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- (71) Applicant: HORTICULTURAL INNOVATIONS PTY LTD [AU/AU]; The National Innovation Centre, Suite 145, 2-4 Cornwallis Street, Eveleigh, New South Wales 2015 (AU).
- (72) Inventor: WILKINS, Chris; 10a Osborn Rd, Normanhurst, New South Wales 2076 (AU).
- (74) Agent: GRIFFITH HACK; GPO Box 4164, Sydney, New South Wales 2001 (AU).

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(54) Title: VERTICAL PLANT CULTIVATION SYSTEM

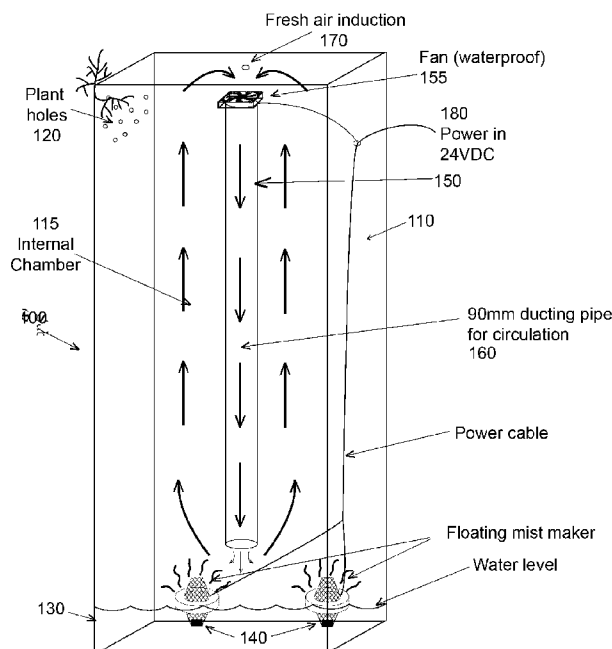


FIGURE 1

(57) Abstract: The invention provides a vertical plant cultivation system utilising aeroponics. The system comprises a shell having an external surface, a vertically extending internal chamber, and plant support apertures extending through external surface to the internal chamber, each aperture formed and arranged to support a plant therein with the plant foliage extending from the external surface and the plant roots extending into the internal chamber. A water reservoir is provided in a lower portion of the internal chamber to hold water and nutrient solution. A least one mist generator module floats within water in the reservoir and generate mist from water within the reservoir. At least one mist circulation module is supported within the internal chamber to cause mist generated by the mist generator module to move upwardly through the plant roots in the internal chamber.



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VERTICAL PLANT CULTIVATION SYSTEM

Technical field

The present invention relates to soil-less plant cultivation systems, in particular
5 aeroponic plant cultivation systems. An application of the invention is in architectural installations such as green walls.

Background

Urbanisation of human populations has led to increasing population density and
10 the use of hard surface construction materials such as concrete which has resulted in a decrease in urban plantlife. Anthropogenic effects on the planet has resulted in a global loss of topsoil required for plantlife. Shifting or irregular weather rainfall patterns has increased the vulnerability of agricultural methods dependant on seasonal rainfall, and nutrient depletion of agricultural land has impacted on crop quality and placed
15 additional stress on natural resources.

Cultivation technologies such as hydroponics have been developed aiming to facilitate cultivation in inhospitable environments, provide alternatives to soil medium cultivation in cities, and to improve agricultural efficiency and decrease environmental impact.

20 Hydroponics relates to the work of cultivating plants with water. This broad term has come to describe the cultivation of plants without the need for soil. Various different types of hydroponics exist including aquaponics, bubbleponics, fogponics, and aeroponics each with notably different nutrient water delivery methods. Aeroponics is a type of hydroponics where plant roots are fed by a mist of nutrient solution
25 continuously or periodically. The plants are supported so that their roots are suspended in a growth chamber with water and nutrients delivered directly to the roots. Aeration of the plant roots is a significant advantage of aeroponics over traditional hydroponics.

Traditional hydroponics is now used widely in commercial food production and
30 some aeroponic technology has been used successfully for commercial plant propagation and some food production. In commercial nursery environments the systems can be well monitored and controlled.

Hydroponics has limited application in urban environments because of the prevalence of pathogenic bacteria (pythium) which destroy plant roots preventing
35 nutrient uptake. Soil grown plants can also be susceptible to this condition known as

“root rot”. It is commonly believed that this issue exists due to overly frequent watering. Research indicates that the proliferation of pathogenic bacteria may be equally due to water temperature and available oxygen in the root zone. In most hydroponic systems water is stored at room temperature and circulated to the plants roots via a pumping system which further elevates the temperature and increases the risk. Plants have a natural ability to resist this infection to a certain degree in nature this may be to survive periods of flooding or sustained rainfall; however, in hydroponic or controlled cultivation environments cyclical circulation watering often provides a favourable cultivation and transmission environment for root rot to infect all plants that come in contact with it. Thus a high degree of supervision and maintenance is required to keep the growing environment healthy.

In urban settings plants can be aesthetically pleasing and enhance the environment an example of this is green walls in spaces such as office buildings, public spaces, and commercial facilities. But often such environments present difficult growing conditions or require a level of ongoing maintenance that is commercially unacceptable. Vertical gardens known as ‘greenwalls’ include gardens using a series of horizontal platforms to stack potted plants vertically, or by using climbing plants and suspended cables. Some of these systems employ hydroponics but can also be soil based. More recently, hydroponic green walls employing a wet blanket approach have become popular. This system requires that a wall be waterproofed and have a thick geotextile material fastened to it with pockets created for small plants and soil. The material is then irrigated at regular intervals and the material should allow for the even distribution of water throughout the material.

