Project title:	Preliminary evaluation of green compost as a growing media for module Brassica production.
Project number:	FV303
Project leader:	Nigel MacDonald, ADAS
Report:	Final report, October 2007
Previous report:	None
Key staff:	Nigel MacDonald, ADAS Martyn Watling, ADAS Martin Grey, WHRI
Location of project:	WHRI Kirton for plant propagation Commercial crops in Lincs for siting field trials
Project coordinator:	Phillip Effingham, Marshalls of Butterwick
Date project commenced:	September 2006
Date project completed (or expected completion date):	September 2007
Key words:	Module raising, Brassicas, green compost.

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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.

Nigel MacDonald
Principal Consultant
ADAS UK Ltd

Signature .... Date ....

Report authorised by:

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Horticultural Research & Consultancy Manager

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GROWER SUMMARY

Headline

- Green waste/peat mixed compost produced similar numbers of usable module calabrese and cauliflower plants with similar vigour and marketability as plants grown in 100% peat.
- Careful analysis and amelioration of the green compost prior to and after mixing with peat is essential to ensure the quality of the compost as a growing media for brassica module production.
- In a spring-sown experiment, 504 trays produced the highest useable plant counts in cauliflowers and the highest percentage Class 1 at harvest irrespective of growing media.
- Spring-sown calabrese and cauliflower peat grown plants produced the highest vigour scores with better uniformity in the trays when compared with the green compost mixes in all tray sizes (126, 345 and 504).

Background and expected deliverables

Ongoing work investigating the use of composted municipal green waste as an alternative to peat has proved successful in other sectors of horticulture. In 2005, the vegetable propagating sector used approximately 59,000 m^3 of peat, amounting to 7.8% of all peat used in the professional horticultural sector. There is potential to reduce this level of peat usage by incorporating composted green waste that has achieved PAS100 quality standards into peat-based growing media for use in Brassica module production.

The overall aim of the project is to determine the suitability of peat mixed with composted municipal green waste for the propagation of module-grown cauliflower and calabrese when compared with 100% peat media. The specific objectives are:

1. To raise healthy cauliflower and calabrese plants through the winter and early spring periods using growing media incorporating two different sources of green compost blended with peat.
2. To determine the effect of if cell size and source of green compost on seedling quality.

3. To compare the effect on seedling quality of green compost made in the summer with green compost made during the winter.

4. To assess levels of *Escherichia coli* (*E. coli*) and *Salmonella* on planted material.

5. To determine the effect of cell size and source of compost on final marketable quality.

Summary of the project and main conclusions

Calabrese and cauliflower seeds were sown in autumn 2006 into 126, 216 and 345 tray sizes containing two types of green compost at 25 and 50% inclusion rates. Sowings were repeated in spring 2007 using 216, 345 and 504 trays containing a further two mixes of green compost. Useable plant counts, vigour and uniformity scores were taken during the plant-raising stage (prior to planting). At the harvest, records of percentage Class 1, 2 and Unmarketable were taken for cauliflower and total marketable weight for calabrese. Data analysis included assessing any interactions between media type and tray size on plant quality.

Small stones and twigs caused only minor difficulties during the filling of the trays prior to sowing of the over-wintered experiments. In the spring-sown experiments, all tray sizes filled with green compost with comparative ease but media particles must be <3 mm in size if the smaller 504 trays are used or else bridging and incomplete cell filling will result.

At planting of both the over-wintered and spring sown experiments, the rooting media of all treatments adhered together around the roots when the plants were removed from the trays.

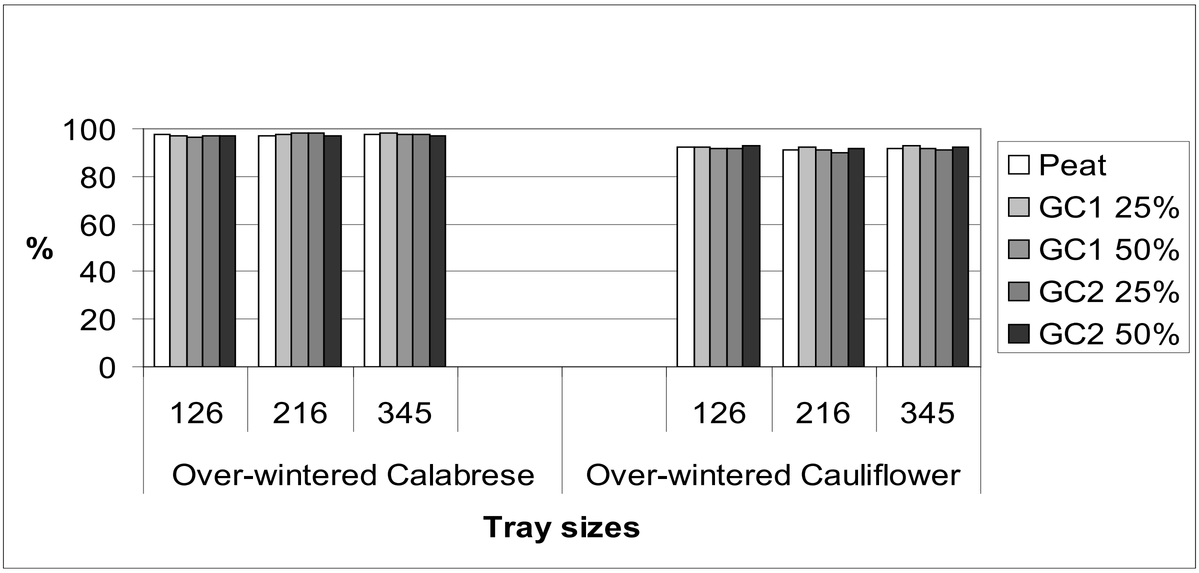
Over-wintered experiments

Green compost and peat in all tray sizes produced similar high percentages of useable calabrese and cauliflower plants when assessed 14 days after sowing (Plate 1, Figure 1).

Plate 1a. Over-wintered calabrese 15/11/2006, sown 20/09/2006

Plate 1b. Over-wintered cauliflower 20/11/2006. sown, 13/10/2006

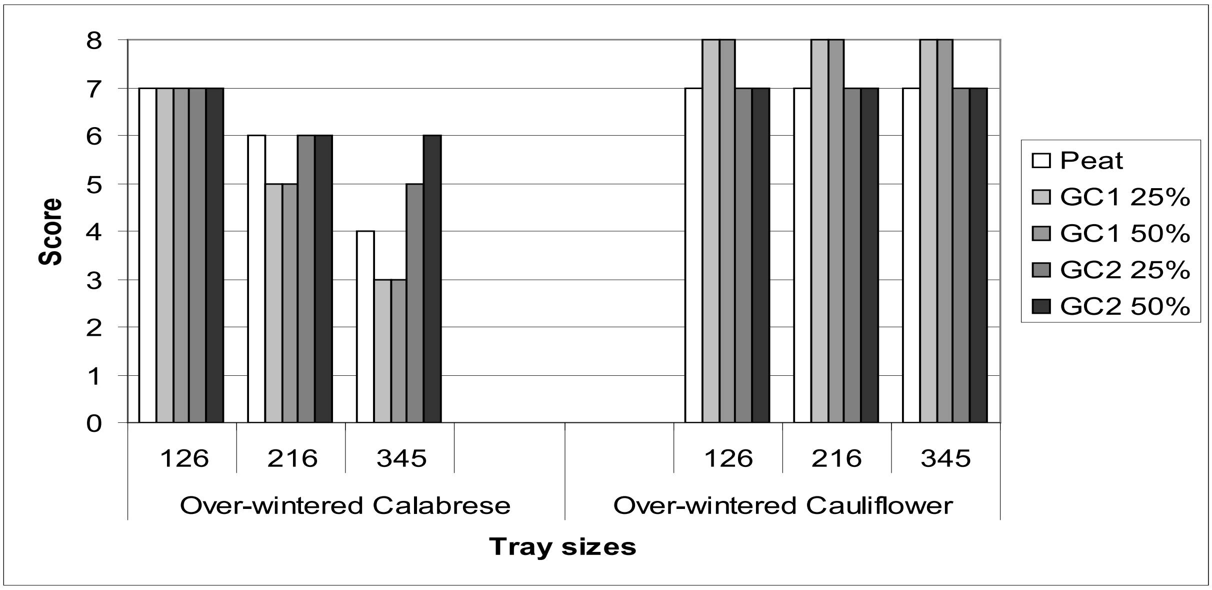
Figure 1. Percentage useable autumn-sown calabrese and cauliflower plants grown in different tray sizes (126, 216, 345) in different compost mixes. Calabrese assessed on 3 October 2006 and cauliflower 27 October 2006 (GC1 = green compost 1, GC2 = green compost 2).



Calabrese seedling produced more vigorous plants in the larger 126 trays compared with smaller 216 or 345 trays (Figure 2). Green compost containing higher nitrogen levels (as in GC2) tended to improve the vigour of the calabrese in the smaller tray sizes. High levels of nitrogen in the compost can cause stem to bend, reduce the quality of final plants and lead to bolting in over-wintered calabrese.

The vigour of cauliflower showed no preference for tray size and initially produced more vigorous plants in the green compost containing the lower level of nitrogen (Figure 2). However, this effect was short-lived and ceased to be apparent once the roots in the module had grown and more fully exploited the higher nitrogen media (GC2).

