ECORECYCLE MARKET DEVELOPMENT GRANT 2000

Newsprint-Coal Mixtures as a Peat Replacement in the Horticultural Industry

Project Report March 2001

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A Collaborative Research Project between The Centre for Applied Colloid & BioColloid Science Swinburne University of Technology, Visy Industries Ltd, the CRC for International Food Manufacture and Packaging Science and Envirogreen.

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Executive Summary - Newsprint-Coal Mixtures as a Peat replacement in the Horticultural Industry

The project investigated the potential for a brown coal/newspaper based product to be used as a peat replacement for horticultural applications. The applications that were investigated in particular were its use as a casing material for the mushroom industry and as a potting mix alternative for home garden use.

A series of trials were performed to evaluate the material's ability to promote and sustain mushroom growth and to sustain growth of commonly purchased plants. Results of the mushroom trial showed that it was comparable to the commercially-used growth medium in terms of physical and chemical properties. It also resulted in a comparable, if not slightly improved, yield of mushrooms in that the size distribution of the mushroom caps was restricted (i.e. more uniform), which is desirable from a commercial perspective. Further investigation would involve larger scale trials, to evaluate the outcomes of the laboratory growth trials statistically, and to also elucidate the specific microbiological characteristics that have made peat such a successful medium for the presently used casing material.

As a gardening potting mix, the growth medium developed was able to sustain growth of a variety of garden plants, with a marked effect on growth and leaf colouring for several of the plant species tested. These results were encouraging, as the material had contained no further chemical additives, unlike the commercial potting mix that was used for comparison. Further work would require the involvement of a horticultural organization to investigate the need and effects of adding commonly used growth additives to the alternative mix.

A cost comparison between the growth medium developed in this study, and presently used growth media was not performed because of the inability to obtain relevant data pertaining to the increased scale of production of the paper-based growth medium. .

Project Background and Summary

Peat is used popularly in two main areas: as a medium for the growth and support of plants and also in the mushroom industry as a casing material. This project aimed specifically to develop a substitute casing material with the desired physical and chemical characteristics of the currently used peat based material in commercial mushroom production. An initial exploration into the material ability to support plant growth in terms of an alternative horticultural product was also conducted.

The "casing layer" refers to the soil-like layer placed upon a compost substrate rich in mycelial growth of the mushroom to be farmed commercially. It triggers and supports the growth of pins (or primordia), which develop into mushrooms during several flushes, and bursts of growth. Peat has been long been held as the ideal growth medium for use as a casing layer, however there has been much discussion as to what it is that makes peat such as good medium for mushroom growth.

There have been several ideas proposed as to the importance of the properties of peat varying from mainly acting as water reservoir to acting as a substrate for the necessary micro-organisms (or bacteria) to stimulate primordia formation. It has excellent water holding properties and allows exchange of CO_2 and air through the casing layer into the mycelial rich compost. A variety of alternative media have been trialled, ranging from natural by-products such as granulated pine bark and pumice soil to synthetic products such as rock wool (1) and recycled brown vermiculite, brick dust, slag and gypsum (2). This wide range suggests that although some bacteria may normally be vital, probably to remove metabolic by-products (3), a naturally occurring inoculum is usually sufficient. Published discussions and investigations are currently placing more importance on the physical and chemical properties rather than the microbiological aspect.

In terms of horticultural applications, peat has been used as the base for many successful products, such as peat moss and potting mixes (general and specialised), predominantly due to consumer desired properties such as "feel" and "appearance". It was therefore seen as an important aspect of this project to develop a base product possessing these intangible properties so that it could be tailored and applied to this large section of the market.

In both cases, the ongoing cost effectiveness associated with using peat as a base for a range of horticultural products is threatened due to environmental sensitivity. This is because of the damage caused through the extraction of peat from wetlands and therefore there is an uncertainty regarding continued availability of this product. This is a global issue with access to peat reserves worldwide becoming more restricted. Peat can be obtained within Australia, however it is a lower quality "sedge" peat and the quality of the mushroom yield is found to be lacking when compared to peat obtained from overseas (4). European and Canadian peat is obtained from wetlands, which are being rapidly depleted, causing environmental concerns and as a result individual countries are limiting the extent of peat mining and prices are increasing as a result. Coupled with the high associated freight charges, the increasing cost is contributing to the uncertainty with regard to the continued viability of peat as a casing layer. As such, there is real concern within the mushroom industry that peat may become too costly and at worst unavailable.

