

HORTICULTURAL APPARATUS AND METHODS

TECHNICAL FIELD

The invention relates to the fields of horticulture, agriculture and floriculture and particularly to apparatus and methods for growth and production of plants, including in controlled environments and/or on a commercial scale.

BACKGROUND

Traditional agriculture and horticulture rely on use of a combination of soil, water, fertiliser and sunlight to support plant growth during crop production. Pests, such as insects or their larvae, are a problem where they attack the crop or carry diseases. The continuity of suitable climatic conditions, such as temperature, humidity, duration of sunlight, wind and rainfall, is also a potentially problematic issue affecting crop yield.

In order to aid the control of pests, spread of disease and also climate, crop enclosures such as glasshouses or greenhouses have been developed. These enclosures are now complex structures that are engineered for optimum light, ventilation, temperature and irrigation for crop growth. However, known complex growth enclosures in the form of glasshouses typically use relatively large amounts of energy to achieve optimum conditions. For example, glasshouses generally run very high ventilation rates, typically laterally across horizontal beds or trays, and thereby consume energy at a relatively high rate in order to maintain a desired temperature.

Nevertheless, glasshouses are only more intense versions of standard agriculture and horticulture arrangements where plants are conventionally grown on raised horizontal beds with greatest light impact from overhead.

Vertical agriculture is an emerging technology due to perceived increased efficiency in use of space. There are generally two types of "vertical agriculture" presently known, viz:

1. Vertical hydroponic agriculture using multiple horizontal trays containing plants, employing overhead artificial lighting, such as LED lights. The trays are usually insulated and subject to temperature control. This first type generally has the highest degree of light and climate control, for example to the point of using different colour/spectrum lights for different desired growth attributes. The hydroponic system is employed as the primary source of moisture and nutrients for the crop.

2. Vertical agriculture can involve crop cultivation using upright columns. These columns may be used either indoors or outdoors. The columns are disposed vertically and conventionally use flowing water. Flowing water is continuously supplied to the columns as typical solid growth media do not adequately hold water against the effect of gravity. See for example the disclosure in Australian Patent Application AU-A-37195/84 that is concerned with a hydroponic plant cultivation device. Furthermore, the density of planting is relatively low due to the need to ensure adequate lighting for all parts of the crop, as the upper plants tend to shade those below.

Apart from its efficient use of space, hydroponics is otherwise attractive because, water is easy to pump, water is an excellent system for transport of nutrients, water is in any event usually required for growth and transpiration of plants. Conveniently, water can be heated or chilled relatively quickly when sufficient energy is available to aid temperature control. In terms of water transport to the crop, it is also flexible since equipment like pumps, hoses, hose fittings and sprays are mass produced and cheap, and fluid dynamic systems are generally well understood.

Pests and disease of a plant's roots can also be controlled through use of liquid fungicides and disinfectant. Several hydroponics systems are now available for home use. However, these systems are not efficient, cost-effective nor will be sustainable in terms of labour input required.

Solid growth media has not been favoured for vertical farming in view of a range of associated problems; including: difficulty in managing the weight normally associated with such media; the desirability of holding water against gravity to allow the plants at both the top and bottom of a vertical column to achieve adequate continual moisture content; soil media that is messy in spills and prone to disease due to the tendency of organic matter therein acting to hold disease.

A further problem associated with "static" horticultural arrangements, such as hydroponics or vertical soil systems is the optimisation of light. Light exposure is typically sub-optimal when only tracked over the top of the plants in stationary arrangements.

Any references to methods, apparatus or documents of the prior art are not to be taken as constituting any evidence or admission that they formed, or form part of the common general knowledge.

It is an object of the present invention to provide horticultural apparatus and methods for vertical agriculture employing solid growth media which overcome or address one or more of the problems of the prior art, or at least provides the public

with a useful alternative to existing vertical agricultural arrangements employing hydroponics.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a modular container for particulate plant growth media, the container comprising:

5 an elongate tubular body having a longitudinal axis and arranged to be supported in an upright orientation;

the tubular body defining an internal space and including a continuous wall having plurality of ventilation openings and a plurality of apertures for receiving

10 tubelets for plants or blanking caps;

the tubular body further including a first collar portion at one end of the continuous wall and a second collar portion at an opposed end of the continuous wall; and

the first collar portion being engageable by a first end cover and the second

15 collar portion being engageable by a second end cover; wherein

individual apertures in the continuous wall either closed by the blanking caps or populated by a tubelet that communicates with the internal space of the tubular body and is selectively removable from a respective aperture.

20 Preferably the continuous wall of the tubular body is of substantially cylindrical configuration.

In preference, the ventilation openings are in the form of windows each having a mesh screen, wherein a gauge of the mesh screen is suitably selected to retain the particulate growth media whilst facilitating air flow through the internal space.

25 Preferably, the plurality of apertures in the continuous wall each include an oblique mouth portion.

Suitably the first collar portion includes a first engagement formation, such as an external screw-thread; and the opposed collar portion includes a second engagement formation, such as an internal screw-thread. If required, the first engagement formation is complementary to the second engagement formation,

30 whereby a series of tubular bodies may be inter-connected.

Preferably, an end cover (such as the first end cover) is orientated at an in-use top end of the modular container, the first cover is of annular configuration including an aperture in an end wall thereof. The first cover may further include a plurality of radially extending holes provided in a circumferential wall thereof, the holes

35 suitably facilitating support of the modular container.

Preferably, an end cover (such as the second end cover) is orientated at an in-use bottom end of the modular container, the end cover has an end wall that is either closed or formed with a mesh screen. The second end cover formed from a mesh screen has a mesh size selected to retain the particulate growth media whilst facilitating air flow through the internal space.