Figure 2. Mean vigour scores (1 = low, 9 = high) for autumn-sown calabrese and cauliflower plants grown in different tray sizes (126, 216, 345) in different compost mixes. Calabrese assessed on 6 October 2006 and the cauliflower on 30 October 2006 (GC1 = green compost 1, GC2 = green compost 2).

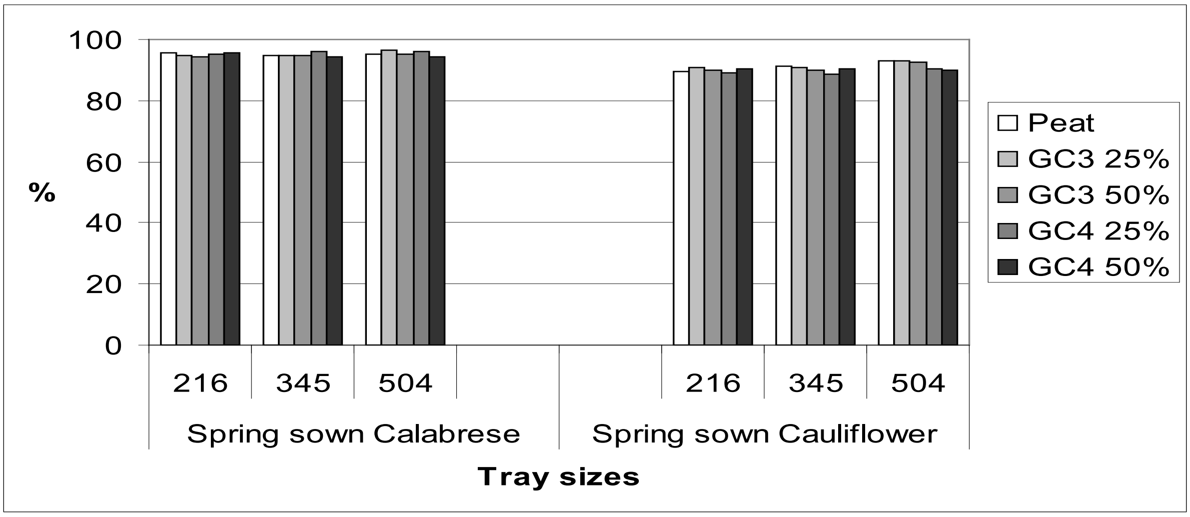


Calabrese plants from both green compost and peat established equally well in the field and at the harvest of the over-wintered calabrese experiment on 20 June 2007, there were no marketable yield differences between the plants grown in different trays or media. The over-wintered cauliflower trial failed to establish due to attack by hares, pigeons and cabbage root fly consequently no yield data is available.

Spring-sown experiments

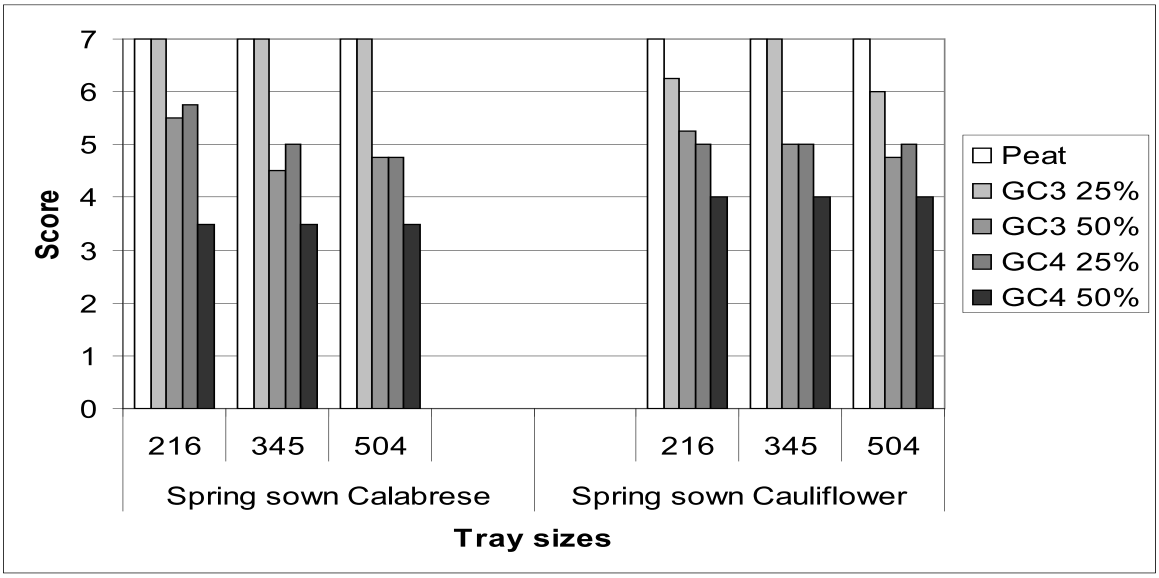
All media and trays of spring-sown calabrese and cauliflower produced a high percentage of useable plants with 504 trays producing the highest proportion of useable cauliflower plants (Figure 3). Careful management of water and feed is required to ensure this advantage is maintained as *Rhizoctonia* can become established.

Figure 3. Percentage useable spring-sown calabrese and cauliflower plants grown in different tray sizes (216, 345, 504) in different compost mixes were assessed on 21 March 2007 prior to planting (GC3 = green compost 3, GC4 = green compost 4).



Peat and the peat/GC3 25% mix (similar nitrogen levels to 100% peat) produced the highest mean score for vigour for calabrese plants; a similar trend was observed for cauliflower, although 100% peat tended to produce the most vigorous plants (Figure 4, Plate 2). The green composts producing the least vigorous seedlings contained higher levels of chloride and potassium ions that interfered with nitrogen uptake. Cauliflower were more demanding of the media, more readily showing up variations in growth across trays if the media was not thoroughly mixed.

Figure 4. Mean plant vigour score for spring-sown calabrese and cauliflower plants grown in different tray sizes (216, 345, 504) in different compost mixes assessed on 12 April 2007 prior to planting (GC3 = green compost 3, GC4 = green compost 4).



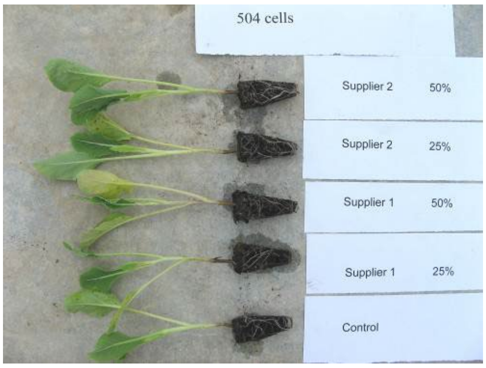


Plate 2a. Spring-sown cauliflower seedlings in 504 trays at planting on 15/05/2007

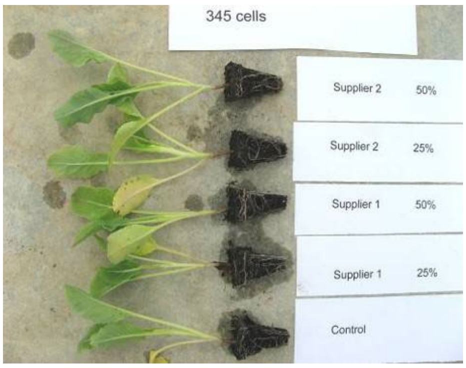
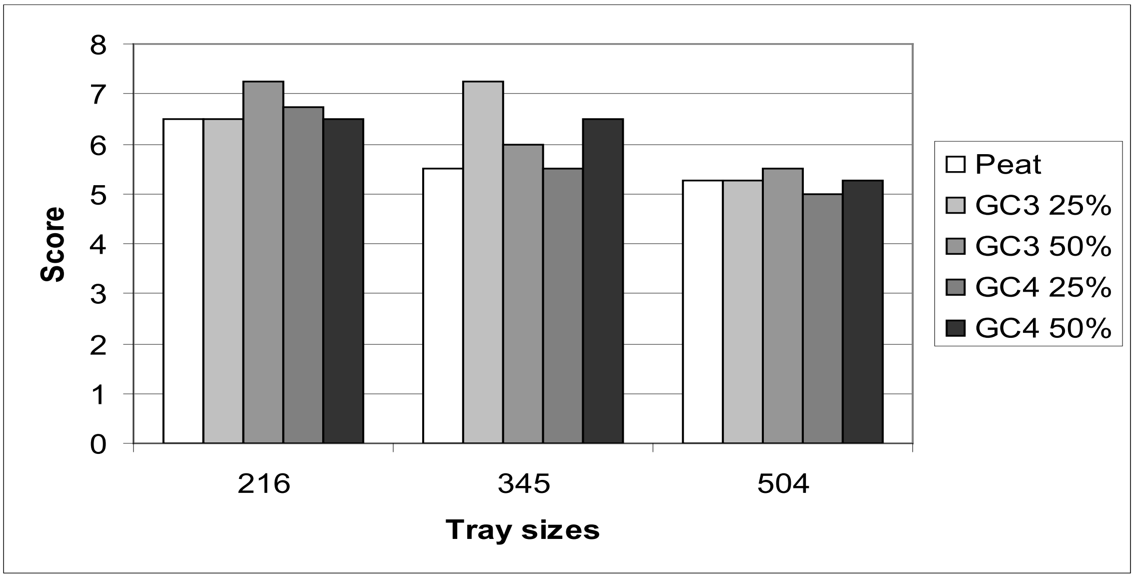


Plate 2b. Spring-sown cauliflower seedlings in 345 trays at planting on 15/05/2007

Once planted out in the field, calabrese from the larger 216 trays established best in the field producing a more vigorous plant than the 345 and 504 trays (Figure 5). A row effect at planting prevented meaningful field establishment scores for the cauliflower to be taken.

