Grower summary

HL 0172

Producing high quality horticultural growing media through the retention of plant structure in composted food-processing waste

Second report (12-months) 2005

Project title:	Producing high quality horticultural growing media through the retention of plant structure in composted food-processing waste
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Contents

Grower Summary

Research activities from 01/10/2004-30/09/2005

1) *Windrows*

First Trial

Four windrows each of about 30m^3 have been constructed and matured at Organic Recycling Ltd. They were based on straw and one of the following food processing waste streams:

- mixed leaf (brassicas),
- onion,
- brewers' grain,
- fruit (melon and pineapple peel).

The windrows were turned weekly for 3 months (prior to each sampling) and then allowed to mature. During the first 2 months, the internal temperatures rose to about 70-80^{o}C. They then dropped back to about 40^{o}C.

Second Trial

A further twelve windrows were constructed at Organic Recycling Ltd. in April 2005. Six different mixes were prepared in duplicate based on straw & brewers' grain together with mixed leaf or fruit in four of the mixes.

The windrows heated up rapidly and for several months were turned weekly prior to each sampling and then allowed to mature. The surface and core temperatures of the windrows were measured and recorded.

2) *Analysis*

Samples from freshly-turned windrows were analysed as follows:

- Microscopy: light microscopy of windrows sampled on a range of dates.
- Chemical: preparation of plant cell walls by extraction in hot alcohol followed by measurement of yield, sugar and composition of the phenolic compounds in the cell walls
- Microbiological evaluation
- Selected prepared samples for water relations using a 5-bar pressure plate (below)

3) *Peat evaluation*

Selected samples of peat were evaluated for physical properties. A 5 bar pressure plate extractor was commissioned and moisture retention curves for three samples of peat (Ballycommon, Sedge and Baltic) and selected composted materials were initiated.

4) Results

Selected samples from the windrows from Windrow Trial 1 were stabilised against continued degradation. The results show that the Brewers' Grain / straw windrow produce interesting compost which, after appropriate stabilisation, exhibits good water-retention and drainage characteristics. Initial germination trials using marigolds (by Bulrush) were most encouraging. Other physical and chemical properties have also been evaluated and indicate a highly structure growing medium. However, there is a high level of conductivity. Further, more detailed growing trials with Viola plug-plants and coriander seed germination trials indicate that this will need to be addressed.

A second trial of larger (60m^3 X 12) windrows is on-going. The use of windrows has proved to be a most unreliable approach for controlled composting. The rate, nature and extent of biodegradation throughout the windrows is strongly influenced by weather conditions, particularly rainfall. However, as of October 2005, several of the large windrows are yielding material which is intended to be stabilised, treated to address conductivity, and then evaluated by the professional Growers.

5) Conclusions

1) The composting process can be controllably terminated at a point where high-levels of plant structure remain in the compost
2) The retained structure provides the following physicochemical characteristics important in high-quality growing media:
    a. Residual plant cell wall structure as indicated by the retention of cell wall sugars and lignin commensurate with the functional levels found in high-quality peat;
    b. Relevant particle size distribution;
    c. Good water retention, similar to that in peat and considerably higher than in loams and traditional composts;
    d. Good air-filled porosity;
3) There are several characteristics which require attention in order to optimise the growing media as a potential peat alternative:
    a. Windrow composting is not sufficient to create a uniform product
    b. The conductivity is too high and this has a negative impact on germination
    c. Possible nitrogen deficiency in trialled plants may result from a surfeit of insufficiently degraded straw;
4) The compost can be used successfully as a 50% peat substitute in the cultivation of viola plants from plugs, If the above issues in 3) can be addressed, it should have the potential to be used as a 100% peat substitute as perceived

Scientific Research

Introduction

The aim of this proposal is to assess the feasibility of producing high-quality horticultural growing media from the controlled composting of traceable, **sustainable** and locally-produced plant-based food processing waste. This will involve replicating **plant-structure-**dependent physicochemical characteristics found in high-quality growing media. The research will translate into the development of improved composting technologies for growing media production via a Core Research LINK project.

Commercial and Technical Background

The requirement for horticultural growing media has increased rapidly since the 1950's as a result of the growth of the Professional Growers industry including nursery stock, pot plants/herbs, bedding plants etc., and amateur gardening. Sphagnum peat has been used as the main constituent of growing media, and the demand has been met principally by UK peat sources, but also by increased import (30%). UK professional growers utilise approximately 1.2 million m^3 peat annually. Sphagnum peat satisfies a range of generic grower requirements. These include air porosity (10% at 1kPa), water holding capacity (WHC; 30%-65%), low nutrient and nitrogen status (that can be regulated), good rehydration and drainage characteristics and structural stability. All of these underpin modern water and nutrient management practices.

The Problem/Opportunity

The current supply of peat is under threat as a result of various EU directives, particularly the Wetland Habitats Directive. In addition, targets to reduce biowaste (e.g. landfill directive) has encouraged National Government to set aspirational targets for reducing peat use in Horticulture (40% reduction by 2005; 90% by 2010), the hope being that the reduction will be addressed by the use of the composted materials. Major retail chains have declared support for these initiatives, and are ***pressurising their supply chains*** accordingly. ***However, many Growers are reluctant to change***, due to bad experiences with poorly formulated peat alternatives produced in the early 1990's.

Fruit, vegetable and cereal processing co-products represent a considerable, sustainable and consistent (plant structure) resource for the development of new and high-specification compost-based growing media. However, the development of the latter is attenuated by: 1) a paucity of knowledge of biological **structure-function** relationships of peat-based media and a lack of effective quality measurement; 2) a very poor understanding of the composting process in relation to the microbiological degradation of plant structure and the resultant physicochemical properties. Accordingly, the composting of processed fruit, vegetable and cereal waste needs to be understood in order that it can be controlled so as to provide optimum growing media characteristics.

The study will assess the potential to develop new and novel materials as growing media which will both prove to be reliable, consistent and predictable for growers in various horticultural sectors. The annual benefit from the development of compost-based growing media could be £6- 12 million across the whole industry. In addition, there are potential economic and environmental benefits from reducing the quantity of bio waste sent to landfill.

Scientific Background

The beneficial properties of peat-based growing media reflect the macro, micro and molecular structure of the vitrified sphagnum plants. The hollow leaves provide the high WHC, whilst phenolic-rich hydrophobic stem and leaf cell walls facilitate good drainage and appropriate ion-exchange characteristics. In contrast, composting involves microbial degradation of plant (and other) materials. For poorly lignified tissues, composting generally results in total degradation to a bacterial/sand mixture (IFR, unpublished) i.e. ***there is little or no structural material*** to provide a useful growing medium. Hence, most composted materials are of low value. However, if the degree of degradation can be controlled and reduced, it is likely that sufficient plant structure may be retained to provide suitable growing media characteristics. There is little compost-related literature on this topic.

Scientific Approach

We will exploit IFR expertise on plant structure and microbial interaction, and build on previous cross-industrial R&D to:

1) Examine and define the **molecular and structural** basis for the key physicochemical characteristics of peat-based growing media; (assessment of peat structure at different length scales, molecular through to cellular and tissue);
2) Elucidate the microbial and biochemical nature, and changes in **structure** of a range of defined plant materials during closely-monitored composting with particular reference to properties identified in (1) and horticultural suitability; this will involve close collaboration with **compost producers, major growers, representative bodies and food processors**.

Exploit data from 1&2 to ***identify criteria for monitoring, controlling and enhancing growing-media quality*** from composted food process waste with a view to commercial application and dissemination via a Core Research LINK project

Materials & Methods

Task 1: structure-function of current high quality growing media

See Task 2.3 below

Task 2.1: Method development

Preparation of the windrows
Trial 1 windrows: four of these were produced at Organic Recycling. The feedstocks (brewers' spent grain, leafy greens, fruit waste and onions) were each mixed with straw to a formulation poised to optimise the water content and the C: N ratio.

Sampling the windrows
Temperature was measured periodically by inserting a probe 15 cm ("surface temperature") and 1 metre ("core temperature") into the windrow.

Samples were removed for laboratory analysis after each turning of the windrows.

Task 2.2: Full composting study

Preparation of the windrows
A further twelve windrows were constructed at Organic Recycling Ltd. Six different mixes were prepared in duplicate based on straw & brewers' grain together with mixed leaf or fruit in four of the mixes.

All windrows incorporated some brewers' grain since this appeared to give the best results from the first trial windrows. The formulations (provided by Claire Donkin) were again designed to optimise the water content and the C:N ratio.

Sampling the windrows
Temperature was measured as previously on a weekly basis and samples taken on a fortnightly basis.

Task 2.3: Physicochemical analysis

Material properties

Soil moisture-retention studies

Fig. 1. Pressure plate apparatus

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Moisture retention studies were performed using a 5 bar pressure plate extractor (Soil Moisture Equipment Corporation, Santa Barbara, California, USA) equipped with a ceramic pressure plate cell rated to 0.5 bar.

Duplicate 25g soil samples (15g for peat samples) were placed on the pressure plate cell retained by brass soil retaining rings with a section of gauze cloth on the base of each ring. The samples were levelled in each ring and allowed to stand overnight with an excess of water on the plate to saturate the samples. When the samples were ready, the excess water was removed from the ceramic plate with a syringe. The extractor was then closed and pressure increased to the required value via a regulated compressed air supply.

After the initial outflow of water, the outflow tube was connected to the tip of a burette to enable the approach to equilibrium to be followed.

At the end of a run, before releasing the air pressure in the extractor, the ends of the outflow tubes were sealed to prevent backflow of water to the samples. The equilibrated samples were then transferred quickly to Petri dishes and weighed. The moisture content was determined by drying to constant weight at 105°C using a fan-assisted oven (Gallenkamp Hotbox oven).

Water potential measurements

Fig. 2. Dewpoint potentiometer

Water potential measurements were performed using a Decagon WP4-T Dewpoint Potentiameter (Decagon Devices, Inc., Pullman, USA).

After allowing the instrument to warm-up for 30 minutes, the instrument was calibrated using the standards supplied (Decagon KCl Performance Verification Standard). If necessary, the instrument was adjusted to the correct value.

Samples were measured by placing in a disposable sample cup, completely covering the bottom of the cup, if possible, taking care not fill the sample cup more than half full. After ensuring that the rim and outside of the sample cup were clean, the sample drawer was closed. When the sample was close to the measuring temperature, the drawer knob was turned to the READ position. The samples are measured in continuous mode until stable to give an accurate value of water potential.

Water potential, Ψ, can be related back to water activity through the following equation:

$$a_w = \exp \frac{\Psi \, Mw}{RT}$$

where R is the universal gas constant, T is the absolute temperature in Kelvin, M is the molecular weight of water (g/mol) and a_w is the water activity.

Dry weight determinations (infra-red dryer)

Dry weight measurements were also performed using an infra-red dryer balance (Mettler LP-16, Mettler Instruments, Beaumont Leys, Leicester, UK). Samples were dried at 105°C for a fixed time of 30 minutes. The time course was monitored at 2 minute intervals.

Water sorption isotherms

Aliquots of each sample were equilibrated in plastic Petri dishes over salt solutions in closed desiccators at 20˚C for three weeks. After equilibration, the samples were dried using an infra-red dryer balance at 105˚C for 15/20 minutes to determine the moisture content.

The determined moisture contents were then fitted to the GAB[1] & BET[2] models using Water Analyser 97.4 software (WebbTech, Australia).

[1] Guggenheim-Anderson-de Boer model
[2] Bruner-Emmett-Teller model

Compaction
Compaction tests were performed using a Texture Analyser (Stable Micro Systems, UK) equipped with a 30kg load cell and compaction plate (Ollett *et al*, 1993).

The Heckel stress was derived through the following equation:

$\ln (1/(1-D)) = p/\sigma + A$

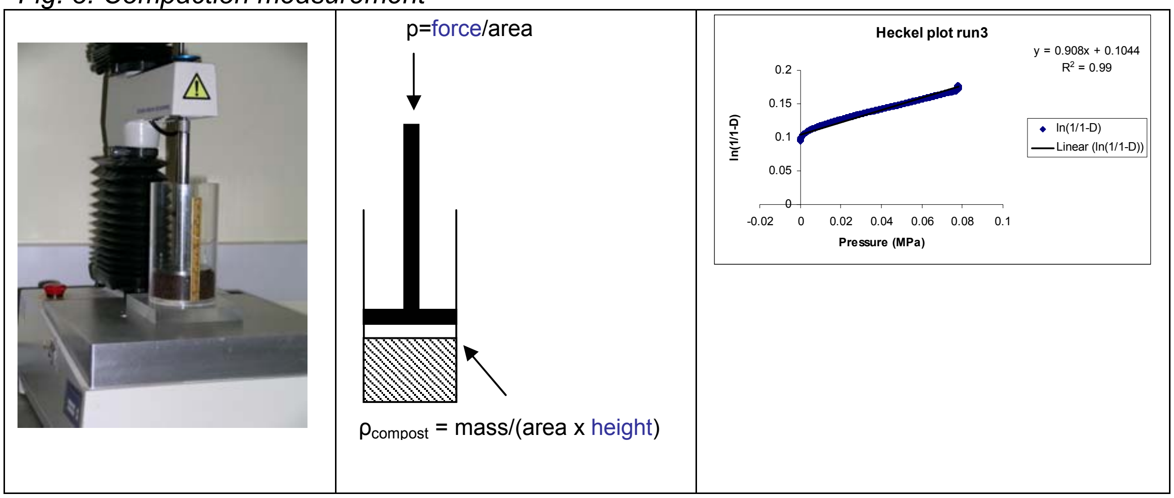
where:

D is relative density (=ρ compost / ρ matrix),

p is applied pressure and

σ is mean deformation (Heckel) stress

Fig. 3. Compaction measurement



pH & electrical conductivity measurements

Suspensions of 5g of compost: 25g distilled water were prepared for each sample in duplicate for pH measurement and shaken using an orbital shaker for 1 hour. The pH electrode was immersed in each suspension and the meter reading recorded when the pH stabilised.

The conductivity electrode was immersed in the same compost-water suspension after the one hour shake and the meter reading recorded.

Particle size distribution by sieve analysis

The particle size distributions of the peat & peat alternatives were examined using the method given in the PAS 100:2002 standard. All samples were dried overnight to below 15% moisture in a fan oven at 40 C before sieving for 7 minutes at a pre-determined amplitude using a Fritsch Vibratory Sieve Shaker (Fritsch, Idar-Oberstein, Germany). All determinations were performed in triplicate.

Air-filled porosity

The air-filled porosity of the range of peat and peat alternatives was determined using the method of Bragg & Chambers (1988). All determinations were carried out in triplicate using apparatus supplied by Bulrush Horticulture.

Plant cell wall characteristics

Preparation of alcohol insoluble residues (AIRs)
Frozen tissue (approximately 250 g) was purified according to a modified method of Parker & Waldron (1995). The windrow mix was blended, homogenised and hot-ethanol extracted. After several washes with acetone the alcohol-insoluble residue (AIR) was air-dried overnight and the final recovery obtained was approximately 20% of the original weight.

Sequential extraction of wall bound ester linked phenolics
AIR (30 mg) was extracted by the method adapted from Hartley and Morrison (1991) modified according to Parker & Waldron (1995). Trans-cinnamic acid (200 μl, 1.67 mg/50 ml methanol) was added as an internal standard and extracts analysed by HPLC.

Analysis of carbohydrate composition
Neutral sugars were released from AIR by suspending 2 mg into 200 μl of 72 % H_2SO_4, reduced with $NaBH_4$ and acetylated by the method of Blakeney et al (1983) using 2-deoxyglucose (200 μl, 1 mg/ml) as an internal standard. Alditol acetates were quantified by gas chromatography (Perkin Elmer, P.E. Auto system XL Gas Chromatograph).

Klason lignin analysis

Klason lignin was quantified gravimetrically by a modification of the method of Theander and Westerlund (1986). The residues were recovered by filtration through pre-weighed sintered glass funnels. The glass funnels were dried until a constant weight was obtained and Klason lignin calculated gravimetrically.

