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RESEARCH TOPIC REVIEW: Organic plant raising

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1. Scope and Objectives of the Research Topic Review:

The objectives of this review were to identify and review research undertaken on the topic of organic plant raising, to draw on grower experience and to summarize the practical implications for organic growing. The issues to be addressed by the review included the following:

- Use of bare root versus modules
- Growing media formulations and management
- Avoidance of peat
- Nutrient release and liquid feed
- Plant propagation using modules
- Management of bare root transplants

1.1 Background – The historical context

The use of vegetable transplants gives a number of advantages to organic as well as conventional growers. Transplants can help extend the season and allow the grower more time for weed strikes and for soil temperatures and biological activity to increase. Transplanting gives the crop a head start over weeds and can save labour and cost of hand weeding. They can also enable longer time in the ground for fertility-building crops. Up until the 'sixties transplants of field crops such as brassicas and leeks were grown as bare-root transplants or 'pegs'.

Over the last 50 years we have seen the development of propagation techniques move from pegs to plants grown in hand made containers filled with soil-based substrates then to the use of bloxers, peat blocks and eventually cellular modules. Forty years ago the polythene bloxers systems provided many small vegetable holdings with their only form of transplants other than bare root plants. It consisted of a polythene strip wound between metal posts on a jig that fitted into a seed tray. The bloxers were filled with peat substrate and the plants grew in their own self-contained square. At planting, usually by hand, one end of the polythene was pulled free and the whole batch of independently rooted plants was removed. Plastic pots, vermi/peat cubes and peat blocks became popular in turn. Initially blocks were developed mainly for the glasshouse lettuce industry but were eventually also adopted for field grown crops like early cauliflower. The peat block revolution was spurred on in the 1970's when results of trials carried out in Norway shown advantages both in earliness and total yield of block raised crops. The Dutch began to mechanise the making, seeding and handling of peat blocks, which soon resulted in the establishment of specialist peat block propagators also in the UK, catering for the outdoor vegetable industry in addition to the glasshouse sector.
In Holland developments led to the fully discrete block in a polystyrene container which segregated one plant from its neighbours. The chocolate slab style of peat block produced in the UK were cheaper but because the individual blocks were not completely separate, had the drawback of allowing roots to intermingle. The blocks were also difficult to separate quickly.

In the mid 70's, UK growers began to adopt the invention of the module systems and with the help of the plastic manufacturers the first 308-cell plastic tray was developed. (Grower, 1994)

While many organic growers continued using pegs, many followed the conventional growers in adopting systems based around modules and/or blocks. Up until 1997 the organic standards still allowed organic growers to use non-organic modules.

Conventional practice for modules was to raise transplants in peat-based media; the physical (able to hold both water and air) and the chemical properties of peat made it ideal for this purpose. The low or negligible levels of nutrients in the peat were considered an advantage for conventional production as the supply of nutrients could then be controlled by adding precise amounts of readily available or control release fertilizers. All of the phosphate (as single super phosphate) and micro-nutrients that the transplant would need were added to the peat, but only relatively low levels of nitrogen and potassium to avoid phyto-toxic concentrations of nutrients in the medium. The nitrogen and potassium that the transplants required during growth was provided by liquid feeding several times per week with nutrient solutions containing up to 200:200 mg/l nitrogen/potassium (ADAS 1990). This system provided benefits in that the growth of the transplants could be manipulated; by adjusting the nutrient supply growth could be slowed-down or speeded-up to fit in with planting dates or manipulated to produced transplants of specific qualities eg ‘hard plants’. Growing the transplants in small cells provided costs benefits and also the development of a root system/plug that was suitable for mechanised planting.

As early as in 1981, The Organic Growers Association (OGA) set up trials to test different growing media and the results were reported in a session on growing media at the BOF/OGA conference in 1985 (The Organic Grower #2 2007). The need was recognised to develop growing media using materials that met organic standards and not simply to replace the conventional liquid feed with an organically permitted one. A number of research projects, both privately and publicly funded, followed which will be referred to in this review. The first Soil Association symbol for growing media, approved for use in organic systems, was granted to Turning Worms in 1986 and by 1997 seven different organic module composts were available for evaluation in seven years of Defra-funded trials (Anon 2001). By 2007, only 4 module composts were available and the production of Sinclair’s (previously ICI) which had been used by the majority of organic growers without problems until 2005 had been discontinued. In response to this the Organic Centre Wales conducted grower trials in 2007 on commercially available substrates organic modular transplant raising (Little., *et al* 2007) and the Organic Growers Alliance (OGA) appealed to its members for their experiences of using the available composts (The Organic Grower 2007). A resultant session at the Cirencester Producer conference in December 2007 discussed why despite much research into growing media, the industry seems to be no further ahead than in 1981. Hence the need for this review, to pull together the research.

2. Summary of Research Projects and the Results

2.1 Systems

Vegetable crops are generally established either by direct sowing or by transplanting them into the final growing position. Before transplanting plants may need to be ‘hardened off’ for a period to acclimatise them to field conditions and in many cases will need to be watered in, especially under dry conditions. Transplants can be raised as bare-roots, blocks or in modular trays or pots. Professional organic plant-raisers exist and are generally used by larger organic growers with simpler systems. Professional plants raisers have heated greenhouses (for early production at least) and automated systems of tray-filling and seeding trays, enabling costs to be kept down. According to the Horticulture Development Council (2005) only 10% of module plant raisers move their plants to a hardening off area during the production cycle, due to a lack of investment in mechanization of module tray handling. Many smaller-scale producers with complex multi-cropping systems for direct-marketing favour raising their own plants. This allows more flexibility for the grower and cuts down on deliveries. Bought-in bare-root transplants are not permitted in organic systems.

2.2 Bare-root transplants

Bare root transplants can be a realistic option for organic growers (see analysis and conclusions) but are only suitable for brassicas (with the exception of roots and oriental salads) and leeks.

An area of 0.1 ha (0.25ac) with rows 25 cm (10”) apart should produce around 40,000 brassica plants, while leeks can be raised at the rate of 10,000 plants per 120 m of row length. Rows can be spaced further apart to allow for easier weed control, depending on space available. Brassica plants can be targeted at 2 to 2.5 cm apart in the row. Leeks can be 3 to 4 times denser than this (Deane, 2005). If brassicas are raised under protection, ventilation needs to be good, because there is no opportunity to harden them off prior to planting out. Flea beetle can be a problem with outdoor sowings and crop covers will be needed. Depending on sowing time and variety (aiming for six true leaves) 6 to 8 weeks should be allowed in the seedbed for brassicas though 10 weeks would not be too long if the planting mechanism will accept a plant of the resulting size. Leeks should be pencil thick at planting - about 12 weeks from sowing. At these stages both leeks and brassicas are pretty tough. Irrigation may be necessary for lifting from the seedbed. For brassicas as much root as possible should be retained, whereas leeks will re-grow roots on transplanting. Trimming may be necessary for ease of handling and to reduce wilting on planting. Leeks are best planted immediately after lifting. With brassicas the traditional scheme (with no irrigation available) was to plant immediately in cool and moist weather, but to cover and store the plants for two days in a shed (or even hedge bottom) in less favourable conditions. During this time they will start to produce new secondary roots, which will actively grow into the soil at planting. So long as the plants are placed at a good depth and well firmed, and are not already under root fly attack, there is no reason to anticipate losses (Deane, 2005).

2.3. Modular tray transplants

Today most transplants, organically and conventionally, are raised in plastic module trays, which are divided up into discrete cells. Seeds are directly sown into the pre-filled trays. Both tray-filling and sowing can be mechanised. The plastic module trays have the advantage over polystyrene, their predecessor, in that they can be more easily cleaned between seasons and can be re-used more easily. They are relatively cheap and handling is easy for mechanical planting in the field. Modules are suitable for most transplants, although some growers favour blocks for lettuce and celery raising (Schofield, 2007). Plastic modular trays are available in different colours, though the colour of the tray has been shown to have little or no effect on the temperature of the growing media, according to research in Tennessee who tested black, grey and white module trays (Greer and Adam, 2005).

2.4 Cell size

Propagation trials at HDRA in 1994-95 as part of the Defra (MAFF) OF0109 project (EFRC 1996) concluded that for all crops, the choice of cell size had a clear effect on the growth of the organic transplants and was more important than the choice of growing medium. Transplants grown in the larger cell sizes, providing individual plants with a larger volume of substrate, tended to be larger and of superior quality. Cabbages grown in either Dickensons or ICI organic (later to be Sinclairs) grew best in 150 trays, 308’s were satisfactory, thought the plants were slightly purple indicating shortage of nutrients. Those grown in 104 trays were considered to be too large for transplanting mechanically. The use of a larger cell size for organic transplants than that used conventionally is now accepted practice. Professional plant-raisers Delfland

Nurseries use 216 trays for organic brassicas and 345's for conventional. For leeks and onions 345's are used for organic plants and 600's conventionally (The Organic Grower #3, 2008).

Results from an EFRC field trial using organic transplants at a commercial organic grower's holding in Herefordshire in 1995 suggested that there may be a benefit, under adverse conditions (e.g. pest attack or drought), from using a larger plant. Larger transplants withstood flea beetle attack and drought conditions better (EFRC 1996). The disadvantages of larger cell size is that they make less efficient use of greenhouse propagating space and cost more in use of substrate, transport and handling. It also means (if using peat in growing media) that organic growers may be using proportionally more peat in propagation than conventional growers.

