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Horticultural Development Council

Peat

and its alternatives

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Commercial in Confidence

A Review of: Peat Reserves and Peat usage in Horticulture and alternative materials.

Contract Review on behalf of:

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Dedication:

The author wishes to dedicate this review to the memory of Chris Bunt, who for over 40 years steadfastly worked on the development of Growth mixes, Composts, Substrates, JI mixes and all aspects of raising plants in containers.

His unexpected death in July 1990, took away from us all a dear friend whom all the industry and people who met him will miss for his humility, constant enthusiasm for his work and encyclopaedic memory for details.

In what for the industry will prove changing times with regard to growth media let us try to take heed of his example, always looking for the truth and balancing the facts with reality.

NEIL BRAGG

August 1990

A Review of: Peat Reserves and Peat usage in Horticulture and alternative materials.

Special attention is given to why peat is used in the various Horticultural sectors and figures are presented as to how much peat is used by the different sectors. Some sectors are identified where the continued use of peat is considered essential.

Priorities for future developments/evaluations are highlighted, with particular reference to those alternatives existing in the UK.

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Edited by John Williams, ADAS Publications.

SUMMARY

This review identifies the origins of peat, the reserves of peat in the UK (1.5 million ha) and the area currently owned by the Peat Producers Association (8,000 ha). The review estimates that the likely life of these reserves at current usage levels would be between 40-50 years, even if no new extraction licences were granted in the UK. The currently owned reserves (8,000 ha) are also set in the context of world resources of peat, which are variously estimated in excess of 400 million ha.

An attempt is also made to look at the rate of peat regeneration compared to loss, and to address the problems of carbon dioxide (CO_2) generation from the drainage of peatlands.

The review then identifies the current annual use of peat (and other substrates) by the various sectors of horticulture. It shows that horticultural use of peat by amateurs accounts for at least one half of all UK current peat usage. 'Professional horticulture' uses between one third and one half and use by the landscape industry accounts for the balance of all the peat used in the UK.

Known alternatives to peat, either as additives or diluents or total replacements for peat are examined. Each material is reviewed in terms of its source, availability, chemical, physical and microbiological properties. The current use in horticulture and the evaluation and development of the alternatives is considered. Of the potential alternatives the following are considered worthy of development; wood wastes, arable wastes (including straw), municipal

composted waste and animal and human excreta.

Finally certain sectors of horticulture, e.g. soil conditioning and mulching, are identified as areas where immediate replacement of peat is both desirable and essential if peat wastage is to be avoided.

CONTENTS

SECTION 1 INTRODUCTION

Previous changes in the materials used as growth substrates have generally been borne out of necessity. The change to the 'John Innes' (JI) range of mixes resulted from enormous variation in home-made mixes. JI was a move to set clear standards and achieved very good results (Bunt 1988). But there were shortcomings with JI mixes: variable loam sources, the unpredictable nature of fertiliser release. Commercially the shortcomings of JI mixes could have been tolerated but the final problem was their weight per unit volume when compared to peat-based substrates (Bunt 1988). The move towards peat as the major constituent of substrate was a development from JI mixes to give more control in growing plants, and lighter mixes.

The development above spans at least 40 years. Although key dates could be identified, the development and refinement of products has been gradual as the understanding of peats has expanded and particular requirements of plant species have been elucidated.

Therefore in writing this review I have been conscious that, whilst we are probably at a significant point in substrate development, (with more recycling, use of previously shunned materials, and environmental issues clamouring for attention), much work lies ahead to develop any one material and to establish its long term suitability for use as a sustainable alternative to the substrates currently used.

Methodology used in preparing the Review.

1) Consultation with ADAS National Specialists on the use of peat and other materials in the various horticultural sectors. The various specialists supplied census data and also any other figures relating to the professional use of substrates.

2) Consultation outside ADAS with: peat producers, substrate and compost manufacturers, trade representatives and persons associated with allied industries.

3) Visits and discussions to research institutes and stations - to observe work being undertaken in 1990 or to discuss proposed work on materials which might be replacements for peat.

4) Literature reviews.

5) Chemical, physical and microbiological examination, using standard MAFF procedures for many of the materials suggested as alternatives to peat.

6) Consultation with various overseas workers to clarify the position over the use of peat and alternatives in other countries.

7) Consultation with M/S S Pryce, Manchester University to exchange technical information, particularly with reference to the landscape/ amenity sectors.

SECTION 2

PEAT ORIGINS

Peat is a very poorly defined material within the horticultural market place. Whilst various work as long ago as 1924 (Von Post) took care to define both the degree of decomposition and the species composition, many people currently using and describing peat think of it as all of a similar nature, i.e. 'peat' has become a generic term.

Peat, in generic terms, is formed when plant material dies and accumulates in stagnant or slowly moving water. Rapid use of available oxygen prevents normal aerobic decomposition and gradually plant debris accumulates (Godwin 1979). However the processes of stabilisation of the organic carbon sources within peat is not well understood, although it is clear that when peat is extracted there is not the breakdown of carbon normally expected with fresh organic matter sources. (Robinson & Lamb 1975).

- The species of plants forming the initial peat layer tend to be fen type plants, i.e. sedges and reeds (*Carex* and *Phragmites* spp.). Beyond this initial phase, the type of long term deposit depends on rainfall, the geographical position of the site and the drainage into the site by major rivers which themselves may be nutrient rich (Godwin 1979).

- If the drainage from surrounding high ground does exceed rainfall and the water entering the site is nutrient rich, this will encourage further growth of species such as *Phragmites* and *Cladium*. If the site later dries due to non-sustainable water levels, then natural woody species such as alder, birch, and willow (*Alnus*, *Betula* and *Salix* spp.), known collectively as 'Carr vegetation', will increasingly dominate the site.

- Where rainfall remains dominant, growth of mosses, such as *Hypnum* and *Sphagnum* spp. is encouraged. *Sphagnum* spp. show the unique ability to grow upon themselves, such that eventually the centre of the moss may well be raised above the lips of the original basin. This gives rise to the term 'Raised-bog'. The moss may be likened to a terrestrial sponge in as much as it grows upon itself and requires little mineral nutrition (which generally can be obtained from incidental rainfall). A much more detailed account can be found in Godwin 1979, 1981.

It is apparent then that even within England and Wales it is possible to have a range of peat types of differing botanical composition and, more importantly, peats of different ages (depending on their position within a vertical section through the bog). Consequently any lowland bog may yield:

- Very young sphagnum peats;
- Peats with mixes of grasses and heath type vegetation;
- Pure sedge peats;
- Sedge peats adulterated with woody species.

In lowland England and Wales sites in the wetter Northwest have been dominated by sphagnum moss development over and above the original sedge peat types. Further east and south the fen peats have remained dominant. The Southwest shows mixtures of raised bog and lowland bogs (Godwin 1981).

Even within the wetter climate conditions of the West the drier margins of the mosses do allow species such as myrtle to establish eventually; gradually

'Carr vegetation', Alnus sp. Calluna sp. and Betula sp. scrub may develop. During the climatic sequences over the last 10,000 years there have been drier periods where Carr vegetation may have been dominant over a larger area of the moss surface.

Table 1 summarises climatic changes that have taken place in the last 10-12,000 years.

Table 1. Chronology, post-glacial climate and sediment type for Western Europe.

Years before present time	Climate	Period	Sediment Type
12,000	Cold Mild Cool	Late-glacial	Clay Limnic/Telmatic (aquatic/ semi-aquatic) Clay
10,300	Temperature rising	Pre-boreal	Limnic (aquatic)
9,600	Warm-dry	Early boreal	Limnic/Telmatic (aquatic/ semi-aquatic)
8,000	Climatic optimum	Late boreal	Terrestrial
7,500	Warm-wet	Atlantic	Mainly ombrogenous terrestrial
5,100	Warm but rather dry	Sub-boreal	Mainly ombrogenous terrestrial
2,500	Increasing wetness and falling temperature	Sub-atlantic	Mainly ombrogenous terrestrial

After Robinson and Lamb 1975
Sub section Hammond

In upland areas of England and Wales the development of bogs is possible on shallower slopes and in hollows on plateaux. Godwin (1981) indicated that in extreme maritime conditions (West Coast of Ireland) blanket bogs could be found on isolated rocky out-crops. The upland bogs are generally thinner and are dominated by mixtures of mosses such as Sphagnum, Hypnum spp., by grasses such as Eriophnum sp. (cotton grass), Trichophorum sp.(deer grass), Molinia sp. and by Erica tetralix. In this case the peats are more greasy than the pure sphagnum of the lowland raised mosses due to the roots of the grasses and heather.

PEAT FORMATION

There is really no reason to expect that peats worldwide will be different to those in the UK, as conditions favourable to their development will be similar. The only difference which might reasonably be encountered is due to continental type climates giving rise to large areas of similar peat types, e.g. the large reserves of young sphagnum moss peats such as occur in Russia and Finland, which together account for 70 per cent of the world's reserves (Robinson and Lamb 1975).

In the Republic of Ireland there is a more maritime climate than in most of the UK, and this is reflected in the very large areas of sphagnum raised-bogs formed on both the west coast and in the central plateau region.

Rate of Growth and Regeneration

The rate of growth of raised moss is uncertain, other than the estimate that between 1 and 10 metres of peat have been produced during the last 10,000 years - the period since the retreat of the last major UK ice incursion; the exact time period may obviously be longer when viewed in relation to the lack of ice incursions in the Republic of Ireland (See Table 1).

Importantly, since the ice retreat even the UK has experienced variable climatic fluctuations, including such periods when 'Savanna' conditions were experienced and also conditions which were almost certainly wetter and cooler.

Categoric statements on the rate of peat regeneration are difficult. Work in Germany, specifically at the Peat Research Institute at Bad Zwischenahn

(Gunther et al, 1986), suggests a growth potential of 1 mm per year. However this is somewhat generous, as, if it were true, 10 metres of peat would have accumulated over 10,000 years in all peat-forming areas. Few of our moss peats were in fact 10 metres in depth before working, although it is possible that erosion has taken place in the 10,000 year period, particularly during drier periods, when the moss surface would crack and break up (See Table 1).

Realistically a rate of regeneration between 0.5 and 1 mm per year can be anticipated, assuming that climatic and environmental factors (rainfall, ground-water quality and atmospheric pollution/deposition) do not reduce this potential. For example, in upland areas where attempts have been made to limit the effects of acid rain by the use of lime, the secondary effect has been to kill out or severely reduce the growth and regeneration of sphagnum type mosses on UK blanket bogs. Therefore according to several reports in New Scientist in 1990 attempts to ameliorate acid rain to prevent deforestation, may actually harm long term moss growth.

In certain areas of lowland England and Wales where statutory documents exist for dealing with peat mosses and their use after extraction, assumptions about regeneration have been made with no reference whatsoever to ground water quality (Anon 1987, The Mossland Strategy). Nitrate and phosphate levels collecting in the basins as a result of run-off from domestic/industrial and agricultural uses will probably mean that anticipated regeneration will be severely limited (Gunther et al 1986).

Rate of Decomposition of Peat

Peat, as described earlier, is the accumulation of organic debris: an accumulation always associated with very wet conditions and occurring where aerobic processes of decomposition are prevented. The result is the partial decomposition under anaerobic conditions and then stabilization of the remaining organic matter. Drainage and lowering of ground water allow the re-establishment of aerobic conditions and further decomposition of the plant remains can then take place. However, it is apparently by no means as rapid as would be expected if the original fresh material had been allowed to aerobically decompose.

A paper by Waksman and Purvis (1932) deals specifically with the influence of moisture upon the decomposition of peat. Figures are presented showing that the rate of evolution of carbon dioxide depends on moisture content. The work shows quite clearly that CO_2 evolution is at its highest between 53-71 per cent moisture, below 50 and above 80 per cent decomposition is severely arrested.

Table 2. Decomposition of Lowmoor Peat

Moisture Content	Wt of Original Peat*	Incubation	Carbon Dioxide Liberation
(per cent)	(g)	(days)	(mg C)
78	100	54	81.0
55	100	54	196.2
40	100	54	89.0
28	100	54	29.4

* moisture content of original peat 78 per cent

After Waksman and Purvis (1932).

From Table 2 it is clear that drainage and surface milling of peat lead to considerable evolution of carbon dioxide (CO_2) very quickly as the moisture content of the bog is lowered from saturation to 70-80 per cent by volume. The figures in Table 2 for the influence of moisture content on decomposition rate are substantiated by Handrick and Black (1986). Handrick and Black suggest for most composting operations, approximately 60 per cent of the carbon lost is converted to CO_2. Therefore, whilst peat bog drainage and extraction leads to CO_2 generation, so will all composting operations. More work is needed to calculate the precise CO_2 loads from different composting processes using different ingredients. It should, however, be noted that the loss of CO_2 from a cut or milled peat bog is considered a release of fossil CO_2, whilst composting of renewable crop residues is providing no net increase in the current atmospheric CO_2 levels.

Various estimates have been made as to the world's resources of peat. A figure of 150 million hectares was quoted in the 1970s (Robinson and Lamb 1975). More recently figures in excess of 400 million hectares of peat-land have been given (see Table 3); this accounts for approximately 8 per cent of the earth's surface (Bunt 1988, Kivinen and Pakavinen 1980, Anon 1990).

Table 3 Peat Areas and Production

Country	Area of Peatland (million ha)		Peat Production[c] (1000 tonnes/year; 40% moisture)	
	(a)	(b)	Horticulture	Fuel
Canada	170	150	400	-
USSR	150	170	100,000	100,000
			USSR figures are not reliable, see p. 27.	
Finland	10.4	10	220	1,500
USA (-Alaska)				
(+Alaska)	10.25	60	700	-
Indonesia	-	25	-	-
Sweden	7	7	300	-
China	-	4	-	-
Norway	3	3	90	-
Malaysia	-	2.5	-	-
UK	1.58	1.5	500	50
Brazilia	-	1.5	-	-
Poland	1.35	1.3	340	-
Uganda	-	1.4	-	-
Ireland	1.18	1.2	450	6,000
Germany	1.11		250	2,000
Total	438		103,250*	109,550
Secondary Total**			13,250*	

source: after Bunt 1988

\- not reported

a Kivinen & Pakavinen 1980. Peatland areas and the proportion of virgin Peatlands in different countries. Proceedings 6th Int. Peat Congress, 52-4.

b Anon 1990, Pers Comm, A C Bunt

c Kivinen, E 1981. Utilisation of Peatlands in some countries. Int. Peat Soc. Bull. 12, 21-30.

* Assuming Volume of 2.5 litre/kg,
then 103,250,000 tonnes = 258 million m^3
13,250,000 tonnes=33 million m^3.

** Secondary total substituting 10,000 tonnes, (for The Russian production.)

Figures in Table 3 indicate that UK accounts for just over 0.4 per cent of the 400 million hectares. This is taken to equate to 1.6 million hectares of peat (See figures below).

Table 4 Estimates of peat in UK

Source of Estimate	Area (hectares)
Fraser (1948-49)	1,618,743
Moore/Bellamy (1978)	1,581,841
Kivinen et al (1980)	1,500,000
Fisons (Quote in Grower May 31 st 1990)	1,619,433
Peat Producers Association (1990)	1,619,433
Peat Report (Anon 1989)	1,500,000
FoE (1990)	1,500,000

An estimate of around 1.6 million hectares which Bellamy had in 1978 appears reliable. This UK total is further sub-divided in Table 5.