Suitably the tubelets are arranged for snap fitting to respective apertures. Preferably, the tubelets are fitted to the body of tubular body at an oblique angle to the longitudinal (in use upright) axis. Desirably the tubelets are fitted at an oblique angle between about 25° and 60° to the longitudinal axis, most preferably between 35° and 50° to said axis.

Preferably the tubelets are constructed in two inter-fitting tubular sections, including a first outer section having an external, oblique groove for cooperation with the aperture mouth portion and a second inner section receivable within the first outer section, suitably in telescopic relationship.

Desirably, both the first outer section and the second inner section of a tubelet include an array of openings that, in use, are alignable with one another to facilitate communication between the tubelet and the internal space of the tubular body. Preferably the array of alignable openings is in the form of circumferentially extending elongate slots in respective tubular walls of the tubelet sections. If required, the tubelet sections may further include a mechanism for enforcing alignment of the openings when the inner and outer sections are fitted together, such as a tongue and slot formation.

In a grossly elongated variant of the modular container, there may be a series of tubular wall sections inter-engaged with one another by way of the complimentary engagement formations at opposed ends of each section, thereby forming a multi-section tubular wall structure disposed between a first (or in-use top) end cover and a second (or in-use bottom) end cover.

Suitably the grossly elongated modular container variant includes between 2 and 5 tubular wall sections inter-connected in series between the first and second end covers.

In another aspect of the invention, there is provided a method for growing plants using a modular container for horticulture, the method comprising the steps of:

providing a modular container including an elongate tubular body provided with a plurality of ventilation openings and a plurality of apertures for respective tubelets;

introducing a first mixture of particulate growth media into a plurality of tubelets;

seeding the first mixture contained in the plurality of tubelets;

- preparing a second mixture of particulate growth media including zeolite having an average particle size in the range of 2mm to 8mm by soaking the second mixture in a liquid including water;
- filling the tubular body of the modular container with the second mixture of particulate growth media;
- 5 locating the modular container in an upright orientation;
- within a pre-selected period after germination of the seeds, transferring the plurality of tubelets carrying seedlings into selected apertures of the tubular body; and
- 10 providing a suitable growth environment to support further plant growth to maturity.

Suitably, the step of introducing a first mixture of particulate growth media is conducted when the tubelets are separated from the tubular body of the modular container.

- 15 Preferably, the step of providing a suitable growth environment for the plants includes provision of one or more of adequate water, nutrients, ventilation and light. Suitably, the provision of adequate water and nutrients involves provision of an irrigation system for water entrained with the nutrients and having an outlet alignable relative to the longitudinal axis of the modular container. Suitably, the
- 20 provision of ventilation involves suspending the modular container in an environmental enclosure having a ventilation sub-system providing air flow substantially congruent with the longitudinal axis. Preferably, the provision of light involves providing the environmental enclosure with a light exposure sub-system including movable supports for suspending the modular container and/or light re-
- 25 directing panels for re-directing ambient light.

- In a further aspect of the invention there is provided an environmental enclosure for vertical horticulture, the enclosure comprising:
- a plurality of walls, a floor and a roof defining roof void;
- 30 a chamber for a crop, the chamber set above said floor, within the walls and below the roof void;
- a plenum located below the floor having inlets for ambient air and outlet vents provided in the floor and in fluid communication with the chamber;
- the roof including a plurality of outlets allowing escape of air rising into the
- 35 roof void; and
- a support system for movably supporting a plurality of upright tubular containers for cultivating growth of plants.

- Preferably, the plurality of walls and/ or the roof comprise, at least in part, rigid panels of transparent or of at least translucent material. In one form, the rigid
- 40 panels are constructed from plastics material such as polycarbonate. If required the rigid panels are of sandwich construction, including at least one air gap.

Most preferably, the walls include at least two opposed elongate walls for extending substantially East-West. At least a lower portion of the elongate walls

may include light reflection panels, suitably pivotally mounted to the enclosure. The light reflection panels suitably include an internal light diffusion layer.

Suitably, the roof void extends above said plurality of walls. The plurality of outlets may include mechanical exhausts, such as fans, for drawing air out of the roof void.

If desired, the plurality of walls may comprise a continuous arcuate wall.

Suitably the floor includes outlet vents in the form of floor grates or grids.

In one form, the support system may include an overhead support rail extending across the chamber between said opposed elongate walls. The support system may further include a carrier bar from which the tubular containers may be suspended. Suitably a plurality of overhead support rails are provided in rows.

In an alternative form, the support system may include an overhead conveyor having a drive for moving a spaced series of tubular containers along a path traversing the chamber. The overhead conveyor suitably includes a chain from which the individual tubular containers may be suspended and direction changers, such as chain wheels, arranged in a serpentine path. Desirably, the serpentine path is piece-wise linear, including lines of tubular containers extending in substantially the same direction as the elongate walls.

Preferably, provision of the modular containers involves the horticultural containers as set out in the statements above concerning such containers.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows:

Figure 1 is a top perspective view illustrating a modular container for solid growth media in the form of a tubular growth pod of a preferred embodiment of a first aspect of the invention;

Figure 2 is a bottom perspective view of the tubular growth pod of the embodiment of Fig. 1;

Figure 3 is an exploded top perspective view of the tubular growth pod of the embodiment of Fig. 1 showing removable components;

Figure 4 is a front elevational view of the tubular growth pod of the embodiment of Fig. 1;

Figure 5A is a top plan view of the tubular growth pod of the embodiment of Fig. 1;

Figure 5B is a bottom plan view of the tubular growth pod of the embodiment of Fig. 1;

Figure 6A is a side elevational view of the tubular growth pod of the embodiment of Fig. 1;

Figure 6B is a sectional front elevational view of the tubular growth pod taken along line B- B of Fig. 6A;