Defra project OF0144 (Anon 2001) on overwinter transplant production for extended season organic cropping found that the effect of cell size (and thus plant density) on disease spread was minimal with both the cell sizes tested having similar spread of disease over 12 – 14 days. This would suggest that cell size is not a suitable method to control the spread of disease in organic transplant production systems.

Cell size will affect the watering schedule – see watering. For larger containers, water must be added to thoroughly moisten the entire medium profile, whereas for smaller containers a less than saturating amount of water can be added without detrimental effects to roots since the water will distribute adequately (Greer and Adam, 2005).

2.5 Overwinter transplant production

The objective of Defra project OF0144 (Anon 2001) was to develop and evaluate protocols for organic transplant production during autumn, winter and early spring, taking particular account of nutrient supply, cell size and disease (particularly mildew) control for brassicas, allium and lettuce. This resulted from concerns outlined in a previous MAFF-funded project (OF0109/CSA 2634) about the production of transplants during the more demanding late autumn, winter and early spring period. The work on disease control is outlined further on in this review. The overall findings were that production protocols could relatively easily produced and tested successfully on a range of crops in a research scale situation. Production time for overwinter production was longer than for production in the spring. Lettuce was relatively easy to produce with acceptable plants being raised in a range of media and block sizes; no feed was needed for lettuce. Cabbage transplants were also relatively easy to produce in a range of media, and cell sizes. However, supplementary feeding was required for cabbage. The second brassica tested – Cauliflower – may have been affected by improving conditions in the glasshouse and high levels of nutrition in one of the media (Sinclair organic). Acceptable transplants were produced for cauliflower using smaller a cell size (345) and full nutrient substrate. The knowledge gained under this objective was used to further test the protocols under commercial conditions.

Protocols were tested for a range of crop species and varieties, growing media, block or cell size and feeding regimes over three seasons under commercial conditions. It was considerably easier than initially feared to produce organic transplants of suitable quality during the overwinter period. However, propagation time was generally longer than would be needed to produce comparable transplants at more favourable times of the year. Overall conclusions are shown in Table 1.

Table 1: Overwinter organic transplant propagation systems – conclusions of trials 1997 – 2000. (Anon, 2001)

	Brassica				
	Cabbage	Cauliflower	Calabrese	Leek	Lettuce
Cell/block sizes	308, 150	126, 216, 345	216	216	3.2cm^2 4.3cm^2
Growing medium[1]	S, B	S,	SLow, VLow	S, K, V, Vveg	S, K
Feeding	Nu-Gro , Fish emulsion	Nu-Gro	Nu-Gro	Nu-Gro	Not required
Species/variety	Only 1 variety tested	Similar requirements	Only one variety tested	Only 1 variety tested	Set & Little Gem similar
Propagation period (days)	55	123 -159	132	68	24-38

[1]Growing media: B = Bullrush Peat Free, K = Klasmann Organic; S = Sinclair Organic; SLow = Sinclair Low Nutrient; V = Vapo-Gro Organic; VLow = Vapo-Gro Low nutrient; VVeg = Vapo-Gro Organic Veg-based.

2.6 Blocks

Blocks were widely used prior to the uptake of thermo-formed plastic module trays and are still used by some organic growers today. The system is based on a blocking machine that compresses the moist substrate into squares or blocks which have a dimple for sowing the seed. Schofield describes the system used at Growing with Nature; "Our system is based upon a hand block making machine which produces 20 blocks a time placed on 2ft x 1ft correx sheets, giving 120 blocks per sheet. These are seeded manually, germinated in a home-made germination box and then grown on with frost protection in a 30ft x 20ft insulated glasshouse until hardened off in either a cold polytunnel or outside. We have two block makers to produce both 25mm and 40mm blocks. The smaller size we use for smaller seed (brassicas, alliums, lettuce etc) the larger for seeds like beans, squash, courgettes etc. We use a proprietary blocking medium suitable for use in an organic system produced by the German company Klasmann. This growing media is composed of a mixture of dark and light peats and 20% green waste compost, with added nutrients. We have used this product for the last 13 seasons and have had consistent results. It is the addition of the black peats that make it suitable for blocking." (Schofield, 2007)

Eliot Coleman in the US is a big proponent of blocks, which are normally based on peat. (Coleman, 1995)

2.7 Pots

Pots are used for larger plants, usually higher value crops such as tomatoes, cucumbers. Peppers, aubergines etc. These crops are normally sown in modules and then transplanted into pots or raised in seed trays and pricked out into pots. They can also be used for frost-tender plants to enable them to grow bigger prior to planting for early crops (e.g.courgettes).

Raising potted plants, including herbs and ornamentals for sale entails different rules than that which governs plants raised for transplanting. See Substrates.

2.8 Substrates

Vaughan (Organic Grower, 2008) of Delfland Nurseries outlined the general requirements of organic growing media from a plant-raisers perspective. The physical requirements for organic growing media are that there is a suitable balance of water, air and particle sizes. It must be capable of being made into blocks or filled into modules or pots mechanically, anchoring plant roots and also holding together for mechanical planting. It should wet up and re-wet evenly and not slump. The biological requirements are that it is free of plant pathogens or viruses, pests and weed seeds. It should be biologically active and safe to handle for operators. The chemical requirements are suitable pH, correct levels of nutrients for germination and growth, some buffering capacity and no contamination. Other requirements are that it should be ready to use, perform consistently and reliably and have a reasonable shelf-life. Rigorous quality control and full traceability are important, with a full and open specification. Schimilewski (2008) summarises the characteristics that need to be taken into account (Table 2).

Table 2. Properties of growing media and their constituents that pertain to "quality." (Schimilewski, 2008)

PHYSICAL	CHEMICAL	BIOLOGICAL	ECONOMIC
structure and structural stability	pH	weeds, seeds and viable plant propagules	availability
water capacity	nutrient content	pathogens	consistency of quality
air capacity	organic matter	pests	cultivation technique
bulk density	noxious substances	microbial activity	plant requirements
Wettability	buffering capacity	storage life	price

Growing media approved for use in organic plant-raising must always be used when propagating organic crops. Acceptable media can either be home-made formulations or bought-in substrates, either way the media should be composed of acceptable ingredients. While media that are not registered with an organic certification scheme may not necessarily be prohibited any grower using non-certified media must be able to prove that the media consist only of ingredients approved by the certification body, including a declarations that the ingredients are GMO-free (Soil Association, 2007). It is important to note that some growing media sold in the domestic retail sector e.g. at garden centres, may be labelled as 'organic', but this is not adequate as it may not necessarily mean that they have been approved or verified for use in organic transplant production by an organic certification body. It is therefore important for growers to check with the certification body.

For a propagating media itself to be labelled as organic all agricultural ingredients must be from organic origins. However, for production of vegetable transplants the medium in itself does not to be labelled organic, though its ingredients needs to be approved for this purpose. There is no specification for the percentage of agricultural ingredients required. Propagating substrates may contain ingredients which would be prohibited in any other type of growing media (Soil Association, 2007) e.g. meat, blood, bone, hoof and horn meals, fish meals and fish emulsion, provided they are free of substances not permitted in standards.

The transplants must not be described as organic but may be described as 'plants suitable for organic growing' or 'transplants suitable for organic production'.

For a potting substrate to be labelled as organic, and therefore be suitable for use in the production of potted herbs or ornamental plants to be sold as organic, it must be composed of a minimum 51% (by fresh weight of the end product) of materials from organic farming origin. The balance of the substrate must be made up of non-organic materials listed in the standards. This can include composted or stacked animal manures from non-intensive systems, green waste compost (needs approval and should be source segregated and preferably PAS100 approved) and composted bark or wood fibre.

2.8.1 Peat

Peat can be defined as partially decomposed plant residues derived from bogs, mires or fens consisting principally of mosses such as Sphagnum species, sedges or reeds. Traditionally peat has been the standard substrate for growing media production in the UK and North West Europe (Waller and Temple-Heald, 2003) and the major constituent of blocking and modular composts. All peats are acid, have a low bulk density, a high level of readily available water, variable air-filled porosity at container capacity and high buffer capacity (the ability of growing media to resist changes in pH), which is desirable (Handreck and Black, 1994). Lime is often added to mixtures containing peat to balance the pH. Light, dark and black peats describe peats in various stages of decomposition. Darker peats are more advanced in decomposition than lighter ones. Younger, lighter-coloured peats provide more air spaces than older, darker peat that has few large pores (Kuepper and Everett, 2004). Peat provides low or negligible levels of available nutrients.

2.8.2 Soil

Soil-based growing media were the norm prior to the advent of soil-less media based on peat. In the late 1940's the John Innes Horticultural Institute came up with a 'base mix' to be added to a growers own soil for propagation purposes and then two loam-based growing media for seed raising and potting-on (Schofield, 2007). The major problem with soil is maintaining access to a supply of consistent quality. Potting mixes with more than 30% soil by volume usually have poor aeration in pots. These mixes also have a high bulk density and can have a low level of available water if too much clay in the soil. Clay soils can increase cation exchange capacity and can contribute micro-organisms and nutrients, especially iron and other trace elements. A small amount of some, but not all clays can protect sensitive plants against P toxicity. Sandy loams will usually decrease the cation exchange capacity of a mix composed mainly of materials rich in humus. Soil will contain pathogens including weed seeds, which are normally destroyed by air-steaming (Handreck and Black, 1994).