Existing hydroponic green wall systems are limited in both their function and application, as evidences in the examples below.

a. The typical water delivery method of pumped green wall systems is unreliable. Most systems for providing green walls rely on watering cycles. These cycles are, at best, estimated by the installer. If the cycles are too frequent the plants will become sick and die from root rot. If the cycles are too infrequent the plants will die from dehydration. Each environment is unique and scheduling the frequency of watering a wall is based on temperature, humidity, air circulation, species, and size of each plant. It is therefore difficult for an installer to accurately schedule watering for the plants without a long trial and error phase.

b. In wet blanket type systems the water distribution is often uneven. Most systems pump water from a reservoir up to a distribution hose near the top of the

system and rely on gravity for the water to track back down to the reservoir. There is often an issue with dry spots occurring as water will naturally follow the path of least resistance. Plants will die in the dry spots from lack of water and it can be difficult or even impossible to replace the plants and restore even water distribution to recover the aesthetic of the green wall.

c. Bacterial root infections namely the pathogen Pythium are transported in water and can colonise the root zone. In a potted green wall with a circulated watering system, pythium can be spread very rapidly from plant to plant, colonising the root zones of each plant.

d. Traditional flood and drain systems are essentially open to the environment. These systems use pot plants which are positioned on shelves and watered by small hoses. There is currently a serious concern about leakage and flooding as a result of mechanical failure such as a burst pipe, as well as runoff from plants growing under other plants water supply and channeling the water onto the floor.

e. Evaporative losses occur when the growing medium loses moisture to the air. Many green walls use soil or fabric for the plants to grow in and deliver water to this medium for the plants to absorb. Environmental conditions such as humidity, temperature, light intensity, and wind can dehydrate this medium and consume significant amounts of water requiring unpredictable and frequent refilling.

f. Hair root growth and water/oxygen access is limited in traditional systems either because of suffocation from excess watering or abrasion from soil or growing mediums.

These system require a substantial amount of water and maintenance. Weight of the plants and growing medium can be substantial limiting the areas where such green walls can be used. Structural features to support such green walls, deliver the required water and contain runoff may also need to be designed into the architecture of the building, increasing cost initially and on an ongoing basis to maintain the green wall feature.

There is a need for alternative systems for growing plants in urban environments.

Summary of the invention

According to aspects of the present invention there is provided a vertical plant cultivation system comprising:

a shell having an external surface, a vertically extending internal chamber, and

plant support apertures extending through external surface to the internal chamber, each aperture formed and arranged to support a plant therein with the plant foliage extending from the external surface and the plant roots extending into the internal chamber;

5 a water reservoir provided in a lower portion of the internal chamber to hold water and nutrient solution;

at least one mist generator module configured to float within water in the reservoir and generate mist from water within the reservoir; and

at least one mist circulation module supported within the internal chamber and
10 configured to cause mist generated by the mist generator module to move upwardly through the plant roots in the internal chamber.

Each mist generator module can comprise a nebulizer, and a buoyancy device configured to support the ultrasonic nebulizer to float at a constant depth. In an embodiment, the nebuliser is a piezoelectric ultrasonic wave nebuliser. In an
15 alternative embodiment, the nebulizer is an ultrasonic vibrating mesh technology (VMT) mister. The buoyancy device can be a floatation ring surrounding the nebulizer.

Each mist circulation module can comprise an air conduit supported and oriented to extend vertically within the interior chamber, and a fan. The fan can be
20 located in the conduit to cause mist to move upwardly through the chamber outside the conduit by drawing mist into the conduit at the upper end of the chamber to be released out at the lower end of the conduit. In an embodiment, the air conduit is a tube extending vertically through the chamber from an upper portion of the chamber to a lower portion of the chamber above the reservoir maximum water level.

25 An embodiment of the system further comprises a monitoring system comprising:

a controller module configured to control operation of the one or more mist generator modules and one or more mist circulation modules; and

one or more sensors configured to monitor operating conditions of the system
30 and in data communication with the controller to provide sensor data to the controller, wherein the controller module is configured to process sensor data and automatically control operation of the mist generators and mist circulation modules to aim to maintain operating conditions within a target operating range.

The monitored operating conditions can include any one or more of: water level,
35 water temperature, chamber temperature, humidity, mist density, mist turbidity, light

spectrum, dissolved oxygen levels, nutrient concentration, pH level, reduction potential, and electronic conductivity. The monitoring system can further comprise a wireless communication interface, and the controller module be configured to transmit data regarding system operation via the communication interface to an external system.

- 5 The controller module can be configured to transmit a warning signal when one or more operating conditions are outside a target operating range.

The system can further comprise one or more controller module actuated valves connecting supplementary water and nutrient supply for the reservoir, whereby the controller can be configured to actuate one or more valves to top up one or more of
10 water and nutrients in the reservoir. The controller can be configured to actuate one or more valves in response to a signal received from a remote module via the communication interface.

In an embodiment of the system, the plants are supported in the apertures in a support structure. The support structure can be a plug formed of cross linked
15 polyethylene foam. In an embodiment the support structure can include a seed encapsulated with nutrient and growing media to allow a plant to be grown from the seed.