In this project, the use of recycled newsprint and Victorian brown coal, in conjunction with a base of composted green waste, was studied in order to develop an economically viable casing product that is at least equal in horticultural performance to peat based products. The role of the composted material was to act as a base to the newsprint and brown coal as well as providing a more accepted texture and appearance, important for investigations into future consumer orientated applications.

Various blends were formulated using brown coal, shredded newsprint and compost. They were then characterised in terms of their physical and chemical properties. The main aim of this project was to produce a blend that would match the most important physical properties of the peat based casing material. These properties are water holding capacity and porosity. The blends were prepared by two different methods: mixing of the three separate components by hand and also by composting the newsprint and brown coal with the green waste together to make a homogenous composted blend. Evaluation of performance of the blends was determined by the growth of *Agaricus bisporus*, the common edible mushroom, under laboratory conditions. Simple growth trials of common domestic plants were also conducted. These trials were predominantly qualitative, and the product was used without the additives commonly found in traditional peat based compost mixes.

Overall Project Objectives

To produce a horticultural product with similar appearance and feel to peat products currently in the marketplace.

To identify an alternative application for recycled newsprint and brown coal and as such an economic alternative to commercial peat horticultural products

To develop a horticultural product specifically tailored for use in the mushroom industry

Summary of Experimental Methods

Equipment

A Thermoline growth cabinet was purchased and modified to enable control and simulation of the growth conditions required for mushroom production as used on a commercial scale.

Protocols were developed in order to evaluate the growing cycle within the laboratory. Careful preparation was needed in order to avoid contamination.

Measurement and Characterisation

American Standard Testing Methods (ASTM) were used to measure physical and chemical properties and thereby characterise the blends.

The chemical properties evaluated were:

- Electrical conductivity
- pH
- carbon and nitrogen content

The physical properties evaluated were:

- air filled porosity
- bulk density
- water holding capacity
- moisture content
- organic matter (ash) content

Evaluation

Mushroom Growth Trials

Suitability of the blends for mushroom growth was evaluated using the growth of *Agaricus bisporus*, the common button mushroom.

Plant Growth Trials

An initial study was also conducted into suitability of the blends as a growth medium for some common domestic plants. Evaluation was predominantly done through visual comparison. Data was also collected to determine relative increase in height and circumference of foliage for each plant.

Experimental Procedures

Growth Cabinet Modifications

A Thermoline Temperature and Humidity Growth cabinet was purchased and installed in the laboratory at Swinburne. It enabled control of temperature between +10°C and 45°C with a humidity range of 50% relative humidity (RH) to 90% RH. Air can be circulated through the interior by fans and humidification provided by a steam generator. A watering system was installed to enable sufficient amount of water to be added to each tray of substrate and casing material.

Raw Material and Blend Characterisation

Each component used in the preparation of the blends was characterised using ASTM protocols, which were applicable to horticultural/soil products. The materials used in the various casing layers for this series of trials were:

Morwell brown coal
Newsprint (The Age, The Herald Sun, the Financial Times), shredded
Commercial peat casing (imported peat, lime and other additives)
Green waste compost (developed at The Centre for Applied Colloid & BioColloid Science)

Each of the above materials was characterised in terms of physical and chemical properties as detailed in the summary Table. The formulated blends were also tested and characterised. The methods used are attached in Appendices in the Milestone 1 and 2 reports.

Chemical and Physical Properties

The significance of the evaluated physical and chemical properties investigated is summarised below:

(i) *Bulk Density*

Bulk density is the mass of a given volume of soil or soil-like material including the pore spaces. It is an indicator of the ease of penetration of root systems through the soil. Coarse soils or substrates have a higher bulk density

(ii) *Water Holding Capacity*

The ability of the substrate to retain water is termed the water holding capability. The substrate acts a water reservoir and therefore increases availability to plants. This is especially applicable to growth of the mushroom, as it is comprised almost totally of water.

(iii) *Air-filled Porosity*

This property influences water holding capacity and aeration. Good structure, coarse texture, and the presence of organic matter increase the movement of moisture through the layer. Compaction, poor structure, high clay content and high water content decrease porosity. Texture, structure and organic matter are all determinants in the porosity of the material. The open structure enables movement of air and water, allowing the soil to drain.

(iv) *pH*

The value indicates the favourability of growing conditions. Most plants grow best in the range 7.0 - 7.5. Values below 4 and above 9 can be toxic to root systems. In acidic soil/soil-like substrates where the pH is less than 5.5, there is reduced availability of Ca^{2+}, Mg^{2+}, fixation of PO_4^{3-}, B and Mo along with increased levels of soluble Al, Mn, Zn, and Fe. In alkaline substrates there is reduced availability of B, Fe, P, Mn, Zn, Cu, and if Na^{+}, is high then Ca^{2+} and Mg^{2+} levels are also reduced. The pH of the soil can also affect the activities of the microorganisms, which then affects the levels of nitrogen, phosphorus and sulphur. Outside the near-neutral pH, the number of microorganisms and the rates of their biochemical activities decrease.