2.8.3 Sand

Sand is sometimes included as and ingredient in growing media substrates, and many grades are available. Those with medium to very coarse particle sizes are generally preferred as are sharp sands as rounded particles can separate out during mixing. Sand provides ballast and helps overcome re-wetting problems (Handreck and Black, 1994). Calcareous sands should be avoided, as they will cause a rise in the pH that could lead to lock-up of trace elements.

2.8.4 Perlite

Perlite is a porous siliceous material produced by rapidly heating a natural volcanic glass to 1200ºC. It is sterile immediately after production and supplies no nutrients. The addition of coarser grades perlite to media can be useful for improving the aeration of finer materials. (Handreck and Black, 1994) Perlite will hold from three to four times its weight in water, yet will not become soggy. (Kuepper and Everett, 2004)

2.8.5 Vermiculite

Vermiculite is a flaky naturally occurring mineral that comes mainly from African and Australian sources. It is crushed and size-graded before heated very rapidly to between 700 and 1000ºC. The particles expand (exfoliate) to many times their original volume. Exfoliated vermiculite has a low bulk density. In pots it has a lower air-filled porosity than perlite (of a similar size), but holds more water. It needs to be mixed dry as its physical properties deteriorate when mixed wet as the particles tend to collapse flat. It supplies magnesium and some potassium.

2.8.6 Zeolite

Zeolite is a type of silicate mineral. Trials at ADAS, Kirton EHS in 1998/99 investigated making organic transplant substrates with an inclusion of zeolite and seeding it from an organic source (ADAS 1989). The type of zeolite used was clinoptilolite 1010A, sourced from Italy. This zeolite had a very high cation exchange capacity and was capable of absorbing high levels of ammonium ions whilst it naturally contained 4% potassium by weight. Therefore, when seeded with ammonium (from a source such as ammonium sulphate) zeolite could act as a slow release fertiliser and supply high levels of nitrogen and potassium to small volumes of compost whilst preventing ammoniacal phytotoxicity. A medium was made with 90% peat and 10% zeolite. Hoof and horn was used as the basic nitrogen source, basic slag as the phosphate and trace element source and worm casts as a starter. The mixture was composted for four weeks at 21ºC. It was then tested by growing direct seeded onions, lettuce and cabbage in both modules and blocks and compared with a commercially available organic substrate (Turning Worms) and the conventional raising system. The plants grew well in the compost and were compatible with the conventional system until close to planting when the plants in modules ran out of nitrogen. The trial was repeated to confirm that the zeolite could hold and release nitrogen of various levels over the propagation period. Finally, a complex experiment was set up to obtain sufficient data to be able to design substrates for any occasion. Formulations were made up containing 10, 15 and 20% zeolite and seeded to contain 600,900,1200,1500, 1800 and 2400 mg/l nitrogen from either hoof and horn or dried blood as the nitrogen source. This gave a total of 42 formulations to be compared with conventionally raised controls. Soon after emergence un-uniform growth of plants was noted in all zeolite composts, later manifesting itself into abnormal petiole growth and very brittle plants, even though compost and plant tissues showed normal levels of the macro-nutrients and those trace elements tested for. It was considered likely that it was the basic slag (a new batch), used in the later trial, that could have contained toxins or phytotoxic materials. The report suggested that the dilution trial be repeated but with bone meal replacing basic slag as the phosphate source and calcified seaweed as the trace element source.

2.8.7 Manures

Composted animal manures can be used as an ingredient in growing media but they must be fully matured. The quality can be variable and depends on the straw used for bedding and the fodder of the cattle. The C/N ratio should be around 15:1. 20-50% by volume of mature compost is said to be suitable for a propagation mixture. (Riit'aho, 1996) In the USA trials were carried out using compost produced from horse bedding. Crop growth for lettuce and tatsoi in horse-bedding compost, used at 100% or in a 50/50% mixture with a commercial substrate of bark, peat and sand was found to be unacceptable for commercial organic production. The compost showed net N immobilization, perhaps due to high salinity (Clark and Cavigelli, 2005).

2.8.8 Green waste compost

This is compost derived from the controlled aerobic composting of post-consumer waste material of botanical origin that derives from gardens, parks and other horticultural activities; includes tree and shrub prunings, grass and other whole plant material and may include kitchen or vegetable processing waste (Waller and Temple-Heald 2003). Vegetable processing or wood waste from industrial sources can affect the processing requirements and/or increase the electrical conductivity. According to the Waste & Resources Action Programme (WRAP) guidelines (WRAP, 2004) it shall not contain:

a. sewage sludge;
b. manure or any other added material of animal origin;
c. kitchen or industrial catering waste;
d. mixed municipal waste (unseparated domestic waste from dustbins etc.);
e. post-consumer wood waste (for example window frames and other demolition waste that may be contaminated with metal, glass and potentially toxic elements [PTE]).

Schmilewski (2008) said the solid fraction of composted biowastes is most often dominated not by organic matter but by mineral material, which sometimes reaches levels of 70% or more by mass (m/m). This is primarily the result of the composting process used (complete degradation of the organic matter) but it is also due to the high proportion of mineral materials, eg soil, in the feedstock. Nonetheless, the German RAL standard for compost as a growing media constituent fixes the minimum organic matter content at only 15% (m/m). Even high quality green waste compost cannot serve as the sole constituent of a growing medium, in particular due to very high pH of 8.6 and the high K_2O content of 1,650 mg L-1 which are typical standards for compost (Schmilewski, 2008). Even this compost has 25% mineral content. Due to its high mineral fraction, compost has rather high bulk density and this can considerably increase the weight of the medium which increases the cost of transportation. The pH value, the salinity and the K_2O content of green waste compost are incompatible with the desired requirements for plant growth, so compost must always be blended with material with lower pH and concentrations of these compounds in such a way that risks are avoided Schmilewski (2008). Based on its physical and chemical characteristics, peat is a suitable blending material (Schmilewski, 2008), though from an environmental point of view the use of peat for this purpose is increasingly considered unacceptable.

Green waste compost can be certified to BSI PAS 100, which was developed by WRAP and The Composting Association. This sets out the minimum requirements for the process of composting, the selection of materials from which compost is made and how it is labelled. Furthermore, building on the BSI PAS 100, the fundamental requirements of a composted green material supplied as a component of a growing medium according to the ‘WRAP Guidelines for the specification of composted green materials used as a growing media component’ (WRAP, 2004) have been specified as follows:

The compost shall:
a. be produced only from approved green waste inputs (see above);
b. be sanitised, mature and stable;
c. be free of all ‘sharps’ (inorganic contaminants such as glass fragments, nails and needles, that are greater than 2mm);
d. contain no materials, contaminants, weeds, pathogens or PTEs that adversely affect the user, equipment or plant growth (beyond those that are within the permitted limits set out in the PAS100 standards);

e. be dark in colour and have an earthy smell;
f. be free-flowing and friable and be neither wet and sticky nor dry and dusty;
g. be low in density and electrical conductivity.
These parameters are outlined in detail in the guidelines and include limits for weed seeds and tests for club root (*Plasmodiophora brassicae*), *Fusarium oxysporum f.sp. lycopersici*, in addition to human pathogens and heavy metals as per the PAS 100 standards. Note that green waste compost can be certified to BSI PAS 100 as well as being certified for use in organic production by an organic certification body, though at present there is no requirement that the compost is certified to BSI PAS 100 for it to be certified for organic production. (Soil Association, 2007)

The WRAP guidelines suggest that composted green material conforming to the quality parameters would normally be suitable for use at a maximum rate of 33 % by volume in combination with peat and/or other suitable low nutrient substrate(s) such as bark, processed wood, forestry co-products or coir.

Composts made from a variety of input materials have shown to prevent or control root and soil-borne diseases when utilized as components of container media. (Litterick *et al*., 2004)

The Horticulture Development Council (HDC) has investigated the use of green waste compost as a growing media for conventional brassica module production (HDC, 2007). Their trials used municipally collected green waste, composted to PAS100 standards, mixed with up to 50% peat. Green waste/peat mixtures produced similar numbers of useable calabrese and cauliflower plants when compared with plants grown in 100% peat. Seedling vigour and percentage marketability at harvest were also acceptably high for different peat/green waste compost mixes in different tray sizes. It was noted that careful analysis and amelioration of the green waste compost is required prior to and after mixing with the peat. Quality, consistency, availability and safety of the media need to be assured. It was concluded that green waste compost can produce quality transplants with no reduction in marketable yield. Proximity to the source would influence take-up due to the higher bulk density of green waste composts as compared with peat and thus higher transport costs. Further research, funded by the HDC is currently being undertaken.