PEAT USE IN THE UNITED KINGDOM
AREA OF PEAT RESERVES

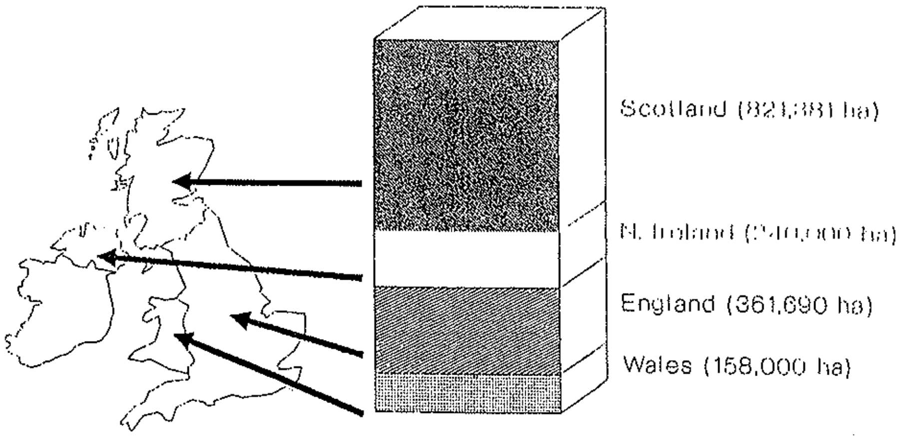


FIGURE 1

Table 5 Peat Distribution in the UK

Country	Area of Peatland (ha)	% of land surface
Scotland	821,380	10.7
England	361,690	2.8
N. Ireland	240,000	17.8
Wales	158,000	7.5
	1,581,840	6.6

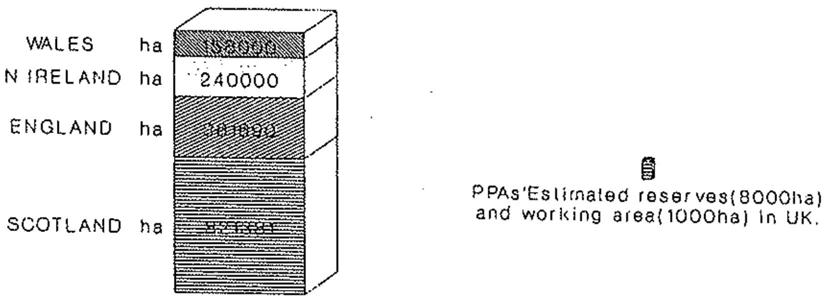
Source: Robertson and Jowsey (1968).

For England and Wales the most reliable recent data are from the Soil Survey (Burton and Hodgson 1987) who quote for peatlands below 200 metres O.D.* a figure of 103,122 hectares. This represents 19.8 per cent of the total peatlands in England and Wales (Table 5).

For Scotland the most recent estimate of the reserves are 830,000 hectares (Dalyell 1990); while earlier estimates only put the figure at 738,147 ha Fraser (1948-49) and 821,400 ha in Peatland (Anon 1973). A further sub-division of Scottish reserves is given in Table 6.

* O.D. = Ordnance Datum

PEAT RESERVES IN THE UNITED KINGDOM and PPAs' ESTIMATED WORKING AREA.



Area of peat reserves in UK.

FIGURE 2

Table 6 Peat Distribution in Scotland

Region	Area of Peatland (ha)
N.W. Highlands	540,148
Central/S./W. Highlands	87,389
N.E. Region	29,200
Midland Valley	79,693
Southern Uplands	84,951
TOTAL	821,381

Source: Robertson (1971).

The remainder of the UK i.e. N. Ireland accounts for 240,000 ha (Table 5). This is near to the 242,915 ha given earlier by N. Ireland Peat Bog Survey (Anon 1952).

In The Republic of Ireland, the area of peat is estimated in excess of 1 million hectares (1,217,295 ha, Frazer 1948-49). However this figure is refined by Bord na Mona who suggest that only 1 per cent is 'horticultural peat', i.e. about 12,000 hectares.

Peat Areas Worked in UK

The Peat Producers Association in the UK estimate that they occupy and/or extract from 0.5 per cent of the estimated 1.6 million hectares of peat reserves, i.e. 8,000 hectares. This is equivalent to 0.002 per cent of world peat reserves. Various reports in 1990 seem to agree that the 8,000 hectares is a reliable estimate of workings.

The author can find no available figures for the amount of peat which is actually being worked in Scotland, although it is estimated that there are only 10,000 hectares of the 821,380 hectares in Scotland which are fit for development. By the term 'development' the author assumes it to mean peat extraction.

It is worth noting two rather contradictory statements to the above figures. One was quoted by Pritchard (May 1990), when he suggested that only 9,500 hectares of peat were left in the UK: the other was in the ENDS Report, (No. 183, April 1990) where the figure of 10,000 hectares is quoted as the area of remaining peat. The author suspects in both cases these reports are referring to the areas of peat being worked as neither relate to the amounts calculated and accurately surveyed by the Soil Survey. Therefore the author can only suggest that the figures quoted by ENDS and RSPB must be considered unreliable or incorrectly assigned or both. (Following discussion with an RSNC representative (late August 1990) the author was informed that the RSPB and ENDS figures referred to areas considered as 'Conservation Grade Bogs'. However an actual definition of the term 'Conservation Grade Bog' was not available. It can only be assumed that conservation grade bog includes, for example, the 4,000 ha of peat referred to by Soil Survey (1987) as being 'unworked', raised bog, sphagnum peat. But this terminology also includes bogs which are lowland fen types, little altered by change and/or extraction and possibly includes peat areas currently under alternative management, i.e. Somerset summer grazing areas with 'wet-fences' which have their own particular qualities from a conservation point of view).

Peat Resources (A Summary)

- The author believes that in England and Wales, of the 103,122 ha identified by Soil Survey (1987) as peat below 200 m O.D., 10-12,000 ha are potentially of use to horticulture. In Scotland there are probably 10,000 ha of useful peat which could be made available. In N. Ireland, only total peat area is known to the author - not the area extractable.

  In the Republic of Ireland, there are 12,000 ha, suitable and potentially available.

Rate of Loss of Resource in UK

The author wishes to stress that he assumes that the 8,000 ha of peatlands occupied by the peat producers includes areas which have been almost fully exploited, those currently being worked, those drained prior to use and those held in reserve. The author believes that only 1,000 hectares are being worked for the following reasons.

UK currently uses an estimated average 2.7 million m^3 of horticultural peat (see p 26).

UK currently imports approximately 1-1.2 million m^3 of peat, (the figure varies depending on the success of our own peat harvest).

Therefore we have to produce at least 1.5million m^3 from 8,000 ha,

$$= 18.75 \text{ litres/m}^2 \text{ to give } 1.5 \text{ million m}^3$$
$$= 18.75 \text{ mm/m}^2\text{/year from } 8{,}000 \text{ ha.}$$

However colleagues in Northern Ireland report that a peat producer would expect to work or cut 150 mm/year. Herlihy (1973) reports the same figure (150 mm/year) for the Republic of Ireland. To produce 1.5 million m^3 at a cut rate of 150 mm/year you would only actually need 1,000 ha of worked surface (or in global terms 0.00025 per cent of world reserve).

Assuming the latter paragraph to be correct and, assuming that for economic reasons at least 2 metres of peat is needed per hectare to make an operation economically viable , then the current peat area being worked, i.e. 1,000 ha , if it were all 2 m deep would last 13 years if peat usage stayed at

2.7 million m^3/year with a continuing 1-1.2 million m^3 being imported. Obviously peat extraction is a shifting operation, in as much that some resources will be almost exhausted whilst others will have more than 2 metres and only just becoming 'ripe' for working.

From this however it is obvious that if the current retail market for peat declined, or if increases were made in the imports from, for example Russia, then our existing committed peat reserves (8,000 ha) would last to sometime approaching the middle of the next century.

Therefore figures which quote anything in the order of 10 or less years before exhaustion of UK peat reserves can only be taken as misleading.

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SECTION 3

CURRENT UK USE OF PEAT IN HORTICULTURE

Advantages of peat

Horticultural peat usage in the UK has developed over a 40 year period, peat has replaced previously favoured, loam (soil) - based growth substrates. In the 40 year period, peat has been evaluated under different growing conditions and management regimes. The ways in which peat is used have expanded with the increased movement of 'finished plant' material and marketing by large retail outlets, although many sectors now use less peat per plant than hitherto.

The advantages of peat as a major constituent of substrates are seen as follows:

1) Excellent air/water relationships,

2) Slow rate of decomposition when used in containers,

3) Generally pathogen (plant and human) free,

4) Dark brown colour,

5) Low pH and nutrient content allow easy adjustment for all crops.

At the time of writing, evaluation of primary peat-based products is still continuing. Therefore in subsequent sections, when considering possible alternatives, the reader should be aware that the use of alternatives to peat will only occur after sound development work in which products are fully assessed.

The current estimated, total, UK usage of horticultural peat (by both professionals and amateurs) is 2.3-3.2 million cubic metres. This compares with 2.0 million cubic metres used 10 years ago (Cull 1981).

The current figure is derived from a variety of sources although it may be somewhat difficult to substantiate because of the vague nature of some areas of the trade.

Table 7 Comparison of UK use with other countries

Country	Peat used in horticulture (million m^3)
UK	2.7
Holland[1]	2.0
USA[2]	3.75
Germany[3]	11.5
Belgium[4]	0.55
Denmark[5]	0.60

Source 1 Schie (1990) RHP Handbook

2 Cantrell 1988 Peat Minerals Yearbook (Note: according to the US figures 2/3rds of this peat is used in general soil conditioning.

3 Pers Comm. (1990) G Schmilewski. Germany.

4 Pers Comm. (1990) R Gabriels. Belgium.

5 Pers Comm. (1990) J Hayes. Denmark.

From Table 7 it is evident that only 20.90 million m^3 of peat are used by six major countries. The author would therefore strongly suggest that the Russian extraction figures included in Table 3 are gross over-estimates of their hortiucltural production. (A similar estimated figure is given in the 'Peat Minerals Yearbook 1988' with no explanation). In Table 3, world peat production for horticulture is guessed conservatively at 33 million m^3.

Table 8 Peat use in UK per annum on major user basis

User	Amount (million m^3)
Retail horticulture	0.8-1.2
Amenity/landscape	0.5
Professional horticulture	1.0-1.5

Retail Use of Horticultural Peat in the UK

Use of horticultural peat by the amateur/retail market is estimated to have a current value of £63 million (Which?, June 1990a, Retail Horticulture, Sept. 1990b). If a figure of £5.00 per 100 litres of product is assumed, retail sales account for the use of 1.2 million cubic metres of peat per annum.

Horticultural Trade Association (HTA) figures suggest 0.3 million tonnes of peat are sold in retail horticulture which, if based on a density figure of 0.4 g/litre = 750,000 m^3. However other figures used by HTA suggest that the density figure they use is nearer 0.285 g/litre: therefore 0.3 million tonnes = 1.05 million m^3. The author concludes that the retail horticultural market totals between 0.75 and 1.2 million m^3 of peat per annum.

Amenity/Landscape Use

Use of peat in amenity/landscape horticulture is uncertain. It is estimated to be 500,000 m^3 per annum, although some peat products such as mushroom compost with its associated peat 'casing' are recycled.

USE OF PEAT BY VARIOUS SECTORS OF PROFESSIONAL HORTICULTURE

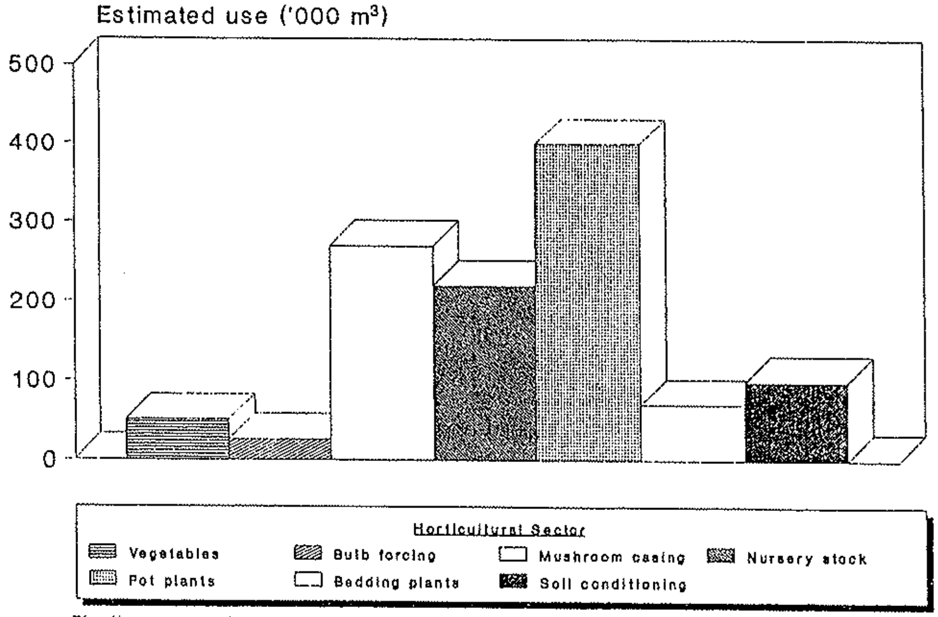

Figure 3 The figures quoted are derived from discussions with National Specialists within ADAS

The Sectors of Professional Horticulture and their Use of Peat

Table 9 Use of peat by various sectors of professional horticulture

Sector	Estimated Use ('000 m^3)	% of Total Use (2.7 million m^3)
Vegetables: Propagation and Transplants	50	2
Bulb forcing	25	1
Mushroom casing	250-290	10-11.6
Hardy ornamental Nursery Stock Container Plants	220	9
Pot Plants	300-500	12-20
Bedding Plants	60-80	2 - 3
Soil Conditioning in glasshouses	100	4
Total	1,005-1,485	40-50% of total

The figures quoted are derived from discussions with National Specialists within ADAS and with other specialists coupled with census returns and import figures. Various commercial organisations (see Appendix I) concur with the figures.

> Estimated Total Professional Use Ranges between:-
>
> 1.0 and 1.5 million cubic metres per annum.

Vegetable Transplants

Current estimate of peat usage: 50,000 m^3/annum.

Two forms of units are basically used for raising young vegetable transplants:

1. Blocks
2. Cellular trays (modules/plugs)

Peat blocks were a direct substitute for the soil blocks, previously used for raising young plants. Peat, particularly the darker, more highly decomposed sedge peat, provides ideal material for blocking as it can be compressed into stable units. The higher the percentage of sphagnum peat used the more difficult it becomes to make a stable block and the greater the shrinkage after making the block. The mere production of a slurry and its formation into a block dictates a far from ideal medium; peat and soil are almost unique in producing compressed blocks with pores for air movement. It should be stressed here that an attempt to produce a block from future alternatives to peat may well be an unrealistic proposition. Other material should not be expected to behave in a similar manner to soil or peat.

Cellular Trays (Modules, Plugs)

The development of a system of plug-raising young brassica plants, using pre-formed rigid or semi-rigid or polystyrene trays has followed from work internationally and, more particularly, work within the UK at Kirton EHS. Module or plug size has generally decreased with increasing understanding of physical and nutritional requirements of young plants (Hiron and Symonds 1985). The basic requirement is for high quality sphagnum peat, of uniform particle size. This avoids clogging or blocking of fine pores between particles and allows gravitational drainage and, more importantly, oxygen interchange at the root surface. The problem with small plugs or modules is that their height limits gravitational drainage, regardless of the size of pores in between particles of the peat. (Koranski 1987, 1989, Hiron and Symonds 1985, Bragg and Chambers 1987, Bragg 1989).