(v) Specific Electrical Conductivity

The electrical conductivity of a soil suspension is used to estimate the soluble salts in the solid. Soluble salts consist predominantly of the cations Na^{+}, Mg^{2+}, Ca^{2+} and the anions Cl^{-}, SO_4^{2-} and HCO_3^{-}. High electrical conductivities correspond to high soluble salts.

(vi) Mineral Matter (Ash content)

The amount of mineral matter is an indication of the presence or absence of any nutrients and other inorganic matter in the solid. A growth promoting substrate should supply these nutrients to meet the nutrient requirements of the plants.

(vii) Moisture Content

The moisture content determines the amount of water a solid holds at a temperature in equilibrium with the atmosphere. The importance of determining moisture content is that the water controls almost everything including: nutrient/metal movement, chemical reactions, mineral solubility, aeration, microbial movement and plant and microbial activity. It was applicable in this case in ensuring that when comparing to peat, that the starting point for each material was approximately the same.

Mushroom Trial Overview

In this series of trials, mycelial rich compost was obtained from a commercial mushroom farm. It had been conditioned, pasteurised and inoculated with *Agaricus bisporus* grain. Conditioning and pasteurisation of compost is a necessary process to ensure that nematodes, eggs, larvae, harmful fungi and spores are killed. The elevated temperatures also remove excess ammonia, which tends to retard growth of mycelium throughout the compost during spawning. Therefore this process aids in gaining a higher yield of mushrooms.

This form of the compost substrate was used in order to evaluate the alternative casing layers on a compost substrate that is proven to be successful, thereby acting as a control.

Yields of subsequent mushrooms were evaluated in terms of kg m^{-2}, number of mushrooms harvested and the diameter of the mushroom cap.

Plant Trial Overview

The raw materials were composted together (brown coal, newsprint, organic green waste) and used as a substitute growth medium. The viability of the compost as growth medium was down primarily qualitatively but also with attention paid to height and circumference growth rates by comparing directly to a basic commercial potting mix. Plants grown in this medium were those commonly found in a suburban backyard.

Experimental Results

Characterisation of Raw Materials

The brown coal used was a sample obtained from Morwell and stored in a sealed drum. It was ground and passed through a 50 mm mesh sieve. For larger quantities, the brown coal was dried to approximately 20% in a warm room (37°C) and run through a large garden shredder. The newsprint, to replicate a typical batch of recycled paper, was a mixture of The Age, the Australian and The Herald Sun newspapers and was run through an office scale paper shredder. Lengths of 15 to 20 cm with an average diameter of 4mm were obtained and used to make the blends.

Chemical and physical properties of the raw materials were measured according to standard methods and are detailed in an earlier reports (5). The chemical and physical analyses of the raw materials are summarised below in Table 1.

		Brown Coal	Newsprint	Commercial Peat Casing[1]	Organic Compost
pH (10%w/v)		5.35	4.03	7.58	7.62
Ash (dry weight) %		2.14	2.37	48.71	65.66
Specific Electrical Conductivity (mS)		0.485	1.01	2.08	
Carbon (dry weight) %		67.43	45.92	31.14	29.35
Nitrogen (dry weight) %		0.58	0.06	0.48	1.57
C:N ratio (dry weight)		116	811	65	19
Moisture @55°C		58.59	3.47	76.79	
Heavy metals ppm	Al	536	2287	429	
	As	0	0	0	
	B	2	0	0	
	Ca	2575	856	64670	
	Cd	0	0	0	
	Co	1	0	0	
	Cr	5	5	6	
	Cu	3	9	4	
	Fe	674	88	781	
	K	128	111	216	
	Mg	2015	282	11144	
	Mn	9	12	28	
	Mo	0	0	0	
	Na	1375	695	100	
	Ni	3	4	4	
	P	0	13	293	
	Pb	0	0	0	
	S	2090	224	999	
	Se	21	0	24	
	Si	51	111	357	
	Ti	26	1	5	
	Zn	4	3	7	

1. commercial casing layer material.
2. green organic waste compost.

Table 1: Chemical Properties of Raw Materials

Formulation and Characterisation of Initial Blends

Blends of brown coal and newsprint were made according to the following ratios (Table 2) and the physical and chemical properties characterised. Note that these blends do not contain the green waste compost.

