Project title	Brassicas: evaluating alternative media to peat for growing Brassica modules
Project number:	FV 320
Project leader:	Nigel MacDonald, ADAS
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Previous report	None
Key staff:	Nigel MacDonald, ADAS Martyn Watling, ADAS Martin Grey, WHRI
Location of project:	WHRI Kirton for plant propagation Field trial sites provided by Marshall's of Butterwick
Project coordinator:	Phillip Effingham, Marshall's of Butterwick
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Date project completed (or expected completion date):	January 2008
Key words:	Module raising, Brassicas, peat alternatives media, Miscanthus, bark

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
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ADAS

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Report authorised by:

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GROWER SUMMARY

Headline

- Trials suggest there are considerable opportunities for growers and plant propagators to reduce peat use as a growing media for Brassicas through the use of a number of viable alternatives.
- All of media alternatives tested when mixed with peat in different proportions can be used successfully for growing Brassica modules.
- Many of the alternative mixes produced seedling vigour, percentage marketability and yields at harvest of calabrese and cauliflower similar to those achieved using peat alone.
- The dry weight of plants at transplanting in 216 trays was heavier in all media compared with those produced in 345 and 504 trays with no weight advantage using 345 over 504 trays.
- Growers should consider undertaking their own trials using peat alternatives so they gain confidence in their ability to produce very acceptable plants.

Background and expected deliverables

While progress has been made in some sectors of horticulture to reduce reliance on peat, progress to find replacements in module propagation has been slow. It is anticipated that by 2010 the Brassica industry will only have reduced peat use by 10% over the amount used in 2005 (59,000 tonnes) while the whole of horticulture (including 'professional', amenity and domestic) will have reduced peat use by 75%. To date only coir has been exploited to any extent but the uptake has not been widespread due to its high cost compared with peat.

This experiment investigated the opportunity to exploit some novel media mixed in different proportions with peat for the propagation of calabrese and cauliflower modules.

The specific deliverables are:

1. To determine if peat mixed with non-peat based media at different rates can be used in modules to produce cauliflower and calabrese seedlings of similar quality to those grown in standard peat
2. To determine if there are any differences in field performance, crop yield and quality at harvest between plants grown in mixed media and those grown in standard pet compost.

Summary of the project and main conclusions

Calabrese and cauliflower seeds were sown on 14 June 2007 into 216, 345 and 504 tray sizes containing peat and alternative media mixed with peat in three replicates per treatment (Plate 1). These included Miscanthus straw, composted bark fines, pine bark, wood chip (all at 25, 50 and 75% inclusion rates), wood fibre at 25 and 50% mixes and 100% pine bark. Useable plant counts, vigour and uniformity scores were taken during the plant raising stage; plant dry weights (grams) were assessed prior to planting.

At planting, the roots held the media together to allow the plants to be removed from the trays without the root-ball falling apart. Peat and low inclusion rates of Miscanthus and wood chip produced the best quality plants, probably due to the lower levels of nitrate in these media.

After establishment, viable rooted plants were assessed in the field. At harvest, records of percentage Class 1, 2 and unmarketable were taken for cauliflower and mean weight of marketable heads and percentage marketable for calabrese. Data analysis included assessing any interactions between media type and tray size on plant quality.

Difficulty was experienced filling smaller trays with Miscanthus straw chopped to 10 mm length, so Miscanthus was not used at higher inclusion rates for the smaller tray sizes; a finer milling to 5 mm would facilitate easier filling of smaller trays and improved germination uniformity. Only pine bark was considered a viable growing media at the 100% inclusion rate.

The percentage germination and useable plant counts for both calabrese and cauliflower in all media and trays sizes were high. Analysis of plant vigour scores indicated a significant tray and media interaction but the effects were not consistent across treatments.

Plate 1. Cauliflower (left) and calabrese (right) grown in different media and tray sizes.

Calabrese experiments

Calabrese grown in 216 trays produced slightly more useable plants than those grown in 345 or 504 trays. The media producing the highest vigour score in calabrese scored at the second true leaf stage was wood fibre at 50% inclusion with peat followed by 100% pine bark and pine bark at 75% inclusion with peat, all producing higher or the same scores as 100% peat in all three tray sizes.

The highest uniformity scores taken at the same time as vigour scores were produced by 100% peat and 100% pine bark in all three tray sizes followed by pine bark at 75% inclusion and wood fibre at 50% inclusion. When the trays were compared, plants grown in 216 trays produced the highest mean uniformity score followed by plants grown in 504 trays.

Figure 1. Calabrese plant dry weights (grams) taken on 16 July 2007, 32 days after sowing prior to transplanting.

Significantly higher (P=0.05) calabrese plant dry weights (grams) were produced in all media in the larger 216 tray sizes compared with 345 and 504 trays (Fig. 1). There was a consistent pattern of dry weight reduction moving from larger to smaller tray size. Pine bark at 75% and 100% inclusion rates produced consistently high weights of plants in all cell sizes. The peat-filled trays of all sizes produced plant weights similar to the tray size means. There was no difference between the media treatments or the tray sizes on the plant establishment of calabrese or cauliflower. The mean weights of calabrese plants were similar in all tray sizes.

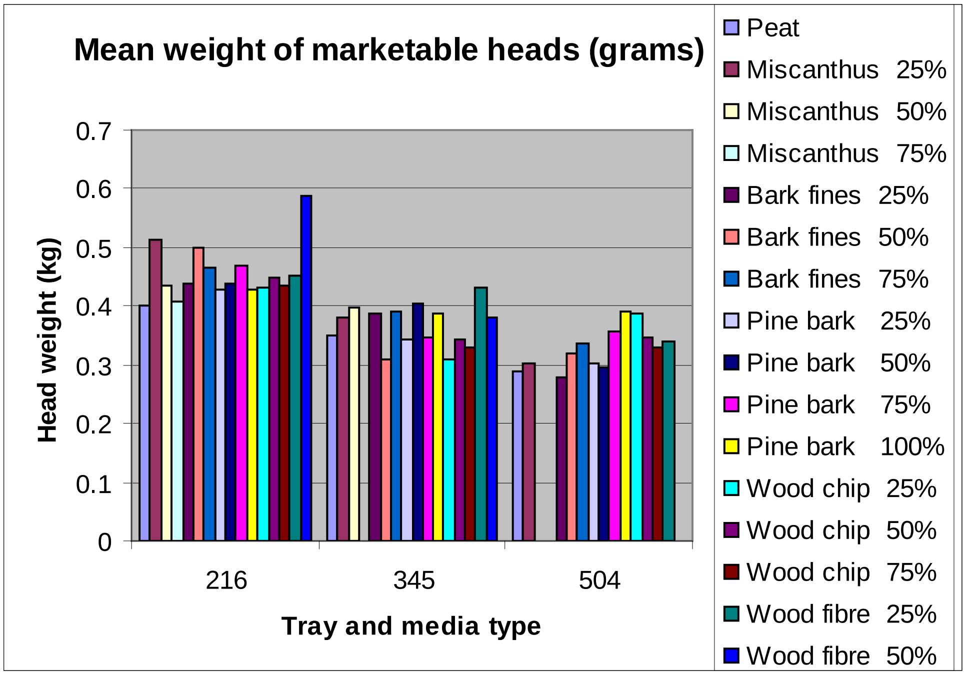

Figure 2. Calabrese mean head weights at harvest

At the harvest of the calabrese, good head weights were produced by all media. Wood fibre at 50% inclusion produced the heaviest tray mean weights with the heaviest head weights in 216 trays. 100% pine bark also consistently produced a high mean weight across all three tray sizes. In all tray sizes, several media produced plants with heavier head weights than those grown in 100% peat.

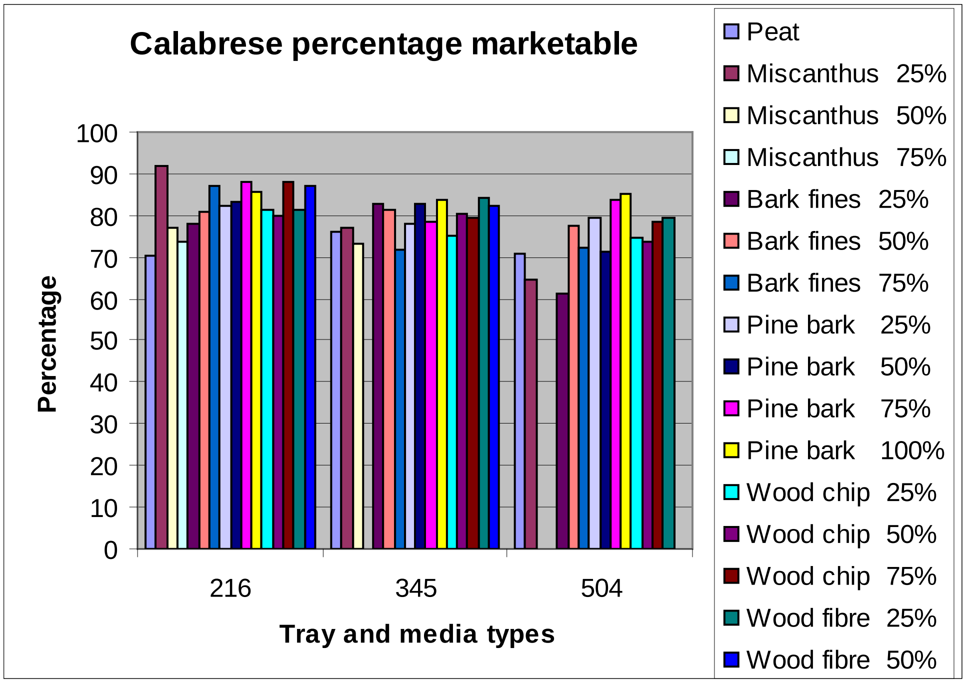

Figure 3. Percentage of marketable calabrese plants at harvest.