Other materials to fill small module trays have been examined by various workers. Materials which can easily be used are:

Rockwool
Perlite
Vermiculite with and without perlite
Polystyrene beads
Fine matured or composted bark
Polyurethane foam, e.g. Oasis

Bunt (1988) lists other suitable materials.

Watering and management of nutrition does have to be modified for each material selected. The main problems are:

- materials do not always hold together well during transplanting,
- there is inadequate contact between the material and soil after planting.
- Further developments of new materials is needed in this area, particularly as a replacement for peat in modules.

Hanging Basket, Patio Tub Mixes

This is undoubtedly a niche market, exploited by major peat producers who occasionally launch peat-based mixes which are expensive, relative to their real unit cost. Good fibrous peat mixes, possibly with wetting agents or 10 per cent grit, are perfectly adequate for hanging baskets and patio tubs.

However the development of a number of alternatives to peat mixes for these is extremely desirable, particularly as the substrate is only acting as a physical support and nutrients are supplied either in the form of liquid or as controlled release fertilisers.

- Work within this sector to evaluate products should really go hand-in-hand with pot-plant development work.

- Work by ADAS Wolverhampton in 1987/88 showed clearly the potential for the use of bark products, and perlite with polymers as good alternatives to peat for hanging baskets. An examination of material such as waste hops, chopped and composted straw would be of benefit.

Herbs as Fresh Plants

Although peat is often used within this sector, a number of supermarket chains have already considered and are actively pursuing the use of other inert media, such as rockwool, vermiculite and perlite to raise fresh herbs. These materials can be easily washed through with chlorinated water prior to despatch to avoid the build-up of organisms such as listeria.

However, the actual usage of peat in this sector is currently small and therefore work on an alternative simply to replace peat, for any reason other than the ease with which disinfection can be achieved at dispatch, is not worth a big development investment.

Grow-bags

In 1976 this sector professionally accounted for 110,160 m^3 of peat.

Grow-bags traditionally and even now within the retail sector, have often attracted manufacturers to use poor quality peats of fine particle size and high water holding capacity. As they are used during periods of vigorous growth, few problems are experienced, particularly when well-maintained drainage away from the bags avoids water stagnation and discourages root rot diseases.

The overall professional use of grow-bags has significantly declined since the mid 1970s and most of the protected crops are now grown in alternative substrates.

1970 Very little peat was used for grow-bags, until the introduction of peat bags from 1972 onwards.

1976 Was the peak year for grow-bags, used for:

75 per cent of heated tomatoes, i.e. 340 hectares.
10 per cent of heated cucumbers, i.e. 15 hectares.
Some carnations, 10 hectares approximately.
Total 365 hectares.

Considering tomatoes alone; 340 ha in 1976 represents the following use of peat:

Allowing for 27,000 plants/ha at 12 litres peat/plant
or 3-plant bags = 9,000 bags/ha at 36 litres/bag
= 324 m^3 peat/ha
Total Use = 110,160 m^3/annum

<u>1980</u> NFT was adopted for tomatoes by some South Coast, Lee Valley growers, and Vale of Evesham growers throughout the mid 70s. Most Humberside cucumbers were grown on rockwool by 1980 or within the next couple of years. In 1980, 60 per cent of heated tomatoes (260 hectares) were in peat; as were 10 per cent of heated cucumbers (15 hectares) and a few carnations (8 hectares); 283 hectares in total.

<u>1990</u> By this time most of the commercial production of tomatoes and cucumbers had moved into rockwool, perlite or NFT. Only a few carnations in limited areas were still being grown in peat or on peat boards.

♦ Therefore by 1990 grow-bags were almost entirely used within the amateur market. This is an area where the development or use of alternatives would be seen to be of particular advantage. Work by the Scottish Colleges on recycling spent mushroom compost could be useful and should be fostered; along with development of materials such as hop waste and wood fibre.

As will be seen from the figures, considerable savings in peat have been made by the change to full or semi-hydroponic system since 1976.

Pot Plant Substrates

Current use of peat is between 300 and 500,000 cubic metres per annum. In professional horticulture this sector appears to use the most peat.

Plants as rooted cuttings The cultivation of foliage and pot plants uses peat in a variety of ways, e.g. indirect filling plastic or net pots, or compressed peat pellets. Some materials such as expanded polyurethane foam (e.g. Oasis), perlite, vermiculite, and polystyrene are already established alternatives to peat. All are successfully used and there would appear little purpose in immediately investing resources, time or money for this sub-section.

Potted-on Subjects Once plants are moved from the rooted-cutting stage into pots (size 7 cm upwards), the choice of substrate is governed by nutrient management systems and watering regimes. On the Continent many pot plants are raised on flood benching, ebb/flow systems and the media used are very open, fibrous peat mixes, often amended with rockwool, clay granules or ganulated bark.

- It is possible to evaluate mixes which are peat-free for this sector and some work has already been started at the Scottish Agricultural Colleges by Dr David Hall.

- It is strongly recommended that this work is extended and developed using different watering/nutritional systems.

- Materials particularly worthy of development within this sector are coir, wood fibre, hard and soft wood waste/fibre, vermiculite, perlite and polystyrene as a recycled product.

Micropropagation

Estimated quantity of peat used is 45 m^3 per annum. Other materials used include rockwool, vermiculite, perlite, bark, polyurethane foam.

The transplanting of micro-propagules from their rooting, hormone-impregnated gel to their weaning and growing-on media is a particularly sensitive period. Most weaning is done using some form of plug or cell tray, usually of small volumes, i.e. 3-10 ml. There has been a tendency by some micro-propagation 'houses' to use proprietary substrates/compost mixes. This can only be considered unsatisfactory, particularly as the nutrition may be totally inappropriate for the young plantlets. More recent work has tended to be based on the use of selected/sieved, quality sphagnum peats, with the addition of fine barks, fine rockwool granules, perlite or vermiculite. These latter materials can be used on their own. Nutrition has then been based on low-level lime additions and low base nutrition followed by liquid feeding. For many salt-sensitive species being propagated this is a much sounder way of producing them than using proprietary mixes.

When weaning after micro-propagation, a sterile, disease-free material, with well defined particle size is required, avoiding inclusion of 'fines' in mixes which reduce air capacity. This can best be satisfied by using materials identified above although it may be worth examining the use of materials such as coir, if consistent supplies can be obtained.

- As the volume of peat used for weaning after micro-propagation is very small, work on a replacement is of low priority.

Bedding Plant Mixes

Quantity of peat currently being used is 60-80,000 cubic metres per annum.

There are various types of bedding to consider:

1. Traditional seedlings raised in wooden boxes, polystyrene or plastic trays.
2. Plug or cellular trays of plastic or polystyrene.
3. Block-raised.
4. Potting-on mixes for raising 'pack' or pot bedding.

(1) The volume of peat in the traditional seed tray system has declined as the understanding of conditions for even germination and associated management has improved. Currently 1.5 and 3 litres maximum are used in trays (previously 4 litres was common). Whilst 3-4 litre trays will increase depth and hence help avoid waterlogging, it is not justified on cost or on technical grounds. Increasingly high standards of peat quality are being demanded by this sector and much of the 25 per cent fine sand once included within such mixtures for this work has now been dropped completely or reduced to a maximum of 5 per cent by volume (Bragg and Chambers 1988, Bragg 1989).

(2) Plug or cell tray mixes. The demand in physical terms of small plugs or cells is extremely high. Individual cells should be regarded as individual trays: even 'fertigation' (fertiliser and water management) and good seed quality are essential. Therefore the type of peat selected for such plug or cell trays has to be of high quality and generally only the best grade sphagnum peats and well-sorted, sedge/sphagnum mixes are adequate to meet the high demands.

Sand is not generally included but wetting agents are usually essential to allow even watering and rewetting of dry cells. Watering is best achieved by gantry/fine nozzle applications. With very small plugs some difficulty is experienced balancing the physical requirements of the substrate against the problems of plug 'breakup' when transplanting, particularly by machine.

(3) **Block raised.** Blocking is still extremely popular as a means of raising bedding plants for the municipal or amenity markets on the Continent, particularly in Germany. Peat that, once thoroughly wetted, will easily ball and allow itself to be compressed into stable units is needed for block production. Peats which are more decomposed and consist of a higher percentage of Sedge spp. are most suitable. Currently there is little obvious expansion within this sub-section and resources to look for alternatives to peat are not justified.

(4) **Potting-on and Pack-bedding.** This is by far the greatest user of peat within the bedding plant sector (although some of the pot-bedding might be accredited to the pot plant sector). Much of the marketing moves are currently aimed at selling newly finished plants for patio pots, tubs, hanging baskets etc. The peat used in this sub-sector varies considerably but as many of the plants are grown in vigorous conditions of spring and summer, nutrition is more important than physical aspects.

- This is a sub-sector in which alternatives to peat could make considerable differences and active research should be undertaken. The alternatives which immediately suggest themselves are perlite, vermiculite, barks and coir, and mixtures of separated animal manures to act as fertiliser, i.e. fibre separated from slurry of cattle, pigs or poultry manures.

Container Grown Nursery Stock

Peat is used most widely for container-grown nursery stock, in all stages from propagation of cuttings through to final containers of marketing. Currently container-grown nursery stock uses 220,000 m^3 of substrate per annum, but up to 30 per cent of this figure may be in the form of 'bark' (particularly pine bark) or rockwool (Bragg 1990). Many materials other than peat or materials in combination with peat have already been trialled within this sector. Much of the work in the UK has been done at Efford EHS under the direction of Miss M A Scott.

In the propagation stages peat/bark mixes with up to 50 per cent bark are widely recommended. Perlite and polystyrene have also been used in propagation mixes, particularly where physically open mixes for use under mist watering systems are required. Various other ingredients such as coated/chopped straw, wood products, furnace wastes (as grit replacements), composted municipal waste and separated animal solids have also been tried within this sector (Scott 1984).

It is considered that the continued use of peat, perlite, vermiculite and bark is justified for propagation and 'liner' production as these offer the best way of achieving high quality, uniform plants. Alternatives to peat for the final potting stage should then be evaluated.

It is recognised that many plants will eventually be used within amenity planting schemes. Therefore as these plants will be often faced with harsh or hostile environments it is logical to gradually wean them into alternative materials in which it may be difficult for the plant to establish initially. The interface of alternative substrates and the type of soil/rubble in which plants are eventually set out may, in fact, be far better than if peat had been used.

- With this in mind materials such as composted municipal solid waste, co-composted with sewage sludge, straw, woodwastes, sawdust barks, coconut husk should be evaluated for potting mixes of these amenity plants.

- The development of mixes which also include biological separates, animal or human or vegetable waste should be looked at and compared for their fertiliser and biological value as well as any physical advantage they might offer in 'interfacing' - improving establishment of plants in amenity landscapes.

- Whilst it is anticipated that much of this work could be and would be done at Efford EHS and East Malling, further development of promising products should be extended to other sites, i.e. lanscape/amenity areas. These would provide greater experience of alternative materials and of the different management techniques needed. This implies a far closer link between commercial nurseries, landscape designers, Department of Transport and Forestry Commission to achieve the best results.

Bulb Forcing

Use of peat as bulb fibre is currently estimated at 25,000 m^3 per year. Bulb fibre is only used to support the bulb physically and to provide a moisture reserve. 'Fibre' traditionally was stripped-out peat sods to which lime was added to give a slightly higher than neutral pH of 7+. More recently manufacturers have included fertilisers in bulb fibre mixes, plus other additives such as vermiculite, perlite, polystyrene and super-absorbent polymers.

- The crucial physical support can be achieved using media such as peat, rockwool, perlite, vermiculite or coir. New materials such as sewage sludge and straw, waste paper, wood shavings and rice husks could possibly be used. Some evaluation trials are now underway at Kirton EHS (Dr C Rahn, Personal Communication 1990), but more work will be needed.

Mushroom Casing

The amount of peat currently being used in mushroom casing is estimated at between 250 and 290,000 cubic metres a year. Work from long established, mushroom units at Lea Valley and Littlehampton have generally found that peat plus chalk forms a highly successful casing material. The casing acts as a stimulus for mushroom mycelia to produce fruiting bodies. The actual quantities of chalk needed within the peat casing are probably lower than current practice and this is an area for development work. (Dr R Noble, Private Communication). Peat is particularly successful as 'casing' as it provides extremely clean end products, but it has some disadvantages, such as its wetting and drying characteristics and tendency to 'thatch' on the surface.

Other materials such as polystyrene, vermiculite and rockwool have been evaluated to a limited extent but without any real enthusiasm from mushroom growers for their overall development. Pressures to reduce peat usage overall may now stimulate renewed interest into examination of potential alternative to peat. Previous work is well reported in Lea Valley EHS Annual Reports of the 70s and 80s.

It should be noted that whilst the current use of peat within this sector appears large, much of spent compost and casing is recycled into tree-planting mixes. However this recycling needs further investigation to make the best use of the resource which, when considered in conjunction with spent mushroom compost itself, accounts for 750,000 m^3 of potential recyclable material for landscaping, soil ameliorants etc. Quantities of chalk have a bearing on its value for recycling as a soil ameliorant.

Planting Compost

The amount of peat used in 'tree planting mixes' and in soil amelioration may be as high as 500,000 m^3 per annum.

This sector of 'tree planting' uses a whole range of materials, from extremely degraded peats to recycled spent mushroom compost and casing. Definition of material used when tree-planting is very loose and different Local Authorities and Government Departments each have specifications to accompany tender forms. Recent work undertaken by the Forestry Commission on behalf of the Department of Transport suggests that peat and other bulky organics offer no real advantage in the circumstances. (Anon 1990c). However, this is somewhat conflicting with other work reviewed by Kendle (1990) where he points out that whilst Forestry Commission work revealed no advantage in use of peat, Bradshaw, shows small but significant advantages in use of peat (Hunt, Walmsley and Bradshaw 1990).

♦ Urgent evaluation of the different nursery stock substrates combined with a range of tree-planting mixes is needed. It would appear to the author that little information is available on the interfacing of different growing media and the establishment of plants when set out. Current engineering practice on roadside, opencast coal sites (Bragg et al 1984) offers little chance of good interfacing and therefore the media in which a plant is raised may have little effect on the plants chances of survival. Further work is essential in this sector.

Soil Amelioration

Soil ameliorants, together with the planting compost sector may use as much as 500,000 m^3 of peat per annum.

Soil ameliorants broadly fall into two areas:

(1) Soil amendment (conditioning) is probably the biggest use of peat in both amenity and amateur markets. Peat as a soil amendment is considered beneficial on soils with very light and very heavy textures. Addition of peat to light soil improves soil water holding capacity and additions of peat to heavy soils helps to break up clods and improve soil tilth. Other than physically improving soil, peat does not add any significant nutrient content and will not do anything to improve microbial activity. Few studies are known where effects of addition of peat and animal waste were compared. Work on reclaimed opencast coal sites showed considerable advantage could be expected when animal waste was used as a soil conditioner: physical, chemical and biological improvement occurred and soil structural stability increased. (Russell 1978, Armstrong and Bragg 1987, Bragg et al 1984, Stewart and Scullion 1989).

(2) Mulches, top dressing In amateur gardens large amounts of peat are used. Peat looks attractive and uniform and suppresses weed growth. Peat helps moisture retention, particularly on difficult soil textures such as sand and clay. However other materials could easily be used as mulching material, e.g. bark, old carpet, newspaper; and a number of these have been reviewed recently by Gardening Which?. They are constantly assessed by HDRC at Ryton, the National Centre for Organic Gardening.

