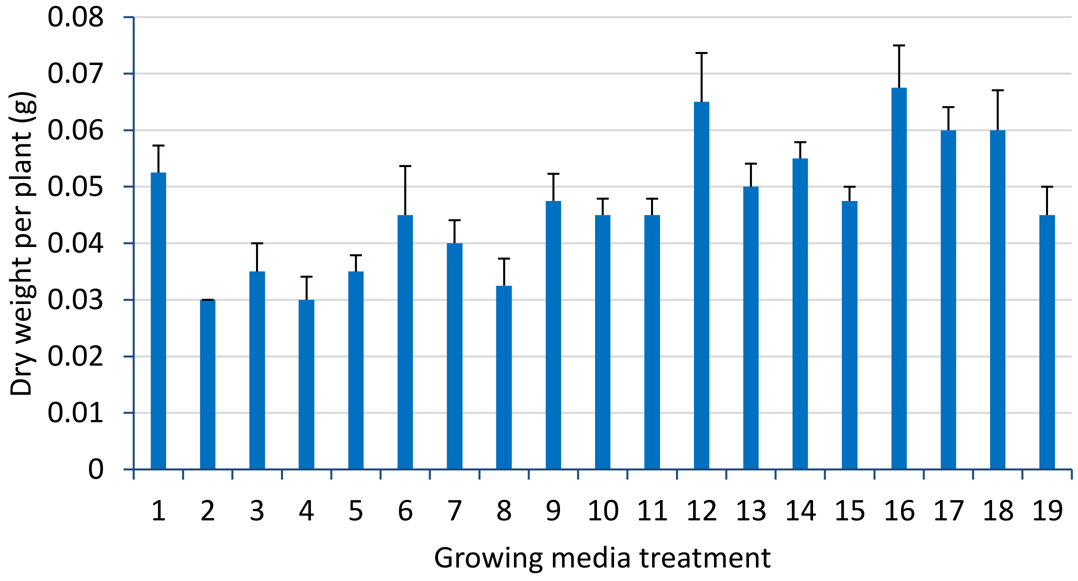
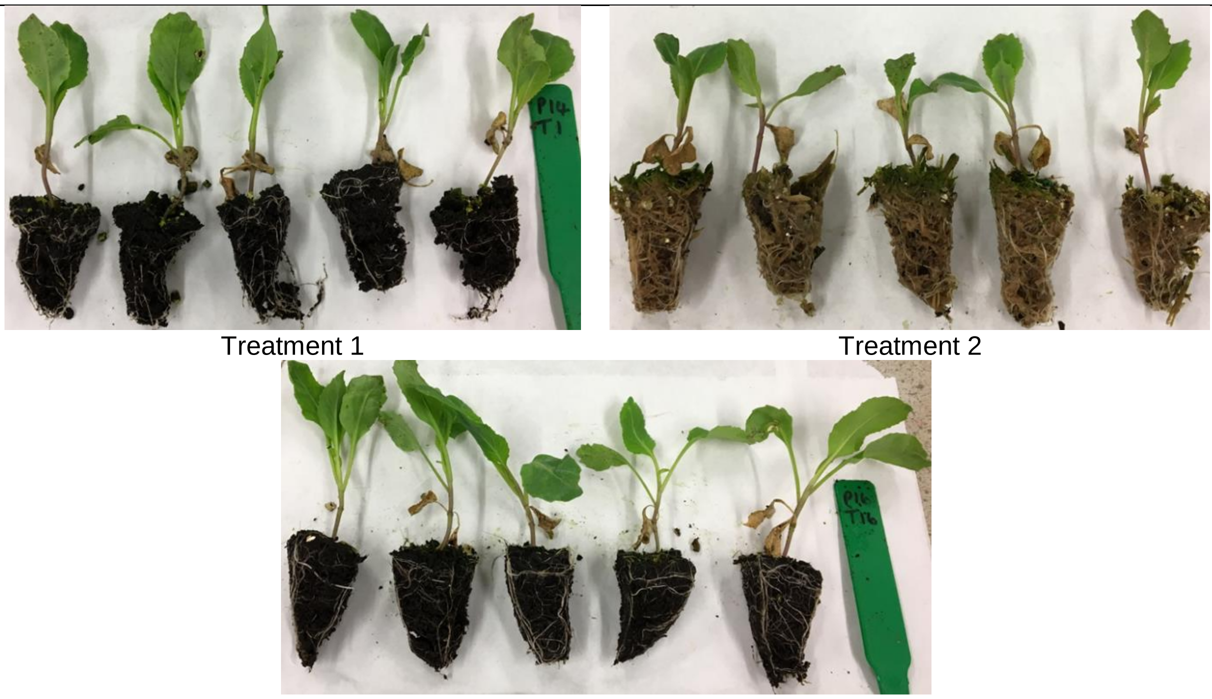


Figure 36. Average dry weight (g) of Spring cabbage grown in different growing media blends. Differences across treatments are statistically significant (p <0.001). Error bars represent 1 standard error, with 18 degrees of freedom (d.f.).