Figure 7 depicts an exploded sectional front elevational view of the tubular growth pod comparable with Fig. 3;

5 Figure 7A shows an enlarged view of a mesh screen identified as detail A of the tubular growth pod of Fig 7;

Figure 8A is an enlarged image of a tubelet for the growth pod of the type illustrated in Figs 1-7;

10 Figure 8B is an image of a lower portion of a growth pod together with the tubelet of Fig. 8A and several inner tubelet sections of the kind discussed in relation to Fig. 7;

Figure 9 is an image of the growth pod of Fig. 8B. with alternatively disposed blanking caps and tubelets suspended by the top cap by a support means;

15 Figure 10 is a top perspective view of an environmental chamber in the form of a greenhouse of a first embodiment;

Figure 11 is front elevational view of the first embodiment of the greenhouse in Fig. 10;

Figure 12 is a partially sectioned side elevational view of the greenhouse of Fig. 10;

20 Figure 13 is a sectional top plan view of the greenhouse of Fig. 10;

Figure 14 is a front elevational view of a greenhouse of a second embodiment of the environmental chamber;

Figure 15 is a side elevational view of the greenhouse of Fig. 14;

25 Figure 16A is a top perspective view of a horticultural container comprising a plurality of growth pods coupled together;

Figure 16B is an exploded side elevational view of the horticultural container of Fig. 16A;

Figure 17 is a side elevation view of a variant of the greenhouse of the second embodiment of the environmental chamber; and

30 .Figure 18 is a top plan view of the variant of the greenhouse of Fig. 17.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Modular container

Referring now to Figures 1-4, there is depicted a tubular module 10 or "pod" type container for holding solid particulate growth media for horticulture relating to a first aspect of the present invention. The container, here in a cylindrical elongate configuration, is used for growing or cultivating plants in the growth media from seedling stage to full maturity. The tubular module 10 comprises a main body 12 that is formed by a continuous tubular wall 14 and when used is normally positioned in an upright, preferably vertical, orientation as shown in the drawings. A first or top end of the main body 12 includes an engagement formation, here in the form of a first collar 16 on the tubular wall 14 having an external screw thread, whilst a second opposed or bottom end of the main body includes a complementary

engagement formation, here in the form of a second collar 18 on the tubular wall 14 provided with an internal screw thread (see also Fig. 7).

Where a single main body 12 is employed in a pod or container 10, a first cover in the form of top cap 26 having an internal screw-thread is engaged with the first or top collar 16. The cap 26 is substantially annular having a port 27p in an end wall 27 and provided with support arrangement, here in the form of a plurality of radially extending holes 26c in a circumferential wall. The holes 26c are suitably engageable by an overhead support from which each container 10 may be suspended, as shown in Figure 9. A second cover in the form of bottom cover 28 having an external screw-thread is engaged with the second or bottom collar 18. An end wall 29 of the bottom cover is suitably closed or alternatively includes a mesh screen for retention of solid particulate growth media.

The preferred arrangement of complimentary engagements, such as screw-threads, on opposed ends of the main body 12 also allows a series of, for example up to five (5), main body sections to be inter-connected to form a lengthened container (see also Figs 10-12, 16A and 16B). In such an arrangement, a bottom cover 28 having a mesh screen (not shown) in the end wall 29 of bottom cover provides for improved ventilation and drainage of liquid, if desired.

The tubular module 10 is composed of a food grade plastics material, such as a high density polyethylene (HDPE). For typical single module, dimensions of 425 mm long (excluding end covers 26, 28) and 100 mm in diameter, a filled module could weigh up to about 20kg. The fill includes solid particulate growth media and mature plants, as discussed further below. Accordingly, the screw-threads of the first and second collars 16, 18 of the present embodiment are designed to carry a static load of at least 100 kg. However, the pods could be of various sizes and shapes and employ other engagement formations (such as snap fittings or employing fasteners), depending on crop application and anticipated environmental conditions, such as ambient temperature and available air flow.

The continuous tubular wall 14 includes a plurality of window openings 20 for ventilation that are each provided with a mesh screen 22 which only partially obstructs fluid flow therethrough. If required the mesh screen 22 may be removable in order to allow different gauges of mesh to be selectively employed in the growth module 10. An enlarged view of a window 20 with mesh screen 22 is shown in Fig. 7A. The tubular wall 14 further includes a plurality of apertures 24, suitably in longitudinal arrays, for receiving respective tubelets 30. The aperture arrays are shown spaced at 180° from one another (suitable for static use when a module is aligned East-West), but could also be arranged in arrays spaced at 90° from one another, with a commensurate reduction in the size or number of ventilation windows 20 (suitable for use in modules that are periodically rotated relative to a light source).

In the embodiment and as shown in Figs 3 and 5A-8B, the tubelets 30 each include an outer tubelet section 32 retained within a respective aperture 24 and an inner tubelet section 34 removably supported by the outer tubelet section 32, suitably in telescopic relation with each other. Both outer tubelet section 32 and inner tubelet section 34 are provided with alignable openings, here in the form of a series of laterally disposed slots 36, 38 which, in use, facilitate physical (including fluid) communication between tubelet interiors and an internal space 25 bounded by the continuous tubular wall 14. Similarly, both tubelet sections are provided with closed end walls 37, 39 (see Figure 7). An end wall 37 of the outer tubelet section 32 prevents back-filling of growth media into the tubelet 30, including whilst the inner tubelet section is removed; whilst the end wall 39 in the inner section 34 retains the separate growth media provided therein together with seeds or resulting plant growth. In a preferred embodiment, discussed further below, the growth media mixtures of particulate solids differ in view of their specific roles.