In an embodiment the shell includes at least one fresh air intake aperture located in an upper portion of the shell proximate the mist circulation module.

- 20 In an embodiment the shell is configured to be modular and allow interconnection of two or more shells.

Brief description of the drawings

An embodiment, incorporating all aspects of the invention, will now be
25 described by way of example only with reference to the accompanying drawings in which

Figure 1, is an illustrative example of an embodiment of the system;

Figure 2, is an example of a plant support plug in accordance with an embodiment of the system;

- 30 Figure 3 is an exploded view of an example of an embodiment of the system; and

Figure 4 is a block diagram of a monitoring system in accordance with an embodiment of the system.

Detailed description

Embodiments of the present invention provide a vertical plant cultivation system. The system utilises a type of hydroponics known as aeroponics and more specifically ultrasonic aeroponics, sometimes referred to as fogponics. An example of the system is shown in Figure 1.

The system 100 includes a shell 110 having an external surface, a vertically extending internal chamber 115, and plant support apertures 120 extending through external surface to the internal chamber. Each aperture is formed and arranged to support a plant therein with the plant foliage extending from the external surface and the plant roots extending into the internal chamber.

A water reservoir 130 is provided in a lower portion of the internal chamber 115 to hold a water and nutrient solution. The system uses at least one mist generator module 140 configured to float in the water in the reservoir 130 and generate mist from the solution within the reservoir, for example an ultrasonic nebulizer can be used as a mist generator. Water in the reservoir 130 at the bottom of the internal chamber also acts as ballast helping to stabilise the system.

At least one mist circulation module 150 is supported within the internal chamber and configured to cause mist generated by the mist generator module to move upwardly through the plant roots in the internal chamber 115.

The system provides in the internal chamber 115 an aeroponic environment, a saturation of air with micro water droplets, allowing even distribution of water throughout the internal chamber to all plants. In this system the plant roots are able to access both oxygen and water simultaneously without having to grow through an abrasive medium like soil, the plants roots grow and extensive network of hair roots which greatly increases the total root surface area. This allows the plant to absorb more nutrient water more rapidly and as a result increases the potential growth rate. Embodiments of the system can be provided as a stand-alone portable unit, providing a user friendly way to grow plants. An application of the invention is green walls, although the system may be used in other applications such as indoor or patio gardens of varying shapes.

Embodiments of the system use ultrasonic nebulisation for mist generation. For example, piezoelectric ultrasonic nebulisers may be used. Ultrasonic nebulisation has a sterilising effect on the water. The combination of vibration pressure gradient stresses and increases oxygen concentration making an environment unfavourable for pythium colonisation.

The mist generators 140 are configured to float in the water in the reservoir 130 so that the apparatus is supported in the water at the desired submersion in the water. This has an advantage of reducing the need to maintain a specific water level for effective operation of the mist generator 140. The level water in the reservoir needs to
5 be maintained above a minimum level, for example around 50mm, where the mist maker will cease working as the transducer disk of the mist maker has insufficient water coverage to work effectively. However, above the minimum water level for the mist generator the system can operate effectively with any water level. For example, the reservoir in the base of the shell may be filled to within 40mm of the lowest plant
10 apertures (to minimise any leakage risks), a water depth of say 250mm and the mist maker will operate effectively until the water level falls below about 50mm (where the mist generator is inadequately submerged). Thus, the requirements for monitoring the water level are significantly reduced.

The mist generator may be configured to float or may be supported by a
15 buoyancy device at a constant depth. In an embodiment the mist generator is a nebuliser supported by a floatation ring surrounding the nebuliser. However, any suitable means of floatingly supporting the mist generator is envisaged within the scope of the invention. The buoyancy device supporting the mist generator must have sufficient buoyancy to support the mist generator/nebuliser at an effective operating
20 depth. It is also desirable for the buoyancy device to not lose buoyancy over time due to becoming waterlogged. The buoyancy device should also be formed of material that is essentially sterile to the cultivation environment and not be something that is likely to introduce plant bacteria or become contaminated/encourage bacterial growth.

The number of mist generators used can vary between embodiments based on
25 the size of the shell, number of plants and the required conditions for the plant species. For example for a small unit one mist generator may be adequate, whereas for bigger (wider or taller) units 2 or three generators may be required. Any number for mist generators may be used. The size and capacity of the mist generators can also be chosen based on the growing requirements for the system. It should be appreciated
30 that in some system configurations, for example a long low unit, several small mist generators distributing mist throughout the chamber may be preferable to a single larger mist generator.

An example of a mist generator used in prototype systems is a DK24 mist
maker from Foshinani Techsin supported in a flotation ring of extruded polystyrene,
35 although multiple other suitable nebulisers are commercially available. The mist

generators can be free floating within the reservoir. Alternatively movement of the floating mist generators may be limited, for example by a tether, anchor, or barrier elements (i.e. one or more posts, nets or lattices). In an embodiment using multiple mist generators it may be desirable to restrict each mist generators movement to an
5 allowed zone to maintain mist generation distribution throughout the chamber. It should be appreciated that any means used to limit movement of the mist generators should inhibit lateral movement only, allowing the mist generators to move vertically with fluctuations in water level. The mist from the generator 140 will form a mist layer above the water. The mist produced typically settles in a blanket sitting 50mm above
10 the surface of the water. The circulation module is used to distribute the mist throughout the internal chamber and through the plant roots. By including an ingress protected (waterproof) axial fan, turbulence is created inside the chamber and the mist is evenly distributed to the plants hanging roots. This is done by positioning the fan in a long pipe to ensure adequate circulation from top to bottom. The result of this process
15 is the uniform dispersal of small water droplets in the root zone of the plants allowing for the rapid absorption of these micro droplets as they are more easily diffused across the root membrane.