2.8.9 Home-made compost

Home-made compost can be used as a basis for grower-mixed formulations. Consistency is the main problem and quality is directly affected by the ingredients used in the feedstock. If the feedstocks are low in nutrients, the resulting compost will be nutrient poor. The ATTRA Horticultural Technical Note from the USA Potting Mixes for Certified Organic Production (Kuepper and Everett, 2004) suggests making it according to a recipe, using a specific blend of balanced ingredients. Premium compost for nursery mixes should have:

• pH of 6.5 to 8.0
• no (or only a trace of) sulphides
• <0.05 ppm (parts per million) ammonia
• 0.2 to 3.0 ppm ammonium
• <1 ppm nitrites
• <300 ppm nitrates
• <1% CO_2
• moisture content of 30 to 35%
• >25% organic matter

• <3mmhos/cm soluble salts

When making compost for media, Kuepper and Everett (2004) recommend planning at least six months in advance of when it will be needed. For spring transplants, compost should be made the previous summer and allowed to age through the autumn and winter. Animal manures and bedding, farm and garden waste, grass and lucerne hay, and other materials can be combined to make a high-quality, reasonably consistent compost. Organic amendments such as greensand and rock phosphate can be added during the composting process to increase nutrient content. Protein-rich sources such as lucerne and seed meals can also be included, if additional nitrogen is needed. While most compost will provide adequate amounts of phosphate, potash, and the necessary micronutrients, nitrogen has proved to be the most variable element and the most important to manage. A potting mix containing 20-30% compost is recommended as they are too porous and soluble salt levels are often too high to use alone. (Kuepper and Everett, 2004)

2.8.10 Coir

This is a generic name for material derived from the outer husk of the coconut. The fibre portion is used for the production of mats and ropes etc. and the residual pith is a by-product that is a very useful, if expensive (due to shipping costs), horticultural substrate. It is transported in dry compressed blocks to the site of growing media manufacture where it is reconstituted with water (Waller and Temple-Heald, 2003). The chemical and physical characteristics of coir materials vary greatly with their origin, time in storage and the duration of the treatment process (Schmilewski, 2008). Coir has a pH of 5.5 to 6.8 and usually contains higher levels of potassium, sodium and chlorine than peat. It is easier to wet than peat as there is no waxy cutin to repel water and it has a greater water-holding capacity than peat. Supplemental fertilisation with potassium may need to be cut back (as compared to peat) and nitrogen increased. There may be a possibility of salt damage, as salt water is customarily used in the processing of coir products and it is important to purchase only low-salt coir products. (Kuepper and Everett, 2004). Coir pith has a better balance between water and air capacity and can be used systematically in all areas of growing media production. The characteristics of coir pith come rather close to those of peat, which means that the market has considerable potential, despite its high price. It can be used as a peat replacement or in a reduced peat mixture. Trials in Italy of growing lettuce transplants in coir alone and peat/coir mixes found that the optimum combination was about 50% peat and 50% coir (Colla *et al*., 2007) In the US one distributor recommends a mix of 3 parts coir to one of compost and another offers a product containing 35 to 45% peat moss, vermiculite and pine bark (Kuepper and Everett, 2004). Organically certified coir based growing media have been produced by Fertile Fibre in the UK for a number of years.

2.8.11 Bark-based products

The lignified outer protective tissue from the trunks of trees that is removed at sawmills and thereafter may be aged or composted and screened to provide material that may serve as a growing media constituent (Waller and Temple-Heald, 2003). In a report commissioned by WRAP it was found that France uses much more bark in substrates (28% of substrates used) than other Northern European countries. The UK uses 4%. This may be partly due to France's lack of significant peat deposits and their distance from Europe's commercially workable deposits but also a ready availability of bark and composted materials. This could point the way towards future substrate use in the UK (Waller and Temple-Heald, 2003). Finely composted wood fibre, finely composted conifer bark and pine bark chips are available in the UK and approved (with prior permission required) for use as growing media ingredients (Soil Association, 2007). Usually, spruce and other softwood barks composted prior to use for this purpose. The aim is to eliminate the N immobilisation, which would otherwise lead to plant growth problems. Nitrogen is added to bark, mostly in the form of urea to accelerate microbial activity. Mixing composted bark with growing media can increase air capacity and drainability, raise the cation exchange capacity and achieve a pH buffering effect. However the pH and salt content can be too high. It is used in quantities of up to 50% by some growing media producers but mixtures need careful formulation using peat, green waste compost or wood fibre products (Schmilewski, 2008). A range of bark-based products (pine bark and mixed conifer barks) approved as ingredients in organic media are produced by Melcourt Industries Ltd .(Soil Association, 2007)

2.8.12 Wood fibres

Wood fibres are mechanically/thermally extracted from wood and wood waste. Only mechanically treated wood is permitted as the raw material. There have been commercial wood fibre products available such as Toresa® which has had moderate use in the UK, German and Swiss growing media industries and Hortifibre®, which is a French product. Sylvafibre® is available from Melcourt Industries, and is approved by Soil Association Certification as a certified input. Wood fibres are fibrous in structure, porous, loose and elastic. They have low bulk density, very high air capacity (good drainability) and very low water capacity. Due to their low shrinkage value they can reduce the shrinkage of a peat mix in the pot. Furthermore, they have good rewettability and are free of weed seeds and pathogens. Their pH is between 4.5 and 6.0 ($H2O$) (Schmilewski, 2008). Trials in Germany on wood fibre substrates (WFS) as growing media for tomato transplants found no significant differences compared to white peat and concluded that they are a good alternative to peat-based systems. The plants in WFS showed well-developed root systems. Differences were found related to the degree of compression of the substrate, however and moderate compression is recommended when filling containers (Gruda and Schnitzler, 2003). A number of standard growing media contain up to 30% by volume of wood fibres, and the potential for co-use of wood fibres in growing media has not yet been fully exploited. (Schmilewski, 2008)

2.9 Substrate ingredients - nutrient sources

Many of the bulky organic materials listed above as potential ingredients for growing media will contain some nutrients, but most of them will not contain sufficient or balanced levels of nutrients to satisfy the requirements of the transplants. Additional nutrients are therefore often required, and the option is to add these to the medium or to supply them as supplementary feeding during the growth of the transplants. In organic systems, the addition of nutrients to the medium is considered more compatible with the principles of organic growing i.e. nutrients from plant or animal based materials become available following microbial degradation. However, these types of nutrients sources pose a challenge in that it is difficult to accurately predict the release of nutrients from them and once they have been added to the substrate the release can not be manipulated which in turn reduces the ability to manipulate the growth of the plants. As mentioned above, adding the entire nutrient requirements to the medium can create phytotoxic nutrient concentrations (electrical conductivity levels) in the medium, which is a particular problem when the transplants are grown in small cells. For many plants there is therefore a need to provide additional nutrients, particularly nitrogen, as supplementary feeds, during the growth of the plants.

A list of organic nutrient sources with their nutrient values and rates of release, which are used in organic growing media in the US is given in Table 3.

Table 3 A selection of organic nutrient sources for use in growing media in the US. (Kuepper and Everett, 2004)

Fertiliser material	Estimated N-P-K			Rate of Nutrient Release	Salt and pH Effects
Lucerne meal	2.5	0.5	2.0	Slow	
Blood meal	12.5	1.5	1.5	Medium-fast	
Bone meal	4.0	21.0	21.0	Slow	
Cottonseed meal[1]	7.0	2.5	2.5	Slow-medium	Tends to acidify
Crab meal	10.0	0.3	0.3	Slow	
Feather meal	15.0	0.0	0.0	Slow	
Fish meal	10.0	5.0	5.0	Medium	
Granite meal	0.0	0.0	0.0		
Greensand	0.0	1.5	1.5		
Bat guano	5.5	8.6	8.6	Medium	
Seabird guano	12.3	11.0	11.0	Medium	
Kelp meal	1.0	0.5	0.5	Slow	Possibly high-salt
Dried manure				Medium	Possibly high-salt
Colloidal phosphate	0.0	16.0	16.0	Slow-medium[2]	
Rock phosphate	0.0	18.0	18.0	Very slow-slow[2]	
Soybean meal	6.5	1.5	1.5	Slow-medium	
Wood ash	0.0	1.5	1.5	Fast	Very alkaline, salts
Worm casts	1.5	2.5	2.5	Medium	

1. Cottonseed meal needs to be from an organic source as otherwise risks pesticide contamination.
2. The availability of phosphorus in different forms of rock phosphate depends on the pH of the mix, biological activity, fineness of grind, and the chemical composition of the source rock. Precise performance is not easy to predict.

2.9.1 Hoof and horn

Hoof and Horn contains 10.9% N in a less readily available form. It is usually mixed into the substrate before sowing, allowing a gradual release of nitrogen during the propagation period (Riit'aho, 1996). HRI found that Hoof and Horn was a useful material for ensuring nutrition is adequate to the end of the propagation period. It acts as a slow-release nitrogen source but is not controllable as high temperatures and over-watering will release N more rapidly and flush it out before plants can use it. In HDRA trials Hoof and Horn appeared to be the best source of plant nutrients for leeks. In cabbages, however, the addition of Hoof and Horn (3g/l) inclined the plants to become tall and spindly. Because it is added to the growing medium there is less ability to manipulate the rate of growth than with liquid feeding.

2.9.2 Pelleted manures

Pelleted chicken manures are available. Chicken manure contains high levels of ammonium nitrogen. It should be mixed together with the other media 1-2 months prior to sowing so as to achieve a homogenous mixture. (Riit'aho, 1996)

2.9.3 Feather meal

Feather meal is a by-product of the poultry processing industry. It has a slow release organic nitrogen (15%) fertiliser. It is widely used in North Carolina due to availability and low cost (Kuepper, 2004).