Task 2.4: Microbiological and biochemical analysis

Microbiological assessment

Samples were removed from each windrow. Sample heterogeneity was great, but the particle size was decreased by using a proprietary food mixer fitted with a cutting blade. The resultant material could be reliably sub-sampled. Aliquots (40g) were taken in duplicate and each blended with 360mls of a peptone salt dilution fluid (PSDF) in a Stomacher Lab-blender for 1 minute.

Samples of the supernatant were removed immediately and this suspensions (and further dilutions of it made in PSDF) were plated to the surface of a range of microbiological culture media in duplicate using a Spiral Plate Maker.

Culture media, incubation conditions and the microflora enumerated on those media are shown in the following table.

Table 1. Incubation conditions for different microflora

Medium	Conditions of incubation	Microorganisms enumerated
Plate Count Agar (PCA)	Air, 20^{o}C	Mesophilic Aerobic bacteria

Plate Count Agar (PCA)	Air, 55°C	Thermophilic Aerobic bacteria
Cephaloridine, Fucidin, Cetrimide Agar (CFC)	Air, 25°C	*Pseudomonas* spp.
Oxytetracyline, Dextrose, Yeast Extract Agar (ODY)	Air, 20°C	Yeasts and moulds
De Man, Rogosa, Sharpe Agar (MRS)	Not pre-reduced, but incubated in H_2:CO_2, 9:1 v/v 25°C	Microaerophilic bacteria
Reinforced Clostridial Medium (RCM)	Pre-reduced and incubated in H_2:CO_2, 9:1 v/v 25°C	Strictly anaerobic bacteria

Further sampling.
In addition, the following samples were also analysed:

- IFR seedling trial compost, harvested from the Brewer's Spent Grain Windrow, February 2005
- IFR seedling trial compost, harvested from the Brewer's Spent Grain Windrow, June 2005

The samples harvested in June were enumerated with and without a heat treatment intended for the inactivation of vegetative cells.

Presumptive identification of key components of the microflora
The aim here was to isolate and identify the components of the microflora responsible for the degradation of plant tissues.

It was inevitable that the windrows were contaminated with a wide range of microorganisms, some of which would multiply to large numbers, but without being responsible for the degradative processes.

Accordingly, the following protocol was adopted. The predominant colony forms on each of the enumeration media described above were isolated and purified. They were then presumptively grouped by using tests shown below:
- Gram reaction
- Possession of Oxidase
- Possession of Catalase
- Ability to grow in broth at 20°C
- Ability to grow in broth at 55°C
- Ability to degrade plant tissues

Cell-wall degrading enzymes

Measurement of xylanase activity

Xylanase activity was measured according to the method of Bailey et al. using birchwood substrate.

Substrate

1.0g of birchwood xylan (X-502, Sigma Chemical Company) was mixed with 80ml of 0.05M Na citrate buffer, pH 5.3 at 60°C before heating to boiling point on a heated magnetic stirrer. The suspension was cooled with continued stirring, covered and stirred slowly overnight. The suspension was filtered through glass wool before making up to a volume of 100ml with buffer. The substrate was stored in a freezer.

Standard curve

Xylose stock solution (1mg/ml) was prepared in Na citrate buffer (0.05M, pH 5.3). The stock solution was diluted so that the final concentration of xylose in a series of test tubes was 0.1 – 0.6 mg/ml by adding 0.9 – 0.4 ml of buffer to 0.1 - 0.6 ml of stock solution. An additional 1ml of buffer was added and then 3ml of DNS* reagent before mixing and heating in an oil bath (Grant W14, Grant Instruments, Cambridge, UK) for 5 minutes at 100°C and cooling with cold water. The colour developed was measured in a spectrophotometer (Varian Cary 3 UV-Visible Spectrophotometer) at 540nm using the reagent blank as control.

* The DNS reagent was prepared by dissolving 20g dinitrosalicylic acid, 4g phenol, 1g sodium sulphite and 400g of sodium potassium tartarate in 1 litre of 2%w/v NaOH. When a clear solution was obtained, the solution was diluted using water to 2 litres and stored wrapped in foil. All chemicals used were of analytical grade.

Extraction of enzymes from compost samples

1g of compost sample was extracted at room temperature using 9g of deionised water for 1 hour on a magnetic stirrer. The supernatant was filtered through GF/C filter paper and retained.

Procedure

Xylan substrate (1.8ml) was added to test tubes and heated to 50°C before adding 200µl of enzyme solution and mixing. The tubes were incubated for 300s at 50°C. 3.0ml of DNS reagent were added to the tubes before mixing and removing from the water bath (Grant W28, Grant Instruments, Cambridge, UK). The tubes were then heated to 100°C in an oil bath and then cooled in cold water. The colour produced was measured using a spectrophotometer at 540nm against the reagent blank correcting for the enzyme blank. Using the standard curve, the corrected absorbance was converted to give the enzyme activity in the original sample.

Results and Discussion

Objective 1: Elucidate structure-function of current high-quality growing media

For ease of comparison, much of the data pertaining to this section is presented in later parts of the report.

Task 1.1: Procurement of peat and related growing media

The following growing media have been obtained and are currently being examined for comparison with soil materials (Table 2).

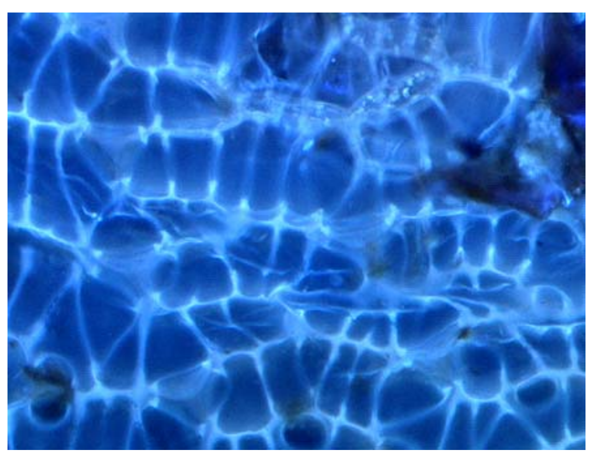
Table 2. Peat and growing media

Material	Description
Baltic (Latvian) Blonde Peat	H2-3
Irish (Ballycommon) Peat	H4-5
Somerset Sedge Peat	H7-8
J. Arthur Bowers Sterilised Loam	
J. Arthur Bowers John Innes potting compost No.1	
Shamrock Potting Compost – General Potting Medium	
Bettaland compost	
J. Arthur Bowers Peat-free Compost	
B & Q Coir-based Peat-free Compost	

The physicochemical properties of these materials are compared below with those of composted material produced in Task 2.1.

Microscopic analysis

Fig. 4. Examples of light and fluorescent micrographs of sphagnum tissues indicating cell wall phenolics.



As reported previously, the cell walls and tissue structures are largely intact in moss-derived peat, possibly because of the presence of cell-wall simple phenolics (Fig. 4).

Objective 2: Elucidate microbiological and biochemical basis of compost characteristics

Task 2.1: Method development

Windrow Design

Four windrows each of about 30m^3 have been constructed at Organic Recycling Ltd. They contain straw and one of the following food processing waste streams (provided by the Partners):

- mixed leaf (brassicas),
- onion,
- brewers' grain,
- fruit (melon and pineapple peel).

The compositions are shown in Table. 3

Table 3. Composition of trial windrows (courtesy of Claire Donkin, Swedeponic UK Ltd.)

Leaf Mix	
Loose leaf (T or Kg)	20
Straw (T or Kg)	3.8
Moisture content (%)	73
C:N (ratio)	30

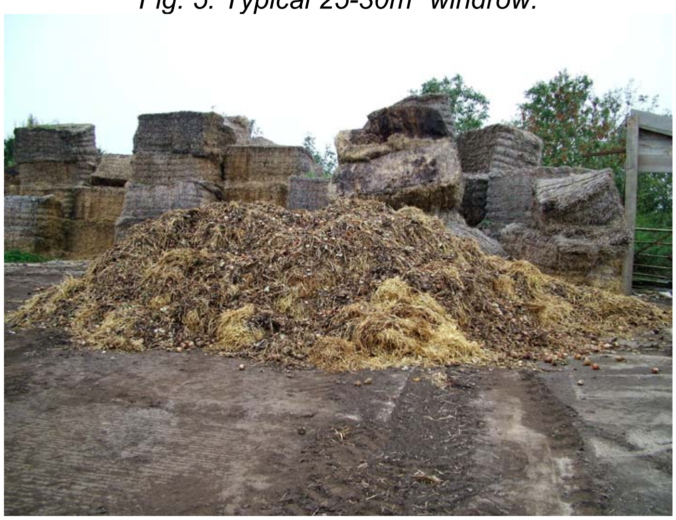
Melon Mix	
Melon (T or Kg)	20
Straw (T or Kg)	8
Moisture content (%)	60
C:N (ratio)	69.5

Brewers grain mix	
Bgrains (T or Kg)	20
Straw (T or Kg)	8.34
Moisture content (%)	59.4
C:N (ratio)	30

Onion Mix	
Onions (T or Kg)	20
Straw (T or Kg)	2.21
Moisture content (%)	79.3
C:N (ratio)	30

The windrows have been turned on a weekly basis for 3 months (prior to each sampling) and then monthly up to a total of approximately 120 days. A typical windrow is shown (Fig.5).

Fig. 5. Typical 25-30m^3 windrow.



Temperature was monitored regularly – the results are presented in the graphs below:

Fig. 6. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of onion and straw

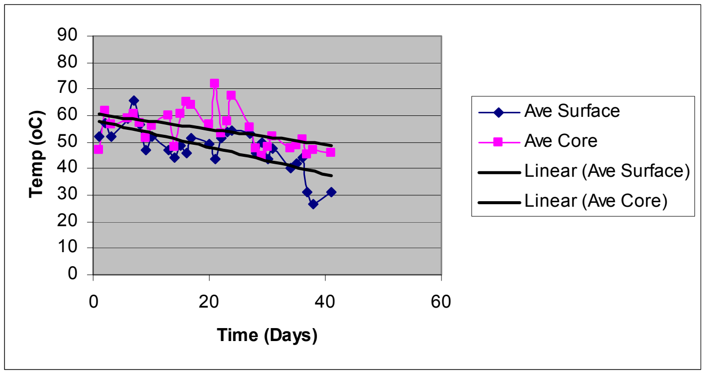


Fig. 7. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of leafy greens and straw

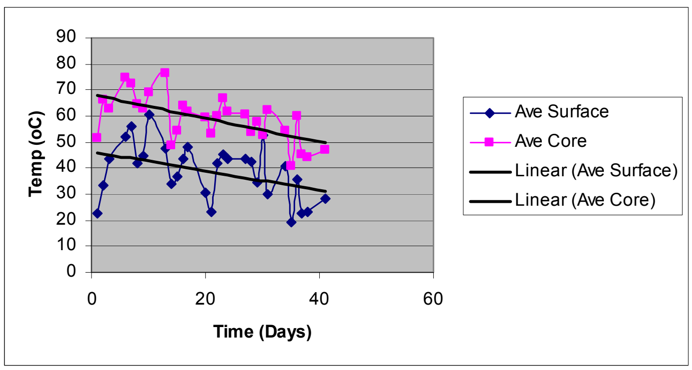


Fig. 8. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of brewers' spent grain and straw

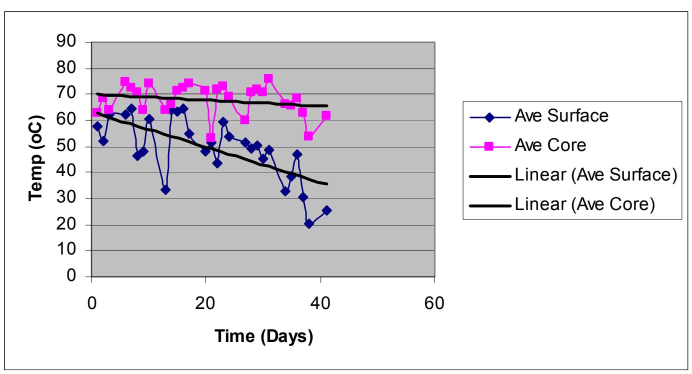
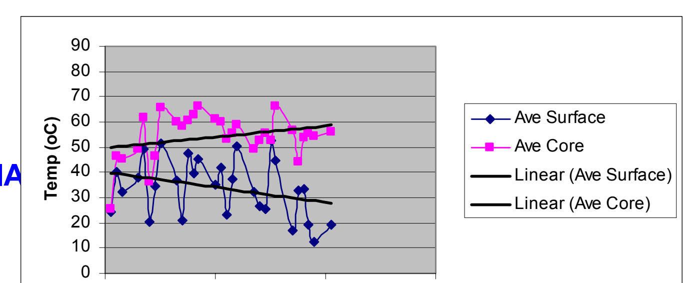


Fig. 9. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of melon and straw



Task 2.2: Full composting study

Table 4. Composition of second (main) trial windrows (courtesy of Claire Donkin, Swedeponic UK Ltd.)

Brewer's Grain + Leaf 1	
Brewers' grain (Tonnes)	20
Leaf (Tonnes)	5
Straw (Tonnes)	8.99
Moisture content (%)	59.6
C:N (ratio)	30

Brewers' Grain + Leaf 2	
Brewers' grain (Tonnes)	50
Leaf (Tonnes)	10
Straw (Tonnes)	15
Moisture content (%)	63.5
C:N (ratio)	25.6

Brewers grain mix	
Brewers' grains (Tonnes)	20
Straw (Tonnes)	8.34
Moisture content (%)	55.5
C:N (ratio)	30.7

High Brewers' Grain Test	
Brewers' grains (Tonnes)	40
Straw (Tonnes)	5
Moisture content (%)	67.3
C:N (ratio)	20

Brewer's Grain + Fruit 1	
Brewers' grain (Tonnes)	40
Fruit (Tonnes)	10
Straw (Tonnes)	15
Moisture content (%)	61.5
C:N (ratio)	28.7

Brewers' Grain + Fruit 2	
Brewers' grain (Tonnes)	50
Fruit (Tonnes)	5
Straw (Tonnes)	20
Moisture content (%)	58.1
C:N (ratio)	29.8

Fig. 10. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and leaf (Brewer's Grain + Leaf 1)

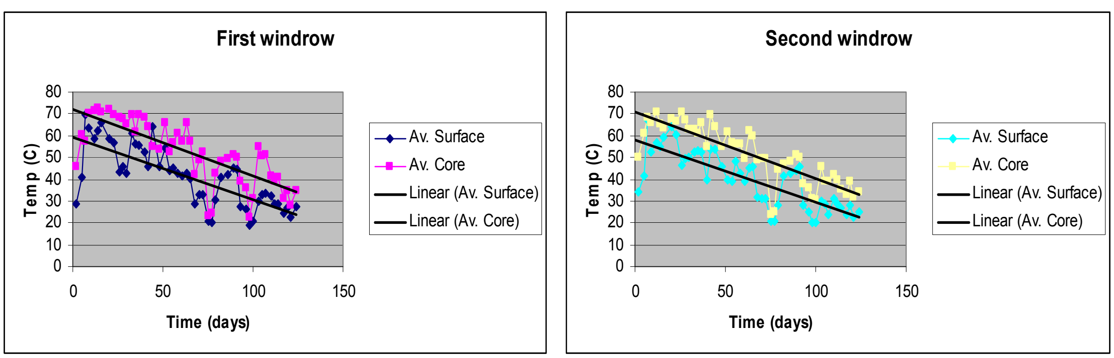


Fig. 11. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and leaf (Brewer's Grain + Leaf 2)

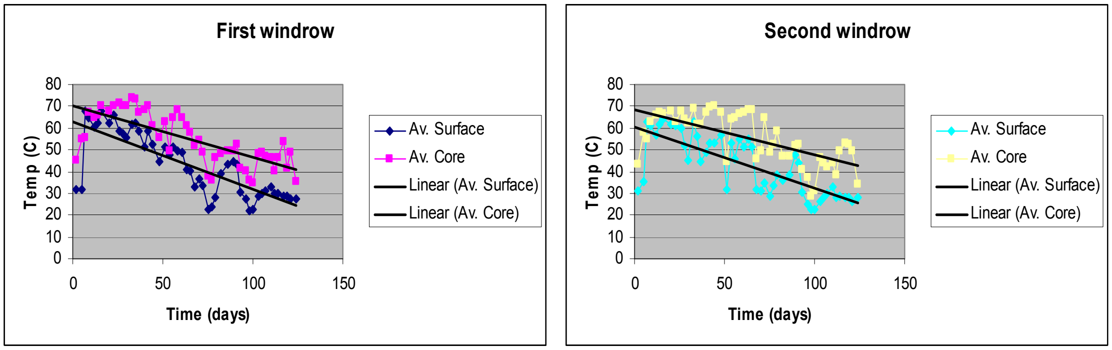


Fig. 12. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain and straw (Brewer's Grain mix)