Figure 5. Mean plant vigour score (1 = low, 9 = high) for spring-sown calabrese in the field (planted out 01/05/2007, assessed 03/07/2007).



All calabrese plants growing in 216 trays produced high marketable weights of calabrese irrespective of media type; yields from plants grown in 504 trays produced the lowest yields, again irrespective of media type (Figure 6). The influence of tray size on marketable yield is clearly more important than media type.

Figure 6. Marketable yield (kg) for spring-sown calabrese (planted out 01/05/2007, assessed 20/07/2007 to 26/07/2007).

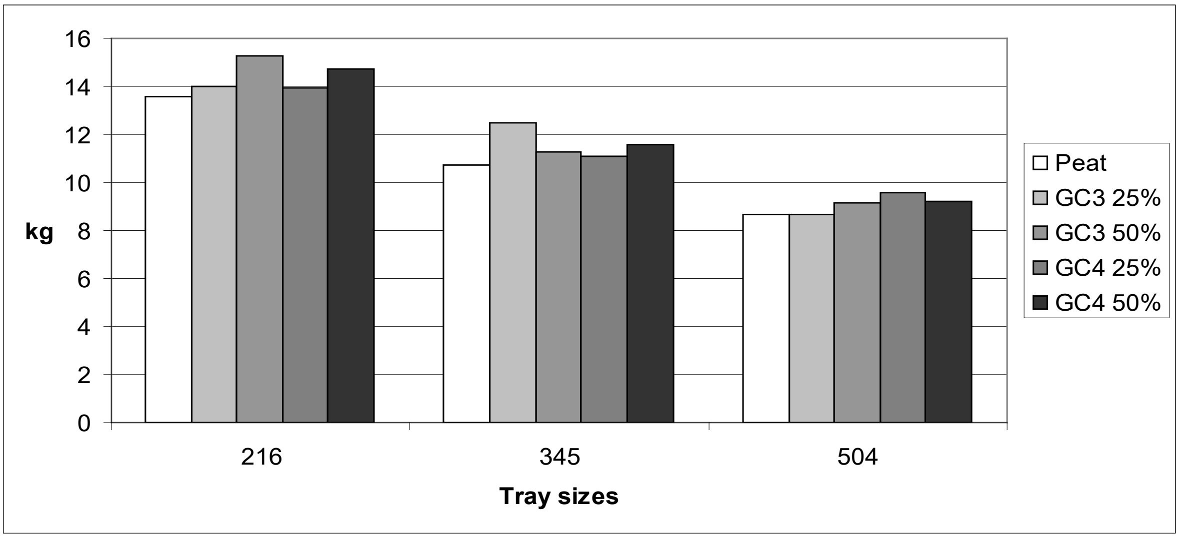
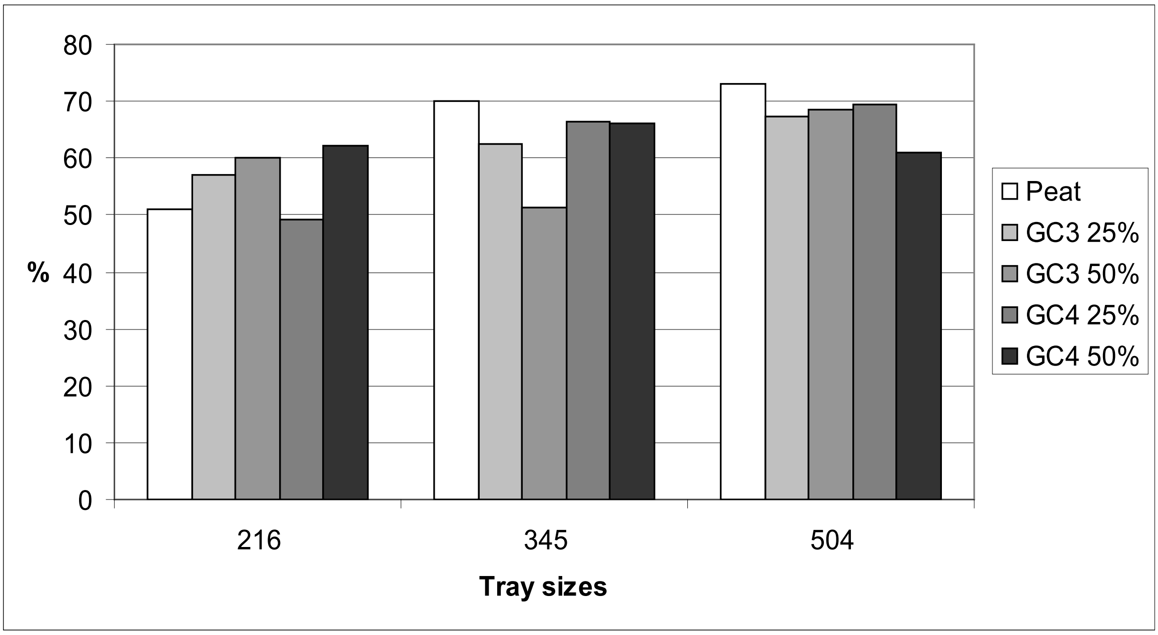


Figure 7. Percentage of Class 1 cauliflowers produced from spring-sown plants (planted out 15/05/2007, assessed 13/07/2007 to 29/07/2007).



The highest percentage of Class 1 cauliflowers were produced from plants grown in 100% peat in 504 trays, though plants grown in other media in the 504 trays also produced acceptable yields. The lowest proportion of Class 1 heads was produced by plants grown in 216 trays.

Summary of main points

- Municipally-collected green waste, composted to PAS100 standards, was mixed with up to 50% peat for use as propagation growing media for producing Brassica seedlings. Green waste/peat mixtures produced similar numbers of useable calabrese and cauliflower plants when compared with plants grown in 100% peat. Seedling vigour and percentage marketability at harvest were also acceptably high for different peat/green compost mixes in different tray sizes.
- Careful analysis and amelioration of the green compost prior to and after mixing with peat is essential to ensure the quality of the compost as a growing media for Brassica module production.

- In experiments with over-wintered plants, there were no differences in the percentage useable plants when green compost mixes were compared with 100% peat in different tray sizes. In a spring-sown experiment, 504 trays produced the highest useable plant counts in cauliflowers and the highest percentage Class 1 at harvest irrespective of growing media.
- Spring-sown calabrese and cauliflower peat grown plants produced the highest vigour scores with better uniformity in the trays when compared with the green compost mixes in all tray sizes (126, 345 and 504).
- Further work is required to establish the availability, consistency, price and safety of green compost throughout the year before plant propagators can consider using it in commercial batches of plants. Any cost:benefit in using green compost will be dependant on the proximity to the source as the higher bulk density of green composts compared with peat influences transport costs.

Financial benefits

There is potential with further investigation of the availability, consistency and safety for plant propagators and growers to reduce the cost of Brassica growing media by using locally sourced green compost providing it can be mixed locally after adjustment into a suitable media.

Action points for growers

- 504 trays are mainly used for growing spring cabbage plants and occasionally calabrese. Growers could consider growing cauliflower plants in 504 trays as they offer the potential to save money by reducing transport, handling and plant-raising costs yet produce a high percentage of Class 1 heads at harvest. Savings can be made in reducing transport costs and handling in the field. The management of the plants during raising would need to ensure that *Rhizoctonia* was not an issue and that rooting was improved by accurate watering and feeding. They offer the potential to be later in maturing that plants produced in 345 trays, providing an additional tool for achieving continuity of supply.
- Be aware that green compost can offer the opportunity to produce a quality transplant with no reduction in marketable yield.
- Quality, consistency, availability and safety of the media product need to be assured.

- Peat remains an ideal media of growing Brassica seedlings irrespective of the species or the tray size.

SCIENCE SECTION

Introduction

It is estimated the amount of peat used for vegetable propagation in 2005 was 59,000 cubic metres, amounting to 7.8% of all peat used in the professional horticultural sector (Holmes, 2005). The Government target for a 40% reduction in the total volume of peat used in professional horticulture was met in 2005 (Department of the Environment,2005) but the greater challenge for the whole of horticulture is to meet the 2010 target for a reduction of 90% with replacement from peat alternatives.

Considerable progress has been made in other sectors of horticulture, notably bedding plants and hardy nursery stock, in reducing the reliance on peat as a growing media. In module Brassica production, part-substitution with coir has up until now been considered to be the only viable alternative to peat. Government policy on sustainable use of resources and conservation of peatland as a consequence of the Wetlands Habitats Directive means that reducing peat usage remains an important political and conservation priority. Similarly, most UK retailers have a desire for peat use to be minimised in all areas where it is used as a growing media, including in the production of fresh produce. The Brassica industry therefore remains under pressure to find viable ways of reducing peat usage.