2.9.4 Vermicomposts

Vermicomposting is the decomposition process in which earthworms mechanically break down materials while microbes biochemically decompose the material resulting in a stabilised compost rich in organic matter with a low C:N ratio, high rate of mineralization and greatly enhanced nutrient availability to plants (Larrea, 2005). As with composts the source of waste materials that are worked by the worms is vital as is the maturity. Worm-composted sheep manure will have a greater bulk density but a decreased pore space than that from horses or cattle.

2.9.5 Plant-based nutrients

There has been growing interest in alternative, non-animal nutrient sources over concerns related to BSE and CJD. In Switzerland, transplants for organic vegetable growing have been fertilised traditionally with slaughterhouse by-products (Koller., *et al* 2004). In autumn 2000, the Swiss government restricted the use of such products because of the BSE crisis. To maintain the production of organic transplants, alternative fertilisers needed to be tested. Eleven alternatives to horn meal (standard fertiliser) were selected based on the organic standards of the European Union, including feather powder (as an animal based product without BSE risk). The products were mixed with a standard growing media for organic transplants in a concentration of 300 mg nitrogen L-1 growing media. When planting immediately after mixing, potato protein, vinasse (wastes of food processing), and feather meal resulted in the highest weight per plant. Plants fertilised with horn meal, sunflower oil cake and ground field beans had the lowest weight per plant (40% less). Horn powder, ground malt sprouts, vinasse, potato protein and feather powder with stored growing media produced the strongest transplants. Phytotoxicity tests (four different methods) showed significant differences between horn meal (slight damage) and field beans (seriously harmed). Horn meal was still the best fertiliser for organic transplant production followed by feather meal. Horn meal caused little phytotoxicity to the crop even under extreme conditions. The most promising pure plant products were potato protein, malt sprouts and vinasse. Plant-based fertilisers need to be applied carefully; the fertiliser should be mixed with the growing media at least two weeks before sowing.

Lucerne must be processed before use in growing media. Dried Lucerne is ground and passed through a 2 cm screen. Water is added and it is allowed to decompose for 20 days. It is then air-dried for another 20 days before use (Kuepper and Everett, 2004).

A number of ready formulated mixtures of plant based nutrient sources are available in the UK, e.g. from W.L Dingley & Co., Ilex Organics, Greenvale etc. For a full list see the *Fertilisers for use in organic production* factsheet produced by the Soil Association (2007), which is updated regularly. Some manufacturers have signed 'Animal-free declarations' ensuring they are suitable for stockfree systems (Hall and Tolhurst, 2006).

2.10 Commercially available substrates

The Defra/MAFF funded work on transplants has generally looked at organic substrates that were approved for organic growing and were commercially available at time of trials. The latest study to do this was the Organic Centre Wales *Assessing quality of plant raising media for organic systems* project in 2007 (Little *et al*., 2007). Growers were supplied with samples of organically approved products, as described in Table 4, and were asked to test them on range of crops. In addition, scientifically robust trials were carried out by a plant-raising specialist on cabbage, leek and lettuce.

Table 4. Products assessed in Organic Centre Wales Trials. (Little *et al*., 2007)

Product	Base	Additives
Bulrush Horticulture Ltd	Peat	DCM; Lime/ Dolodust
Fertile Fibre Seed mix	Coir	MB1 (Nitrogen source including hoof and horn); Vermiculite
Klasmann Bio Tray	Peat	N, P , K Mg
West Riding Organics Bio pak 10	Moorland Gold Peat	Vermiculite; Coir; Lime; Sugar beet based fertiliser; Basalt minerals
Development product * (Formal Trials only)	Peat & green waste	DCM; Dolomite lime; Zeolite

* This is not an approved product. It was included to investigate the potential for green waste based products to be developed for organic plant raising.

The quality of media was assessed against various aspects of plant performance and an analysis of their physical properties and nutrient levels. It was concluded that;

- Bulrush delivered a high proportion of usable plants of reasonable quality, although some cabbage and lettuce plants were starting to show signs of stress towards the end. This was probably related to low N levels. It did particularly well in leeks and this may be because of a slower rate of release of nutrients, which minimises losses through leaching. This was also reflected by the growers' experience.
- Fertile Fibre produced lettuce plants of reasonable quality in the formal trials, although the leaves were quite tough and veined. There were problems with cabbage and leeks, which were small and weak, and suffered from tipburn in the case of cabbage. It is unlikely they would have been robust enough to pass through a planter. However, growers did not appear to experience similar problems. Subsequent laboratory analysis suggested that the difficulties were probably due to mixing problems and/or storage conditions.
- Klasmann had a tendency to 'run out steam' in both the formal and the grower trials, especially in leeks and cabbage. Many plants were small and stressed and would not have been strong enough to pass through a planter. This was probably due to low nutrient levels compared to many other products, and it is possible that early mineralisation of N leading to leaching may have contributed to this
- West Riding Organic had problems with weeds, and the weed susceptible crops such as leeks were completely smothered. This is unfortunate because in all other respects it appeared to perform very well. However, the problem carries through to the field phase – growers don't like planting out weeds!
- The development product (tested only in the formal trials) raised large, healthy plants for all crops with no significant problems and few visible signs of stress. These results indicate that green-waste based products could have a role to play in organic horticulture in the future, but there is more work needed to commercialise and approve them for use.

A full list of commercially available growing media approved for use for organic transplant raising is available from Soil Association (Soil Association, 2007) and this is updated regularly.

2.11 Home-made mixtures

Due to problems with commercially available substrates, many organic growers, particularly smaller-scale, are making up their own mixes. A number of home-made recipes were given by growers in The Organic Grower (2007) and are detailed in the appendix (5.1).

There are many more examples of recipes for growing media, including blocking mixes and mixes for potting and modular use, in the ATTRA Horticultural Technical Note from the USA - Potting Mixes for Certified Organic Production. (Kuepper and Everett, 2004)

2.12 Supplementary feeding

The need for supplementary feeding is dependent on crop grown, the cell size used, and the levels of nutrients in the growing medium. As outlined above the use of larger cell sizes, and thus a larger volume of substrate per plant, will need less or no supplementary feeding as most of the nutrient requirement can then be added to the substrate prior to sowing. However, for some crop systems it is not possible to incorporate the entire nutrient requirement into the medium as this will create phytotoxic conditions (high electrical conductivity) or it may not be desirable to do so as this limits the ability to manipulate the supply of nutrients and thus the ability to manipulate the growth of the plants e.g. to 'hold' the plants. For many crops there is therefore a need to provide additional nutrients, particularly nitrogen, as supplementary feeds, during the growth of the plants. Supplementary feeds can be supplied in solid or liquid form and the materials used needs to be approved for this purpose in organic systems.

2.12.1 Dried blood

Dried blood is comparatively rich in organic nitrogen (typically 11.8%). It has a low C/N ratio and the N is therefore easily mineralised and made available (Riit'aho, 1996). Dried blood and hoof and horn were used as supplementary feeds in propagation trials at HDRA and Horticulture Research International (HRI) in 1994-5 in Defra OF0109 (EFRC 1996). Dried blood was an effective nutrient source, though with variable results. Applications of dried blood to cabbages (up to 2g/l 3 times/week had no clear effect on the growth of cabbage transplants, though higher levels (5g/l and 10 g/l 3 times/week did increase the growth. In 1994, HDRA used a finely ground suspension of dried blood and HRI used a steeped supernatant which was variable in N content; in neither case was there a consistent or substantial response. 'Dry sprinkling' of dried blood worked well at HDRA in 1995, where application as a suspension was also tried.

2.12.2 Non-animal based nutrient sources

Defra project (OF0308) looked at alternative, non-animal based nutrient sources, for organic plant raising (Anon, 2003). This work arose after concerns over the use of animal based nutrients and links with adverse affects on human health in the wake of BSE. This work aimed to identify suitable non-animal based nutrient sources to be used as base nutrients for growing media and as supplementary feeds and to assess these non-animal based nutrient sources under UK organic plant raising conditions. Table 5 shows the non-animal based sources of nutrients that were available in or suitable for UK systems based on a UK, European and international search.

Table 5. Non-animal based nutrient sources for organic plant-raising identified in Defra OF0308 (Anon 2003)

Product Name	Contents / NPK	Supplier	Other Info
Supplementary feeds.			
AmegA BIOFEED 5.0-0-	Organic Sugar beet extract N 5%, P	AmegA Sciences	100% organic raw