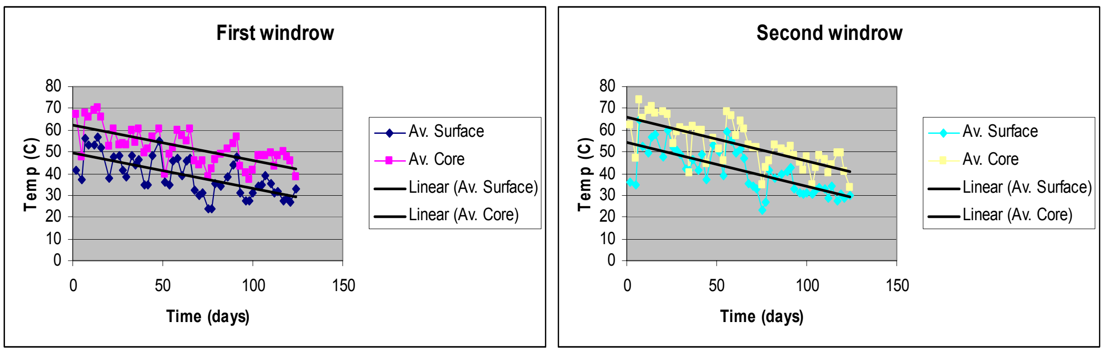


Fig. 13. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain and straw (High Brewer's Grain test)

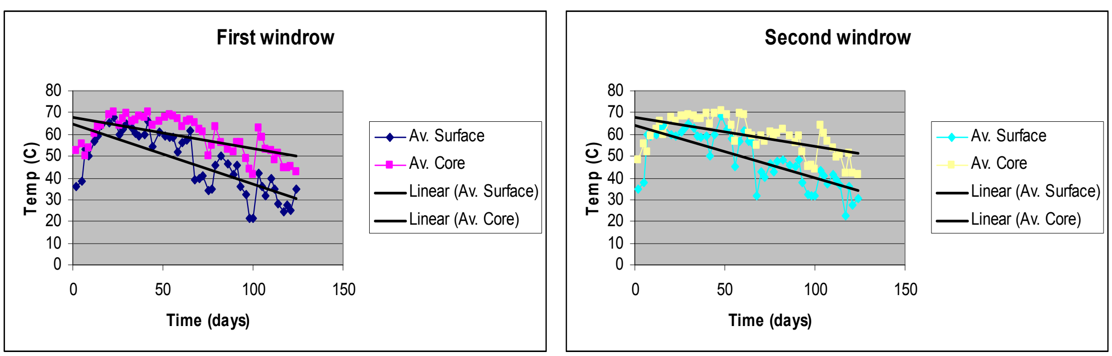


Fig. 14. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and fruit (Brewer's Grain + Fruit 1)

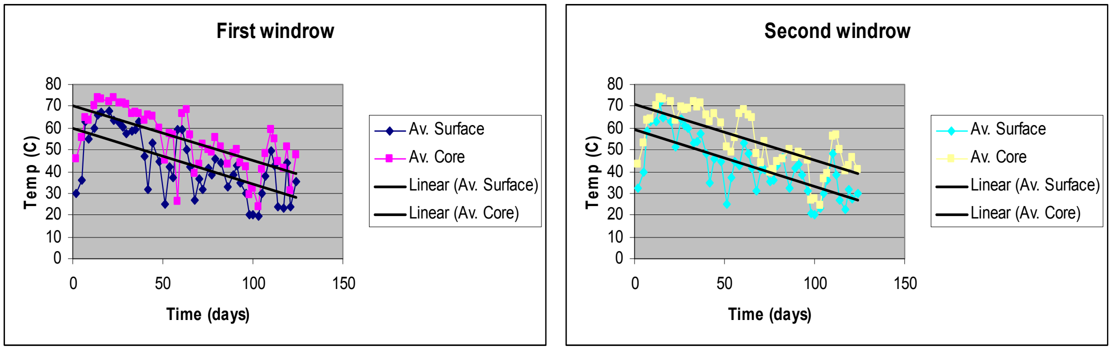
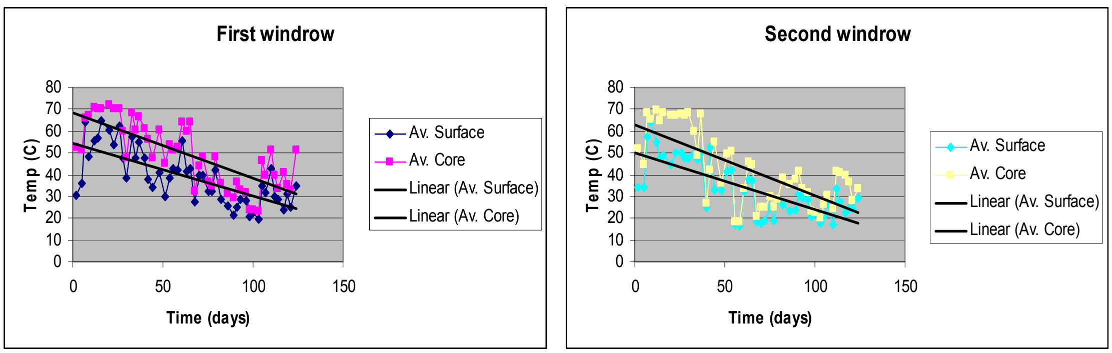


Fig. 15. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and fruit (Brewer's Grain + Fruit 2)



Samples were taken on a fortnightly basis for further analysis. The samples were generally taken from the top of the windrows for consistency although there was widespread variation in the moisture content and level of degradation within the trial windrow. The relatively dry weather throughout the course of the second trial tended to retard the level of degradation.

The inherent variability of the windrow system justifies the consideration of a vessel-type system for future trials.

Task 2.3: Physicochemical analysis

Material properties

Soil moisture-retention studies

The pressure plate cell extractor works by removing soil moisture from soil samples through the creation of a pressure gradient in an extractor. Moisture flows around each of the soil particles and out through a ceramic plate which serves as a hydraulic link. Equilibrium is reached when water flow ceases.

Moisture retention curves relate the soil suction at which moisture is held in the soil to its moisture content.

Initial experiments using the pressure plate extractor have aimed to commission the apparatus and characterise the moisture retention properties of a range of peat and commercially-available soil / compost samples.

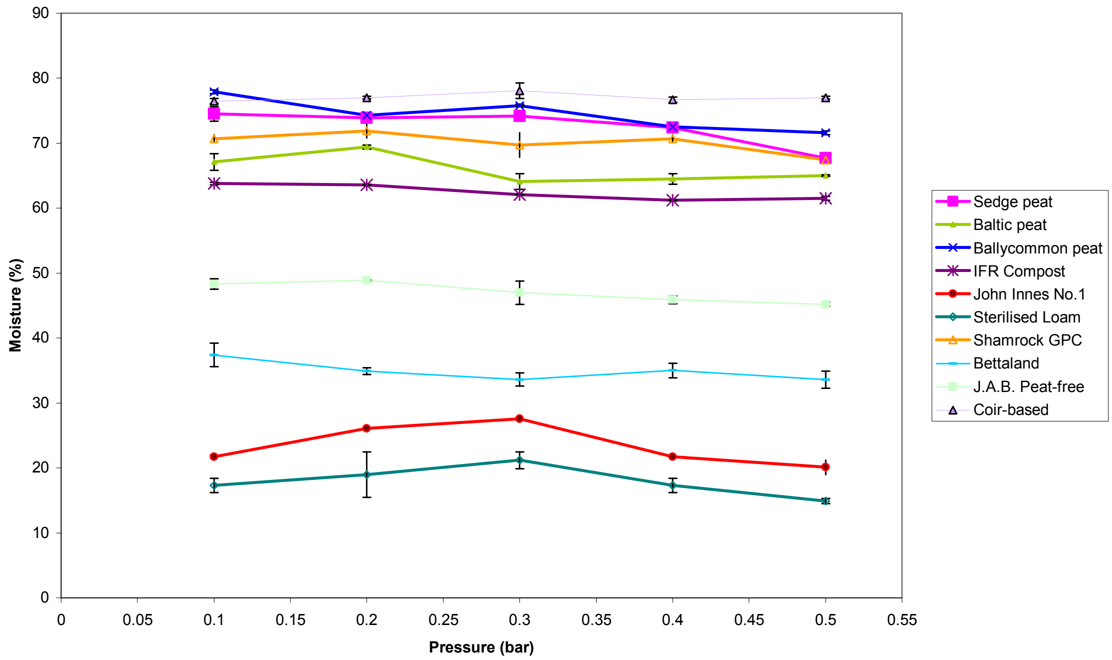
The samples examined were as follows:

- Latvian Peat
- Ballycommon Peat
- Sedge Peat
- J. Arthur Bowers John Innes Potting Compost No.1
- J. Arthur Bowers Sterilised Loam
- Shamrock Potting Compost – General Potting Medium
- Bettaland compost
- J. Arthur Bowers Organic Peat-free Compost
- B & Q Coir-based Peat-free Multipurpose Compost

In addition, the moisture retention characteristics of an initial sample of "compost" produced at IFR / Organic Recycling were examined.

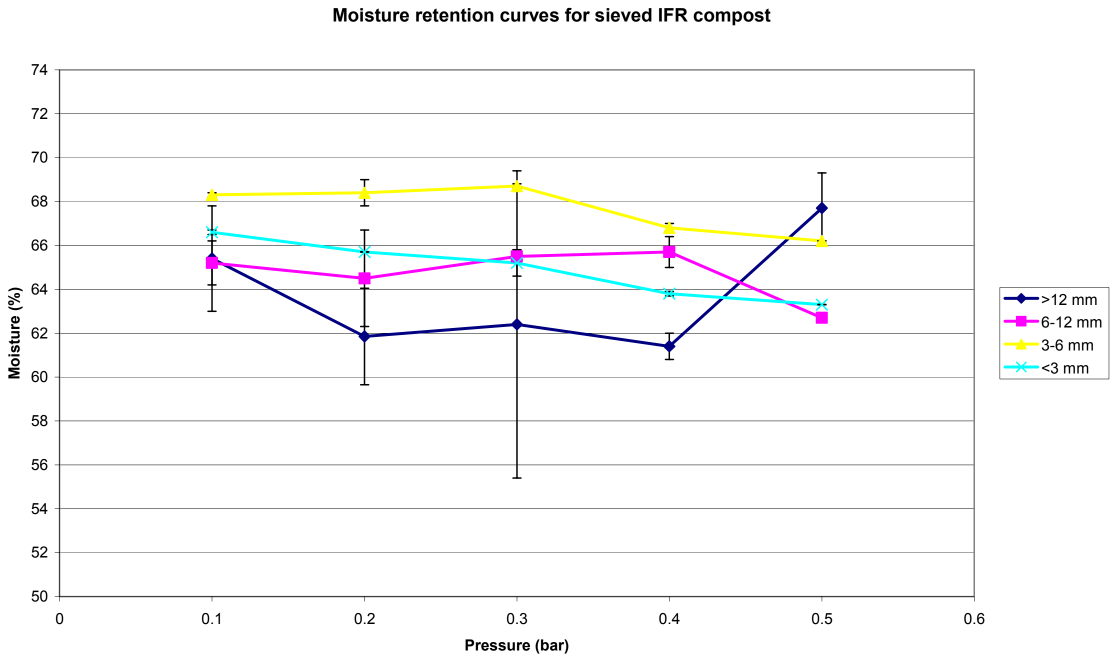
The results (Fig. 16) show that the IFR compost has moisture-retention properties similar to those of the 4 peats examined, and much higher than the John Innes, Bettaland & J. Arthur Bowers Organic Peat-free products. It is also interesting to note that the coir-based product also has a very high moisture retention.

Fig. 16. Moisture retention of a range of peats and growing media.



Material collected from the IFR compost windrows was sieved in its "as recovered" form to ascertain the sensitivity of moisture retention characteristics to the particle size distribution of a particular compost.

Fig. 17. Moisture retention curves for sieved fractions from IFR compost



No particular trends were observed but it should be remembered that the “wet” material will contain aggregates of material of a wide particle size distribution potentially masking any differences which may be present.

Water potential measurements

The dewpoint water potential apparatus was delivered and commissioned in early February 2005. Selected samples of soils, composts and cereals having a wide range of water potentials were measured and the corresponding dry weights determined using the infra-red dryer.

The apparatus measures the sum of the osmotic and matric water potential in a given sample. Soils bind water mainly through matric forces. The results (Table 4) show that all the growing media exhibit similar a_w values.

Table 5. Water potential and a_w of samples.

Sample	Water potential (MPa)	a_w	Dry wt (%)
Destarched wheat bran	-176.12	0.278	92.66
Microcrystalline cellulose	-139.96	0.362	95.64

Barley	-168.64	0.293	92.98
Brewers Spent Grain	-127.41	0.396	92.95
Ballycommon Peat	-0.28	0.998	33.42
Sedge Peat	-0.30	0.998	30.99
Latvian Peat	-0.40	0.997	48.03
J. Arthur Bowers John Innes No.1 Potting Compost	-0.88	0.994	84.30
J. Arthur Bowers Sterilised Loam	-0.32	0.998	85.28
Shamrock Potting Compost – General Potting Medium	-0.59	0.996	44.90
J. Arthur Bowers Peat-free Organic Garden Compost	-0.34	0.998	58.67
Bettaland Product	-1.60	0.988	72.22
IFR “Compost”	-1.08	0.992	39.37

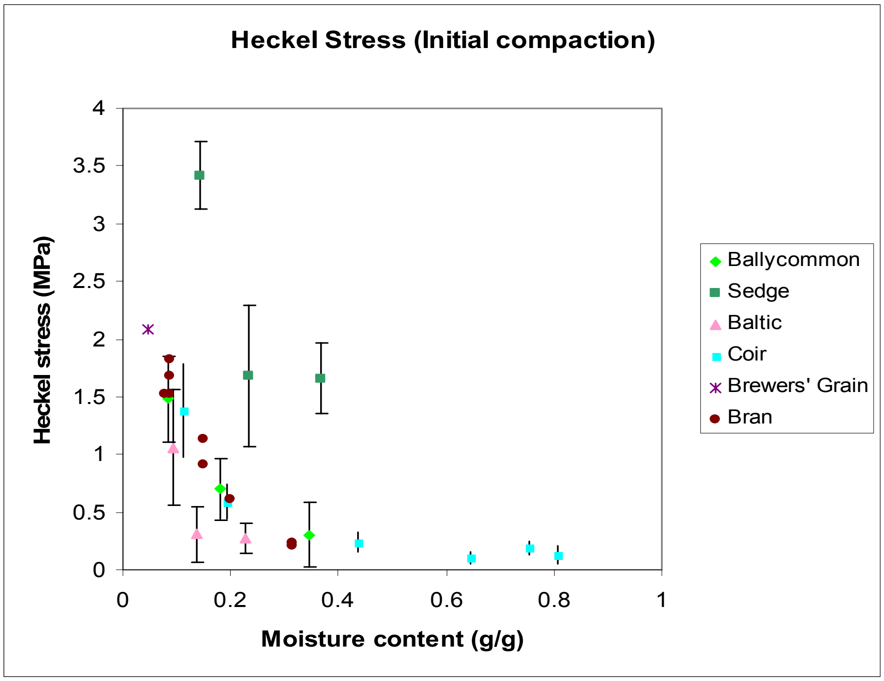
Water sorption characteristics

The water sorption isotherms of a range of peat / compost samples were determined. All results were fitted using the GAB & BET models.