Previous work on using 25% inclusion of green waste for vegetable production undertaken for WRAP (Waste and Resources Action Programme) indicated that germination and propagation of leeks, lettuce and cabbage was comparable with a proprietary brand of peat to the point of transplanting (WRAP, . Green waste is seen as a good source of slow release nutrients and can be cheap if sourced locally. However, as highlighted in HDC Report CP 41 (A Review of peat usage and alternatives for commercial plant production in the UK) the challenges of green waste are that the soluble salt concentration can be high when inclusion rates are over 50% but most importantly, the bulk density can be very high adding substantially to transport cost. Fundamentally, the requirements of green compost mixtures for the propagation of edible crops must include the physical, chemical and biological properties that make sphagnum peat such an ideal growing media.

The overall aim of the project is to determine the suitability of peat mixed with composted municipal green waste for the propagation of module-raised cauliflower and calabrese when compared with 100% peat. The specific objectives are:

1. Raise healthy cauliflower and calabrese plants through the winter and early spring periods from two different sources of green compost blended with peat.

2. Determine if cell size and source of green compost has any impact on seedling quality.
3. Compare green compost made in the summer with green compost made during the winter.
4. Assess levels of *Escherichia coli* (*E. coli*) and *Salmonella* on planted material.
5. Determine if there is any impact of cell size and source of compost on final marketable quality.

Materials and methods

Growing media sourcing & characteristics

The green waste composts were made to PAS 100 standards by two different green compost manufacturers; one based in Fife, Scotland and the other in Bournemouth, Dorset, and mixed with peat by Bulrush Horticulture Ltd. PAS 100 ('Guidelines for the specification of composted green materials used as a growing medium component'), launched in November 2002, is the British Standards Institution's Publicly Available Specification (PAS) for composted material. It provides the national benchmark for the minimum requirements for the process of composting, the selection of materials from which compost is made and how it is labelled.

The raw compost was analyzed for chemical and physical characteristics before being enhanced to make suitable for sowing Brassica seedling production. Details of the analysis of the green composts and peat before and after modification are given in Tables 1 and 2 for both the over-wintered and spring sowings respectively.

Any difficulties encountered in filling the trays by hand caused by physical contaminants in the media or while seeding the trays were noted. Two samples of the 50% mixes from each batch were taken for microbiological determination of levels of *Escherichia coli* (*E. coli*) and *Salmonella*.

Plant production

All seeds were sown in hand-filled trays of compost mixes and covered with a thin layer of topping containing a mixture of 80% peat, 10% coir and 10% vermiculite to aid germination and reduce drying out of the compost.

Autumn-sown plants

Seeds of calabrese, *Brassica oleracea* var *italica* cv. Ironman were sown on 20 September 2006, into three different module tray sizes (126, 216 and 345), containing 25 and 50% peat/green compost mixes. Trays filled with 100% peat were used as controls. Green composts derived from two different sources of municipally-collected green waste (GC1 and GC2, see Table 1) were used. The same compost mixes were used on the 13 October 2006 to sow cauliflower *Brassica oleracea* cv. Mayflower using the same module tray sizes. Each tray size/media combination was replicated four times for each plant type. When the plants in the control Brassica peat mix were ready for planting, 60 healthy plants were selected from the four replicates per media/tray combination. The over-wintered cauliflower were planted first on 22 March 2007 followed by the over-wintered calabrese on 26 March 2007.

Spring-sown plants

Spring sowings of calabrese *Brassica oleracea* var *italica* cv. Ironman and cauliflower *Brassica oleracea* cv. Forward were both made on the 28 February 2007 using two green composts from a different source to the autumn-sown experiment (Table 2). As per the autumn sowings, 25 and 50% peat/green compost mixes were used, with 100% peat used as a control. Tray sizes in this experiment were 216, 345 and 504. Each treatment was replicated four times for each plant type. As with the autumn-sown plants, 60 healthy plants were selected from each media treatment tray for planting out in a single row. The spring-sown calabrese were planted on 1 May 2007 and the spring-sown cauliflower on 15 May.

Plant care

After sowing, the trays were laid down on the glasshouse floor in a randomised complete block design. Plants were watered and fed with proprietary feeds as determined by the appearance of the plants in each media treatment. A diary of all watering and feeding events was kept throughout the propagation period. Applications of fungicides and insecticides were applied to all treatments as necessary. Photographs were taken of the seedlings in all media after emergence and prior to planting out illustrating differences in both root and foliar growth in each cell size. Before planting, an visual examination of the roots on the underside of each tray for early signs of clubroot infection *(Plasmodiophora Brassicae)* proved negative.

Assessments

1. *Percentage useable plants*: an assessment of the percentage useable plants was done on all treatments in all replicates 14 days after sowing providing. This was done by counting the number of healthy seedlings that would produce viable plants and abnormal seedlings, and calculating a percentage based on the number of plants per tray.

2. *Plant vigour and uniformity during propagation*: Once the young plants had reached the second true leaf stage, a subjective score (1=poor, 9=good) assessment for plant vigour and uniformity on all media treatments in all trays. An assessment of uniformity of seedling size within each tray using (1=poor, 9=good) gave an indication of the consistency of the media mix and the impact on growth.

Table 1. Chemical analyses of a) raw green compost material and b) experimental peat-amended mixes used for autumn-sown experiments (Den = bulk density; Cond = conductivity; TON = total organic nitrogen)

a) Raw material analyses

	Den	**pH**	**Cond**	**NH_4-N**	**NO_3-N**	**TON**	**Cl**	**K**	**Mg**	**Ca**	**Na**	**Fe**	**P**	**Cu**	**Mn**	**Zn**	**B**	**SO4**
Sample Name	g/l	-	us/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Green compost 1	715	8.27	608	3.8	82.3	86.1	464.6	945.7	18.8	55.4	107	18.9	6.2	0.13	0.45	0.24	1.06	223.9
Green compost 2	652	8.4	914	3.2	57.8	61	1060	1285	23.5	98.8	274.4	59	18.3	0.21	0.6	0.51	1.22	86.7

b) Green compost/peat mixture analyses

	Den	**pH**	**Cond**	**NH_4-N**	**NO_3-N**	**TON**	**Cl**	**K**	**Mg**	**Ca**	**Na**	**Fe**	**P**	**Cu**	**Mn**	**Zn**	**B**	**SO4**
Sample name	g/l	-	us/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Standard Brassica peat mix	359	5.16	176	34.1	37.5	71.6	29.2	76.7	23.7	29.7	29.7	2.8	42.7	0.1	0.2	0.1	0.2	169.4
Green compost 1- 25%	419	6.38	260	1	55.9	56.9	161.8	234.6	21.9	50.9	87.8	2.12	38.2	<0.06	0.16	0.33	0.35	129.5
Green compost 1-50%	471	7.09	290	1.8	24.7	26.5	240.3	333.2	9.6	32.2	116.9	2.37	36.6	<0.06	0.22	1	0.49	88.7
Green compost 2-25%	485	6.16	445	1.3	158.5	159.8	155.2	526.1	42.0	78.2	63.0	3.2	44.6	0.1	0.1	0.2	0.4	239.8
Green compost 2-50%	600	6.59	664	1.4	248.4	249.8	305.2	979.6	35.0	78.4	91.9	3.9	45.2	0.1	0.1	0.3	0.7	298.1

Table 2. Chemical analyses of a) raw green compost material and b) experimental peat-amended mixes used for autumn-sown experiments (Den = bulk density; Cond = conductivity; TON = total organic nitrogen)

a) Raw material analyses

	Den	**pH**	**Cond**	**NH_4-N**	**NO_3-N**	**TON**	**Cl**	**K**	**Mg**	**Ca**	**Na**	**Fe**	**P**	**Cu**	**Mn**	**Zn**	**B**	**SO4**
Sample Name	g/l	-	us/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Green compost 3	752	7.9	475	11.2	<0.6	11.2	234	660	38.2	81.9	106	9.65	3.6	0.11	0.77	0.32	0.35	59.2
Green compost 4	606	8.4	586	8	17.1	25.1	723	858	11	52	153	12.8	23.3	0.15	0.63	0.47	0.43	24.5

b) Green compost/peat mixture analyses

	Den	**pH**	**Cond**	**NH_4-N**	**NO_3-N**	**TON**	**Cl**	**K**	**Mg**	**Ca**	**Na**	**Fe**	**P**	**Cu**	**Mn**	**Zn**	**B**	**SO4**
Sample name	g/l	-	us/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Standard Brassica peat mix	357	5.61	180	45.7	65.7	111	20.5	65.2	23.2	29	34.5	1.55	17.1	<0.06	0.14	<0.06	0.11	146
Green compost 3- 25%	431	6.12	225	28.6	80.9	110	43.8	172	24.1	36.8	45.3	6.2	10	<0.06	0.29	0.1	0.22	133
Green compost 3- 50%	621	7.1	317	7.7	73.9	81.6	149	383	22.6	43.9	72.3	9.61	2.7	0.07	0.39	0.21	0.4	131.8
Green compost 4- 25%	423	6.44	312	36.7	60.9	97.6	180	304	20.5	40.9	71.4	7.19	33.2	<0.06	0.23	0.19	0.31	125
Green compost 4- 50%	511	7.3	475	10.6	41.2	51.8	456	620	17.3	58	119	10.4	32.1	0.1	0.48	0.44	0.41	71.8

3. *Plant vigour in the field*: once the plants in each experiment were established (approximately three weeks after planting), a subjective field vigour score (1=poor, 9=good) was assigned to each plot in each replicate.
4. *Harvest quality*: as plants in the experiments approached maturity, 50 plants in each plot were marked out for harvesting. When mature, the cauliflower heads were assessed according to the EU Marketing Standards for Class 1, Class 2 and Unmarketable on a number of successive harvest dates until all 50 plants were harvested. The date of harvest for each plant provides a determination of the 50% harvest date for each treatment. Each head in the calabrese experiments was weighed to give a weight of marketable and unmarketable heads for each treatment using a minimum head weight of 250 g in the over-wintered experiment and 110 g in the spring-sown experiment. The reasons for downgrading quality were recorded for both cauliflower and calabrese.