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SECTION 4

ALTERNATIVES OR ADDITIVES TO PEAT

It is apparent from the literature that a great number of substitutes or dilutents for peat have already been examined over the last 30 years. Materials investigated include; tobacco waste, straw, separated animal solids, pulverised fuel ash, vermiculite, furnace waste, polystyrene, rockwool, wood by-products such as barks.

Some of these materials are regularly used in mixes, e.g. for propagation, bark is used at up to 50 per cent by volume. Some of the materials have only been used to replace other additives to peat, e.g. slate waste or furnace waste instead of grit. Some have been tested as possible 'stand-alone' material to replace peat, i.e. rockwool instead of peat grow-bags, perlite in a similar situation and spruce/larch bark for propagation in small pots. The major problems which have prevented further commercial development of these materials have been because of a number of limiting factors;

(a) Financial and economic, i.e. the cost of the material relative to peat or existing additives.

(b) Inconsistency as shown by chemical and physical analysis, e.g. variable pH, elevated levels of soluble salts.

(c) Unreliable source, (in terms of quantity, e.g. seasonal availability dependant on a harvest) - this point could also be made against peat.

(d) Problems of storage for long-term use, i.e. many of the materials are biologically active, and hence change chemically and physically during storage.

Biddlestone, Gray, and Cooper (1986)[1] made an attempt to quantify material which could be used as alternatives to peat.

Table 10 Estimates of Organic Wastes in UK

Waste Source	Millions of tonnes per annum (Freshweight)	Comments on ease of collection
Wood Shavings sawdust & bark	Greater than 1	Yes
Food processing waste brewers grain	Greater than 1	Yes
Silage effluent	Greater than 1	No but possible
Sugar beet tops potato haulms	1.6	Labour intensive/costly
Garden & nursery waste *	Possibly greater than 5	Contaminated with other waste
Cereal straw surplus to other uses	6	Yes
Municipal Waste Greater than 50% organic	18	Yes
Sewage	35 (1.2% dry solids)	Yes
Farm Manures	120	Yes

* Note the Americans call this Yard-waste and huge schemes for collection and composting exist in numerous states, with apparent success.

From Table 10 it is obvious that large resources of potentially reusable/renewable materials do exist. The main problem is the individual evaluation of the materials for particular purposes.

In the following sections each individual alternative will be examined. Where possible, reference to both its known properties and use within horticulture,

1 = Full reference under straw products. (see page 91)

past, present or future, is presented. The recommendations on how best to develop the material will also be put forward.

BARK - PINE

1. BACKGROUND: Waste product from forestry industry. Pine bark is normally won from trees by a chipping process, such that little white wood should be obvious in the end product. The bark needs to be stacked to allow maturing to take place; this drives off turpentine oils which would otherwise be phytotoxic.

2. SOURCE(S): Camland Products Ltd, Cambridge; M & B Products, Stafford; Melcourt Industry, Gloucester.

3. AVAILABILITY: Widely available within the horticultural market place and amenity sectors.

4. PRICE: 1.5 to 2 times price of peat.

5. COLOUR: 5 YR 4/3 reddish brown[1]

6. TEXTURE: Granular

7. ODOUR: Aromatic

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec*(µs)		P	K	Mg	NO_3-N	NH_4-N
6.5	82	(mg/l)	36	103	<5	2.0	<1
	0	(Index)	5	3	0	0	0

Water soluble analysis method as described in MAFF Ref. Book 427, The Analysis of Agricultural Materials, HMSO (1986).

* Ec = conductivity in microsiemen cm^{-1}
Index as ascribed by ADAS.

9. COMMENTS ON ANALYSIS: Typical matured sample but with no additional nitrogen having been added in the maturing phase.

10. ADDITIONAL ANALYSIS: Air Filled Porosity (AFP): 35 per cent in the raw material, although the amount of fines in the material will make alterations to this actual value.

Density : Slightly less than peat if coarsely chipped. (150-250 g/l).

Problem: Manganese levels can be very variable depending on source of trees and may be as high as 0.02 per cent of dry matter in some samples. The pine bark should be analysed by extraction with magnesium nitrate according to the Norwegian standard method (Selmor-Olsen et al, 1983), and the manganese level should be expressed on a percentage of the dry matter basis.

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1 Maunsell Soil Colour Chart; Macbeth Division of Kollmorgen Corporation, Baltimore

11. GENERAL NOTES ON THE USE OF THE MATERIAL IN HORTICULTURE: Currently pine bark is used widely within container nursery stock mixes, both as propagation, liner and growing mixes. Proportion varies between 50 and 20 per cent by volume, depending on the size and purpose of the actual mix. The work by Ms M A Scott at Efford Experimental Horticulture Station has clearly indicated that matured bark requires the addition of some additional nitrogen to make it acceptable for use, but other than this the product is well-defined. It is unlikely that, if bark were to be used in larger quantities, the UK sources would be able to meet the increased demands. On recommendations by the Forestry Commission imports of bark are banned because of spruce/larch beetle.

12. CAUTIONARY NOTES: There are reports of heating of bulk piles of bark, as with peat: this could produce phenolic type compounds which would then cause poor growth of plants.

    In Northern Ireland there are reports of dust problems to operators and skin irritation. Operators using this type of material should use dust masks to prevent dust inhalation, and people with sensitive skins should possibly wear gloves.

13. FUTURE WORK: As pine bark is well established within the market and is already well advanced in its use and take-up by horticulturists, new experimental work is probably not required. However producers need to improve their quality control, and to better describe products, particularly as regards source, more clearly.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

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BARK - SPRUCE/LARCH MIXES

1. BACKGROUND: Large volumes are won from trees each year, mainly by a flailing-type process which leaves a stringy product containing some white wood. Usually this material is composted with nitrogen (in the form of either urea or poultry manure) before marketing.

2. SOURCE(S): Melcourt Industries; M & B Products; ICI; Fisons; SHL Lincoln. There are also Irish and Scottish sources.

3. AVAILABILITY: Widespread in UK

4. PRICE: 1.5 times price of peat

5. COLOUR: 5 YR 3/3 dark reddish brown

6. TEXTURE: Stringy/spiky (see cautionary note).

7. ODOUR: Aromatic

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
6.5	103	(mg/l)	36	103	<5	2.0	<1
	0	(Index)	5	3	0	0	0

9. COMMENTS ON THE ANALYSIS: Very useful material -as basic substrate ingredient.

10. ADDITIONAL ANALYSIS: AFP: 20-30 per cent in raw material.

Manganese levels: may be as high as 0.1 per cent of dry weight. It is very important to identify the source of bark, i.e. where the trees are being harvested in relation to soil type.

Density: similar to peat.

Problems: Attempts have been made, certainly in Ireland, by both the Department in the North and by the Irish Peat Research Institute, to identify where different bark samples are coming from in Ireland and the levels of manganese within them. The type of soil on which trees grow and the age of tree influence the accumulated level of manganese in bark.

11. GENERAL NOTES ON THE USE OF THE MATERIAL IN HORTICULTURE: The material has been used with varying success in various nursery stock and propagation mixes within horticulture. In early work, Scott had greater success using pine bark than using spruce-larch mixes as pine bark appeared to give more consistent results. Further developments could be made in using the material for propagation on a wider scale. It is also used successfully for mulching round plants. The product needs to be made more consistent and manganese toxicity problems have to be overcome.

12. CAUTIONARY NOTES: Some problems are reported: operator's skin may initially be sensitive to this product as it is quite 'spiky'. Dust arises from the material and a dust mask is advisable.

13. FUTURE WORK: All sources of this bark need to be identified as it is effectively a renewable resource. Work should continue to look at manganese toxicity: this has already been started in Ireland and similar work should be undertaken by researchers in the UK.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) AARON, J R (1973) Bark: a potentially useful by-product. Journal of Institute of Wood Science 33, Vol 6, No 3, 22-27.

2) AARON, J R (1982) Conifer bark: its properties and uses. Forestry Commision, Forest Record 110 (Very good overall review of bark/bark products).

3) ANON (1986) Use of bark in composts. ARMIS* No 0105

* Southern Irish Research Notes.

4) ANON (1987) Use of bark in composts. ARMIS No. 3230

5) DARBYSHIRE, J F, DAVISON, M S, GASKIN, G J and CAMPBELL C D (1987) Forced aeration composting of coniferous bark. Biological Wastes 30, 278-287.

6) HOITINIK, H and POOLE, H (1980) Factors affecting quality of composts for utilization in container media. Hort. Science 15 (2), 171-173.

7) SOLBRAA, K and SELMAR-OLSEN, A R (1981) Manganese toxicity - in particular when growing plants in bark compost. Acta. Agri. Scandinavica 31, 29-39.

POLYSTYRENE

1. BACKGROUND: Polystyrene is a product produced from petrochemicals. It is widely used for packaging of materials, both inert and fresh, vegetable-like materials. Polystyrene is considered as environmentally unfriendly because it is relatively inert, does not biodegrade and simple disposal by burial is not very satisfactory. But if the product could be recycled and re-used within co-composting operations this would at least make it somewhat more acceptable.

2. SOURCE(S): Various manufacturers who jointly trade under the Polystyrene Manufacturers Association, e.g. Styropak, GT Enterprises. Lin Pac.

3. AVAILABILITY: Very large

4. PRICE: As a current waste product it has little value, and costs users in disposal charges.

5. COLOUR: Various colours, e.g. white, blue, brown and green, depending on the manufacturers' requirements for packaging.

6. TEXTURE: Granular after reshredding.

7. ODOUR: Nil

8. CHEMICAL ANALYSIS OF WATER EXTRACT: Not applicable.

9. COMMENTS ON THE ANALYSIS: Inert material.

10. ADDITIONAL ANALYSIS: AFP: Good at physically amending other materials. For example, a peat of 8 per cent AFP, when mixed 70 : 30 with shredded polystyrene gave a substrate with AFP value consistently around 14 per cent (Bragg 1990).

    Density: Very low : 18 g/litre, granular form after shredding of packaging boxes.

11. GENERAL NOTES ON THE USE OF THE MATERIAL IN HORTICULTURE: Polystyrene has been used by various nursery stock nurseries in order to physically improve the properties of the mixes, e.g. where using large quanitities of irrigation in propagation systems.

    Problems: Polystyrene tends to blow around and be electrostatically attracted to other surfaces: this means that mixing on nurseries can prove somewhat difficult! However, by the use of water and wetting agents it is possible to make mixing easier.

12. CAUTIONARY NOTES: Manufacturers should be able to show that there is little or no plasticiser left within the material after it has been shredded and that there is no residual boron which might cause problems. (Bunt 1988).

13. FUTURE WORK: Because of the amount of polystyrene in the waste stream at present it is sensible to try and recycle some of it. It is useful to bulk-up other materials which are to be composted, e.g. sewage sludge and straw or municipal town waste. It then enhances their physical qualities during composting. During composting the polystyrene is pasteurised or sterilised of any disease. Work is necessary on this material to further evaluate and develop its use in horticulture.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

BRAGG, N (1990) Contract report for Styropak, ref: V Davies, Littlehampton. (unpublished data).

BUNT, A C (1988) Media and mixes for container grown plants. Unwin Hyman, London.

PERLITE

1. BACKGROUND: Perlite is heat expanded volcanic rock; it comes both as graded and ungraded products. It is considered to be chemically inert although it has high porosity which allows it to take up water by capillary action.

2. SOURCE(S): It is mined as a mineral and may, long-term, be considered environmentally unfriendly. Various UK and Dutch firms supply, e.g. SHL Lincoln.

3. AVAILABILITY: Widespread

4. PRICE: Similar to Pine Bark - 2 x price of peat.

5. COLOUR: White

6. TEXTURE: Granular of various grades, from fine powder to 203 mm particles.

7. ODOUR: None

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
7.2	20	(mg/l)	<2	<10	<5	5	<1
	0	(Index)	0	0	0	0	0

9. COMMENTS ON THE ANALYSIS: Inert to all intents. Little buffering capacity.

10. ADDITIONAL ANALYSIS: AFP: Very good, 20-30 per cent depending on grade. Very good at increasing AFP of other materials.

    Density: Very low - but easier to handle than polystyrene.

11. GENERAL NOTES ON THE USE OF PERLITE IN HORTICULTURE:

    It is used widely in hydroponic systems, particularly in the Scottish Clyde Valley area and to a limited extent in the Evesham area. It has proved extremely successful as a method of supporting and raising tomatoes on a semi-hydroponic system, acting as an alternative to peat bags.

    It is also used in propagation mixes for nursery stock and other plants under mist and other similar watering systems, and has been successfully shown to be suitable if blended in various grades and mixed with other materials such as vermiculite, as a material for raising pot plants and for nursery stock cuttings. Much of the development work has been done so far at the West of Scotland College by Dr David Hall and associates.

12. CAUTIONARY NOTES: Dust is the major concern and operators when using the fresh material are advised to moisten it before use and/or wear a dust mask.

13. FUTURE WORK: Work in 1990 has shown clearly that perlite can be used successfully for raising different types of pot plants and this work should continue and be expanded even though long-term the material may be rejected as being environmentally unfriendly. The expertise in management of this material currently lies with Dr David Hall and his associates at the West of Scotland College and they should be encouraged to research further.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BRAGG, N and CHAMBERS, B J (1988) Interpretation and advisory application of compost AFP measurements. Acta. Hort 221, 35-44.

2) BUNT, A C (1988) Media and mixes for container grown plants. Unwin Hyman London.

3) CHAMBERS, B J (1989) The perlite hydroponic system. SCI Meeting, Pershore. Journal of Food Science and Agriculture 1990.

4) SZMIDT, R A et al (1988) Development of perlite cultural systems for the production of glasshouse tomatoes, Acta. Hort. 221, 371-378.

5) WILSON, G, HALL, D A and MACGREGOR, A J (1984) Perlite culture of tomatoes. West of Scotland College Technical Note 219.

VERMICULITE

1. BACKGROUND: Vermiculite is naturally occurring, micaceous mineral. It is found and mined in various parts of the world, e.g. Southern Africa and Northern America. The material has to be heat treated (1000°C) to exfoliate the mineral before it can be used in horticulture. (The material is also used as a fire retardant prevention material). Long-term it may be considered as a non-environmentally friendly material as it is a mineral that is being mined and therefore non-renewable; there are also some worries about its asbestos content.

2. SOURCE(S): Various UK firms such as Dupres, SHL and Vitagrow are all importers and processors of Vermiculite from various worldwide locations.

3. AVAILABILITY: Worldwide

4. PRICE: Similar to Perlite and Pine Bark.

5. COLOUR: 10 YR 8/3 very pale brown (African)
10 YR 6/2 pale brown (North American)

6. TEXTURE: Soft/silk like plates once exfoliated.

7. ODOUR: None

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
8.5	35	(mg/l)	<2	12	5	<1	<1
	0	(Index)	0	0	0	0	0

9. COMMENTS ON THE ANALYSIS: Some sources of vermiculite are slightly acidic whilst others tend to contain magnesian limestone and hence, after exfoliation, give rise to pHs above 7. These latter sources may cause problems unless they are treated with an acid to neutralise the limestone content prior to use.

10. ADDITIONAL ANALYSIS: Cation Exchange Capacity (CEC) relatively high 100-150 meq/100 g. This means that the material is on a par with other mineral materials and can be used therefore to 'hold back' particular cations such as potassium and ammonium nitrogen; it can also hold back some of the water soluble phosphorus.

