HortLINK Report

HL 0172

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

Final report (18-months) 2006

Project title:	Producing high quality horticultural growing media through the retention of plant structure in composted food-processing waste
Project number:	HL 0172
Project leaders:	Dr Keith Waldron Institute of Food Research Norwich Research Park Colney Norwich NR4 7UA
Report:	18-month report, March 2006
Previous reports:	6-month report, March 2005 12-month report, September 2005
Key (IFR) workers:	Keith Waldron (Plant Biochemist) Andrew Smith (Materials Scientist) Tim Brocklehurst (Microbiologist)
Location:	IFR, Norwich & Organic Recycling, Peterborough
Consortium members:	Institute of Food Research Organic Recycling Ltd Bulrush Horticulture Ltd Swedeponic UK Del Monte Fresh Packaged Produce Ltd Farplant Sales Horticultural Development Council The Composting Association Scottish Courage plc
Government Sponsor:	DEFRA
Project co-ordinator:	David Cole HortLINK Co-ordinator, Room 702 Cromwell House London SW1P 3JH
Date commenced:	1 October 2004
Completion due:	31 March 2006
Key words:	Compost, peat, plant material, organic, waste, recycling, viola, coriander

The following are members of the Consortium for LINK project HL 0172:

Institute of Food Research
Organic Recycling Ltd
Bulrush Horticulture Ltd
Swedeponic UK
Del Monte Fresh Packaged Produce Ltd
Farplant Sales
Horticultural Development Council
The Composting Association
Scottish Courage plc

Disclaimer

The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the experiment was carried out and the results obtained have been reported with detail and 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.

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Intellectual Property Rights are invested in the Institute of Food Research on behalf of the Consortium members for LINK project number HL 0172.

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Grower Summary

Headline

Compost was successfully produced on a semi-commercial scale from food processing waste streams whilst retaining structure similar to that found in peat. Incorporation of the product in reduced peat growing media at a level of up to 50% showed comparable results to peat alone in plant growth trials. The feasibility study show promising results – however the financial benefits have yet to be quantified.

Background and expected deliverables

The current supply of peat is under threat as a result of various EU directives, particularly the Wetland Habitats Directive. In addition, waste food streams such as fruit and vegetable products present a considerable sustainable resource for providing a structured growing medium.

Due to paucity of knowledge regarding biological functions related to composting, most of the compost produced from biowaste results in low-value, completely degraded material without structure.

The expected deliverables from this project include:

- Exploiting IFR expertise of plant biochemistry to elucidate peat structure
- To emulate peat-like characteristics in composted food waste stream
- Bring about controlled degradation of plant material
- Produce and market value-added, peat-free, commercial growing media

Summary of the project and main conclusions

The project has achieved its key aim: compost was successfully produced with high-levels of plant structure remaining in the mixture. The retained structure provided the following physicochemical characteristics important in high-quality growing media:

- Good water retention, similar to that in peat and considerably higher than in loams and traditional composts; and
- Good air-filled porosity.
- Reasonable bulk density
- Good conductivity

There are several characteristics which require attention in order to optimise the growing medium as a potential to peat alternative:

(a) The windrow composting is not sufficient to create a uniform product
(b) Possible nitrogen deficiency in trial plants.

Results show that the compost can be used effectively as a 50% peat substitute in the cultivation of viola plants from plugs. However, if the above issues can be addressed there should be a potential to use this compost as a 100% peat substitute.

Financial benefits

To be quantified.

Action points for growers

The product is still in its early stages of development – no action is therefore necessary from growers at this point.

Milestones

Primary Milestone	Title	Completion date	Background information	On Target
M1.1	HQ growing media obtained	14/10/2004	T1.1 Provision of high-quality growing media	Yes
M1.2	HQ-growing media assessment complete	30/12/2004	T1.2 Characterisation of high-quality growing media	Yes
M2.1	Method Development complete	30/12/2004	T2.1 Methods development	Yes
M2.2	Completed composting trials	22/09/2005	T2.2 Full composting study (temp/time)	Yes
M2.3	Physicochemical Data available	22/09/2005	T2.3 Physicochemical analysis	Yes
M2.4	Moisture release curves available		T2.4 Water status measurement and analysis	Yes
M2.5	Microbiol. and biochem. data available	20/10/2005	T2.5 microbiological and biochemical investigation	Yes
M2.6	Horticultural suitability data: comparison with peat and coir completed	09/02/2005	T2.6 Horticultural evaluation of media	Yes
M3.1	Identify criteria that underlie quality of compost growing media	16/02/2006	T3.1 Identify criteria that underlie quality of compost growing media	Yes
M4.1	Project Complete and Reported	30/03/2006	T4.1 Dissemination and exploitation	Yes

Science Section

1.0 Introduction

Aim

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. ***<u>However, many Growers are reluctant to change</u>***, 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

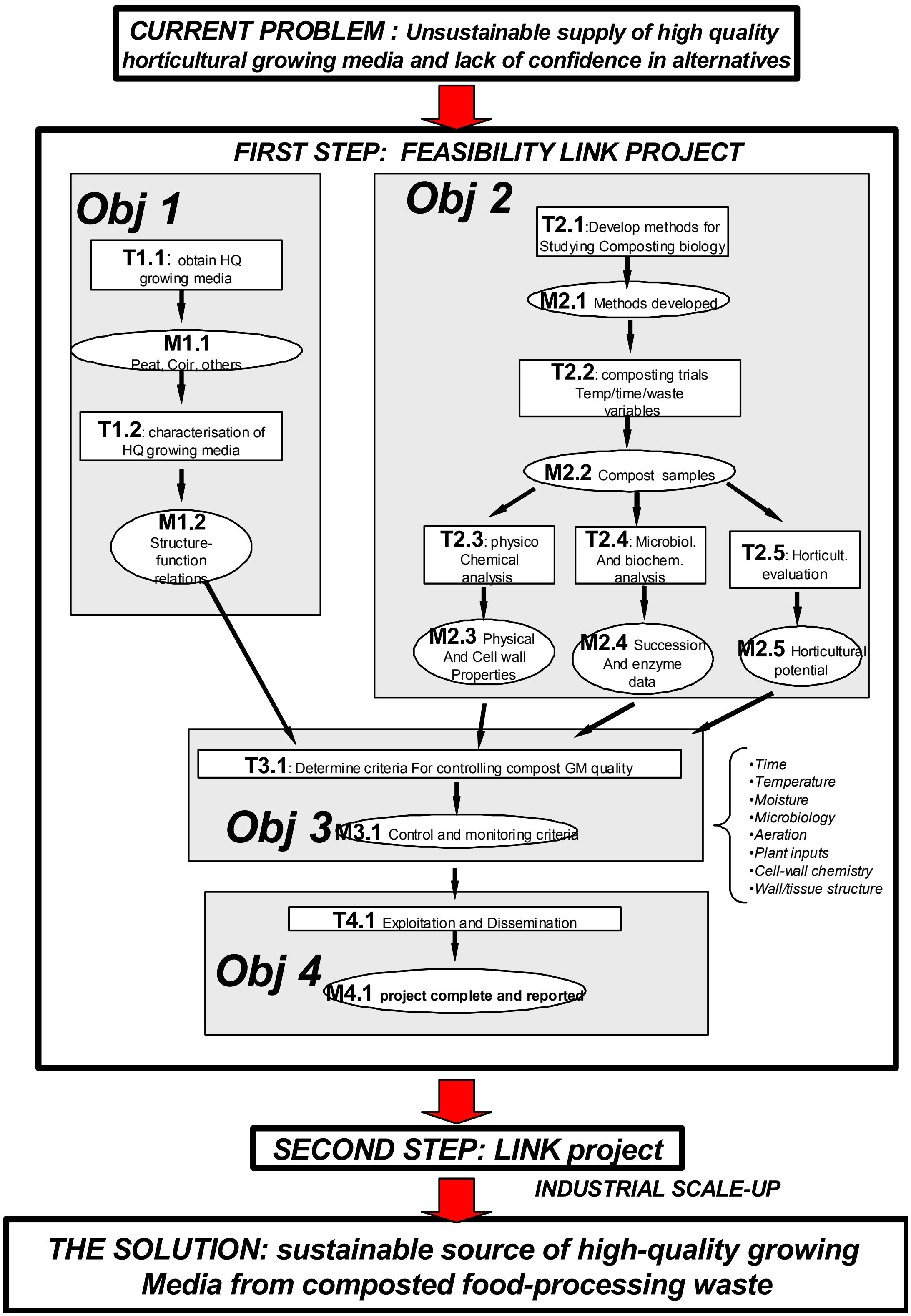
The beneficial properties of peat-based growing media reflect the macro, micro and molecular structure of the vitrified sphagnum plants. The hollow leaves provide the high WHC, whilst phenolic-rich hydrophobic stem and leaf cell walls facilitate good drainage and appropriate ion-exchange characteristics. 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 (see scheme below).


CURRENT PROBLEM : Unsustainable supply of high quality horticultural growing media and lack of confidence in alternatives
FIRST STEP: FEASIBILITY LINK PROJECT
Obj 1
T1.1: obtain HQ growing media
M1.1 Peat, Coir, others
T1.2: characterisation of HQ growing media
M1.2 Structure-function relations
Obj 2
T2.1:Develop methods for Studying Composting biology
M2.1 Methods developed
T2.2: composting trials Temp/time/waste variables
M2.2 Compost samples
T2.3: physico Chemical analysis
T2.4: Microbiol. And biochem. analysis
T2.5: Horticult. evaluation
M2.3 Physical And Cell wall Properties
M2.4 Succession And enzyme data
M2.5 Horticultural potential
T3.1: Determine criteria For controlling compost GM quality
Obj 3
M3.1 Control and monitoring criteria
•Time
•Temperature
•Moisture
•Microbiology
•Aeration
•Plant inputs
•Cell-wall chemistry
•Wall/tissue structure
T4.1 Exploitation and Dissemination
Obj 4
M4.1 project complete and reported
SECOND STEP: LINK project
INDUSTRIAL SCALE-UP
THE SOLUTION: sustainable source of high-quality growing Media from composted food-processing waste

2.0 Materials & Methods

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

Aim: to evaluate structure-function relationships of current high-quality growing media.

Task 1.1: Procurement of peat and related growing media

Peat layers and associated material were collected from Newferry bog, Bellaghy, Magherafelt, Northern Ireland. A drainage ditch between an untouched area of bog and an area which had been harvested exhaustively enabled the collection of samples through the section of a bog from green Sphagnum moss following the process of humification to the base of the bog. The material at the base of the bog is usually not harvested as it lacks the desirable properties for horticultural purposes.

Fig 1. Sphagnum moss at the surface of the peat bog

Fig 2. Sub-layers of semi-degraded moss at the surface of the peat bog, undergoing initial stages of humification.

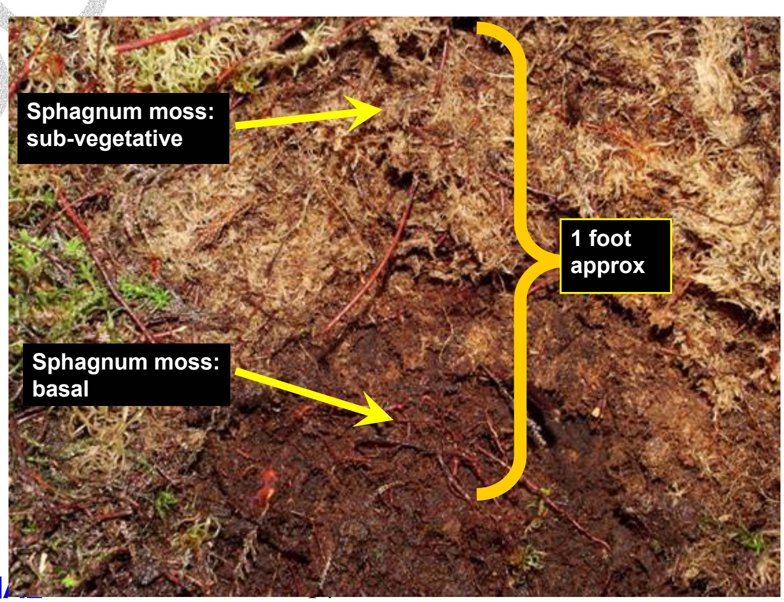
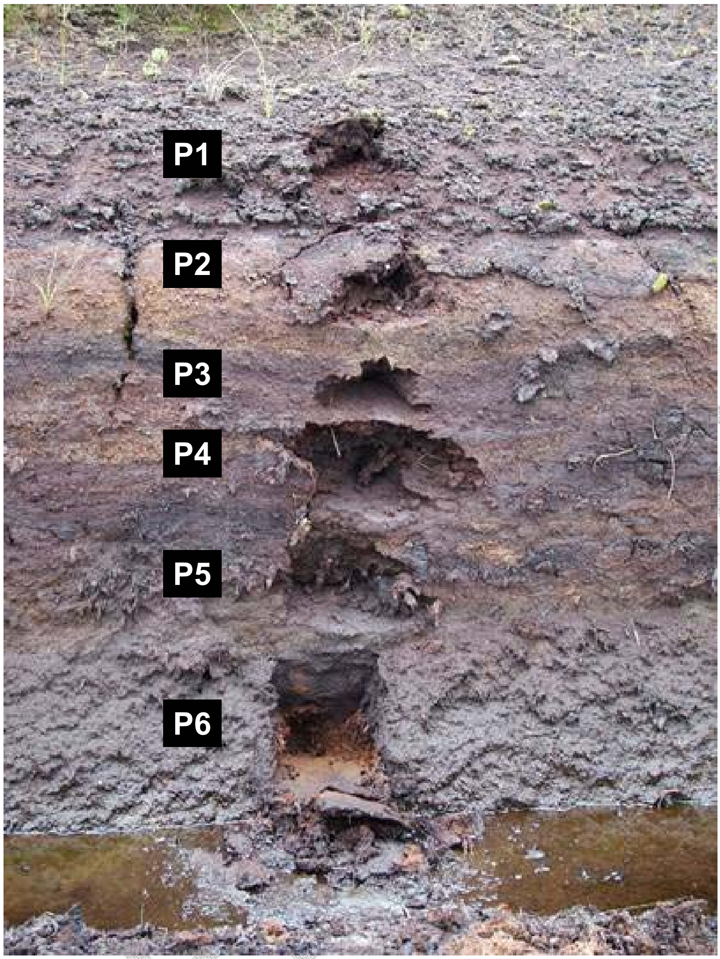


Fig 3. Positions of sampling throughout 1.5m bog section



Additional growing media were obtained from commercial sources. A summary of high quality growing media studied is presented in Table 1.

Table 1. Peat and growing media

Material	**Description**
Baltic (Latvian) Blonde Peat	Unprocessed, H2-3
Irish (Ballycommon) Peat	Unprocessed, H4-5
Somerset Sedge Peat	Unprocessed, H7-8
J. Arthur Bowers Sterilised Loam	Commercial
J. Arthur Bowers John Innes potting compost No.1	Commercial
Shamrock Potting Compost – General Potting Medium	Commercial
Bettaland compost	Commercial
Four Seasons Organic Compost	Commercial
Scottish Agricultural College Compost	Commercial
J. Arthur Bowers Peat-free Compost	Commercial
B & Q Coir-based Peat-free Compost	Commercial
ECO Composting Ecomix	Commercial
ECO Composting Supersoil	Commercial
Fresh coir (Cocopeat)	Commercial
Toressa Nova woodfibre	Commercial
Rice husks	Commercial
Sphagnum moss from Newferry bog, Northern Ireland	Experimental only

Vegetated layer (top) from Newferry bog, Northern Ireland	Experimental only
Vegetated layer (sub-surface) from Newferry bog, Northern Ireland	Experimental only
Vegetated layer (basal) from Newferry bog, Northern Ireland	Experimental only
Peat layers from Newferry bog, Northern Ireland (P1 – P6)	Unprocessed, H4-5

Task 1.2: characterisation of HQ growing media

HQ growing media were evaluated for current industry-relevant characteristics and physicochemical properties described in Task 2.3 below.

Objective 2: Elucidate microbiological and biochemical basis of compost characteristics

Aim: to compost a range of food processing co-products and to investigate the microbiological and biochemical basis for the biodegradation.

Task 2.1: Method development

Aim: a single trial of four windrows was carried out to (a) evaluate the windrow process for selected co-products, and (b) to develop methods for analysis.

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.

Table 2. 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

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

Aim: on the basis of trial 1 (Task 2.1 above) and results thereof, a full composting study was carried out.

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.

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

Brewer's Grain + Leaf 1		Brewers' Grain + Leaf 2	
Brewers' grain (Tonnes)	20	Brewers' grain (Tonnes)	50
Leaf (Tonnes)	5	Leaf (Tonnes)	10
Straw (Tonnes)	8.99	Straw (Tonnes)	15
Moisture content (%)	59.6	Moisture content (%)	63.5
C:N (ratio)	30	C:N (ratio)	25.6

Brewers grain mix		High Brewers' Grain Test	
Brewers' grains (Tonnes)	20	Brewers' grains (Tonnes)	40
Straw (Tonnes)	8.34	Straw (Tonnes)	5
Moisture content (%)	55.5	Moisture content (%)	67.3
C:N (ratio)	30.7	C:N (ratio)	20

Brewer's Grain + Fruit 1		Brewers' Grain + Fruit 2	
Brewers' grain (Tonnes)	40	Brewers' grain (Tonnes)	50
Fruit (Tonnes)	10	Fruit (Tonnes)	5
Straw (Tonnes)	15	Straw (Tonnes)	20
Moisture content (%)	61.5	Moisture content (%)	58.1
C:N (ratio)	28.7	C:N (ratio)	29.8

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

Aim: This section describes the methods used for evaluating physicochemical characteristics of high quality growing media, and composted material.

Material properties

Soil moisture-retention studies

Fig. 4. 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

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

Fig.5. Dewpoint potentiameter

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

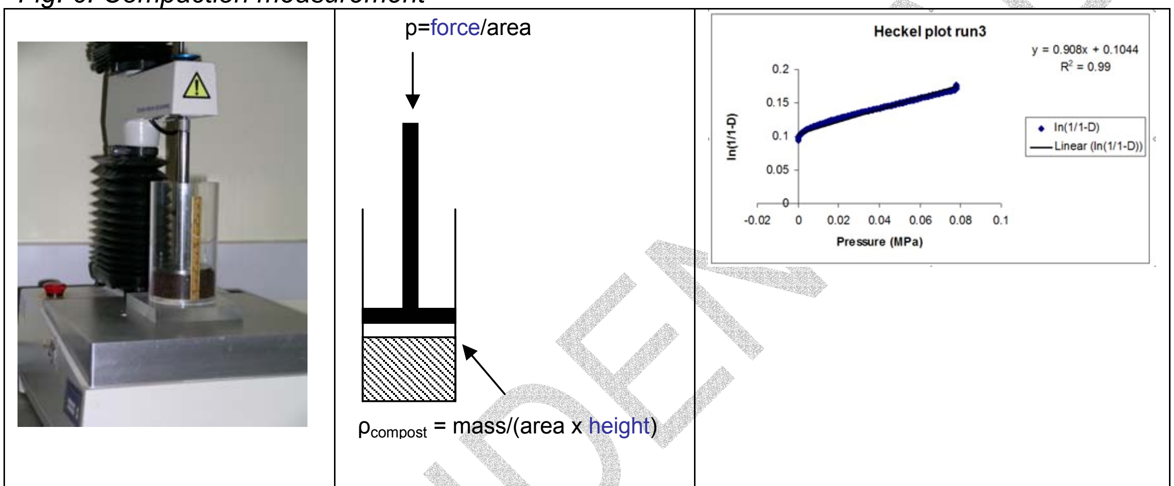
Compaction
Compaction tests were performed using a Texture Analyser (Stable Micro Systems, UK) equipped with a 30kg load cell and compaction plate (Ollett *et al*, 1993).

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. 6. 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.

Bulk density
The method for bulk densities of soil given in British Standard EN 12580:2000 was modified to allow for smaller quantities.

A section of plastic tube (i.d. 153mm) with a height to diameter ratio of 1.1 was glued to a Perspex base. An additional section of tube was located on top of this by means of 3 locating pins. A 16mm sieve was used as a fall controller on top of this section. The apparatus was determined to have a volume of 2.035 litres.

The tube was filled with the sample before removing the collar and levelling using a straight edge in a sawing manner. The total sample and pot was weighed and the tare weight subtracted to give the weight of a known volume.

The dry weight of the sample was ascertained at the same time using the Mettler LP16 dryer balance.

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
Aim: to evaluate the microbiology and selected enzyme profiles of the composted materials.

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 4. Incubation conditions for different microflora

Medium	Conditions of incubation	Microorganisms enumerated
Plate Count Agar (PCA)	Air, 20°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^{o}C
- Ability to grow in broth at 55^{o}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

Aim: to evaluate structure-function relationships 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

See Materials and Methods for Task 1.1 for details of procurement of high quality growing media.

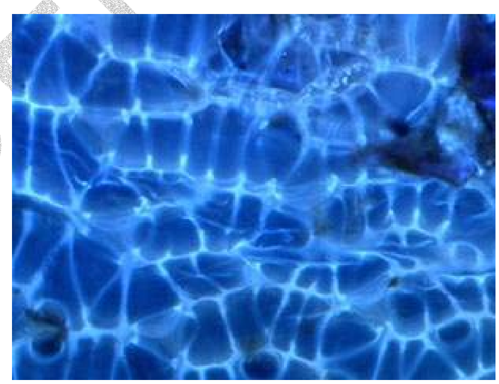
Task 1.2: Characterisation of HQ growing media

Aim: the peat samples will be assessed at IFR for current industry-relevant characteristics in relation to structure-function relationships.