Miscanthus straw at 25% inclusion with peat produced the highest percentage marketable calabrese plants in 216 trays (Figure 3). A significantly higher percentage of marketable heads were produced by 216 trays over 345 and 345 trays over 504 trays. The percentage marketable heads produced by plants grown in 100% peat was below the tray mean for all tray size. Wood fibre at 25% inclusion rate was the only media to produce significantly more marketable plants in all tray sizes compared with peat.

Cauliflower experiments

There were significant differences in the useable plant count between the different media with Miscanthus at 25%, bark fines at 50%, pine bark at 25% and 75%, woodchip at 75% and wood fibre at 25% all producing significantly higher (*P*=0.05) percentages of useable plants. Miscanthus at 75% inclusion produced the lowest percentage useable plants at 79% based on limited data.

Overall, plants grown in 345 trays scored the lowest for vigour with those grown in 216 and 504 trays producing equally vigorous plants. Performance between trays sizes was inconsistent – wood fibre and wood chip produced plants with high vigour scores in 345 trays but not in 216 or 504 trays. All plants grown in 100% peat (as industry standard), produced vigour scores lower than the overall experiment mean and the individual tray means. Generally 504 trays produced cauliflower plants with the highest uniformity score closely followed by plants grown in 216 trays.

Pine bark at 75% inclusion rates and 100% pine bark both produced the highest uniformity scores. 100% pine bark produced plants with the highest mean uniformity scores across all trays.

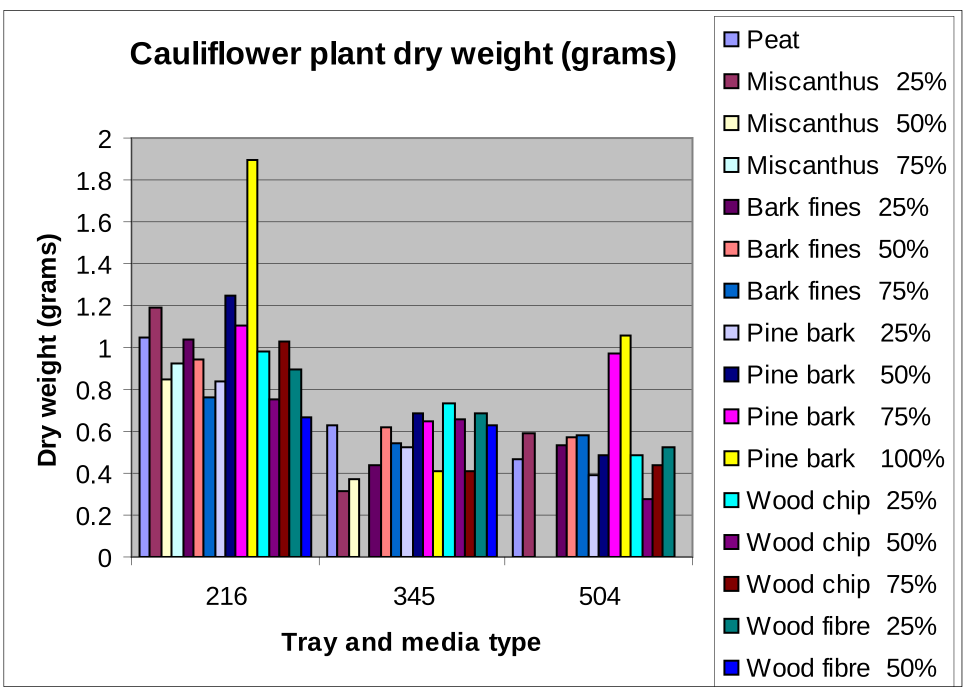

Figure 4. Cauliflower dry weights (grams) taken on 16 July 2007, 32 days after sowing and prior to transplanting.

In 216 trays, cauliflower plants grown in Miscanthus at 25%, pine bark at 50%, 75% and 100% produced high plant dry weights. Plants grown in 504 trays in pine bark at 75% and 100% also produced high plant weights compared with those grown in other media in the same tray size. As in the calabrese experiment, plants grown in 100% peat produced dry weights similar to the overall experimental mean.

Cauliflower harvesting was delayed and prolonged due to difficult soil conditions resulting in a lower percentage Class 1 and percentage marketable. No media performed consistently well in all trays. Across all three tray sizes, wood fibre at 25% inclusion and 100% peat produced the highest percentage marketable yields of cauliflower. In 216 trays, plants grown in wood fibre at 25% inclusion produced the highest percentage marketable yields, while in 345 trays, plants grown in pine bark at 50% inclusion gave high percentage marketable yields. In 504 trays, plants grown in Miscanthus at 25% inclusion or 100% pine bark produced the highest percentage marketable yields.

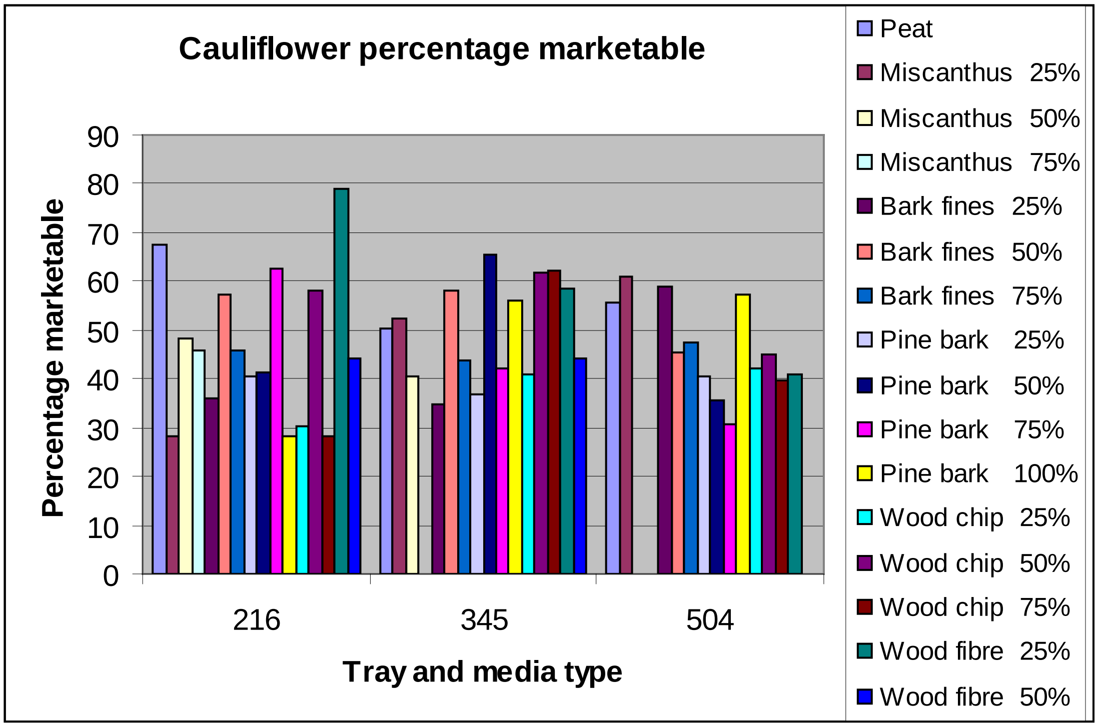

Figure 5. Percentage of cauliflower plants marketable at harvest.

Financial benefits

- Calabrese grown in 216 trays produced on average a mean head weight increase of 100 grams over heads grown from 345 trays. This equates to an addition 4.2 tonnes per hectare on commercial populations (44,804 plants per ha). While the head weight of 360 grams achieved by the plants grown in 345 trays meets current fresh market specifications, where large heads are grown for processing, such yield advantages should be taken seriously if the additional costs of the larger cell and transport can be off set by the increased tonnage gained. In addition, the experiment also found across all media, a 4% increase in percentage marketable attributed to the larger cell size. The additional cost per hectare of plants in 216 trays over 345 trays approximates £195/ha. To this needs added the higher costs of transporting larger cells from the nursery to the farm/field. A lorry will cost £3.25 per mile to transport 662,400 plants in 345 trays or 414,720 plants in 216 trays making 216 plants 62% more expensive to haul. Clearly the grower closer to the nursery can benefit most from using 216 trays with the considerably higher yield.

- In the similar way, savings can be made by utilising 504 trays over 345 trays as it has been shown that there is very little head weight reduction in calabrese (360 grams to 330 grams) by using 504 trays. The savings in plant costs by using 504 cells are only £25 per hectare but if the plants are being transported far from nursery to farm, the savings may be considerable with 33% more 504 trays carried per lorry. To counter this benefit, the percentage marketable from 504 trays was lower then 345 trays by 3.5% across all media types. On good soils and with a better growing season, the differences in quality may have been less apparent. Wherever possible growers should take full advantage of these savings.
- Peat as a media costs £25 per cubic metre (ex packaging). Alternatives such as wood chip and pine bark may be viable media alternative but wood chip does not store well due to potential heating problems and pine bark is expensive at £38 per cubic metre. Pine bark which also produced good results as a growing media is more expensive (£38.00 per cubic metre) due to higher import costs than peat. Wood fibre is viewed as a primary alternative to peat at a cost of only £14.00 per cubic metre (at the time of the project) and is available in commercial quantities for plant propagators. Miscanthus although not a top performer is reliably cheaper that peat. A cost has to be included for fine milling the Miscanthus straw for smaller cells but its very low bulk density also results in it being cheaper

to haul than peat. There is scope to further evaluate how best to use Miscanthus which costs less than half the price of peat.