In an embodiment the mist circulation module 150 is simply a conduit, length of tubing or pipe 160 supported through the centre of the vertically extending internal
20 chamber with a fan 155 located in the upper end to cause, when the fan 155 is operating, fluid to flow downwardly through the pipe 160. Operation of the fan causes fluid in the chamber to be drawn into the top of the conduit in the upper part of the inner chamber, thus drawing the mist upward through the chamber from the surface of the water where it is generated. The fluid exiting the conduit at the lower end also
25 causes turbulence to disturb the mist in the lower part of the internal chamber near the surface of the water.

In the embodiment shown the pipe 160 is positioned through the middle of the internal chamber extending through most of the length of the chamber. Both the top and bottom open ends of the pipe 160 finish about 75mm's above the water level and
30 below the inside roof. The lower pipe opening should be above the mist layer to allow the air to dump down on top of the mist layer to create adequate turbulence. Turbulence in the mist causes fine droplets of water to coalesce into larger droplets for more effective wetting of plant roots. If adequate turbulence is not created only the fine mist (smaller) droplets are circulated which may not adequately condense on the roots
35 and therefore do not provide adequate watering. Other problems with too fine droplets

can be that these smaller droplets do not carry sufficient nutrient, or lose their nutrients nourishing value in transition (oxidised out). Too smaller droplets may also create precipitation of minerals onto the roots causing toxicity (a problem reported in some known fog aeroponic systems). In the example shown, the system uses two mist makers and the circulation module causes significant turbulence in the mist layer as well as drawing the water droplets up through the roots. The applicants have observed that this causes bigger droplets and the roots are consistently wet enough to have a rinsing effect and preventing the build-up of precipitated salts. Inadequate wetting of roots has been found to be a growth limiting problem in some known aeroponics systems.

Typically the fan will be a waterproof or moisture tolerant fan. The fan 155 may be positioned anywhere along the pipe 160 for an adequately working system. The position of the fan at the top of the chamber is preferable to minimise the risk of hanging roots being drawn into the fan. The fan may also be located inside the tube 160 to minimise this risk. Further, the environment near the top of the chamber will typically have lower mist density and hence be less moist than near the reservoir and less likely to encounter splashes (for example during movement of the system for if it is kicked or knocked) and therefore lower waterproofing/water resistance for the fan and power supply components can be tolerated.

In the example shown in Figure 1 the shell 110 also has a fresh air intake aperture 170 above the fan 155. The positioning of the aperture 170 above the fan can also be advantageous to create a lower pressure area at the top of the chamber to reduce mist escaping the chamber via the air intake aperture. The low pressure zone in the top of the chamber allows fresh air induction via a hole in the top without having too much mist escaping. The plants need fresh oxygen as plants consume oxygen from the root zone and exhaust CO_2 . It is therefore important that the root zone has plenty of oxygen. Fresh air is also important to inhibit the growth of bacteria which is pathogenic to the roots of the plants. This bacteria is known as pythium and is very common in hydroponic systems as roots are often suffocated and warm which provide ideal conditions for this bacteria commonly known as 'root rot' to colonise a plant. By having a hole (say about 40mm) in the lowest pressure zone (directly above the fan) fresh air is inducted into the mix as some of the air inside the chamber is leaked out of the holes and around the plants held in the unit. This process is also important for keeping the plants healthy and humid. The size of the air intake inlet may vary between embodiments. The bigger the hole the more exchange between the

environment internal the chamber and the ambient environment and while this is not a concern for the mist density, in an enclosed office environment this can lead to an over humidifying of the office or a smell. Plugs (for example, foam tubing) with different sized apertures or variable sized apertures may be used to vary the aperture size to
5 suit different environments and growing conditions. Plugs with a variety of hole sizes or variable apertures may be used to vary the induction rate and 'tune' the system post installation. In some embodiments the air intake hole may be located elsewhere than in the top of the chamber, for example in the middle or lower portion of the chamber. However, it is more practical to have the air intake in the upper portion of the chamber
10 where the environment is less moist so any exchange with the external, typically drier environment, has less impact.

Although the examples shown in the drawings show one centrally located circulation tube and fan, embodiments are envisaged where more than one circulation module is used. Further the circulation system need not be centrally located, provided
15 adequate mist distribution is achieved to adequately water all plants. The tube 160 is shown extending through most of the length of the chamber and this is preferred to avoid plant roots inhibiting circulation, resulting in "dry" spots. Adequate unrestricted air flow is also required below the pipe to ensure sufficient turbulence in the mist layer. A shorter pipe may be adequate for embodiments where the risk of plant roots
20 interfering with circulation is reduced, for example by way of plant species choice, or geometry of the shell. For example a conical or pyramid shaped shell may reduce the risk of plant roots inhibiting circulation and mist layer turbulence.