	Brown Coal/Newsprint Blend Ratio				**Peat Product**
Brown Coal	80	60	40	20	N/A
Newsprint	20	40	60	80	N/A
Blend Ratio	80/20	60/40	40/60	20/80	N/A
Moisture% @55°C	54.0	47.1	39.1	26.8	77
pH (10% w/v)	5.92	5.80	5.83	5.93	7.8
Carbon (dry weight) % Nitrogen (dry weight) %	49.9 0.46	49.5 0.41	47.2 0.30	45.53 0.22	31.14 0.48
C:N ratio (dry weight)	108:1	120:1	159:1	206:1	65:1
Water Holding Capacity (%)	25.76	19.33	16.15	20.38	73.5
Air-filled Porosity (%)	23.55	57.01	56.79	65.78	5.9
Bulk Density (g mL^{-1})	0.121	0.023	0.045	0.065	0.12

Table 2: Formulation and Characterisation of Blends used in Mushroom Growth Trial

These blends were formulated according to the details in Table 3 by mixing the newsprint and brown coal initially with addition of a small amount of water and then added to the green waste compost. The moisture was adjusted to the maximum level before drainage was observed on handling the material. The pH was also adjusted to come into line with the peat-based product and to minimise risk of contamination with species such as trichoderma.

The casing layers were formulated and labeled as detailed below in Table 3.

	R01	**R02**	**R03**	**R04**	**R05**	**R06**
Green waste Compost Base (50% w/w of total)	CC	CC	CC	CC	CC	CC
Casing layer 50/50 mix (50% w/w of total)	CCA	CCA B1	CCA B2	RC B1	RC B2	CCA RC

Abbreviations:

CC – Mycelial Rich Chiquita Compost
CCA – Chiquita Casing Material (Canadian White Peat and Irish Black Peat)
RC – Organic Compost
B1 – 80%/20% Brown Coal/Newsprint Blend
B2 – 20%/80% Brown Coal/Newsprint Blend

Table 3: Formulation of Casing Material Blends for Mushroom Growth Trial.

Physical properties such as water holding capacity, porosity and density were measured to enable comparison of these properties for each blend type and to evaluate the difference between the peat based and composted based blends.

The blends were characterised and properties such as pH and moisture content adjusted prior to placing on then mushroom substrate in order to simulate the properties of the current peat product (R01) more closely.

	Casing Layer Blends					
	Peat Only	**Peat Based**		**Compost Based**		**Peat/Compost Blend**
	R01	*R02*	*R03*	*R04*	*R05*	*R06*
Moisture% @55°C	79.64	76.47	71.13	54.95	41.99	53.72
Ash (dry weight) %	54.5	81.1	80.3	76.1	67.4	57.7
Specific Electrical Conductivity (mS)	3.00	2.31	2.51	5.97	6.46	4.70
pH (10%w/v)	7.93	7.43	7.78	6.35	6.89	7.63
Lime adjusted pH				7.62	7.72	
Lime added (%w/w)				3.8%	8.0%	
Carbon (dry weight) % Nitrogen (dry weight) %	32.79 0.442	47.94 0.424	43.24 0.242	39.82 1.356	35.83 1.119	27.52 0.946
C:N ratio (dry weight)	74:1	113:1	179:1	29:1	32:1	29:1

Table 4: Chemical Properties of Blends Used in Growth Trials

	Casing Layer Blends					
	Peat Only	**Peat Based**		**Compost Based**		**Peat/Compost Blend**
	R01	*R02*	*R03*	*R04*	*R05*	*R06*
Water Holding Capacity (%)	59.13	66.19		47.18	48.36	60.38
Air-filled Porosity (%)	18.65	19.48		46.42	41.55	7.17
Bulk Density (g mL^{-1})	0.526	0.241		0.042	0.113	0.536

Table 5: Physical Properties of Blends Used in Growth Trials

Graphical Representation and Discussion

pH of Raw Materials and Casing Blends

From the graph below the pH of the peat casing and compost are both slightly alkaline. Newsprint and brown coal were slightly acidic ranging between pH 4.05 to 5.36. The pH of the newsprint was similar to the pH of several peat samples used in previous studies, suggesting that the peat casing material that we used had been modified by the addition of nutrients.

For mushroom growth, a pH of above 7.5 is desirable to inhibit growth of particular green moulds (in particular Trichoderma) and to facilitate higher mycelial growth. The pH of R04 and R05 were adjusted to bring up the pH to a more alkaline level by addition of 3.8 and 5% w/w lime respectively.