Microscopic analysis

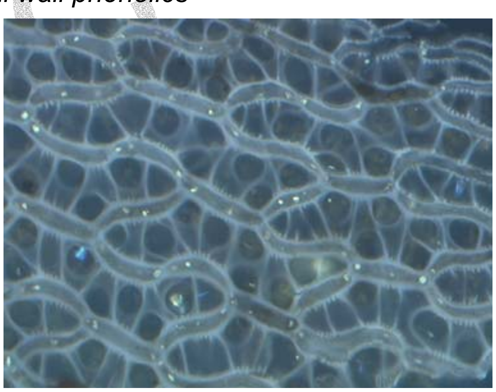
Fig. 7. Examples of light and fluorescent micrographs of sphagnum tissues from Ballycommon peat indicating cell wall phenolics

(a) Light micrograph

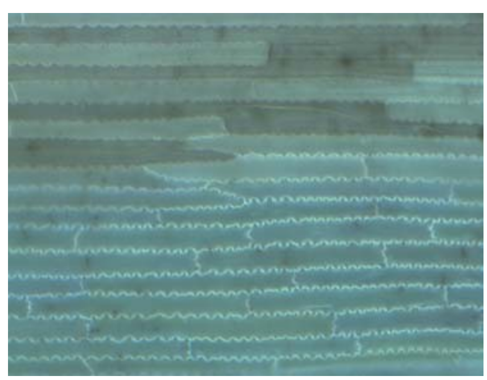


(b) Fluorescence micrograph

Fig. 8. Examples of fluorescent micrographs of peat from Newferry bog, Bellaghy indicating cell wall phenolics



(a) Sphagnum-derived (layer 4)



(b) Grass-derived (layer 5)

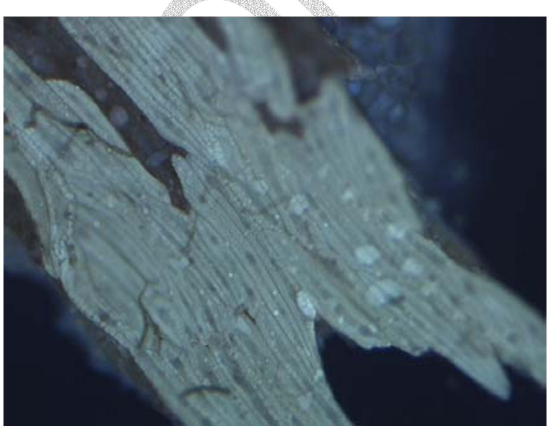
Fig. 9. Light micrographs of aerial materials from Newferry bog, Bellaghy peat bog.

(a) Aerial sphagnum moss

(b) root area

(c) Basal area.

Fig. 10. Examples of light and fluorescent micrographs of woody residues from commercial growing media



(a) Woody fragments

(b) fibre

As stated in the original proposal the cell walls and tissue structures are largely intact in moss-derived peat, possibly because of the presence of cell-wall simple phenolics (Fig. 7&8).

Fig. 9 shows the sphagnum moss from which the peat is derived. Fig. 10 provides examples of woody fibres found in other commercial growing media.

Chemical composition of peat layers

Peat samples were extracted to prepare alcohol-insoluble residues. These were then analysed for their cell-wall chemical composition. The results are shown in figures 11 – 13.

Fig. 11. Cell wall carbohydrate and lignin composition of descending moss and peat layers

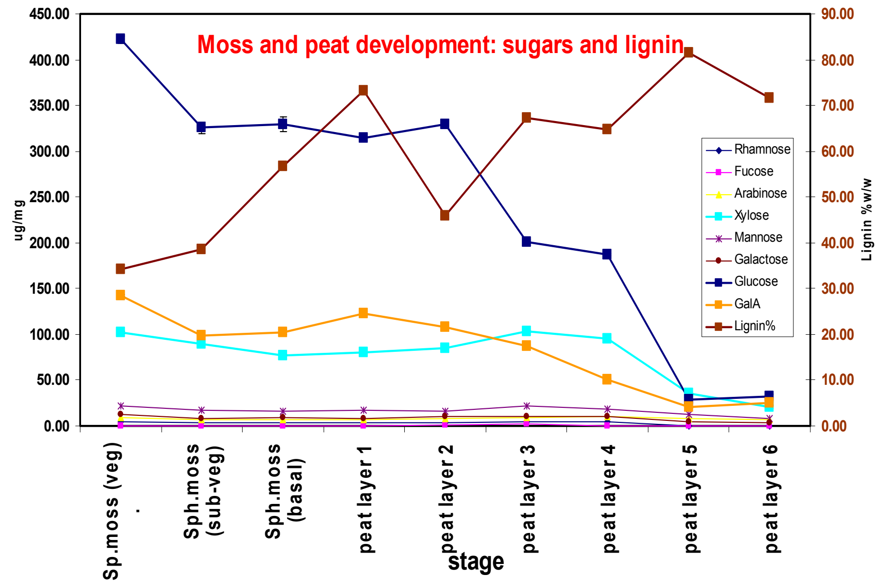


Fig 12. Cell wall phenolic ester in descending peat layers.

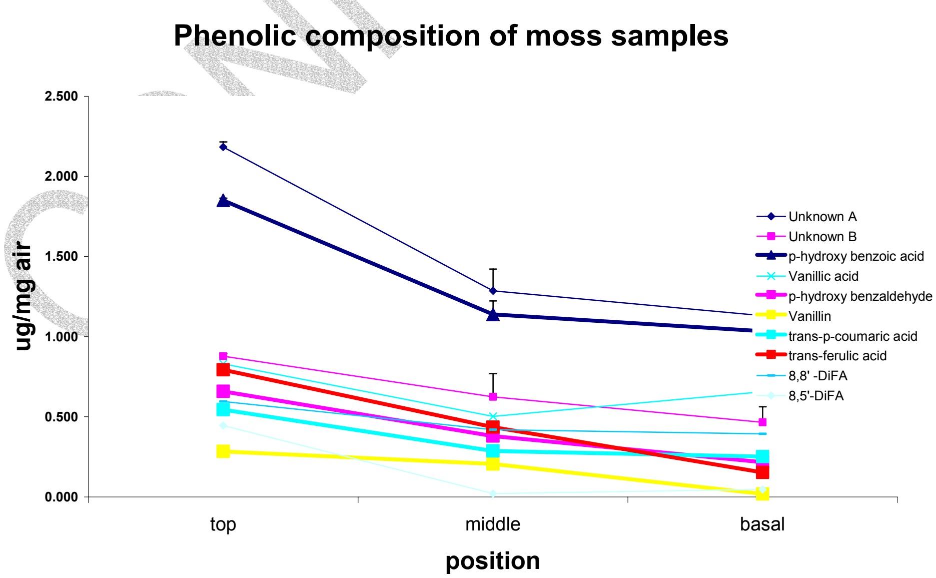
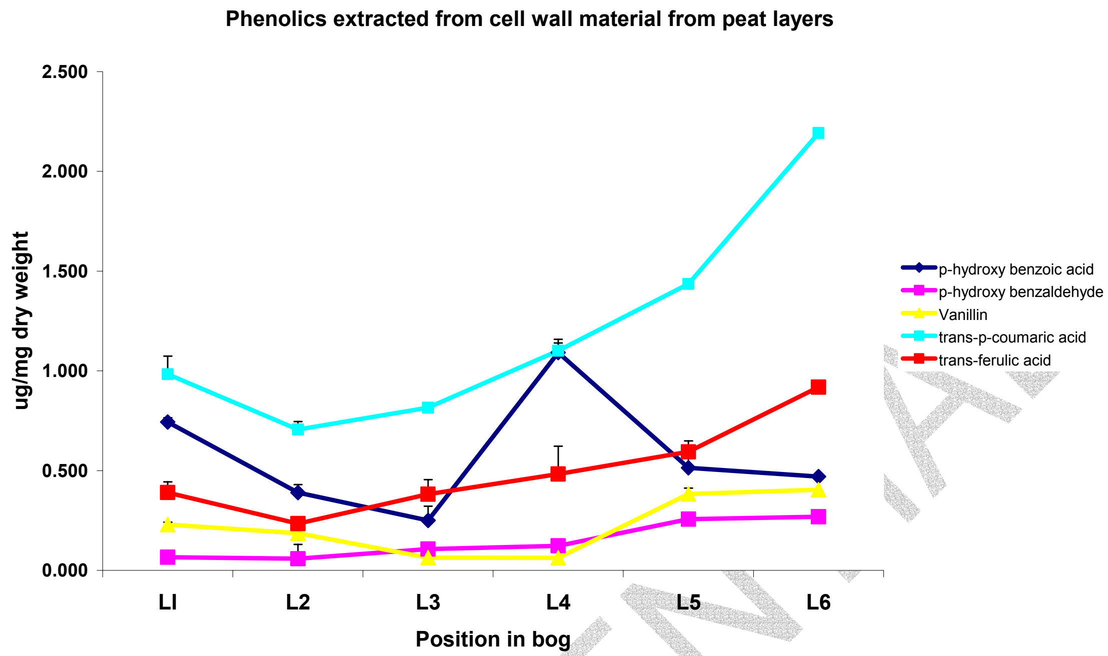


Fig 13. Phenolic composition of peat samples from different depths of peat bog



Conclusions from Task 1.2

- Microscopic analysis shows that the aerial material and upper bog layers are dominated by sphagnum and related moss components. Further down into the bog, cotton grass becomes more prominent, and is the dominant remaining material in the most basal layers 5&6.
- Cell wall composition data shows that moss layers and top peat layers 1&2 exhibit very similar wall compositions. However, in peat layers 3 and beyond, the carbohydrate components drop rapidly to very low levels in layers 5 & 6 reflecting bio- or chemical-degradation during the humification process.
- Accompanying the decrease in cell-wall carbohydrate, lignin shows a concomitant increase to over 40% in the lowest layers.
- The wall phenolic esters also exhibit changes. In the top aerial layers, these phenolics generally decrease with depth. In the bog layers, the moss-derived components generally decrease as the moss degrades, but the cotton-grass dominance in the lower levels results in an increase in ferulic acid and coumaric acid in monomeric forms only.
- Interestingly, it is layers 3 & 4 that provide the best quality peat material, layers 1 & 2 being too immature, and layers 5 and 6 being of poor quality.

Objective 2: Elucidate microbiological and biochemical basis of compost characteristics

Aim: to compost a range of food processing co-products and to investigate the microbiological and biochemical basis for the biodegradation.

Task 2.1: Method development

Aim: a single trial of four windrows was carried out to (a) evaluate the windrow process for selected co-products, and (b) to develop methods for analysis.

Windrow Design

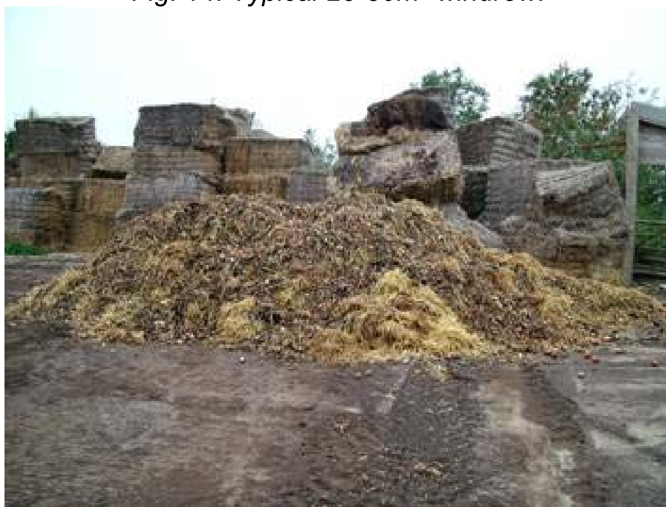
Four windrows each of about $30m^3$ have been constructed at Organic Recycling Ltd. They contain straw and one of the following food processing waste streams (provided by the Partners):

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

The compositions (mixes) of the windrows are shown in the Materials & Methods Section.

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 14).

Fig. 14. Typical 25-30m^3 windrow.



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

Fig. 15. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of onion and straw

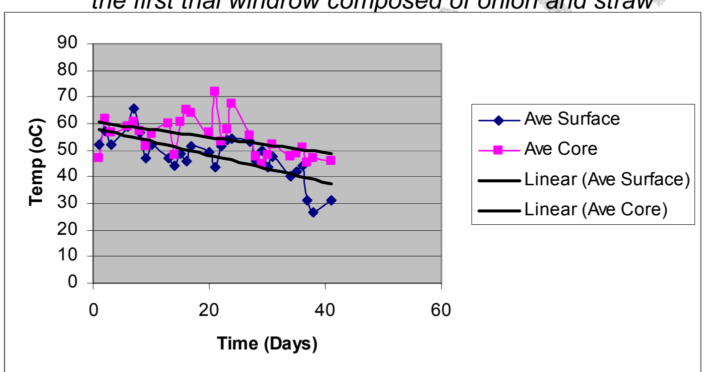


Fig. 16. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of leafy greens and straw

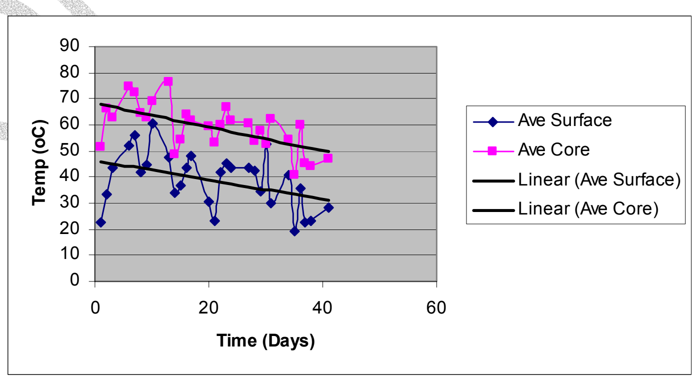


Fig. 17. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of brewers' spent grain and straw

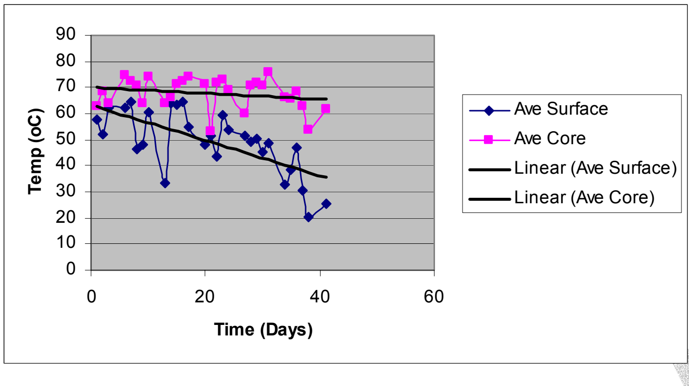
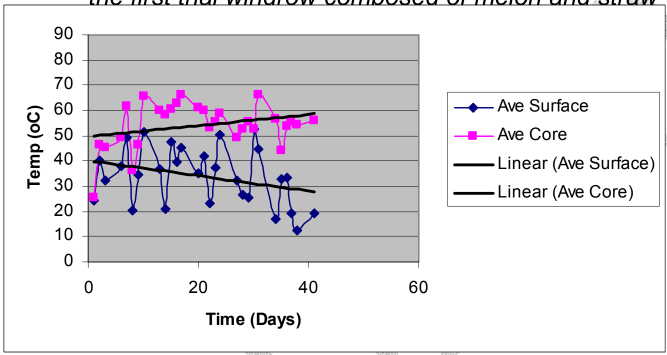


Fig. 18. Average surface and core temperatures (and linear regression fits of these temperatures) in the first trial windrow composed of melon and straw



The results demonstrate that the windrows in all trials rapidly achieved high internal temperatures commensurate with a successful windrow operation. The PAS requirement of 60^{o}C was achieved, and maintained for several weeks in most cases. However, the quality of material was certainly not uniform within the windrows:

- Firstly, there was great heterogeneity in nature, rate and extent of composting throughout each windrow due to the temperature gradient.
- Secondly, the impact of weather conditions differed between windrows. The autumn and winter conditions included considerable precipitation. The vegetable-based windrows became waterlogged by early January, and then appeared to become quite anaerobic within. This probably reflects the propensity for water retention by the vegetable components. In contrast, the Brewers Spent Grain windrow drained more efficiently, and remained well aerated.
- The onion windrows failed to degrade properly due to the resistant nature of the onion organs. Despite being put through the "Organic Recycling" shredder, most remained intact and resisted breakdown for 4-5 months.

These characteristics are considered further in the sections below.

Conclusions of Task 2.1.

- Trial windrows of 30m^3 were successfully created, and demonstrated differences in composting behaviour as a function of weather conditions and composition.

Task 2.2: Full composting study

Aim: Based on the results of Trial 1 (Task 2.1 above), a second trial of twelve windrows (six duplicates) was carried out to evaluate co-product mixtures in more detail.

Windrow Design

Twelve windrows each of about 60m^3 were constructed at Organic Recycling Ltd. They contained straw, brewers spent grain and were selectively supplemented with the food processing waste streams (provided by the Partners):

- mixed leaf (leeks),
- fruit (melon and pineapple peel).

The compositions (mixes) of the windrows are shown in the Materials & Methods Section.

The windrows were 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.19).

Fig. 19. 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)

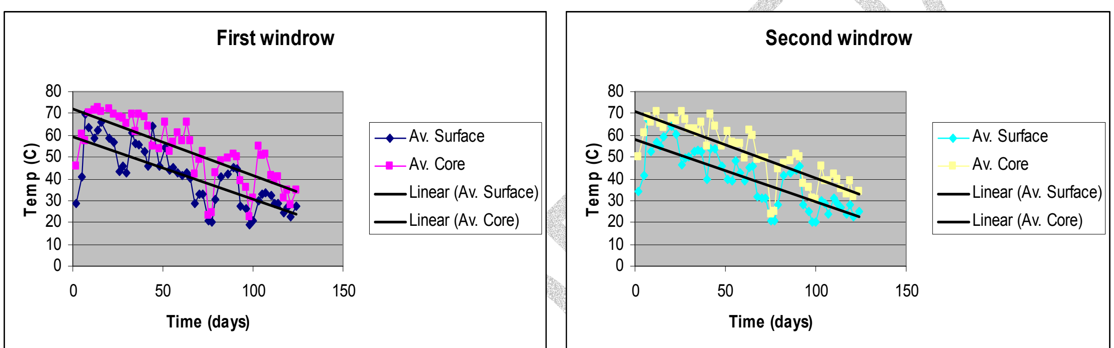


Fig. 20. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and leaf (Brewer's Grain + Leaf 2)

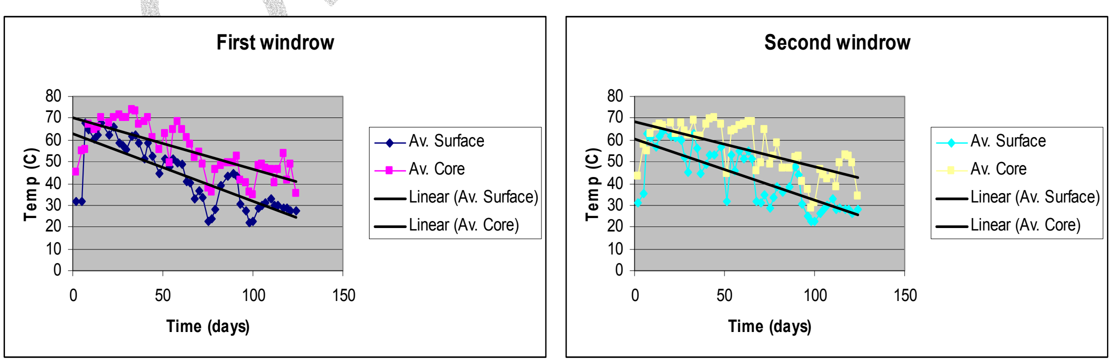


Fig. 21. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain and straw (Brewer's Grain mix)

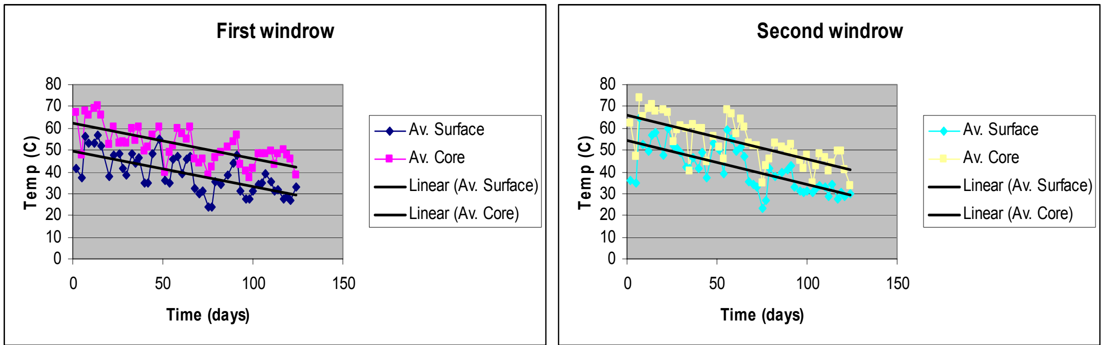


Fig. 22. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain and straw (High Brewer's Grain test)

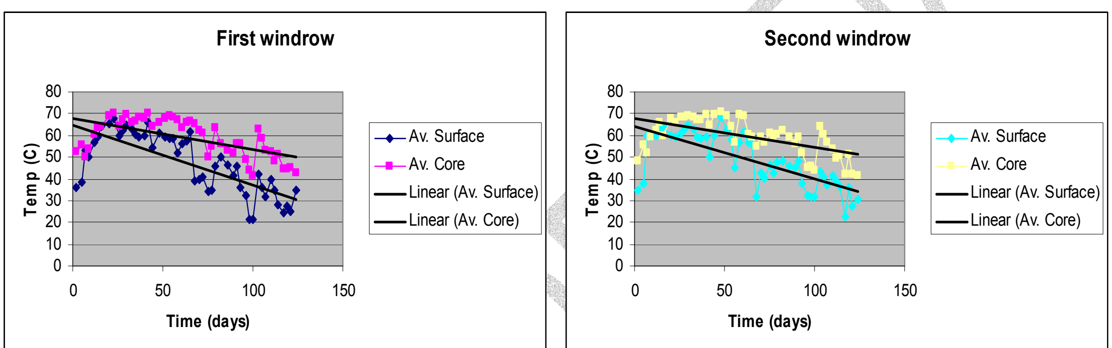


Fig. 23. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and fruit (Brewer's Grain + Fruit 1)

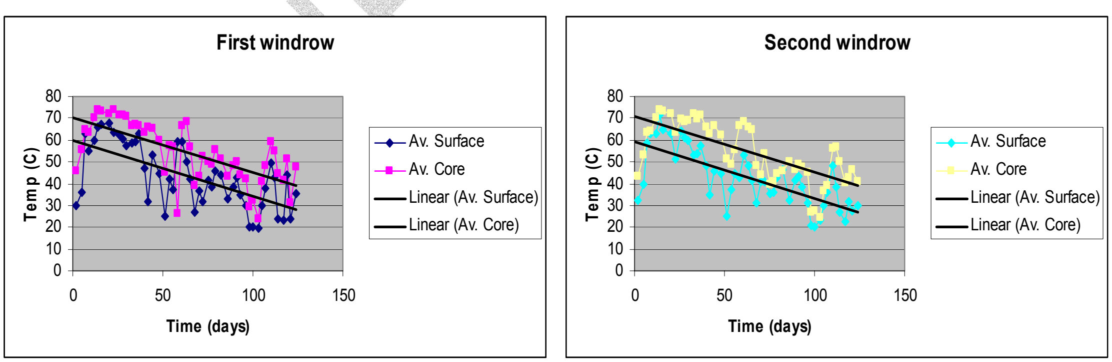
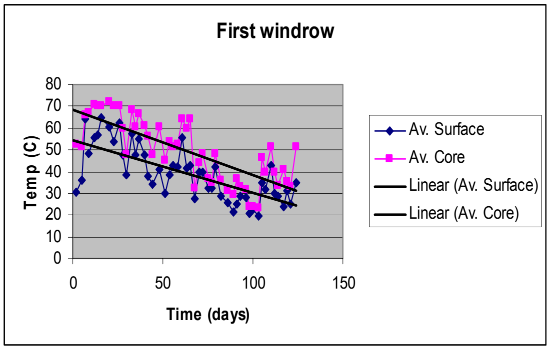
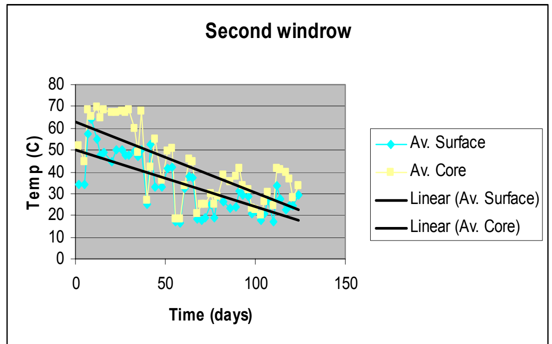


Fig. 24. Average surface and core temperatures (and linear regression fits of these temperatures) in the second trial windrow composed of brewers' spent grain, straw and fruit (Brewer's Grain + Fruit 2)





Samples were taken on a fortnightly basis for further analysis. The samples were generally taken from the top of the windrows (but several feet down) 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. In this respect, the composting activities were very different to those of trial 1. Indeed, the fruit and vegetable windrows composted more rapidly because they retained more water (due to the vegetable material). In contrast, the brewer's grain windrows that were identical to those in Trial 1 became quite dry and eventually failed to compost properly. Interestingly, the high BG windrows seemed to compost quite well. These issues are discussed later in relation to physical and chemical properties.