The fan 155 and mist generators 140 can be connected to a power supply, such as a 24V direct current power supply 180 received from a conventional mains
25 power AC/DC transformer power supply. Alternatively battery power and a low power fan may be used. Battery operated power supplies may be suitable for temporary installations but typically not for long term use. Depending on the installation a solar power supply with rechargeable batteries may be utilised. For example such an embodiment may be highly suitable for outdoor use as access to a mains power supply
30 is not required. Such an embodiment may only be suitable for an environment with adequate sunlight exposure and may not be suitable for all indoor environments.

An application of the invention is an environmentally sustainable, modular, portable, free standing green wall. It relies on the combination of a piezoelectric ultrasonic nebuliser, a flotation ring, a waterproof fan, internal ducting, and a sealed yet
35 perforated vertical chamber. By employing the use of an ultrasonic wave nebulizer

with flotation buoy, and fan, water is transported to the roots in the form of tiny droplets. The creation of these droplets via ultrasonic transduction places intolerable stresses on the membrane of bacteria that may be living in the water. This effectively has a sterilising effect on the water before it is transmitted to the root zone.

5 In a preferred embodiment the system is provided as a kit of parts for constructing a green wall module. An example is shown in Figure 3. The kit 300 consists of a floating ultrasonic mist generator 310, a fan 320, tube 330, a reservoir and a series of connectible pieces for the shell 340, 342, 344, 346. In some
10 embodiments the base of the shell may be watertight when assembled, and in such embodiments the reservoir is simply the lower portion of the internal chamber of the shell. Alternatively a separate trough may be provided, shaped to fit within the lower portion of the shell for the reservoir.

In this embodiment the tube is made from PVC and the shell is made from ABS these materials bond very well via a cold solvent cement weld (methyl ethyl ketone or
15 acetone). The circulation module (tube with Fan) can be attached by simply solvent welding the length of pipe onto the inside back wall 342 of the unit. An embodiment of the invention is fabricated from 2mm ABS plastic sheets and can be made as thin as 200 millimetres diameter. This embodiment can be fabricated with 30mm thick sheets of XPS foam as top and bottom plates. An alternative embodiment can use 10mm
20 foamed PVC as the top and bottom plates. The above manufacturing and material selection makes the design lightweight. Averaging less than 10 kilograms per 2.8 square meter unit, the invention is not a workplace safety hazard and it is easy to carry or move by 1 person. Additionally, this results in the weight of the water reservoir located in the base of the unit acting as ballast adding to its stability. However,
25 different materials may also be used.

In an embodiment the shell is a tall, thin, wide box with approximately 170 holes on each side measuring approximately 40 millimetres in diameter each. These holes are for holding plants. The plants are transplanted, propagated, or sown from seed into a foam supporting disk or ring (for example as shown in Figure 2), into an inert growth
30 medium, or into a hydroponic basket sized to fit within the holes. These plant holding devices 200 allow for the roots of each plant 240 to hang in mid-air inside the chamber and grow without any soil. Naturally the foliage 230 is therefore allowed to grow outside the chamber creating a green wall effect and humid root zone support system. The invention is portable. As the invention is a sealed stand-alone system it can be
35 simply placed in front of any wall and does not require preparation or infrastructure.

Additionally it can be built on wheels for easy mobility.

The system is completely enclosed, a sealed box with all water and watering contained inside the unit. Additionally, there are no pumps, pipes, or nozzles and no pressurised water which could cause mechanical leaks. The shell being enclosed also
5 minimises water loss from the system. In embodiments of the system very little water is lost and the water that is consumed is only that transpired by the plants as there is no exposed growing medium. The system does not have any waste water and no or very minimal evaporation, and as a recirculation system it requires only a very small amount of water and infrequent refilling.

10 The volume of the reservoir may vary between embodiments, in particular based on the size of the base of the shell. Reservoir depth may also vary. The rate of water use in the system will also vary based on a number of different factors, for example, unit size, type of plants, number of plants, total amount of foliage, temperature and respiration rate, ambient humidity, etc. In an embodiment the
15 reservoir holds a maximum of 50 litres of water and this lasts between one and six weeks depending on operating environment.

In an embodiment the reservoir is filled simply by pulling out one of the lower plants from the unit and pouring in water, for example using a watering can, hose or submersible pump in a bucket. This allows the system to be free standing and
20 portable. In alternative embodiments a separate water inlet aperture may be provided. Some embodiments may be connected to a supplementary water supply with an actuator to allow automatic water top up. For example, a mechanical cistern float to cause a valve to the water supply inlet to open when the water level falls below a minimum level. Alternatively a water level sensor may be used to trigger a relay or
25 solenoid to top up the reservoir from a mains water supply or backup reservoir, for example from an elevated or pressurised make up tank.

The core piezoelectric technology described above is quite commonly understood in the aeroponic field of study. The technology has not been readily adopted due to some instabilities in the environment (pH fluctuations, calcification of
30 misting devices, and inappropriate plant selection). The process of ultrasonically producing and circulating nutrient water typically results in an unstable pH level in the water. Decorative plants often have a much higher tolerance to pH fluctuations. Edible plants do not. While this can, and is being addressed manually by skilled operators, embodiments of the invention can include a monitoring system and automatic
35 correction system.

In some embodiments sensors and remote monitoring will allow the user to monitor operating condition fluctuations. This embodiment enables a gardener to supervise the growing conditions and intervene as necessary. In some embodiments the system may issue an alert to a gardener when operating conditions, such as pH
5 levels, fall outside a desired or optimal growing range to enable the gardener to respond. In some embodiments the system may allow the gardener to take action remotely, for example canisters of water and/or nutrient solution may be provided in the system connected to dosing mechanisms or valves that can be triggered remotely to adjust operating conditions. For example, the system controller may be configured
10 for auto dosing via solenoids for automatic correction of operating conditions. The automatic dosing mechanism may also be triggered remotely by a gardener.