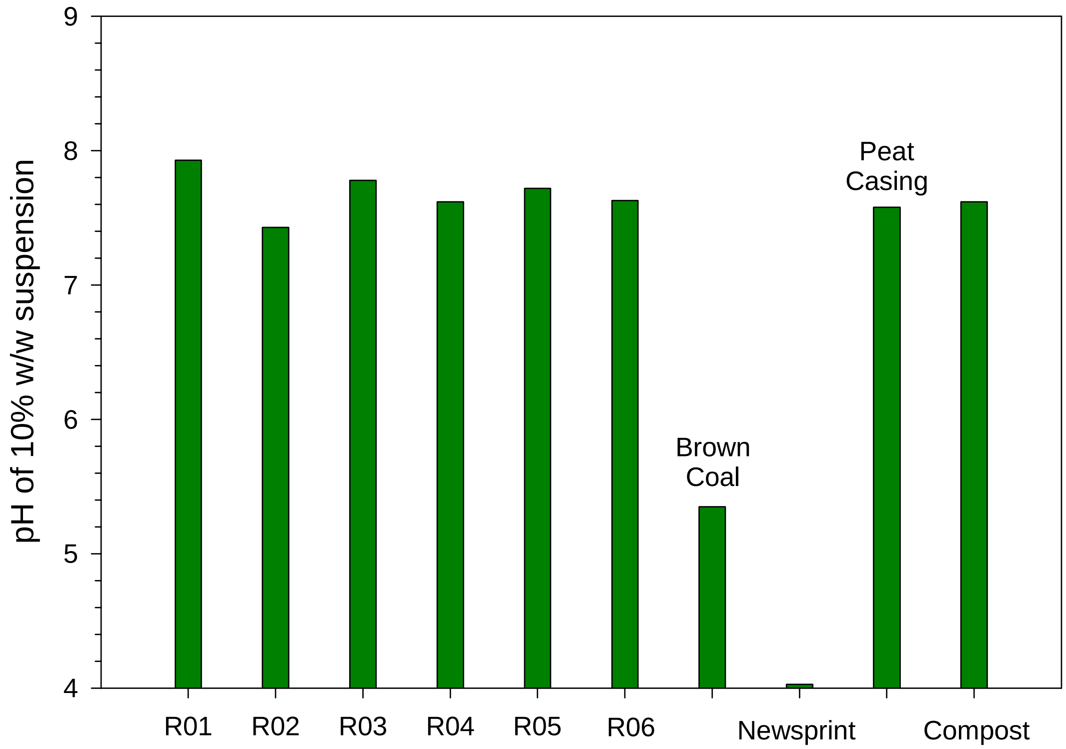


Figure 1: Final pH of Raw Materials and Blends Used in Mushroom Trial

C:N Ratios of Raw Materials and Casing Blends

The carbon:nitrogen ratio for each of the casing blends, R01 through to R06 is dependent on whether the peat casing material or organic compost was the base mixed with the brown coal/newsprint blend. The ratio of brown coal to newsprint did not have a great effect on carbon content, however the nitrogen content was halved in R03 compared to R02.