Compaction

The compaction analysis system has been set up. Preliminary results are shown in Fig. 18. The general scheme is similar to previous observations for food components and larger cereal particles (Georget et al., 1994) in that the Heckel stress decreases with increasing moisture content. The Heckel stress was related to a material property, the yield stress (Heckel 1961). Subsequently it has been described as having contributions due to elastic deformation, plastic flow and particle fragmentation (Paronen and Juslin, 1983). Particle failure and re-arrangement are involved in the compaction process. A consideration of bulk density values and the relationship to other properties, e.g. particle size, will be carried out to understand the origin of the observed differences between samples.

Fig. 18. Compaction data.



pH & electrical conductivity measurements

The pH and electrical conductivity measurements taken in accordance with the PAS 100 method are shown in the table below.

Table 6. pH and electrical conductivity of selected samples.

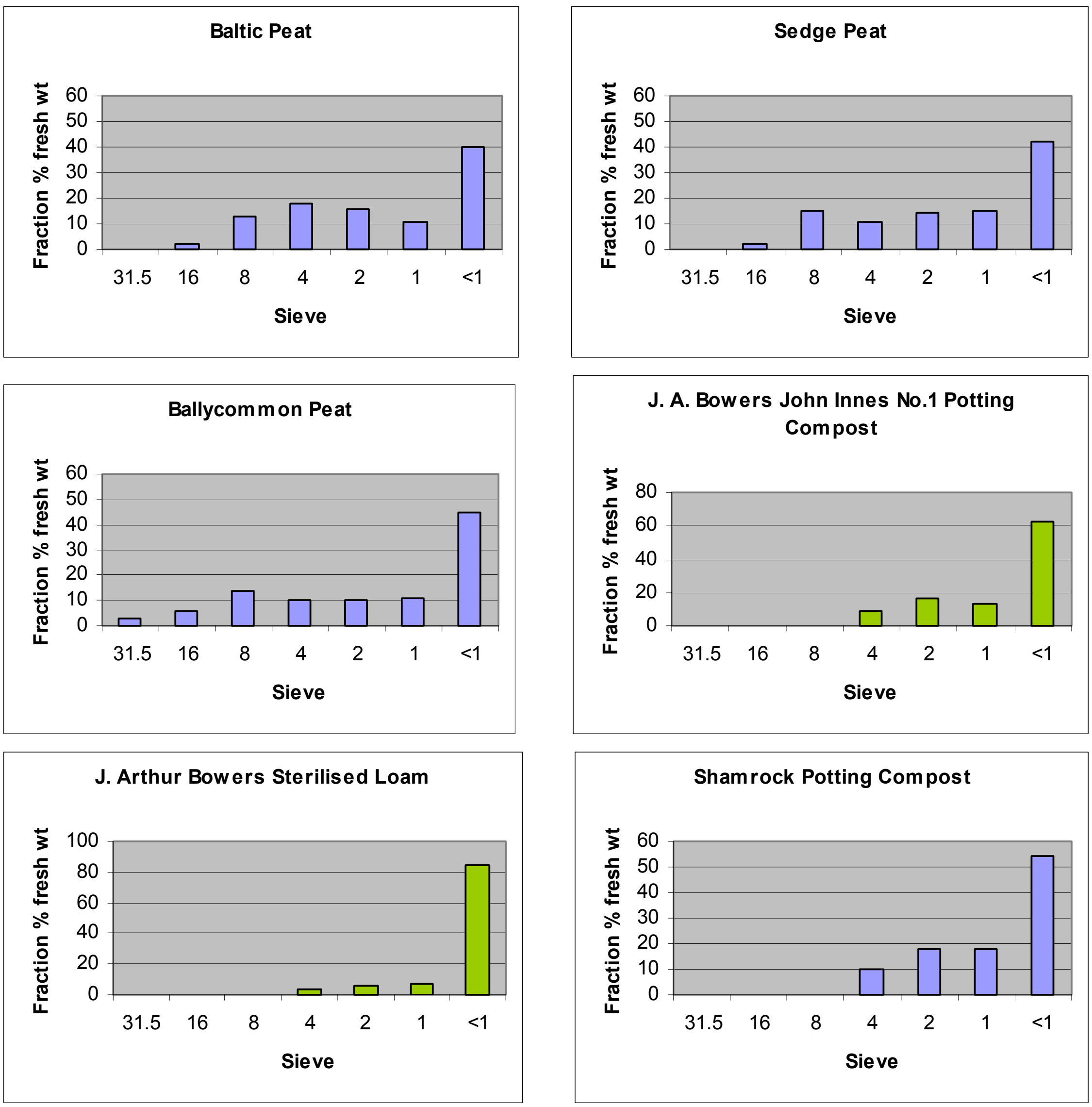
Sample	pH	Electrical conductivity
Ballycommon peat	3.95	10.4 mS/m
Baltic peat	3.87	12.2 mS/m
Sedge peat	4.43	67 mS/m
Shamrock Potting Compost	5.06	167mS/m
B&Q Coir-based compost	5.08	230 mS/m
IFR compost	6.23	396 mS/m
J. Arthur Bowers John Innes No.1	7.27	75 mS/m
J. Arthur Bowers Sterilised Loam	7.43	36 mS/m
Bettaland compost	7.60	381 mS/m
J. Arthur Bowers Peat-free Compost	8.39	153mS/m

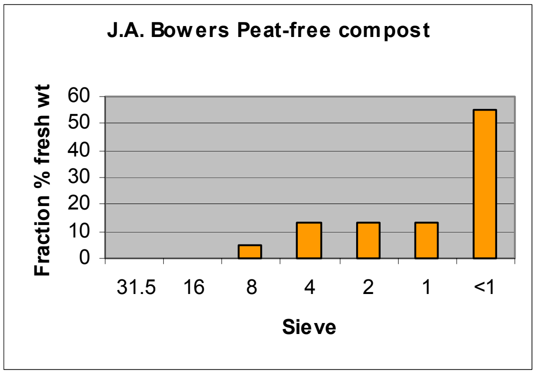
Other selected materials will be measured in the next six months. It is, however, particularly noticeable that the composted materials exhibit naturally high electrical conductivity. This may limit incorporation rates for composted material due to its negative effect on germination, rates of root growth and flower development compared with peat-based mixes.

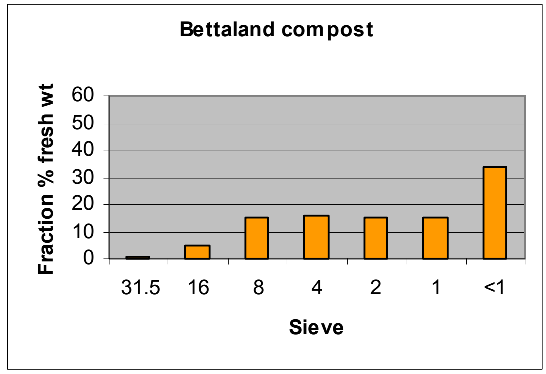
Particle size distribution by sieve analysis

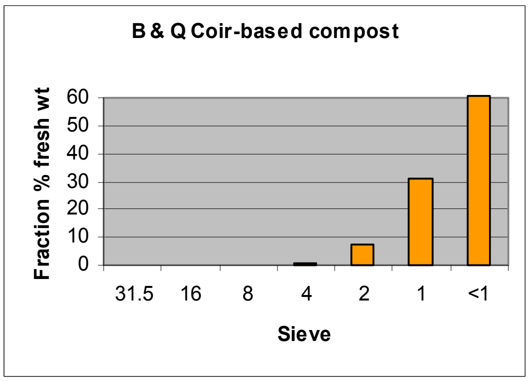
The particle size distributions of the peats & peat alternatives are shown in the following graphs (Figure 19). It can be seen that the IFR compost collected on 28th February 2005 has a noticeably different particle size distribution to the other materials. The IFR compost collected on 8th June 2005 would seem to have undergone further structural degradation.

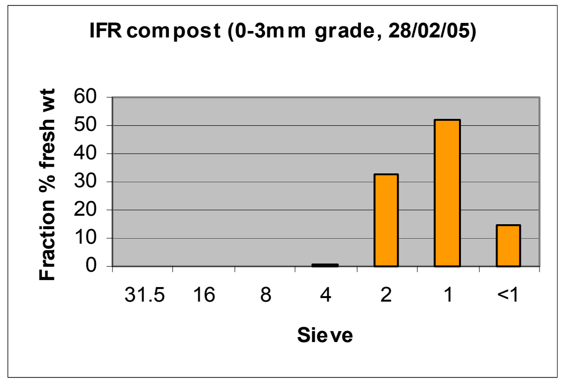
Fig. 19. Particle size distributions of selected samples

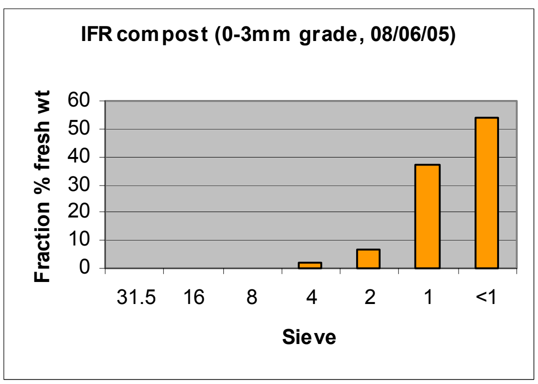












Air-filled porosity

An advisory classification system relating air-filled porosity (AFP) values to the ease of compost management (Bragg & Chambers, 1988) is reproduced below:

Table 7. Advisory classification system for air-filled porosity values.

Classification		Suggested suitability	Conditions
Index 0	AFP (%) <7	- Short term pot plants / bedding plants	- Very careful watering, especially under low transpiration conditions (capillary matting)
Index 1	AFP (%) 7-10	- Nursery stock in large pots - Pot & foliage plants (large pots) - Bedding plants	- Drained sand beds for overwintering - Careful watering management
Index	AFP (%)	- Pot and foliage plants	- Watering management less

2	10-15	- Bedding plants - Nursery stock (small / medium pots)	critical, as compost relatively freely draining.
Index 3	AFP (%) 15-25	- Pot and foliage plants (small pots) - Long term nursery stock - Azaleas, orchids (eriphytes)	- Frequent watering will be required

AFP values were determined for a range of peat / peat alternatives and soils at IFR. The values are shown in the table below:

Table 8. Air-filled porosity values of samples.

Sample	AFP (%)	S.D.
J. Arthur Bowers Sterilised Loam	4.5	2.4
J. Arthur Bowers John Innes No.1 Potting Compost	4.8	0.8
J. Arthur Bowers Organic Peat-free Potting Compost	9.6	3.1
Sedge Peat	11.6	0.6
Bettaland compost	13.6	3.5
Shamrock Potting Compost – General Potting Medium	15.8	4.8
IFR compost (<3mm)	25.8	2.1
B & Q Coir-based Peat-free Multipurpose Compost	34.8	4.3

Discussions with Neil Bragg indicate that (apart for the Bettaland compost), the values obtained are in the expected range for the various samples.

Having looked at the various physiochemical measurements, the next step will be to consult with growers / peat producers to ascertain which of the characteristics are desirable. It may well be necessary to blend the IFR compost with other materials to produce the optimum growing medium.