- Consideration has to be given to the cost of transporting media to the nursery. This will be affected by the bulk density of the material. Pine bark performed well in these experiments but transport costs of this material will be high due to its high bulk density. When mixed with a percentage of peat, the bulk density will be reduced. Wood fibre also performed well as a media and has a lower bulk density. As a further study, an assessment of the number of trays filled per tonne of Miscanthus, wood fibre and pine bark compared with peat is required to give a true comparison of costs.
- 216 trays are the most commonly used by growers for the early part of the season for earlier crop maturity where their additional cost is justified. For the maincrop period, calabrese are most commonly grown in 345 trays. Where these cell sizes are used for calabrese, there was no significant difference in the yield at harvest between the different media. Added to that, pine bark, wood chip and wood fibre at all inclusion rates produced a higher percentage marketable than 100% peat. Where cauliflower were grown in 345 trays, 50% inclusion of bark fines, pine bark and wood chip (also 75%) produced a higher percentage marketable than peat. This leaves considerable scope when growing both calabrese and cauliflower for selecting media based on price at the time of requirement as these experiments show that there are several viable alternatives to peat.
- In many cases there are few advantages in using 345 trays over 504 trays. 504 trays offer the grower considerable savings in media costs in propagation and transport costs from the nursery to the farm and from the farm to the field.

Action points for growers

- Trays with larger cell sizes produced higher yields of calabrese but there appeared to be no consistent interaction of tray size and media type with either calabrese or cauliflower.
- Pine bark at 75% and 100% and wood fibre 50% were the media that consistently produced plants with above average vigour, plant weight and marketable yield. The results with these media were often better than those achieved with plants grown in 100% peat. The above three alternative media are referred to as the 'top performers' in *Figure* 6 to 9 below.

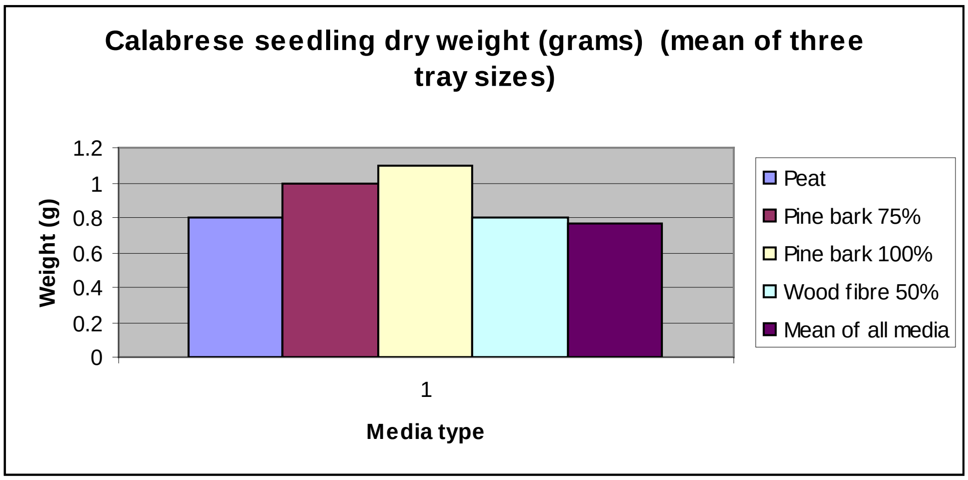

Figure 6. Mean dry weight of calabrese seedlings from 216, 345 and 504 trays are compared when grown in 'top performing' media against peat.

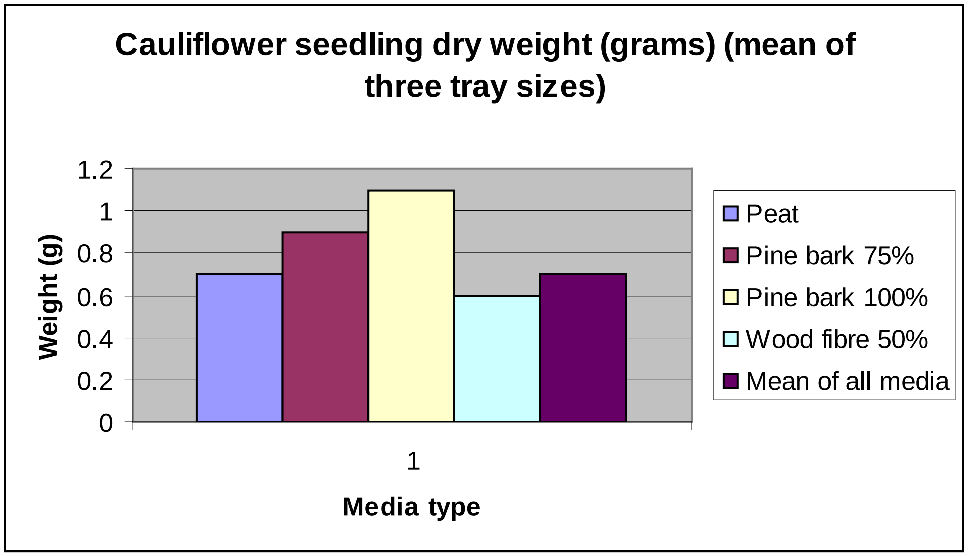

Figure 7. Mean dry weight of cauliflower seedling from 216, 345 and 504 trays Are compared when growm in 'top performing' media against peat

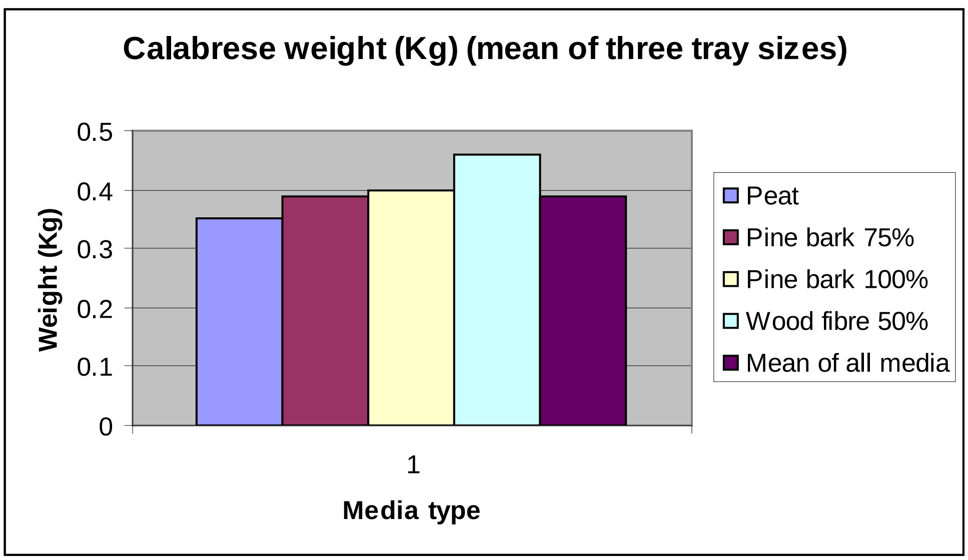

Figure 8. Mean weight of calabrese at harvest from 216, 345 and 504 trays Are compared when grown in 'top performing' media compared with peat.

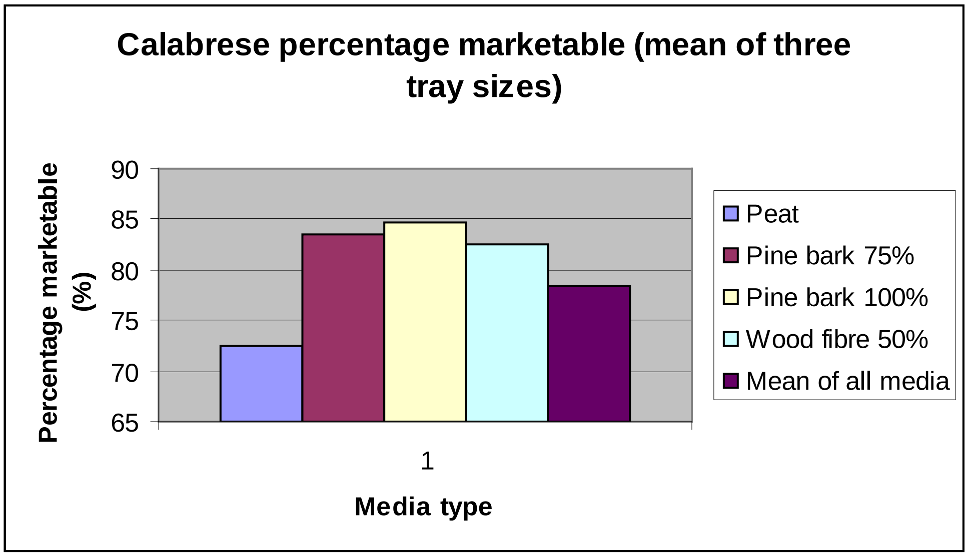

Figure 9. Calabrese percentage marketable from the mean of three

Tray sizes are compared when grown in 'top performing' media compared with peat .

- Media analysis and modification is essential for ensuring healthy quality transplants, particularly with regard to levels of available nitrate nitrogen. The media supplier plays an essential role in ensuring that all nutrients in the media are available to the plant in the right quantity and balanced with each other. An excess of nitrogen is worse than a deficiency as the plants can be fed earlier. Compost should contain no more than 120 mg/litre of nitrate and 40 mg/litre ammonia to produce healthy transplants. In addition to the nutrient content of the media, is the requirement to ensure it is milled to the required specification, determined by the tray size. 345 and 504 trays require the media to be finely milled.
- These trials demonstrate to growers and plant propagators how dependence on peat can be reduced through the use of alternative media. In particular, growers

and plant propagators should look to replacing peat with wood fibre as an economically viable alternative at almost half the cost of peat.

- Growers should consider undertaking their own trials using peat alternatives so they gain confidence in their ability to produce very acceptable plants.
- Using peat alternatives including composted green waste may offer plant propagators the opportunities to reduce pesticide inputs. *Trichoderma* can utilise the organic matter in some peat alternatives as a feed-source to compete effectively with *Rhizoctonia* spp, the organism responsible for wirestem. Exploiting these opportunities fully requires further trials and evaluation.