Density - Very low

11. GENERAL NOTES ON THE USE OF VERMICULITE IN HORTICULTURE: Vermiculite is currently used in a variety of mixes for bedding plants, pot plants, young herb plants and is also incorporated with materials, other than peat, such as perlite to improve the overall chemical and physical properties of mixes.

12. CAUTIONARY NOTES: Because of the possible problems with dust and possibly asbestos associated with some sources, operators are advised to use dust masks when handling the material in a raw form.

13. FUTURE WORK: Currently the expertise in development of this material, particularly for pot plants, is West of Scotland College under the leadership of Dr David Hall and further work of management systems, and wider use of the material in other areas than those already identified, should be looked upon as a priority.

Vermiculite also has a role to play as both a fertiliser and pesticide carrier. Some firms in the UK do offer fertiliser enriched Vermiculite and this can be used to improve fertiliser mixing and distribution.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BAKER, K (1957) The UC system for producing healthy container-grown plants. University of California Manual 23.

2) BODDLEY, J W and SHELDRAKE, R (1972) Cornell peat-lite mixes for commercial plant growing, New York College of Agriculture Bulletin No. 43.

3) BUNT, A C (1988) Media and mixes for container-grown plants. Unwin Hyman London.

HOP WASTE

1. BACKGROUND: Hop waste comes from the brewing industry. It has been used as a bulking agent in grow-bags by some producers and, in the Low Countries, hop waste is used as a source of nitrogen, particularly for azaleas and rhododendrons. The material has a fibrous content and also relatively high protein content.

2. SOURCE(S): Breweries, although decreasing on actual brewery sites as many of the major brewers now use hop extract, or grain and pelletized hops which give no fibrous waste.

3. AVAILABILITY: Limited - main competition is as animal feed.

4. PRICE: Where available, cost of disposal is currently the only likely charge.

5. COLOUR: 10 YR 5/6 yellowish brown

6. TEXTURE: Fibrous but slightly greasy when fresh.

7. ODOUR: Soporific

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
6.4	100	(mg/l)	101	10	49	<1	<1
	0	(Index)	9	0	5	0	0

9. COMMENTS ON THE ANALYSIS: Although little available nitrogen actually appears by the water soluble analysis of the fresh material, there is considerable residue of organic nitrogen in the form of proteins which subsequently break down and release Nitrogen to the plant. (See MAFF/ADAS Organic Manures and Fertilisers Handbook 1958)

10. ADDITIONAL ANALYSIS: Density : Initially high as product may be 73 per cent water - on drying density similar to peat.

    The material does tend to become hydrophobic with time and this may be a problem.

11. GENERAL NOTES ON THE USE OF HOP WASTE IN HORTICULTURE: It has been used as a source of nitrogen, particularly for inclusion with pine litter, for raising azaleas in Belgium. It has also been used as a bulking ingredient for poorer-grade peats and has proved successful in grow-bags.

12. CAUTIONARY NOTES: Hop waste needs composting to avoid growth of fungi: these could possibly give rise to spores and may cause respiratory irritations. Dust masks are advised.

13. FUTURE WORK: An assessment of the reserves is needed. It should also be evaluated in mixes with other complimentary sources of composted materials which provide potassium but are short of nitrogen and phosphorus. Some fundamental work could be usefully done alongside work on straw waste; straw waste itself is high in soluble potash but requires phosphorus and nitrogen in order to give it balance.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BRAGG, N (1990) Contract report for Richmoor Peat Co. Unpublished.

2) BUNT, A C (1988) Media and mixes for container grown plants. Unwin Hyman London.

GRAIN WASTE

1. BACKGROUND: Grain waste is an industrial waste product. Currently it is used by the animal feed industry, but may attract higher value if used in horticulture.

2. SOURCE(S): Breweries and distilleries.

3. AVAILABILITY: Limited at present by competition for animal feed usage.

4. PRICE: Depends on transport costs.

5. COLOUR: 7.5 YR 4/6 dark reddish brown.

6. TEXTURE: Soft granular texture.

7. ODOUR: 'Rotting-meat' (if stood for any time in anaerobic conditions).

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
4.3	150	(mg/l)	44	126	25	2	7
	0	(Index)	6	3	3	0	0

9. COMMENTS ON THE ANALYSIS: The nitrogen is mainly held in the form of protein which releases gradually once either composted or used in the growing media.

10. ADDITIONAL ANALYSIS: Density: Low when dry - initially like spent hops.

    Analysis of total and exchangeable copper should be undertaken. Some sources of grain are particularly high in copper which may cause problems of phytotoxicity.

11. GENERAL NOTES ON THE USE OF GRAIN WASTE IN HORTICULTURE: Could be used as a soil amendment/fertiliser to support amenity grasses.

12. CAUTIONARY NOTES: Fungal spores indicate a risk of respiratory diseases. Dust masks are advised.

13. FUTURE WORK: Grain waste could be well worth developing as a co-composting ingredient, with products such as straw, to produce a useful growing media for containers.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE: None.

MUNICIPAL SOLID WASTE (MSW) OR REFUSE-DERIVED HUMUS (AFTER COMPOSTING).

1. BACKGROUND: Each year, the UK produces 50 million tonnes refuse (solid) per annum, of which 50 per cent is roughly compostable. A recent "Warmer" Bulletin, no 26, August 1990 suggested that the MSW. stream has the following composition :

Paper and card	33%
Putrescible Organic waste	20%
Metals	8%
Glass	9%
Plastics	6%

(Putrescible = degradable by biological processes.)

The remainder being made up by textiles and fines, i.e. grit/ash. A more detailed breakdown of MSW can be found in the Royal Commission on Environmental Pollution No 11 - Waste and waste management, where trends in MSW composition are followed over the last 50 years. It should also be borne in mind that one of the major problems with MSW is consistency of supply, as there are marked seasonal variations. Significant attempts have been made in the past to introduce the composted product into the horticultural market by various local authorities, notably Leicester, Newcastle, Walsall, and Canterbury. Currently the material is seen as a low value substitute for peat in the landscape/soil conditioning sectors.

2. SOURCE(S): UK sources: Secondary Resources plc; Bicker, Newcastle; Motherwell Bridge, Glasgow.

3. AVAILABILITY: Not in consistent quantities at the time of writing this report.

4. PRICE: £12-30/m^3, therefore similar to peat prices.

5. COLOUR: 10 YR/4.2 dark greyish brown

6. TEXTURE: soil-like to granular

7. ODOUR: sweet, sickly when fresh, earthy when mature.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
7.7	130	(mg/l)	49	200	30	10	120
	4	(Index)	6	4	4	0	3

9. COMMENTS ON THE ANALYSIS: Nitrogen is mainly as microbial protein and not therefore water-soluble.

Actual analysis will vary between batches and depends on type of pre sorting separation of waste stream.

10. ADDITIONAL ANALYSIS: Problems: Pathogen survival.

Heavy metal loading, particularly zinc, copper, cadmium, mercury, chromium should be considered.

Phytotoxins due to inadequate composting, i.e. anaerobic zones.

Glass, i.e. if this is not properly separated or blasted to 'round' the particles.

Density : Depends on degree of processing, can eventually end up similar to density of soil; may be 3 times as heavy as peat.

Microbiological Examination: Screening for moulds and humus pathogen of all batches.

11. GENERAL NOTES ON THE USE OF MSW IN HORTICULTURE: MSW or refuse derived humus has been produced by numerous operatives, i.e. Lescos, Bicker, Secondary Resources plc, and Walsall/Perry Barr, all of which have been shown to support, with varying degrees of success, container-plant growth and act well as soil fertilisers, topsoil replacements for lower grade 'end' use.

12. CAUTIONARY NOTES: Risks arise to humans and plants from the heavy metal content, glass content, pathogen content.

13. FUTURE WORK: The process of cleaning/sorting/washing established by Secondary Resources in Birmingham are steps forward to the production of a much more useful end product. Further work is needed on the composting and co-composting with other ingredients which will physically improve the nature of the mixes so far used. Strategic work is needed on pathogen identification and elimination to reduce risks to end users, and also work to give consistent products. As a renewable resource the material has considerable merits and research work should be supported.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BENTLEY, R, BRAGG, N, BRITT, C and WALKER, J (1990) Use of aerobically composted municipal solid waste for raising container grown nursery stock plants. (in preparation).

2) CHARPENTIER, S and VASSOUT, F (1985) Soluble salt concentration and chemical equilibria in water extracts from town refuse compost during compost periods. Acta. Hort. 172, 87-94.

3) DE VLEESCHAUWER, D, VERDONCK, O and DE BOODT, M (1980). The use of town refuse compost in horticultural substrates. Acta. Hort. 99, 149-155.

4) LUTZ, W (1981) The use of compost with special consideration of heavy metal contents. Conservation & Recycling Vol. 4, 167-176.

5) Numerous articles in "Biocycle" on the use and production of municipal solid waste composts and their use.

COIR

1. BACKGROUND: Coir (as used in horticultural substrates) is the residue from the production of fibre for coconut mats. The coconut husk is broken down by washing processes which soften the fibre. Some fibre is removed by a saline water process, to produce the 'white' fibre. This latter fibre and its waste is not suitable for horticulture due to high salt (sodium and chloride) content. The waste husk material has accumulated in heaps in various parts of the Indian Sub-continent over a number of years. However, only material which is 4 months old is apparently suitable for use. Phytotoxins are present in both the fresh and the older material, and the older material is likely to be contaminated with soil from the country of origin, plus organic acids due to the inadequate composting.

2. SOURCE(S): Sri Lanka, West Coast of India, Philippines, Indonesia.

3. AVAILABILITY: This is somewhat erratic at present and there is no real knowledge of the actual amount available to the market. It should be borne in mind that other countries such as Japan and Australia would also like to use the material as a horticultural medium.

4. PRICE: 2-3 times price of peat

5. COLOUR: 7.5 YR 3/4 dark brown

6. TEXTURE: Fine, granular, some fibre, some coarse chopped grades.

7. ODOUR: Little

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (μs)		P	K	Mg	NO_3-N	NH_4-N
5.7	60	(mg/l)	<2	50	<5	2	<1
	1	(Index)	0	1	0	0	0
5.9	170	(mg/l)	<2	203	<10	2	2
	1	(Index)	0	4	0	0	0

9. COMMENTS ON THE ANALYSIS: There is some variability between products Raised conductivity levels indicate (salinity) contamination due to quality of water used in husk extraction.

10. ADDITIONAL ANALYSIS: AFP: 10 per cent for the material which has so far been examined.

It would also be worth considering bromine residues as some of the material is apparently treated with methyl bromide.

Density: Similar to peat.

Microbiological examination - Screening for moulds and pathogens.

11. GENERAL NOTES ON THE USE OF COIR IN HORTICULTURE: Coir has been trialed on a limited basis in the UK by ADAS. So far it is showing promising signs, e.g. good root establishment by plants. No long term data is yet available.

12. CAUTIONARY NOTES: Pathogen and fungal spores may be present. Dust masks are essential and hands must be washed after using it.

13. FUTURE WORK: Long-term - the importation of coconut waste is not environmentally friendly, particularly as the biggest problem in the Third World is soil erosion due to the loss of organic matter. Therefore it would be better to develop its use to improve soil organic matter content and soil stabilisation in the Third World.

In the short term, the material is attractive, in appearance and in other characteristics,as a peat replacement. It needs evaluating for all professional horticultural sectors, but it should be realised that there is a limit to supply and therefore not all sectors will be satisfied.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) VERDONCK, O, DE VLEESCHAUWER, D and PENNINCK, R (1983) Cocoa fibre dust: a new growing media for plants in the tropics. Acta. Hort. 133, 215-220.

2) VERDONCK, O (1983) Reviewing an evaluation of new materials used as substrates. Acta. Hort. 150, 467-473.

ANIMAL WASTES AND SEPARATED SOLIDS

1. BACKGROUND: A variety of animal waste sources - pig, cow, poultry, sheep - give rise to an estimated 160 million tonnes of excreta in the form of dung or urine per annum. This is based on a 1983 report by Smith and Unwin; there is probably little change since 1983.

   All the manure sources, be they slurry or separated solids, have similar problems of high levels of available nutrients releasing unpredicted levels of protein nitrogen. This protein nitrogen also becomes available during co-composting with other materials. None of these animal wastes immediately offer themselves as single suitable alternatives as growth media and if they are to be used as container-growing media, they should only be regarded as materials either to be mixed and diluted with peat or alternatives such as coco-fibre or straw. Some of the materials would undoubtedly be suitable for use as soil conditioner/fertilisers and as mulching materials: the major problem is then in obtaining large and consistent sources to supply particular market demands.

2. SOURCE(S): Source varies from traditionally housed cattle to intensive systems; from free range poultry through to broiler poultry.

3. AVAILABILITY: Widely available in UK, although sources are rather dispersed.

4. PRICE: Products on market are slightly dearer than peat.

5. COLOUR: 10 YR 4/1, Dark grey.

6. TEXTURE: Variable depending on the type of material; range from slurry material (which would be used for co-composting with other materials) to the crumb produced as a dark-brown compost and with a similar appearance to medium-grade peat (Pryce 1980).

7. ODOUR: Very variable depending on source; even some of the pelletised poultry manures when slightly damp have an extremely high smell associated with fresh manure.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

	pH	Ec (µs)	P	K	Mg	NO_3-N	NH_4-N
Cow crumb	7.9	N/A	330	1794	113	174	156
Duck	8.0	N/A	414	3300	110	264	<6
ADCM	7.7	1020	252	1572	61	144	1
CRAP	8.3	4650	615	3888	47	0.7	2724

ADCM = anaerobically digested cow manure
CRAP = commercially recommended available product - sold as soil conditioner

9. COMMENTS ON THE ANALYSIS: There are obvious high initial pHs, and high although varied levels of nutrients, particularly of potassium and nitrogen, be it in the form of nitrate or ammonium-N. These materials are therefore best considered initially as fertilisers or soil conditioners/ amendments. It should be noted that the low nitrate

nitrogen, apparent in some samples, is simply an indication that the composting process has been incomplete and that the protein reserves of biomas have not been broken down into nitrate. It should also be noted that the performance of these products, once mixed into other materials to form a growing media, can be variable. (Efford EHS Annual report 1982/83).

10. ADDITIONAL ANALYSIS: It is suggested that samples should not only be analysed for water soluble nutrients but also treated as 'farmyard manure' and the dry matter plus percentage N, P, K determined in order to give a fertiliser value on a fresh weight basis.

Microbiological screening advisable.

11. GENERAL NOTES ON THE USE OF ANIMAL WASTES IN HORTICULTURE: Some new investigations are currently underway to re-examine use of these materials in both straight, separated and pelletised form. Basically none are peat substitutes but rather fertilisers of varying values.

12. CAUTIONARY NOTES: Composting, if done to DOE sewage treatment standards should suppress any likelihood of contamination by pathogens. However these materials need careful handling with the operator wearing a dust mask whenever the material is handled, and washing after use.

13. FUTURE WORK: Work to evaluate use of separated animal manures, mainly as soil conditioners or fertilisers but also as organic fertiliser source for container-grown plants should be continued. Some of this work is currently being done at Pershore College and Efford EHS.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) CHEN, Y et al (1983) The use of slurry produced by methanogenic fermentation of cow manure as a peat substitute in horticulture - physical and chemical characteristics. Acta.Hort. 150, 553-561.