The leaf-supplemented BG-containing windrows were sufficiently composted to provide material for main trials.

CONCLUSIONS FROM TASK 2.2

- Windrows behaved differently to trial 1 mainly due to differences in precipitation.
- Leaf-BG windrows provided material sufficiently composted for trials.
- The inherent variability of the windrow system justifies the consideration of a vessel-type system for future trials.

Task 2.3: Physicochemical analysis

Aim: To characterise the physicochemistry of high quality growing media, and composted material from Trials 1 & 2.

Material Properties

Introduction

The materials properties of compost, peat and their mixtures include soil mechanics terms such as stress transmission, compaction and cohesion related to structural characteristics such as porosity and particle size distributions as well as water content (Briscoe et al 1987; Ollett *et al* 1993; Zeytin and Barab 2003; Pefferkorn 1997; Das and Keener 1997). The water potential shows hysteresis effects with water content when drying and wetting. Their relationship constitutes the moisture release curve which will be constructed, analysed and compared for the different materials. The particular contribution of the matric potential will be measured. All of the properties may vary spatially within a given volume of material (Van Ginkel *et al* 1999), but representative samples will be taken within the scope of this study.

Soil water availability studies

The pressure plate cell extractor works by removing soil moisture from soil samples through the creation of a pressure gradient in an extractor (see materials and methods). 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. Water availability curves relate the soil suction at which moisture is held in the soil to its moisture content.

Samples examined (see materials and methods section also):

- 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
- Four Seasons Organic Compost
- Scottish Agricultural College Compost
- ECO Composting Ecomix
- ECO Composting Supersoil
- J. Arthur Bowers Organic Peat-free Compost
- B & Q Coir-based Peat-free Multipurpose Compost
- Fresh coir (Cocopeat)
- Toressa Nova woodfibre
- Rice husks
- IFR compost (Trial 1, BG & straw; 29th Feb 2005; 0-3mm fraction)
- IFR compost (Trial 1, BG & straw; June 2005; 0-6mm fraction)
- IFR compost (Trial 2, BG & straw & leaf; Dec 2005; 0-6mm fraction)

The results (Fig. 25) show that the IFR compost has water availability characteristics 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 water availability. Fresh coir (Cocopeat) and Toressa Nova woodfibre were added for comparison.

Fig. 25. Water availability characteristics of a range of peats and growing media.

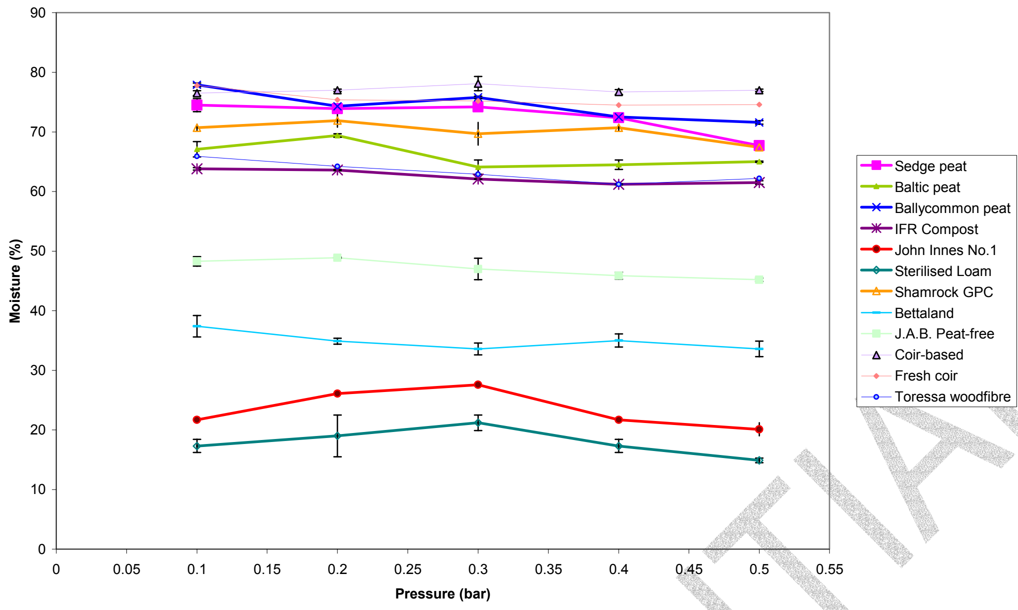


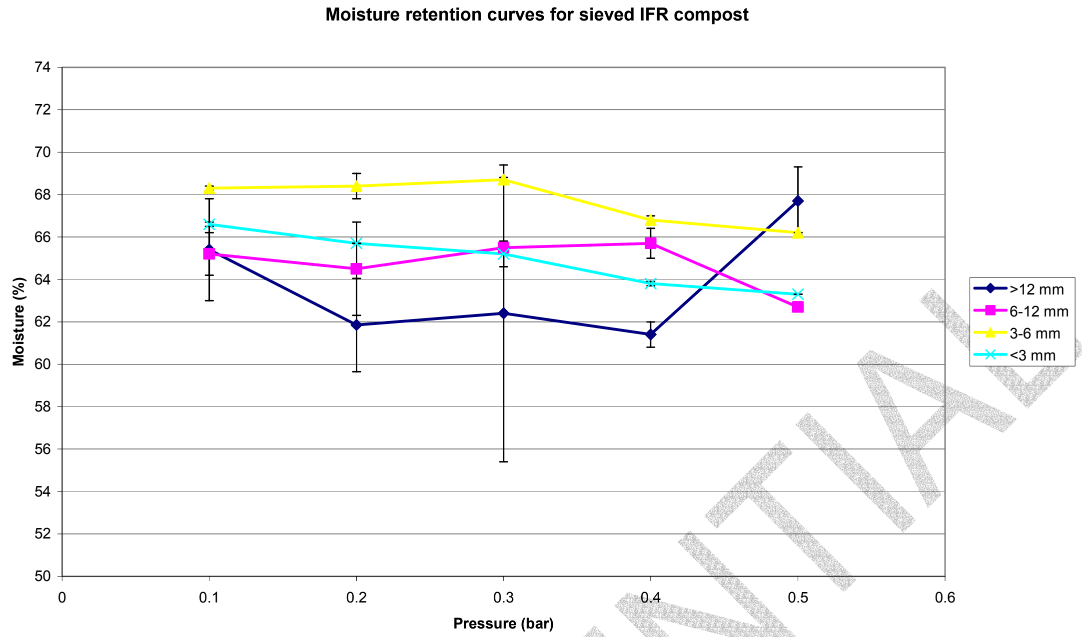
Table 5. Moisture retention values of samples (at 0.1 bar).

Sample	Moisture retention at 0.1 bar	S.D.
ECO Composting Supersoil	15.8	0.6
J. Arthur Bowers Sterilised Loam	17.3	1.1
J. Arthur Bowers John Innes No.1 Potting Compost	21.7	0.3
Bettaland compost	37.4	1.8
Rice husks	40.1	2.5
ECO Composting Ecomix	40.7	0.3
Scottish Agricultural College Compost	47.8	0.4
J. Arthur Bowers Organic Peat-free Potting Compost	48.3	0.8
IFR Compost (Second trial, Dec 05, <6mm, unwashed)	55.4	0.1
IFR Compost (Second trial, Dec 05, <6mm, washed)	59.9	0.4
IFR Compost (First trial, BG June 05, 0-6mm)	62.2	0.3
Four Seasons Organic Compost	65.9	0.0
Toressa Nova wood fibre	65.9	2.1
Baltic peat	67.1	1.3
Shamrock Potting Compost – General Potting Medium	70.7	0.6
Sedge peat	74.5	1.1
B & Q Coir-based Peat-free Multipurpose Compost	76.5	0.4
Fresh coir (Cocopeat)	77.8	0.1
Ballycommon peat	77.9	0.3

More detailed evaluation of IFR compost

Material collected from the IFR compost windrow (BG & straw, 28th February, 2005) was size fractionated by sieving in its "as recovered" form to ascertain the sensitivity of water availability characteristics to the particle size distribution of a particular compost.

Fig. 26. Water availability curves for sieved fractions from IFR compost (28 Feb 2005)



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. Nevertheless, all fractions exhibited high water characteristics similar to values obtained with peat.

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 6) show that all the growing media exhibit similar a_w values.

Table 6. 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
Rice husks	-55.64	0.668	88.67
IFR Compost (Second trial, Dec 05, <6mm, unwashed)	-2.08	0.985	56.47
Bettaland Product	-1.60	0.988	72.22
IFR Compost (First trial, BG June 05, 0-6mm)	-1.50	0.989	40.90
IFR Compost (First trial, BG 28/02/05, 0-3mm)	-1.08	0.992	39.37
J. Arthur Bowers John Innes No.1 Potting Compost	-0.88	0.994	84.30
IFR Compost (Second trial, Dec 05, <6mm, washed)	-0.65	0.995	45.87

Shamrock Potting Compost – General Potting Medium	-0.59	0.996	44.90
Latvian Peat	-0.40	0.997	48.03
J. Arthur Bowers Peat-free Organic Garden Compost	-0.34	0.998	58.67
ECO Composting Supersoil	-0.33	0.998	82.40
J. Arthur Bowers Sterilised Loam	-0.32	0.998	85.28
Sedge Peat	-0.30	0.998	30.99
Ballycommon Peat	-0.28	0.998	33.42
Toressa Nova wood fibre	-0.23	0.998	46.74
Four Seasons Organic Compost	-0.09	0.999	38.43
Fresh coir (Cocopeat)	-0.06	1.000	19.52
ECO Composting Ecomix	-0.04	1.000	61.28
Scottish Agricultural College Compost	0.00	1.000	57.73

Water sorption characteristics

The water sorption isotherms of a range of peat / compost samples were determined. All results were fitted using the GAB models. The generally observed behaviour for microporous substrates is that the amount of water sorbed increases sharply as the relative humidity approaches 100%. The amount of water sorbed will also be influenced by the degree of crystallinity of the sample (Moates, 1997).

Fig 27. Sorption isotherms for Ballycommon & sedge peats

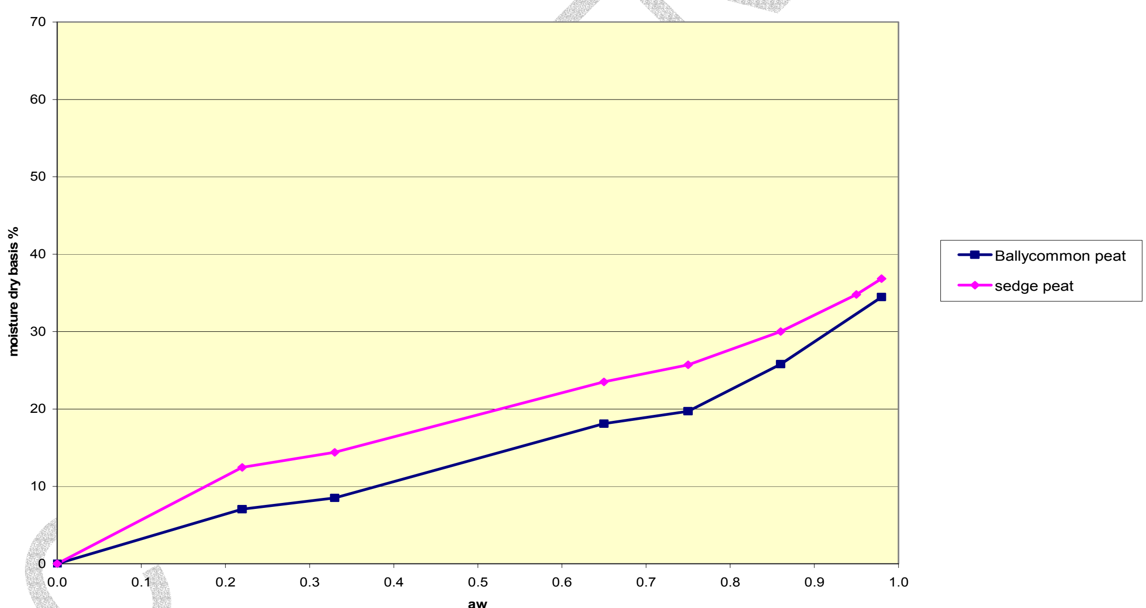


Fig 28. Sorption isotherm for J. Arthur Bowers Peat-free compost

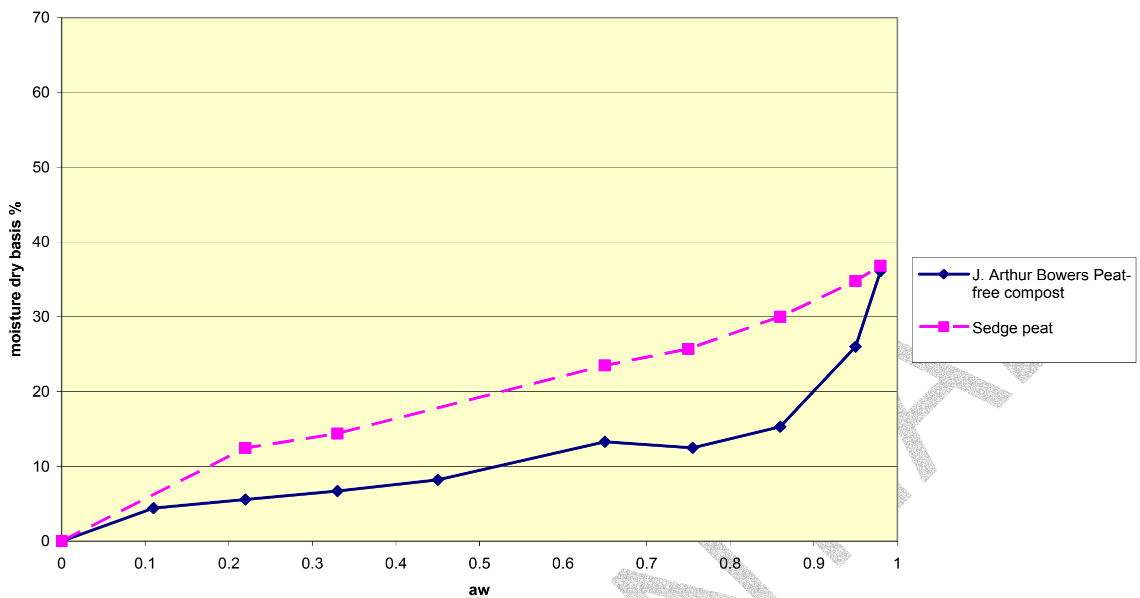


Fig 29. Sorption isotherm for IFR compost (0-3mm, 28 Feb 2005)