Assessment of* E. coli *and* Salmonella *on planted material

One of the main concerns growers and retailers have with the use of green compost is the risk of pathogen transfer from the compost to the young plant and eventually into the edible portion of the plant. These concerns have little foundation as the PAS 100 standards specifically limit the feedstock of composted materials to collected green waste from which the risk of transmitting harmful pathogens is minimal. In addition, the composting process if followed correctly should prevent the survival of human and plant pathogen from entering the final product.

Two 1 kg random samples (from a total batch size of 160 kg) of the four green compost mixes at the 50% inclusion rates were taken prior to tray filling. Two separate microbiological determinations were done by a contract laboratory on each sample. Consideration was given to sampling the compost mixes at planting rather than at tray filling but faecal contamination from pied wagtails *(Motacilla alba)* perched over the seedlings during the propagation in the glasshouse could have adversely influenced the results.

Results

Objectives 1 & 2

Data to fulfill Objective 1 (raise healthy cauliflower and calabrese plants through the winter and early spring periods from two different sources of green compost blended with peat) and Objective 2 (determine if cell size and source of green compost has any impact on seedling quality) are considered together.

Over-wintered trials

Minor difficulties were experienced filling the trays with both green composts (GC1 and GC2) due to small stones, twigs and fibres that tended to clog the augers and prevent cell-filling especially of 345 trays. The PAS 100 standard clearly sets acceptable limits for each of these materials which were met by these mixes.

<u>Percentage useable plants</u>

The germination of the seed in all treatments was high. There was no significant difference in the percentage useable plants for either calabrese (assessed 6 October 2006, 16 days after sowing) or cauliflower (assessed 27 October 2006, 14 days after sowing) between the different compost mix/tray combinations (Table 3).

<u>Plant vigour and uniformity during propagation</u>

Vigour scores were collected when the calabrese plants reached the second true leaf stage on 6 October 2006, 16 days after sowing. The 126 trays produced the most vigorous calabrese seedlings probably due to the greater volume of media available to the seedlings, while the 345 trays tended to produce seedlings with lowest vigour. In the 216 trays, the GC2 produced similar- sized seedlings to the peat control at both inclusion rates. Plants grown in GC2 tended to be darker in colour that seedlings grown in GC1 (Table 4).

For calabrese, GC1 at both 25 and 50% and 100% peat all produced significantly smaller seedlings in the 345 trays compared with GC2. In this tray size the cotyledons and first true leaves of GC1 were not as large as peat or GC2. By 20 October 2006, seedlings in 126 trays of GC2 compost were starting to form bent stems due to excessive growth. Although these plants had not been fed, the higher level of nitrogen in the compost (Table 1) combined with warm autumn weather, was causing excessive growth. Seedlings in GC1 at 50% were at this stage shorter with smaller leaves and starting to turn purple so required feeding. Seedlings growing in the 216 trays with 100% peat and GC1 at 25% were at a good size and stage of development while seedlings in GC1 at 50% were small. In the 345 trays, seedlings in the GC2 mixes were excessively large, whereas those in 100% peat and GC1 mixes were of an ideal size.

Table 3. Percentage useable calabrese and cauliflower plants in autumn-sown experiments assessed 16 and 14 days after sowing respectively

	Calabrese			**Cauliflower**		
	Tray sizes			**Tray sizes**		
Media	**126**	**216**	**345**	**126**	**216**	**345**
Peat 100%	97.6	97.3	97.7	92.2	91.4	92.0
GC1 at 25%	97.2	97.9	98.1	92.6	92.6	92.7
GC1 at 50%	96.6	98.4	97.4	91.6	91.3	91.5
GC2 at 25%	97.0	98.1	97.9	91.7	90.1	90.9
GC2 at 50%	97.2	97.3	97.2	92.6	91.8	92.2
Grand mean		97.5			91.8	
d.f.		42.0			42.0	
SED		0.78			1.58	
LSD (P=0.05)		1.58			3.19	

Table 4. Mean plant vigour score for calabrese and cauliflower plants at second true leaf stage in autumn-sown experiments assessed 16 and 17 days after sowing respectively

	Calabrese			**Cauliflower**		
	Tray sizes			**Tray sizes**		
Media	**126**	**216**	**345**	**126**	**216**	**345**
Peat 100%	7.0	6.0	4.0	7.0	7.0	7.0
GC1 at 25%	7.0	5.0	3.0	8.0	8.0	8.0
GC1 at 50%	7.0	5.0	3.0	8.0	8.0	8.0
GC2 at 25%	7.0	6.0	5.0	7.0	7.0	7.0
GC2 at 50%	7.0	6.0	6.0	7.0	7.0	7.0
Grand mean		5.6			7.4	
	Media		Tray size	Media		Tray size
d.f.	53		53	No analysis done		
SED	0.22		0.17			
LSD (P=0.05)	0.44		0.34			

The cauliflower seedlings were scored for vigour on 30 October 2006. The cauliflower reacted differently to the calabrese with seedlings grown in GC1 at both 25 and 50% inclusion rates showing stronger plants with more expanded leaves compared with the 100% peat control and GC2 mixes. This is likely to be due to the slower growth of cauliflower seedlings. By 10 November 2006, the position was reversed with cauliflower seedlings growing in GC2 at both levels of inclusion in 345 trays being larger than those growing in peat and GC1. In the 126 trays all seedlings were of a similar size.

Plants were scored for uniformity in each treatment on 30 October 2006; there were no differences between treatments indicating high uniformity within and between treatments.

On 30 January, flower buds appeared in the calabrese growing in 126 trays of GC2 compost, probably due to the early rapid growth of plants in this medium. No new bolters were produced after the initial number and on 21 March 2007 the proportion of bolters in the four replicates averaged 28.25%.

Feeding of calabrese began with GC1 in 345 trays 27 days after sowing and again including 216 trays five days later with the 126 added two days later. All treatments including peat had been fed by 28 November.

Cauliflower in GC1 mixes in both 216 and 345 trays required feeding 33 days after sowing followed by another feed five days later for the 345 trays. All 126 trays and GC2 mixes in other trays did not receive a full feed until 9 February.

<u>Plant vigour in the field</u>

At planting, no difficulties were encountered with transferring the plants onto the planter and into the soil. Rooting in the module was good for both calabrese and cauliflower. Field vigour scores were taken after establishment for the over-wintered calabrese trial only. All plots established well with consistently high vigour scores (8) resulting in no differences between treatments. The over-wintered cauliflower trial suffered from severe pigeon, hare and cabbage root fly attack that subsequently resulted in the loss of the trial. Cabbage root fly protection was not applied to the modules pre-planting due to the early planting date.

Spring sown trials

No difficulties were experienced filling the trays with any of the mixes of green compost.

Percentage of useable plants

In the calabrese experiment, there was no effect of tray size or media type on the percentage of useable plants (Table 5). In the cauliflower trial, higher useable plant counts were produced by seedlings in the 504 trays compared with 216 and 345. Differences in useable plant counts were only significant between plants grown in 504 and 216 trays in the GC3 at 50% medium.

Table 5. Percentage useable calabrese and cauliflower plants in spring-sown experiments assessed 21 March 2007 (21 days after sowing)

	Calabrese			**Cauliflower**		
	Tray sizes			**Tray sizes**		
Media	**216**	**345**	**504**	**216**	**345**	**504**
Peat 100%	95.4	95.0	95.4	89.4	91.4	92.9
GC3 at 25%	94.8	94.7	96.4	90.7	90.7	93.1
GC3 at 50%	94.4	95.0	95.4	89.8	89.9	92.7
GC4 at 25%	95.4	96.1	96.2	89.0	88.7	90.4
GC4 at 50%	95.8	94.5	94.4	90.5	90.5	89.8
Grand mean	95.3			90.6		
d.f.	42.0			42.0		
SED	1.02			1.42		
LSD (P=0.05)	2.06			2.86		

Table 6. Mean plant vigour score for calabrese and cauliflower plants at second true leaf stage in spring-sown experiments assessed on 11 April 2007 (42 days after sowing).