An example of a block diagram of a monitoring system is shown in Figure 4, the monitoring system comprises a controller module 400 configured to control operation of the one or more mist generator modules 420 and one or more mist circulation
15 modules 410. One or more sensors 450 are configured to monitor operating conditions of the system and are in data communication with the controller 400 to provide sensor data to the controller. The controller module 400 is configured to process sensor data and automatically control operation of the mist generators 420 and mist circulation modules 410 aiming to maintain operating conditions within a target operating range.
20 For example increasing mist generation and circulation in high temperature conditions or reducing mist generation if humidity gets too high. In an embodiment the controller may also be connected to a water top up actuator 460 and/or nutrient dosing actuator 470 to enable the controller to automatically take action aiming to correct operation of the system. For example, to actuate a solenoid, relay, valve or other trigger
25 mechanism connected to a top up water supply to add water to the reservoir if the water level falls below a threshold level. In response to water being topped up the PPM of nutrient in the water would be decreased due to the new addition of fresh water. The auto dosing could then use something like a peristaltic pump to drop some concentrated nutrient into the water to bring the total dissolved solids or PPM back to
30 the stable level. This could also be incorporated into a monitoring system which continuously monitors the conductivity of the water and adds nutrient as required. This may be automatically actuated by the controller or in response to user input. In an embodiment the reservoir may also be automatically topped up using a pre-prepared water and nutrient solution alleviating the need for separate water to top up and nutrient
35 dose actuators.

The monitored operating conditions can include any one or more of: water level, water temperature, chamber temperature, humidity, mist density, mist turbidity, light spectrum, dissolved oxygen levels, nutrient concentration, pH level, reduction potential, electronic conductivity, movement and tampering. Monitoring may be more
5 sophisticated for embodiments used for growing more sensitive food plants than for foliage plants.

In an embodiment the monitoring system can include a wireless communication interface 440, and the controller module 400 is configured to transmit data regarding system operation via the communication interface 440 to an external system. For
10 example, the communication interface may include a WiFi, Bluetooth or telecommunication network transceiver, configured to transmit data to a user device 490, directly or via a communication network. For example, in the case of Bluetooth a user table or mobile phone may run a software application to communication with the controller to query operating conditions and monitored data via Bluetooth when the
15 user is in the vicinity of the system and in Bluetooth range. This embodiment may be suitable where adjustment such as water and nutrient top up are done manually. In an office environment where WiFi is available the communication interface may send messages to the user device 490 via the WiFi network and the internet, for example as an e-mail, via a web portal or software application. In a further embodiment the
20 communication interface may be configured to communicate via a telecommunication network, for example GSM, 3G or 4G enabled using a SIM card, using messaging such as SMS or MMS. For example, a user may run a software application in their smartphone to display operating conditions for the system, this could display current and past operation data to enable the user to monitor the operating conditions and if
25 necessary make adjustments manually (i.e. add water and nutrient using a watering can, replace faulty components, etc.) or send signals to the controller to cause the controller to adjust operating conditions, for example by controlling the dosing and water top up actuators, mist generator & fan. The system can include controller module actuated valves connecting supplementary water and nutrient supply for the
30 reservoir, and the controller can be configured to actuate one or more valves to top up one or more of water and nutrients in the reservoir. The controller can also be configured to actuate one or more valves in response to a signal received from a remote module via the communication interface.

The communication interface may also allow the controller to send an alert
35 message to a user. The controller module can be configured to transmit a warning

signal when one or more operating conditions are outside a target operating range.

For example, if operating conditions are outside a prescribed range, component break down or other incident such as the system being knocked over or otherwise tampered with.

5 By combining existing products such as a single board microprocessor (Arduino type device) with multiple sensors (humidity, optical fog, temperature, light spectrum, dissolved oxygen, water level, reduction potential, electronic conductivity) GSM data transfer and cloud computing, with relays, solenoids or peristaltic pumps and reservoirs. It is possible to monitor and control the environment to ensure optimal
10 conditions for plant growth. A preferred embodiment uses a sim card for connectivity via a telecommunication network rather than relying on WiFi connectivity to enable greater flexibility for the installation environment.

The system has been described above with reference to some preferred embodiments, however many variations on the specifically described embodiments are
15 considered within the scope of the present invention and some of these variations are described below.

The core component the piezoelectric ultrasonic mist maker may be replaced with an ultrasonic vibrating mesh technology (VMT) mister. Other misting and fogging technologies developed in the future may also be applicable to the system of the
20 invention and all such mist generators are considered within the scope of the invention.

The system is sensitive to hard water that is tap water with a high concentration of dissolved minerals. It is common for tap water to have around 100 parts per million of calcium, chlorine, fluoride, and other minerals which can precipitate onto the transducer disk and body. The use of distilled or reverse osmosis water mixed with
25 nutrient fertiliser may also become a consumable product or a warranty requirement, alternatively the installation of a filtration system may be included in some embodiments.

Supplementary lighting is a simple yet valuable addition. With varying lighting conditions in offices, plants grow with varying success. The addition of overhanging
30 light modules provides plants with target light spectrum colours to ensure healthy growth. This could be done with the addition of simple overhanging kitchen cabinet downlights or any variety of grow light bulb such as compact fluorescents, LED lighting, or sulphur plasma lighting.