The inner tubelet section 34 further includes a protrusion, here in the form of an annular band 35, which engages an end face of the outer tubelet section 32, see cross-sectional view in Figure 6B. A normally top edge portion 35t of the annular band 35 is truncated to provide a visual indication of the correct relative orientation (i.e. openings aligned) with the outer tubelet section 32; see Figure 7. In a modification of the present embodiment, the tubelet sections may instead include a mechanism for enforcing alignment of the respective sets of openings 36, 38 when the inner and outer sections of tubelet 30 are fitted together, such as a tongue and slot formation on respective sections.

An external surface of the outer tubelet section 32 is provided with a retainer in the form of an oblique groove 33 and is arranged for snap or similar removable fitting into a respective aperture 24 of continuous wall 14, as best shown in Figs 6B and 8A. Furthermore, the apertures 24 are provided with an angled mouth 24m (see Figure 6B) for reception within the groove 33, resulting in the tubelets being disposed at an oblique angle to a longitudinal axis B of the main body 12, for example at 50° from the axis as shown in Fig. 4. However, in other embodiments, tubelet angles in the range of 25° to 60° from the (in use vertical) longitudinal axis (B) may also be employed. In use, the angled arrangement of the tubelets 30 aims to maximise the amount of light available to plants disposed in each vertically spaced tubelet 30, particularly where the containers are manually or mechanically moved relative to a light source, such as overhead artificial lighting or more particularly the sun. Applicant believes that a tubelet 30 (and consequent plant growth) angle of around 35° allows for greatest potential for height and plant growth. On that angle the plants receive light and have the ability to grow to about 20cm high with minimal blocking of light on neighbouring plants, including above and below.

If required, for example due to the typical mature size of plants to be grown, blanking caps 40 are providing for closing selected apertures 24 of the tubular wall

14 at the option of a user. For example, the tubelets may be inserted into each other aperture 24 in order to provide additional space for mature plants or relatively larger size, as depicted in Figure 9. The blanking caps 40 of the embodiment include a foreshortened tubular section 42 carrying a groove 43 for retention by the angled mouth of a selected aperture 24, see especially the sectional view in Fig. 6B. The number of plants per module 10 can also vary depending on the plant's light requirements, the plant root radius, its water requirements and the time the plant is required in the container to grow to maturity.

10 In use, the inner tubelet sections 34 are (if necessary removed from the modular container 10 and) separately filled with a first mixture of solid particulate growth media formulated to suit a desired crop. A planting tray (not shown) having suitably sized apertures can be employed to support the inner tubelet sections 34 by engaging the protruding annular band 35. Once inserted into such a tray, the horizontal array of filled tubelets may be seeded by a conventional horticultural seeder. If required, the seeder can also be arranged to insert a charge of growth media, plant the seed and then cover the seed with further media. The seeded tubelet sections 34 are then cultivated in the horizontal trays until germination, for example in a standard glasshouse for approximately 10-30 days, depending on the crop.

20 The first mixture or "seeding mix" contain seed raising materials suitable for germination and growth of seedlings, providing appropriate basis for the control of environmental conditions, including pH, temperature, moisture content, nutrient content, and microbial conditions. The solid particulate media may contain, in natural or synthetic forms, a mixture of the following materials (in alphabetical order): appatite; calcined kaolinite; carbon in form of charcoal, biochar, activated carbon or other derivatives; chitin; composted organic material; fulvic acid; gibberelic acid; graphene; humic acid; kaolinite; leonardite; organo-metallic framework (OMF) materials; perlite; silica gel; titanium dioxide; vermiculite; and zeolite. The solid media contains the mixture in a range of particle sizes prepared specifically to allow the optimum moisture content, nutrient retention, microbial population and ventilation air flow.

35 In one embodiment, the first mixture may comprise a mixture of organic compost, biochar, zeolite of fine particle size (for the lower portion of the tubelet section) to maximise water holding potential, and larger particulate zeolite (e.g. 4-6mm average particle size) to allow infiltration of air to the seed or root system. As germination is a respiratory process, oxygen is required to allow the energy in the seed to be utilised.

40 A significant issue with plant production, particularly in tropical climates, is balancing light energy requirements, ambient air flow and their influence on plant temperature, especially root zone temperature. Ambient temperature of the plants is relatively less critical, provided it can be held within about +/- 5 °C of a target root

- zone temperature for plants. Applicant believes that selection of suitable solid growth media can provide for adsorption cooling and energy conversion, because the enthalpy of adsorption is significantly greater than latent heat of (water) evaporation. For example, it takes around 5 – 10 times the energy to remove water from a particulate absorbent material, such as zeolite as it does from direct evaporation of water. In order to take advantage of the adsorption cooling effect it is highly desirable to provide sufficient air flow. The ventilation windows provided in the wall 14 tubular body 12 are provided to facilitate this necessary air flow, including in the vicinity of the plant root zone.
- 10 The material in a second mixture for the pod containers which includes at least 75%, preferably greater than 80%, zeolite that may be delivered into the pod as a homogenous mixture or may be added in concentric layers containing differing size and shaped particulates. Particle size for the zeolite may range from 2mm up to 8mm, preferably 4-6mm. Generally, the selection of zeolite involves a trade-off amongst a variety of properties, including bulk density (i.e. particle size and associated mass), nutrient storage, water retention and acquisition cost. In particular, particle size influences surface area available for the adsorption/desorption process, air porosity, mass, air flow/ventilation, energy removal rate and root growth properties, when loaded into a growth container.
- 15 Zeolite has further desirable characteristics as a soil ameliorant due to its high cation exchange capacity (CEC). The selection of a particular zeolite, including from natural and synthetic types, is to be considered with regard to uptake of nutrients, including cations such as ammonium calcium, magnesium and potassium. Perlite is also employed to ensure a lower bulk density of the second mixture and to provide air filled porosities. The second mixture may also include some charcoal which provides a very high surface area for nutrient adsorption and water uptake. Chitin may also be added to the mixture to adsorb anions (e.g. phosphate and sulphate) from the zeolite, charcoal and other selected particulates.
- 20 Some of the materials in the second mixture may be used as coatings for surfaces of other materials in particulate form, as required. For example, materials capable of forming biofilms may be provided for integrated pest management purposes. The second mixture loaded into the tubular body 12, occupying the enclosed space 25 is (preferably prior to use for plant growth) saturated in water for up to 24 hours. If desired, the saturating water may also contain high concentrations of ammonium, potassium, calcium and/or magnesium in solution, to provide a buffer of nutrients – later available for plant growth. Immediately prior to use, the second mixture is desirably washed with fresh water.
- 30 Within a period of 1-3 weeks of germination, the individual (inner) tubelet sections 34 including seedlings growing therein are re-located or transferred into selected apertures 24 of the modular container 10. The individual containers can be located in houses, gardens, balconies, restaurants where there is sufficient natural or
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artificial light or, on a larger commercial scale, in green houses as will be discussed further below in relation to a second aspect of the present invention.