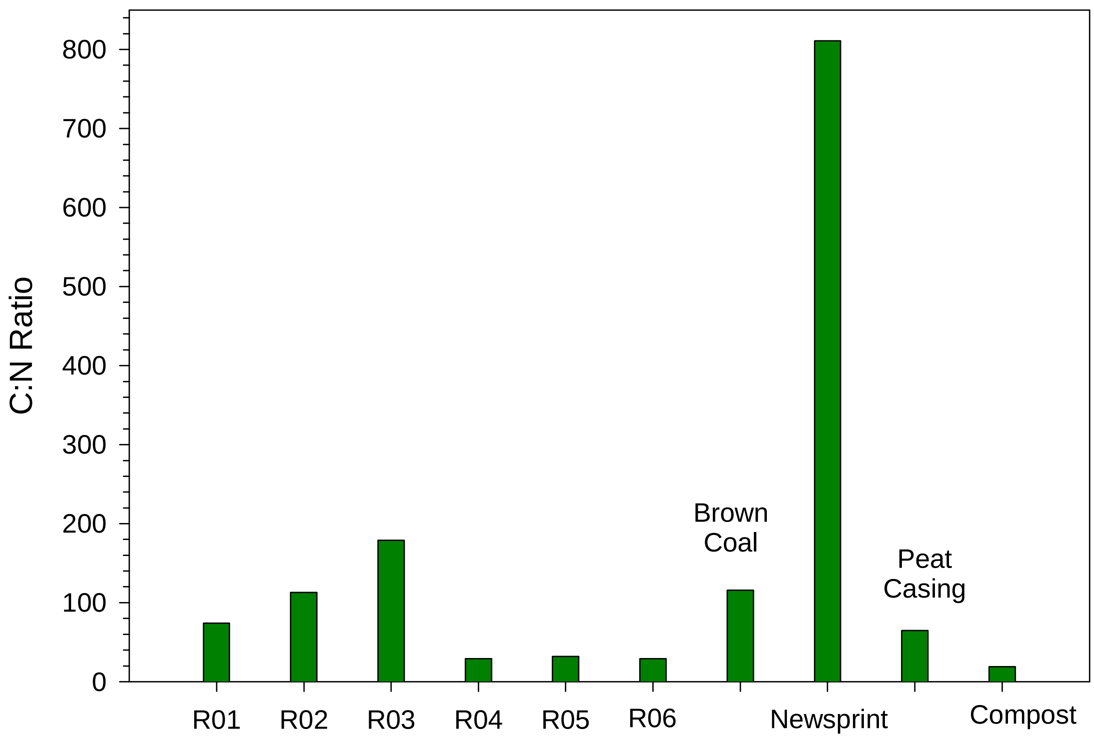


Figure 2: Carbon : Nitrogen Ratio in Raw Materials and Blends

Moisture Content of Raw Materials and Casing Blends

The Chiquita peat formulation had high moisture content (76.69%) and the moisture of the blends was adjusted to this value. However the moisture was adjusted to the point at which the blend did not lose excess water on compaction or squeezing. As the moisture content of newsprint was quite low, a significant amount of water was added to the blends with a 20/80 mix of coal and newsprint. The difference in final moisture content was a result of the variation in the level reached where water could not be held by the substrate.

Mushroom Growth Trial

Methodology

The tray consisted of the commercial mushroom farms inoculated compost. It was sampled directly from the "production line". It was then cased with the commercial peat casing used by and obtained form the farm. The casing was put on the compost once it had reached temperature in the growth cabinet.

The other casing layers were prepared and consisted of either peat or organic compost as a base and mixed with blends of brown coal and newsprint.

The general methodology of the trial was as follows:

Step 1	Phase I Composting of organic materials
Step 2	Phase II Conditioning and pasteurising for 10 days
Step 3	Inoculation of compost with spawn and trays of compost placed in growth cabinet at 25°C and 90% RH
Step 4	Evidence of extensive mycelial growth and therefore addition of casing layer.
Step 5	Pinning observed and transferred to cabinet set at 17°C and 90% RH
Step 6	Harvest of first flush over approximately 4 days
Step 7	Successive flushes harvested.

Using the mushroom farm inoculated compost enabled the trial to commence at Step 4. The growing cycle is further shown in Figure 1.