Monitoring and controlling the water reservoir is crucially important and making
35 this accessible to consumers relies on integrating this task into existing technology,

namely cloud technology, computing, sensors, and solenoids. The combination of these devices allows for the monitoring and adjustment of the reservoirs water remotely.

Plant supports may vary with different embodiments of the invention.

- 5 Embodiments as described can use 'nets', 'baskets', or 'plugs'. In an example plugs formed of cross linked polyethylene foam are used to secure the plants in the holes. It is a common practice in aeroponics to use a foam 'disk' to hold plants and cuttings in a device. Such embodiments are particularly suited for installing developed plants. A development is envisaged to provide a plant support structure to enable plants to be
- 10 grown from seed in the system. This embodiment provides a seed encapsulated with some nutrient and growing media. For example a seed encapsulated in a medium impregnated with nutrients to encourage germination and initial growth. The encapsulated seed may be placed directly into a plant aperture or place in a plant aperture in an additional supporting structure (such as a plug as described above).
- 15 The encapsulated seed may include a combination of recycled paper, recycled glassfibre, slow release soluble nutrients, and a seed. Alternatively a slow release fertiliser and some fiberglass or rock wool compressed into a disk. The idea is that, they make the unit more 'plug and play' and can be a consumable product. The combination of materials encapsulating the seed provides a good starting point for the
- 20 seed. The encapsulated seeds are inserted into the unit where they become saturated with water from the misting process and as a result germinate. For example, the material encapsulating the seed can be hydrophilic to absorb the water from mist and allow germination of the seed.

- Embodiments of the system are described in relation to a green wall application
- 25 where the shells are substantially tall and wide but not deep, so they may be place against a wall or used to partition spaces. The units may have plants growing from one or two sides. In some embodiments the shells may be modular to enable interconnection of the shells to make the green wall wider or taller by stacking modules or interconnecting different shell extension components. The number of mist
- 30 generators and circulation module can also be increased for taller and wider units. Alternatively several units may be placed adjacent each other. However other configurations are also envisaged, from example column, barrel, pyramid or cone shaped shells may also be used. Embodiments of the invention tailored to industrial scale agriculture may require different shell shapes as many plants will not grow
- 35 normally hanging. For example, it was observed that lettuce can be grown in this

system however when grown vertically, it grows more like a vine. Therefore sloped sides may be better and the shell shape may end up being more like a triangular prism.

Embodiments of this invention make the application of aeroponics possible beyond just a science laboratory or high tech greenhouse because the design focus is on the user. This invention has sought to ameliorate the limitations placed on the practical application of hydroponics in the urban landscape. It has done this by identifying and sourcing the best combination of technology and the most suitable commercial application. The end result is a green wall which is low maintenance, low power and water consuming, does not require infrastructure, and is plug and play. The result is that this system makes owning a green wall cheap enough for a larger portion of the market as the installation and service costs are reduced.

The system of this invention is better than existing green wall systems because it provides even, disease free distribution of watering to all plants. Flood and Drain systems often underwater sections as water naturally tracks around portions of the wall. Embodiments of the invention also reduce flooding risks as all moisture is contained within the shell. Conventional systems expose the watering to the outside environment and can be subject to water being diverted across the foliage and pooling on the floor. The invention provides oxygenated water air mixture to the plants roots reducing the risk of bacterial infection in the root zone.

In essence, the system is a tall thin box with numerous perforations, each perforation is a site from which a plant can be grown. The box is constructed from predominantly extruded closed cell polystyrene foam. It features a top and bottom part. The top part exists to support plants as their roots hang inside the box and their foliage outside. The bottom contains the water reservoir, misting components, connectivity and sensing devices. The top and bottom fit together to create a uniform tall slim wall, suitable for office partitions, as a mobile green wall, or in agriculture.

Embodiments can be made vertical and slimline making it possible to install it into any space without compromise on floor space. The system is lightweight making it easy to install and to reposition in office spaces. The system mobilises the water by circulating it in the air. The method of circulating nutrient water in air means that there is nearly no limit to the height of the wall. This allows for walls of almost unlimited height to be constructed without a significant increase in power consumption, as opposed to the pumping power required to combat hydrostatic pressure.

Embodiments of the system can be "plug and play", not requiring hard installation or infrastructure, the system can be wheeled in fully populated and simply

plugged in for an instant green wall. The system is lightweight so even a fully populated wall module can be easily moved on a skateboard type dolly device or wheels attached to the underside.

5 The aeroponic environment does not require wet dry cycles as it has a static environment of simultaneous air and water access. Additionally, the small water droplet size allows for simultaneous water / oxygen uptake, further preventing a bacterial infection. This airborne water is then transported to the plants via a circulation fan.

There are no shortages of applications for the system. Below is a list of anticipated market applications:

- 10 1. Single sided decorative green walls for small and medium office spaces;
2. Single sided decorative green walls for big corporate office spaces;
3. Single sided large (floor to high ceiling) decorative green walls for innovative spaces;
4. Double sided portable green walls for events;
5. Double sided portable green walls office partitions for co-working spaces;
- 15 6. Single sided edible green walls for the hospitality industry;
7. Single sided edible green walls for the corporate industry;
8. Single sided edible green walls for the domestic market;
9. Small to medium size urban agriculture projects and community gardening initiatives;
- 20 10. Large agriculture projects;
11. Mycology (the cultivation of mushrooms) for agricultural use;
12. Modular agriculture solutions for military, mining, and other popup remote or mobile communities; and
13. Controlled cultivation devices for clinical research.