Returning to discussion of the growth modules 10, the outer tubelet section 32 provides a barrier to the second mixture migrating into the inner tubelet section 34 whilst allowing an entry for water which can be supplied from the top via the port 27p in top cap 26. The slots 36, 38 provided in each of the outer tubelet section 32 and inner tubelet section 34 allow root growth into the interior space 25 of body 12 of the growth module 10 whilst allowing interchange of fluids including air, water and entrained nutrients. The second or bottom cover 28 is shaped like a cup in order to provide a reservoir for water, nutrients and solid growth media. Suitably, upon watering or timed irrigation of the plants via port 27p, excess water will drain into the bottom cover 28 from the lowest plants in the module 10, thus helping to mitigate water-logging. The reserved water can later be "wicked upwards" for use in evapo-transpiration of the plants. The reservoir in bottom cover 28 conveniently allows for free movement of the growth modules 10 in order to maximise available light, minimise run-off and to optimise use of available space.

In an alternative embodiment, a mesh screen (not shown) may be provided in the end wall 29 of the bottom cover 28, allowing water to drain freely whilst retaining the solid particulate media therein. Suitably, the mesh screen can be similar dimensions to the screens 22 provided for the ventilation windows 20, e.g. 2mm openings. Water passing out from the pods 12 may be collected below by a re-cycling system, if desired. Generally, it is desired to balance irrigation with plant requirements in order to minimise run-off.

Environmental enclosure

A further aspect of the invention is concerned with an environmental enclosure, in a first embodiment in the form of greenhouse 100 as illustrated in Figures 10-13. The greenhouse allows a degree of control to be exercised over environmental conditions and particularly to suit vertical agriculture that utilizes solid particulate growth media. In one particularly preferred arrangement, the greenhouse of this embodiment is fitted with a plurality of the tubular growth modules 10 of the first aspect of the invention, and is arranged to facilitate air flow control and improve capture of sunlight. Most suitably, elongate growth modules 153 of the kind including a plurality, for example five (5) main body sections 12 coupled end-to-end, are utilized (see Fig. 16A). However, the enclosure may be used with any horticultural container including an elongate tubular body set in an upright orientation and provided with a plurality of ventilation openings and a plurality of apertures for plant growth.

The greenhouse 100 includes an outer enclosure that may be of conventional framed construction having, with reference to Figure 13, opposed end walls including front wall 102 and rear wall 104 and relatively elongated opposed side walls, suitably including an Eastern wall 106 and a Western wall 108. The

greenhouse includes a mild steel frame wherein the walls are provided between vertical support members or posts 109 and covered by a pitched type roof 110 which provides a roof void 112 above a top edge of the walls and of horizontal supporting members such as joists 114 and beams 115; see Figures 10-12. The
5 roof void 112 is closed at each end by gable end walls 113; see Figure 12. Note that front wall 102 and a portion of roof 110 is omitted from Figure 10 for clarity (and the roof 110 is omitted entirely from the plan view in Figure 13 for the same reason).

The walls and roof are composed of transparent rigid panels (such as laminated
10 glass or high strength polycarbonate, usually referred to as a "glasshouse") or flexible panels (such as plastic sheeting or insect screens) of selected light transmissibility, and/or panels of at least of translucent material (such as woven shade cloth held on a deploying roller) to optionally moderate sunlight capture. The
15 panels may use a double or triple sandwich panel arrangement with interposed air gaps to improve insulation properties. The elongate side walls 106, 108 of the embodiment are located East-West in order to maximize sunlight incident on the greenhouse, although other locations may also be viable.

Below the joists 114 and beams 115 there is defined a controlled environment chamber 116, being of a parallelepiped shape in the present embodiment. Other
20 chamber shapes employing a continuous arcuate wall or semi-continuous arcuate wall sections or panels may also be utilized. In the particular example, the overall height of the greenhouse 100 is about 4.1m and a length of just over 12.0m, the walls are about 2.7m high from ground level. This height provides clearance for a walk-space within the chamber 116 for users 70, conveniently enabling manual
25 loading of the tubelets 30 into elongate growth modules 153 and subsequent harvesting of a mature crop, as described further below.