	Calabrese			**Cauliflower**		
	Tray sizes			**Tray sizes**		
Media	**216**	**345**	**504**	**216**	**345**	**504**
Peat 100%	7.0	7.0	7.0	7.0	7.0	7.0
GC3 at 25%	7.0	7.0	7.0	6.3	7.0	6.0
GC3 at 50%	5.5	4.5	4.8	5.3	5.0	4.8
GC4 at 25%	5.8	5.0	4.8	5.0	5.0	5.0
GC4 at 50%	3.5	3.5	3.5	4.0	4.0	4.0
Grand mean	5.5			5.5		
d.f.	42.0			42.0		
SED	0.29			0.16		
LSD (P=0.05)	0.59			0.33		

Plant vigour during propagation

Plants grown in 100% peat produced the most vigorous calabrese and cauliflower plants across the three tray sizes. The 100% peat control and GC3 at 25% produced calabrese and cauliflower seedlings in all tray sizes with significantly higher vigour levels than the other media treatments. GC3 at 50% and GC4 at 25% in all tray sizes produced seedlings with significantly better vigour than GC4 at 50%. The latter media was the first to show signs of nitrogen deficiency and require feeding.

In the calabrese, an interaction between the effect of smaller tray size on media was apparent for GC3 at 50% and GC4 at 25% while there was no affect on 100% peat, GC3 at 25% or GC4 at 50%. In the cauliflower, the interaction of smaller tray size and media was most apparent in GC3 at 50%.

Calabrese and cauliflower plants in all treatments were scored for uniformity on 11 April 2007 (Table 7). The 100% peat (control) had consistently high scores for both calabrese and cauliflower. GC3 at 50% had the lowest scores in both experiments. In the cauliflower experiment, GC3 at 50% produced low uniformity scores in all tray sizes while GC4 at 50% scored low in the 216 trays compared with 345 and 504 trays. This may have been a tray position effect in the glasshouse.

Table 7. Mean uniformity scores (1=poor, 9=good) for spring-sown calabrese and cauliflower plants assessed at the two true leaf stage on 11 April 2007 (42 days after sowing)

	Calabrese			**Cauliflower**		
	Tray sizes			**Tray sizes**		
Media	**216**	**345**	**504**	**216**	**345**	**504**
Peat 100%	8.0	8.0	8.0	8.0	8.0	7.3
GC3 at 25%	7.8	8.0	8.0	6.8	6.3	6.8
GC3 at 50%	7.8	6.5	7.0	5.3	5.3	5.3
GC4 at 25%	7.8	7.8	8.0	5.8	5.5	6.8
GC4 at 50%	8.0	7.8	8.0	5.8	7.0	7.0
Grand mean	7.8			6.4		
d.f.	42.0			42.0		
SED	0.21			0.44		
LSD (P=0.05)	0.43			0.89		

The cauliflower seedlings were more demanding of the media than the calabrese with variations in compost consistency showing up between trays of the same media and highlighted in the uniformity scores.

Feeding of both cauliflower and calabrese began 27 days after sowing with GC4 at 50% in 345 and 504 trays with 216 trays added five days later. The seedlings in 504 trays required feeding twice at this stage. CG3 at 25% in 216 trays were the last to require feeding on 15 April 2007, 46 days after sowing.

Plant vigour in the field

Rooting of cauliflower in the 504 trays appeared weak compared with the calabrese. Rooting had improved by mid-May. Observations suggested that *Rhizoctonia* (wirestem) infection was worse in plants from the 504 trays compared with those grown in 345 trays, possibly due to the dense, damp conditions below the leaves being an ideal environment for the development of the disease. All media treatments seemed to be equally affected. Field vigour scores for all treatments are given in Table 8.

Table 8. Field vigour score (1=poor, 9=good) for calabrese plants three weeks after planting in spring-sown experiments

	Tray sizes		
Media	**216**	**345**	**504**
Peat 100%	6.5	5.5	5.3
GC3 at 25%	6.5	7.3	5.3
GC3 at 50%	7.3	6.0	5.5
GC4 at 25%	6.8	5.5	5.0
GC4 at 50%	6.5	6.5	5.3
Grand mean		6.0	
d.f.		42.0	
SED		0.47	
LSD (P=0.05)		0.94	

All 504 trays irrespective of media type produced calabrese plants with lower vigour scores compared with plants from 216 and 345 trays. The lowest vigour was produced by GC4 at 25% in 504 trays.

Field vigour scores were not taken for the spring cauliflower trial due to planter effects that were observed after planting and persisted close to harvest.

Objective 3

The detailed analyses of the chemical composition of the raw green composts, and the experimental mixes, have already been presented (Tables 1 and 2). The aim of this objective was to compare the chemical content and properties of green compost made in the summer (GC1 and GC2, used to propagate over-wintered plants) with green compost made during the winter (GC3 and GC4, used to propagate spring-sown plants). The analysis of the peat used in both over-wintered experiment and in the spring-sown experiment was similar with the only significant difference being the higher NO_3 -N and Total Organic Nitrogen (TON) in the spring-sown trials (Figure 8).

It is apparent from Figures 8 and 9 (which are plotted on the same scale) that batch-to-batch variation in the chemical composition of 100% peat composts is very low. The degree of variation in individual nutrients in green compost batches was much higher. In addition, variation in green compost batches was at least as great between batches made at the same time of year, as the variation between batches made at different times of year. For example, the summer-made compost had higher levels of nitrate (NO_3-N), Total Organic Nitrogen (TON) and Chlorine (Cl) compared with the winter composts, but the two samples of summer-made composts also differed from each other with GC2 having substantially higher levels of Chlorine, Potassium (K), Sodium (Na) and Iron (Fe) than GC1.

The analysis of all mixes after incorporation of peat (Figure 10 & 11) showed that inclusion of peat resulted in a progressive reduction in the density, pH, conductivity, Chlorine, Calcium, Sodium, Iron, Manganese, Zinc, Boron and SO_4 (sulphate) content as the proportion of peat increased.

Figure 8. Relative differences in the chemical composition of 100% peat compost used for growing over-wintered ('summer' compost) and spring-sown ('winter' compost) calabrese and cauliflower (negative values indicate lower values in the 'summer' compost compared with the 'winter' compost; positive values indicate higher values in the 'summer'' compost compared with the 'winter' compost).

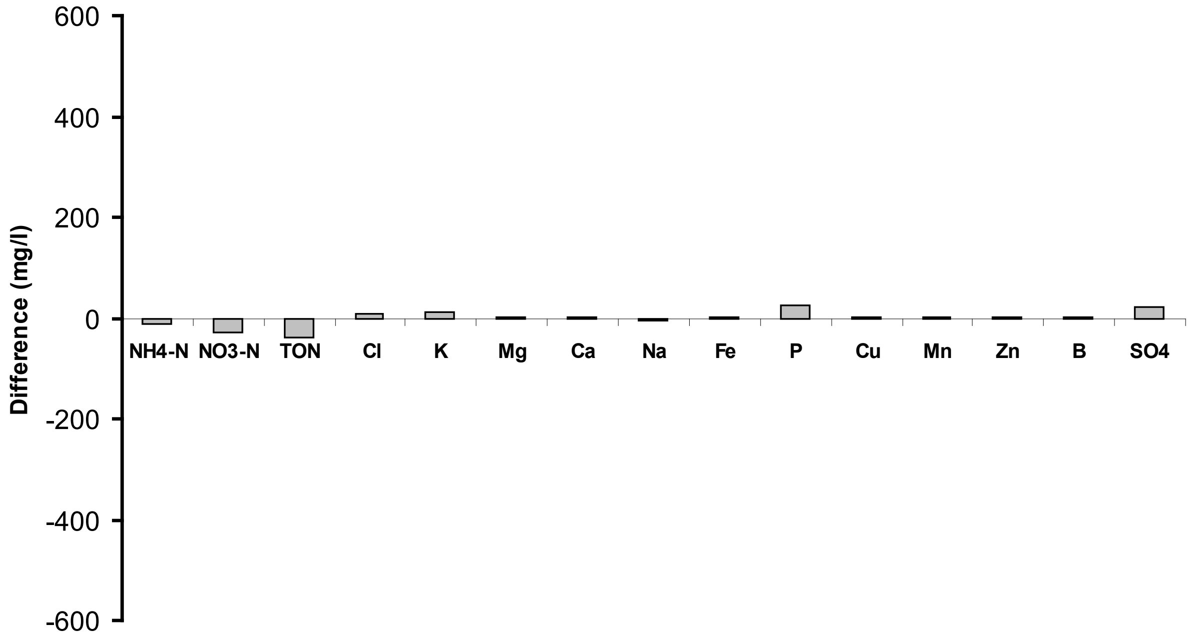


Figure 9. Relative differences in the chemical composition of the two summer-prepared composts (GC1 vs GC2), the two winter-prepared composts (GC3 vs GC4), and the mean of the summer and winter composts (mean of GC1 & 2 vs mean of GC3 & 4).