Science Section

Introduction

In 2005, approximately 59,000 m^3 of peat was used to raise module Brassicas. Considerable success has already been achieved in other sectors of horticulture, particularly in bedding plant and hardy nursery stock production, in significantly reducing the reliance on peat as a growing media by screening for alternatives. However, in module Brassica production, progress has been more limited. A previous HDC study (CP41 – A Review of peat usage and alternatives for commercial plant production in the UK – Final report 2006) indicated that peat use in vegetable propagation in 2010 would still be 90% of the volume used in 2005 compared with a reduction to 72% for the whole of horticulture. Government policy on sustainable use of resources and conservation of peatland seeks to reduce peat use, and most UK retailers are pushing for peat use to be minimised in all areas where it is used as a growing media, including in the production of fresh produce. Part-substitution with coir is the only viable alternative that has had some limited commercial appeal to date, but its cost is double that of peat. In experiments done by Peatering Out for WRAP in 2005, the use of mixed green compost with bark fines as a media to raise a number of vegetable species was investigated. It was found that plants grown in these media gave germination, performance and field establishment levels similar to those achieved from plants grown in peat.

HDC project FV303 demonstrated that the use of composted municipal green waste in module Brassica production can be successful when incorporated at 25% and 50% mixes with peat in three different tray sizes. However, despite the potential of composted green waste as a growing media, concerns over its use include the possible transmission of human pathogens in the compost and onto the edible parts of the plant. These issues are unlikely to be resolved while a perceived low level of risk remains due to the uncertainty of the source of the original material and the effectiveness of the composting process. Full traceability of the source of all batches needs to be assured.

In addition, the limited storability of green composted materials for use throughout most of the year and the volume required by the industry may limit its suitability as a growing media for Brassica module production.

A potential alternative to composted green waste is waste products from crop and forestry sources. These are consistent in quality, and available in sufficient volume throughout the year. These materials are also fully traceable, can be considered to be safe to the consumer, and potentially affordable to the grower. However, they have yet to be rigorously tested for use in Brassica module production.

The overall aim of the project is to determine the suitability of five alternative media derived from crop and forestry waste, mixed with peat in three different module tray sizes for raising calabrese and cauliflower plants when compared with a 100% peat growing medium. The specific objectives are:

1. To determine if peat mixed with non-peat based media at different rates can be used in modules to produce cauliflower and calabrese seedlings of similar quality to those grown in standard peat
2. To determine if there are any differences in field performance, crop yield and quality at harvest between plants grown in mixed media and those grown in standard pet compost.

Materials and methods

Treatments

The five alternative media treatments plus standard peat were delivered to Warwick HRI Kirton from Bulrush Horticulture Ltd for filling three replicates each of 216, 345 and 504 module tray sizes. Pine bark was the only media supplied at 100% inclusion rate.

Table 1. Breakdown of the media treatments, their rates of inclusion and the tray sizes into which summer cauliflower and calabrese seeds were sown

Code	Treatment	Media inclusion rates with peat			
		25%	**50%**	**75%**	**100%**
M1	Peat control	216, 345, 504	216, 345, 504	216, 345, 504	216, 345, 504
M2	Miscanthus	216, 345, 504	216, 345	216 only	Not available
M3	Composted bark fines	216, 345, 504	216, 345, 504	216, 345, 504	Not available
M4	Pine bark	216, 345, 504	216, 345, 504	216, 345, 504	216, 345, 504
M5	Wood chip	216, 345, 504	216, 345, 504	216, 345, 504	Not available
M6	Wood fibre	216, 345, 504	216, 345	Not available	Not available

Limited quantities of delivered media resulted in some trays sizes not being included namely Miscanthus (75%) in 345 and 504 trays and wood fibre (75%) in all tray sizes.

Growing media and characteristics

Miscanthus when dried, chopped and shredded has been shown to be a useful medium for growing ornamental plants even at high inclusion rates. It is readily available in the eastern counties of England where it is used as a fuel source for some power stations and bedding for domestic animals. The material used in this experiment was chopped and milled to 10 mm. Miscanthus has not previously been used as a growing media for Brassicas. It was advised while the media were being prepared that 100% Miscanthus would not produce Brassica plants due to the lack of moisture retention. At 75% Miscanthus inclusion, 354 and 504 trays were difficult to fill while the in 216 trays, the germination percentage was affected by lack of moisture retention.

Plate 1. Miscanthus 75% with peat 25%.

Plate 2. Composted Bark Fines 50% with peat 50%.

Composted bark fines are sourced only from non-deciduous trees such as Spruce (*Picea spp*) and Larch (*Larix spp*) so avoiding phytotoxic substances. The bark needs to be well composted to avoid nitrogen lock-up that occurs if breakdown of the material is not complete. A measured amount of fines were included in the mix to ensure the media was not excessively open in structure. The 100% inclusion rate was not included in the trial due to the excessively open nature of the media.

Pine bark has been used for some time to blend with peat at up to 25% inclusion rates and up to 50% for some propagation media to improve drainage and air capacity. It will accelerate root development and provide a measure of nutrient buffering along with the suppression of root pathogens. This product has a low energy input during its production. Up to 100% inclusion was used in the experiment.

Plate 3. Pine bark 100%. *Plate 4*. Woodchip (Toresa) 75%, peat 25%

Wood chip is made from white woods such as pine. Toresa is one such product in this sector. Although coarse, the product used in this experiment was graded such that only less than 10 mm chips were used to ensure easy filling of the cells in the smaller 504 tray size. 100% inclusion rate of wood chip was not used in the experiment.

Wood fibre is produced by subjecting wood chips to steam under pressure. Forest Gold Plus is one product in this sector. It has low bulk density and low nutrient content so is a useful non-peat bulk ingredient. Good results have been obtained using mixes in nursery stock where the wood fibre offers increased air capacity and drainage. Wood fibre at rates higher than 50% will not mix well with peat and were not included in the experiment.

Plate 5. Wood fibre 50% with peat 50%

To ensure the media were suitable for Brassica raising in small trays, the media were milled to 10 mm where possible before mixing with peat and enhanced with nutrients.

Clay was added to the 100% pine bark to provide some chemical cohesion for the added nutrients without which the seedling would show early deficiency symptoms. The other media are considered to be too open at 100% inclusion without peat in the mix due to their very open texture and lack of moisture and nutrient retention capability.

Details of the analysis of the media mixes after modification to ensure their suitability for sowing Brassica seedlings are given in Table 2. The density (g/l) of both bark treatments, M3 and M4, are higher than peat at all inclusion rates while treatments M5 and M6, woodchip and wood fibre, have lower densities than peat.

The levels of ammonia nitrogen NH4- N in media M5 (woodchip) were lower than the peat while most of the alternative media mixes had higher concentrations of nitrate nitrogen (NO_3-N) compared with peat, the highest being in the in 50% wood chip mix and the 75% composted bark fines. The latter treatment had the highest total organic nitrogen of all treatments.

The pH, conductivity and levels of other elements were all at similar levels to the 100% peat.

Table 2. Analysis of peat and alternative media treatments use for sowing cauliflower and calabrese seeds

Code	Media	Den.	pH	Cond.	NH_4-N	NO_3-N	TON	Cl	K	Mg	Ca	Na	Fe	P	Cu	Mn	Zn
		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
M1	**100% peat**	371	5.15	287	34.4	65.3	99.7	20.4	122	41.1	78	34.8	4.76	28.6	<0.06	0.57	<0.06
M2	**25% Miscanthus**	327	5.32	283	51.5	44.1	95.6	22.3	197	20.9	33.2	31.5	6.24	40.7	0.08	0.22	0.07
	50% Miscanthus	283	5.44	329	39.1	38.6	77.7	21.5	246	24.5	38.8	31.3	6.42	42.2	0.12	0.29	0.16
	75% Miscanthus	168	5.55	250	38.9	76.2	115.0	25.8	255	19.2	33.6	21.7	3.27	26.8	0.17	0.34	0.53
M3	**25% bark fines**	419	5.61	328	22.3	100.8	123.0	31.8	245	43.9	86.2	49.6	4.96	41.4	<0.06	0.81	0.18
	50% bark fines	428	5.85	266	13.3	47.5	60.8	37.3	265	24.9	50.8	47.7	4.07	46.0	<0.06	0.53	0.39
	75% bark fines	475	6.00	426	32.6	176.7	209.0	37.3	358	45.0	105	52.9	2.75	50.8	0.07	2.08	1.55
M4	**25% pine bark**	412	5.35	325	25.0	82.0	107.0	32.2	188	38.5	60	48.0	3.50	32.8	<0.06	0.3	0.25
	50% pine bark	436	5.52	352	18.0	102.0	120.0	33.0	256	42.0	98	35.0	4.20	28.6	0.08	0.62	0.45
	75% pine bark	459	5.90	302	30.0	95.0	125.0	28.9	202	36.0	89	26.0	3.80	29.9	<0.06	0.81	0.6
	100% pine bark	495	6.10	365	18.3	125.0	143.0	18.6	187	33.0	110	28.0	3.50	41.2	<0.06	1.5	0.62
M5	**25% wood chip**	350	5.53	274	6.0	78.3	84.3	20.6	150	52.2	93	30.9	3.48	17.7	<0.06	0.55	0.07
	50% wood chip	288	5.96	326	12.5	118.9	131.0	20.8	188	61.1	124	24.0	3.91	17.4	0.09	0.71	0.19
	75% wood chip	227	6.48	319	4.1	96.4	101.0	9.5	213	51.0	129	19.5	3.60	17.2	0.12	1.04	0.36
M6	**25% wood fibre**	303	5.67	310	39.2	69.7	109.0	31.9	177	46.7	86.4	36.2	5.12	36.3	<0.06	0.34	0.07
	50% wood fibre	250	5.70	346	45.0	82.0	127.0	25.6	189	42.0	95	30.0	5.12	35.0	<0.06	0.32	0.16

Den. = bulk density; Cond. = conductivity

Plant production

Seeds of calabrese, *Brassica oleracea* var *italica* cv. Ironman and cauliflower, *Brassica oleracea* var cv. Forward were sown on 14 June 2007, into three tray sizes (216, 345 and 504) containing six different media treatments at 25, 50 and 75% inclusion rates with peat and one treatment, pine bark, at 100%. Each tray size/media combination was replicated three times and compared with 100% peat as control.