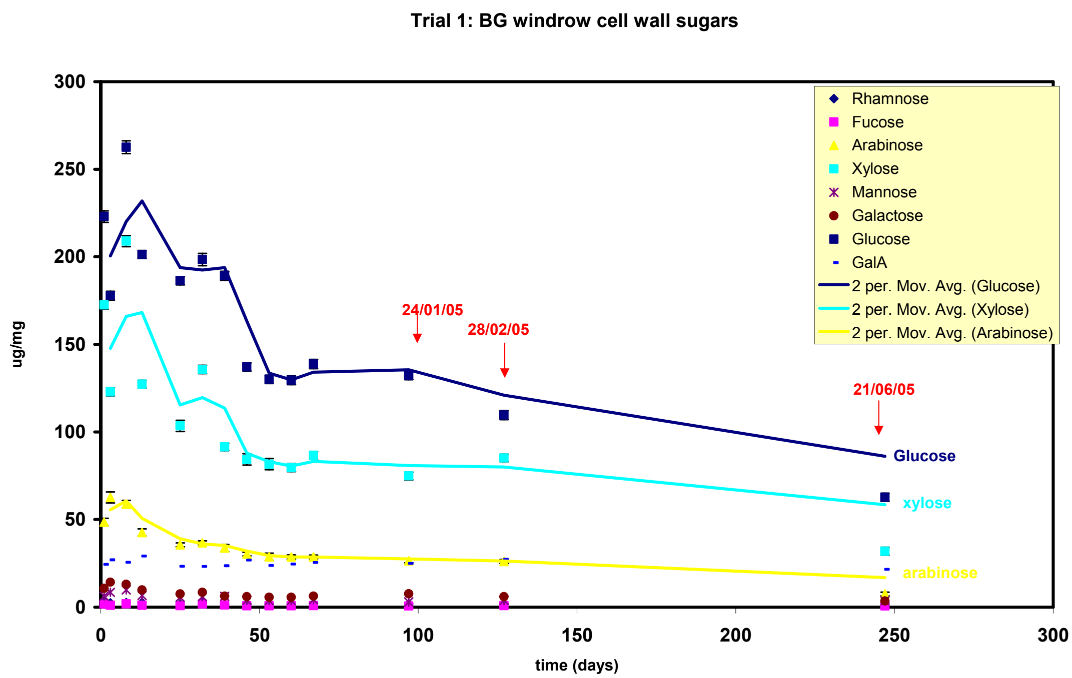
Plant cell wall characteristics

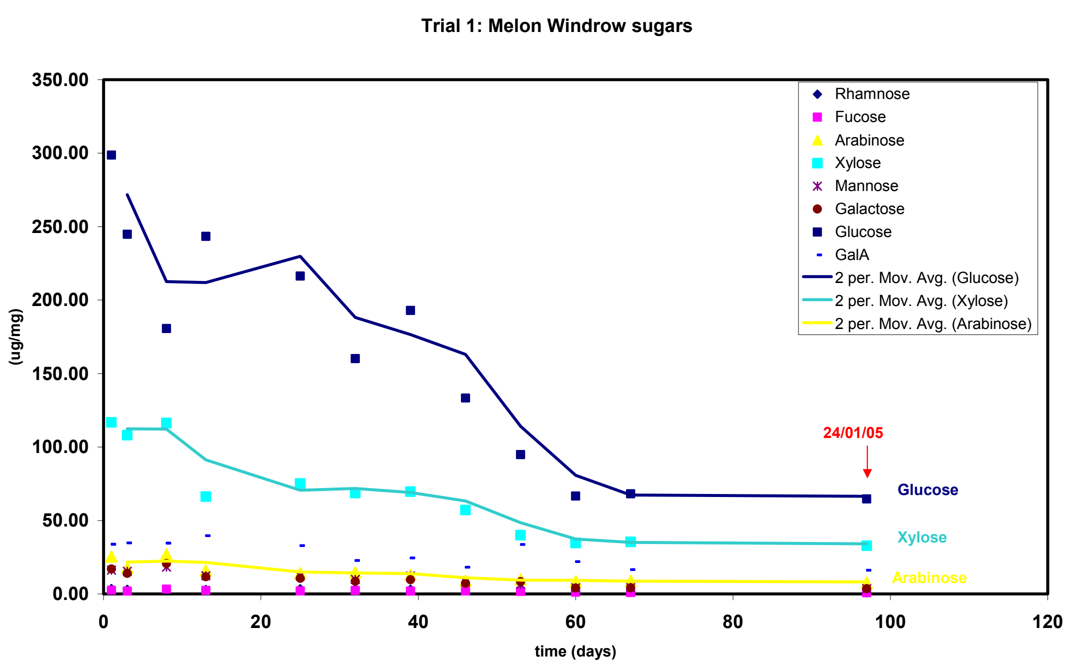
Trial 1

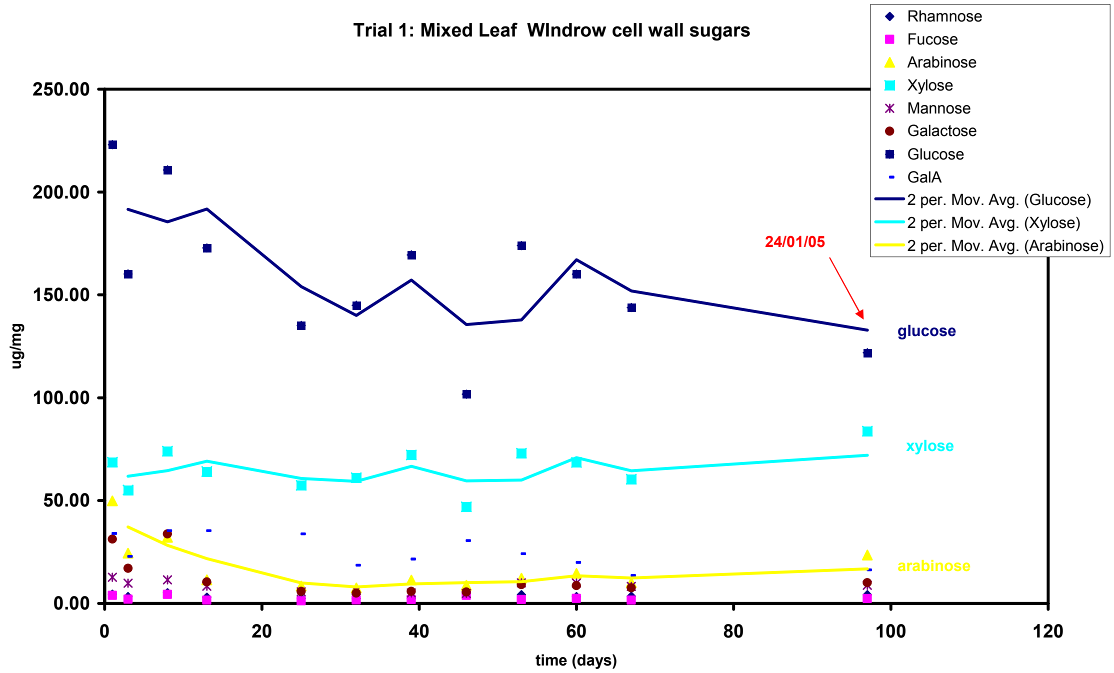
Yields of AIRs and carbohydrate content

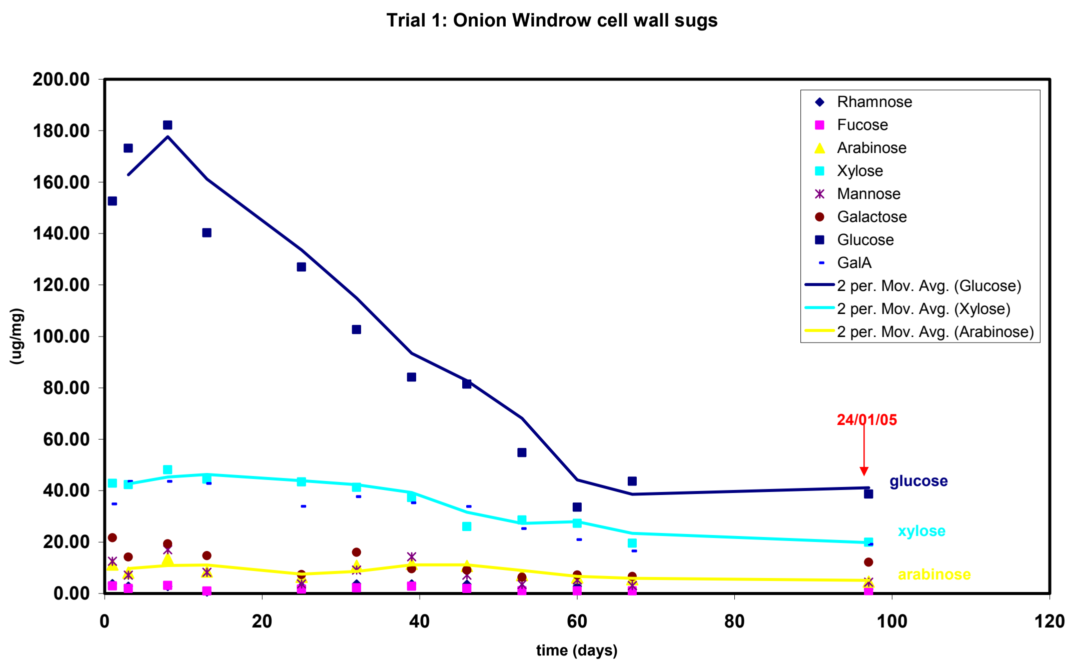
The AIRs were prepared by purifying the compost mixes so that the remaining residue consisted solely of the cell wall material (CWM) minus the cellular contents. The yields of the AIRs obtained were ~25% on average which increased with time except for the brewer's grain (BG) mix. The increases in the yields were correlated by depletion in the carbohydrate content (see Figure 20) suggesting that in these mixes all the readily-available carbon source had been utilised. The yield of BG mix remains stable over time suggesting carbon reserve capable of maintaining metabolism.

Fig. 20. Changes in cell wall composition of composted food processing wastes and straw. Key to main lines: Dark blue: glucose; Light blue: xylose; Yellow: arabinose.


Trial 1: BG windrow cell wall sugars
ug/mg
300
250
200
150
100
50
0
0
50
100
150
200
250
300
time (days)
Rhamnose
Fucose
Arabinose
Xylose
Mannose
Galactose
Glucose
GalA
2 per. Mov. Avg. (Glucose)
2 per. Mov. Avg. (Xylose)
2 per. Mov. Avg. (Arabinose)
24/01/05
28/02/05
21/06/05
Glucose
xylose
arabinose


Trial 1: Melon Windrow sugars
(ug/mg)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
20
40
60
80
100
120
time (days)
Rhamnose
Fucose
Arabinose
Xylose
Mannose
Galactose
Glucose
GalA
2 per. Mov. Avg. (Glucose)
2 per. Mov. Avg. (Xylose)
2 per. Mov. Avg. (Arabinose)
24/01/05
Glucose
Xylose
Arabinose



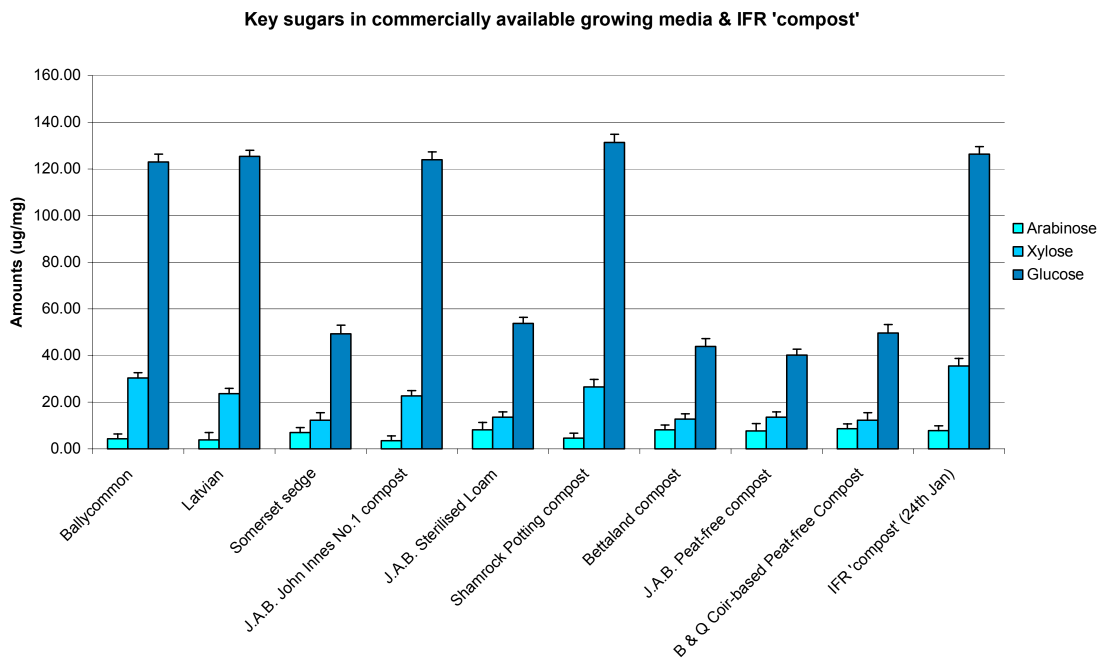


Composted material was analysed for the cell wall carbohydrate composition. The results (Fig. 20) showed that in all cases (except for mixed leaf) the sugars had declined to a stable value after 70 days.

The BG windrow material, being of a quality which lent itself to potential exploitation, was sampled up to 150 days. It is clear that some further but slow degradation occurred during that period.

Comparison of compost mixes with peat yielded alcohol-insoluble residues (AIRs) ranging from 48% to 24%. Interestingly, Somerset sedge, Bettaland, JAB peat-free compost and Coir depicted the least amount of sugars and correspondingly the lowest yield of AIR (Fig. 21).

Fig. 21. The amount of sugars present in AIRs of commercially available growing media and IFR compost samples.



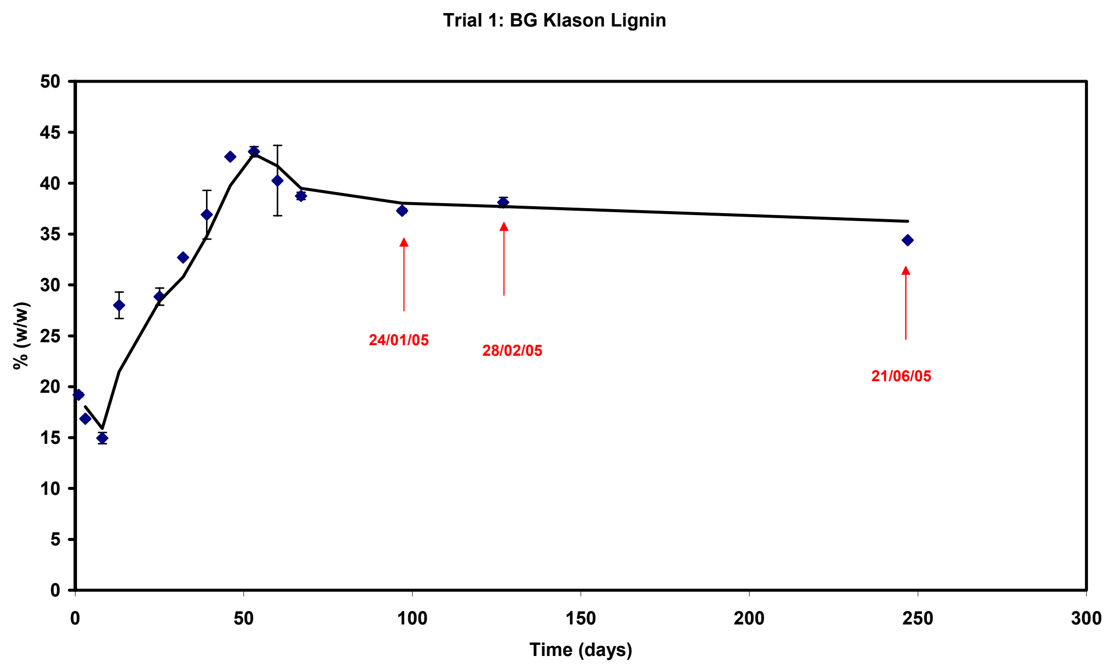
Phenolic acid analysis

Phenolics are ubiquitous plant components which have a function in plant defence and structure. The phenolic profile between BG mix and straw was very similar affording a total of 5 and 14 µg/mg dry weight. In all the other mixes a similar but lower level of phenolic content of 2µg/mg dry weight was measured on average (results not shown). The results showed a general decrease in the compounds over time but we could not unequivocally designate any specific trends in relation to degradation. The total amount of phenolics measured in the peat were similar to the other windrow mixes but lower than either straw or BG.

Klason Lignin analysis

Lignin is derived (in part) from the same pathway as the phenolics and imparts strength and rigidity to plant structure. Klason lignin is a gravimetric measure of the residue remaining after acid hydrolysis and normally indicates the toughness of a tissue. Lignin analysis of AIRs depicted a gradual increase in the lignin content of BG and melon mixes. By far the highest lignin content was measured in the BG mix at 42% followed by the melon mix at 22% respectively. Analysis of commercial peats demonstrated maximum values of 48% and minimum values of 22% (figure below).

Figure 22. Klason lignin in Brewer's Grain windrow compost



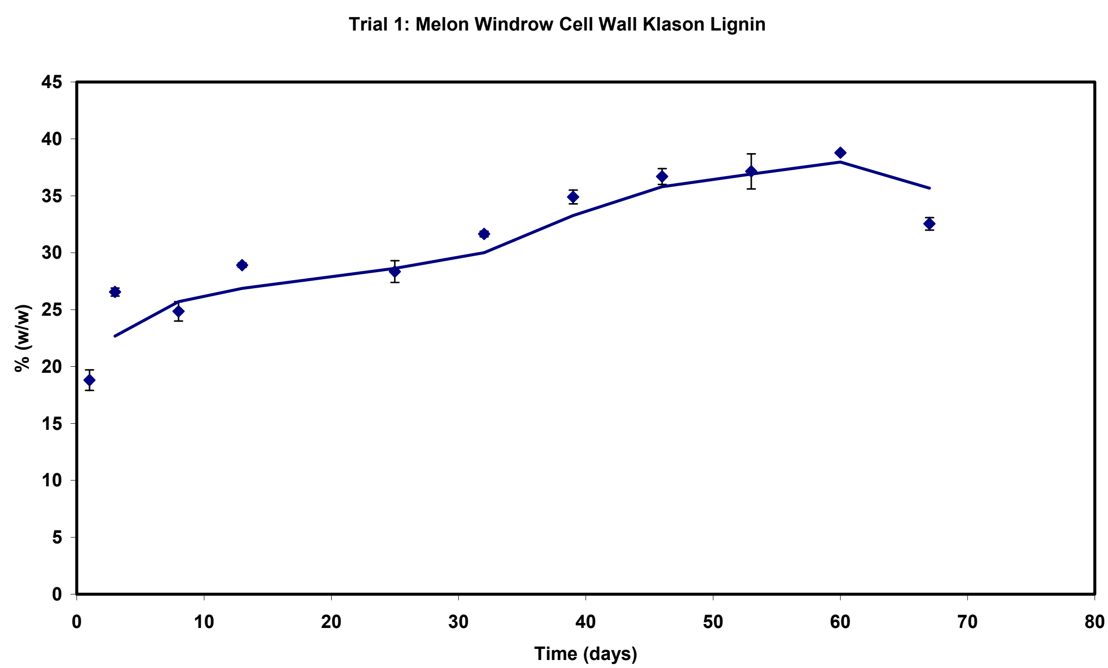
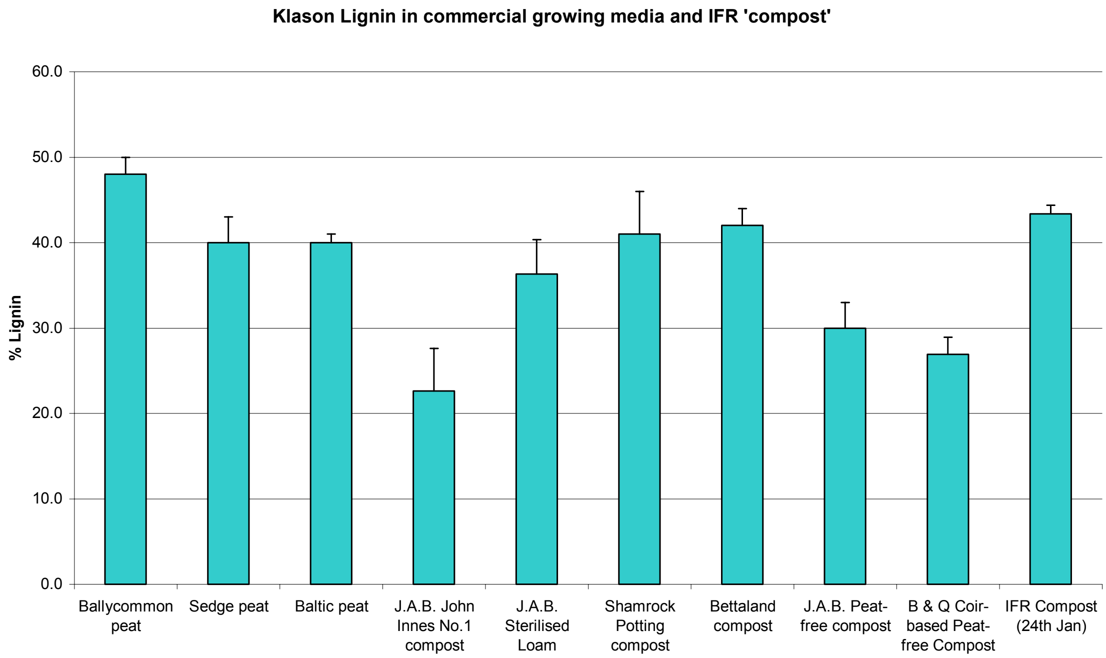


Figure 23. Klason lignin in commercial growing media and IFR compost



Microscopy

Fig. 24: (1) onion mix, (2) mixed leaf, (3) melon and (4) brewer's grain

Microscopy after composting (January 24th 2005)

(a) Onion: onions are relatively intact amongst the semi-rotted straw although the tissues are discoloured and waterlogged. Fungal colonies and slimy bacterial colonies are present on the surface of the onion scales and probably within the onion flesh. A heavy, wet and blackened malodorous sample (Fig. 24 – 1).

