Horticultural Fellowship Awards

Interim Report Form

Project title:	Sustainable resource use in horticulture: a systems approach to delivering high quality plants grown in sustainable substrates, with efficient water use and novel nutrient sources
Project number:	CP 095
Project leader:	Dr Paul Alexander, The Royal Horticultural Society (RHS).
Report:	Annual Report, June 2014
Previous report:	Annual Report, June 2013
Fellowship staff:	Dr Paul Alexander, Principal Horticultural Scientist, RHS, Wisley (Project leader/mentor) Rachael Tanner, Research Assistant, RHS Wisley (Technical Support) Dr John David, Chief Scientist, RHS Wisley (Project sponsor) Dr Steve Robinson (Senior lecturer, The University of Reading (Academic Mentor)
(“Trainees”)	Dr Gracie Barrett (Fellowship trainee, horticultural scientist)
Location of project:	RHS Garden Wisley

Industry Representative: Neil Bragg

Date project commenced: 13 November 2013

Date project completed (or expected completion date): 13 November 2017

DISCLAIMER

AUTHENTICATION

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

Paul Alexander

Project Leader

RHS

Signature .... Date 28/06/2013..................................

[Name]

[Position]

[Organisation]

Signature .... Date ....

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[Name]

[Position]

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Signature .... Date ....

[Name]

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[Organisation]

Signature .... Date ....

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Progress Against Objectives

Summary of Progress

The fellowship project commenced in November 2012 rather than July 2012 so this interim report covers the first 18 months of work. In the year since the last report, two experiments have been completed and a third is now underway. These are described in the science section.

Objective 1: *Develop & initiate experiment focusing on efficient water delivery/use:* Our experience with proprietary growing media to date indicates that using them in experiments to examine water-use efficiency will be impractical. We have therefore decided to focus on developing our own peat-free and peat-reduced substrates in year 2 (Objective 1, year 3) in which we can minimise within batch variability and ensure consistent physical and chemical properties between experiments. We will then go on to explore water-use efficiency in these bespoke mixes in Year 3 (see section 5, future work). **Original completion date/revised completion date:** Sept. 2014/Sept 2015

Objective 2: *Deliver literature review of existing knowledge of nutrient sources. Publish if suitable:* As outlined in the year 1 report, the focus of the literature has been on growing media materials rather than novel nutrient sources. The literature review of growing media materials has been completed and write-up is now under-way. Work will continue over the next few months and a completed draft will be delivered winter 2014, with a view to publishing it as a peer reviewed paper. Dec. 2014/Dec. 2015

Objective 3: *Proposals for experiments in year 3 to explore nutrient provision, initially focusing on one substrate and then expanding into mixes of materials*: Proposals for year 3 will now be concerned with the impact of water-use efficiency in our own bespoke growing media mixes. These are summarised in the science section. Work on novel nutrient sources will commence in the second half of year 3 and year 4. Dec. 2014

Objective 4: *Development of methodologies to deliver experimental aims*: Methodologies have been developed both at Wisley and the UoR to characterise the physical, chemical and biological characteristics of growing media. These are on-going and are summarised in the science section. Dec. 2014

Objective 5: *Presenting information at grower/technical meetings/conferences. Exposure to talking to audiences*: A talk will be given to the HDC HNS panel in September 2014 outlining the rationale and findings of experiment 3. Further opportunities for talking at technical meetings will be sought as year 2 progresses. Nursery visits and attendance of relevant technical meetings has been on-going. July 2014/November 2014

Objective 6: *Present research findings to RHS Science committee, HDC studentship meeting and at appropriate staff seminars at UoR, EMR & RHS*: Data from experiment 1 has been presented at the HDC studentship meeting and at various RHS staff seminars. A well-received presentation was given to the RHS science committee in April. July 2014/November 2014

Objective 7: *Exposure to RHS shows, advisory support and experience of RHS press office*: The horticultural Scientist has worked in an advisory capacity at the RHS Hampton Court flower show and been involved in events at RHS Wisley to promote science and learning. This work will continue at the Hampton Court Flower show in July. September 2014

Objective 8: *Chair workshop for relevant UoR, EMR and RHS staff to identify research themes for collaboration*: It is anticipated that the work on irrigation in peat-free and peat-reduced substrates planned for Year 3 will provide the platform for this workshop (see section 5). As a result it is anticipated that this will take place early in the New Year 2015. July 2014/January 2015

Training undertaken

Training was undertaken at the UoR in the set-up and operation of an autoanalyser for the analysis of nitrate and ammonium in water extracts (for nitrogen draw-down determination, see section 3).

Expertise gained by trainees

The trainee is developing an understanding of:

a) The growing media industry, including the complexity of growing media itself

b) Plant growers, including the complexity of plant production and associated growing systems

Other achievements in the last year not originally in the objectives

The trainee horticultural scientist has been involved in the RHS drive to encourage more people to get engaged with horticultural science. This has involved helping to design and plan a stand at the RHS Hampton Court flower show in July. This stand will engage the public by allowing them to see into the ‘invisible garden’. It will contain interactive microscope exhibits where people can see the tiny life that inhabits their own gardens from bees to protozoa. The trainee has used existing skills and knowledge in microbiology to create exhibits and will help run the stand, be engaging with the public, improving communication skills and gaining confidence.

Changes to Project

Are the current objectives still appropriate for the Fellowship?

As highlighted in the summary section, there have been a couple of minor changes to the order in which we are going to address the fellowship objectives for Years 2 and 3.

SCIENCE SECTION – COMPLETED WORK

Introduction

In the last 20 years there has been an increasing drive by the UK government to move horticulture away from peat-containing growing media. This has presented a challenge for amateur and professional growers alike, as they strive to produce quality plant growth in peat-reduced and peat-free materials. For amateur gardeners in particular, the availability of peat-free growing media is limited and there are few guidelines for water and nutrient management in these materials. This is problematic because different peat-free growing media are based on various materials including coir, wood fibre or green waste compost. The physical and chemical properties of these materials vary widely, thus each growing media product is likely to behave differently under the same watering and feeding regime. For gardeners, matters are further complicated because off-the-shelf peat-free and peat-reduced media or 'multi-purpose composts' tend to vary widely in composition from batch to batch. This means that different bags of the same product can exhibit large differences in key properties such as nutrient content. This makes it challenging for gardeners to achieve consistent plant quality even within the same brand of peat-free or peat-reduced media.

Whilst the RHS has undertaken research into the management of water in a variety of growing media mixes (peat-reduced and peat-free), there has been a limited focus on plant nutrition. There are many basic questions which need to be addressed so that gardeners can be provided with basic information on fertiliser usage in peat-free media; Do fertilisers work equally well in growing media based on different materials? Does it matter whether fertilizers are based on organic or inorganic forms? Is there a need to vary the rate or type of feed in use depending on the material on which the growing media is based?

To start to address some of these questions, we have carried out two experiments using two brands of liquid fertilisers (an inorganic product and a product based on organic nutrient sources) with five different growing media products (based on coir, wood fibre, peat & green compost). The following aims have been addressed:

1. To determine how off-the shelf amateur growing media impact on plant quality when used alone or in combination with two different liquid feeds
2. To investigate the factors responsible for differences in plant quality between different media/feed combinations (Nutrient availability, media moisture retention ability etc.