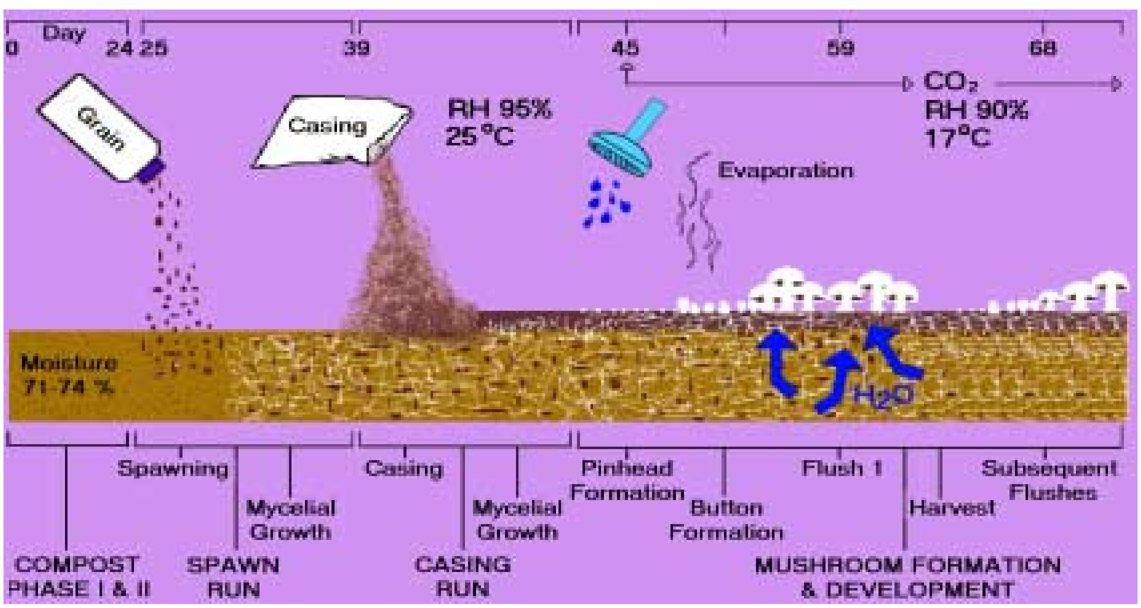
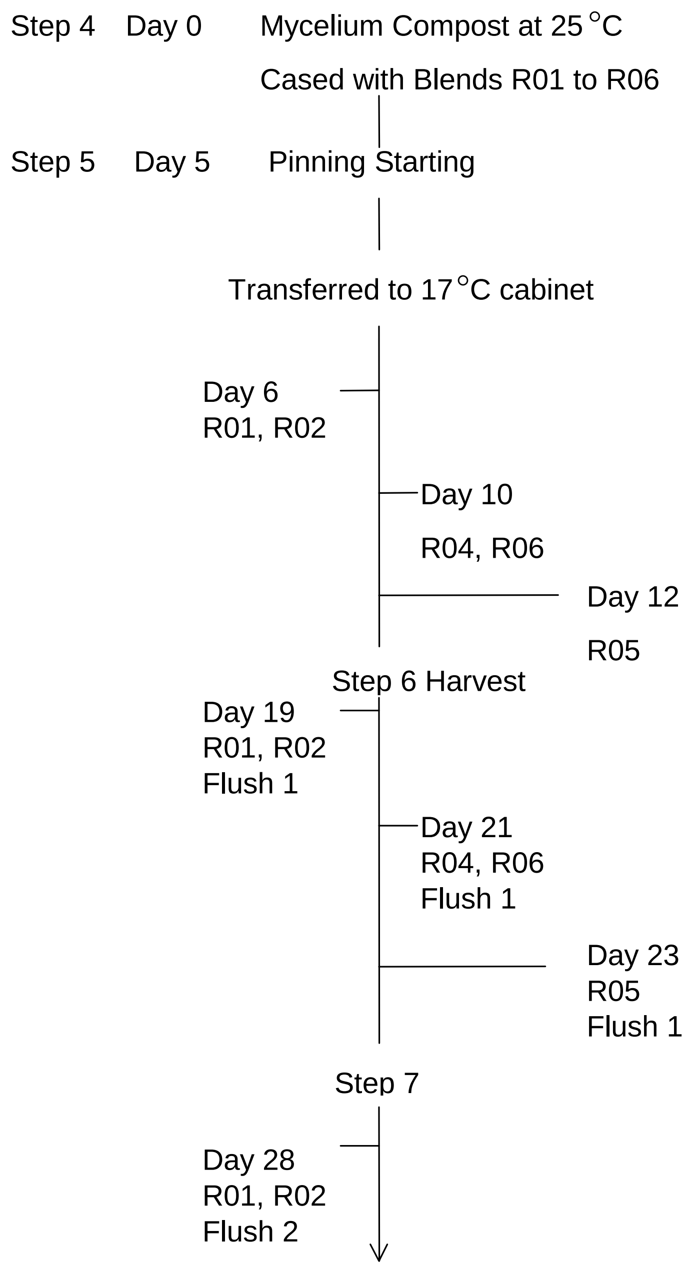


Figure 3: Growth Cycle and Methods for *Agaricus bisporus*

The following time line details when each tray containing a different casing blend attained each step. There is a major difference in the steps required in this trial due to a compost sample being obtained from a commercial mushroom farm. It had already been pasteurised and inoculated with grain and was rich in mycelial growth. Therefore the trial commenced at Step 4 with the casing layers added on signs of the mycelial network settling down after being broken up and placed in trays



Summary of Results and Discussion

A control (RO1) consisting of the commercial peat blend was used to:

(1) indicate suitability of growing conditions for mushrooms
(2) act as a base for comparison of flush yields and distribution under laboratory conditions

Distribution of Cap Diameter

For each day during the flush, mushrooms were harvested and the stem height and cap diameter measured.