The greenhouse is provided with a floor 120 and a sub-floor area providing a plenum space 122, of about 1m in depth in the embodiment, for air flow 124. The
30 plenum 122, a component of a ventilation sub-system, allows ambient air to be drawn from the exterior of the greenhouse 100, by intakes 125 nearby to ground level. If required (such as in a tropical climate), the ambient air 126 from the intakes may be cooled by a pre-conditioning apparatus 127 which feeds conditioned air into the plenum 122 for distribution into the chamber 116. The floor 120 includes
35 an arrangement of vents 128 which feed the (optionally pre-cooled) air upwardly from the plenum into the chamber 116. The vents may be provided by a grid type floor or floor grates (not shown) and optionally provided with insect resistant screening. Alternatively, insect screening may be provided over the ambient air
40 intakes 125. It will be appreciated that, in a variation to the embodiment for a cooler climate and depending on the crop desired to be grown (e.g. plants suited to a temperate climate), the ambient air may instead be warmed by an air pre-conditioner 127 prior to entering the plenum 122.

In the present embodiment, a movable support system 130 attached to the roof joists 114 is provided for two banks 150, 152 of growth pods, each bank having multiple rows of pods. Suitably pairs of rows, one from each bank are manually movable relative to a respective common lateral support rail 132; as best appreciated from Figs 11 and 13. Individual elongate growth modules 153 are arranged in each bank so that the tubelets 30 and thus plant growth are normally orientated East-West to take advantage of incident sunlight (and thus the ventilation windows 20 are typically orientated North-South).

Focusing on a front-most row of the first or western bank 150 of vertical growth modules 153 depicted in Fig. 11, the support system 130 includes a first carrier bar 134 movably carried by lateral support rail 132. The support rail extends across the chamber 116 from western wall 108 to eastern wall 106. In a second or eastern bank 152, the support system further includes a second carrier bar 136 from which are suspended a further, adjacent row of individual vertical growth modules 153, which second carrier bar of an adjacent row is also carried by the lateral support rail 132 in that row. This arrangement of pairs of carrier bars 134, 136 on a common lateral support rail 132 is repeated for co-linear rows of the first and second banks 150, 152 of pods; see Figs 12 and 13. The carrier bars suitably include rollers which engage with a support surface of the overhead support rails, and are provided with a series of spaced hooks for suspending each the growth containers 153.

Since the length of each carrier bar 134, 136 is approximately one third of the overall length of the lateral support rail 132, it will be appreciated that a row from one of the banks 150, 152 may be conveniently moved from a position adjacent to an elongate side wall 108, 106 to a central position - as desired - without disturbing the corresponding row of the other bank. Figs 11-13 depict all carrier bars for rows of the respective banks parted from one another (i.e. located adjacent to respective side walls), so as to provide a central access or walk-space for users 70 within chamber 116.

The rows of vertically disposed growth pods 153 in each bank 150, 152 allow multiple paths for air to flow upwards from the floor vents 128, around the growing crop, and towards the roof void 112. The rising air flows to outlets provided in the roof 110 including hatchways 140 with closable doors 142 in longitudinal series adjacent to the roof peak. Further air outlets, here in the form of ports 144 with exhaust fans 146, are provided in a gable end 113 of the green house, also adjacent to the peak of roof 110 as shown in Fig. 11.

The air flow rate past the pods 10 in each bank 150, 152 should be high enough to allow the zeolite included in the particulate growth media to effect temperature control, including through de-adsorption and evaporation of water stored in the zeolite particles, whilst providing sufficient carbon dioxide for plant growth. Applicant believes that upon the zeolite particles being saturated with water and

employed in the second mixture for filling the growth pods, the water de-absorption and subsequent evaporation will consume about 5-10x the heat energy from the air, as compared to merely just using water in liquid form for evaporative cooling (for example water mist spray alone)..

- 5 The air flow rate should also be sufficiently high to discourage condensation on the outer surfaces of the growth pods 10, since this may lead to undesirable algal growth. In general air flow rate is dependent on ambient air temperature. In one particular installation, Applicant has found that the plants located in the pods 10
- 10 evapo-transpire on the E-W sides to achieve a temperature reduction in a region of between 50-100mm from a line of plants at a ventilation rate of from 1-5 gas exchanges per minute (or approximately 0.01 – 0.1 m/s in velocity), depending on the height of the environmental chamber 116. In this example with ambient temperature was of the order of 33°, up to a 10° reduction in temperate of the plants was able to be maintained by the greenhouse 100 of the embodiment.
- 15 The ventilation sub-system for the greenhouse 100 can use either passive or active ventilation methods to control air flow, including for providing sufficient carbon dioxide for efficient plant photosynthesis. In the passive ventilation method, which is suited to climatic areas where there is a sufficient heat build-up in the roof void 112, warmer air rises by natural convection and drags the air through the array
- 20 of vertical pods 153. In the active ventilation method, fans – such as exhaust fan 146 – are used to draw air in from the bottom plenum 122. Alternatively, or in combination, further fans (not shown) may be employed in conjunction with the pre-conditioners to force or blow air. Active ventilation using at least exhaust fans is desirable in tropical climates, since the air entering the chamber 116 from the pre-conditioner 127 will likely be cooler and will otherwise sink. The air exiting (i.e. after moving upwardly through the array of pods 153) may not be hot enough to provide sufficient chimney effect – hot air rising – to operate efficiently.
- 25

The light control sub-system of the environmental enclosure, here greenhouse 100, of the first embodiment, includes two parts. The first part is facilitated by the

30 movable mounting of the rows of growth containers in respective banks 150, 152 hooked onto the carrier bars 134, 136 which roll on lateral rail 132. For example, as and when desired, the carrier bars in a bank from either the Western or Eastern side may be moved, here manually, towards the other of the elongate walls, i.e. toward the Eastern or Western wall. A further variation on this movable mounting

35 of growth containers is discussed further below in relation to a serpentine conveyor arrangement in a second embodiment.