2) CHEN, Y et al (1988) Composted agricultural wastes as potting media for ornamental plants. Soil Science, 145 (4), 298-303.

3) DE VLEESCHAUWER, D et al (1983). The use of chicken and piggery manure in composts. Acta.Hort. 126, 105-111.

4) GASSER, J (Ed) (1984) Composting of Agricultural and other wastes, Elsevier applied science.

5) PRYCE, S (1980) The potential for utilising bulky organic waste in British horticulture. Thesis as part of Bsc degree course, Bath University.

6) SCOTT, M (1988) The Use of Worm Digested Animal Wastes as a Supplement to Peat in Loamless Composts in Hardy Ornamental Nursery Stock. Earthworms in waste and environment management; edited C A Edwards & E F Neuhauser.

7) SMITH, K and UNWIN, R (1983) Fertiliser Value of organic manures in UK. The Fertiliser Society No. 221

8) TARRE, S, RAVIV, M and HELEF, G (1987) Composting of fibrous solid fresh cow manure and digested manures. Biological Wastes 19 299-308.

EXPANDED/CALCINED AGGREGATES AND SLATE WASTE

1. BACKGROUND: These usually occur as clay waste or from other micaceous sources such as slate or Fullers earth workings. Processes vary, some bake the raw material, but other processors use higher temperatures which result in thermal expansion of the raw material.

2. SOURCE(S): Mined mineral source or as waste from other primary quarrying processes, e.g. Laportes' Fullers Earth.

3. AVAILABILITY: Limited, i.e. hole in the ground which can only expand according to planning regulations.

4. PRICE: £30-40/tonne. 2-3 times price of grits.

5. COLOUR: 10 YR 5/4 Yellowish brown, some other colours such as terracotta and grey depending on source.

6. TEXTURE: Hard granular but of low density if heat expanded.

7. ODOUR: None.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
8.1	150	(mg/l)	5	33	5	339	<15
	0	(Index)	1	1	0	2	0

9. COMMENTS ON THE ANALYSIS: The above is only for one source: analysis will vary depending on the origin, although it is unlikely that water soluble analysis of materials of this type would be any greater than that shown.

10. ADDITIONAL ANALYSIS: Density is low, i.e. 200-300 g per litre. Cation exchange capacity for Fullers earth was quoted at 25 meq/100g, for some other micaceous minerals it may be as high as 150 meq/100.

11. GENERAL NOTES ON THE USE OF EXPANDING CLAY AGGREGGATES IN HORTICULTURE: Some of these materials are already used as horticultural turf dressing and are included in certain potting mixes to improve the buffering capacity. The advantage is their light weight and they can be used to replace traditional aggregates such as sand and grit. They also have the advantage of higher buffering capacities.

12. CAUTIONARY NOTES: Some of these products are highly silicaceous: therefore a dust mask is essential.

13. FUTURE WORK: Development of these products, particularly for subjects such as alpines and salt-sensitive plants, would seem appropriate. These materials would obviously be used as additives in the place of other heavy aggregates. They may also have a place as the basis of semi-hydroponic systems where they could provide physical support for plant growing in containers. Work should be done on these materials in

conjunction with the work on perlite and vermiculite at West of Scotland Colleges.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) ANON (1988) Article in "The Garden" Journal Royal Horticultural Society Vol 113. No.5 207-209.

2) BUNT, A C (1988) Media mixes for container grown plants. Unwin Hyman London.

3) CARLILE, W and BEDFORD, I (1988) Plant growth in container media amended with calcined clay. Acta.Hort. 221, 117-131.

4) WILDON C, O'ROURKE, F undated, The effect of arcillite in media for pot plants. Research report Michigan State University.(Author holds copy).

LOAM

1. BACKGROUND: Loam is the traditional material used for John Innes (JI) composts. Its definition is difficult, i.e. it can be anything between sandy loam to clay loam texture. Formerly when loam was the basis of JI composts, it was acid loam of medium clay texture taken from permanent pasture, stacked and composted and then sterilised. Today, continuous supplies of reliable, high quality material to meet the specifications, as originally laid down for JI composts, are scarce.

2. SOURCE(S): varied within the UK.

3. AVAILABILITY: Limited.

4. PRICE: £15-20/tonne.

5. COLOUR: 7.5 YR 4/2 brownish grey.

6. TEXTURE: Clay loam, sandy clay loam, sandy loam.

7. ODOUR: Earthy when freshly sterilised.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

9. COMMENTS ON THE ANALYSIS: None appropriate.

10. ADDITIONAL ANALYSIS: Loam's high density is its major disadvantage. Its cation exchange capacity is high, i.e. 100 meq/100g, and it is therefore a good buffer against salt build-up.

11. GENERAL NOTES ON THE USE OF LOAM IN HORTICULTURE: Loam has been successfully used for many years in horticulture and its case is well reviewed.

12. CAUTIONARY NOTES: Possible contamination with residual herbicides and/or heavy metal due to dumping are the main concerns. Analysis should always be undertaken, also checks of lime and pH values.

13. FUTURE WORK: Little future work is perceived as necessary on this material if the cautionary notes are considered.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

BUNT, A C (1988) Media mixes for container grown plants. Unwin Hyman London.

ROCKWOOL (MINERAL WOOL)

1. BACKGROUND: Rockwool is produced by a blast-furnace type process by heating igneous rock with limestone and coke at approximately 1,500°C. The molten material is spun off a spinning disk to form flocks which can then be coated with oil to make them water repellent, if necessary, and can also be weaved into matting or slabs.

2. SOURCE(S): Pilkingtons UK, Grodan Denmark

3. AVAILABILITY: Widely available in UK.

4. PRICE: 1.5-2 x price of peat.

5. COLOUR: 5 Y/6/3 pale olive (UK)

6. TEXTURE: Fibrous

7. ODOUR: None; some suggestion of 'bad egg gas' when mixed with acid media such as peat.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
8.0		(mg/l) (Index)					

9. COMMENTS ON THE ANALYSIS: Inert to all intents and purposes other than reaction of residual calcium oxide which gives rise to increasing pH of media mix.

10. ADDITIONAL ANALYSIS: AFP: very high; density very low.

11. GENERAL NOTES ON THE USE OF ROCKWOOL IN HORTICULTURE:

It is used widely for tomato and cucumber production, both in propagation blocks and as the slabs for watering and fertilising the plants. It is also used as plugs for micro-propagation, cuttings and raising seed plants. In container mixes for nursery stock on some major nurseries in the UK, rockwool 'flock' is added to peat. The Orchid Foundation in Jersey and Wellbank Nurseries in East Anglia, use rockwool in orchid production.

12. CAUTIONARY NOTES: Rockwool causes some skin irritations to operators when first exposed but they rapidly become desensitised. Dust masks are advisable (although the fibres have been shown by medical consultants to be harmless) as there is obviously a high fibre content in the atmosphere where the material is being mixed. (Pilkingtons for Health and Safety, COSHH recommendations).

pH effect: 20 per cent by volume in peat mix is equivalent to adding 2 kg/m^3 of lime, i.e. it causes 1 pH unit rise. (ADAS Soil Science Department, Wolverhampton, 1990)

13. FUTURE WORK: Currently little further work is needed. Rockwool is well established as an alternative or partial replacement to peat.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BUNT, A C (1988) Media mixes for container grown plants. Unwin Hyman London.

2) SMITH, D (1987) Rockwool in horticulture. Grower Publications.

3) VAUGHAN, C (1989) Rockwood hydroponic update SCI meeting Pershore, Journal of Food Science & Agriculture 1990.

PUMICE

1. BACKGROUND: Pumice is an alumino/silicate mineral formed by fast water cooling of volcanic larva flow. It contains traces of other minerals such as potassium, sodium, calcium, magnesium and iron. Gas escaping during the cooling process makes it a porous material. It is used as an additive to peat and as 'stand alone' growing medium.

2. SOURCE(S): Iceland

3. AVAILABILITY: Low

4. PRICE: £30-40/tonne.

5. COLOUR: White

6. TEXTURE: Granular, sharp, gritty

7. ODOUR: None.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)
7.5	1000
9.5	

9. COMMENTS ON THE ANALYSIS: It is relatively inert: the initial high pH and conductivity are results of sea water incursions causing sodium chloride concentration. They can be easily reduced by leaching with water prior to use.

10. ADDITIONAL ANALYSIS: AFP: high; density: very low.

11. GENERAL NOTES ON THE USE OF THE MATERIAL IN HORTICULTURE: Carnation production in Jersey is the major current use in the UK.

12. CAUTIONARY NOTES: A dust mask is recommended due to the alumino-silicate base of the material.

13. FUTURE WORK: Could usefully be further evaluated alongside materials such as perlite and vermiculite at the West of Scotland College.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

BUNT, A C (1988) Media mixes for container grown plants. Unwin Hyman London.

ZEOLITE: SIMILAR ORIGIN TO PUMICE

1. BACKGROUND: Widely used by the chemical industry to 'mop up' spillages of chemicals.

2. SOURCE(S): Limited, volcanic regions.

3. AVAILABILITY: Limited - competing uses.

4. PRICE: Relatively very expensive - approximately £100/tonne.

5. COLOUR: Creamy White

6. TEXTURE: Granular

7. ODOUR: None.

8. CHEMICAL ANALYSIS OF WATER EXTRACT: N/A

9. COMMENTS ON THE ANALYSIS: High cation exchange capacity, acts as a slow release mechanism for both ammonium and potassium ions if absorbed onto the material initially.

10. ADDITIONAL ANALYSIS:

    Density: very low.

    Sodium content - some sources heavily contaminated.

11. GENERAL NOTES ON THE USE OF ZEOLITE IN HORTICULTURE: There is reference to use of Zeolites in chrysanthemum media. It is used in composting processes in Holland to absorb ammonia gas and therefore prevent contamination of the atmosphere.

12. CAUTIONARY NOTES: A dust mask is advisable (in the same way as with Pumice due to alumino-silicate content).

13. FUTURE WORK: Possible work is needed by West of Scotland Colleges to develop this material further in a semi-hydroponic system, and mixed with spent mushroom compost to adsorb the high levels of available nutrients.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BUNT, A C (1988) Media mixes for container grown plants. Unwin Hyman London.

2) HERSHEY, D, PAUL, J and CORLSON, R (1980) Evaluation of Pot-enriched clinoptilolite as a Potassium Source for Potting media. Hort. Science 15, 87-89.

3) PIRELA, H, WESTFALL, D and BARBARICK, K (1983). Use of Slinoptilolite in combination with Nitrogen fertilisation to increase plant growth. Int. Comm. on Natural Zeolite.

4) WITTER, E and KIRCHMANN, H (1989) Peat, Zeolite, Basalt as absorbents of ammoniacal nitrogen during manure decomposition. Plant and Soil 115, 43-51.

SEWAGE SLUDGE

1. BACKGROUND: This can take many forms. Separated raw slurry is used for co-composting with other bulky organic waste such as straw. The result of digestion and treatment with slaked lime is a crumb-like material resembling soil. The major problem is identification of source and knowledge of likely contaminants.

2. SOURCE(S): All water companies have different types of sewage products available.

3. AVAILABILITY: Wide

4. PRICE:

5. COLOUR: 10YR4/0, very dark brown.

6. TEXTURE: Runny; but greasy to crumby, when dried.

7. ODOUR: Distinct in as much that it can be high to earthy when treated.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

	pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
Straw/ sewage (co-composted)	6.6	1780	(mg/l)	35	1440	115	3	104
		9	(Index)	5	8	7	0	3

9. COMMENTS ON THE ANALYSIS: None appropriate as this material could be co-composted with other ingredients - straw, wood shaving chips, barks.

10. ADDITIONAL ANALYSIS: Boron and heavy metal analysis - (Zn, Pb, Cu) bio-assay to determine organic residues is also essential on each batch - i.e. presence of phenols, herbicides.

11. GENERAL NOTES ON THE USE OF SEWAGE SLUDGE IN HORTICULTURE:

Currently it is used for soil conditioning/amendment and as a co-composting agent. End products of co-composting have all the visual appearances of a good, earthy compost. However, results of growing trials are not always as consistent as the material appears. This is mainly due to problems as outlined below.

12. CAUTIONARY NOTES: A number of likely problems exist in the use of any sewage sludge cake or digested products,

a) Metal content - zinc, copper, cadmium, mercury, chromium, nickel,
b) Herbicide content - growth regulants,
c) Organic contaminants - phenols,
d) Pathogen survival - bacterial, virus.

All samples supplied by water companies and composting firms should carry an analysis of the batch. Most importantly workers and users should do all they can to protect themselves from inhalation/digestion of aerosols or solids.

Where the material has been co-composted with other materials, e.g. straw, then the end product should be free of pathogens, although virus may be able to survive under the process of composting and there is a lack of information at the present time. Further strategic work is needed.

13. FUTURE WORK: Work is already under way by a number of commercial concerns to study the use of clean sewage as a co-composting additive. Work is needed to look at ways of cleaning contaminated sources and at the increase of levels of available metals which occur during the composting periods, i.e. as the organic volume changes this leads to breakdown of organic complexes and hence increased availability of any metals which are present. (See general section on composting) There is also a need to check for pathogen survival. It is inadequate to report that there are 'so few' of a particular organism, e.g. hepatitis B, and that they cannot be found after composting. Laboratory work needs to be done to see whether or not the processes of composting are in fact adequate to suppress or kill particular pathogens or their 'resting bodies'. Work in Belgium and America gives clear guidelines on how to set up small bench scale tests to test composting processes. Anybody seriously considering undertaking any composting operations involving sewage should look seriously at putting resources into strategic work. Sewage products should be considered seriously as a soil amendment and fertiliser. An examination should be made of the use of sewage co-composted with other materials for use in container mixes.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) EFEIRA-NETA, J P, STENTIFORD, E and MARA, D (1986) Pathogen survival in a refuse/sludge forced aeration compost system. Pergermon Press in Effluent treatment and disposal.

2) MORGAN, W (1980) Sewage sludge: Processing and marketing,converts a problem into beneficial products. Hort.Science 15 No 2, 168-169.

3) SANDERSON, K (1980) Use of sewage/refuse compost in the production of ornamental plants. Hort.Science 15 No 2, 173-178.

4) SIMEONI, L, BARBARICK, K S and SABEY, B (1984) Effect of small scale composting of sewage sludge on heavy metal availability to plants. J.Environ.Qual. Vol 13, No 2 246-268.

SPENT MUSHROOM COMPOST (SMC).

1. BACKGROUND: The production of mushrooms is based on a compost using chopped straw, horse or poultry manure, calcium sulphate gypsum and a sugar source such as molasses. The production of the compost is well regulated and generally the end product can be considered consistent (see problems below). Currently the material is mainly used in horticulture as a recycled ingredient for tree planting mixes or as a soil conditioner.

2. SOURCE(S): Spent compost from mushroom manufacturers/growers.

3. AVAILABILITY: Estimated at 750,000 m^3 per year in UK.

4. PRICE:

5. COLOUR: 10YR4/1.

6. TEXTURE: Fibrous when dry but can be greasy when wet.

7. ODOUR: Earthy, can become sour if anaerobic conditions are allowed to occur.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
7.3	1400	(mg/l)	9.0	1426	89.0	19.0	<1.0
	9	(Index)	2	8	7	5	0

9. COMMENTS ON THE ANALYSIS: Very high soluble potassium and Ec, (conductivity).

The major source of nitrogen (protein) becomes available during the tertiary composting and maturing of the material.