2.5	0% & K 2.5%		materials, 100% non-animal origin, based entirely on plant extracts
AmegA BIOFEED 2.5-0-5.0	Organic Sugar beet extract N 2.5%, P 0% & K 5.0%	AmegA Sciences	100% organic raw materials, 100% non-animal origin, based entirely on plant extracts
AmegA BIOFEED 4.0-0-4.0	Organic Sugar beet extract N 4%, P 0% & K 4%	AmegA Sciences	100% organic raw materials, 100% non-animal origin, based entirely on plant extracts
Bio-system	Microbial based powder	Humate International and John McLauchlan Horticulture	Use with Humate – plants flower better and crops yield improves
Bioplasma NATURAL GROW	Suspension of algae N 0.07%, P 0.018% & K 0.07%	Bioplasma Australia Pty Ltd	Foliar or root feed.
Comfrey Plant Fertiliser	Comfrey crop cut 3 times a year, placed in barrels to disintegrate leaving black liquor – after a month is drained and pasteurised.	HDRA, Chase Organics or Ragman's Farm	Ideal for vegetables, flowers, lawns & young tree's. Highly commended for tomatoes & peppers
Gem Fruit 'n' Veg Fertilizer.	Suspension Nitrogen fixing bacteria and organic nutrients (no data on major nutrients)	Joseph Metcalf Ltd	All fruit, vegetable and salad crops
Humate Granular	Composition is approx 70% (Humic & Fulvic acids) and 30% inorganic	Humate International and John McLauchlan Horticulture	Granular –spread onto soil where breaks down slowly
Humate As (soluble)	Humic and Fulvic acid content is between 64 – 74%	Humate International and John McLauchlan Horticulture	Dissolved in water, ideal for root and foliar application
Humate Iron Chelate	Total Nitrogen 6%, soluble potash 2%, chelated iron 10%	Humate International and John McLauchlan Horticulture	Dissolved in water, ideal for root and foliar application to correct deficiencies of Iron in soil and composts
Maxicrop liquid seaweed – professional strength	Made from Norwegian seaweed	Maxicrop International Ltd	Liquid –improves soil conditions, enhances natural development & resistance to stresses.
Maxicrop liquid seaweed – soluble seaweed and kelp meal	Made from Norwegian seaweed	Maxicrop International Ltd	Liquid –improves soil conditions, enhances natural development & resistance to stresses.
Maxicrop liquid seaweed (plus Iron)	Made from Norwegian seaweed	Maxicrop International Ltd	Liquid –improves soil conditions, enhances natural development & resistance to stresses.
Organic Liquid Fertilisers & composts	Free of animal input	West Riding Organics, HDRA, Chase Organics,	Liquid and compost
Perform TOG 8% Calcium Premium liquid	Total nitrogen 4%, soluble calcium 8%	Aqua-aid and John McLauchlan Horticulture	Ensures calcium and other nutrients are available to

nutrient			plant
Vitagrow 5+1+10 100% organic pure vegetable	Total nitrogen 5%, P_2O_5 1%, K_2O 10% and 43% organic matter from vegetables	Avoncrop Ltd and Vapo Gro Ltd	For soil grown crops under glass & outside, where animal sourced fertilisers are prohibited.
Westland Tomato and Vegetable feed	Lucerne meal, yaka, kali vanasse, rock sulphate, molasses, sugars (N 4%, P 2%, K 6% & trace elements)	Westland Horticulture	For all fruit and Vegetables

Aside from the health issues surrounding the use of animal products, there is also a growing movement of Stockfree producers, growing to the standards developed by The Vegan Organic Network, to cater for those with an ideological objection to the use of animal manures etc. in horticulture.

2.12.3 Liquid feeds

In the ADAS project undertaken by Bob Hiron at Kirton in 1989 an evaluation of commercially available organic liquid feeds was carried out to see if an organic conversion of the conventional system of modular plant-raising could be carried out, ie. to establish if it was possible to raise plants in a medium low in nitrogen and potassium and to supply the remaining nitrogen and potassium in an organic liquid feed. Four organic liquid feeds were tested: Fertosan Liquid Plant Feed; Turning Worms Liquid Feed and SM3 Organic Liquid Seaweed were each tested at recommended rate and double the recommended rate applied as a replacement watering three or seven times a week and compared with a conventional liquid feed of 100:200 mg/l nitrogen:potassium using SHL compost which would supply the phosphate and micro-nutrients. None of the organic liquid feeds tested produced acceptable growth due to lack of nitrogen. It was decided that the development of a high nitrogen organic feed was not a viable option in the short-term and that another way of growing organic transplants needed testing. (ADAS 1990)

Defra project (OF0308) identified four commercially available non-animal derived, organic supplementary feeds (Anon 2003): (AmegA BIOFEED 5.0-0-2.5; Westland Organic Tomato and Vegetable liquid feed (WTV); Bioplasma NATURAL GROW and Gem Fruit 'n' Veg Fertilizer). These were tested against a standard animal derived organic feed and conventional mineral fertiliser feed. Two species with contrasting requirements (leek and cabbage) were used to assess the efficacy of these feeds in a single growing media (Vapogro).The study concluded that

- Two of the feeds, WTV and AmegaA (with added phosphorus) produced cabbage and leek transplants of acceptable quality, broadly equivalent to those fed Nu-Gro, the standard organic supplementary feed,
- AmegaA without added phosphorus produced lower quality transplants,
- Bioplasma NATURAL GROW and Gem Fruit 'n' Veg Fertilizer produced poor quality transplants, not significantly different from zero feed in most respects,
- The exception to this was the degree of rooting, which was lower in the feeds with largest shoots, AmegaA with added phosphorus, and WTV and highest with the Bioplasma NATURAL GROW feed,
- Leeks grown with AmegaA with added phosphorus suffered severe sciarid fly attack,
- The use of AmegaA and WTV merit further investigation, particularly regards their field performance.

2.12.4 Nettles (*Urtica dioica*)

Nettles are commonly used by growers in Sweden and by some smaller-scale organic growers and amateur gardeners in the UK to make a liquid feed. To make a liquid feed 1kg of fresh nettle can be put in 10 litres of water and allowed to stand for 1 week at 15-20ºC. Some growers stir daily to avoid anaerobic processes. The mixture is then diluted 1:5 or more often 1:10 before use. Extract from younger plants contains the highest amounts of N, P and K, while older nettles produce a liquid feed higher in Ca, Mg and S. The soluble N in the feed consists mainly of ammonium. (Riit'aho, 1996)

2.12.5 Comfrey (*Symphytum officinale*)

A liquid feed made from comfrey leaves can be made in the same way as for nettle extract but contains less N and more K (Riit'aho, 1996). Due to the relatively low N content, it was concluded that comfrey liquid was not suitable as a supplementary feed for vegetable transplants. (EFRC, 1996).

2.12.6 Chicken manure extract

Chicken manure extract can also be used as a liquid feed by steeping 1 litre of manure in 10 litres of water overnight and diluting 1:10 Supplementary feeding should not contain more than 500 mg NO_3/l and more than 100 mg NH_4/l. the pH of the feed should be between 5 nad 8 and the EC preferably under 2, but not over 3. (Riit'aho, 1996).

2.13 Holdability

The ability to hold plants is as important in organic systems as in conventional. Delays to cultivations can occur in both organic and conventional systems due to adverse weather conditions. Organic systems are often very complex including multi-cropping and if a plant can stand for a week or two until transplanting is possible it will enable the grower to be more flexible. In conventional transplant raising if a transplant runs out of nutrients at the end of its normal growing period it can be 'kick-started with a high rate feed. Due to the slow acting nature of organic nutrient sources, this is not possible. Results of the holding trials at HDRA showed that the 'holdability' of a particular species depended on a combination of cell size, growing media and feeding.

Researchers at Kansas State University tested several species in cold storage at 7ºC and with light and found that Tomatoes could hold for up to four weeks and peppers for two weeks. (Greer and Adam, 2005)

2.14 Growth regulation

transplants are generally grown in cold (frost-free) glasshouses. Supplementary heating and lighting can increase transplant quality though generally not needed apart from in winter for season extension as low light levels can result in leggy plants. Researchers at Cornell have found that brushing can be an alternative to chemical growth regulators to control plant size. They used a piece of polystyrene foam on tomato seedlings and found that ten strokes a day reduced the seedlings ultimate height by about 20%. Another study found that cucurbits and aubergines respond well to brushing but peppers are damaged by it. Brassicas respond reasonably well if brushing is started at the second or third leaf stage. (Greer and Adam, 2005)

2.15 Water quality

Irrigation waters will invariably contain some salts. Bunt (1988) outlines a general classification of water quality for irrigating plants (table 6)

Table 6. Suitability of water for irrigating pot plants (Bunt, 1988)

Water Classification	Electrical Conductance (nmho cm^{-1} at 25^0C)	Total dissolved solids (salts) (p.p.m.)	Sodium (% of total solids)	Boron (p.p.m.)
Excellent	<0.25	<175	<20	<0.33
Good	0.25-0.75	175-525	20-40	0.33-0.67

Permissible	0.75-2.0	525-1400	40-60	0.67-1.00
Doubtful	2.0-3.0	1400-2100	60-80	1.00-1.25
Unsuitable	>3.0	>2100	>80	>1.25

2.16 Crop protection

Defra project OF0144 (Anon 2001) on overwinter transplant production for extended season organic cropping evaluated a range of biocides under laboratory and glasshouse conditions for their efficacy in controlling mildews; *Peronospora parasitica* on cabbage, *Peronospora destructor* on onion and *Bremia lactuacae* on lettuce. The objective was to identify organically acceptable fungicidal products. L-Carvone, Mycosin, Fennel and Clove oils all showed potential in controlling mildew on a range of crop species. Experiments of combinations of these compounds did not show increased benefits. Products that induced systemic acquired resistance (SAR) showed some potential. Salicyclic acid produced no effect but Bion successful protected the plants from mildew infection. However, after discussions of the acceptability of such compounds in organic production, work on SAR inducing compounds was not continued within the project. The work on spectral filters was disappointing with no benefits being found. This was preliminary work and should not be taken as proof that spectral filters could not be used in as part of an integrated control programme within organic production systems.