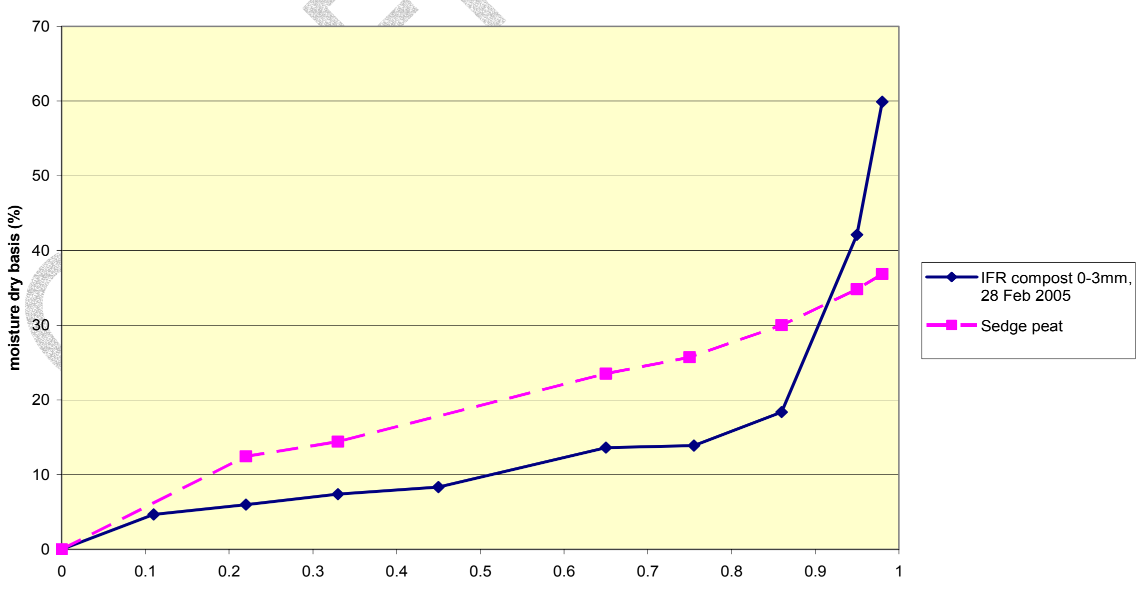


Fig 30. Sorption isotherm for Brewer's Grain

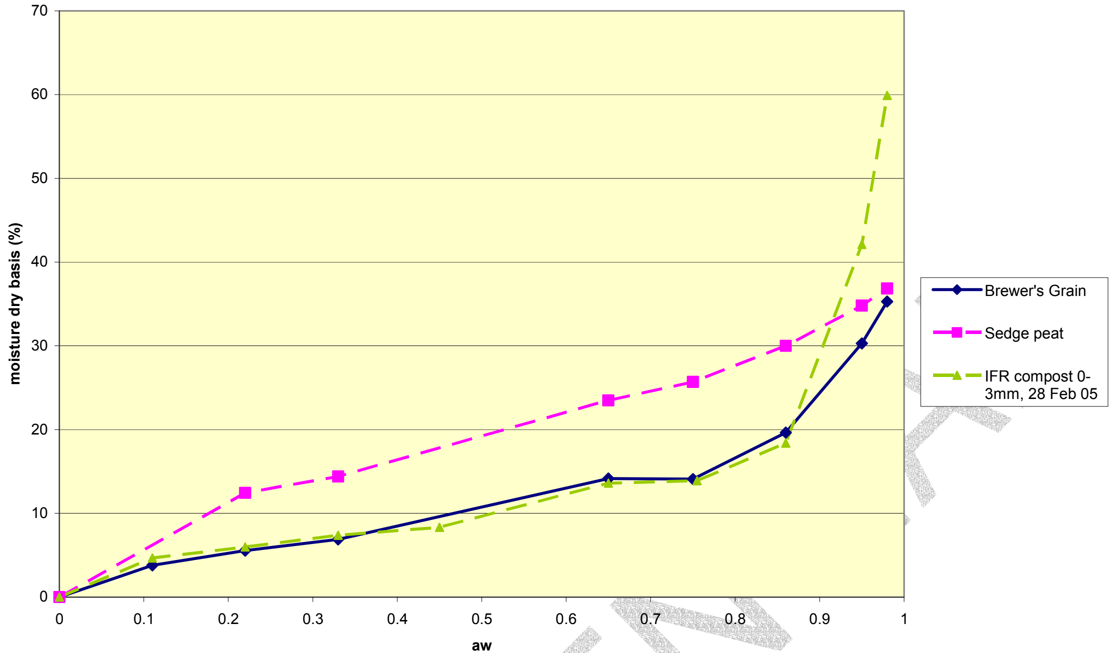


Fig 31. Sorption isotherm for B&Q coir-based compost

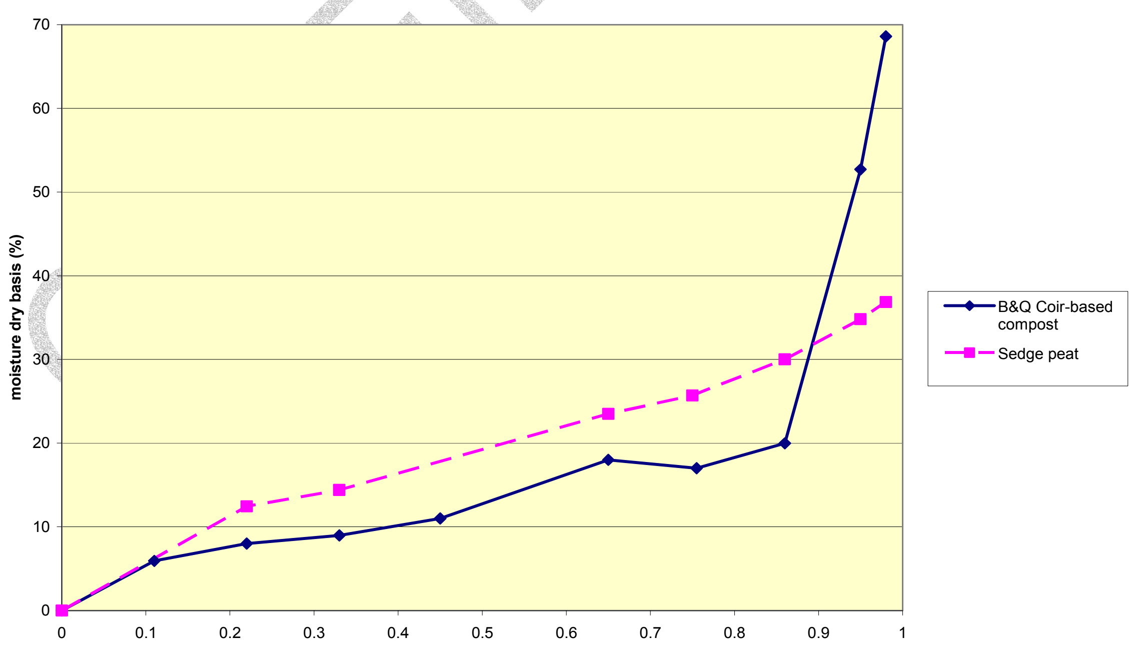


Fig 32. Sorption isotherm for Baltic peat

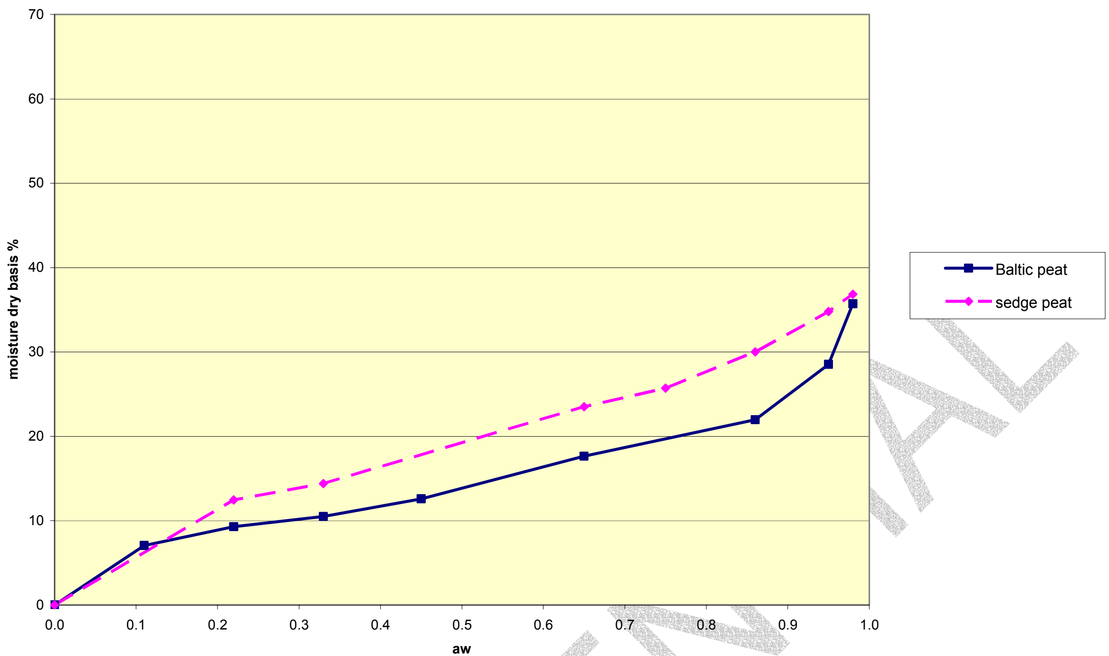


Fig 33. Sorption isotherm for Shamrock potting compost

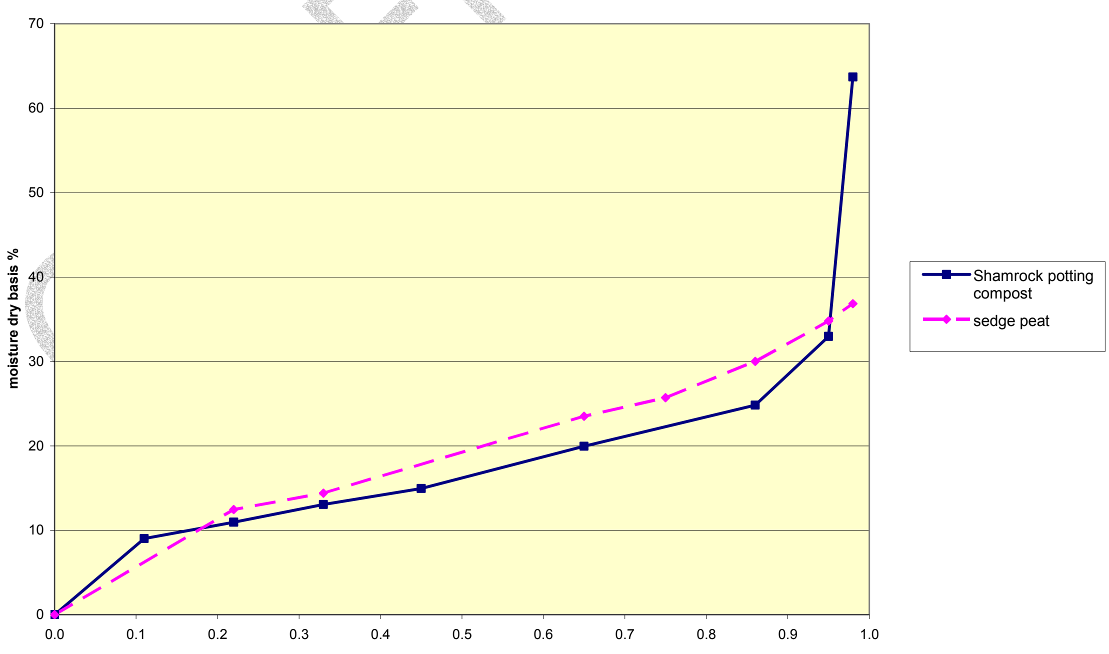


Fig 34. Sorption isotherm for J. Arthur Bowers John Innes No.1 potting compost

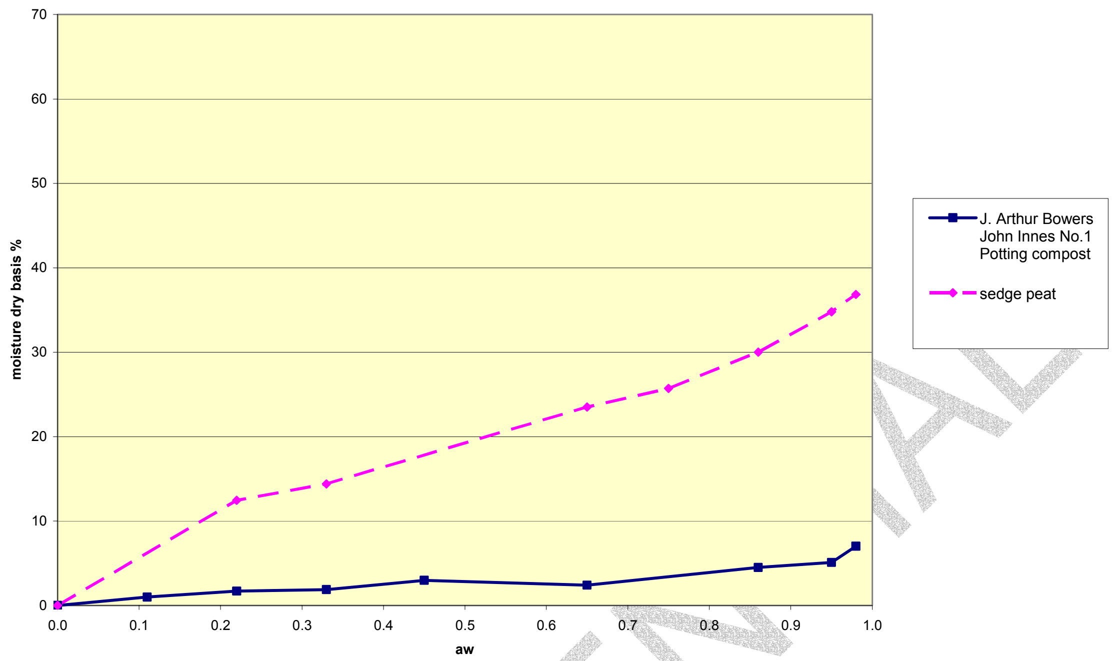


Fig 35. Sorption isotherm for J. Arthur Bowers Sterilised loam

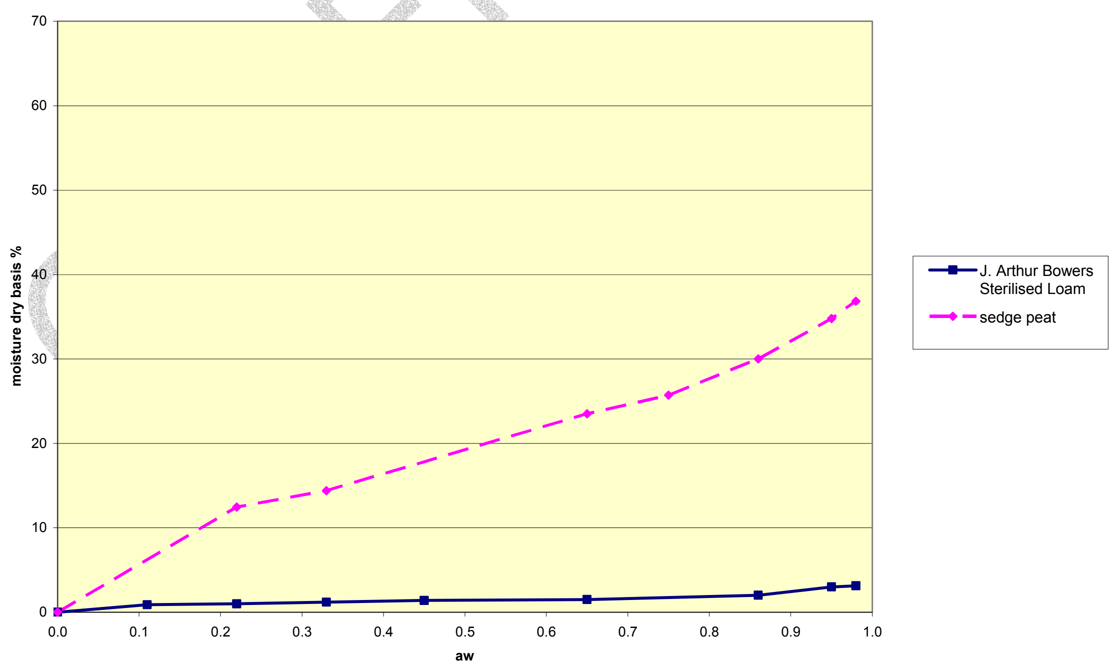


Fig 36. Sorption isotherm for J. Arthur Bowers Sterilised loam

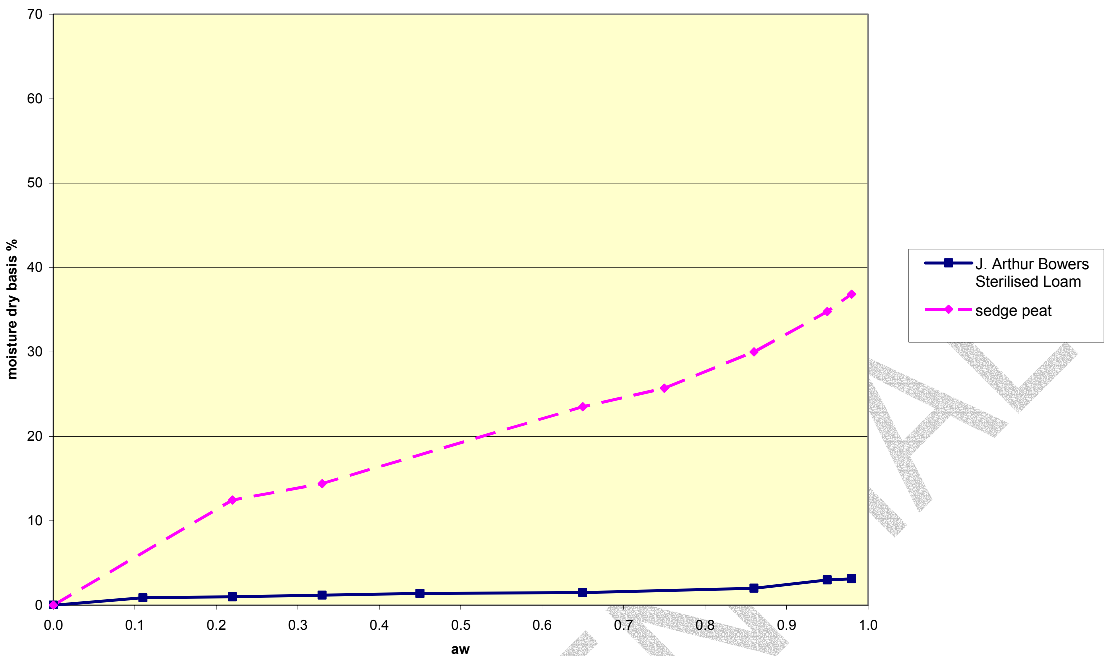


Fig 37. Sorption isotherm for Bettaland compost

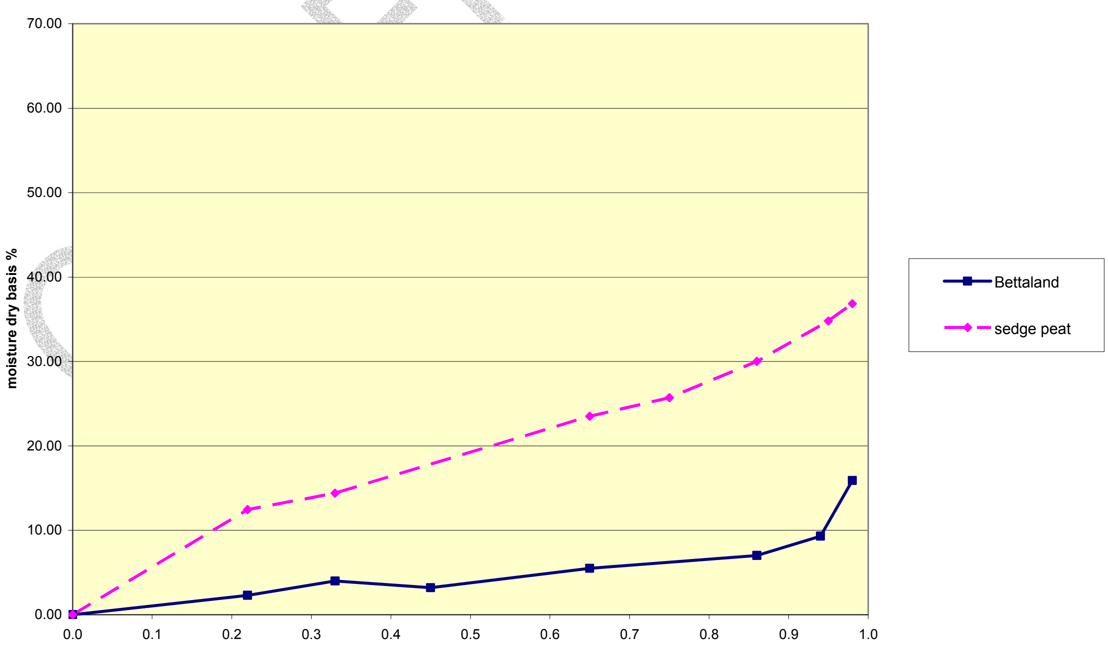


Table 7. Sorption parameters from GAB model

	m_o	c	k	R^2
Sedge peat	0.1492	14.7726	0.6500	0.9557
Ballycommon peat	0.1058	5.9779	0.7281	0.9951
Shamrock potting compost	0.0924	424.5596	0.8012	0.7852
Baltic peat	0.0888	32.4267	0.7421	0.9730
B&Q coir-based compost	0.0631	226.561	0.8960	0.8810
Brewers Grain	0.0605	13.1463	0.8385	0.9865
J. Arthur Bowers Peat-free compost	0.0520	36.6891	0.8396	0.9264
IFR compost 0-3mm, 28 Feb 05	0.0490	156.1534	0.9134	0.9215
Bettaland compost	0.0235	48.6612	0.8315	0.8573
J. Arthur Bowers J.I. No.1 compost	0.0159	23.4597	0.7609	0.9252
J. Arthur Bowers Sterilised loam	0.0082	200.000	0.7468	0.9624

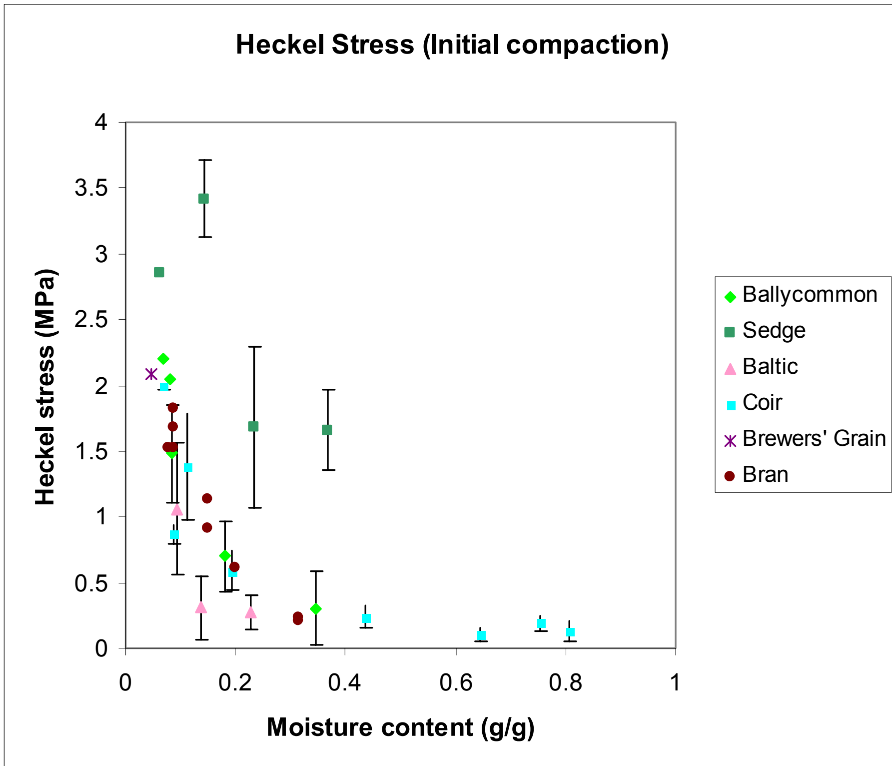
Table 7 shows that the peats have different sorption parameters to the three alternatives studied.

m_o is an estimate of the water monolayer determined by extrapolation of the sorption isotherm at the lower water activities. The three peats together with Shamrock potting compost have the highest values whilst John Innes No.1, Bettaland compost & Loam have the lowest values.
k is a measure of the association of the water. The GAB model assumes multiple layers of water. For comparison, starchy products would typically give a k value of 0.70-0.77 whilst proteins a value of 0.82-0.88 (Chirife, 1992).
c is a measure of the ease with which water can be removed from the substrate.

Compaction

Compaction results are shown in Fig. 38. 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. 38. 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 8. pH and electrical conductivity of selected samples.