After sowing, the seeds were 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 media. Any difficulties encountered in filling trays by hand with media or seeding trays were noted. The trays were laid out on the glasshouse floor in a randomised complete block design.

Plants were watered and fed with a proprietary feed 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 phase. Applications of fungicides and insecticides were applied to all treatments as necessary. Photographs were taken of seedlings in all media after emergence and prior to planting out illustrating the differences in both root and foliar growth in each media/tray size. All trays were treated with a Dursban WG (chlorpyrifos) drench prior to planting at a rate of 10ml/m^2 and washed off the leaf with water (2 litres/m^2).

Prior to transplanting, 60 healthy plants were selected from each of the three replicate of tray/media combinations. The calabrese were planted on 18 July and the cauliflower six days later on 24 July. The soil conditions after a prolonged wet spell during the summer were not ideal for planting but plant size and further forecasted wet weather dictated that they needed planting without further delay.

Assessments

1. *Percentage useable plants*: an assessment of the percentage useable plants from one replicate of all treatments for cauliflower and calabrese was done 19 days after sowing. A count of the number of healthy seedlings that would produce viable plants and abnormal seedlings provided a percentage based on the number of plants in the tray.
2. *Plant vigour and uniformity during propagation*: once the young plants had reached the second true leaf staged, 24 days after sowing, a subjective score (1= poor, 9 = good) assessment for plant vigour on all media treatments in all tray sizes. 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.
3. *Plant dry weight:* before transplanting, ten module plants with media from each replicate of each treatment of calabrese and cauliflower were sampled for dry weight determination by oven drying. Blank cells containing media only (excluding plants) were also oven dried and to provide a weight to allow for plant only weights.
4. *Percentage of plant establishment in the field:* three weeks after planting the calabrese and two weeks after planting the cauliflower, 50 plants were counted for establishment in each plot of each replicate in both trials. Only plants securely rooted and showing new growth was considered to be established.
5. *Harvest quality:* 50 plants in each plot were marked out with harvest commencing when 10% of plants in each plot approached maturity. All calabrese heads of marketable quality over 250 grams were weighed to give a mean weight of marketable head per plot until all heads were harvested. Unmarketable heads were

counted to enable a percentage marketable to be calculated the date of harvest for each marketable plant provided a determination of the 50% harvest date for each treatment. 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 and recorded. Heads <11 cm were considered unmarketable. The date of harvest for each plant provides a determination of the 50% harvest date for each treatment.

Statistical analysis

Data were subjected to Analysis of variance (ANOVA). Where only limited quantities of delivered media resulted in some trays sizes not being included (Miscanthus (75% inclusion) in 345 and 504 trays and wood fibre (75% inclusion) in all tray sizes), estimated missing values were used in the ANOVA.

Results

Objective 1: Quality seedling production – Assessment of seedling growth and quality.

In general, plants germinated and grew in all media and tray sizes. Supplementary plant feeding began on 9 July, 25 days after sowing. All calabrese and cauliflower plants in 345 trays were fed on this date except for plants grown in pine bark included at 75% and 100%, and wood fibre included at 50%. Plants in 504 trays were also fed on 9 July except those grown in 100% pine bark. All plants (all media an dtray combinations) were fed on 12 July.

Percentage useable plants for calabrese and cauliflower:

A count of abnormal and healthy plants in each tray of calabrese and cauliflower was undertaken to determine the useable plant count for each media in each tray size. The results are given in Tables 3 and 4.

Table 3. Percentage useable plants for calabrese assessed on 3 July, 19 days after sowing in different media and trays (* = missing value).

	Tray size			
Media	**216**	**345**	**504**	**Media mean**
Peat	95.83	96.52	95.63	96
Miscanthus 25%	97.69	95.94	95.63	96.42
Miscanthus 50%	93.98	89.86	*	91.74
Miscanthus 75%	90.74	*	*	89.67
Bark fines 25%	96.76	95.36	95.83	95.98
Bark fines 50%	97.22	92.17	96.23	95.21
Bark fines 75%	96.30	92.75	94.84	94.63
Pine bark 25%	92.59	93.33	91.27	92.40
Pine bark 50%	94.44	94.49	94.44	94.46
Pine bark 75%	94.44	95.65	95.83	95.31
Pine bark 100%	96.30	92.46	91.47	93.41
Wood chip 25%	94.44	93.33	96.63	94.80
Wood chip 25%	97.22	92.17	97.22	95.54
Wood chip 50%	93.52	93.91	96.43	94.62
Wood fibre 25%	94.44	95.94	84.33	91.57
Wood fibre 50%	97.22	91.30	*	94.09
Grand mean %		94.12		
Tray size mean%	95.20	93.39	93.77	
SED media	1.94			
SED tray size	0.84			

Table 4. Percentage useable plants for cauliflower assessed on 3 July, 19 days after sowing in different media and trays.

Media	Tray size 216	345	504	Media mean
Peat	90.74	94.20	92.86	92.60
Miscanthus 25%	92.13	94.20	94.25	93.53
Miscanthus 50%	90.28	90.14	*	90.59
Miscanthus 75%	78.70	*	*	79.19
Bark fines 25%	93.06	91.30	91.27	91.88
Bark fines 50%	92.13	95.07	96.43	94.54
Bark fines 75%	90.28	93.04	93.65	92.32
Pine bark 25%	93.06	95.36	95.44	94.62
Pine bark 50%	92.13	88.99	94.25	91.79
Pine bark 75%	94.44	92.46	94.44	93.78
Pine bark 100%	88.89	93.33	93.25	91.83
Wood chip 25%	92.59	91.30	94.44	92.78
Wood chip 50%	91.67	90.14	90.48	90.76
Wood chip 75%	95.83	93.04	94.44	94.44
Wood fibre 25%	93.98	92.46	92.46	92.97
Wood fibre 50%	91.20	90.43	*	91.20
Grand mean %		91.80		
Tray size mean%	91.32	91.53	92.56	
SED media	1.25			
SED tray size	0.54			

For calabrese, the germination of the seed in all media and trays was high with the exception of seeds grown in Miscanthus included at 75%. These germinated unevenly, probably due to intermittent water availability in the media. There were no significant differences (P=0.05) between the percentage useable plants when calabrese were grown in any of the media or in any tray size (Table 3).

As with the calabrese, the germination of the cauliflower seed was high (Table 4). There were significant differences in the useable plant count between the different media with Miscanthus included at 25%, bark fines included at 50%, pine bark included at 25% and 75%, wood chip included at 75% and wood fibre included at 25% all producing significantly higher (P=0.05) percentage of useable plants. Miscanthus included at 75% produced the lowest percentage useable plants at 79% (note that the data for this treatment is based on the assessment of only one replicate tray due to insufficient media). There were no significant differences produced by the effect of tray size on useable plants.

Plant vigour and uniformity of calabrese and cauliflower seedlings during propagation

Vigour and uniformity scores (1=poor, 9=good) were collected on all three replicates of each tray size and treatment when the seedlings reached the second true leaf stage on 6 July, 21 days after sowing. The results are given in Tables 5 (calabrese) and 6 (cauliflower).

Table 5. Mean plant vigour and uniformity scores for calabrese plants at second true leaf stage assessed 21 days after sowing (* = missing values)

	Vigour score				**Uniformity score**			
	Tray size				**Tray size**			
Media	**216**	**345**	**504**	**Media means**	**216**	**345**	**504**	**Media means**
Peat	8.0	6.7	7.0	7.2	8.0	8.0	8.0	8.0
Miscanthus 25%	8.0	6.3	7.3	7.2	8.0	6.3	7.0	7.1
Miscanthus 50%	8.0	6.7	*	7.4	8.0	6.3	*	7.2
Miscanthus 75%	5.3	*	*	5.3	5.0	*	*	4.8
Bark fines 25%	8.0	7.0	7.0	7.3	8.0	7.0	8.0	7.7
Bark fines 50%	7.0	7.0	7.0	7.0	8.0	7.0	8.0	7.7
Bark fines 75%	6.0	6.0	6.5	6.2	8.0	6.3	7.0	7.1
Pine bark 25%	7.0	7.0	7.5	7.2	8.0	7.0	7.3	7.4

Pine bark 50%	8.0	7.5	7.5	7.7	8.0	8.0	6.7	7.6
Pine bark 75%	8.0	8.0	8.0	8.0	8.0	8.0	7.7	7.9
Pine bark 100%	9.0	8.0	8.5	8.5	8.0	8.0	8.0	8.0
Wood chip 25%	6.0	7.0	7.5	6.8	6.3	7.0	7.0	6.8
Wood chip 50%	7.3	7.0	7.5	7.3	8.0	8.0	7.0	7.7
Wood chip 75%	6.7	6.3	7.5	6.8	6.3	5.7	7.0	6.3
Wood fibre 25%	7.0	7.5	7.4	7.3	6.7	7.0	7.0	6.9
Wood fibre 50%	8.3	8.7	8.7	8.6	8.0	8.0	*	8.0
Grand mean		7.23				7.256		
Tray size mean	7.34	6.98	7.37		7.52	7.02	7.22	
SED media	0.13				0.13			
SED tray size	0.06				0.06			

For calabrese (Table 5), high vigour scores were produced by plants grown in all media and tray treatments except Miscanthus included at 75%. With the Miscanthus 75% score removed, plants grown in the 216 trays would have produced the highest mean score. The vigour scores of plants grown in peat averaged across the three different tray sizes mirrored the overall (grand) mean vigour score of plants averaged across all the media. There was significant tray and media interaction but the effects were not consistent across treatments. 100% pine bark and pine bark included at 75%, both produced significantly (p=0.05 level) higher vigour scores in all three tray sizes. Generally 345 trays produced a lower mean vigour score across all media while 504 trays produced the highest (not significant). Bark fines 75% produced consistently lower scores in all tray sizes. Peat and 100% pine bark produced consistently high uniformity scores in all three tray sizes followed by pine bark included at 75% and wood fibre included at 50%. 216 trays produced the highest mean uniformity score followed by 504 trays. Overall lowest score was produced by Miscanthus included at 75%. Wood chip included at 50% produced the lowest score across all three tray sizes with a particularly poor performance in 345 trays. This may have been exacerbated by drips from the roof of the glasshouse.