The warm humid atmosphere of plant raising houses is ideal for the spread of diseases. Xanthomonas (*Xanthomonas campestris pv. Campestrisis*) an important disease of brassicas, that can spread rapidly plant to plant, from initial infected seed sources, in favourable conditions such as under irrigation in plant raising houses. The bacteria can be present at a pre-symptomatic level, leading to infected transplants being planted out in the field. Symptom development later in the growing season can make produce unsuitable for marketing and cause considerable economic loss. Diagnostic tests are available that have the potential for identifying pre-symptomatic infection in plants (NIAB, 2008). Rates of spread during plant-raising can be considerable and HDC work has investigated the potential of using copper oxychloride. (Roberts and Brough, 2000)

Sciarid flies or fungus gnats can be a problem in the damp conditions of propagating houses as they feed on wild and cultivated fungi and decaying plant material. The species that cause most problems are *Bradsysia*, *Lycoriella* and *Sciara*. Damage occurs when the fly larvae, which live in the seed or potting compost, feed on roots and stems. Seedlings, cuttings and younger plants are most susceptible, and these may collapse and die. Mature plants may not be so badly affected, but if severely infested will grow poorly, wilt and even die. An additional problem is that fungal diseases can gain entry to plants through wounds caused by the fly larvae. Adult sciarid flies can also carry spores of pathogenic fungi from plant to plant, spreading diseases such as Pythium and Phytophthora. Some composts and amendments can encourage Sciarids such as AmegaA (with added phosphorus), used in the overwinter transplant trials (see 2.29). According to Garden Organic (2004) Sciarid fly have become more of a problem with widespread use of seed and potting mixtures based on peat, coir and other types of organic matter. Covering the surface of pot plants with horticultural sand or grit with a layer about 1cm thick will prevent adults from laying eggs. Sciarid larvae thrive in moist conditions so reduce watering to a minimum when infestations are high. This is especially important in winter when lower temperatures and light levels reduce plant growth. There are two biological control agents for sciarid fly. *Hypoaspis* mites and *Steinernema feltiae*, a nematode. Both the biological controls will also attack other soil-dwelling creatures including beneficial ones. For this reason, it is probably best not to use them at the same time as the biological control for aphids, *Aphidoletes aphidimyza*. A gap of 4-6 weeks between applications of the two controls should ensure best results. (Garden Organic, 2004)

2.17 Plant hygiene

Cleanliness of module trays and equipment is important to prevent infection from diseases such as damping off (*Pythium*). Aside from brushing off excess compost from trays only permitted disinfectants, such as Jet 5 are allowed. Methods commonly used for the cleaning/sanitisation of trays are tank dipping, line washing and stand alone washing (HDC, 2005). Tank dipping involves immersing the trays in a disinfectant, which is topped up as required. Trays need to be knocked out and free of physical contamination prior to dipping. Line washing equipment is available which knocks out and brushes the trays. Trays are then pressure washed with hot water and/or a disinfectant. A final rinse is given before trays return to the seeding line. Stand-alone washers are the same design concept as the in-line washers but the gap between washing and the seeder allows contact time for the disinfectant to work. The HDC identified some risks involved in the tray cleaning process after a survey of plant propagators (HDC, 2005). Large quantities of water are used in the tray washers, and wash-water is re-circulated but this has potential for build-up of contaminants. Sanitisers are often used at too low a concentration (commonly 1%) and/or for not sufficient contact time to be effective. There are also other sources of potential contamination in the nursery including contact with the ground and unsanitised structures and vehicle, pedestrian and stillage movements within the nursery.

As much dust as possible should be excluded from propagation areas, as it is a main source of *Rhizoctonia* infection. (Handreck and Black, 1994)

Any dead plant material around plants or in propagation houses should be removed to reduce favourable breeding sites for sciarid fly. (Garden Organic, 2004)

2.18 Watering

Thorough and even watering is important for successful transplant production. Water stress can set plants back and effect establishment and susceptibility to pests and diseases once planted out. It is common practice to support the plants off the ground, either on grids or on up-turned 4-5" plant pots, to allow good air circulation, root pruning and to prevent waterlogging. As a general rule they should not be watered in late afternoon to prevent leaves remaining wet through the night. Cell size will affect the watering schedule. For larger containers, water must be added to thoroughly moisten the entire medium profile, whereas for smaller containers a less than saturating amount of water can be added without detrimental effects to roots since the water will distribute adequately (Greer and Adam, 2005). Trays with smaller cell size will need to be watered more often as they can dry out easily, especially around the edges of hand-filled trays. Overwatering can contribute to poor plant growth and health and encourage the spread of pathogens that thrive in wet conditions. Overwatering is common in newly sown trays and underwatering in older trays. Automatic watering can be used but where a mixture of crops are grown it is likely that spot watering will also be needed.

Research in the US at the University of Georgia has shown that moisture stress tends to increase aphid populations on Impatiens and marigolds but has little effect on spider mite or thrips populations (Greer and Adam, 2005). Research at North Carolina State University found that environmental conditions rather than plant growth may dictate irrigation practices. They also found that:

- Module trays leach fertiliser, sometimes heavily,
- Module trays (288's) can take 500 to 1000 ml of water per tray at each irrigation,
- Plants may use less than 2% of the water applied to the tray,

- Water per tray may be more affected by air humidity than by temperature or plant condition. (Greer and Adam, 2005)

2.19 Sowing

Mechanical seeders are available for large-scale production. For small-scale plant-raising hand-held seeders are available. It is also possible to make a simple seeder out of plastic. Dr. Charles Marr developed a planting template in the early 1990s at Kansas State University (Greer and Adam, 2005). Here are his specifications:
The template consists of two sheets of 3-mm acrylic plastic cut to rectangular dimensions of the seed flat (module tray). The upper sheet has a 6-cm-tall “wall” glued to the outside with a small opening in the wall at one end, so excess seeds can be poured out. The bottom sheet is held in place by four glued tabs on each side, so that the bottom sheet could slide laterally. The bottom sheet is left slightly longer with a slot cut as a handle.

3. Analysis and Conclusions

3.1. Introduction

In order to compete commercially, organic growers in the eighties and nineties adopted the innovations of conventional growing and moved away from bare root transplants into blocks and modules. When it was no longer considered acceptable to use conventional transplants research into organically acceptable alternatives was carried out. It was soon discovered that it was not possible to simply replace the conventional system of module-raising, relying on liquid feeding of nitrogen to control growth of transplants, with organic alternatives. It has become accepted that the nutrition for the transplant should be provided, as far as possible, by the substrate and not by liquid feeding, though organic liquid feeds can be used, under derogation. This has meant the use of larger cell sizes in organic production. Many of the research projects have evaluated commercially available composts. Due to the relatively small size of the market for organic plant raising media.

3.2 Use of peat and peat alternatives

The growing media industry has been very reliant on peat over the years and there is a recognition and a will that this should change. Peatlands are an important habitat and carbon store globally and it is now widely recognised that it is important to minimise further drainage of peat bogs and peat extraction. In the UK the Environment Act 1995 required reviews of all old planning permissions for peat extraction and the European Habitats Directive (92/409/EEC) included active lowland raised bogs as a priority habitat for conservation and provided for the protection of damaged bogs (Lennartsson, 1997). The UK Biodiversity Action Plan (1997) stated that the horticultural industry should aim for a minimum of 40% of total market requirements (soil improver plus growing media products) to be peat-free by 2005 and 90% by 2010. The 2005 target has been met due to the combined efforts of suppliers, growers and retailers in the horticulture sector. The Growing Media Initiative (GMI) is a scheme developed by the Horticultural Trades Association in conjunction with the Growing Media Association, DIY and Garden Centre retailers, Defra, the RSPB and the Royal Horticultural Society. The GMI has been developed in order to help the horticultural industry in the UK meet government targets for reduction in peat use and to act as a catalyst for a greater rate of change in peat replacement (The Horticultural Trades Association, 2008). In 2005 the vegetable propagating industry as a whole used 59,000 m^3 of peat, accounting for 7.8% of all peat used in the professional horticultural sector (HDC, 2007). The price of peat is likely to increase as availability in Europe comes under pressure from a reduction in UK and German peat extraction. This will lead to increased dependence on peat from Ireland, the Baltic States and Scandinavia. Peat from these sources is not of course, infinite and may be restricted by environmental concerns (Waller and Temple-Heald, 2003). The organic sector needs to play its part in reducing reliance on peat and indeed can be criticised for using disproportionately more peat than in conventional production due to the use of larger cell sizes. Because of the consistent and reliable qualities of peat many growers are reluctant to consider alternatives.

One alternative to peat extracted from endangered habitats is peat collected by using silt traps to collect the peat that is continuously washed downstream into upland drinking-water reservoirs. Collection also prevents the reservoirs from becoming clogged up with sediment. West Riding Organics of Huddersfield uses a mixture of peat and silt from these traps to formulate a growing media called Moorland Gold.

There has been a lot of research into the use of green waste compost, supported by the government's Waste & Resources Action Programme, which is committed to promoting stable and efficient markets for compost products. The guidelines they have produced should help reassure growers who are suspicious of potential contamination problems that might arise over the use of composted green material. The PAS100 standards should also ensure consistency of quality. There are, however, still some risks of contamination from herbicide and pesticide residues as it is not practical to screen for all pesticide residues (WRAP, 2004). The Soil Association recognises that the use of green waste compost is compatible with the basic principles of sustainability (Soil Association, 2007). In order to increase the use of green waste compost it needs to be made available to growing media manufacturers at the right price, which means it should be produced very close to their sites in order to minimise transport costs of the bulky material. In Germany Klasmann have taken control of the process by making green waste compost on site for blending with peat. They use a maximum of 20% green waste compost in their growing media. (The Organic Grower, 2008)

There are also environmental concerns over the use of coir as a peat alternative due to the distances it is shipped, though its advocates would say that it mostly comes to Britain in surplus cargo capacity in ships. According to Fertile Fibre, producers of commercial coir based growing media certified for organic production, who import their coir by sea, it is relatively low impact. One 40-foot container brings in 285 cubic metres of finished material (Fertile Fibre, 2008). Personal experience is that Fertile Fibre products have improved in quality and consistency over the years that they have been available.