(b) Mixed leaf: the leaf material has collapsed into a slime amongst the semi-degraded straw. Only the lignified xylem survives in the slime in this wet, dark malodorous sample (Fig. 24 – 2).

(c) Fruit: as in mixed leaf, the fruit tissue has mostly degraded, apart from the melon seeds which have rotted internally. This sample does not contain the wet, slimy and malodorous components seen in the mixed leaf compost (Fig. 24 – 3).

(d) Brewers' Grain: the internal tissues of the grain have degraded and there is an abundance of surface fungal mycelium throughout the sample. The outer glumes (palea and lemma) of the grain, being of similar composition to the straw, have resisted major breakdown, and together with the semi-degraded straw have produced a light-coloured, relatively-dry and pleasant-smelling sample (Fig. 24 -4).

In all cases, the straw was largely intact, but had become spongy in texture, allowing water penetration. The Brewers' Grain compost was the best-drained sample. That derived from onion or mixed leaf waste was the heaviest and foulest smelling.

Task 2.4: Microbiological and biochemical analysis

Microbiological assessment

First trial

The microflora was categorised as either:

- aerobic mesophilic bacteria,
- aerobic thermophilic bacteria,
- *Pseudomonas* spp.,
- yeasts and moulds,
- microaerophilic bacteria
- strict anaerobic bacteria.

Interestingly, the microbiological composition of the windrows was broadly similar, with the exception of the initial numbers of thermophilic aerobic bacteria. The numbers of these bacteria are tabulated below, and (as representative data), the microbiological composition of the windrows containing onion and straw is shown (Table 9, Figs 25-20).

Table 9: Numbers of thermophilic aerobic bacteria isolated from the separate feedstocks and from the windrows below

Windrow feed stock	Numbers of bacteria (log_{10} colony forming units per gramme):

	In the individual feedstocks at:	In the windrows at:	
	Day zero	40 days	61 days
Straw	3.97		
Onion	3.89	7.48	7.60
Melon	5.43	7.73	7.47
Leafy greens	4.54	7.36	7.65
Brewers' Spent Grain	6.86	7.62	7.71

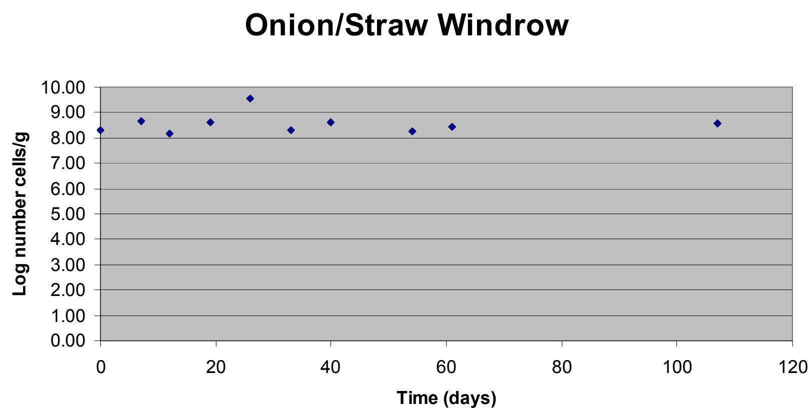


Fig. 25. Numbers of aerobic mesophilic bacteria

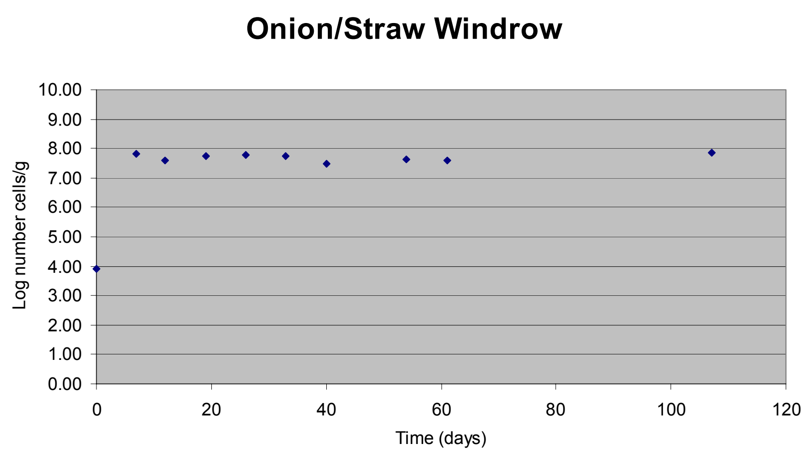


Fig. 26. Numbers of aerobic thermophilic bacteria

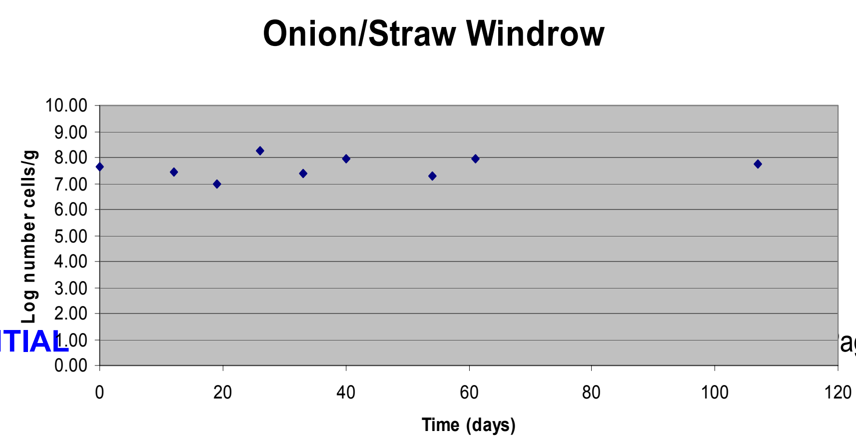


Fig. 27. Numbers of *Pseudomonas* spp.

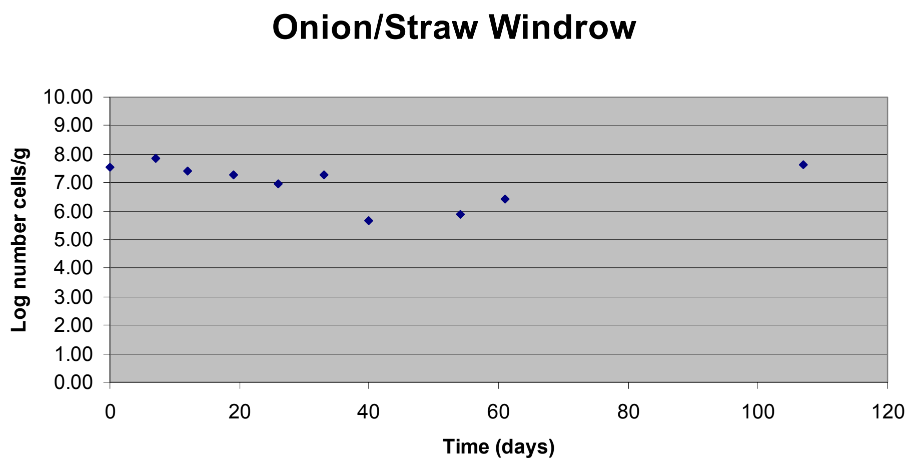


Fig. 28. Numbers of yeasts and moulds.

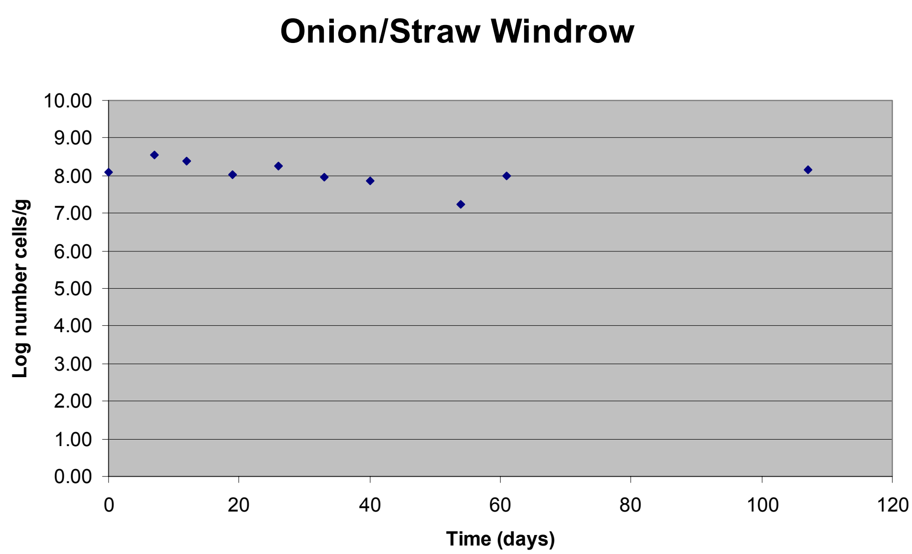


Fig. 29. Numbers of microaerophilic bacteria.

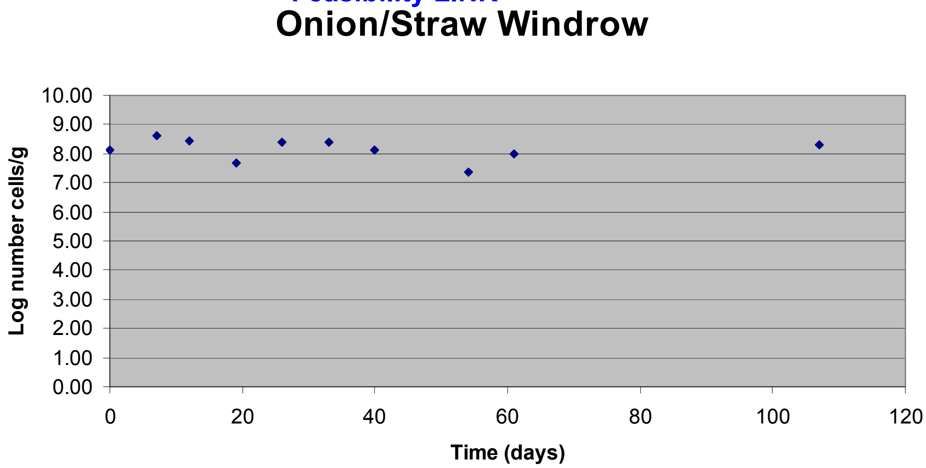


Fig. 30. Numbers of strictly aerobic mesophilic bacteria.

Further sampling

The following table compares the numbers of key microorganisms in the IFR seedling trial compost, harvested from the Brewer's Spent Grain Windrow, February 2005, and the IFR seedling trial compost, harvested from the Brewer's Spent Grain Windrow, June 2005 (with and without a heat treatment).

Table 10.

IFR seedling trial compost harvested:	Number of viable microorganisms (log_{10}) per gramme compost:					
	aerobic mesophilic bacteria	**aerobic thermophilic bacteria**	***Pseudomonas* spp.**	**yeasts and moulds**	**micro-aerophilic bacteria**	**strict anaerobic bacteria**
February	7.61	7.72	5.80	4.81	5.70	6.53
June (with heat treatment)	6.59	7.70	<2	<2	6.12	6.38
June (without heat treatment)	7.29	7.33	6.08	5.62	6.18	6.44

Table 11. Presumptive identification of key components of the microflora.

Windrow source	Colony description	Gram reaction	Oxidase	Catalase	Growth in broth at: 20°C	55°C
			***Pseudomonas* spp.**			
Onion	1. large dry white	- rods	+	+	+	
	2. pink dimpled	- rods	-	+	+	
	3. cream/pink high domed mucoid	- rods	+	+	+	
Melon	1. flat yellow spreading	- rods	+	+	+	
	2. cream/white domed	Tiny - rods (coccobacilli)	-	+	+	
Leafy greens	1. flat yellow translucent spreading	Small feint - rods	+	Slow weak +	+	
	2. cream/white domed mucoid	- rods	Slow +	+	+	
	3. flat cream/pink	- rods	+	+	+	
Brewer's spent grain	1. flat yellow translucent spreading	- rods	+	+	+	
	2. cream domed mucoid	- rods	+	+	+	
	3. red shiny	- rods	-	+	+	
			Aerobic thermophilic bacteria			
Onion	1. flat grey/clear spreading	+ rods	+	+	+ with pellicle	+
Melon	1. flat grey/clear spreading	+ rods with spores	+	+	+ as above	+
Leafy Greens	1. grey/clear spreading	+ rods	+	+	+ as above	+
	2. small dry white irregular	+ cocci			+ cloudy growth but pellicle	+
Brewer's spent grain	1. grey/clear spreading	+ rods some distended by spores	slow+	+	+ as above with pellicle	+
			Aerobic mesophilic bacteria			
Onion	1. medium domed centre white/grey	+ coccobacilli	-	+	+	-(5 days)
Melon	1. large flat dry	Fat + rods with spores	-	+	+	-(5 days)
Leafy greens	1. medium domed shiny pink/cream (pseud like sheen)	Small – rods	+	+	+	-(5 days)
Brewer's spent grain	1. small shiny white	Small + rods	-	+	+	- (5 days)

			Yeasts and moulds			
Onion	1. small white dry	Yeasts	-	+		
	2. white cols fungal hyphae					
Melon	1. medium grey shiny with oily sheen	+ rods some long	-	+		
	2. small grey dry dimpled	- rods	-	+		
Leafy greens	1. Small white shiny/wet	very small - rods/cocco bacilli	-	+		
Brewer's spent grain	1. grey medium slimy	small – rods/cocco bacilli	-	+		
			Microaerophilic bacteria			
Onion	1. small white shiny	+ rods	-	-		
Melon	1. medium pink/matt	Yeasts	-	+		
	2. small white shiny	+ cocci	-	-		
Leafy greens	1. small white shiny	+ small rods or cocci	-	-		
Brewer's spent grain	1. small white shiny	+ cocci	-	-		
			Strict anaerobic bacteria			
Onion	1. small white shiny	+ rods	-	-		
	2. medium pink/white matt	Yeasts	-	+		
Melon	1. medium cream/pink shiny	- rods	+	-		
Leafy greens	1. small white/cream shiny	- rods v feint	+	+		
Brewer's spent grain	1. small white shiny domed	+ cocci	-	-		

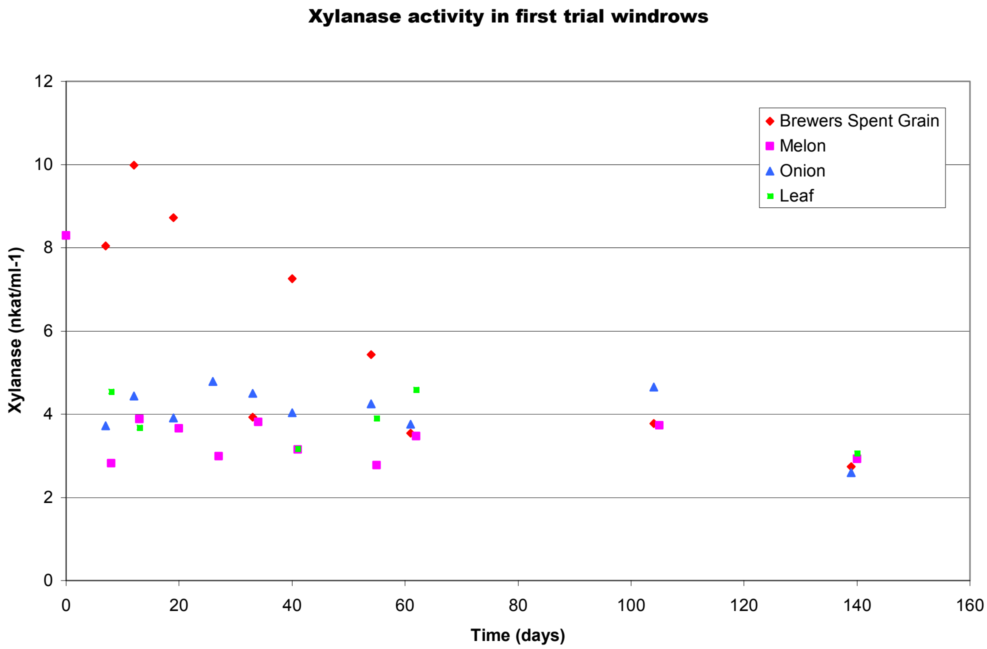
Cell-wall degrading enzymes

Measurement of xylanase activity

Cellulolytic, hemicellulolytic and pectinolytic activities will be measured in samples collected at different stages of composting using standard methods. The first assay to be set up was that to measure xylanase activity (Bailey et al, 1992) as described in the Materials & Methods section.