For cauliflower (Table 6), plants grown in Miscanthus included at 75% produced the lowest vigour and uniformity scores (as with calabrese). Although overall plants grown in the 345 trays scored the lowest for vigour, where the tray contained wood fibre and wood chip, plants generally produced high scores. Similarly, both 216 and 504 trays produced variable results. Plants grown in wood fibre included at 75% produced the highest mean media vigour score (from only two tray sizes) followed by plants grown in 100% pine bark. Plants grown in 100% peat (all trays) produced scores lower than the overall (grand) mean and overall tray mean for the experiment. Plants grown in 100% peat also produced uniformity scores similar to the overall tray means. Generally 504 trays produced cauliflower plants with the highest uniformity score closely followed by 216 trays. Plant grown in pine bark included at 75% and 100% both produced the highest uniformity scores and the latter the highest mean media score across all trays.

Table 6. Mean plant vigour and uniformity scores for cauliflower plants at second true leaf stage assessed 21 days after sowing.

	Vigour score				Uniformity score			
	Tray size				Tray size			
Media	**216**	**345**	**504**	**Media means**	**216**	**345**	**504**	**Media means**
Peat	6.0	6.0	6.0	6.0	7.0	6.3	7.0	6.8
Miscanthus 25%	7.0	6.0	7.0	6.7	6.7	5.7	7.0	6.4
Miscanthus 50%	7.0	6.0	*	6.6	7.3	6.0	*	6.8
Miscanthus 75%	5.3	*	*	5.3	5.0	*	*	5.1
Bark fines 25%	6.0	6.0	7.0	6.3	6.7	5.7	7.3	6.6
Bark fines 50%	6.0	6.0	6.7	6.2	6.3	5.7	6.7	6.2
Bark fines 75%	6.0	6.0	6.0	6.0	6.0	6.3	7.3	6.6
Pine bark 25%	6.5	6.0	6.0	6.1	6.7	6.3	7.0	6.7
Pine bark 50%	6.7	7.0	7.0	6.9	6.3	7.0	7.0	6.8
Pine bark 75%	7.0	7.0	7.0	7.0	7.7	7.0	7.0	7.2
Pine bark 100%	7.0	7.0	8.0	7.3	7.7	7.7	7.3	7.6
Wood chip 25%	7.0	6.0	6.5	6.5	7.0	6.3	6.3	6.6
Wood chip 50%	7.0	7.3	7.0	7.1	7.0	6.3	6.7	6.7
Wood chip 75%	7.3	7.3	7.0	7.2	6.3	7.0	6.3	6.6
Wood fibre 25%	7.7	7.3	7.0	7.3	7.0	7.0	6.4	6.8
Wood fibre 50%	7.7	8.0	*	7.9	7.0	7.3	*	7.3
Grand mean		6.65				6.56		
Tray size mean	6.69	6.51	6.76		6.72	6.4	6.82	
SED media	0.12				0.23			
SED tray size	0.05				0.10			

Plant dry weight (grams) of calabrese and cauliflower at planting

The results of the plant dry weight assessments are given in Table 7. The mean plant weights produced by calabrese and cauliflower plants in the same trays sizes were similar when sampled on the same day. Pine bark included at 75% and 100% produced the heaviest plants of both calabrese and cauliflower.

For calabrese, there was a tray size effect with significantly higher (P=0.05) dry weights produced in all media in the larger 216 tray sizes compared with 345 and 504 trays. There was a consistent pattern of dry weight reduction moving from larger to smaller tray size. The peat filled trays of all sizes produced plant weights similar to the tray size means. Plants grown in pine bark included at 75% and 100% tended to produce the highest weights but these differences were not significant.

Table 7. Plant dry weight (grams) of calabrese and cauliflower plants taken on 16 July, 32 days after sowing

	Calabrese plants				Cauliflower plants			
	Tray size				Tray size			
Media	216	345	504	Media means	216	345	504	Media means
Peat	1.3	0.6	0.5	0.8	1.1	0.6	0.5	0.7
Miscanthus 25%	0.9	0.5	0.7	0.7	1.2	0.3	0.6	0.7
Miscanthus 50%	1.2	0.5	*	0.8	0.9	0.4	*	0.5
Miscanthus 75%	0.9	*	*	0.5	0.9	*	*	0.6
Bark fines 25%	1.2	0.8	0.7	0.9	1.0	0.4	0.5	0.7
Bark fines 50%	0.9	0.7	0.6	0.7	0.9	0.6	0.6	0.7
Bark fines 75%	0.9	0.6	0.7	0.7	0.8	0.5	0.6	0.6
Pine bark 25%	1.0	0.6	0.5	0.7	0.8	0.5	0.4	0.6
Pine bark 50%	1.2	0.6	0.5	0.8	1.3	0.7	0.5	0.8
Pine bark 75%	1.4	0.8	0.7	1.0	1.1	0.7	1.0	0.9
Pine bark 100%	1.7	0.8	0.8	1.1	1.9	0.4	1.1	1.1
Wood chip 25%	1.3	0.6	0.5	0.8	1.0	0.7	0.5	0.7
Wood chip 50%	1.2	0.7	0.3	0.7	0.8	0.7	0.3	0.6
Wood chip 75%	0.9	0,46	0.4	0.6	1.0	0.4	0.4	0.6
Wood fibre 25%	1.2	0.5	0.6	0.8	0.9	0.7	0.5	0.7
Wood fibre 50%	1.2	0.7	*	0.8	0.7	0.6	*	0.6

Grand mean	0.77			0.7		
Tray size mean	1.14	0.61	0.55	1.01	0.55	0.54
SED media	0.15			0.12		
SED tray size	0.07			0.05		

For cauliflower, there was a significant interaction between media type and tray type on plant dry weight. The 216 trays produced plants with significantly higher (P=0.05) dry weights than those grown in 345 and 504 trays. In 216 trays, pine bark included at 50% and 100% pine bark produced significantly heavier plants than those grown in wood fibre included at 50%, wood chip included at 50% or bark fines included at 75%. In the 345 and 504 trays there was not always consistency in the performance of the media in the two different trays. Plants grown in wood chip included at 25% produced good weights in 345 trays but below average tray mean weights in 504 trays. Plants grown in pine bark included at 75% and 100% pine bark tended to produce heavier plants, while those grown in 100% pine bark 345 trays produced lower weights. At the lower level of pine bark inclusion, the performance of plants in 345 and 504 trays was poor as was the performance of those grown in both wood chip and Miscanthus included at 50%. As with calabrese, plants grown in 100% peat produced plant dry weights similar to the overall experiment mean.

When the calabrese and cauliflower plants were pulled from the trays for transfer to the field, the rootball of most media treatments remained intact as the roots had grown well into the media. The pine bark media at the higher rates of inclusion (75 and 100%) tended to fall apart unless handled very carefully due to the gritty heavy nature of the media after watering, possibly due to the clay additive. Pine bark media-raised plants also tended to have bent stems indicative of rapid seedling growth. This may be attributed to the high density and higher levels of NO_3-N present (See Table 2).

Wood fibre included at 50% also tended to produce poor cohesion of the rootball while the best quality plants in terms of straight stems with an intact rootball were produced by 100% peat. Composted bark fines at all rates produced reasonable plants as did the Miscanthus.

The calabrese were planted on 18 July, 34 days from sowing and the cauliflower six days later on the 24 July. No difficulties were encountered during planting except the wet conditions in the cauliflower field.

Percentage of plants established in the field:

Three weeks after planting the calabrese and two weeks after planting the cauliflower, establishment was assessed by examining 50 plants per plot in all plots. Only plants securely rooted and showing re-growth were considered to be established. While the calabrese had established well with up to 8 expanded true leaves on many plants, the difficult soil conditions into which the cauliflower trial were planted made determination of well established plants more difficult. The results are given in Table 8.

Table 8. Percentage of plants of calabrese and cauliflower established in the field on 9 August, 21 days after planting the calabrese and 13 days after planting cauliflower

	Calabrese plants				Cauliflower plants			
	Tray size				Tray size			
Media	216	345	504	Media means	216	345	504	Media means
Peat	84.6	96.6	91.3	90.9	98.0	97.3	92.6	96.0
Miscanthus 25%	99.3	96.0	91.3	95.6	95.3	89.3	98.0	94.2
Miscanthus 50%	92.6	94.6	*	93.1	99.3	100.0	*	99.1
Miscanthus 75%	98.6	*	*	97.9	98.6	*	*	98.4
Bark fines 25%	98.0	98.6	94.0	96.9	98.0	94.2	97.3	96.5
Bark fines 50%	98.0	96.0	96.0	96.7	94.6	95.3	96.6	95.5
Bark fines 75%	98.0	95.3	96.6	96.7	90.6	94.6	94.6	93.3
Pine bark 25%	97.3	94.0	94.6	95.3	89.0	98.6	95.3	94.3

Pine bark 50%	99.3	91.3	96.6	95.9	96.1	97.3	88.0	93.8
Pine bark 75%	98.0	96.0	97.3	97.1	96.6	97.3	88.7	94.2
Pine bark 100%	94.0	91.3	94.6	93.3	96.6	96.6	94.6	96.0
Wood chip 25%	91.3	94.6	85.3	90.4	94.6	98.6	92.0	95.1
Wood chip 50%	96.6	96.0	92.0	94.9	97.3	97.3	96.6	97.1
Wood chip 75%	96.0	93.3	95.3	94.9	95.3	98.6	94.6	96.2
Wood fibre 25%	96.0	97.3	93.3	95.6	97.3	95.3	95.3	96.0
Wood fibre 50%	91.3	95.3	*	92.7	94.6	100.0	*	96.8
Grand mean		94.8				95.8		
Tray size mean	95.5	95.3	93.67		95.7	96.9	94.7	
SED media	2.33				2.17			
SED tray size	1.01				0.94			

There was no significant difference between the media treatments or the tray sizes on the plant establishment of calabrese or cauliflower.