Materials and methods

Experiment 1

The experiment was carried out at the RHS Field Research Facility (FRF) between February and July 2013. The experiment examined how combinations of widely available, proprietary multi-purpose media and fertilizer products impacted on the growth of *Pelargonium* 'Maverick Red'. Four multi-purpose 'composts' were purchased; these media were based on coir, green compost, wood fibre and peat. The physical and chemical properties of these media are summarised in table 1. With the exception of the peat based mixed (containing 70% peat) all mixes were peat-free.

			Total water soluble				
	pH	**EC**	**N**	**P**	**K**	**Cl**	**Dry BD**
		(µS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(g/cm^3)
Coir	6.97	500	113	18.6	405.4	565.5	0.13
Green Compost	7.23	321	77.8	37.4	372.8	284.4	0.20
70% Peat	5.37	598	389.4	57.4	158.4	19.9	0.11
Wood Fibre	5.40	517	72.6	86.7	551.2	74.7	0.12

Table 1 Summary of the physical and chemical properties of the 'Multi-purpose' compost products used in experiment 1 (Samples extracted using a 1:5 extraction ratio, ref BSEN 13652:2001). Analyses were carried out on one sample of well mixed product in each case.

Three different fertilizer treatments were then established; unfed (UF), inorganic fed (INO) and organic fed (O). The inorganic and organic fertilizers were off-the-shelf liquid products (see Appendix 1, Tables A & B for detail on nutrient content). These were diluted in 10 litres of water following the manufacturer's recommendations. A 300 ml volume of the diluted feed was then applied to each pot.

Pots were laid out on benches in a growth chamber in a fully randomised block design with 6 replicate plants per media x fertilizer treatment (4 media x 3 fertilizer treatments x 6 plant replicates = 72 pots). Conditions within the growth chamber were set to 18°C/12°C day/night and supplemental lighting was provided to ensure a minimum 12 hour day length. Plants were watered uniformly receiving measured volumes of either 250 or 500ml of water as required. Feeding commenced 5 weeks after the start of the experiment, with unfed (UF) plants receiving an equivalent volume of water at each feeding event. Plants were fed once every two weeks for the first 6 weeks and then weekly until the end of the experiment.

Plants were grown for 18 weeks and weekly measurements of growth index (height x widest spread x spread perpendicular to widest / 3) were taken. The experiment was then destructively harvested. At harvest shoot dry weights (oven dried for 48 hours at 70°C), flower counts and leaf area were measured as indicators of plant quality. A visual assessment was also carried out for each plant by 13 randomly selected members of RHS staff. Assessments were made on a 1 to 5 scale of quality with 1 representing poor quality 5 representing excellent quality (Figure 1).

Data from each set of 6 replicates were averaged and means are displayed ± the standard error (SE). Two-way Analysis of Variance (ANOVA) was performed using the factors growing media and fertilizer type to explore the impacts of the combination of media and fertilizer on plant quality.

Figure 1 The 1-5 scale used in the visual assessment of plant quality, with 1 representing poor quality (e.g. Stunted height/poor form, low flower count, pale colour/chlorosis) to 5 representing excellent quality (good height/regular form, good flower number, bright green/no chlorosis). A plant awarded a score of 3 or above was considered as being commercially marketable.

Experiment 2

The experiment took place in the RHS FRF between October and March 2014 and was designed to further investigate the interaction between growing media and fertilizer type observed in experiment 1. There were two objectives:

1. To further investigate the interaction observed in experiment 1 by using the same growing media and fertilizer combinations.
2. To better understand the possible drivers of this interaction by manipulating fertilizer application rates.

The experiment was set-up in a similar way to the first; the same 4 brands of multipurpose growing media were purchased from the same locations as previously. An additional 50% peat-reduced was also included (physical and chemical characteristics of these mixes as purchased are summarised in table 2).

			Total water soluble				
	pH	**EC**	**N**	**P**	**K**	**Cl**	**Dry BD**
		(µS/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(g/cm^3)
Coir	7.05	496	56	9.4	462.9	587.8	0.14
Green Compost	6.90	409	69.6	46.5	582.7	346.4	0.22
70% Peat	6.74	412	175.1	20.7	218.6	39.1	0.12
Wood Fibre	5.45	659	215.3	87	660.1	101.6	0.13
50% Peat	6.68	134	29.2	31.4	128.4	19.6	0.12

Table 2 Summary of the physical and chemical properties of the ‘Multi-purpose’ compost products used in experiment 2 (Samples extracted using a 1:5 extraction ratio, ref BSEN 13652:2001). Analyses were carried out on one sample of well mixed product in each case.

It was hoped this would further elucidate the interaction between organic fertilizer and peat-based media. The two ‘all-purpose’ liquid fertilizer products previously used in experiment 1and an ‘all-purpose’ controlled release fertilizer (CRF) were applied (see Appendix 1, Tables A & B for detail on nutrient content) in the following treatments:

1. Inorganic liquid Feed, standard rate (INO STAN): Applied at the manufacturer’s recommended rate

2. Organic liquid Feed, Standard rate (O STAN): Applied at the manufacturer's recommended rate
3. Inorganic liquid Feed, double rate (INO DOUB): Applied at double the inorganic standard rate.
4. Organic liquid Feed, double rate (O DOUB): Applied at double the organic standard rate.
5. Controlled Release Fertilizer (CRF): Applied at the manufacturer's recommended rate

Six uniform, 3cm plugs of *Pelargonium* 'Maverick Red' were potted into each of the 5 different growing media and pots were laid out in fully randomised blocks within the growth chamber (5 media treatments x 5 Fertilizer Treatments x 6 replicates = 150 pots). Treatment 5 was applied at potting; 2.5 g of 'all-purpose' CRF was added to each replicate pot and mixed thoroughly. Weekly liquid feeding (treatments 1 to 4) commenced 5 weeks after potting, liquid fertilizer products were diluted and applied as outlined in experiment 1. Treatments 3 and 4 (INO DOUB and O DOUB) were created by doubling the volume of liquid feed diluted in 10 litres of water. All four liquid (1-4) fertilizer treatments were applied to the plants in 300 ml volumes as outlined in experiment 1. Conditions within the growth chamber were set to 18°C/12°C day/night and supplemental lighting was provided to ensure a minimum 14 hour day length. Plants were watered uniformly as in experiment 1.

Plants were grown for 18 weeks and measurements of growth index were taken every two weeks (as outlined above). At harvest shoot dry weights, flower counts and leaf area were measured as indicators of plant quality. A visual assessment was also carried out for each plant by 24 randomly selected members of RHS staff.

Data from each of the 5 treatments were averaged (n=6) and means are displayed ± SE. Two-way ANOVA was performed using the factors media and fertilizer type was undertaken to explore the impacts of the combination of media and fertilizer on plant quality. The impact of growing media on CRF fertilised plants was tested with one-way ANOVA.

Results

<u>Experiment 1</u>

Shoot dry weight (Fig. 2a) was representative of much of the plant quality data collected at the destructive harvest (leaf area, flower dry weight and flower count; data not shown). As one might have been expected, unfed (UF) plants were typically less than half the mass of fed plants, although the extent of the difference depended on the media/fertilizer combination. While final plant quality was not affected by growing media, fertilizer type had a highly significant effect ($P<0.001$). There was also a clear interaction between growing media and fertilizer type ($P=0.005$). Plants grown in green compost and wood fibre based media produced similar shoot dry weights regardless of the type of fertilizer applied. In both of these media, plants grown with organic fertilizer tended to produce less shoot mass but only by *c.* 10%. In contrast, shoot dry weight was *c.* 70% lower in organic fed, peat grown plants than in the inorganic fed plants. A similar reduction in plant growth was observed in coir grown plants with final shoot mass reduced by *c.* 50% in organic fed vs. inorganic fed plants.