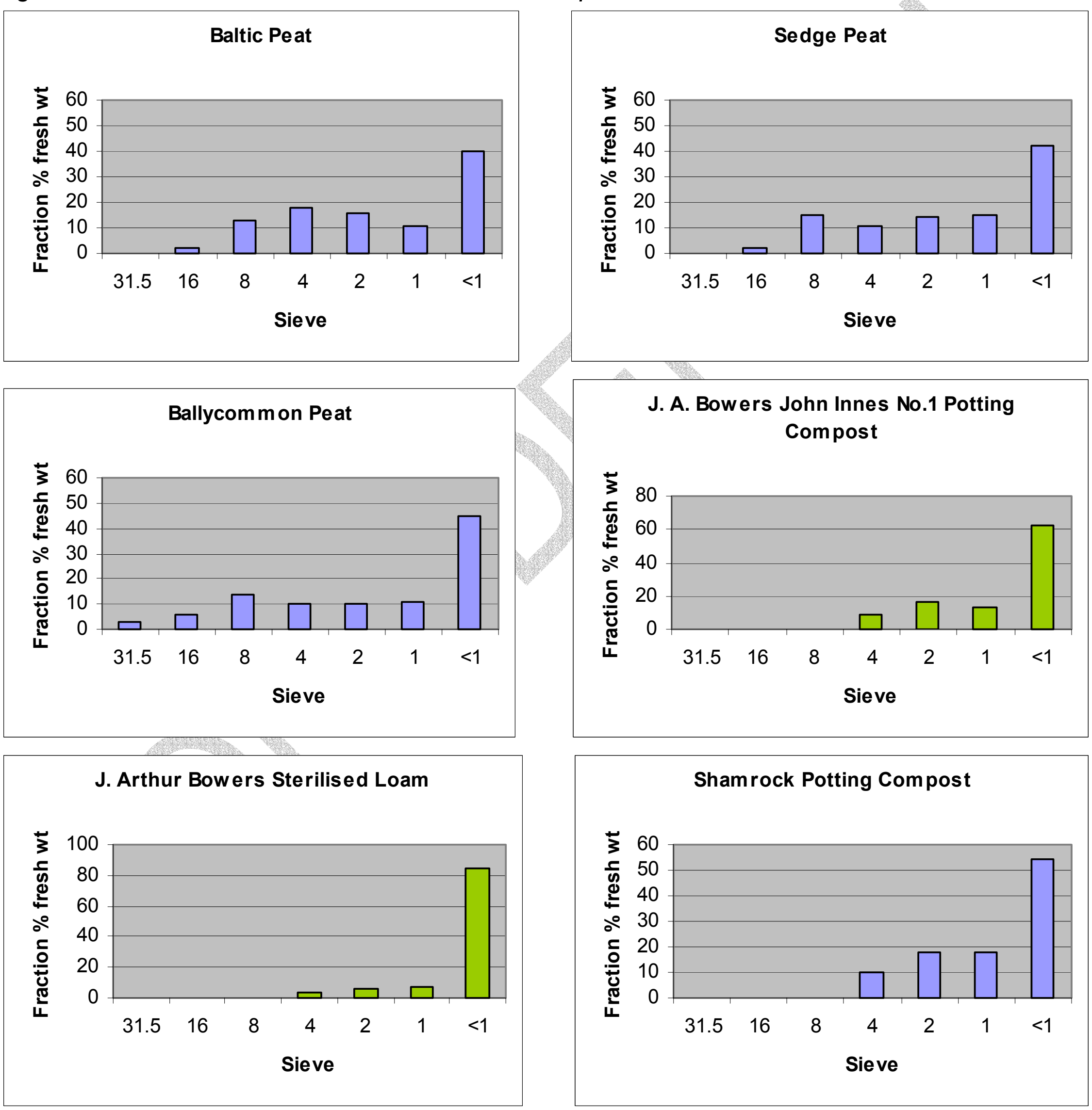
Sample	pH	Electrical conductivity
Ballycommon peat	3.95	10.4 mS/m
Baltic peat	3.87	12.2 mS/m
Sedge peat	4.43	67 mS/m
Shamrock Potting Compost	5.06	167mS/m
B&Q Coir-based compost	5.08	230 mS/m
IFR Compost (Second trial, Dec 05, <6mm, unwashed)	5.87	422 mS/m
Fresh coir (Cocopeat)	6.16	6.7 mS/m
IFR Compost (First trial, BG June 05, 0-6mm)	6.23	396 mS/m
IFR Compost (Second trial, Dec 05, <6mm, washed)	6.25	142 mS/m
Four Seasons Organic Compost	6.45	291 mS/m
Rice husks	6.34	39 mS/m
Toressa Nova wood fibre	7.26	71mS/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
Scottish Agricultural College Compost	7.92	90.4 mS/m
ECO Composting Ecomix	8.38	141 mS/m
J. Arthur Bowers Peat-free Compost	8.39	153mS/m
ECO Composting Supersoil	8.72	30.8 mS/m

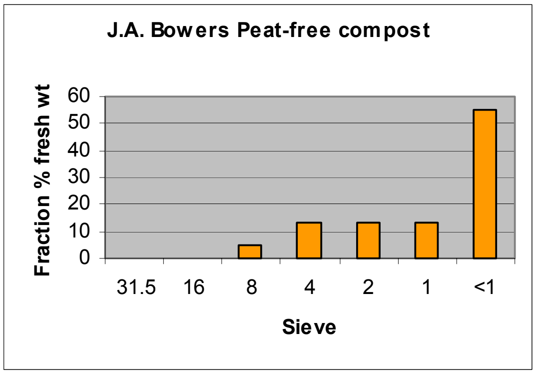
It is particularly noticeable that most of the composted materials exhibit naturally high electrical conductivity. This may limit incorporation rates for composted material due to its negative effect on germination, rates of root growth and flower development compared with peat-based mixes. (See plant trials and approaches to successfully address the issue).

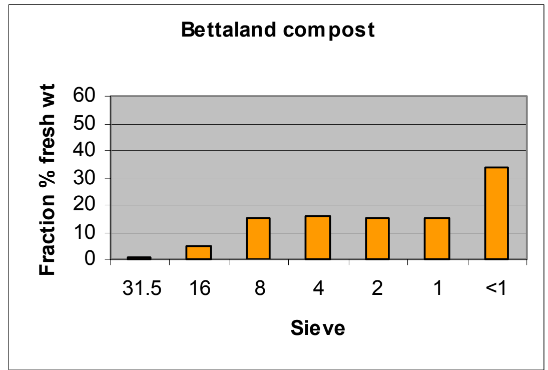
Evaluation of particle size distribution by sieve analysis

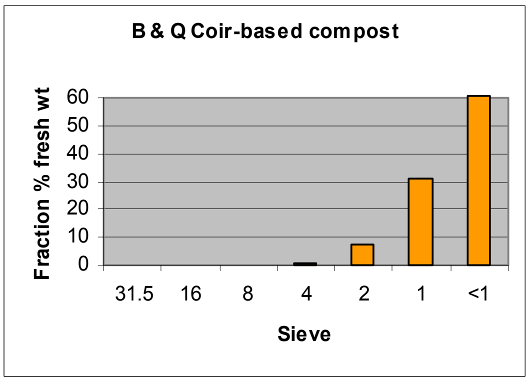
The particle size distributions of the peats & peat alternatives are shown in the following graphs (Figure 39). It can be seen that the IFR compost collected on 28th February 2005 has a noticeably different particle size distribution to the other materials. The IFR compost collected on 8th June 2005 would seem to have undergone further structural degradation.

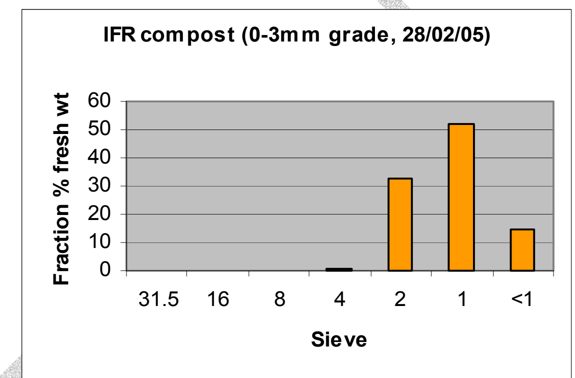
Fig. 39. Particle size distributions of selected samples

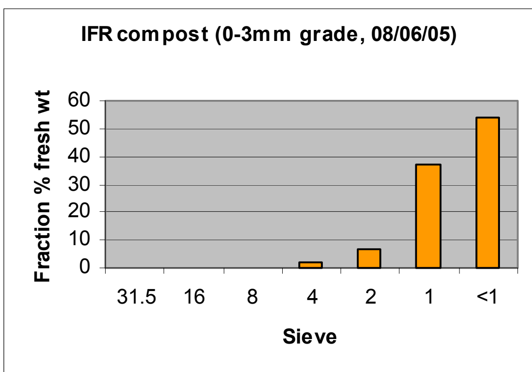


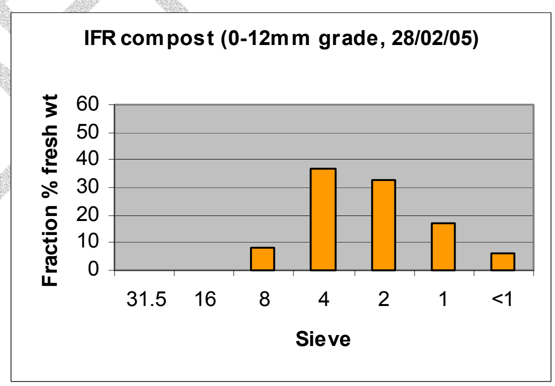

J.A. Bowers Peat-free compost
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

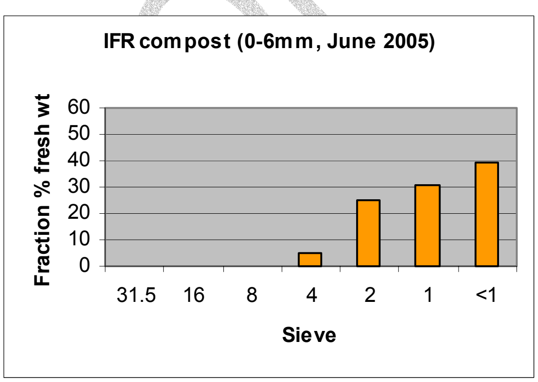

Bettaland compost
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

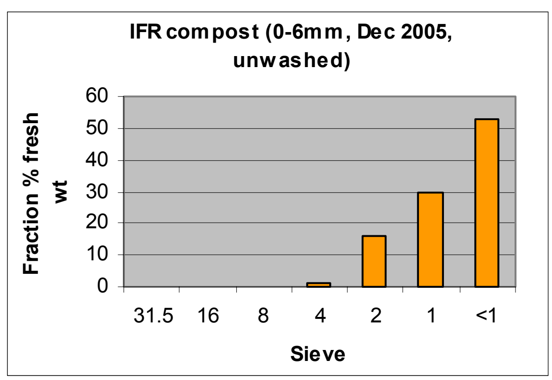

B & Q Coir-based compost
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

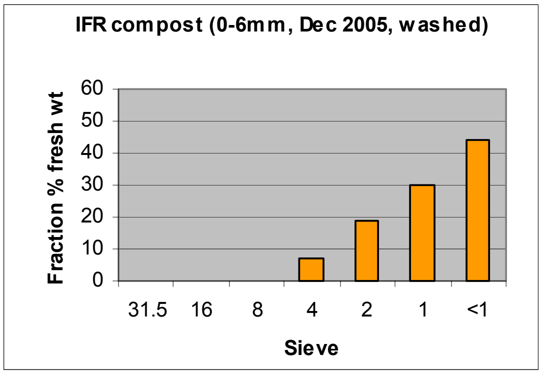

IFR compost (0-3mm grade, 28/02/05)
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

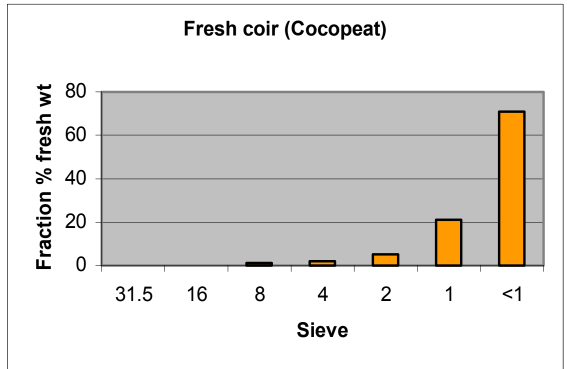

IFR compost (0-3mm grade, 08/06/05)
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

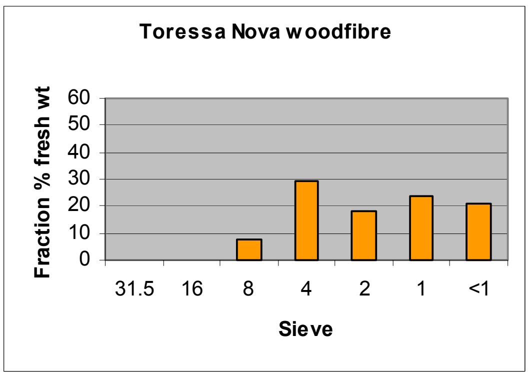

IFR compost (0-12mm grade, 28/02/05)
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

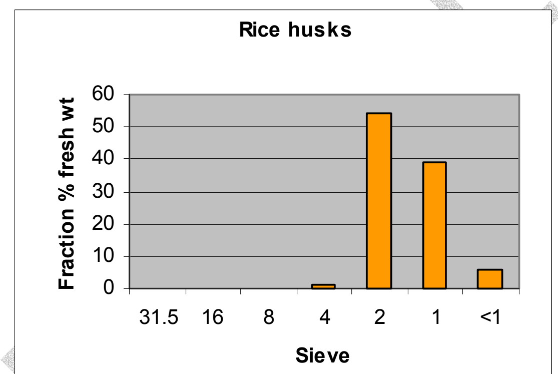

IFR compost (0-6mm, June 2005)
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

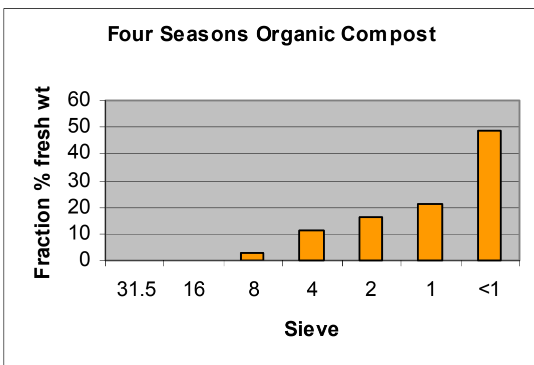

IFR compost (0-6mm, Dec 2005, unwashed)
Fraction % fresh wt
60
50
40
30
20
10
0
31.5
16
8
4
2
1
<1
Sieve

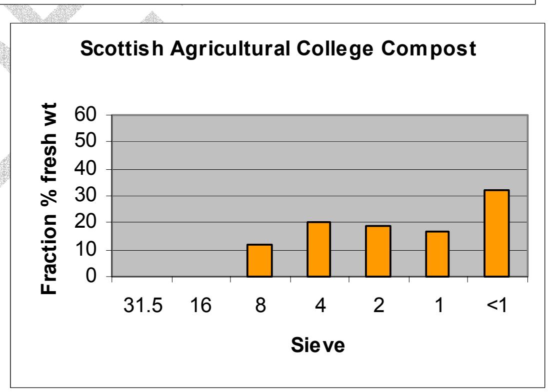


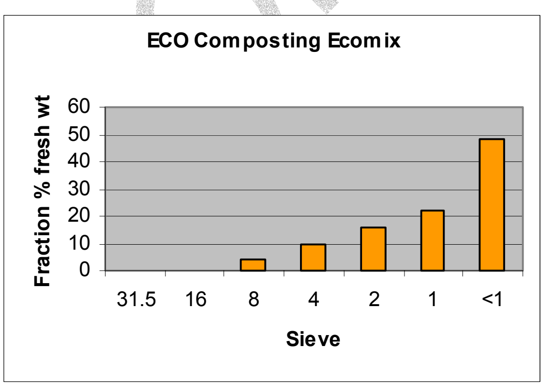


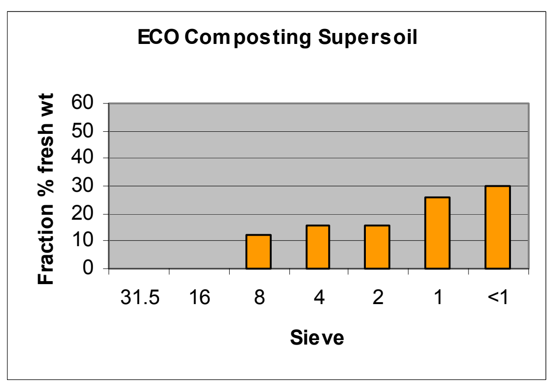












Particle size and distribution has an important impact on the aeration, water-holding and compaction of the growing medium. The peat samples gave a broad range of sizes. The IFR compost evaluated in this section was derived from the 0-3mm grade and hence the particles are distributed towards the right-hand end of each graph. Larger grades (3-6, 6-12 etc) gave a wider profile as expected. Thus, IFR compost may be tailored through sieving and re-blending to suit growers requirements.

Bulk density

The bulk density of the various peat & peat alternatives (determined in accordance with a modified version of BS EN 12580:2000) is given in the table below:

Table 9. Bulk density values of samples.

Sample	Bulk density (g/l)	Dry wt. (%)
Toressa Nova wood fibre	151	46.74
Rice husks	173	88.67
Ballycommon peat	295	41.64
Baltic peat	337	44.56
IFR Compost (Second trial, Dec 05, <6mm, unwashed)	441	56.47
IFR Compost (Second trial, Dec 05, <6mm, washed)	441	45.87
Fresh coir (Cocopeat)	446	19.52
Shamrock Potting Compost – General Potting Medium	466	23.99
IFR Compost (First Trial, June 05, 0-3mm)	536	41.14
IFR Compost (First Trial, June 05, 3-6mm)	542	38.40
IFR Compost (First Trial, June 05, 0-6mm)	586	40.90
Sedge Peat	598	42.80
Four Seasons Organic Compost	739	38.43
ECO Composting Ecomix	827	61.28
Bettaland compost	914	75.96
Scottish Agricultural College Compost	974	57.73
J. Arthur Bowers John Innes No.1 Potting Compost	1226	82.70
ECO Composting Supersoil	1494	82.40
J. Arthur Bowers Sterilised Loam	1539	95.51

The bulk density of the IFR compost is just over 500, and therefore similar to the PAS requirements. The value of bulk density will need to be evaluated further in relation to moisture content, and its propensity for tailoring in relation to particle size and settling characteristics.

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 10. 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 2	AFP (%) 10-15	- Pot and foliage plants - Bedding plants - Nursery stock (small / medium pots)	- Watering management less critical, as compost relatively freely draining.
Index	AFP (%)	- Pot and foliage plants (small pots)	- Frequent watering will be

3	15-25	- Long term nursery stock - Azaleas, orchids (eriphytes)	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 11. Air-filled porosity values of samples.

Sample	AFP (%)	S.D.
ECO Composting Supersoil	1.6	0.1
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
Four Seasons Organic Compost	10.6	0.3
Fresh coir (Cocopeat)	10.9	0.8
ECO Composting Ecomix	11.1	1.7
Sedge Peat	11.6	0.6
Bettaland compost	13.6	3.5
Shamrock Potting Compost – General Potting Medium	15.8	4.8
Scottish Agricultural College Compost	18.2	1.1
IFR Compost (Second trial, Dec 05, <6mm, unwashed)	24.2	0.7
IFR Compost (Second trial, Dec 05, <6mm, washed)	25.2	4.5
IFR Compost (First trial, BG June 05, 0-6mm)	27.9	3.6
B & Q Coir-based Peat-free Multipurpose Compost	34.8	4.3
Toressa Nova wood fibre	43.3	1.2
Rice husks	78.9	0.8

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

The air filled porosity (AFP) of compost is a function of the quality of the original waste material and the degree of control exerted during composting. Conventional composts lack the necessary structure and therefore would normally be expected to have a lower AFP than that of peat. Growers require growing media with sufficiently high air-filled porosity - typically nursery stock growers require an AFP value around 25% whilst bedding plant producers require a value of 15-18%. AFP is important in preventing growing media from becoming anaerobic. Hence, IFR compost provides a good AFP.