The second part of the light control system includes a plurality of light reflection panels 160 that are provided, in the present embodiment, in a lower portion of the elongate side walls 106, 108; see Figs 10-13. The reflection panels are pivotally

40 mounted 162 at a lower edge, adjacent to the floor 120 in order to facilitate adjustment. The individual panels are suitably provided with a diffusing layer (not

shown) on an internal surface so that reflection occurs on many angles back into the chamber 116. The reflection panels reflect diffuse light back from the elongate sides of the greenhouse 100 which permits, particularly in conjunction with the movable mounting of modules 153, a higher intensity of planting crops for given greenhouse area.

The light control sub-system can address the tendency of the outermost bank of growth pods tending to shade light arriving from the opposite side of the greenhouse. Light may be controlled by either moving selected rows of the pods in a bank with the carrier bars 134, 136 and/or adjusting the angle of the light reflection panels as desired. Where the incident light is particularly intense, the roof and/or walls of the greenhouse may be augmented with a flexible light moderating sheet, such as woven fabric or "shade cloth" that can be selectively deployed from a roller (not shown).

The greenhouse 100 is also provided with an irrigation sub-system (not shown) having pipework with overhead outlets provided at indexed positions corresponding to the ports 27p in the top caps 26 of each growth module 153. Watering may be carried out periodically, for example for 1 minute in each hour in order to keep the growth media moist. The water, supplied from a tank which can also be temperature controlled (for example to aid cooling), can include soluble plant nutrients and be applied sufficiently slowly to avoid permeating outwardly from the tubular body 12 (for example via the windows 20), which might encourage undesirable algae growth. The operation of the irrigation sub-system in terms of the volume of water applied is balanced with the ventilation sub-system in terms of air flow rates.

Turning to Figures 14, 15 and 18, there is illustrated a greenhouse 200 of a second embodiment of the environmental enclosure of the invention which includes an alternative movable support system, in the form of a motorized overhead conveyor sub-system 270. For economy of present description, features of this second embodiment already described in relation to the greenhouse 100 of the first embodiment are simply prefixed by "2##" (as distinct from "1##"). By way of example, the greenhouse 200 includes opposed end walls including front wall 202 and rear wall 204 and relatively elongated opposed side walls, suitably including an Eastern wall 206 and a Western wall 208.

In the greenhouse 200, the overhead conveyor 270 includes a carrier for suspending the growth modules 153 that is supported from the roof beams 215, see Fig. 15. The carrier follows a serpentine path 272 within chamber 216, allowing the modules to be moved relative to incident sunlight, including that diffusely reflected by reflector panels 206. The carrier is driven along the path 272 by a drive, such as an electric motor 274, and suitably takes the form of an endless chain 276 comprised of interconnected links which pass around direction changers in the form of chain wheels 278; as best seen in Figure 18.

The serpentine path 272 of the embodiment is piece-wise linear, including lines 280 of spaced growth modules 153 generally extending parallel to, or at least in substantially the same direction as, the Eastern and Western walls 206, 208. The outermost lines 280 are spaced from the elongate walls, in order to provide user 5 70 access for maintenance and related purposes. However, it will be appreciated upon comparing Fig. 18 with Fig. 13 that a driven carrier, such as chain 276, allows for greater spacing between individual growth modules 153 – suitable for cultivating relatively larger plants. The conveyor 270 is operated between irrigation cycles, and each “stop” position of the endless chain 276 returns individual growth modules 10 153 to indexed positions below irrigation system outlets. The motorized conveyor reduces the need for manual labour since the tubular containers can be delivered to a single location and better utilizes the available space in the chamber 216 for cropping.

A variant of the greenhouse 200, having a crop processing annex 290, which 15 shown in plan view in Figure 18 employs the same motorized conveyor sub-system 270 as described in relation to Figures 14 and 15. The serpentine path 272 includes a return line 282, which conveniently passes by the processing annex 290 in the variant shown in Figs 17-18. A Northern wall of the chamber 216 in the greenhouse variant employs one or more flexible wall sections in the form of a plastic strip 20 curtain 292, allowing passage of personnel including for the purpose of harvesting and/or inserting tubelets 30 carrying seedlings ready for further growth. For example, the harvested crop or tubelets with seedlings may be transferred to and from the annex 290 by a transfer device such as roller conveyor 294.

In use, the greenhouses 100, 200 of the preferred embodiments each provide a 25 controlled growth environment for seedlings in tubelets 30 fitted to the growth containers 153, which are each filled with respective solid particulate growth media and suspended from a movable support system in pre-determined spaced relation within the chamber 116, 216. The ventilation windows 20 in the tubular walls 14 cooperate with the natural or forced air flow upwardly directed around the spaced 30 containers 153, to provide a stable temperature. The irrigation system periodically provides water, suitably including soluble nutrients, for the plants and to re-charge the adsorbents within the growth media mixtures which contribute to temperature control. Light control within the greenhouse is achieved by the combination of the selective movement of the growth containers 153 and the diffusing reflection 35 panels 160, 260 for re-directing incident sunlight.

In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. The term “comprises” and its variations, such as “comprising” and “comprised of” is used throughout in an inclusive sense and not to the exclusion of any additional features. It is to be 40 understood that the invention is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or

modifications within the proper scope of the appended claims appropriately interpreted by those skilled in the art.