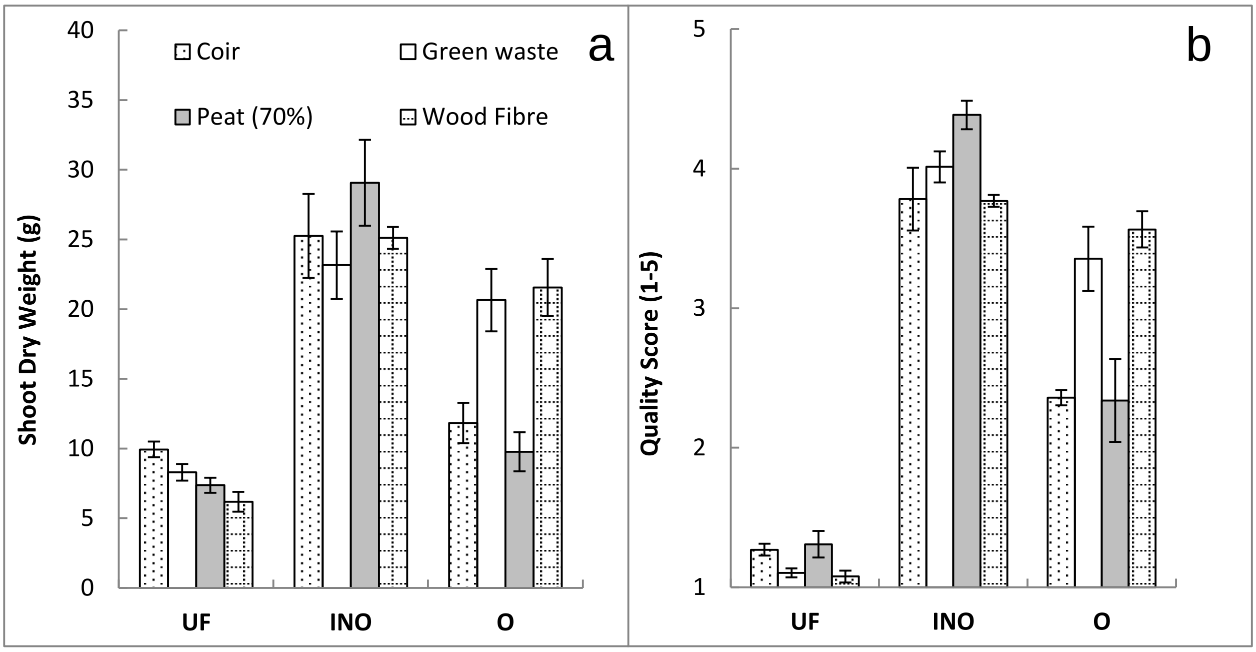

Figure 2 The effect of fertilizer and growing media type on the quality of *Pelargonium* 'Maverick Red' plants after 18 weeks of growth in 4 different multipurpose growing media mixes (based on coir, green compost, peat (70%) and wood fibre) and with 3 different fertilization regimes (UF = unfed, INO = inorganic feed, O = organic feed). (a) Shoot dry weight (g), a significant interaction between the factors growing media and fertilizer was found ($P=0.005$). (b) Visual Quality Score; determined by 13 assessors on a 1-5 scale with 1=poor, 3=acceptable/marketable and 5=excellent. A significant interaction between the factors growing media and fertilizer was found ($P<0.001$). All data are shown as means ± SE ($n=6$).

Figure 2b shows how the impact of fertilizer type and the interaction between fertilizer and growing media was similarly evident in the data from the visual assessment. Participants were clearly able to detect impacts of the various treatments, because of the marked differences in size and colour (Appendix 2, image 1).

The growth index data indicated that plants in all media types were growing at a similar rate before feeding commenced in week 5. After this point the growth index of unfed plants fell rapidly away from that of the fertilized plants (data not presented), suggesting nutrient supplies in all growing media had been severely depleted within first 4-5 weeks of the experiment. By week 9 unfed plants had a growth index of less than half that of fertilized plants and growth had stopped in all media types by weeks 14-15 in unfed plants.

Growth index data for the fertilized plants (INO and O) are displayed in figure 3, and show all plants were growing in a similar fashion up to weeks 7-8 of the experiment. After this point the organic fed coir and peat plants appear to stop showing any increase compared with their inorganic fed counterparts. In contrast wood fibre and green compost grown plants continue to grow in a consistent manner regardless of the fertilizer type applied.

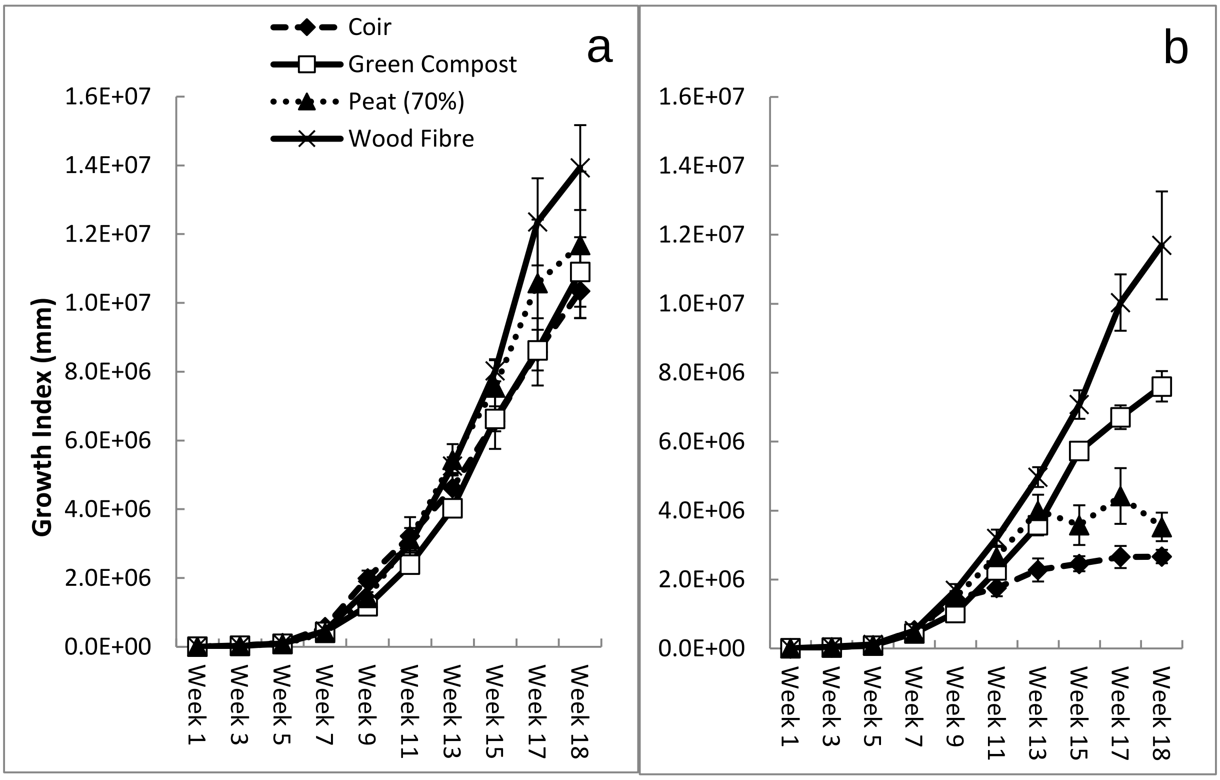

Figure 3 Growth index of *Pelargonium* 'Maverick Red' taken every two weeks over the course of experiment 1 for a) inorganic fed plants and b) organic fed plants in the 4 different

multi-purpose growing media (coir, green compost, peat (70%) and wood fibre). Data are means ±SE (*n*=6).