The results obtained are shown in the graph below:

Fig. 31. Xylanase activity in first trial windrows.



As expected, there is no change in xylanase activities during the degradation of the melon, leaf and onion windrows. There is however variation in the xylanase activity in the brewer's grain windrow which is significantly higher for the first 60 days. It should be noted that the brewers' grain substrate contained no xylanase activity at the start of the composting process presumably due to heat inactivation during the brewing process.

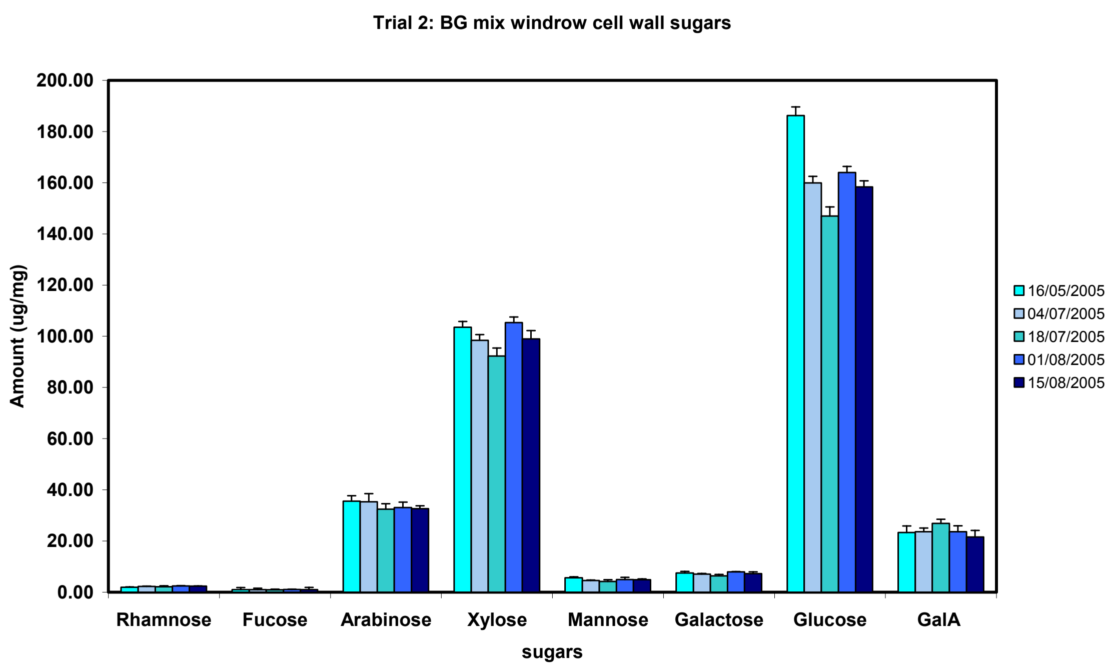
Growing Media Stabilisation

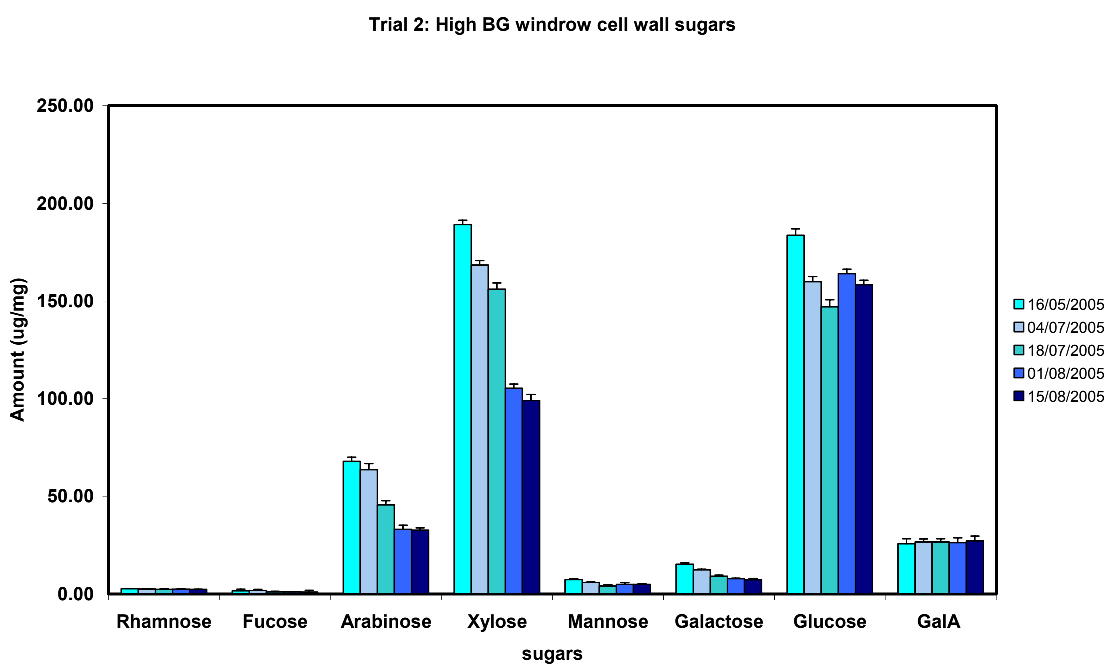
At 104 days, samples of the 4 windrows were stabilised at the IFR and used as a base for producing small quantities of compost (referred to as IFR compost). This is currently being evaluated for physicochemical properties.

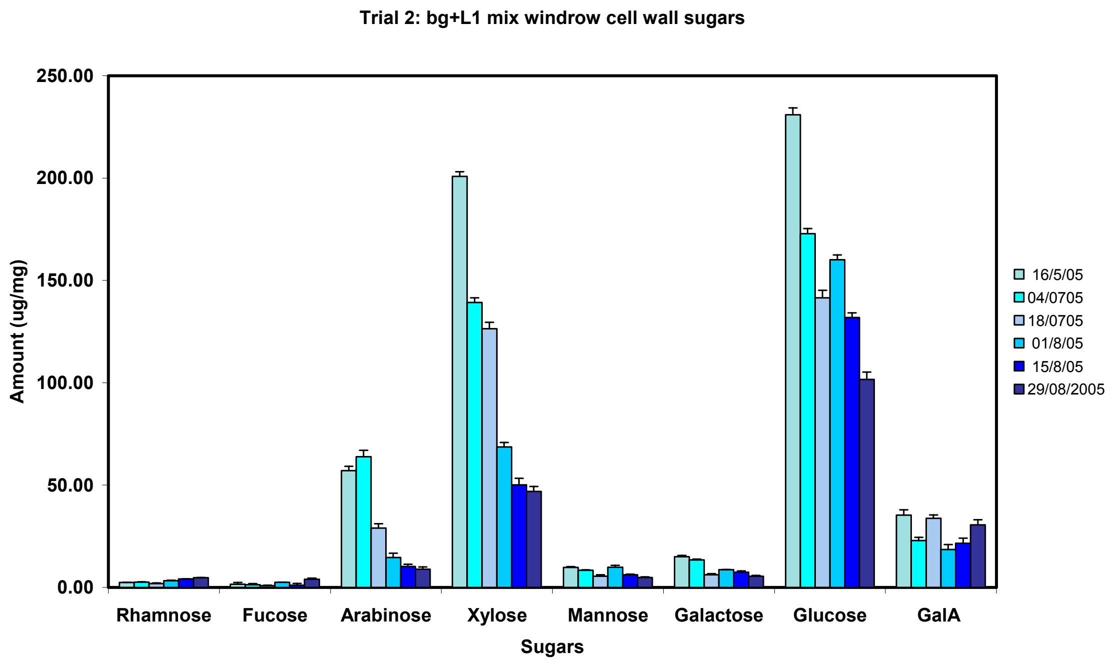
Second Windrow Trials

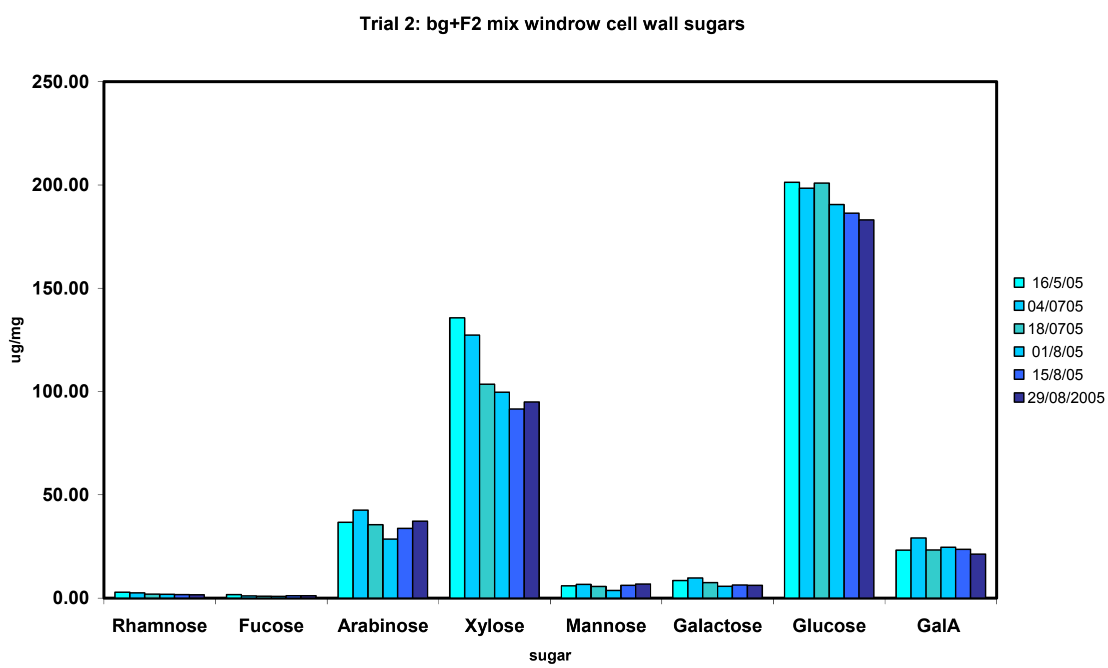
Chemical analysis

Fig. 32. Second trial windrow cell wall sugars






Trial 2: bg+L1 mix windrow cell wall sugars
Amount (ug/mg)
250.00
200.00
150.00
100.00
50.00
0.00
Rhamnose
Fucose
Arabinose
Xylose
Mannose
Galactose
Glucose
GalA
Sugars
16/5/05
04/0705
18/0705
01/8/05
15/8/05
29/08/2005


Trial 2: bg+F2 mix windrow cell wall sugars
ug/mg
250.00
200.00
150.00
100.00
50.00
0.00
Rhamnose
Fucose
Arabinose
Xylose
Mannose
Galactose
Glucose
GalA
sugar
16/5/05
04/0705
18/0705
01/8/05
15/8/05
29/08/2005

Germination Trials

In advance of the evaluation trials by the Commercial Growers, small quantities of IFR compost were subjected to germination trials by Bulrush Horticulture Ltd. The results showed that a 30% IFR compost – peat mix had no negative impacts on germination of marigold seedlings. The mixes compared were as follows:

Mixes: Standard Levington seeding compost
Standard seeding with 30% Toressa woodfibre
Standard seeding with 30% IFR selected material

The results are shown in Fig. 33.

Fig. 33. Germination of marigold seedlings on a range of mixes. Photos taken 27th March 2005 by Neil Bragg.

Standard Levington seeding Standard seeding + 30% WF

Standard Levington seeding Standard seeding + 30% IFR

Germination in all mixes was 100% and plants have all grown successfully to 1st true leaf.

Further more detailed propagation trials are currently underway at Stockbridge Technology Centre (Yorkshire), Fleurie Nursery Ltd (Chichester) and IFR (Norwich) using single colour pansy plug-plants ('Ultima Supreme Yellow'). The compost mixes (prepared by Bulrush Horticulture) are as follows:

Table 12. Composition of trial mixes and nitrogen : phosphorus : potassium levels

Mix no:	Contents	Fertilizer	g/l		N	P	K	Lime g/l
1	100% peat	15 10 20	1.5		225	62	240	4.5
	12mm							
2	25% IFR				82	37	570	
	75% peat	MAP	0.1		12	25		3.3
		$CaNO_3$	0.7		130			
				totals	224	62	570	
3	25% Bettaland				129	40	724	
	75% peat	MAP	0.1		12	25		3.3
		$CaNO_3$	0.45		85			
				totals	226	65	724	
4	25% Toressa							
	75% peat	15 10 20	1.2		177	50	240	3.3
		$CaNO_3$	0.25		48			
				totals	225	50	240	
5	50% IFR				167	75	1000	
	50% peat	$CaNO_3$	0.3		60			2.3
				totals	227			
6	50%Bettaland				259	79	1449	
	50% peat							2.3
7	50% Toressa	$CaNO_3$	0.5		95			
	50% peat	15 10 20	0.86		130	35	138	2.3
				totals	225			
8	100% IFR				334	150	2000	

Fig. 34. Photo of the viola trials underway at IFR Norwich.

Viola trials

Approximately thirty plug-plants (supplied by Wilgro) were grown in each compost mix at each of the three trial sites. These were split into two blocks – both blocks receiving plain water for the duration of the trial. (NOTE: the blocks were later combined as it was decided not to proceed with application of fertiliser to one of the blocks).

An overhead photograph of each batch of plants grown in the different composts was taken on a weekly basis at each location.

The time to rooting out of plants in the different composts was recorded as well as the time to first flower for 50% of the plants and 100% of the plants.

On a weekly basis, the plants were scored on the basis of the following attributes, using a scale of 1 – 5 where 1 is poorest and 5 is best.