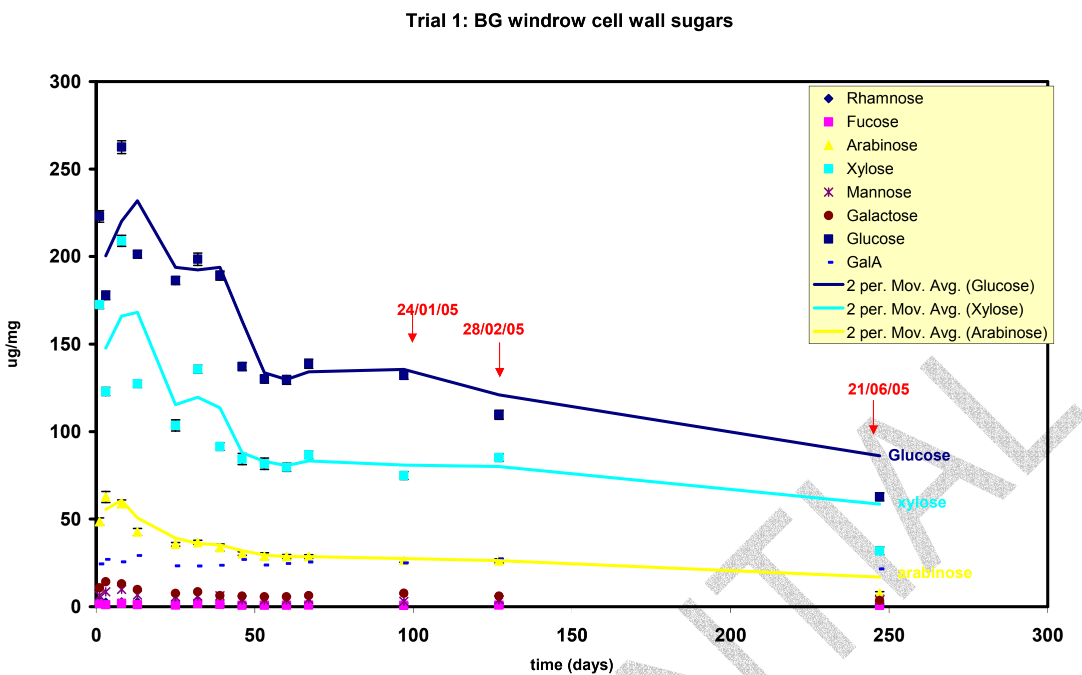
Plant cell wall chemistry

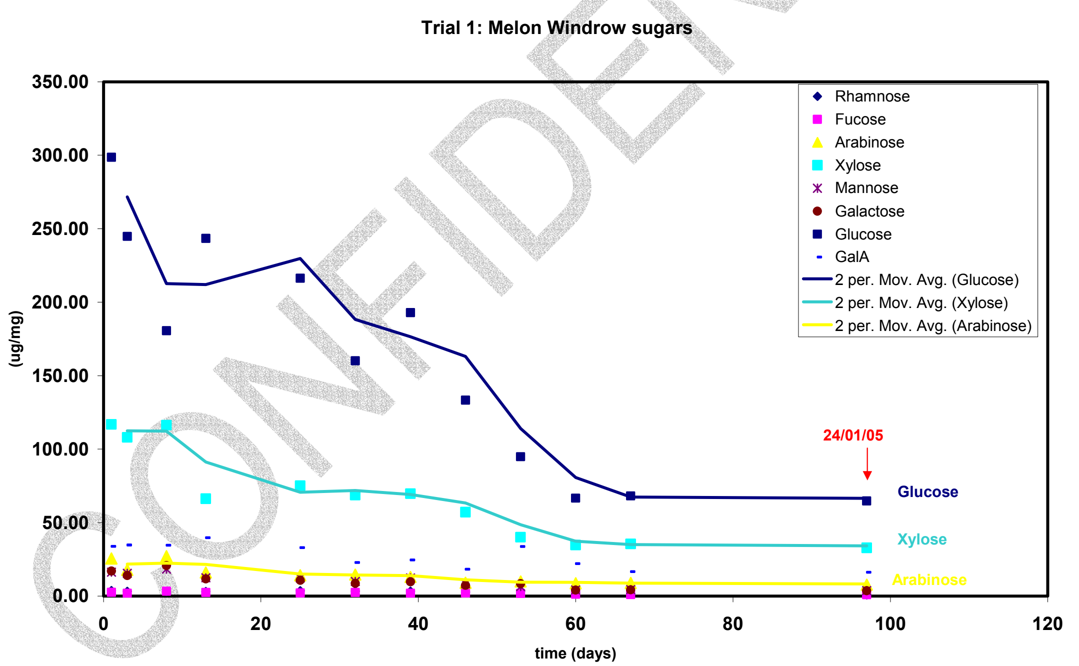
Trial 1

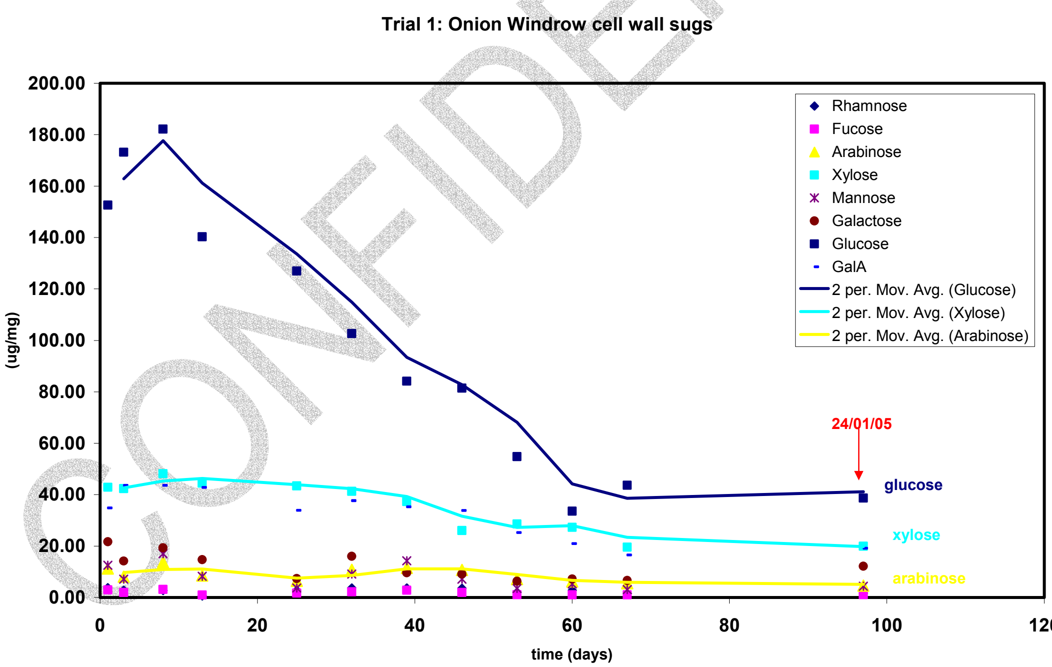
Yields of AIRs and carbohydrate content

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 40) 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. 40. 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
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
0
50
100
150
200
250
300


Trial 1: Melon Windrow sugars
(ug/mg)
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
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
0
20
40
60
80
100
120

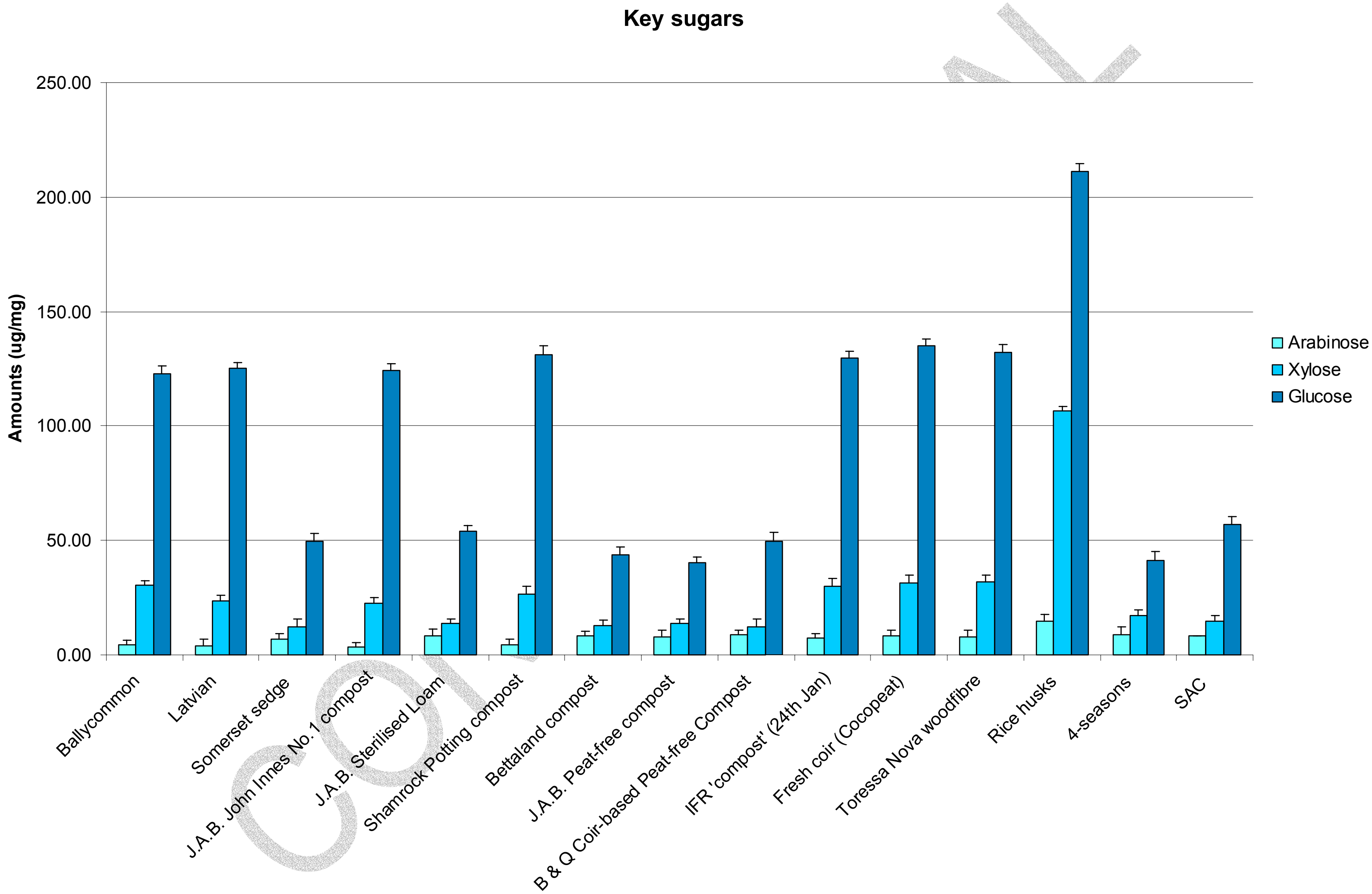


Composted material was analysed for the cell wall carbohydrate composition. The results (Fig. 40) showed that in all cases (except for mixed leaf) the sugars had declined to a stable value after 70 days.

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. 41).

Fig. 41. The amount of sugars present in AIRs of commercially available growing media and IFR compost samples



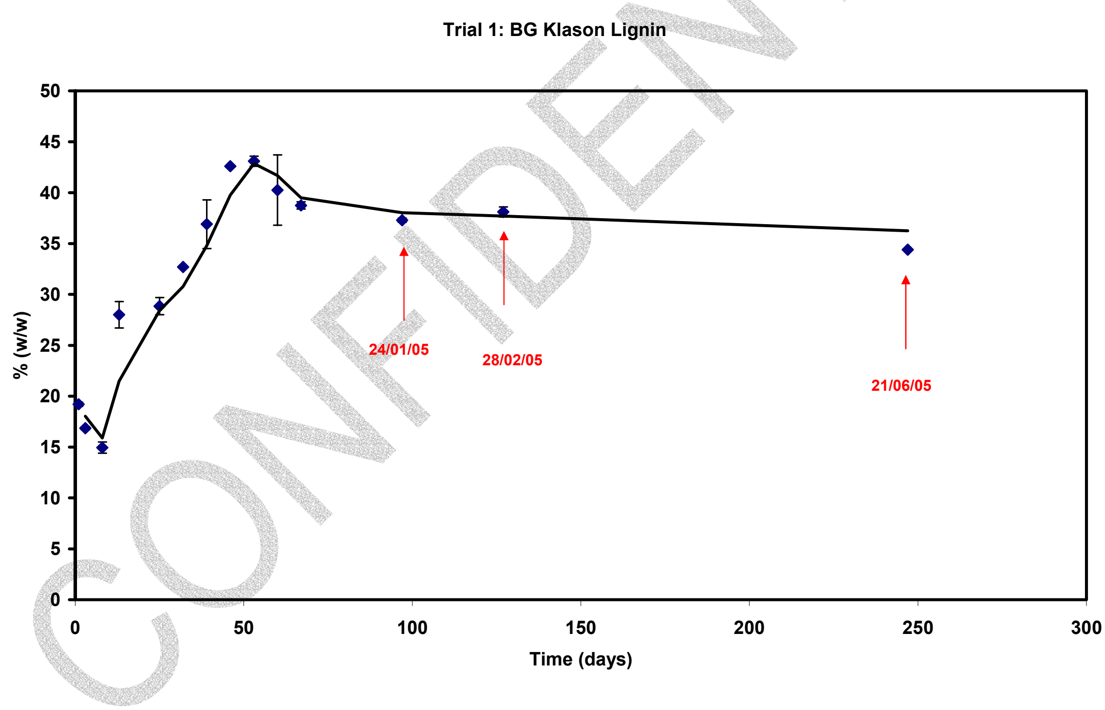
Phenolic acid analysis

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.

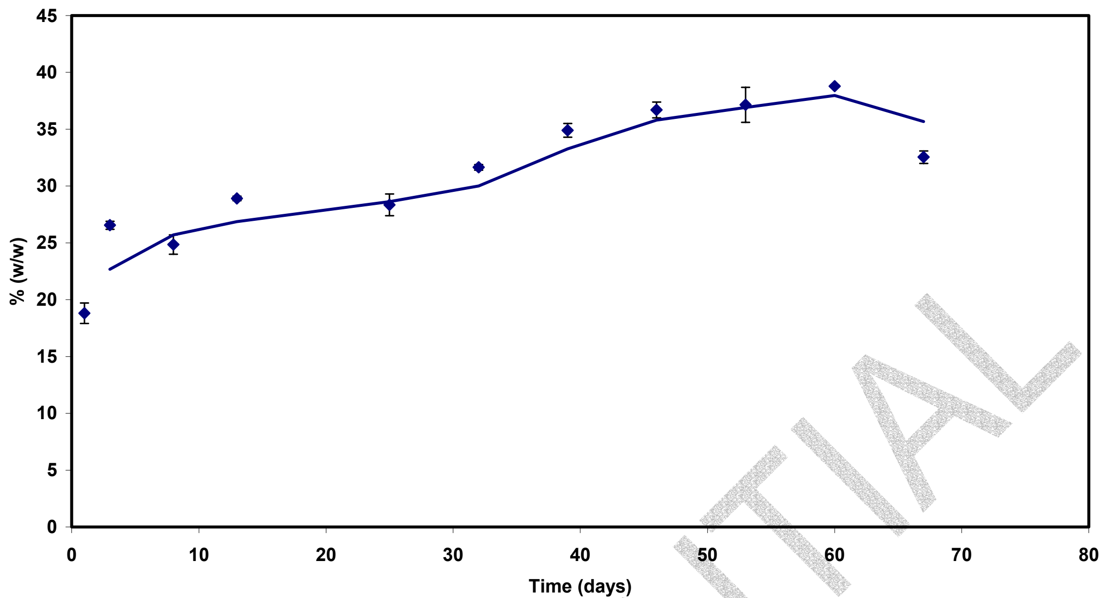
Klason Lignin analysis

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 42. Klason lignin in Brewer's Grain windrow compost



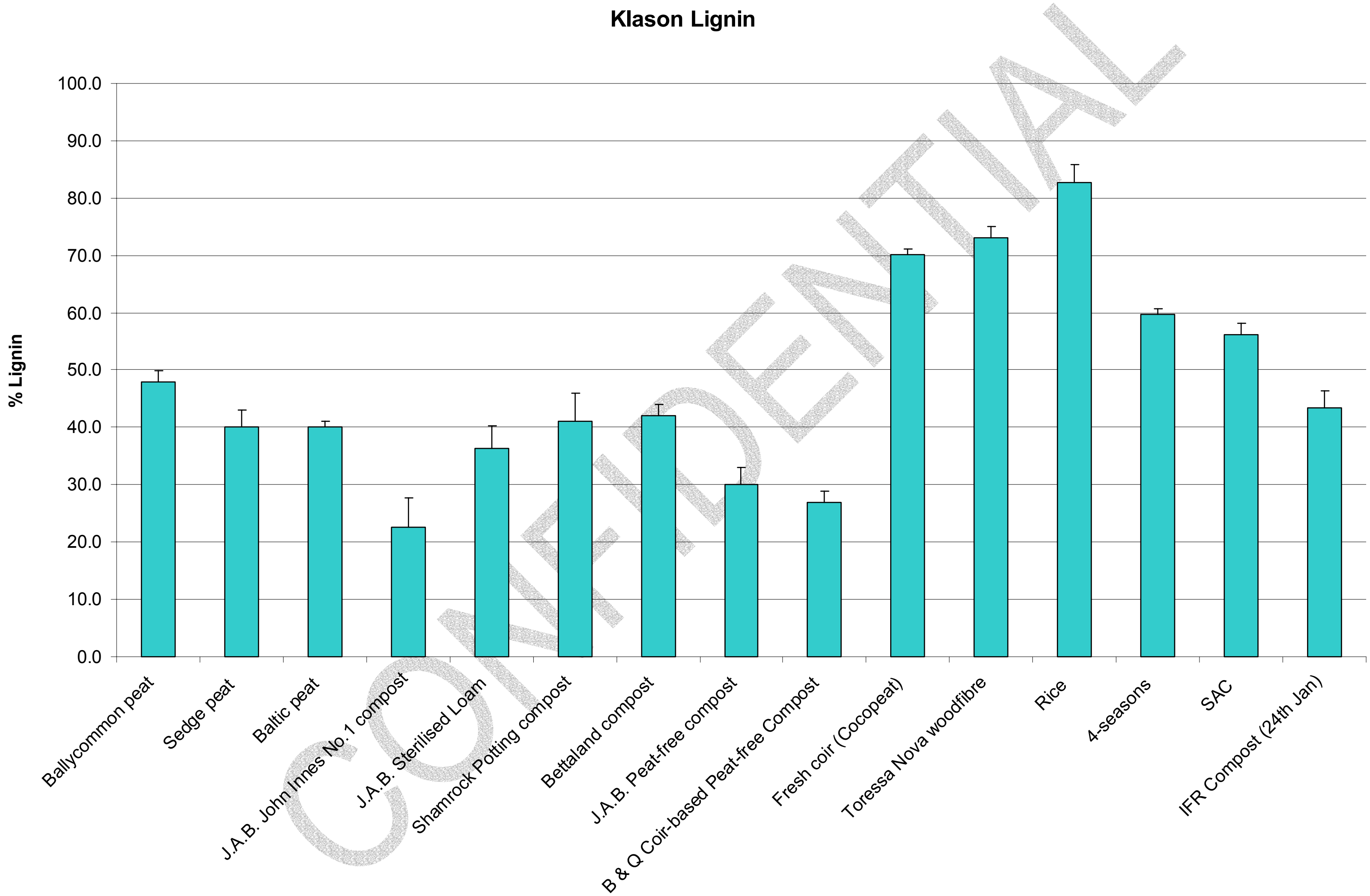
Trial 1: Melon Windrow Cell Wall Klason Lignin



Microscopy

Fig. 43: (1) onion mix, (2) mixed leaf, (3) melon and (4) brewer's grain

Figure 44. Klason lignin in commercial growing media and IFR compost



<u>*Microscopy after composting (January 24th 2005)*</u>

(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. 43 – 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. 43 – 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. 43 – 3).

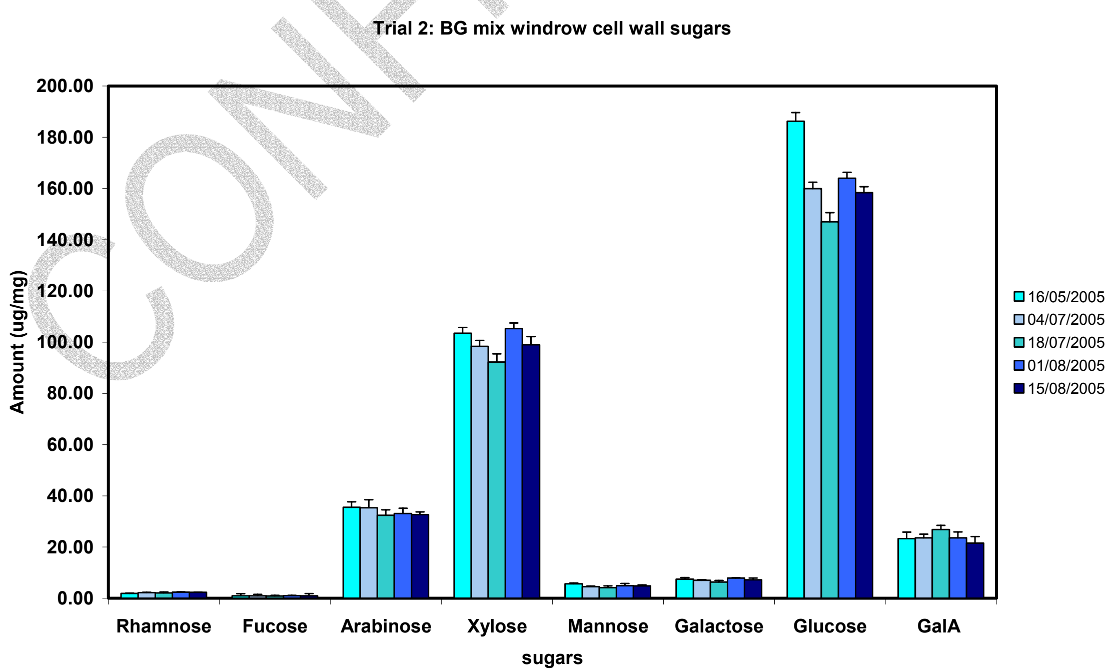
(d) Brewers' Grain: the internal tissues of the grain have degraded and there is an abundance of surface fungal mycelium throughout the sample. The outer glumes (palea and lemma) of the grain, being of similar composition to the straw, have resisted major breakdown, and together with the semi-degraded straw have produced a light-coloured, relatively-dry and pleasant-smelling sample (Fig. 43 -4).

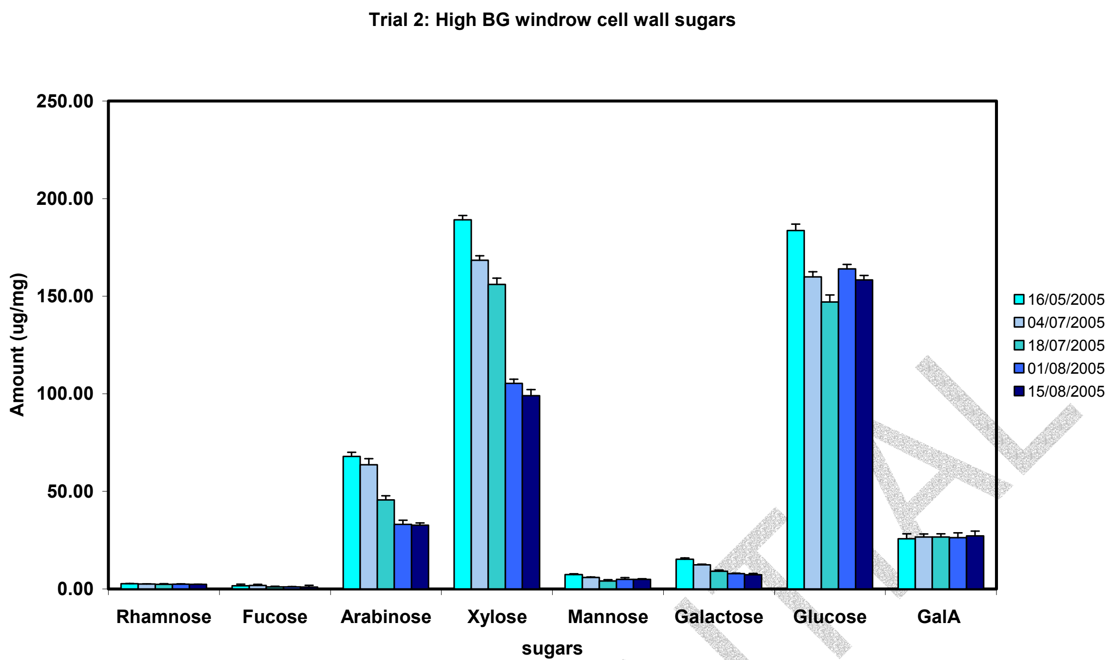
In all cases, the straw was largely intact, but had become spongy in texture, allowing water penetration. The Brewers' Grain compost was the best-drained sample. That derived from onion or mixed leaf waste was the heaviest and foulest smelling.