10. ADDITIONAL ANALYSIS: Density is similar to peat but can increase with age; bio-assay to determine organic contaminants such as herbicides is needed.

11. GENERAL NOTES ON THE USE OF SPENT MUSHROOM COMPOST IN HORTICULTURE:

It is used mainly at present as a low grade product for tree planting/mulches. Some polymers and dilutants are added but there is no major treatment to improve the product and add value. Its major problem is in physical stability and stabilisation (Lemaire et al, 1985).

12. CAUTIONARY NOTES: Herbicides in straw may be tolerated by mushrooms but must be eliminated or identified if persistent, as container grown plants would be affected. However with current laws (COSHH) to ensure safe use of chemicals, their use should now be clearly identified. The major problem is the lack of separation of the spent mushroom compost from the casing material. Casing is generally peat plus chalk. If producers could or would separate the casing, long-term potential for use of spent mushroom compost would be much greater.

13. FUTURE WORK: 750,000m^3 of spent mushroom compost is 'available' each year. This is a consistent and reliable source of a peat alternative.

In commerce, compost is in the 'third stage of composting' during actual mushroom production and harvesting. When commercial production ceases the compost still needs to be matured - and probably co-composted with ingredients such as wood chips. This latter process needs investigation. Ways of reducing soluble potassium, without causing environmental problems from leaching, need to be found: zeolite may well prove useful.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) DEVONALD, V (1987) Spent Mushroom Compost, A possible growing medium ingredient? in Compost: production, quality and use Bertoldi M, et al. (Ed).

2) GERRITS, J (1987) Compost for mushroom production and its subsequent use for soil improvement. in Compost: production, qaulity and use, Bertoldi M, et al (Ed).

3) HENNY, B (1979) Production of six foliage crops in spent mushroom compost potting mixes. Proceedings of the Florida State Horticultural Society 92. 330-333.

4) LEMAIRE, F, DARTIQUES, A and RIVIERE, L (1985) Properties of substrates made with spent mushroom compost. Acta. Hort. 172 13-29.

5) LOHR, V, O'BRIEN, R and COFFEY, D (1984) Spent mushroom compost in soilless media and its effect on the yield and quality of transplants. Hort. Science 19 5) 693-697.

6) LOHR, V, WANG, S and WOLT, J (1984) Physical and chemical characteristics of fresh and aged spent mushroom compost Hort. Science Volume 19, (5) 681-683.

7) WOOD, D et al (1984) Research and the mushroom industry. Journal of the RASE. 144-157.

VERMICOMPOST

1. BACKGROUND: The major advantage of worm working any waste is that the end product becomes a friable odourless material. Vermicompost can be produced from a number of sources . Various commercial attempts to produce worm-worked material have failed in the past because markets have not been closely identified and therefore the product range has been inappropriate. The worm composting or digestion of wastes is particularly useful for dealing with materials which would otherwise be extremely unpleasant to handle; various products such as waste paper, poultry manure, vegetable wastes have been looked at already and R and D work by Edwards and Lofty at Rothamsted was adopted as a commercial concern under the title of "BETA GRO".

2. SOURCE(S): At present, limited to mainly farm gate sales by a few producers left after the "BETA GRO" collapse in 1988.

3. AVAILABILITY: Only local, and one firm turning-worms in South Wales.

4. PRICE: Similar to peat-based potting mixes used in the retail market.

5. COLOUR: 10YR4/2.

6. TEXTURE: Soft friable crumb.

7. ODOUR: Earthy.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
9.3	1510	(mg/l)	249	2866	66	5	8
	9	(Index)	8	8	2	0	0

9. COMMENTS ON THE ANALYSIS: Note - very high pH and conductivity with associated high potassium levels; analyses of samples vary depending on source of manure, but generally worm working wastes produces high avaiable nutrients.

10. ADDITIONAL ANALYSIS: Analysis of heavy metals is necessary, depending on waste source but particularly when some paper waste sources are used.

11. GENERAL NOTES ON THE USE OF VERMICOMPOST IN HORTICULTURE:

    At the present time Vermicompost has several uses; seed compost, universal composts and as a soil improver. However, given the analysis, the material is best considered (depending on the source of the manure) as a fertiliser rather than as a potting compost due to the high soluble salts content. It has been successfully used as a peat amendment by some growers but gives variable results and needs careful management.

12. CAUTIONARY NOTES: Survival of pathogens could pose a risk to humans. Heavy metal content may be a risk depending on source of waste.

13. FUTURE WORK: There is no real advantage in worm working wastes if a manure/waste can be composted aerobically. The latter process is more likely to kill off undesirable organisms. The time and labour costs in producing worm-worked manure dictates that a market niche needs to be established. Its appearance, handling qualities and user perception of the product are key marketing elements.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) ANON Making worm compost, HDRA Coventry. Note - not dated.

2) BRAGG, N (1990) Worm working manures and waste. ADAS Technical Note 90/9.

3) GRIFFIN, C (1990). A Guide to Organic Varieties. Grower June 28.

4) HAIMI, J and HUHTA, V (1987) Comparison of compost produced from identical waste by vermistabilization and conventional composting. Pedobiologia, 30 137-144.

5) HAND, P, HAYES, W A, SATCHELL, J E and FRANKLAND, J (1988). The Vermicomposting of Cow Slurry . Earthworms in waste and environment EDWARDS, C A (Ed). 49-63.

6) HARRIS, G, PLATT, W and PRICE, B (1990). Vermicomposting in a rural community.Biocycle January 48-51.

7) PRICE, J S and PHILLIPS,V (1990) An improved mechanical separation for removing live worms from worm worked organic wastes. Biowastes 33. 25-37.

8) SCOTT, M (1988) The use of worm digested animal waste as a supplement to peat in loamless compost for HONS. Earthworms in waste and environment EDWARDS, C A (Ed). 221-229.

WOOD WASTES

1. BACKGROUND: These are materials, other than bark, which has been dealt with separately, and include shavings, sawdust and separated fibre. It has been suggested that the wood or timber trade produce up to 40 per cent waste during processing, i.e. sawing and planing of imported material and home produced material. Recently, however, a German/Irish consortium have produced a saw blade which markedly reduces such waste (BBC Tomorrows World - July 1990).

2. SOURCE(S): Both hard and softwoods as produced from home and imported material.

3. AVAILABILITY: Competition comes from the fibre-board/chipboard manufacturers.

4. PRICE: N/A

5. COLOUR: White to grey.

6. TEXTURE: Soft to hard chips to fibrous.

7. ODOUR: Resinous to none at all, depending on treatment.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

	pH	Ec (µs)		P	K	Mg	NO_3-N	NH_4-N
Wood waste	7.9	551	(mg/l)	42	647	19	5	60
		4	(Index)	6	6	3	0	2
Wood fibre	5.3	20	(mg/l)	<20	<10	<5	4.0	1.0
		0	(Index)	0	0	0	0	0

9. COMMENTS ON THE ANALYSIS: Analysis depends on how the material has been won; it can be desperately short of nitrogen. Much work has been done on composting wood waste by the Australians and North Americans.

10. ADDITIONAL ANALYSIS: Density: Low similar to peat when in the fibrous state, i.e. 150-200 g/l fresh.

11. GENERAL NOTES ON THE USE OF WOOD WASTE IN HORTICULTURE: It is widely used in Australia and North America after composting with nitrogen as basic ingredients for potting-type mixes for both pot plants and container-nursery stock plants.

12. CAUTIONARY NOTES: Some people may experience slight skin irritation with some products; dust masks are advised if using in enclosed spaces when mixing.

13. FUTURE WORK: Considerable work to examine the possible use of all wood waste products is needed. Stabilised wood fibre presents a very attractive addition to new composts: however questions exist over how the wood fibre has been stabilised and if there is any chance of further breakdown with time. We have little information on stabilised fibre.

Strategic work should be commissioned (University, Polytechnic) and also agronomic trials.

There is a need to do work on other wood waste products such as sawdust and shavings as co-composted products with both animal manures and separates, sewage and domestic refuse. The high cellulose and hemicellulose contents of wood waste can provide some problems of fungal growth but this can be managed if the co-composting operation is done correctly. Work should be done on these materials as a high priority. Work has been done at the West of Scotland College on wood waste products with regard to their use on a semi hydroponic basis and this work should be pursued. (Interestingly where wood wastes are used in semi-hydroponic media, the anticipated problems of toxins from fresh wood wastes seems to be small. Possibly the constant washing through by nutrient solutions removes the risk of any toxic build-up.)

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) BUNT, A C (1988) Media and mixes for container grown plants. Unwin Hyman London.

2) HANDRECK, K and BLACK, N (1986) Growth Media for Container Grown Plants. University Press, N S Wales, Australia.

3) REYNLSKI, F (1982) Evaluation of a Gasifier Residue as a Container Media for Woody Ornamental Plants. Hort.Science 17 (2) 209-210.

STRAW PRODUCTS

1. BACKGROUND: Some straw wads are still used in cucumber production where decomposition of the straw liberates CO_2 and beneficially enriches the atmosphere of the cucumber plants.

   There is increasing interest in alternative uses for straw. The current problem over disposal is likely to become worse with the complete ban on burning (1992) and difficulties of incorporation into certain soil types. The material would need to be collected and processed either centrally or in well organised local units. In its raw form, straw does not have much use as a container substrate.

2. SOURCE(S): All arable farming in UK.

3. AVAILABILITY: At least 6 million tonnes are available; this is distributed widely but evenly across the country.

4. PRICE: -

5. COLOUR: Creamy yellow texture.

6. TEXTURE: Spikey, coarse, fibrous.

7. ODOUR: Some flour like odour.

8. CHEMICAL ANALYSIS OF WATER EXTRACT:

pH	Ec (μs)		P	K	Mg	NO_3-N	NH_4-N
6.7	720	(mg/l)	18	1150	38	8	<1.0
	6	(Index)	3	8	5	0	0

9. COMMENTS ON THE ANALYSIS: In the raw form very little can be deemed from an analysis of straw: it needs composting or processing first.

10. ADDITIONAL ANALYSIS: Bio-assay is necessary if there is uncertainty about which herbicides have been used. The C/N ratio for straw is approximately 150:1 and usually stabilises at 30/40:1 after composting with nitrogen.

11. GENERAL NOTES ON THE USE OF STRAW PRODUCTS IN HORTICULTURE: It is used currently as a mulch material to soft and top fruit; used also for winter protection and in plunge beds.

12. CAUTIONARY NOTES: Herbicide residues are obvious risks. COSHH rules may mean that this is more easy to track down and identify the precise chemicals which have been used on particular crops.

13. FUTURE WORK: Straw is best considered as a co-composting material and a number of materials such as sewage and farmyard slurries have already been used. Vegetable wastes and residues which can supply nitrogen such as hops, together with fishmeal, blood and bone, may well be worth consideration. Considerable experience can be drawn from the use of straw by the mushroom compost production industry. It is suggested that methods of handling straw on a large scale and the co-composting with

other materials should seriously be considered as this would be an ideal way of dealing with a number of currently wasted resources.

Note - However in the composting of straw there are two areas of concern,

1. High levels of potassium become available as a result of the composting process; and

2. Large volume changes can be expected - i.e. 30-40 per cent volume loss, following carbon dioxide production.

14. REFERENCE TO USE OF THE MATERIAL IN HORTICULTURE:

1) ANON (1983) Cucumber production: growing media and nutrition. MAFF Booklet 2092.

2) BIDDLESTONE, A, GRAY, K and COOPER, D (1986) Straw based techniques for composting. Biocycle March edition.

3) BORDER, D, COOMBES, C and SHELLENS, M (1988) Composting straw with untreated liquid sludge. Biocycle July edition.

4) BRAGG, N, RICHARDSON, S and VAIDYANATHAN, L (1990) Straw as a peat substitute in composts. Proceedings of PIRA Conference, Peterborough, England.

5) SCOTT, M (1983) Work on Coated Straw for Container Nursery Stock, Using Resin Coating. Efford Annual Report.

PULVERISED FUEL ASH

1. BACKGROUND. Produced as a waste from Electrical Power Generator plants where coal is burnt. There is a risk of high levels of boron and aluminimum being available and causing phytoxicity symptoms.

2. SOURCE(S): Limited number of power stations.

3. AVAILABILITY: Limited to a small number of stations and competing use is as high value additive to cement. A Podzolannic process - first used by Romans - produces the product Lytag.

4. PRICE: £10-£20/tonne.

5. COLOUR: Dark brick red.

6. TEXTURE: Spherical.

7. ODOUR: None.

8. CHEMICAL ANALYSIS OF WATER EXTRACT: not applicable if sintered.

9. COMMENTS ON THE ANALYSIS: Inert.

10. ADDITIONAL ANALYSIS: None.

11. GENERAL NOTES ON THE USE OF PFA IN HORTICULTURE

    Has been used successfully as a 'ring-culture' media and also used extensively in office/work place planting displays to provide care-free surface and a high localised humidity.

12. CAUTIONARY NOTES: No problems if boron and aluminium levels are low.

13. FUTURE WORK: Use could easily be extended and products with a wider range of particle sizes developed for amateur use.

14. REFERENCE TO USE IN HORTICULTURE:

FRETZ, T, GILLIUM, C, SHEPPARD, and POOLE, H (1980) Aggregated Fly ash as a Medium Amendment for container grown ornamentals. Common, In Soil Science and Plant Analysis 11(4), 379-392.

LISTING OF OTHER MATERIALS, KNOWLEDGE OF WHICH IS LIMITED

1. PAPER WASTES: This is a slurry of paper fibre and clay produced from primary production of paper. The sludge is often grey brown to blue but can be coloured pink or green depending on the source. Reference to its use in horticulture can be found in D V LEESCHAUWER et al (1981). The use of chicken and piggery manure in compost, Acta. Hort. 126, 105-111.

   Small observation trials have been done by ADAS in 1990 and, whilst the material is rather smelly, not unlike sewage, it has no nutrient value and does not appear to upset plant growth although nitrogen management is critical.

   Recycled newsprint might be useful but there is a problem with the printers inks which may give rise to metal and organic contaminants. Work is needed on this type of material to develop it and especially to determine nitrogen requirements and management. It is potentially a useful material.

2. SEAWEED: Seaweed is already being used by Wye College (London) subsidiary Controlled Composting Systems. Undoubtedly the material does have a place in co-composting with other materials, and is a useful source of trace elements.

3. FOOD PROCESSING WASTES: Numerous materials are included among such wastes: waste vegetables, factory washing, peelings from the potato industry, etc. These materials should be considered as a source of both sugars and nitrogen for inclusion in operations of co-composting, e.g. with straw.

4. RICE HUSK OR HULL: In UK there is no readily available source, but in Italy, large amounts of waste husk are available. The material needs steam sterilising but can then be used as an ingredient in a compost/substrate as a physical additive. It is already available in proprietary mixes from Europe and appears successful - some clinical advantages were claimed, i.e. from enhanced silica for cucumber production.

5. SUGAR CANE (BAGASSE), TOBACCO WASTE, COCOA SHELLS, LIQUORICE ROOT: These materials would have to be imported specifically to be of any use. References to them is found in the literature but no recent evaluation has been done on any of the materials with the exception of cocoa shells which are currently sold in the UK as a mulch material. Physically many of these materials do look quite promising. Work in Israel reports that the use of liquorice root is effective at disease suppression. Suppression of Pythium aphanidermatum damping-off in container media containing composted licquorice roots. HADAR, Y and MANDELBAUM, R (1986) Crop Protection 5 (2), 88-92.