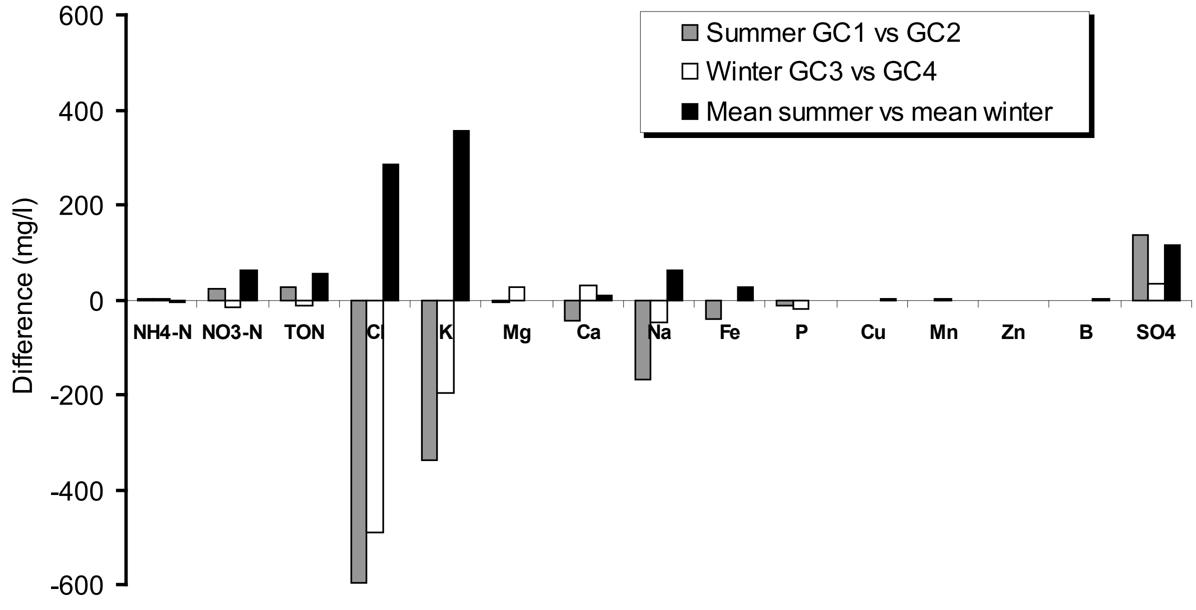


Figure 10. Chemical composition of 'summer' compost mixes used for growing over-wintered calabrese and cauliflower

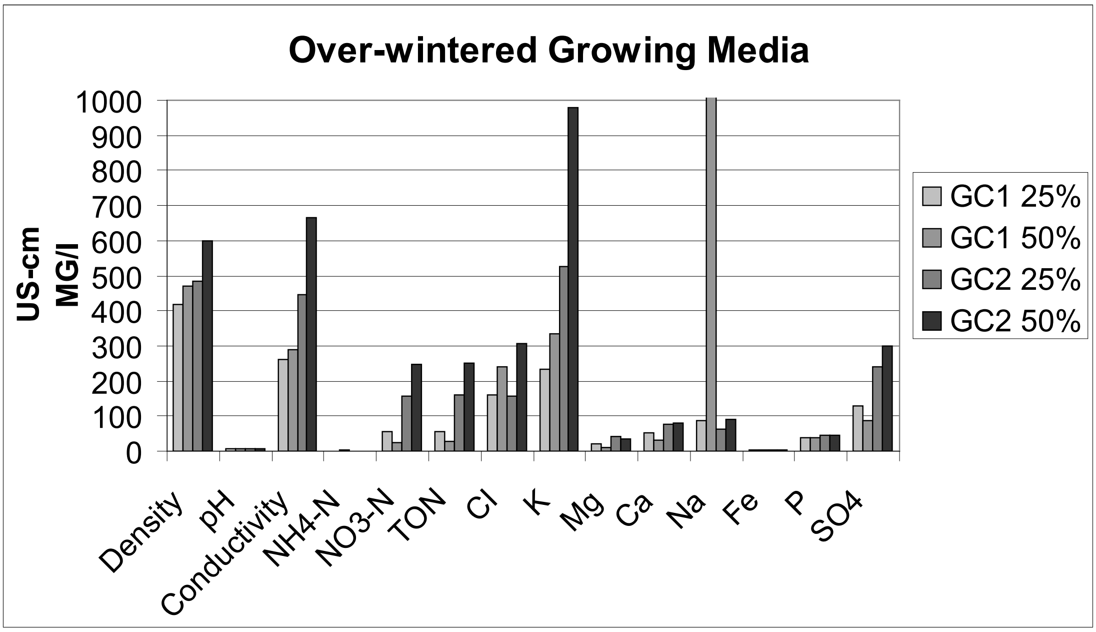
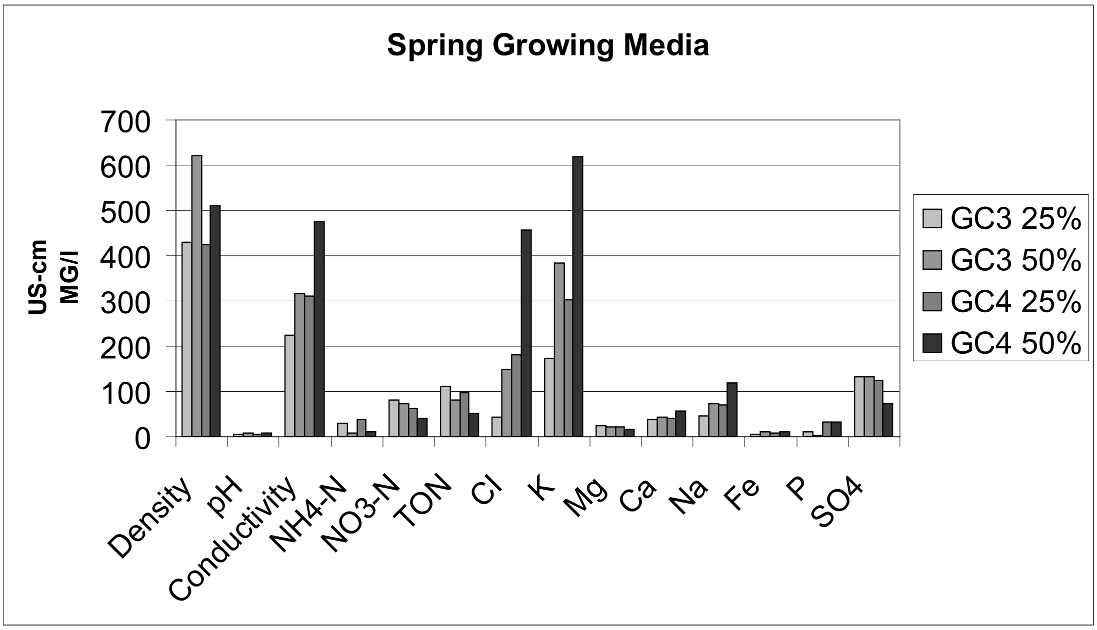


Figure 11. Chemical composition of 'winter compost mixes used for growing spring-sown calabrese and cauliflower



The summer and winter made mixes were similar in density, pH, conductivity, Potassium (K), Magnesium (Mg), Calcium (Ca), Copper (Cu), Manganese (Mn), Zinc (Zn), and Boron (B) but levels of NH_4-N were higher in the winter-made composts.

The two summer-made mixes (Figure 9) have similar density, pH, NH_4-N, Chlorine, Calcium, Sodium, Iron, Phosphorous, Copper, Manganese, Zinc and Boron. CG1 has lower levels of NO_3-N, Total Organic Nitrogen, Potassium, Magnesium, Calcium and SO4 to GC2. The vigorous growth of seedlings in GC2 is the result of the high nitrogen content compared to GC1 and peat. The two winter made mixes have similar density, conductivity, NH_4-N, Total Organic Nitrogen, Magnesium, Calcium, Iron, Copper, Manganese, Zinc and Boron. GC4 at 50% has higher levels of Chlorine, Potassium and Sodium compared with GC at 25% and GC1.

High levels of Potassium and Chlorine in growing media can be detrimental to plant growth. However, the levels of Chlorine, Potassium and Sodium ions in all mixes made during summer and winter did not have any effect on germination levels or useable plant count when compared with the lower levels of ions in the peat control.

Objective 4

The aim of this objective was to assess levels of *E. coli* and *Salmonella* on planted material.

The results for *Salmonella* were ‘Not detected’ per 25g (method ref MICRO/190) and for *E. coli* , <10 cfu/g (method ref EUMM3.02) in all sixteen samples tested. Each sample was tested twice as a cross- check.

These results are within the PAS 100 standard for composted green waste for which the limit for *Salmonella* is zero and *E. coli* <1000cfu/g.

Objective 5

The aim of this objective was to determine if the impact of cell size and source of compost on final marketable yield and harvest date.

Over-wintered experiment

The results of the harvest of the over-wintered calabrese crop are given in Table 9 (the cauliflower experiment was not harvested due to excessive crop damage, see above).

Table 9. Total marketable weight (kg) and days to 50% cut for autumn-sown calabrese

	Total marketable weight			**Days to 50% cut**		
	Tray sizes			**Tray sizes**		
Media	**126**	**216**	**345**	**126**	**216**	**345**
Peat 100%	11.5	10.0	8.3	87.5	87.8	90.5
GC1 at 25%	14.8	12.9	10.4	87.8	86.3	87.8
GC1 at 50%	11.3	11.5	10.5	87.8	87.8	89.0
GC2 at 25%	11.7	11.9	10.0	87.8	87.8	90.5
GC2 at 50%	8.4	10.9	10.3	86.3	87.5	89.0
Grand mean		11.0			87.9	
d.f.		42			442	
SED		1.89			1.72	
LSD (P=0.05)		3.82			3.48	

There were no significant differences in the marketable weight of calabrese heads irrespective of tray size or media. The average number of days is 87 from transplanting to harvest of all treatments. There is no significant difference in the days to 50% cut except plants grown in 345 trays containing peat and GC2 at 25% that are significantly later to mature than 126 trays growing GC1 at 25% and GC2 at 50%.