Experiment 2

Pelargonium shoot dry weight was representative of much of the plant quality data collected at the destructive harvest (leaf area, flower dry weight and flower count; data not shown). As shown in figure 4, most plants had lower shoot dry weights when fertilised with an organic compared with an inorganic liquid feed at standard application rates. At double application rates there was little difference in shoot dry weight between the two liquid fertilizer types. There was no significant interaction between growing media or liquid fertilizer type on shoot dry weight at either application rate. It was though, evident that some media tended to produce more consistent results between fertilizer types than others. For example at the standard rate of liquid fertilizer application, green compost grown plants tended to produce similar shoot dry weights regardless of fertilizer type (inorganic 34.6± 1.4g vs. organic 31.8± 2.5g). In contrast, organic fed plants grown in the 70% peat media had *c.* 20% less shoot mass than inorganic fed plants.

Doubling the rate of fertilizer application significantly reduced shoot dry weight regardless of growing media or whether an inorganic ($P<0.001$) or organic ($P<0.001$) fertilizer was used. This effect was particularly pronounced for inorganic fertilized plants where reductions in plant dry weight between standard and double rates ranged from *c.* 20% for green compost grown plants to 75% for coir grown plants. Reductions in growth for plants receiving the double rate of organic fertilizer were more moderate ranging from *c.* 10% for green compost grown plants to *c.* 60% for coir grown plants.

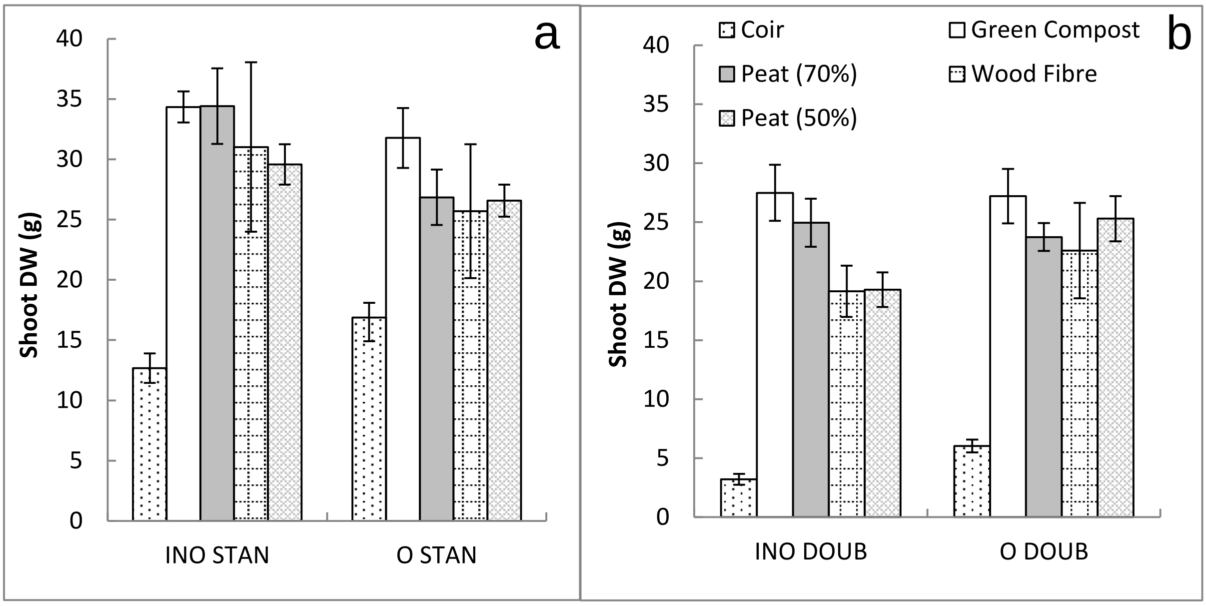

Figure 4 The impact of two types of all-purpose liquid fertilizer inorganic (INO) and organic (O) and 5 multi-purpose growing media (based on coir, green compost, peat (70%) wood fibre and peat (50%)) on the shoot dry weight (g) of *Pelargonium* 'Maverick Red' after 18 weeks of growth. Liquid fertilizers were applied at either a) the standard manufacturer's recommended rate (STAN) or b) double (DOUB) the recommended rate. Shoot dry weight was impacted by both growing media (standard; P<0.001), double P<0.001) and fertilizer type (standard; P=0.041, double P=0.040). All data are shown as means ± SE (n=6).

Participants of the visual assessment were clearly able to recognise treatment effects, with inorganic liquid fed plants consistently scoring better than organic liquid fed plants regardless of application rate (Figure 5). There was also a strong interaction between liquid fertilizer type and growing media at both application rates indicating that perceived plant quality in different growing media varied according to the liquid fertilizer type applied. This was most clearly demonstrated in the peat (70%) grown plants; where at standard inorganic liquid fertilizer application rates, plants were perceived to be by far the best quality (mean quality score of 4.5). Conversely, when fed with the organic liquid feed, perceived quality of these plants dropped to just 2.9, with green compost and wood fibre plants scoring significantly higher (Figure 5).