6. LIGNITE: Lignite is a soft coal deposit associated with English china clay workings in Cornwall. It has been available as a potential substrate ingredient for some time;

   DE KOCK, P and RMECKI, E (1954) An investigation into growth promoting effects of a lignite, Physiologia Plantarum Volume 7.

KAMP, M and EMINO, E (1983) Growth Response for Container Grown Plants in Potting Media Amended with Lignite, Acta.Hort. 133.

Lignite is also currently used in an organic-based substrate in the UK and no doubt will make a good co-composting ingredient. Evaluation of the material, with particular regard to nitrogen management is needed.

7. BIOMASS BYPRODUCTS: Some by-products of biomas production, e.g. wood chip are not suitable for certain fuel requirements and could be available in large quantities. It should be considered as a co-composting ingredient with other materials such as sewage or farm effluents.

It is evident that the list of materials which could be or should be looked at will grow as people become more aware of the potential for these apparent wastes. Consistency and continuity of supply are essential pre-requisites before the necessary and essential product evaluation is undertaken.

SECTION 5

COMPOSTING

The Principles of Composting

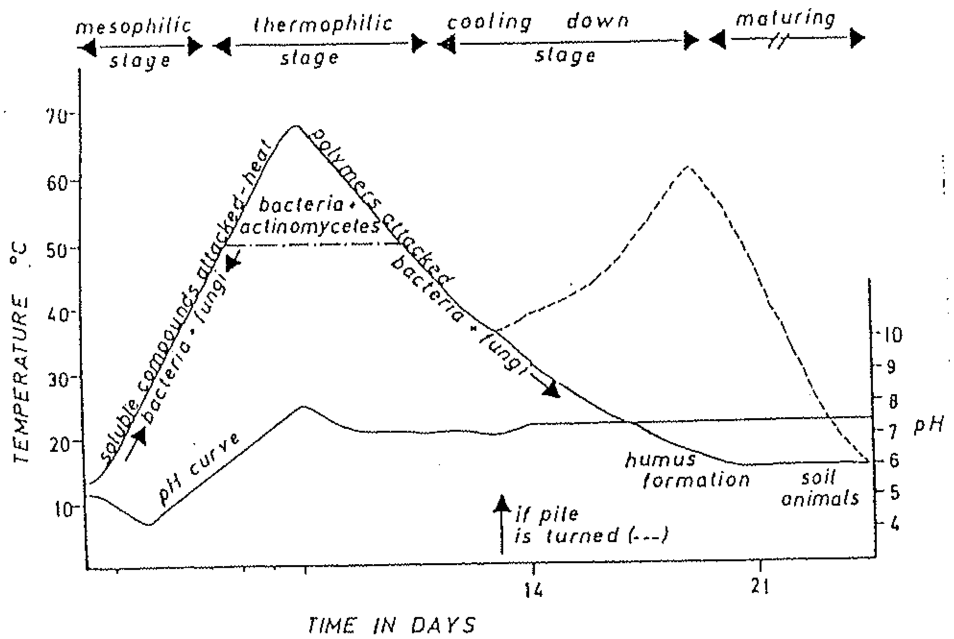
Composting in the true sense is a process in which micro-organisms degrade material to the point where all accessible carbon sources have been depleted. The micro-organisms themselves then mostly break down leaving a small population with reduced activity.

In any composting cycle there are various stages: these have been well described in a review by Lopez-Real (Fertiliser Society Proceedings, 1990) and by Zucconi and Bertoldi (Biocycle, 1987). All composting operations can be split into four stages.

The Composting Cycle

Initially, a mesophilic stage when temperatures reach up to 30°C is followed by a second thermophilic stage when bacteria are killed out. This results in chemical degradation which is followed by an eventual cooling down stage when fungal hyphae may invade the composting heap. Finally there is a maturing stage (Fig. 4).

Figure 4. A Temperature Curve of Composting



After Lopez-Real, 1990

In composting any material a series of changes take place, which offer clear advantages.

a) Reduction of up to 40 per cent of the original volume may occur. It should be noted however that most of the volume loss is because of CO_2 given off to the atmosphere. Therefore all composting operations contribute to global CO_2 production.

b) Loss of water occurs which means the material is actually drying during the composting process. Materials have to be wetted during the process in order to ensure maximum biochemical and microbiological degradation.

c) Stabilisation of end product. This is an important element of the maturing stage.

d) Suppression or removal of pathogens which currently is not thoroughly understood and needs considerable investigation. Stentiford 1990. (See also later section on Health & Safety).

The major limiting factors to successful composting of any material are:

Sufficiently open structure to allow air movement through heaps.

Sufficient moisture to allow even degradation.

Sufficient available nitrogen to meet the microbial demands.

Available nitrogen is of considerable importance, much attention is given in the literature to C/N ratios of materials. However the C/N ratio in itself is not useful in a comparison of breakdown and eventual stabilisation of different products. Two or more materials may both start with similar C/N ratios, i.e. 150:1, but they will not end up with the same C/N ratio after composting. This is because each material has its own particular inherent available sources of carbon. (Golueke and Diaz 1990).
The only meaningful test is to take the material and to incubate it with excess nitrogen and measure its rate of aerobic respiration and hence its stability. This is not a standard procedure but requires further evaluation in order to rapidly assess what will happen to any material during composting and maturing stages.

Requirements for New Raw Materials

To be suitable for composting a new material must be examined and assessed with other materials which will enhance its moisture content, stabilise it physically and provide the nitrogen needed for successful biological degradation.

There are various commercial groups, Controlled Composting Systems, (Wye, Lopez-Real), Hensby Biotech, Water Research Council who are able to act as consultants on composting of new materials. Composting - an introduction to the rational use of organic waste, (Pfirter et al 1981) is essential reading. Composting groups, such as Controlled Composting Systems (Wye), have been established to look specifically at the suitability of mixing different materials in order to achieve the best physical/biological mixes and hence optimise potential composting operations.

Concentration of Metals

The major consequence of any composting operation is to reduce the volume of organic material and to leave a stabilised end product. However, as a result of volume reduction both nutrients and metal contaminants become effectively more available and at apparently higher concentrations (based on a smaller dry matter level) at the end of the composting operation. This potential problem has received wide-scale examination in composting of municipal solid waste (MSW). (See page 68.)

Whilst heavy metals such as cadmium, zinc and lead are possible contaminants, major plant nutrients such as potassium may reach unacceptably high levels which will imbalance the uptake of other nutrients such as magnesium.

Therefore there is the need to carefully consider elemental concentrations in the raw materials and to predict the available concentrations in the composted products.

Particle Size

Particle size is critical in the context of composting operations; for example the inclusion of large wood chips provide good physical conditions when co-composted with sewage sludge in the USA. The wood chips are later recovered from the composted material and re-used numerous times. Once the outer crust of the wood chip has composted, subsequent composting into the centre of the chip is so slow as to make the chip effectively stable. If however the chips were physically broken by milling, then a fresh composting cycle could take place.

SECTION 5 References

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4) PFIRTER, A, VON HIRSCHHEYDT, A, OH, P and VOGTMANN, H (1981) Composting - An Introduction to the rational use of organic waste. 'Migros-S-Production', Migros Co-operative Aargan/Solothurn (Switzerland).

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SECTION 6

HEALTH AND SAFETY ASPECTS OF THE USE OF NEW MATERIALS

In the general section on composting, reference was made to health and safety aspects when undertaking composting operations. Potential risks exist with all biological wastes for a number of reasons and at a number of positions in the processing cycle.

All raw putrescible wastes may contain human pathogens or support the growth of moulds and yeasts which are potentially pathogenic. A complete summary of all the risks is given by Bontie and Moline (1987).

Bontie and Moline's work includes three areas of concern:

1. Primary pathogens of intestinal origin (bacteria, virus, intestinal parasites, cysts or eggs).

2. Secondary pathogenic fungi, mainly moulds, which develop during the composting and stockpiling - here the primary concern is with regard to <u>Aspergillus fumigatus</u>.

3. Bacterial and fungal allergens and toxins.

The paper examines the risks both to the workers involved in the composting operations and also the end users. The paper highlights that at present insufficient data is available and that because of this lack of information no real risk assessments can be made.

In the UK at present the only guidelines for safe composting are given by the DoE - With Reference to Sewage Sludge (1989). "The compost must be maintained at 40°C for 5 days and for 4 hours during this period at a minimum of 55°C within the body of the pile, followed by a period of maturation adequate to ensure that the compost reaction process is substantially complete". This has been challenged by Stentiford (1990). The author feels that the DoE recommendations do not go for enough, nor do they cover operations such as worm working wastes, or anaerobic digestion of wastes. Also no real attempt to look specifically at viral pathogen survival has been identified.

♦ **Strategic work is essential here in order to elucidate the matter further.**

Reference should also be made here to 'COSHH'* with regard to the use of all materials within this Review. Many of the materials identified within this review would require users to consider the use of positive 'air-stream' type respirators and protective clothing (which might need to be disposed of when moving between the workplace and rest area). Further guidance on this area must be sought and any producer of a material must supply Hazard Data information to match COSHH requirements to end users. (Hurst 1986)

* COSHH - Control of Substances Hazardous to Health Regulations 1988 and Section 6 of the Health and Safety at Work etc Act 1974 (See HSE IND(G)97L)

* COSHH Control of Substances Hazardous to Health.

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Waller P	Fisons (Hort) plc
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Section 6 References

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SECTION 7

CONCLUSIONS

Peat

Peat has become a generic term for all accumulations of partially decomposed, relatively stable organic matter which can be used as growth media. Some peats are excellent as components for growth media while others are physically difficult to manage and could easily be replaced by suitable alternative ingredients. Various types of peat can be found throughout the UK depending on the topographical and climatological position.

Peat Formation and Regeneration

No categoric statements can be made with regard to absolute values of rate of regeneration. Whilst 0.5-1 mm per year is quoted as a rate of accumulation, too many assumptions are included with regard to climate and arterial drainage in the re-growth area. Also the quality of both precipitation and groundwater will make considerable difference to the species composition. Closely tied-in with the rate of growth is the rate of decomposition of peat reserves due to arterial drainage and associated lowering of groundwater levels. It is suggested that once the surrounding area of moss is drained, and the moisture changes the moss to below 70 per cent by volume, then the maximum rate of decomposition and CO_2 generation follow.

Current Peat Use

Professional horticulture uses between 1.0-1.5 m^3 of peat/annum: this is estimated to be 40-50 per cent of overall UK use of peat. The Review has detailed this professional use of peat and peat-based products. The other 50-60 per cent of usage is split between the retail market and the landscaping/contracting by local and national authorities such as water companies and the Department of Transport.

As plant growing has become more technical and science based the actual professional use of peat has declined, i.e. in the case of tomato production, most crops are now grown in media such as rockwool, perlite or NFT.

Peat as a Resource

Peat is estimated to cover 8 per cent (400 million plus ha) of the land surface of the world. The UK with 1.6 million hectares of peatland, is estimated to have 0.4 per cent of the 400 million ha. The UK reserves are divided between England and Wales with 519,000 ha, Scotland with 821,380 ha and N. Ireland with 240,000 ha. In the Republic of Ireland as much as 1 million hectares is recorded. However all these figures need refining into peat which has been, is, or could be exploited.

Current Areas Being Worked and Rate of Loss

The overall resource held by the UK peat producers appears to be in the order of 8,000 ha although, from the estimated rate of exploitation, only 1,000 ha is being worked at any one time. If no more extraction licences are granted beyond those existing then the committed peat reserves (8,000 ha)in the UK could reasonably be expected to last 40-50 years, assuming no increase in demand.

* O.D. - Ordnance Data

Imports

Only about 40 per cent of peat used appears to be imported currently although annual imports vary and depend very much on our harvest conditions in any one year. However, if a complete ban on UK peat extraction was imposed, countries such as Russia, which has 64 per cent of world reserves, would undoubtedly increase their exports. The requirement for foreign exchange to maintain their own economy may weigh heavier than conservation.

Other countries such as Finland and West Germany* have already considered conservation needs and have established a policy which allows, at least for the present, exploitation of peat for horticultural use.

The Professional Horticulture Sectors

Of the professional sectors of horticulture, the pot plant industry stands out as using the most peat. Most people would think that nursery stock, because of the large size of containers used, would be using more peat. However good marketing has turned the pot plant into 'the present' for a special occasion and plants have begun to be regarded as disposable products. This suggests that peat is rather wasted in this context even though it gives uniform plant growth.

* now United Germany

Many other sectors' use of peat is less than a 100,000 m^3 per year and attention is drawn to the fact that, as technology has increased, so actual volumes of peat being used have declined whilst the numbers of plants being produced have increased.

In the raising of young plants for the following sectors; vegetable production, bedding plants, micropropagation, nursery stock liner production and pot plants, peat is undoubtedly the most reliable material to achieve uniform quality. Even if the plant is later weaned into a totally peat-free material, for the present the most consistent results are likely to be obtained using peat-based products.

In the other product sectors such as hanging basket, tree planting and general soil amendments, then the use of peat, both by professionals and amateurs, really wastes a resource and the pursuit of alternatives must have a high priority. Many materials other than peat are used currently by these sectors but often the variable results which are obtained only reflect the small effort being put into developing the products to a particular specification.

The Alternatives

No one material can immediately replace the peat which is used in the professional and/or amateur markets. There is not, at present, sufficient quantities of consistent materials, and in many cases insufficient experience/knowledge of necessary long-term management of plants in alternative materials. While attention has been drawn to such products as sewage co-composted with straw and coconut waste the materials are still very new to growers. Most manufacturers/importers realise that, whilst the 1990 season has seen a limited success in the use of these materials, much work is needed over a number of seasons before reliance can be placed on their products.

- Many of the alternatives available differ greatly from peat: they are biologically active and represent relatively young organic matter sources which need stabilisation. As of autumn 1990, no one single material is available in sufficient quantity or produced to a level of consistency to replace all professional peat requirements. Considerable work is necessary before many of these materials can reach their true potential. Particularly attention must be paid to the microbiological status of the material. All new materials should be carefully examined for their potential to support fungal moulds, and tested regularly for human bacterial pathogens. In order to meet with COSHH regulations manufacturers and importers must produce hazard data sheets. All end users have the need to see such data sheets, so that they themselves comply with COSHH regulations.

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APPENDIX I

List of organisations and individuals consulted during preparation of the review

Bailey S	ADAS Lon.
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Braunholtz J Dr	HDC
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Britt C	HRI
Bunt A C	Ex GCRI
Cohen M	DTI London
Coutts S	Four Oaks Nursery
Dale B	Bridgemere
Davis P	Wyevale Nursery
Dawson C Ms	Camland Products
Dobbs E Ms	Gardening from Which?
Dunnit M	Blakedown Nursery
Eames A	ADAS Specialist
Farthing J	ADAS Specialist
Gabriels R Dr	Belgium
Gilbert D	ADAS Specialist
Greenwood D	Wellesbourne HRI
Grice R	Croxden Hort.
Hall D Dr	West of Scotland College
Handreck K Dr	CSIRO Australia
Hamilton G	Barnsdale/BBC
Hayes J	Bulrush Peat Co
Howard B Dr	HRI East Malling
Hubbard I	Richmoor Peat Co Ltd
Kielman F	Hydro Agric Holland
Kitchen H	ADAS Specialist
Joyce M	Woodland Nursery
Lennarston M Dr	HDRC Coventry
Love J	Sainsburys plc
Manley M	Munro Hort
Maynard R	FoE
Monks P	Laporte ind.
Muirhead A	Golden Grow
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