Spring-sown experiment

Calabrese

The results of the yield assessments on the spring-sown calabrese are given in Table 10. There were significant differences between all three tray sizes (tray size Least Significant Difference (LSD) at *P*=0.05 = 1.033) with plants grown in 216 trays producing the highest total marketable weight. There are also significant differences in days to 50% cut with plants grown in 216 trays reaching maturity significantly earlier than those grown in 345 and 504 trayst. Plants grown in 345 trays also reached maturity faster than those grown in 504 trays (tray size LSD at *P*=0.05 = 0.765).

Table 10. Total marketable weight (kg) and days to 50% cut for spring-sown calabrese

	Total marketable weight			**Days to 50% cut**		
	Tray sizes			**Tray sizes**		
Media	**216**	**345**	**504**	**216**	**345**	**504**
Peat 100%	13.6	10.8	8.7	80.5	82.8	82.8
GC3 at 25%	14.0	12.5	8.7	81.3	82.0	85.0
GC3 at 50%	15.3	11.3	9.2	79.0	82.8	84.3
GC4 at 25%	13.9	11.1	9.6	80.5	82.0	83.5
GC4 at 50%	14.7	11.6	9.2	80.5	82.0	82.8
Grand mean	11.6			82.1		
d.f.	42.0			42.0		
SED	1.13			0.85		
LSD (P=0.05)	2.29			1.71		

Cauliflower

The results of the yield assessments for the spring-sown cauliflowers are given in Table 11 (percentage Class 1 & 2 assessments) and Table 12 (percentage unmarketable and days to 50% cut). Plants grown in 504 trays produced a significantly higher proportion of Class 1 heads in all media than those grown in 216 trays. Plants grown in 100% peat in 345 trays producing the highest proportion of Class 1 heads.

There was a significant tray size effect on the percentage of Class 2 heads (Table 11). Plants grown in 216 trays produced a significantly higher proportion of Class 2 heads than plants grown in 345 or 504 trays. The proportion of Class 2 heads was also higher from plants grown in 345 trays compared to those grown in 504 trays. Loose heads were the main reason for downgrading plants grown in 216 trays to Class 2.

Table 11. Percentage of Class 1 and Class 2 heads produced by spring sown cauliflower

	% Class1			% Class 2		
	Tray sizes			Tray sizes		
Media	**216**	**345**	**504**	**216**	**345**	**504**
Peat 100%	51.0	70.1	73.0	35.0	17.2	12.7
GC3 at 25%	57.2	62.5	67.4	25.1	23.5	13.8
GC3 at 50%	60.2	51.3	68.5	26.3	28.0	19.3
GC4 at 25%	49.2	66.4	69.4	35.6	22.8	17.1
GC4 at 50%	62.2	66.0	60.9	25.7	23.8	19.6
Grand mean		11.6			82.1	
d.f.		42.0			42.0	
SED		9.15			7.01	
LSD (P=0.05)		18.46			14.15	

Table 12. Percentage unmarketable heads and days to 50% cut for spring-sown cauliflower

	% Unmarketable			Days to 50% cut		
	Tray sizes			Tray sizes		
Media	**216**	**345**	**504**	**216**	**345**	**504**
Peat 100%	14.0	12.6	14.3	93.0	95.0	101.0
GC3 at 25%	17.7	14.0	18.8	93.0	93.0	97.0
GC3 at 50%	13.5	19.7	11.6	95.0	95.0	93.0
GC4 at 25%	15.2	10.8	13.0	93.0	93.0	95.0
GC4 at 50%	12.1	10.2	19.1	93.0	93.0	96.3
Grand mean		14.4			94.6	
d.f.		42.0			42.0	
SED		5.73			1.89	
LSD (P=0.05)		11.57			3.88	

There were no significant differences in the percentage unmarketable heads between treatments (Table 12). Plants grown in 504 trays reached harvest significantly later than plants grown in both 216 and 345 trays (tray size LSD P=0.05 = 1.709). Plants grown in 100% peat in 504 trays reached harvest last.

Discussion

The experiments reported in this project were designed as a preliminary evaluation of green compost as a potential component of media for growing Brassica seedlings. The number of green composts tested was limited, and as each batch of composted raw material will have different physical and chemical characteristics, the results presented here should be treated with caution as they are specific to the compost batches used in the experiments. The skill of a media supplier is to ensure the resulting mixes with peat meet the demanding requirement of the commercial propagator and have the correct balance of nutrients to ensure healthy seedling growth. The potassium and chloride levels in all raw materials are usually high and can upset the availability of magnesium and calcium if they are not diluted or leached out of the media with watering. High chloride levels can also interfere with nitrate uptake if the mix is dominated by one ion or the other. This is exemplified in GC4 (Table 2) where there was a dominance of chloride ions and low available nitrate ions resulting in starved growth of the young seedlings. Over-dominance of nitrate ions as in GC2 gave too much available nitrate in the over-wintered trial, resulted in excessive growth. The level of nitrogen and other ions in the mixes gives a clear indication of how vigorous the seedlings produced are likely to be. High vigour scores in the over-wintered experiment showed that the 100% peat had the optimum nutrient balance for that experiment and produced healthy seedlings. Ameliorating the green compost mixes to the correct physical and chemical levels is therefore paramount with a requirement for consistency of quality throughout the year.

It is also essential that media are free of stones, wood, polythene and any other coarse material that may obstruct tray filling. Where the smaller 504 cells are used, bridging across the cell walls and poor filling at the bottom of the module is likely if the density of the media is too high or if any particle size is greater than 3 mm. The bulk density of the samples used were only just acceptable for the experiment, but were within the 600 g/l limit set by the PAS 100 standards. Thorough mixing of the media is also essential or lack of uniformity of growth in the media may be experienced (e.g. in the spring-sown cauliflower experiment, Table 7).

In general, all the green composts tested performed very satisfactorily for raising module Brassica plants. Observed differences in growth were predictable from the chemical analyses of the mixes. Some of the differences in plant growth between media, tray type or interactions between them were significant, but in practice these could be managed by adjustment of feeding or watering regimes. Comparing different media in differing tray sizes and raising them all using the same growing regime did not, in effect, realise the full potential of each media/tray combination. However, the work has clearly demonstrated that suitable green composts can be produced which when mixed with peat in up to 50% inclusion rates can produce an ideal growing media for Brassica seedlings, and consequently result in no loss of quality of the final product when compared with plants grown in 100% peat. At planting, no difficulties were experienced with the media root-ball collapsing and preventing the plants being transferred to the soil. Similarly, the application of a chlorpyrifos drench to the plants was effective at preventing cabbage root fly damage, ensuring that the plants established successfully in the field. The 2007 Brassica-growing season was very wet and did have an over-riding effect on the establishment of the over-wintered cauliflower experiment which ultimately could not be harvested. Seasonal effects also increased the number of days taken to reach harvest dates for all experiments.

The 504 trays produced the highest number of useable cauliflower seedlings but the levels of *Rhizoctonia* wirestem at planting appeared to be higher than in plants grown in other tray sizes. This problem may be overcome by altering the feeding and watering regime. In the field, the vigour scores for calabrese were lowest for 504 trays (as was the marketable yield), but the spring-sown cauliflower in 100% peat media in 504 trays produced the highest proportion of Class 1 heads. The 504 trays produced the latest maturing heads of cauliflower.

The origin of the feedstock used to produce the green compost is a concern to some producers due to the potential for contamination from pathogens that could be a transferred on the produce to humans. Although no *E. coli* or *Salmonella* were detected in any of the samples used, the potential for contamination is real. Producers concerns need to be addressed by the Composting Association and WRAP either through demonstrating unequivocally that the existing standards are robust, or by increasing the standards accordingly to ensure complete pathogen elimination.

Other issues, such as consistency of product quality throughout the year, are being addressed by WRAP through an independent survey of compost producers. A key consideration is the availability (volume) and price of green compost material. Growers and plant propagators are of the view that retailers will not pay the additional cost for produce produced using green compost derived media as they anticipate a higher asking price for the media. Invariably green compost has a higher bulk density than peat so the cost of transport is more. Production at a local level therefore is important.

Conclusions

- Composted green waste collected in the summer or autumn may initially appear from analytical data to be totally unacceptable to plant propagation mixes but with careful interpretation of the results and blending with additives is capable of producing commercially-acceptable module raised transplants. This highlights the need for the collection of large data sets on analysis and performance of such materials so that sound judgements can be made on their suitability for use. In particular, nitrate and chloride levels need to be adjusted carefully as they impact on subsequent seedling vigour.
- Generally tray size and source of green compost had little impact on the percentage useable plants except in the spring-sown cauliflower trial where 504 trays produced a significantly higher proportion of plants regardless of the media used.
- Tray size can influence the percentage Class 1 of spring-sown cauliflower and total marketable yield in calabrese. Tray size may have an influence on field vigour after planting.
- Plant propagators and growers need assurance that there is an adequate supply of consistent good quality green compost available throughout the year that meets all the limits set in the PAS 100 standard for physical, biological and chemical composition.

Technology transfer

- An article is planned for HDC News in October 2007 combining the results of this experiment with those from FV321 looking at peat alternatives.

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