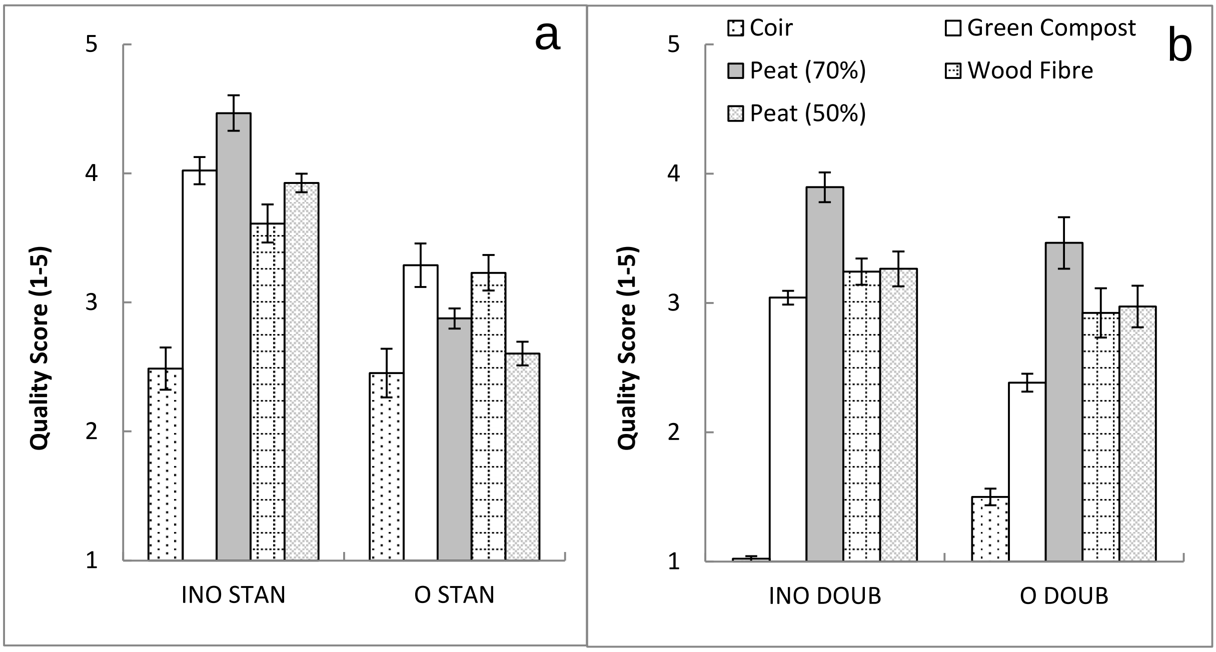

Figure 5 The impact of two types of all-purpose liquid fertilizer inorganic (INO) or organic (O) and 5 multi-purpose growing media (based on coir, green compost, peat (70%) wood fibre and peat (50%)) on the perceived visual Quality Score of *Pelargonium* 'Maverick Red' after 18 weeks of growth. Liquid fertilizers were applied at either a) the standard manufacturer's recommended rate (STAN) or b) double (DOUB) the recommended rate. The visual quality score was determined by 24 assessors on a 1-5 scale with 1=poor, 3=acceptable/marketable and 5=excellent.

Plants grown in the coir based media produced substantially poorer plant quality regardless of fertilizer rate or type. At standard liquid fertilizer application rates coir grown plants achieved at best half the shoot dry weight of plants grown in all other media. This effect was exacerbated when fertilizer application rates were doubled with coir grown plants producing at best 85% less shoot dry weight than plants in any of the other media.

While the different treatments had a clear impact on plant dry mass and perceived visual quality, the growth index showed that in the main, all plants followed a similar pattern of growth over the course of the experiment regardless of growing media, liquid fertilizer type or fertilizer rate (Appendix 2, figure 1A). However, towards the end of the experiment some notable differences in the pattern of plant growth were emerging. At standard fertilizer application rates, green compost grown plants showed a similar pattern of growth regardless of fertiliser type. In contrast, while plants grown in peat (70%) media and receiving inorganic feed continued to grow well, plant growth had more or less stopped by week 15 where organic fertilizer was applied (figure 6).

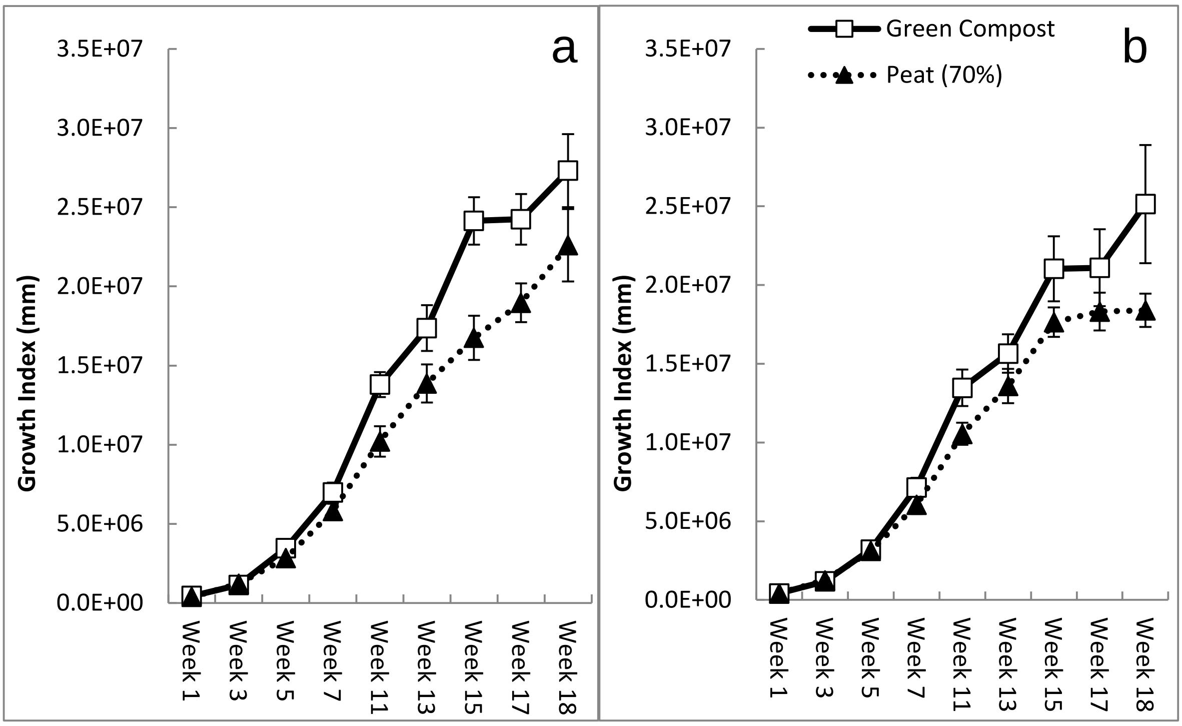

Figure 6 The growth index of *Pelargonium* 'Maverick Red' over the course of the 18 week experiment when grown in two multi-purpose media (based on green compost or peat (70%)) and fed with either a) an inorganic liquid feed at the standard manufacturer's rate (INO STAN) or b) an organic liquid feed at the standard manufacturer's rate (O STAN). Data are means ±SE (*n*=6).

After 18 weeks of growth, shoot dry weight of plants grown with CRF varied greatly according to growing media type ($P<0.001$). Plants grown in the green compost media produced the most shoot mass (33.1± 1.2g) while those grown in the peat (50%) mix were around half the mass (16.6 ±1.5g). When the three fertilizer types (Inorganic, organic and CRF) were compared at recommended application rates, quality varied considerably according to the fertilizer x growing media combination imposed, but only shoot dry weight will be discussed here. Shoot dry weights were impacted by fertilizer type ($P=0.04$) and growing media type ($P<0.001$) and a strong interaction ($P<0.001$) indicated that the influence of fertilizer type depended very much on the growing media used (Figure 7). For instance, coir grown plants had a *c.* 40% more shoot dry mass when grown with a CRF compared with a liquid inorganic or organic feed. Conversely, Plants grown in peat (50%) had *c.* 40% more shoot mass when fertilized with a liquid feed compared with a CRF. Green compost grown plants produced a relatively consistent shoot mass regardless of the fertilizer type imposed.

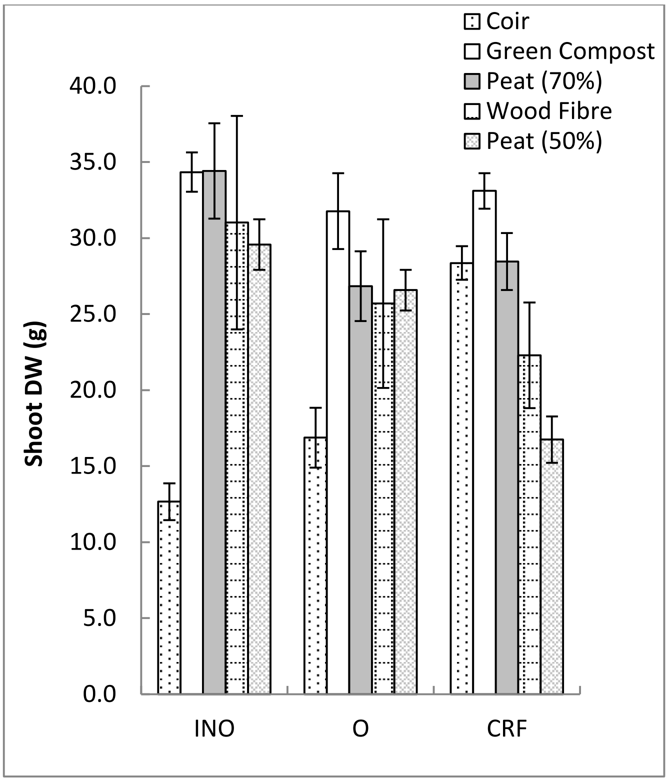

Figure 7 The effect of three ‘all-purpose’ fertilizers applied at the manufacturer’s recommended rate (IN = inorganic, O = organic and CRF = controlled release fertilizer) on the shoot dry weight (DW) of Pelargonium ‘Maverick Red’ after 18 weeks of growth in five different multi-purpose growing media (based on coir, green compost, peat (70%), peat (50%) and wood fibre. There was a strong interaction between growing media and fertilizer type (P<0.001). Data are means ±SE (n=6).