Treatment 1 Treatment 2

Treatment 16

Figure 37. Differences in growth of Spring cabbage seen in week 15, 2018, in treatment 1 (top left), treatment 2 (top right) and treatment 16 (bottom).

Overall the results show that germination was excellent (>90%) in all treatments for Chinese cabbage, and only one treatment gave a significantly lower result for the Spring cabbage germination. Significant differences were found in all assessment criteria for both cabbage species, although there wasn't one particular blend which outshone the rest. Instead, a range of blends with different components gave similar results.

Conclusions

Selected blends comprising different materials showed comparable growth related to the control. More specifically, treatments 14 and 15 performed well across the different plant types tested, and treatments 8 and 17 under-performed. Whilst the work reported is experimental and designed for model development, it has become clear however, that growing media blend selection for trials on grower sites will be crop specific, due to the different needs of the various plant types. Growing media blend selection is currently underway for 2018, and these blends will be selected by plant performance. Based on the findings from the 2017 testing, there is clearly scope for some of the blends to be taken to grower sites in 2018 for commercial trials.

WP4: Workshop and knowledge exchange events

Knowledge exchange is an integral part of CP138, as important messages from the project need to be communicated to growers and the industry. With **WP1** complete, and **WP2** and **3** well underway, 2017 was an effective time to communicate the output and progress of CP138 to the industry by 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 5**.

Table 5. 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	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 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.

In 2017, the project team attended six industry events and hosted four standalone workshops. The industry events were; Herbaceous Perennial Technical Discussion Group meeting, Bedding and Pot Plant Centre (BPPC) Open Evening (ornamentals), G's NIAB Leafy Salads Open Day (salad propagation), Portland Oregon ISHS symposium, British Herbs Field Day (herbs) and Total Food Norwich. At the ornamentals, salad propagation and herbs events, trial plants were demonstrated, along with growing media blends and raw materials, handouts and a project poster. Presentations were given at all events apart from the British Herbs Field Day. All events were very well attended, and overall, approximately 350 growers and industry representatives were spoken to and informed of the project across the six events.

Independent workshops were held at New Farm Produce, Vitacress Herbs, F P Matthews and Lowaters Nursery, and gave attendees the opportunity to view trials in progress. The events were well received, and attended by a total of 120 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 will be added to as the project progresses and will be 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 10 December 2017, the RSGM twitter account has 138 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 **690** members of the horticulture sector. As the project progresses, the number of attendees at workshops has grown, and the project is viewed by many as an important step in moving towards more responsibly sourced growing media in UK horticulture.

Financial benefits

- At this stage the financial benefits of the work cannot be clearly defined.

Action points

- At this stage of the project there are no action points for growers.

Exploitation

- Publication of a technical monograph: Mulholland BJ, Waldron K, Bragg N, Newman S, Tapp H, Hickinbotham R, Moates G, Smith J, Kavanagh A, Marshall A, Whiteside C, Kingston H (2016) Technical Monograph: Growing Media Laboratory Methods. ISBN 978-1-5262-0393-9, 25 pp. (**WP1**).
- Knowledge transfer events and publications promoting and highlighting excellence in growing media development and use. See above **Table 5**; **WP4** for details of activities.

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	31/3/17	Yes	Completed in full and on time
12	Tasks 1.1-1.3 **M12** Create database of growing media	31/3/17	Yes	Completed in full and on time
13-28	All tasks on schedule to complete	30/10/19	Ongoing	On schedule to complete
29-30	All tasks on schedule to complete	31/12/19	Ongoing	On schedule to complete

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

Ivan Ambrose Bedding

Table 1a. The four treatments used in both bedding plant trials.

Treatment number	Growing media blend
1	Nursery Peat-reduced standard
2	Prototype 1
3	Prototype 2
4	Prototype 3

Table 1b. List of scores and definitions used to assess overall plant quality for marketability.

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

Table 1c. 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

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

Trt No.	Product
1	Nursery control
2	Prototype 1
3	Prototype 2
4	Prototype 3

Figure 1a. Trial plan for bedding plants set out on the floor under glass (Ivan Ambrose).

Appendix 2
Lincolnshire Herbs

Table 2a. The four treatments used in each herb trial.

Treatment number	Growing media blend
1	Nursery Peat-reduced standard
2	Prototype 1
3	Prototype 2
4	Prototype 3

Table 2b. List of scores and definitions used to assess overall plant quality for marketability.