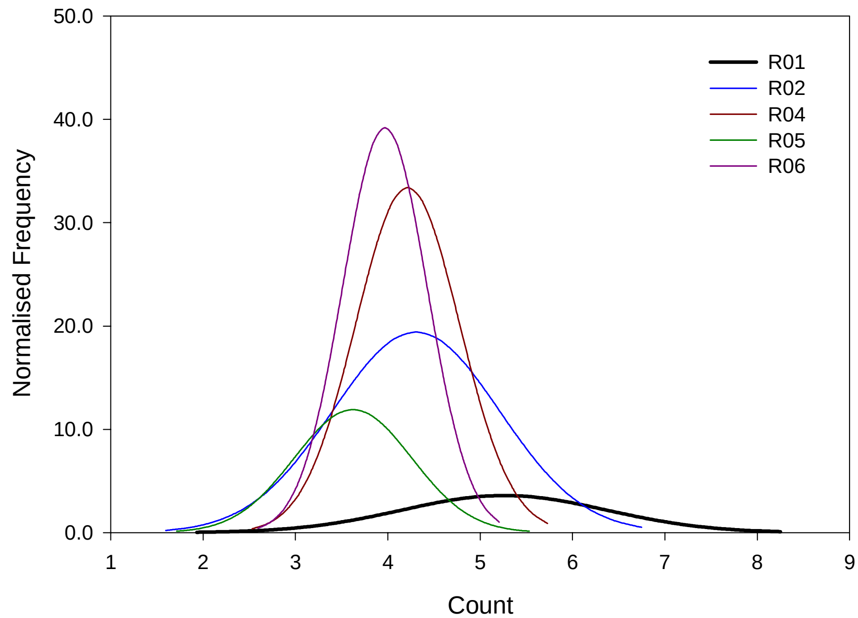


Figure 4: Normal Distribution Curve for each Casing Blend, Flush 1

R01 Flush 1

R02 Flush 1

R04 Flush 1

Figure 5: Flush 1 for three of the blends (the most important note is the uniformity of size of the caps.)

The normal distribution has been calculated for each casing blend from the harvesting results for Flush 1. This method uses the mean and standard deviation. The main outcomes were:

(i) large spread of data of for the control, R01
(ii) shift in mean diameter value across blends

Blend	Brown Coal/Newsprint	Base Material	Mean diameter (cm)
R01	0	Peat	5.26
R02	80/20	Peat	4.31
R04	80/20	Compost	4.21
R05	20/80	Compost	3.62
R06	0	Compost/peat mix	3.97

(iii) narrowing of distribution i.e. more similar size mushrooms

Summary of Results

It was found that the compost base alone had a lower water holding capacity. However by adding newsprint, the water retaining ability improved. This added the added effect of reducing density and hence openness of the structure was improved.

Addition of newsprint and brown coal to the peat base resulted in improved yields and a narrow size distribution.

For blends with the same ratio of newsprint and brown coal, a decrease in yield was observed however the size distribution was much narrower and more caps harvested at the mean value.

Plant Growth Trial Overview

In the plant trials, a composted blend of newsprint, brown coal and organic green waste was used. The materials were composted together, shredded to achieve a finer material and used to examine the viability of plants in this material compared to a basic potting mix. Therefore the main aims of the study were to determine the viability of plants grown in composted blends and to compare appearance of plants grown in composted blends to those grown in standard potting mix

The plants used were those typically found in a suburban garden: lavender, roses, azaleas, hellebores and gardenias. They were placed in 400 mm shelf watering décor tubs and routinely turned and positions rotated throughout the course of the study.

Discussion of Results

For a detailed comparison of the plants grown in both mediums, please see through the Powerpoint presentation, “Plant Trial” in CD contain in the Appendix. There are many pictures, which enable visual comparison and highlight some striking differences.

The plants were also measured for differences in growth rate in terms of height and circumference. These are also presented graphically in the presentation.

Conclusions

As the study was predominantly qualitative the observations are summarised below:

- Composted blends growth rates were comparable to that of the potting mix
- The main striking difference was the colour and size of foliage

The results highlighted that further work needs to be done to investigate the effect of adding “typical” additives to the compost blend and changes to the level of newsprint/brown coal contained in the composted blend.

Further Work and Commercial Direction

Mushroom Casing Material

The mushroom growing aspect of this project is continuing through a research project on conjunction with Chiquita Mushrooms Pty Ltd and Visy Industries. The microbiological properties of the blends are to be investigated and commercial scale trials conducted. This will enable further characterisation of the material and understanding as to how peat has been such a successful material in the industry.

Alternative Horticultural Product

Further studies are needed into using the blends as a horticultural product. The trial showed a positive outcome in that all plants did as well as the potting mix, with only slight changes in growth rates. A more comprehensive study is needed; ideally with the backing and resources of a horticulture partner to further evaluate the material.

References

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Appendix

Attached is a CD with electronic copies of the presentation given on the 24th April 2001 as well as this report.