Discussion

In both experiments it was clear that the combination of growing media and fertilizer type had a large impact on plant quality and that the extent and nature of this impact depended on the type of growing media selected. While specific interactions between growing media and fertilizer products were difficult to replicate between experiments, some consistent relationships were identified. Media containing green compost produced consistently better quality plants than the medium containing a high proportion of peat (70%) when an organic fertilizer was applied. In both experiments there was evidence of a cessation of plant growth towards the end of the experiment in the 70% peat media + organic liquid feed treatment which was not present for other peat-free media. This could be due to the way these media interact with different forms of nitrogen. Both feeds contained a similar amount of total N, but in the organic feed this was in a complex form (4% urea and 2% more complex forms) whereas the inorganic feed contained only plant available N forms (appendix 1, table B). It may be that some aspect of the physical or biological make-up of the green compost containing medium made it a particularly suitable for the microbiological transformation of organic N to plant available N. Although the data were not discussed here there were also clear differences in the way the different media tested retained water and this may also have impacted on the nutrient-use efficiency between treatments.

For all the growing media tested in both experiments there was considerable variability in the physical and chemical properties of the materials within the same brand of product (tables 1 and 2) This was particularly apparent for the coir based media; in experiment 1 it gave the best quality plants with standard rates of inorganic feed but produced the worst plants in experiment 2. The analysis of both batches of material showed that the product used in experiment 2 had half the starting soluble N and P concentration and double the starting sodium concentration of the batch used in experiment 1. This highlights the main problem of using proprietary products to investigate questions about fertilizer management in any plant production system amateur or professional. The contents and character of different bags of the same brand of peat-free or peat-reduced media can vary widely. This makes it extremely difficult to replicate effects observed between experiments and represents an often unappreciated challenge particularly for amateur growers purchasing off-the-shelf, multi-purpose growing media.

What was evident from experiment 2 regardless of fertilizer type applied or growing media used was that doubling fertilizer application rates led to a clear decline in plant quality. There was absolutely no advantage to adding more fertilizer than the manufacturer's standard rate which is perhaps counter-intuitive to the perception that many amateur growers might have that a 'little bit more fertilizer won't do any harm'. The double rate initiated in this study represented in practice two capfuls of product in a 4.5 litre watering can, rather than one. This is not an unrealistic scenario and is likely to be occurring frequently in gardens.

In summary, this work shows that gardeners can achieve quality plant growth in peat-free media but only if they adopt an appropriate fertilisation regime. This would be facilitated by information about the content of growing media products. All multi-purpose composts should, at the very least, include a list of materials contained with the dominant materials clearly indicated. This would allow gardeners to make more informed choices about the fertilization regime they choose to put in place. For example, they might choose to use an organic fertilizer if a product contains green compost. Media manufacturers might also consider recommending particular types of fertilizer products based on the experiences of their own trials. While one or two manufacturers produce companion fertilizer products specially formulated for their particular peat-free or peat-reduced media, it would be beneficial if this practice became more widespread. In a world of peat-free media it unlikely that one 'all-purpose' fertilizer will be suitable for all amateur applications and a new approach to nutrient management needs to be adopted.

Conclusions

These two experiments examined the impacts of multi-purpose growing media and fertilizer products on container grown *Pelargonium* quality. The aim was to better understand how these two components interact and influence the kind of results gardeners might expect when using off-the shelf products. Findings are to be communicated to RHS members and used to plan further experimental work on growing media and nutrient interactions.

- In most cases peat-free and peat-reduced amateur growing media products produced acceptable plant growth when standard rates of fertilizer were applied. However, amateur growers should be aware that big differences in quality between bags of the same product are still apparent in some brands.
- Fertilizer choice has important impacts on achievable plant quality. Certain combinations of fertilizers and growing media produce higher quality, more consistent plant growth e.g. media containing green compost and organic fertilizer.
- There is limited scope to understand these interactions in proprietary products given their inconsistent and variable nature. Batches of the same brand of media often show large differences in physical and chemical characteristics and so understanding the impacts of different water and nutrient regimes is problematic. Ideally work needs to take place with well characterised, consistent mixes which can be compared directly between experiments. To address this issue, work is now under-way to design and produce our own representative peat-free and peat-reduced growing media mixes. This will allow us to create controlled and consistent conditions in which interactions between media, water and nutrients can be closely examined and clearer recommendations on product selection gleaned.
- For amateur growers, a careful and consistent fertilization regime is crucial to achieve the best results from peat-free/peat-reduced mixes. Care should be taken to not to exceed the manufacturer's advised application rates. In our experience these rates proved sufficient to produce good quality plant growth in nearly all media. Increases in

fertilizer application should only be implemented if obvious signs of nutrient deficiency occur and then rates should be upped in small increments and slowly.

SCIENCE SECTION – WORK IN PROGRESS

The following section outlines the work that is currently in progress focusing on the aims and expected outcomes.

Introduction

Experiment 3: What makes a good quality growing media? Examining how the physical and chemical properties of different peat-free and peat-reduced growing media influence plant quality.

Globally growing media is produced from a huge diversity of organic and inorganic materials. In the UK, organic materials are most commonly used; predominately peat, but also coir, wood and green waste compost. The number and proportion of these materials in any given media mix will give it a distinct suite of physical, chemical and biological characteristics. These characteristics have important impacts on container plant quality either directly; by their action on the water-air balance of the substrate, or indirectly through interactions with fertilizer and water-use efficiency. In the UK, peat based media remain the norm for both commercial and amateur growers. As a result peat based substrates have been well characterised and many UK commercial growing systems are optimised for these media. However, concerns about the environmental impact of peat extraction have meant more diverse and sustainable materials are now being used to make growing media. These peat-reduced and peat-free media have physical and chemical properties that differ from peat. This means existing irrigation and fertilization practices need to be modified in order to maintain quality plant growth in these substrates. Unfortunately, there has been little clear information to date on the best way for growers to go about this. As highlighted in experiments 1 and 2, the inconsistent and variable nature of available proprietary growing media has made research into effective management of these substrates problematic. In order to address this issue 14 bespoke growing media mixes are being created using 5 commonly used raw materials. The mixes are to be fully characterised and their impacts on plant quality assessed in a field experiment with two hardy nursery stock (HNS) species. This should provide a clearer understanding of how different peat alternatives affect plant quality and what is driving these effects. There are two main aims:

1. Investigate how combining different materials affects the properties of a media mix and how this relates to differences in plant quality.
2. To produce good quality, fully characterised and replicable model growing media mixes which can be used to address knowledge gaps in our understanding of how to manage water and nutrition in peat-free growing systems.