CLAIMS

1. A modular container for particulate plant growth media, the container comprising:
 - an elongate tubular body having a longitudinal axis and arranged to be supported in an upright orientation;
 - the tubular body defining an internal space and including a continuous wall having plurality of ventilation openings and a plurality of apertures for receiving tubelets for plants or blanking caps;
 - the tubular body further including a first collar portion at one end of the continuous wall and a second collar portion at an opposed end of the continuous wall; and
 - the first collar portion being engageable by a first end cover and the second collar portion being engageable by a second end cover;
 - wherein individual apertures in the continuous wall either closed by the blanking caps or populated by a tubelet that communicates with the internal space of the tubular body and is selectively removable from a respective aperture; and
 - wherein the first end cover further comprises a support arrangement adapted to be suitably engaged by an overhead arrangement for suspending said container.
2. A modular container in accordance with claim 1 wherein the continuous walls of the tubular body is of substantially cylindrical configuration.
3. A modular container in accordance with claim 1 or claim 2 wherein the ventilation openings are in the form of windows each having a mesh screen, wherein a gauge of the mesh screen is suitably selected to retain the particulate growth media whilst facilitating air flow through the internal space.
4. A modular container in accordance with any one of the preceding claims wherein the plurality of apertures in the continuous wall each include an oblique mouth portion.
5. A modular container in accordance with any one of the preceding claims wherein the first collar portion includes a first engagement formation, such as an external screw-thread; and the opposed collar portion includes a second engagement formation, such as an internal screw-thread. If required, the first engagement formation is complementary to the second engagement formation, whereby a series of tubular bodies may be inter-connected.
6. A modular container in accordance with any one of the preceding wherein the first end cover is orientated at an in-use top end of the modular container, the first end cover comprising an annular configuration including an aperture in an end wall thereof.

7. A modular container in accordance with claim 6 wherein the first end cover further comprises a plurality of radially extending holes provided in a circumferential wall thereof, the holes suitably facilitating support of the modular container thereby providing said support arrangement.
8. A modular container in accordance with any one of the preceding claims further comprising the second end cover wherein the second end cover is orientated at an in-use bottom end of the modular container, the second end cover having an end wall that is either closed or formed with a mesh screen.
9. A modular container in accordance with claim 8 wherein the second end cover is formed from a mesh screen and the mesh screen has a mesh size selected to retain the particulate growth media whilst facilitating air flow through the internal space.
10. A modular container in accordance with any one of the preceding claims wherein the tubelets are arranged for snap fitting to respective apertures.
11. A modular container in accordance with claim 10 wherein the tubelets are fitted to the body of tubular body at an oblique angle to a longitudinal (in use upright) axis.
12. A modular container in accordance with claim 11 wherein the tubelets are fitted at an oblique angle between about 25° and 60° to the longitudinal axis, most preferably between 35° and 50° to said axis.
13. A modular container in accordance with any one of the preceding claims wherein the tubelets are constructed in two inter-fitting tubular sections, including a first outer section having an external, oblique groove for cooperation with the aperture mouth portion and a second inner section receivable within the first outer section, suitably in telescopic relationship.
14. A modular container in accordance with claim 13 wherein both the first outer section and the second inner section of a tubelet include an array of openings that, in use, are alignable with one another to facilitate communication between the tubelet and the internal space of the tubular body.
15. A modular container in accordance with claim 14 wherein the array of alignable openings is in the form of circumferentially extending elongate slots in respective tubular walls of the tubelet sections.
16. A modular container in accordance with claim 15 wherein the tubelet sections further include a mechanism for enforcing alignment of the openings when

the inner and outer sections are fitted together, such as a tongue and slot formation.

17. A method for growing plants using a modular container for horticulture, the method comprising the steps of:

- providing a modular container including an elongate tubular body provided with a plurality of ventilation openings and a plurality of apertures for respective tubelets, the tubular body further including a first collar portion at one end of the continuous wall and a second collar portion at an opposed end of the continuous wall; and the first collar portion being engageable by a first end cover and the second collar portion being engageable by a second end cover, the first end cover further comprising a support arrangement adapted to be suitably engaged by an overhead arrangement for suspending said container;

- introducing a first mixture of particulate growth media into a plurality of tubelets;

- seeding the first mixture contained in the plurality of tubelets;

- preparing a second mixture of particulate growth media including zeolite having an average particle size in the range of 2mm to 8mm by soaking the second mixture in a liquid including water;

- filling the tubular body of the modular container with the second mixture of particulate growth media;

- locating the modular container in an upright orientation by suspending said container by engaging said support arrangement with the overhead arrangement in a spaced relationship relative to a floor of an enclosure;

- within a pre-selected period after germination of the seeds, transferring the plurality of tubelets carrying seedlings into selected apertures of the tubular body; and

- providing a suitable growth environment to support further plant growth to maturity.

18. The method of claim 17 wherein the step of providing a modular container involves providing the modular container of any one of claims 1 to 16.

19. An environmental enclosure for vertical horticulture, the enclosure comprising:

- a plurality of walls, a floor and a roof defining roof void;

- a chamber for a crop, the chamber set above said floor, within the walls and below the roof void;

- a plenum located below the floor and having inlets for ambient air and outlet vents provided in the floor and in fluid communication with the chamber;

- the roof including a plurality of outlets allowing escape of air rising into the roof void; and

- a support system for movably supporting a plurality of upright modular tubular containers for plant growth, and

a plurality of said modular container suspended from said support system, each of said modular containers including an elongate tubular body provided with a plurality of ventilation openings and a plurality of apertures for respective tubelets, the tubular body further including a first collar portion at one end of the continuous wall and a second collar portion at an opposed end of the continuous wall; and the first collar portion being engageable by a first end cover and the second collar portion being engageable by a second end cover, the first end cover further comprising a support arrangement adapted to be suitably engaged by an overhead arrangement for suspending said container.

20. An environmental enclosure in accordance with claim 19 wherein the support system comprises:

an overhead support rail extending across the chamber between said opposed elongate walls; and

one or more carrier bars movably mounted relative to the support rail, wherein the carrier bars are adapted to support the tubular containers suspended therefrom.

21. The method of either claim 17 or claim 18 wherein the step of providing a suitable growth environment for plant growth includes suspending the modular containers in the environmental enclosure of claims 19 or 20.