Score	Definition
1	Obvious quality issues not suitable for dispatch
2	Very minor quality issues OK for dispatch
3	Perfect no quality issues

	Benches with commercial crop									
Block	1	1	2	2	3	3	4	4	5	5
Plot	1	2	5	6	9	10	13	14	17	18
Treatment	**4**	**2**	**1**	**3**	**2**	**1**	**3**	**4**	**2**	**3**
Block	1	1	2	2	3	3	4	4	5	5
Plot	3	4	7	8	11	12	15	16	19	20
Treatment	**1**	**3**	**4**	**2**	**4**	**3**	**1**	**2**	**1**	**4**
	Benches with commercial crop									

Trt No.	Product
1	Nursery control
2	Prototype 1
3	Prototype 2
4	Prototype 3

Figure 2a. Trial plan for pot herbs set out on a gutter system (Lincolnshire Herbs).

Appendix 3

G's Growers Mushrooms

Table 3a. The eight treatments used in the mushroom trial.

Treatment number	Growing media blend
1	Nursery 100% Peat standard
2	60% peat, 40% Prototype 1
3	60% peat, 40% Prototype 2
4	60% peat, 40% Prototype 3
5	60% peat, 40% digestate
6	100% Prototype 1
7	100% Prototype 2
8	100% Prototype 3

P1 T3	P3 T1	P5 T7	P7 T2	P9 T7	P11 T4	P13 T8	P15 T2	P17 T4	P19 T1	P21 T8	P23 T7	P25 T2	P27 T8	P29 T6	P31 T4
P2 T5	P4 T8	P6 T4	P8 T6	P10 T3	P12 T6	P14 T5	P16 T1	P18 T6	P20 T3	P22 T5	P24 T2	P26 T1	P28 T3	P30 T7	P32 T5

Treatment No.	Growing media blend
1	Nursery control
2	60% peat, 40% Prototype 1
3	60% peat, 40% Prototype 2
4	60% peat, 40% Prototype 3
5	60% peat, 40% digestate
6	100% Prototype 1
7	100% Prototype 2
8	100% Prototype 3

Figure 3a. Trial plan for mushrooms set out on a bench within a tunnel (G's Growers).

Appendix 4
Experimental trials

Table 4a. Experimental treatment list for the prototype blend trials.

Treatment no.	Growing media blend	Irrigation treatment	Target N concentration
1	Blend 1 - Peat control	Low	100 ppm N
2	Blend 2	Low	100 ppm N
3	Blend 3	Low	100 ppm N
4	Blend 4	Low	100 ppm N
5	Blend 5	Low	100 ppm N
6	Blend 6	Low	100 ppm N
7	Blend 7	Low	100 ppm N
8	Blend 8	Low	100 ppm N
9	Blend 9	Low	100 ppm N
10	Blend 10	Low	100 ppm N
11	Blend 11	Low	100 ppm N
12	Blend 12	Low	100 ppm N
13	Blend 13	Low	100 ppm N
14	Blend 14	Low	100 ppm N
15	Blend 15	Low	100 ppm N
16	Blend 16	Low	100 ppm N
17	Blend 17	Low	100 ppm N
18	Blend 18	Low	100 ppm N
19	Blend 19	Low	100 ppm N

Table 4b. Levels of nutrients delivered to the trial when fertilizers 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 5
Experimental bedding trial

Table 5a. 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 5b. 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

Appendix 6
Experimental HNS trial

Table 6a. List of scores and definitions used to assess overall plant quality at the end of the trial.

Score	Definition
0	Dead
1	Very poor quality, yellowing foliage
2	Uneven growth / small, poor architecture
3	Height slightly uneven, healthy foliage
4	Even growth, healthy foliage, some new growth
5	Excellent quality, healthy foliage, plenty of new growth

Table 6b. 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

Appendix 7
Experimental Vegetable propagation trial

Table 7a. List of scores and definitions used to assess overall crop quality at the end of the trial.

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

Table 7b. 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 cell
2	Rooting in 26 – 50% of cell
3	Rooting in 51 – 75% of cell
4	Rooting in 76 – 100% of cell

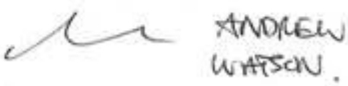
Declaration

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	21/12/2017

Name	Professor Keith Waldron
Position	Project lead and Director, Norwich Research Park Biorefinery Centre
Organisation	Quadram Institute Bioscience
Signature	
Date	21/12/2017

Statistical analyses authorised by:

Name	Andrew Watson
Position	Institute Statistician
Organisation	Quadram Institute Bioscience
Signature	
Date	21/12/2017

Report authorised by:

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

Signature	
Date	21/12/2017

Name	Click here to enter text.
Position	Click here to enter text.
Organisation	Click here to enter text.
Signature	Click here to enter text.
Date	Click here to enter a date.