Materials and methods

Model Peat-free and Peat-reduced mix design

Using what we have learned in the past year and by working with a professional UK growing media manufacturer, 14 growing media mixes have been designed and manufactured. These are based on 5 peat-replacement materials selected because they are widely available in the UK and are already used in both professional and amateur growing media:

- Coir (washed and buffered)
- Wood fibre (machine extruded pine chips)
- Mature Pine Bark (3-15mm)
- Peat (18mm)
- Green compost (produced at RHS Wisley and sieved to 20mm)

Raw materials have been stock-piled and physical and chemical properties are being characterised according to table 3. Preliminary experimental media mixes were manufactured using various proportions of the 5 raw materials. These mixes were then screened according to their physical suitability (bulk density, water retention/drainage) and on advice from the growing media manufacturer, giving 14 final bespoke mixes (table 4). Batches of each of the 14 mixes are currently being physically and chemically characterised in the same way as the raw materials (table 3).

	Complete	In process	In development	Student project
Physical				
Fresh Bulk density	✔			
Dry Bulk density	✔			
Air Filled Porosity		✔		
Total Porosity		✔		
Container capacity		✔		
Particle size distribution		✔		
Plant available water			✔	✔
Wettability			✔	✔
Chemical				
pH	✔			
Electrical Conductivity	✔			
Nitrogen Draw-down Index (NDI)		✔		✔
Plant available Nutrients	✔			
Total N	✔			
C:N ratio	✔			
Biological				
Microbial activity				✔
Microbial diversity				✔

Table 3 Summary of the measurements characterising physical, chemical and biological properties of growing media materials and mixes. Measurements are indicated as complete, in progress, in development (suitable methods have been identified and method development needs to be completed) or as a potential student projects (where a lot of work is required to design or develop a suitable method, collaborative work with the UoR is proposed for the autumn).

Table 4 Composition of the 14 bespoke mixes designed for experiment 3 based on 5 raw materials coir (brown), green compost (green), peat (grey), mature pine bark (blue) and wood fibre (yellow bars). The nursery standard 'control' mix is also displayed.

The impact of the bespoke mixes on the quality of two hardy nursery stock species

The impact of these 14 bespoke mixes is now being investigated in a large scale field experiment with two HNS species (*Viburnum* and *Hebe*). For the experimental design and set-up, commercial nursery practices have been followed as closely as possible by seeking advice from a professional grower.

The 14 bespoke mixes were manufactured in 120 litre batches using a cement mixer. Additives (lime, nitrochalk, base fertilizer, fritted trace elements (FTE), and wetting agent) were added at standard rates on advice from the media manufacturer and commercial grower. Rates of lime addition varied between mixes depending on the starting pH. Rates of nitrochalk were adjusted to account for differences in the nitrogen draw-down index of the different mixes. A nursery standard control mix was also included, this was a 70% peat medium for HNS (table 4).

A large plot of land at RHS Wisley was prepared in March and laid with Mypex ground cover. Fifty-four uniform 9cm liners of *Viburnum tinus* 'French White' were then potted-on into 2 litre pots so that there were 54 replicate pots for each of the 15 mixes (14 bespoke mixes + the control mix). The 54 replicate pots of each mix were then laid-out on the pre-prepared plot in rows of randomised $1m^2$ blocks. Each block contained 9 replicate plants, 8 'edge' plants and 1 'experimental' plant (Appendix 3, Figure 1A). The same process was repeated for *Hebe* 'Red Edge', with plants laid out in exactly the same way on the plot, adjacent to the *Viburnum* (Appendix 3, Image 1). Each block has been designed so that quantitative measurements can be taken from the 'experimental' plant at the centre of the block reducing the impacts of any disparate edge effects that may be present within and between blocks.

The experiment has now been set-up for 7 weeks; plants are being watered as required with over-head sprinklers and laid out according to HDC guidance (Factsheet 16/05). The experiment is planned to run until October when the HDC HNS panel have been invited to come and visually assess the plants for quality. Measurements of volumetric water content, temperature and electrical conductivity in the mixes are being taken weekly. Growth of the plants is being measured every 6 weeks, and plant dry weights will be taken when the plants are destructively harvested at the end of the experiment.

Anticipated outcomes

By the end of the year we hoped to achieve the following outcomes:

- A data-base of the physical & chemical characteristics of the 15 different growing media mixes.
- A clear understanding of how these characteristics impact on the quality of container grown HNS and a better ability to predict which combinations of materials will work well (multivariate analysis may be implemented to help achieve this).
- An evaluation of the costs and practicalities of using our bespoke mixes from the perspective of commercial growers and gardeners.
- A set of fully characterised and replicable model growing media mixes that can be used to conduct further work into optimising water and nutrient management in peat-free and peat-reduced media.

Future Work

Proposed Programme of Research for the next 12 months

1. Investigate the performance of peat-free and peat-reduced media with different irrigation systems and under different irrigation regimes; Identify opportunities for better water-use efficiency

Gardeners and professional growers use a number of different irrigation systems depending on the scale and nature of their enterprise. It would therefore be particularly useful for them to know which types of peat-free/peat-reduced media are best suited to their existing irrigation system. There is also a need to better understand how to modify irrigation regimes to get the best results from a peat-free or peat-reduced media (frequency and/or duration of watering). It is likely that some media will produce much better plant quality for the same volume of water applied than others within a particular growing system. It is therefore proposed that during the next 12 months of the project, experiment(s) investigating water-use efficiency in a selection of the mixes developed in experiment 3 will be carried out. The following questions will be addressed:

- Can peat-reduced and peat-free mixes work across a range of irrigation systems?
- Can some of these mixes maintain plant quality while requiring less water?

- Can the irrigation regime (duration, frequency and volume of water) within a particular system be optimised for specific growing media types (woodfibre based, coir based etc.)?
- Can the composition or physical characteristics of a media mix be used to predict how it will perform in a particular irrigation system or which irrigation regimes may be most suitable?

This work would provide a good opportunity to work in collaboration with East Malling Research (EMR) and make use of their water centre. On this basis, it is proposed that the topic of the proposed workshop listed in the year 2 objectives (Objective 8) could be 'water-use efficiency in peat-free and peat-reduced substrates'. It is hoped that this will start to generate some ideas for collaborative spin-off projects that can extend the remit and funding potential of the Fellowship project (Objective 2, year 3).

2. *Optimising nutrient use efficiency in peat-free and peat-reduced substrates (Objectives 1 & 3, year 3).*

The data from experiments 1 and 2 has indicated an important interaction between different growing media materials and fertilizer types. While organic sources of nitrogen produced poor plant growth in substrates with high peat content, they performed consistently better in those containing green compost. It is therefore proposed that in year 3 some small scale studies are implemented to investigate the effectiveness of different nutrient sources/fertilizer types in the fully characterised mixes developed in experiment 3. Nutrient analysis and methods for quantifying nutrient-use efficiencies are anticipated to be developed at the UoR (Objective 2, Year 3). The consistent, controlled nature of the experimental 3 mixes should make it possible to answer specific questions about the best fertilizers to use in which kinds of substrates:

- Do novel sources of nutrients produce acceptable plant quality in some peat-free media and do they have potential for use in commercial horticulture?
- Do some combinations of materials retain nutrients better and reduce leaching?

These smaller scale- experiments will help to inform the research programme for year 4 where the focus is anticipated to be nutrient-use efficiency in peat-free media.