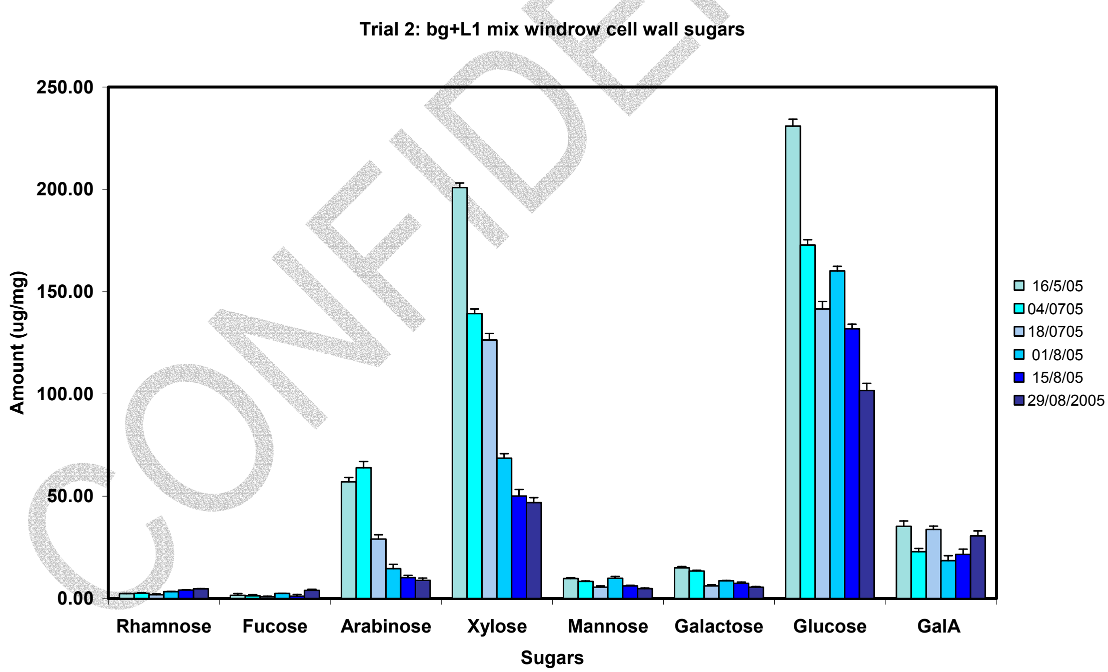
Second Windrow Trials

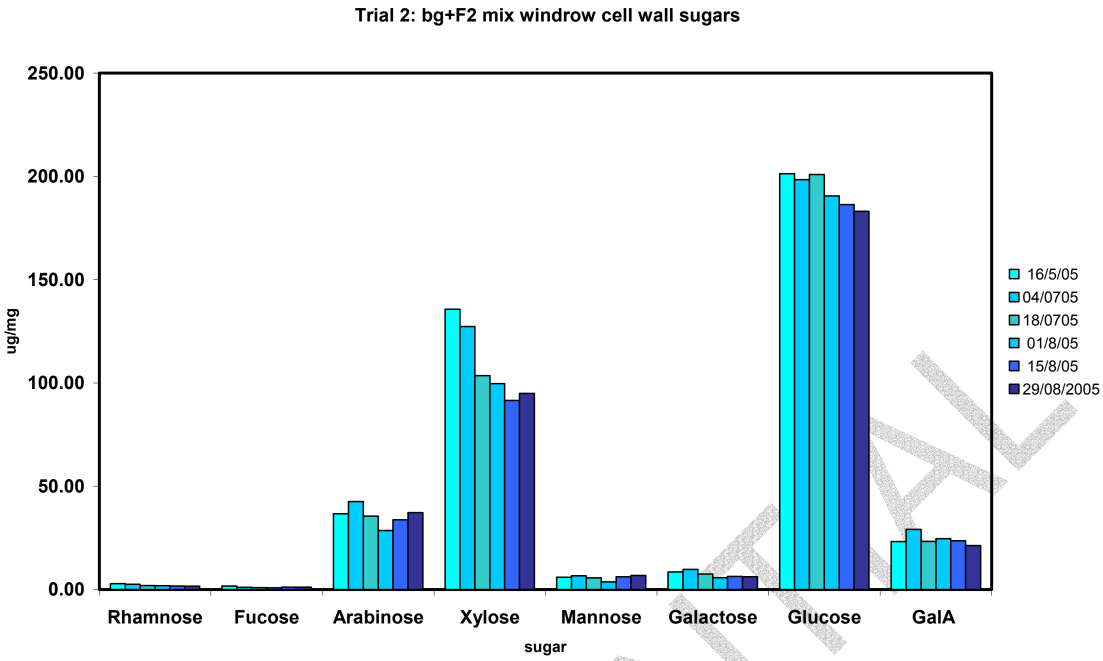
Chemical analysis

Fig. 45. Second trial windrow cell wall sugars




Trial 2: High BG 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
16/05/2005
04/07/2005
18/07/2005
01/08/2005
15/08/2005


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



The second trial of windrows showed a range of composting activities. The BG-mix windrow, which comprised the same mixture as the BG windrow in trial 1, showed little degradation over the 3 months reported. This is consistent with the observation that the windrow dried out, and failed to compost properly. In contrast, the high BG windrow showed significant degradation of cell wall material, with a rapid decrease in hemicellulosic arabinose and xylose. A similar degradation rate was seen with the BG + fruit mix. However, the most rapidly composting mixture was the BG-leaf mix, which showed a ¾ reduction in key structural cell wall sugars during the 4 month period.

Several months later, the leaf-BG mixture windrow was chosen as the source material for full trials.

Conclusions from Task 2.3

- IFR compost (24th January 2004) demonstrated water availability characteristics similar to the 4 high quality peats, and was 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 very high water availability.
- Different grades of the IFR compost (size fractionated) also showed these high moisture retention characteristics.
- Water potential of IFR compost was similar to other growing media.
- pH of IFR compost was naturally neutral
- Electrical conductivity of IFR compost was much higher than peat growing media and has had to be addressed. It has now been reduced to within PAS requirements by aqueous extraction (see below).
- Sieve analysis of IFR compost showed a good particle size distribution, providing an opportunity for tailoring the characteristics through fractionation and re-blending.
- Analysis of plant cell walls show that the carbohydrate components degrade to a basal level after about 60 days and that residual material is rich in lignin. The high levels of lignin in Bettaland compost reflects the high level of sand and wood fragments. The IFR compost (Jan 24th) has similar carbohydrate composition and

levels to peat and peat-rich growing media, indicating the retention of comparable quantities of plant cell wall structure.

- Microscopy of the composting samples showed declining structural material.
- Second windrow trials showed that weather conditions can impact on rate and nature of composting process. Leaf-supplemented BG & Straw windrows appear to compost satisfactorily.

Task 2.4: Microbiological and biochemical analysis

Aim: to measure the numbers and types of predominant micro-organisms during the composting process

Microbiological assessment

First Windrow 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 12, Figs 46-51).

Table 12: 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. 46. Numbers of aerobic mesophilic bacteria

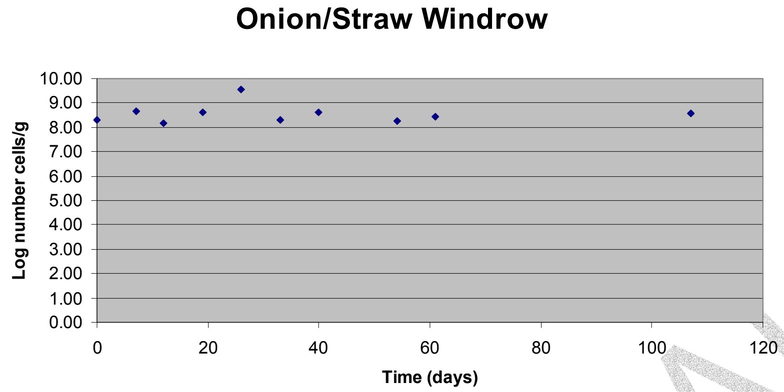


Fig. 47. Numbers of aerobic thermophilic bacteria

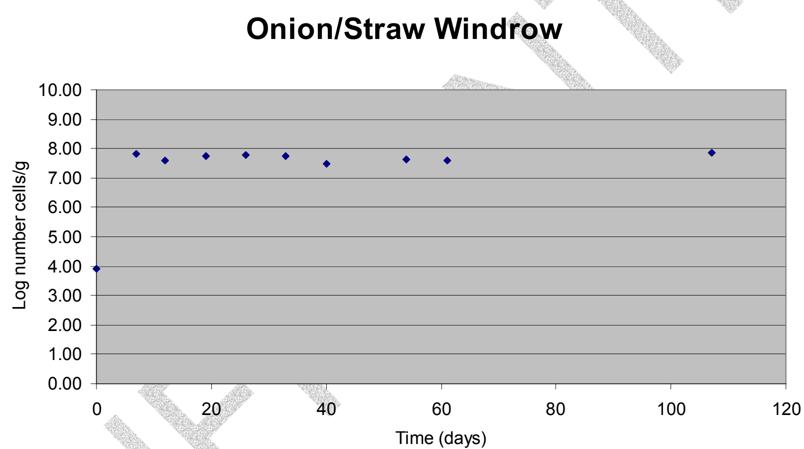


Fig. 48. Numbers of *Pseudomonas* spp.

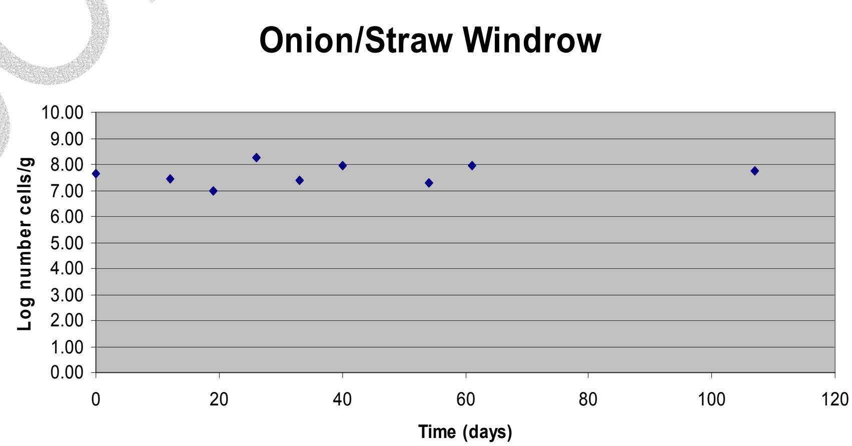


Fig. 49. Numbers of yeasts and moulds

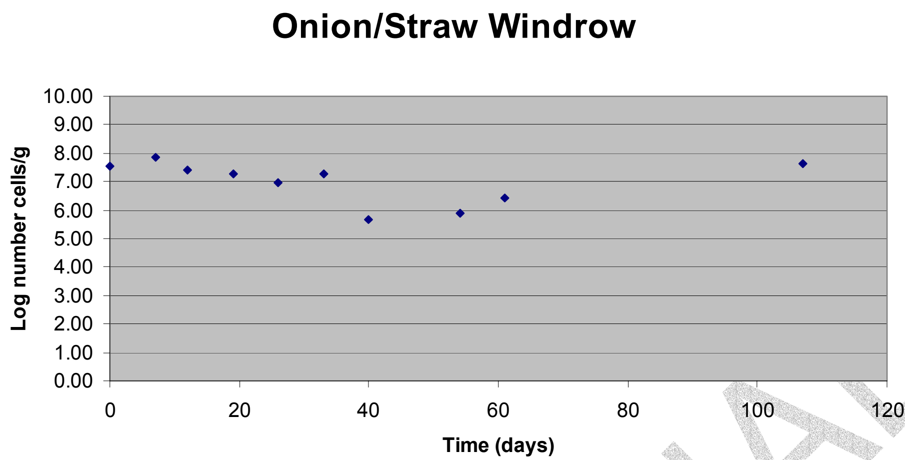


Fig. 50. Numbers of microaerophilic bacteria.

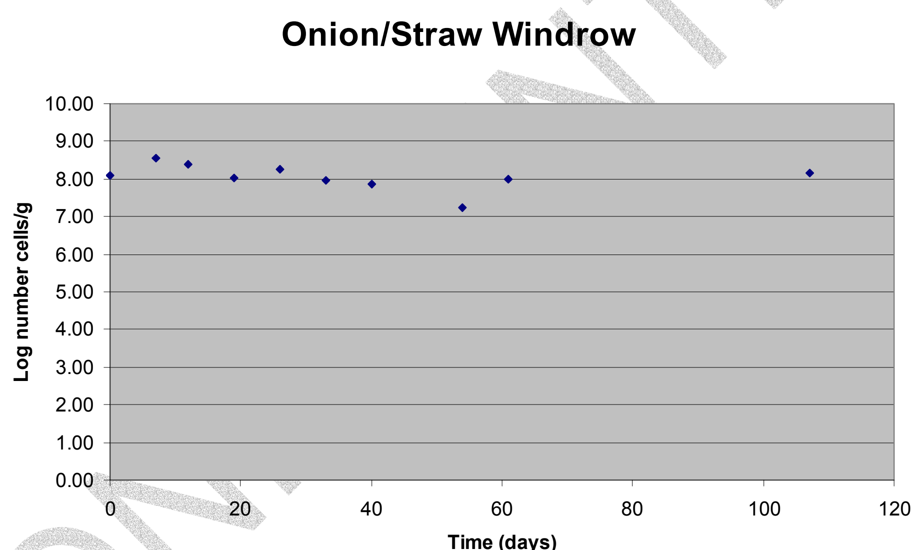
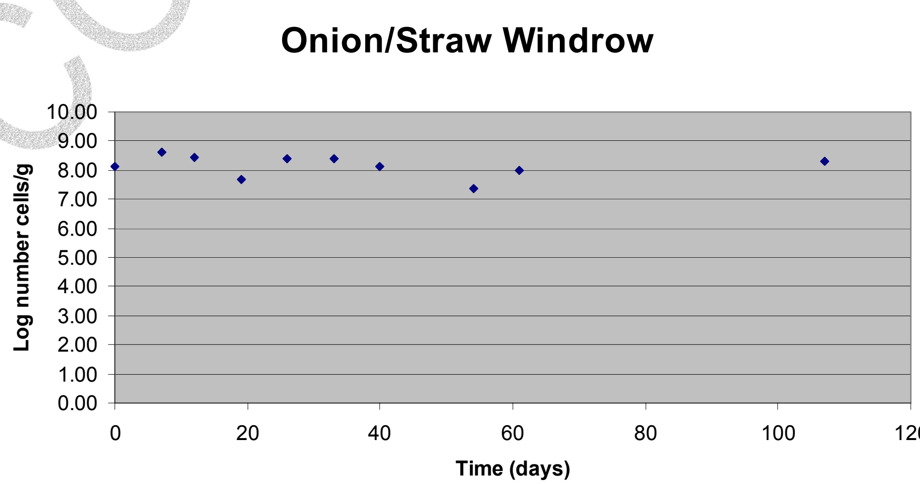


Fig. 51. Numbers of strictly aerobic mesophilic bacteria.



Further sampling

Table 13 compares the numbers of key micro-organisms 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 13.

IFR seedling trial compost harvested:	Number of viable micro-organisms ($\log_{10}$) 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 14. 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	+ coccobacill i	-	+	+	-(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/cocci 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	-	-		

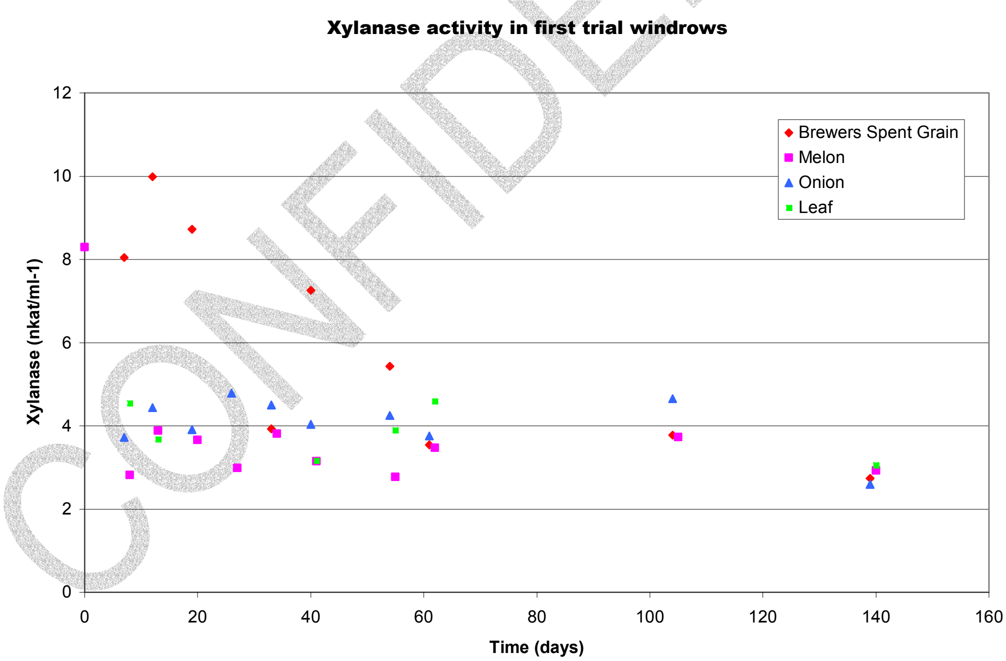
Cell-wall degrading enzymes

Measurement of xylanase activity

Hemicellulolytic (xylanase) activity was selected for measurement in samples collected at different stages of composting using standard methods.

The results obtained are shown in Fig. 52 below:

Fig. 52. 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. This is assumed to be due to the concentration of the microflora on pectinaceous substrates in the other composts. This has not been evaluated further. 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.

Conclusions from Task 2.4

- Microflora of windrows in Trial 1 were of similar numbers and types
- The population was dominated by thermophilic bacteria, predominantly Actinomycetes and a *Bacillus* – like organism (Gram +ve, spore former)
- Xylanase activity reflected the levels of hemicellulose and pectic polysaccharides as potential substrates for bacterial growth and development.

Task 2.5. Horticultural Potential.

Growing Trial 01 – Germination of Marigold Seeds

In advance of the evaluation trials by the Commercial Growers, small quantities of IFR compost (Trial 1, BG + Straw, 24th January 2005, 0-3mm fraction) 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. 53 and show no appreciable difference in germination rate and seedling growth at 30% incorporation of IFR Compost (January 2005, 0-3mm).

Fig. 53. 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.

Growing Trial 02 – Propagation of Viola Plugs

Further more detailed propagation trials were carried out at Stockbridge Technology Centre (Yorkshire), Farplant Sales (Fleurie Nursery, Chichester) and IFR (Norwich) using single colour pansy plug-plants (*Viola cornuta* sp. Ultima Supreme Yellow). The compost mixes (prepared by Bulrush Horticulture) are given in Table 15. Results are shown in Table 16.

Table 15. 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	

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.

Fig. 54. Photo of the viola trials underway at IFR Norwich.

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 16. Viola growing trial results:

IFR Norwich

Mix											Time to rooting (days)	1st flower (days)	
	Weekly Score (Foliage colour)					Weekly Score (Vigour)						50%	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

Farplant Sales

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	4.8	4.7	4.8	4.2	n.d	3.5	4.2	4.5	4.7	n.d			
2	3.5	4.4	4.2	3.7	n.d	2.9	3.7	4.2	4.6	n.d			
3	3.0	4.5	4.7	4.1	n.d	2.1	2.6	3.7	4.2	n.d			
4	4.5	4.8	4.1	3.8	n.d	3.5	4.3	4.7	4.8	n.d			
5	4.4	4.6	3.9	3.5	n.d	3.2	3.5	4.3	4.4	n.d			
6	1.8	2.2	5.0	4.3	n.d	1.6	1.9	2.0	2.4	n.d			
7	4.2	4.9	4.6	3.9	n.d	3.4	4.0	4.3	4.3	n.d			
8	3.8	3.1	2.3	2.5	n.d	2.8	2.5	3.0	3.0	n.d			

(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 17. Overall marketing scores for viola trials

Mix	Overall Marketing Score			Average Score
	IFR	Farplant Sales	Stockbridge	
1	3	3	4.4	3.5
2	3	4	4.1	3.7
3	2	2	3.3	2.4
4	3	3	3.6	3.2
5	2	4	3.3	3.1
6	2	1	1.6	1.5
7	3	1	3.4	2.5
8	1	2	1.7	1.6

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 were 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.

Growing Trial 03 – Germination of Coriander Seeds I

A separate germination trial was conducted at Swedeponic using coriander seed (*Coriandrum sativum*) 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 viola 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 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. 55. Germination of coriander seeds in compost mixes 5 & 6

Fig. 56. Relative germination of coriander seeds in all compost mixes

Fig. 57. Side-view of coriander seed trial.

Fig. 58. Weight of foliage at harvest for coriander seed trials undertaken at Swedeponic.