Clubroot (*Plasmodiophora Brassicae*) affected part of the cauliflower field trial. The disease appeared to have no effect on establishment at the time establishment scores were recorded. Clubroot combined with the difficult soil conditions at planting conspired to delay harvesting and reduce the percentage marketable plants in a number of plots.

Objective 2: Field performance and crop quality – Yield and quality at harvest

Harvest quality for calabrese and cauliflower

The results of the harvest of the calabrese experiment are given in Table 9 to 11. For calabrese, harvesting began on 8 October when 10% of the calabrese heads were marketable, followed by three further harvests (12, 17 and 23 October 2007). Only the weight of marketable heads was taken but all heads were recorded for calculation of percentage marketable.

Table 9. Mean weight of marketable heads (kg) of calabrese at harvest commencing 8 October 2007

	Tray size			
Media	**216**	**345**	**504**	**Media mean**
Peat	0.40	0.35	0.29	0.35
Miscanthus 25%	0.51	0.38	0.30	0.40
Miscanthus 50%	0.44	0.40	*	0.39
Miscanthus 75%	0.41	*	*	0.34
Bark fines 25%	0.44	0.39	0.28	0.37
Bark fines 50%	0.50	0.31	0.32	0.38
Bark fines 75%	0.47	0.39	0.34	0.40
Pine bark 25%	0.43	0.34	0.30	0.36
Pine bark 50%	0.44	0.41	0.30	0.38
Pine bark 75%	0.47	0.35	0.36	0.39
Pine bark 100%	0.43	0.39	0.39	0.40
Wood chip 25%	0.43	0.31	0.39	0.38
Wood chip 50%	0.45	0.34	0.35	0.38
Wood chip 75%	0.44	0.33	0.33	0.37
Wood fibre 25%	0.45	0.43	0.34	0.41
Wood fibre 50%	0.59	0.38	*	0.46
Grand mean %		0.39		
Tray size mean%	0.46	0.36	0.33	
SED media	0.030			

SED tray size	0.013

Good head weights were produced by all media. There were no significant (*P*=0.05) differences in head weights between the media treatments within the same tray size. There were significant differences between tray sizes with plants grown in 216 trays producing heavier heads than those grown in 345 trays. Although the differences between 345 and 504 trays were small, they were significant (*P*=0.05).

Table 10. Percentage of marketable calabrese heads at harvest compared with total plant number

	% marketable heads			
Media treatment	**216**	**345**	**504**	**Media mean**
Peat	70.2	76.3	71.0	72.5
Miscanthus 25%	92.0	77.2	64.4	77.9
Miscanthus 50%	77.1	73.4	*	73.2
Miscanthus 75%	73.5	*	*	69.9
Bark fines 25%	77.8	82.9	61.3	74.0
Bark fines 50%	81.0	81.4	77.5	80.0
Bark fines 75%	87.1	72.0	72.2	77.1
Pine bark 25%	82.3	78.0	79.4	79.9
Pine bark 50%	83.1	82.6	71.5	79.1
Pine bark 75%	87.9	78.7	83.8	83.5
Pine bark 100%	85.7	83.5	84.9	84.7
Wood chip 25%	81.1	75.3	74.7	77.0
Wood chip 50%	79.7	80.3	73.6	77.9
Wood chip 75%	87.9	79.2	78.5	81.9
Wood fibre 25%	81.4	84.2	79.4	81.7
Wood fibre 50%	87.2	82.1	*	82.6
Grand mean		78.3		
Tray size mean	82.2	78.6	74.1	
SED media	3.87			
SED tray size	1.68			

A significantly (P=0.05) higher percentage marketable than peat in all three tray sizes was produced by wood fibre at the 25% inclusion rate. In 216 trays, all mixes of bark fines, pine bark, wood chip and wood fibre were significantly higher than peat while in 504 trays pine bark at 25, 75 and 100% and wood fibre 25% were significantly higher.

The mean percentage marketable produced by the calabrese is acceptable taking into account the difficult season. The main reason for unmarketable heads was undersize (250 grams) and small, loose heads.

The time to harvest (from transplanting) data are summarised in Table 11.

Table 11. Mean number of days from transplanting to 50% marketable cut of calabrese

	Mean no. days to transplanting			
Media treatment	**216**	**345**	**504**	**Media mean**
Peat	83.3	82.3	86.0	84.2
Miscanthus 25%	82.3	82.3	84.7	83.1
Miscanthus 50%	82.3	82.3	*	82.8
Miscanthus 75%	82.3	*	*	83.0
Bark fines 25%	82.3	82.3	83.3	82.7
Bark fines 50%	82.3	83.7	83.7	83.2
Bark fines 75%	82.3	82.3	83.7	82.8
Pine bark 25%	83.7	83.7	84.7	84.0
Pine bark 50%	82.3	82.3	85.0	83.2
Pine bark 75%	82.3	82.3	83.3	82.7
Pine bark 100%	82.3	83.3	82.3	82.7
Wood chip 25%	82.3	84.7	84.7	83.9
Wood chip 50%	82.3	82.3	83.7	83.1
Wood chip 75%	82.3	82.3	84.7	83.4
Wood fibre 25%	82.3	82.3	83.3	82.7
Wood fibre 50%	82.3	82.3	*	82.8
Grand mean		83.1		
Tray size mean	82.5	82.9	84.0	
SED media	0.65			
SED tray size	0.28			

Although small, differences between tray sizes were significant (P=0.05) with plants grown in 216 trays reaching maturity faster than those grown in 345 trays; these in turn grew more quickly than those grown in 504 trays. Peat was the only media to be significantly (p=0.05) slower media to reach 50% cut in 504 trays.

The results of the harvest of the cauliflower experiment are given in Tables 12 to 16. Harvesting of the cauliflower trial began on 29 October 2007 when approximately 10% of heads were mature followed by a further five harvests finishing on 7 December

2007 when it was considered that no further heads would produce marketable quality heads.

Table 12. Mean percentage Class 1 produced by cauliflower harvested over six harvest dates commencing 29 October 2007

	Mean % Class 1 heads			
Media treatment	**216**	**345**	**504**	**Media mean**
Peat	58.7	33.5	29.1	40.4
Miscanthus 25%	14.7	36.4	43.1	31.4
Miscanthus 50%	32.0	29.8	*	30.1
Miscanthus 75%	34.5	*	*	34.0
Bark fines 25%	21.3	24.0	43.1	29.5
Bark fines 50%	38.7	36.8	34.1	36.5
Bark fines 75%	26.2	26.9	25.5	26.2
Pine bark 25%	21.1	17.2	19.3	19.2
Pine bark 50%	25.5	38.2	20.7	28.1
Pine bark 75%	44.9	28.4	21.0	31.4
Pine bark 100%	15.5	36.4	37.5	29.8
Wood chip 25%	21.1	22.2	30.2	24.5
Wood chip 50%	44.7	42.0	30.9	39.2
Wood chip 75%	17.6	41.6	26.0	28.4
Wood fibre 25%	58.7	41.0	26.1	41.9
Wood fibre 50%	26.8	20.8	*	23.0
Grand mean		30.9		
Tray size mean	31.4	31.9	29.3	
SED media	0.19			
SED tray size	0.08			

The experiment produced a very variable, but generally low mean percentage Class 1 due to the combined effects of clubroot infection, unfavourable soil conditions at planting and the use of a summer variety harvested in the late autumn. This resulted in significant block effects (P=0.05) but no media or tray effect.

The percentage of Class 2 heads is given in Table 13, and the combined percentage Class 1 and 2 heads is given in Table 14.

Table 13. Mean % Class 2 produced by cauliflower harvested over 6 harvest dates commencing 29 October 2007.

	Mean % Class 2 heads			
Media treatment	**216**	**345**	**504**	**Media mean**
Peat	8.7	17.0	26.5	17.4
Miscanthus 25%	13.4	16.2	17.9	15.8
Miscanthus 50%	16.2	10.5	*	13.3
Miscanthus 75%	11.2	*	*	12.8
Bark fines 25%	14.7	10.9	16.0	13.9
Bark fines 50%	18.7	21.4	11.6	17.2
Bark fines 75%	19.6	17.0	22.2	19.6
Pine bark 25%	19.5	19.7	21.3	20.2
Pine bark 50%	15.7	27.2	14.7	19.2
Pine bark 75%	17.6	13.7	9.7	13.7
Pine bark 100%	12.9	19.8	19.6	17.4
Wood chip 25%	9.2	18.9	12.1	13.4
Wood chip 50%	13.3	19.7	14.1	15.7
Wood chip 75%	10.7	20.6	13.6	15.0

Wood fibre 25%	20.1	17.3	15.0	17.5
Wood fibre 50%	17.5	23.2	*	20.3
Grand mean		16.4		
Tray size mean	15.0	18.0	16.3	
SED media	3.59			
SED tray size	1.56			

Generally a low percentage Class 2 was produced by all tray sizes. There were no significant media or tray effects.

Table 14. Mean % Class 1 and 2 produced by cauliflower harvested over 6 harvest dates commencing 29 October 2007

Media treatment	Mean % Class 1 and 2 heads 216	345	504	Media mean
Peat	67.3	50.5	55.6	57.8
Miscanthus 25%	28.1	52.5	61.0	47.2
Miscanthus 50%	48.2	40.3	*	43.4
Miscanthus 75%	45.7	*	*	46.7
Bark fines 25%	36.0	34.9	59.1	43.3
Bark fines 50%	57.3	58.2	45.6	53.7
Bark fines 75%	45.8	43.9	47.6	45.8
Pine bark 25%	40.6	36.9	40.5	39.3
Pine bark 50%	41.2	65.4	35.4	47.3
Pine bark 75%	62.4	42.1	30.7	45.1
Pine bark 100%	28.4	56.2	57.1	47.2
Wood chip 25%	30.3	41.1	42.3	37.9
Wood chip 50%	58.0	61.7	45.0	54.9
Wood chip 75%	28.3	62.1	39.6	43.3
Wood fibre 25%	78.8	58.3	41.1	59.4
Wood fibre 50%	44.3	44.0	*	43.3
Grand mean		47.2		
Tray size mean	46.3	49.8	45.6	
SED media	9.53			
SED tray size	4.13			

The combined marketable heads (Class 1 and Class 2) was low with only 47% trial mean. There were no significant differences in the effect of media or tray size on percentage marketable.