3. *DEFRA/HDC growing media project*

The research proposed by the Fellowship has been conceived in the knowledge of a newly established Defra/HDC funded programme of work. It is anticipated that the Fellowship and Defra/HDC project will communicate with each other and possibly collaborate to help move the replacement of peat forwards more quickly and avoid duplication of effort. Both parties have met and informally agreed to share information where appropriate.

Knowledge and Technology Transfer

Publication of the results of experiments 1 and 2 are anticipated in the next 6 months. An article on experiment 3 was published in the RHS science Newsletter in May.

Glossary

FRF: Field Research Facility at RHS Wisley

UoR: University of Reading

EMR: East Malling Research

References

N/A

Appendices

Appendix 1 Analysis of fertilizer products used in experiments 1 & 2

Nutrient content stated on label (%)	Inorganic	Organic	CRF
Content stated on Label (N-P-K)	6-3-6	5:2:5	17-9-11
Total Nitrogen	6.0	5.0	17
Ammoniacal Nitrogen	2.7	N.S.	9.3
Nitric Nitrogen	3.3	N.S.	7.7
Water Soluble Phosphorus as P_2O_5	3.0	2.0	6.5
Water Soluble Potassium as K_2O	6.0	5.0	11.0

Table A Nutrient content as stated on the bottle labels of the three fertilizer types applied in experiments 1 and 2. There was very little nutritional information available on the label of the organic product (N.S. indicates where information was not stated).

All units % w/w	Inorganic	Organic
Total Nitrogen	6.86	6.20
Ureic Nitrogen	< 0.1	4
Ammoniacal Nitrogen	3.13	<0.1
Nitric Nitrogen	3.73	<0.1
Water Soluble Phosphorus as P_2O_5	3.19	2.25
Water Soluble Potassium as K_2O	6.26	6.84

Table B Results of a laboratory analysis to determine the nutrient content of the two liquid fertilizers applied in experiments 1 and 2. The organic fertilizer contained *c.* 2% complex organic nitrogen forms. The CRF did not undergo laboratory analysis.

Appendix 2 Images and figure for experiments 1 and 2

Image 1 Impacts of the different fertilizer treatments on the growth of Pelargonium ‘Maverick red’ in experiment 1. The plants photographed were all grown in the peat (70%) growing medium and a) fed with the inorganic fertilizer (IN), b) fed with the organic fertilizer (O) or c) unfed (UF).

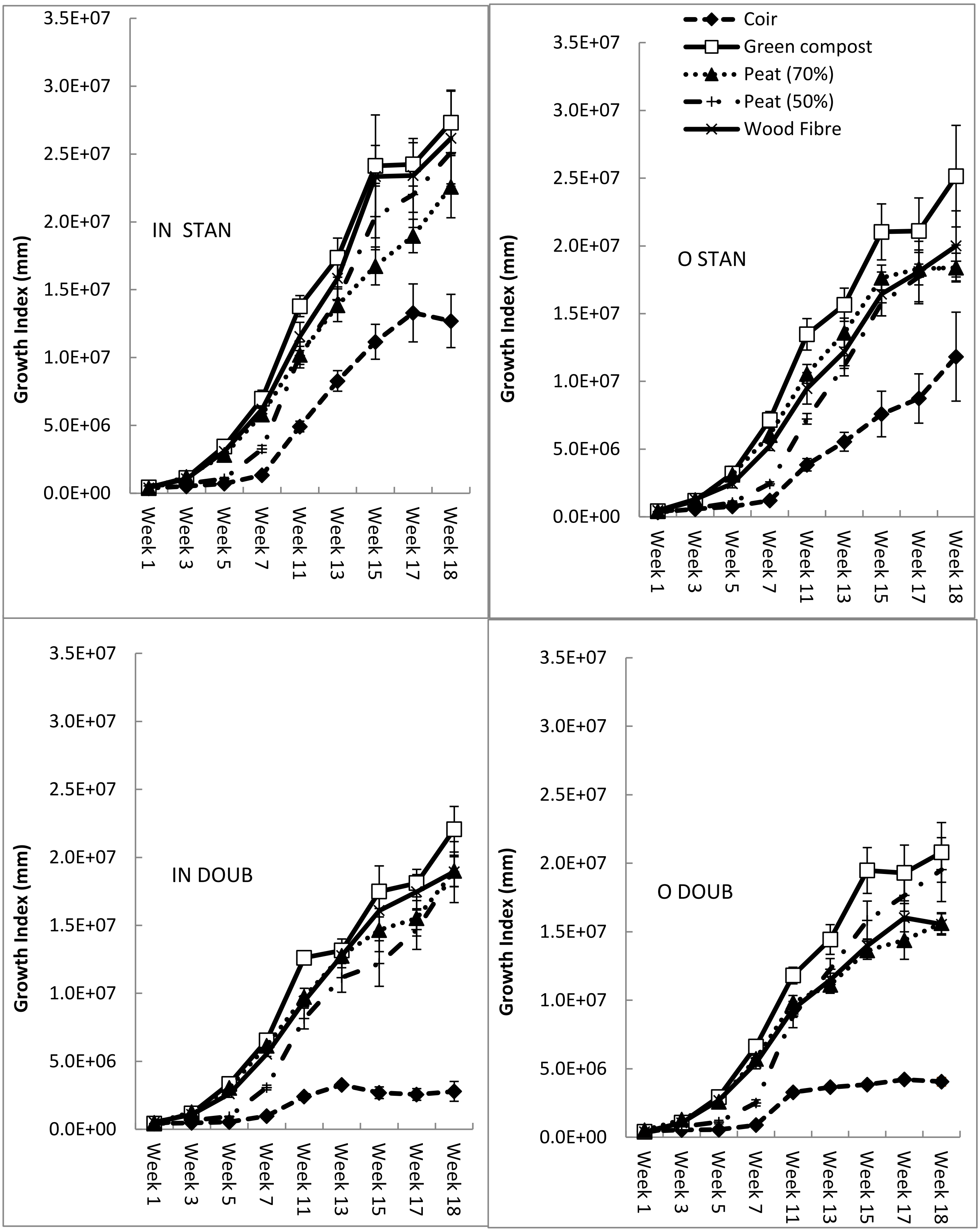

Figure 1A Growth index of *Pelargonium* 'Maverick Red' taken every two weeks over the course of experiment 2 for the 4 liquid fertilizer treatments: a) Inorganic standard rate (IN STAN) b) Organic standard (O STAN) c) Inorganic Double (IN DOUB) and d) Organic double (O DOUB). All data are shown as means ±SE (*n*=6)

Appendix 3 Layout of experiment 3

	Plot A	Plot B	Plot C	Plot D	Plot E	Plot G	Plot H	Plot J	Plot K	Plot L	Plot M	Plot N	Plot O	Plot P	Plot R
Rep Z	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3
Rep Y	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3
Rep X	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3
Rep W	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3
Rep V	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3
Rep T	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3	7 8 9 4 5 6 1 2 3

Figure 1A Layout of the *Viburnum* treatment blocks for experiment 3. Each $1m^2$ block contains 9 replicate plants in 1 of the 15 growing media mixes. Plant 5 in the centre of each block is the 'experimental plant' from which plant quality measurements will be taken. The remaining 8 plants are 'edge' plants. Treatment blocks are fully randomised within each row (T-Z).

Image 1 Layout of experiment 3 with *Viburnum* (white labels) and *Hebe* (yellow labels) replicates. Each block of 9 plants is growing in 1 of 15 different growing media mixes.