- Foliage colour
- Vigour

Table 13. Viola growing trial results:

IFR Norwich

Mix	Weekly Score (Foliage colour)					Weekly Score (Vigour)					Time to rooting (days)	1st flower (days) 50%	1st flower (days) 100 %
1	nd	5	5	5	5	5	5	5	5	5	11	24	29
2	nd	5	5	4	4	5	5	5	5	5	11	22	30
3	nd	5	5	4	4	5	4	5	5	5	11	22	31
4	nd	5	5	4	5	5	5	5	5	5	11	22	31
5	nd	2	3	3	4	5	2	4	4	4	11	22	42
6	nd	5	4	3	3	3	2	3	2	3	15	24	30
7	nd	5	5	4	5	5	5	5	4	4	11	22	30
8	nd	1	1	1	1	4	1	1	1	1	15	24	42

Fleurie Nursery

Mix											Time to rooting (days)	1st flower (days)	
	Weekly Score (Foliage colour)					Weekly Score (Vigour)						50%	100 %
1	nd	5	5	4	4	nd	5	5	5	4	14	27	27
2	nd	5	5	5	4	nd	5	4	5	4	14	27	27
3	nd	5	4	4	4	nd	4	3	3	3	14	27	>34
4	nd	4	4	3	3	nd	4	4	4	4	14	27	34
5	nd	4	3	4	4	nd	4	4	5	4	14	20	27
6	nd	4	4	3	4	nd	3	2	2	1	14	27	>34
7	nd	4	3	3	2	nd	5	4	3	2	14	27	27
8	nd	3	2	2	3	nd	3	3	3	3	14	27	>34

Stockbridge Technology Centre

Mix											Time to rooting (days)	1st flower (days)	
	Weekly Score (Foliage colour)					Weekly Score (Vigour)						50%	100 %
1													
2													
3													
4													
5													
6													
7													
8													

(A photograph of the 5 plants that are used as assessment standards for vigour/foliage scoring was taken for reference purposes).

In addition, four weeks into the trial a marketing score was made based on the following scoring system.

1	Unmarketable – high level of foliar discoloration, disease and/or excessive stretching suitable only for dumping
2	Poor quality plants – some incidence of above, but less pronounced
3	Marketable plants – material that would be suitable for sale at major box stores
4	Above average marketable plants
5	Premium marketable plants – very high quality plants generally not seen for sale at major chains.

Table 14. Overall marketing scores for viola trials

Mix	Overall Marketing Score			Average Score
	IFR	Fleurie Nursery	Stockbridge	
1	3	3		3
2	3	4		3.5
3	2	2		2
4	3	3		3
5	2	4		3
6	2	1		1.5
7	3	1		2
8	1	2		1.5

The above results show that IFR Compost can be incorporated into reduced peat products at a level between 25 & 50%. The plants grown in 100% IFR compost appear stunted in their growth and show signs of nitrogen deficiency (chlorosis).

Further trials will be instigated at IFR (Norwich) to investigate this problem using F1 hybrid viola seeds 'Penny Orange Jump Up' purchased from Mole Seeds, Colchester, Essex and coriander seeds.

Coriander seed trials

A separate germination trial was conducted at Swedeponic using coriander seed grown in the same peat/compost mixes.

For this trial, coriander seed was sown mechanically in approximately 30 pots of each of the eight compost mixes used for the pansy trials and a peat mix regularly used by Swedeponic.

The time to germination or 1st true leaf was recorded during the trial with a final assessment at the expected time of harvest (around four weeks) measuring the following criteria:

- Number of seeds germinated
- Weight of foliage
- (Possibly) height of plant

A visual observation of the different mixes revealed that the seeds in 100% IFR compost & 50% Bettaland failed to germinate after 11 days. All of the other seedlings germinated although it should be noted that none of the seedlings appeared to grow as well as those sown in the Swedeponic peat mix.

The trial finished in early October 2005. Results are shown in Table 15 below – these will be analysed more fully in the final report.

As expected, the standard deviations are quite large. Nevertheless, the results are quite promising - IFR compost can be incorporated into a peat mix at 50% with no significant effect on the weight of foliage at harvest.

The results for 75% Bettaland : 25% peat and 100% IFR compost are noticeably worse than the other mixes in common with the viola trials.

Fig. 35. Germination of coriander seeds in compost mixes 5 & 6

Fig. 36. Relative germination of coriander seeds in all compost mixes

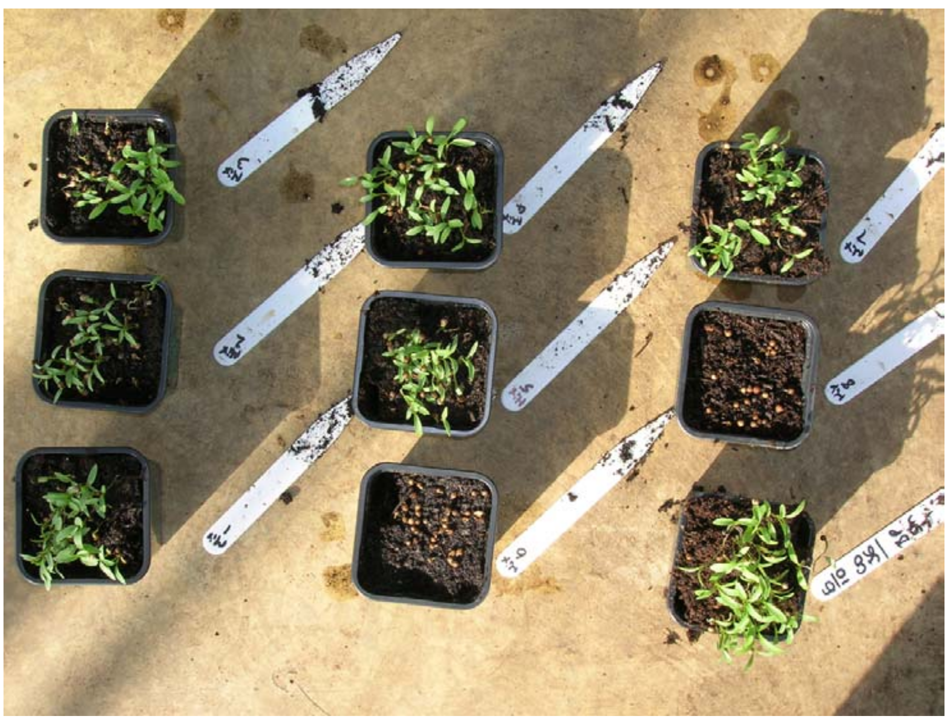


Fig. 37. Side-view of coriander seed trial.

Fig. 38. Weight of foliage at harvest for coriander seed trials undertaken at Swedeponic.

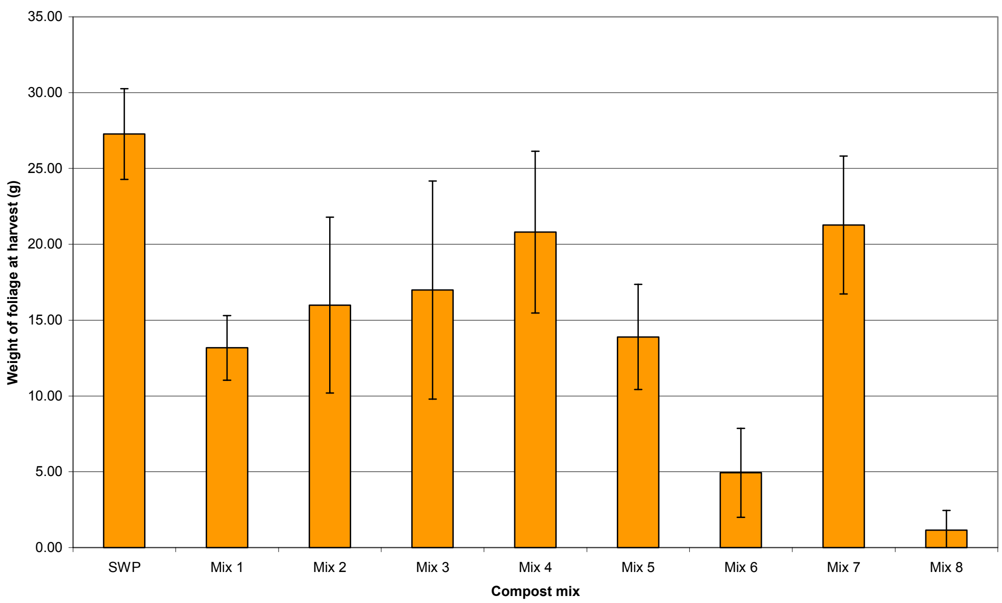
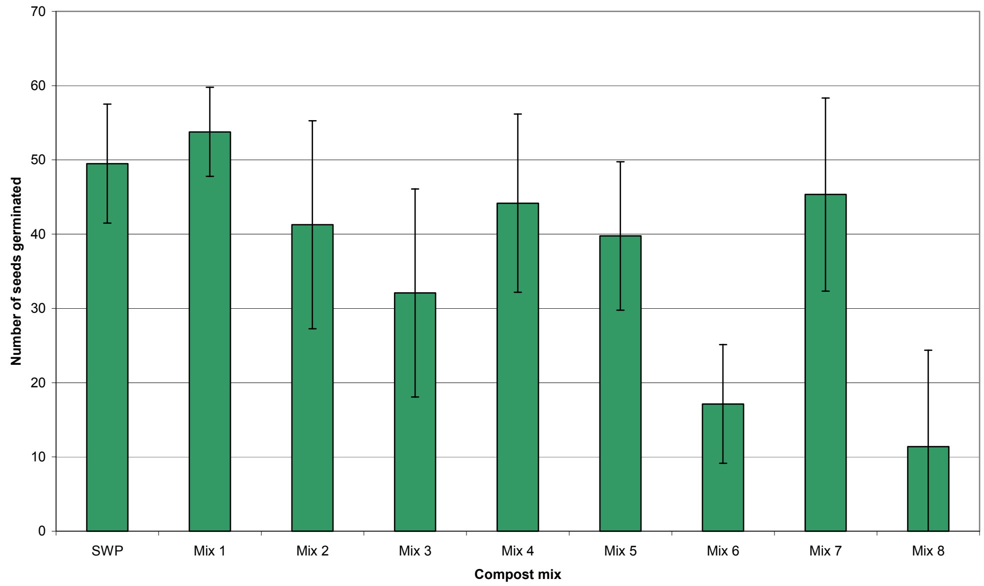


Fig. 39. Number of seeds germinated for coriander seed trials undertaken at Swedeponic.



Overall Conclusions

The main aim of this research is to assess the feasibility of producing high-quality horticultural growing media from the controlled composting of traceable, sustainable and locally-produced plant-based food processing waste. This will involve replicating plant-structure-dependent physicochemical characteristics found in high-quality growing media.

HL0172 research during the first 12 months has demonstrated:

5) The composting process can be controllably terminated at a point where high-levels of plant structure remain in the compost
6) The retained structure provides the following physicochemical characteristics important in high-quality growing media:
    a. Residual plant cell wall structure as indicated by the retention of cell wall sugars and lignin commensurate with the functional levels found in high-quality peat;
    b. Relevant particle size distribution;
    c. Good water retention, similar to that in peat and considerably higher than in loams and traditional composts;
    d. Good air-filled porosity;
7) There are several characteristics which require attention in order to optimise the growing media as a potential peat alternative:
    a. Windrow composting is not sufficient to create a uniform product
    b. The conductivity is too high and this has a negative impact on germination
    c. Possible nitrogen deficiency in trialled plants may result from a surfeit of insufficiently degraded straw;
8) The compost can be used successfully as a 50% peat substitute in the cultivation of viola plants from plugs, If the above issues in 3) can be addressed, it should have the potential to be used as a 100% peat substitute as perceived

To take this work forward requires a two-pronged, approach:

1) Provision of uniform, reliable compost with retained structure:

Windrow composting which results in lack of uniformity and control needs to be addressed through the development of a continuous composting process. This has been initiated through DTI funding in the Zero Emissions Enterprise (ZEE) initiative. A ZEE feasibility study has started which will evaluate the parameters needed to control the composting process.

2) Research to define, control and deliver the functionality that Growers need

The current feasibility study has shown that it is indeed feasible to create high-quality growing media from plant-based food processing waste streams. However, this is a very poorly defined area and the precise physicochemical requirements of growing media required by horticultural growers are still unclear.

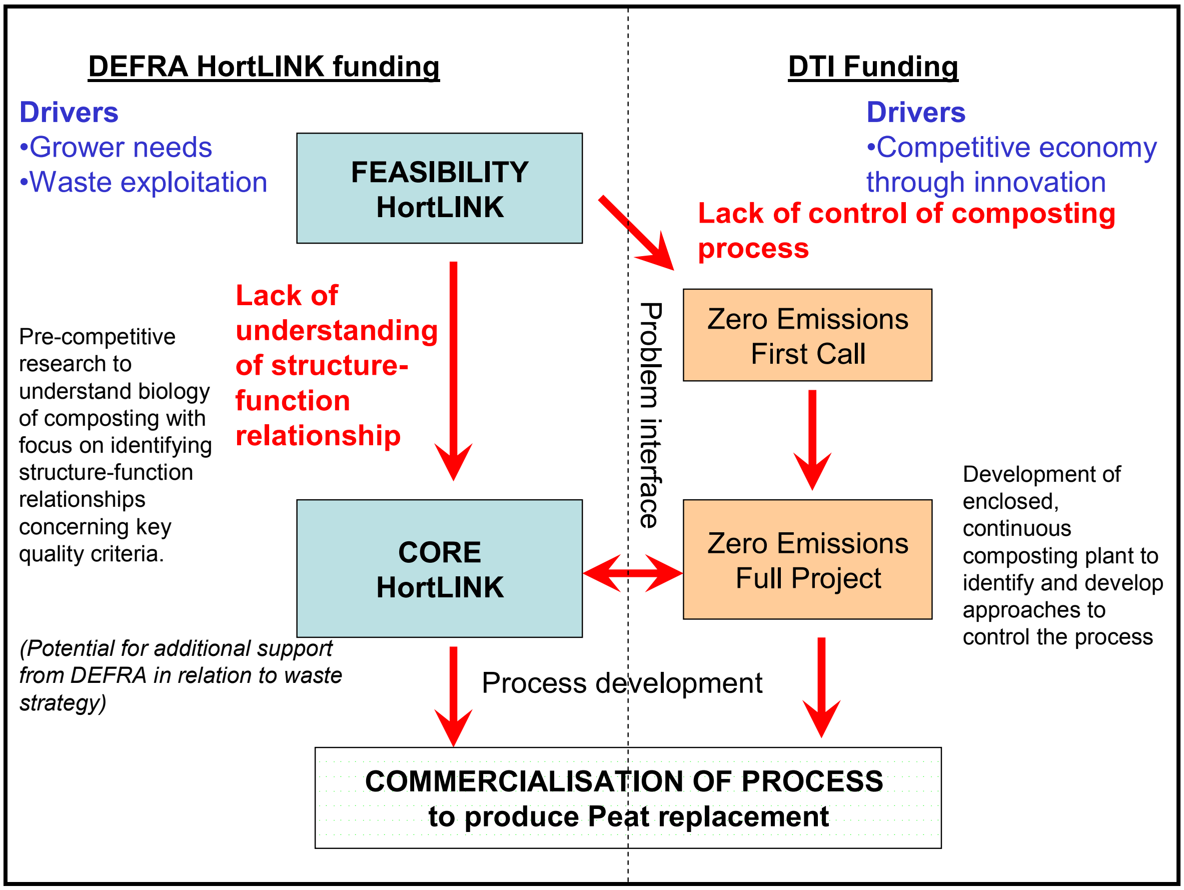
In order to develop a pragmatic understanding of growing media that can be produced through composting, it is important to

- evaluate the range of feedstocks available,
- identify and describe the biological mechanisms involved in transforming these feedstocks into growing media,
- help growers make use of these new media at the nursery level through developing an understanding of plant-media interactions.

This should be addressed through a **Core LINK project** which will run in parallel with the ZEE project activities. The two research areas will thus run in parallel, and will be linked via an understanding of the composting process. Support for the Core-LINK project will be sought from DEFRA, both through Hort-LINK and (via David Cole) the DEFRA waste strategy.

The ultimate goal of both these integrated activities is to develop a commercially-viable process. The overall process is summarised in the figure below:

Fig 38. Strategy for taking research to the market



Technology Transfer

Presentations:

Hort LINK meeting 24 Feb. 2005; Horticulture in Focus

N Bragg, T. F. Brocklehurst, A. C. Smith, M. Bhat and K W. Waldron, The development of sustainable growing media components from composted specific bio-waste streams. International Plant Propagators Society meeting, Winchester, August 30-Sept. 2nd 2005

Brochures:

Waldron K. W. Producing horticultural growing media from composted food processing waste, Hort LINK brochure 2005
Agriculture LINK newsletter
IFR Web site (under construction)

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