Peat and wood fibre 25% produced the highest percentage marketable across the mean of all tray sizes but wood fibres 25% performance in 504 trays was poor. Wood chip 25% and pine bark 25% produced the lowest.

In 216 trays wood fibre 25% produced a commercially acceptable yield of total marketable heads followed by peat. In 345 trays, pine bark 50% and wood chip 50% and 75% produced the highest marketable yields but these would be considered low commercially.

Miscanthus 25% produced the highest marketable in 504 trays.

Table 15. Mean % Unmarketable produced by cauliflower harvested over 6 harvest dates commencing 29 October 2007.

Media treatment	Mean % Unmarketable heads 216	345	504	Media mean
Peat	32.7	49.5	44.4	42.2
Miscanthus 25%	71.9	47.5	39.0	52.8
Miscanthus 50%	51.8	59.7	*	56.6
Miscanthus 75%	54.3	*	*	53.3
Bark fines 25%	64.0	65.1	40.9	56.7
Bark fines 50%	42.7	41.8	54.4	46.3
Bark fines 75%	54.2	56.1	52.4	54.2
Pine bark 25%	59.4	63.1	59.5	60.7
Pine bark 50%	58.8	34.6	64.6	52.7
Pine bark 75%	37.6	57.9	69.3	54.9
Pine bark 100%	71.6	43.8	42.9	52.8
Wood chip 25%	69.7	58.9	57.7	62.1
Wood chip 50%	42.0	38.3	55.0	45.1
Wood chip 75%	71.7	37.9	60.4	56.7
Wood fibre 25%	21.2	41.7	58.9	40.6
Wood fibre 50%	55.7	56.0	*	56.7
Grand mean		52.8		
Tray size mean	45.3	54.5	58.5	
SED media	9.53			
SED tray size	4.13			

A high number of unmarketable heads (Table 15) were produced due to difficult soil conditions and extended late harvest. There was no significant differences between media or trays.

Table 16. Mean number of days from transplanting to 50% marketable cut of cauliflower

Media treatment	Number of days 216	345	504	Media mean
Peat	104.0	109.3	120.0	111.1
Miscanthus 25%	112.0	117.3	117.0	115.4
Miscanthus 50%	117.0	120.0	*	119.3
Miscanthus 75%	107.0	*	*	108.7
Bark fines 25%	117.3	117.0	112.0	115.4
Bark fines 50%	117.0	108.7	108.7	111.4
Bark fines 75%	107.0	112.0	119.7	112.9
Pine bark 25%	125.3	122.3	122.7	123.4
Pine bark 50%	106.3	111.7	120.0	112.7
Pine bark 75%	111.7	114.7	122.3	116.2
Pine bark 100%	117.3	120.0	114.3	117.2
Wood chip 25%	117.3	111.7	108.7	112.6
Wood chip 50%	104.0	114.7	114.3	111.0
Wood chip 75%	109.3	112.0	114.7	112.0
Wood fibre 25%	109.3	111.7	106.3	109.1
Wood fibre 50%	117.0	114.3	*	116.4
Grand mean		114.1		
Tray size mean	112.4	114.1	115.6	
SED media	4.78			
SED tray size	2.07			

The data on number on days from transplanting to harvest for cauliflower are summarised in Table 16. Only marketable plants are used in the estimate of the number of days from transplanting to 50% cut. The number of days to maturity is considerably longer than would be expected for this variety due its late use in the season due to delayed planting. There were no significant differences recorded due to media or tray size.

Discussion

The five alternative media had been carefully prepared and modified by Bulrush Horticulture Ltd to match the nutritional requirements of healthy Brassica plants. Differences in the physical and chemical analysis of the alternative media compared with peat were small resulting in the successful plant raising in all tray sizes and media. At transplanting, there were small differences in the weight and quality of plants produced but all treatments produced satisfactory plants.

Difficulties were experienced with filling 345 and 504 trays with the Miscanthus due to the length of straw that proved difficult to mill finer than 10mm. A finer milling may have increased the useable plant count in Miscanthus 75% by improving the moisture retention in the media.

When the plants reached the second true leaf stage, high useable plant counts were produced by all media in both calabrese and cauliflower with no significant differences between media. Twenty one days after sowing, a vigour and uniformity assessment on the calabrese indicated that the plants grown in peat were performing similarly to the trial mean with no clear advantages seen by any media. 216 trays tended to produce more vigorous and uniform plants than 345 and 504 trays but not significantly. Unexpectedly, 504 trays scored higher for vigour and uniform plants in both calabrese and cauliflower than 345 trays.

Shortly after this assessment, Downy mildew (*Peronospora parasitica*) infected the plants in the peat and composted bark fines media treatments more than the other media. It was not clear why these two media were infected worse or if the other media were having a suppressive effect on the disease. Plants containing more nitrogen are generally considered to be more susceptible to the disease but as already pointed out the peat media was low in nitrate and total organic nitrogen. Some of the composted bark fines treatments (e.g. 75% inclusion rates) were high in nitrates and total organic nitrogen which may explain why plants grown in it became infected.

After a further ten days, the plants in all treatments were weighed with the anticipated outcome that 216 plants of both calabrese and cauliflower were almost twice the mean weight of the plants from the 345 and 504 trays. Unexpectedly there was very little difference in the weight of plants grown in 345 and 504 trays despite the lower volume of media in the latter. Unlike the previous Brassica module raising experiment FV 303, there were no signs of wirestem *(Rhizoctonia)* infecting the base of plants in the smaller trays.

At planting, the best quality plants with strong, straight stems were produced by peat and low inclusion levels of Miscanthus and wood chip. These media tended to produce lower weight plants at transplanting due in part to the lower levels of nitrate in the media. The media producing the heaviest plant weights for both calabrese and cauliflower (pine bark included at 75% and 100% pine bark) tended to produce plants that were difficult to transplant as they had grown quickly resulting in soft lush growth that was easily broken on handling. Most pine bark media contained a raised level of nitrate nitrogen amounting in some cases to almost double the amount contained in peat. Overall the results for pine bark as a media for growing both calabrese and cauliflower were good but the levels of nitrate in the initial media need to be lower. The levels of nitrate in the media are critical to ensuring quality transplants.

When assessed in the field for establishment, all treatments appeared to root out and grow equally well as there was no effect observed of media or tray size on the percentage of plants established for calabrese or cauliflower. Small plants that had not grown since transplanting 14 days earlier were considered not established. The Dursban drench that was applied immediately prior to transplanting prevented any visible cabbage root fly damage implying that chlorpyrifos will bind well to the organic matter in the alternative media just as well as peat.

The calabrese trial grew satisfactorily and produced very acceptable commercial yields with a minimum weight of 250 grams. Several media produced heavier head weights than peat particularly wood fibre 50% and pine bark 100% which produced the heaviest mean weights irrespective of tray size. Calabrese respond well to larger tray sizes with head weights from 216 trays significantly heavier than 345 which in turn were significantly heavier than 504 trays. This effect was reported in a previous media and tray size experiment HDC FV303. Pine bark at the higher inclusion rates also produced the highest percentage marketable heads in all tray sizes. This was not the case with cauliflower where all rates of pine bark inclusion produced a low percentage of marketable heads.

For cauliflower, plants grown in wood fibre included at 25% produced the highest percentage Class 1 and marketable plants in all but 504 trays. In this small tray size, plants grown in Miscanthus included at 25% produced the most marketable heads (61%). Peat was the most consistent media across all three tray sizes for producing above average marketable heads.

Ex factory raw material prices were collected for the different media and compared with peat. Only wood chip could be purchased for a similar price to peat (£25 /cubic metre). Pine bark was the most expensive costing up to £40 /cubic metre. Delivered price to the nursery will be affected by the bulk density of the media resulting in a widening delivery cost for pine bark due to its high bulk density. Bark fines and wood fibre are only marginally more expensive than peat at this present moment but the energy input into the manufacture of wood fibre could results in substantial cost increases with time. Demand for bark and wood chip is increasing from many other sectors for a variety of uses including mulching which will put pressure on cost.

Conclusions

- No media consistently out-performed another when all assessments are considered. The performance of peat was often average suggesting that most of the media would produce satisfactory Brassica transplants.
- The levels of nitrate in the media are critical to ensuring quality transplants.
- All media produced high germination counts and useable plant counts in all tray sizes
- Compared with 345 and 504 trays, 216 trays produced the heavier heads of calabrese, higher vigour and uniformity scores for calabrese and cauliflower, higher plant dry weights (grams), significantly higher percentage marketable calabrese and faster maturity of calabrese and cauliflower.
- Best quality transplants were produced by 100% peat and low inclusion rates of wood chip and Miscanthus due to lower amounts of available nitrogen in the media.
- Prior to transplanting, plants raised in 216 trays were heavier than those in 345 and 504 trays. There was little difference in the weight of calabrese or cauliflower plants grown in 345 and 504 trays. Pine bark tended to produce the heaviest plants.
- The performance of Miscanthus could be improved in the 345 and 504 trays by finer milling of the straw to 5mm rather than 10mm.
- Chlorpyrifos drench (eg Dursban) would appear to be as effective when applied to all the alternative media tested as to peat.
- All media produced very acceptable head weights in calabrese. Although not significant, wood fibre included at 25 and 50% produced the heaviest calabrese head weights of all the media tested including peat.

- Tray size appeared to make no difference to the marketable yield of cauliflower with 216, 345 and 504 trays producing similar marketable yields.

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Technology Transfer

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