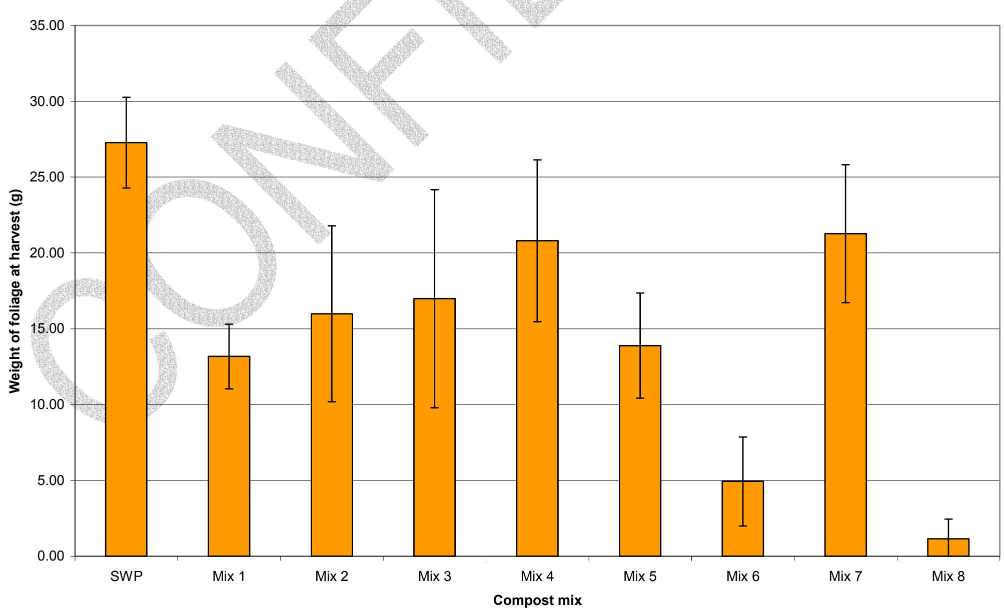
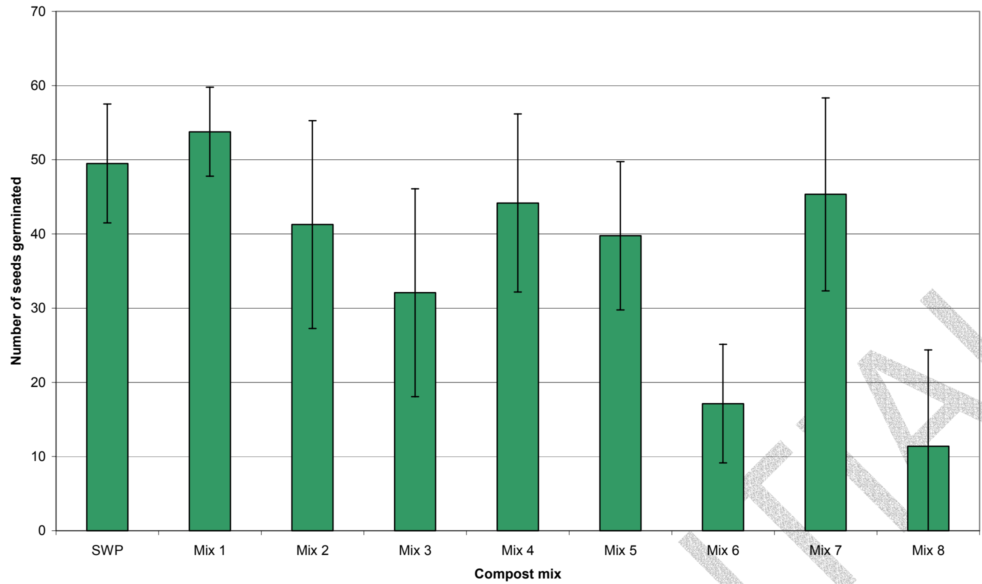


Fig. 59. Number of seeds germinated for coriander seed trials undertaken at Swedeponic.



Growing Trial 04 – Coriander and Viola germination studies in relation to conductivity of IFR compost

Further exploratory trials were carried out at IFR Norwich to examine the effect of lowering the conductivity of the compost mixes (aqueous extraction) and reducing the amount of un-degraded straw in the mix by grading on size.

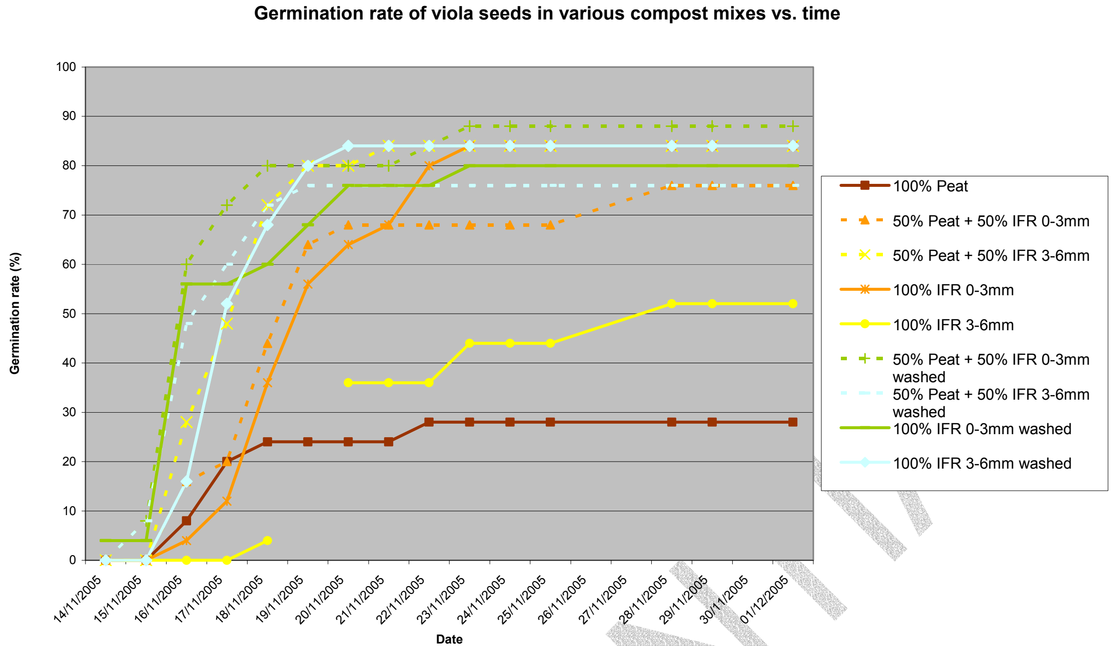
Twenty five seeds (*Viola cornuta* sp. Penny Orange Jump Up) purchased from Mole Seeds, Colchester, Essex were planted in a 3.5" pot containing each of the following mixes.

Mix 1: 100% Shamrock moss peat (commercial, non-supplemented)
Mix 2: 50% Shamrock moss peat: 50% IFR compost (0-3mm BG 06/06/05)
Mix 3: 50% Shamrock moss peat: 50% IFR compost (3-6mm BG 06/06/05)
Mix 4: 100% IFR compost (0-3mm BG 06/06/05)
Mix 5: 100% IFR compost (3-6mm BG 06/06/05)
Mix 6: 50% Shamrock moss peat: 50% IFR compost (0-3mm BG 06/06/05), reduced conductivity
Mix 7: 50% Shamrock moss peat: 50% IFR compost (3-6mm BG 06/06/05), reduced conductivity
Mix 8: 100% IFR compost (0-3mm BG 06/06/05), reduced conductivity
Mix 9: 100% IFR compost (3-6mm BG 06/06/05), reduced conductivity.

In general, the germination of the viola seedlings was much enhanced (probably optimal) through the use of reduced-conductivity compost as opposed to unwashed material. It should be noted that the mixes were not equalized prior to the design of this experiment and this may explain why peat is apparently poorer than the IFR composts.

The effect of increasing the amount of undegraded straw in the mix through using the 3 to 6 mm fraction was not clear although in this trial and the subsequent coriander trial, the 100% IFR (3-6mm unwashed) behaved poorly. We believe this is due to poor water migration to the seeds due to the large particle size in this mix, and lack of capillary action.

Fig. 60. Germination rate of viola seeds in Growing trial 04 at IFR Norwich.



Ten viola seedlings from each compost mixture were then transplanted into pots containing the same mixes for onward growing. Initial observations showed that the seedlings were more advanced in the washed mixes compared with the unwashed equivalents.

The transplanted seedlings performed well in the reduced conductivity mixes (50% peat: 50% IFR 0-3mm washed, 50% peat: 50% IFR 3-6mm washed and 100% IFR 0-3mm washed). These three mixes resulted in healthy plants all reaching flower. The seedlings died in the high conductivity mixes and also the 100% IFR 3-6mm washed sample. The failure of the IFR 3-6mm washed sample is probably due to poor water movement in the compost due to the large particle size.

A similar experiment looking at the germination of coriander seeds was undertaken. Again the germination and growth in the washed material was much superior to that in the unwashed materials.

Fig. 61. Germination rate of coriander seeds in Growing trial 04 at IFR Norwich.

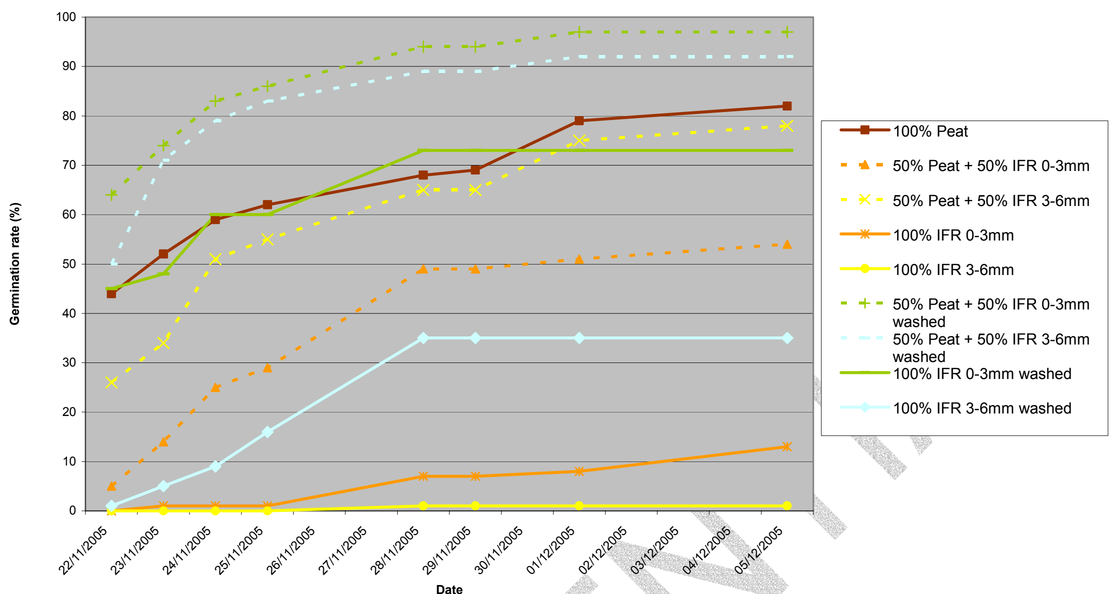


Fig. 62. Coriander seedlings in Growing trial 04 at IFR Norwich.

(a) 50% moss peat: 50% IFR 3-6mm unwashed *(b) 50% moss peat: 50% IFR 3-6mm washed*

(c) 100% IFR 0-3mm unwashed *(d) 100% IFR 0-3mm washed*

Growing Trial 05 – nursery stock trial on poppies (*Papaver orientalis*) and perennial wallflowers (*Erysimum*)

Further IFR compost (0-6mm) was prepared from the second trial windrows by mixing the following samples:

BG + LEAF 1 collected 29th September 2005
BG + LEAF 1 collected 3rd November 2005
BG + LEAF 2 collected 5th October 2005
BG + LEAF 2 collected 3rd November 2005

A total of 400 litres of material was mixed and split into two equal aliquots. One aliquot was washed twice to lower the electrical conductivity and allowed to dry.

The prepared material was sent to Bulrush Horticulture for mixing and onward transportation to Farplant Group for nursery stock trials – these trials are now underway using poppies (*Papaver orientalis*) and perennial wall flowers (*Erysimum* Apricot Delight).

The use of Toressa woodfibre and propagation grade bark as peat replacements along with IFR compost as a 50:50 mix is designed to achieve a 100% peat-free mix without the need for washing and drying. Whilst the initial IFR trials of washed material are very encouraging, it is obviously necessary to evaluate the costs of this process.

Table 18. Composition of trial mixes

Mix Code	IFR	Peat	Bark	Toresa	Washed
A	75%	25%			Y
B		100%			
C	50%		50%		N
D	50%	50%			N
E	100%				Y
F	50%			50%	N
G	100%				N
H	50%	50%			Y
I		50%		50%	
J (Nursery)		75%	25%		

Erysimum plants were potted in each of twenty 2 litre pots during week 51 (16/12/05) at Kirin Agribio Toddington Ltd (part of the Farplants Group). These were assessed for root growth and overall plant development.

Fig 63. Erysimum trials underway at Yoder Toddington (Farplants Group)

Fig 64. Side view of Erysimum trials showing relative root growth in different compost mixes

Table 19 – Initial results

Assessment	Date	A	B	C	D	E	F	G	H	I	J
Handling of Compost / Flowability 1 (lowest) to 5 (highest)	16/01/2006	3	4	3	3	3	4	2	4	4	4
Dryness (requirement for additional water) 1 (lowest) to 5 (highest)	16/01/2006	3	4	3	1	4	2	1	4	2	5
Weeks to root to side of pot	Ongoing	4	3		4	4			3	4	4
Weeks to root around base of pot	Ongoing	6	4			5			4	6	5

Fig 65. Side view of Erysimum growing trial

(a) Erysimum grown in 75% peat : 25% bark *(b) Erysimum grown in Mix E (100% IFR compost)*

The plant was removed along with the soil to assess the amount of root growth. The time taken for the roots to reach the side of the pot and the base of the pot were recorded on a weekly basis. The lack of structure / collapse of the removed soil indicated lack of root growth.

Fig 66. Papaver orientalis

In addition, poppies (*Papaver orientalis*) were potted in 1 litre pots containing the same compost mixes during week 2 (09/01/06) at Sandfield Plants Ltd, Littlehampton, West Sussex – again twenty plants were used per treatment.

The nursery stock trials are on-going and are scheduled to be re-assessed in May 2006 to enable further conclusions to be drawn on the effectiveness of the different compost mixes.

Conclusions from Task 2.5

- Propagation of viola plugs demonstrate that IFR compost, subject only to size grading, is suitable for supplementing other (peat)-based growing media up to 50% and possibly up to 75% with no adverse effects.
- Germination trials with coriander seeds have highlighted a potential problem of high conductivity in un-treated IFR compost.
- The problem of high conductivity has been successfully addressed by aqueous extraction which reduces the conductivity by 80%. Further trials (at IFR) with coriander and viola seeds have demonstrated that the lower conductivity IFR compost no longer reduces the rate and extent of seed germination and subsequent seedling growth.
- IFR compost produced from windrows (second windrow trials) has been treated for use in a full growing trial with nursery stock plants.
- Initial results are very encouraging with good root growth observed in IFR compost comparable to that seen for the standard nursery stock mix.

Overall Conclusions

The main aim of this research was 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 involved replicating plant-structure-dependent physicochemical characteristics found in high-quality growing media.

HL0172 research during the first 12 months has demonstrated:

Peat development
High quality peat results from the partial degradation (mechanism not clear) of plant cell wall material, resulting in lower carbohydrate and higher phenolic components. If degradation is prolonged, the quality of the peat is reduced (as in the lower levels).

Composting of food-processing co-products:
1) The composting process can be controllably terminated at a point where high-levels of plant structure remain in the compost
2) Microflora were of similar numbers and types across windrows, and were dominated by thermophilic bacteria, predominantly Actinomycetes and a *Bacillus*-like organism;
3) 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 which can be tailored for Grower requirements;
    c. Good water retention, similar to that in peat and considerably higher than in loams and traditional composts;
    d. Good air-filled porosity;
    e. High conductivity, which can be lowered to PAS requirements by appropriate extraction processes
4) 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. Possible nitrogen deficiency in trialled plants may result from a surfeit of insufficiently degraded straw;
5) Propagation of viola plugs demonstrate that IFR compost, subject only to size grading, is suitable for supplementing other (peat)-based growing media up to 50% and possibly up to 75% with no adverse effects.
    a. The problem of high conductivity has been successfully addressed by aqueous extraction which reduces the conductivity by 80%. Further trials (at IFR) with coriander and viola seeds have demonstrated that the lower conductivity IFR compost no longer reduces the rate and extent of seed germination and subsequent seedling growth.
    b. IFR compost produced from windrows (second windrow trials) is currently being treated for use in a full growing trial with nursery stock (poppies and perennial wallflowers). The initial results appear promising although further assessments will take place in May 2006.

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.

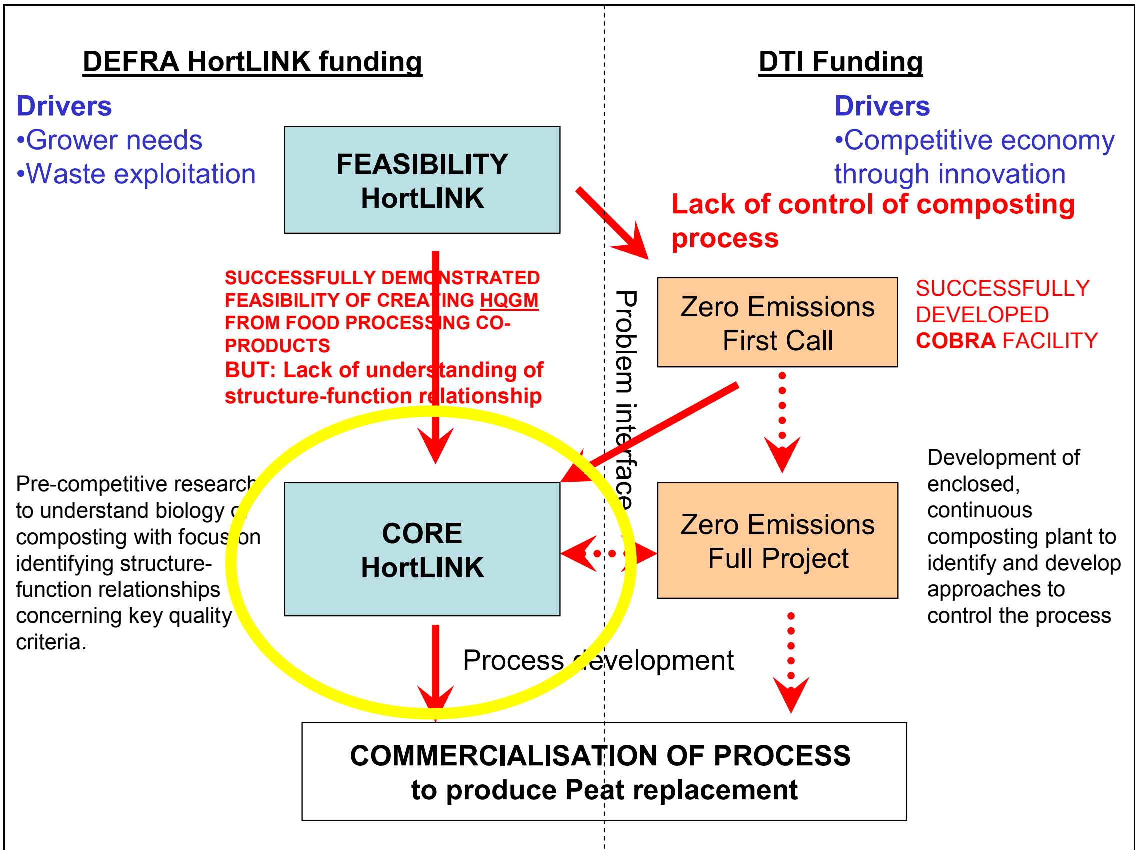
In order to develop a pragmatic understanding of growing media that can be produced through composting, it is important to

- 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 67. 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

Waldron K.W., Brocklehurst T.F., Smith A.C., Newman J., Merali Z. and Moates G.K., "Horticulture LINK 2006'" Thistle Hotel, Buckingham Palace Road, Westminster Thursday 23rd February 2006.

Abstracts submitted:

Waldron K.W., Moates G.K., Merali Z., Parker M.L., Newman J.M., Smith A.C. and Brocklehurst T.F. Producing high-quality horticultural growing media through the retention of plant structure in composted food-processing waste, Sustainability of the Agri-Food Chain 2006 EFFoST Annual Meeting / Total Food 2006, The Hague, The Netherlands, 7-9 November 2006.

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)

Membership of, and contribution to Horticultural Growing Media Forum, Royal Horticultural Society, 31st October 2005.

Glossary

Windrow	*def.* A long, low, narrow pile, such as of compost.
Water potential	*def.* The thermodynamic state of the water within a plant cell, equal to the difference in free energy per unit volume between matrically bound, pressurized, or osmotically constrained, water and that of pure water.
Electrical conductivity	*def.* The measure of a solution's ability to conduct electricity. EC units are used to express salinity levels in soil and water. When salt is dissolved in water the conductivity increases, so the more salt, the higher the EC value.
Air-filled porosity	*def.* The proportion of the volume of a growing medium which contains air, after it has been saturated and allowed to drain. Expressed in terms of percentage, AFP is a useful indicator of compost quality.
Cell wall sugars	*def.* The constituent monosaccharide sugars released upon acid hydrolysis of the plant cell wall, a semirigid, permeable structure composed of cellulose, lignin, and other substances that envelope the plant cells.
Lignin	*def.* A component of the cell walls of plants that occurs naturally, along with cellulose. Lignin is largely responsible for the strength and rigidity of plants.
Phenolics	*def.* Plant compounds (structurally characterized by an alcohol group on an aromatic ring) that impart a variety of functions to plants, including defence mechanisms and interactions with other organisms. Phenolics can also determine plant properties such as flavour and palatability.
Aerobic mesophilic bacteria	*def.* Bacteria capable of growth in air at 25°C.
Aerobic thermophilic bacteria	*def.* Bacteria capable of growth in air at 55°C.
Microaerophilic bacteria	*def.* Bacteria that can only grow in low concentrations of oxygen.
Strict anaerobic bacteria	*def.* Bacteria that can only grow in the absence of oxygen.

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