Composted bark as an indigenous waste material, perhaps has, alongside composted green waste, the best environmental credentials of the peat alternatives with the added advantages of consistent known properties. Like green waste composts it has a higher bulk density than peat, approximately 50% higher (Waller and Temple-Heald, 2003) resulting in increased transport costs and handling problems. In a similar way to many other peat alternatives, costs can be higher than peat as extra processing is required to produce quality products that are needed for use as growing media. There is potential, however for growing media formulations using composted bark combined with green waste compost.

When conducting trials of peat-free media it is important to also look at how the media responds to mechanised handling, for professional plant-raisers and also to do follow-up trials focusing on mechanised planting.

3.3 Use of animal products

Much of the research into non-animal based nutrient sources arose out of the BSE crisis and potential risks of CJD through exposure to animal by-products. There is however a growing number of producers who wish to avoid animal manures and animal products for ethical reasons and also to sell to the vegan and vegetarian markets. The Vegan Organic Network developed a set of Stockfree organic standards in 2004, which are a bolt-on to the Soil Association standards. (Hall and Tolhurst, 2006)

3.4. Bare-root transplants versus modules

There are a number of growers that will argue the case that bare-root transplants are more suitable for organic systems than growing in modules (Deane, 2005). A number of questions have been raised about the environmental credentials of the various substrates available for inclusion in growing media. The issues over peat have been covered above. Coir has to travel long distances by ship from South Asia and it could be argued that it should be recycled and used locally. Many of the supplementary feedstocks and minerals have their own environmental impact in distances travelled and in some cases (e.g.perlite) the energy required in their manufacture. Green waste compost is environmentally more sound but is not based on the products of organic agriculture. Organic production is based on the soil and by accepting modules and blocks there is a risk of departing from the IFOAM *principle of ecology* that Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. This principle roots organic agriculture within living ecological systems. It states that production is to be based on ecological processes, and recycling. Nourishment and well-being are achieved through the ecology of the specific production environment. For example, in the case of crops this is the living soil (IFOAM, 2008). By raising transplants in the soil of a growers own holding (bought in bare-root transplants are prohibited in organic standards), plants will be better adapted to their final environment, in terms of the physical, chemical and biological properties of the soil, including mycorrhizal associations. Bare-root transplants are usually more developed at planting and have greater reserves and vigour than a smaller module plant. For this reason bare-root brassicas may have better resistance to root fly than modules (Deane, 2005). Some of the problems of holding module-raised plants when conditions are unfavourable for planting have been covered. Bare-root transplants allow more flexibility in planting date and provided mechanical transplanting can handle larger plants can extend the period available for planting by 2 weeks for brassicas and 3 weeks for leeks (Deane, 2005). Later planting can allow more time for false seedbeds and deeper planting can enable inter-row weeding to be carried out sooner. Quality of leeks can improve by enabling deeper planting of a larger plant and thus more blanching of the stem. The use of bare-root transplants is more in keeping with organic principles of working within a closed system. It saves on transportation of both growing media and transplants and costs. (Hall and Tolhurst, 2006)

There are also some disadvantages of using bare-root transplants. They are not suitable for all transplanted crops, being most suitable for brassicas and leeks. The cost of seed, given the inevitable losses of sowing into open ground, can be prohibitive for hybrids and/or organic seed. There is more risk involved and there are management implications, particularly in weed control and minimising pest and disease attack. There is also a lot less uniformity than with modules, though, depending on market outlet, size variation at harvest may not be a disadvantage (Deane, 2005).

3.4 Conclusions

It is becoming increasingly important for organic growers and the organic industry as a whole to look at the carbon and wider environmental footprint of its activities. For plant-raising there are many advantages of bare root transplants but this is only going to be possible for brassicas and leeks. For many other crops blocks or modules are still the best method of production due to the advantages they give for weed control and flexibility for crop harvesting and green manure production. There is clearly still a challenge to develop effective systems for raising modular vegetable transplants that closer aligned with the IFOAM *principle of ecology* and this challenge needs to be overcome.

There is pressure on growers and growing media manufacturers to reduce reliance on peat. It is preferable, to use substrates from renewable sources that are locally sourced. There have been a number of projects looking at the use of green waste compost in growing media, which is a good starting point but nothing aimed specifically at the professional organic market. The origin and energy needed to produce minerals and other nutrient sources used in growing media also need to be looked at.

Biological processes are integral to the organic system. By their nature they are complex. In moving from a conventional system with total control of nutrient availability for the growing transplant to an organic system relying on biological activity to release nutrients was never going to be easy. Growing media need to be handled with care and have a ‘shelf-life’. Further fundamental research is needed on the biological processes in organic growing media, including nitrogen availability and disease suppression. (The Organic Grower, 2008)

Consistency and reliability of growing media are crucial to the organic grower as crop failure can be very damaging to businesses and transplants is one area that growers want to reduce risk. There can be problems with growing media and when things go wrong co-operation and communication between the grower and the media manufacturer is needed to identify the causes and liability quickly. Communication is also needed between growers who may not realise that others can be experiencing the same problems. Klasmann is said to be the only manufacturer to provide a proper specification (The Organic Grower, 2008) and often it is difficult to find out what is in the media.

Many of the trials that have been carried out in the past have been evaluating commercially available growing media and liquid feeds. Although this has provided valuable information for growers, it can become quickly outdated. Commercial formulations may change over time and also manufacturers may drop organic lines or go out of business all together. As the success or failure of a crop can be dictated by the quality of the transplants, it is important that this process of independent trialling of growing media certified for organic use is carried out periodically. It is also important to collect experiences of organic growers using different brands.

Despite the potential risks involved, but perhaps also because of the problems for small growers to access small quantities of media and inconsistency associated with commercial growing media, many growers have developed their own mixes for modules and potting. There is potential to develop this further to produce tried and tested recipes that growers can make up from locally sourced (preferably) ingredients.

One issue, hampering progress in this area is the dilemma that the organic plant-raising sector is still relatively small compared to the conventional and research funding has therefore remained limited to address the specific technical issues and the needs of organic growers. Another issue that needs resolving is that of managing risk; by nature organic growing media, being biologically active are more difficult for the manufacturers to manage and there is a risk of litigation if things go wrong.

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5. Appendix

5.1 Recipes for home-made propagating media

A number of recipes were outlined in The Organic Grower (2007):

Recipe 1 – Tolhurst Organic Produce
3 parts (large 3 gallon bucket) green waste compost. This needs to be well matured; sometimes you will have to sieve out the woody bits with a 10mm sieve. You may need to stack the compost for a year to ensure it is well broken down. So you need to plan ahead. Keep covered. Protect from rain.
1 part perlite. Use regular grade not the fine one.
Lime To every mix add approximately 100g finely ground limestone.

Materials are best mixed together in a clean cement mixer, adding water to achieve the desired moisture content. The material is far better for being mixed well in advance of use; this allows the biological activity to kick in. It will need adjustment to make good blocks, but it is great for modules.

For plants in pots such as tomatoes you will need some supplementary feeds. We use "Tamar Gold", which is a mix of sugar beet and lucerne meal, to supply some extra N. Around 100g per mix is enough. Allow the compost to stand for at least two weeks if adding nutrient as it needs to break down and become assimilated within the mix. Too much nutrient will inhibit seed germination and produce sappy plants. In the past we used fish, blood and bone, but stopped using this at the start of the BSE crisis. I didn't think that customers would like the idea, and anyway it tended to make the plants too soft and sappy.

Recipe 2 - Jenny Hall and Keith Griggs
The mix we use is:

- 40 litres sieved green waste (we use Soil Association certified Moorland)
- 20 litres x 5mm perlite
- 1 litre Dingleys ground fertiliser 5-5-5
- 1 litre seaweed meal
- 1 cup lime

We have found that the key is the older the green waste compost the better. This batch is two years old and it performed better than last year. The seaweed is essential for micronutrients (last year we had molybdenum deficiency when we did not use it). Finally the animal free compound fertiliser from Dingley's is a pain to crush. So we put it in the cement mixer once whole and the compost breaks it down. Then put it in the cement mixer again before use.

<u>Recipe 3 – Anne Sandwith</u>
I bought 25kg of W.L. Dingley's Nutrient Base 3 (Analysis 8:5:5 NPK) which is approved by the Soil Association. It is distributed by Thomas Elliott.

For seed and module compost use:
2 kg W.L. Dingley's Nutrient Base 3 (Analysis 8:5:5 NPK)
6.5 kg Lime
Mix with 1 cu metre of fine or medium peat (depending on the size of the seeds – use medium peat for bigger seeds as the drainage is better).
For transplants to be held for a while in modules, or for potting on, the recommendation is to use 4.5kg of NB3 and the same quantity of lime and a medium peat.
This makes 15 x 60 litre bags.