25 It will be understood to persons skilled in the art of the invention that many modifications may be made without departing from the spirit and scope of the invention.

In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary
30 implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

It is to be understood that, if any prior art publication is referred to herein, such reference does not constitute an admission that the publication forms a part of the common general knowledge in the art, in Australia or any other country.

CLAIMS:

1. A vertical plant cultivation system comprising:
 - a shell having an external surface, a vertically extending internal chamber, and
 - 5 plant support apertures extending through external surface to the internal chamber, each aperture formed and arranged to support a plant therein with the plant foliage extending from the external surface and the plant roots extending into the internal chamber;
 - a water reservoir provided in a lower portion of the internal chamber to hold
 - 10 water and nutrient solution;
 - at least one mist generator module configured to float within water in the reservoir and generate mist from water within the reservoir; and
 - at least one mist circulation module supported within the internal chamber and configured to cause mist generated by the mist generator module to move upwardly
 - 15 through the plant roots in the internal chamber.
2. The vertical plant cultivation system as claimed in claim 1 wherein each mist generator module comprises:
 - a nebulizer; and
 - 20 a buoyancy device configured to support the ultrasonic nebulizer to float at a constant depth.
3. The vertical plant cultivation system as claimed in claim 2 wherein the nebuliser is a piezoelectric ultrasonic wave nebuliser.
- 25 4. The vertical plant cultivation system as claimed in claim 2 wherein the nebulizer is an ultrasonic vibrating mesh technology (VMT) mister.
5. The vertical plant cultivation system as claimed in claim 2 wherein the
- 30 buoyancy device is a floatation ring surrounding the nebulizer.
6. The vertical plant cultivation system as claimed in claim 1 wherein each mist circulation module comprises:
 - an air conduit supported and oriented to extend vertically within the interior
 - 35 chamber; and
 - a fan located in the conduit to cause mist to move upwardly through the

chamber outside the conduit by drawing mist into the conduit at the upper end of the chamber to be released out at the lower end of the conduit.

7. The vertical plant cultivation system as claimed in claim 6 wherein the air
5 conduit is a tube extending vertically through the chamber from an upper portion of the chamber to a lower portion of the chamber above the reservoir maximum water level.

8. The vertical plant cultivation system as claimed in claim 1 further comprising a monitoring system comprising:

10 a controller module configured to control operation of the one or more mist generator modules and one or more mist circulation modules; and
one or more sensors configured to monitor operating conditions of the system and in data communication with the controller to provide sensor data to the controller,
wherein the controller module is configured to process sensor data and
15 automatically control operation of the mist generators and mist circulation modules to aim to maintain operating conditions within a target operating range.

9. The vertical plant cultivation system as claimed in claim 8 wherein the
monitored operating conditions are any one or more of: water level, water temperature,
20 chamber temperature, humidity, mist density, mist turbidity, light spectrum, dissolved oxygen levels, nutrient concentration, pH level, reduction potential, and electronic conductivity.

10. The vertical plant cultivation system as claimed in claim 9 further comprising a
25 wireless communication interface, and the controller module is configured to transmit data regarding system operation via the communication interface to an external system.

11. The vertical plant cultivation system as claimed in claim 10 wherein the
30 controller module is configured to transmit a warning signal when one or more operating conditions are outside a target operating range.

12. The vertical plant cultivation system as claimed in claim 11 further comprising
one or more controller module actuated valves connecting supplementary water and
35 nutrient supply for the reservoir, whereby the controller can be configured to actuate one or more valves to top up one or more of water and nutrients in the reservoir.

13. The vertical plant cultivation system as claimed in claim 12 wherein the controller is configured to actuate one or more valves in response to a signal received from a remote module via the communication interface.

5

14. The vertical plant cultivation system as claimed in claim 1 wherein the plants are supported in the apertures in a support structure.

15. The vertical plant cultivation system as claimed in claim 14 wherein the support structure is a plug formed of cross linked polyethylene foam.

10

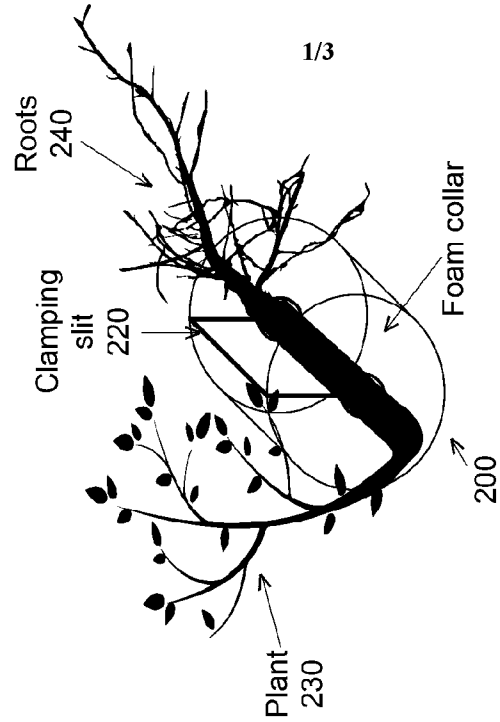
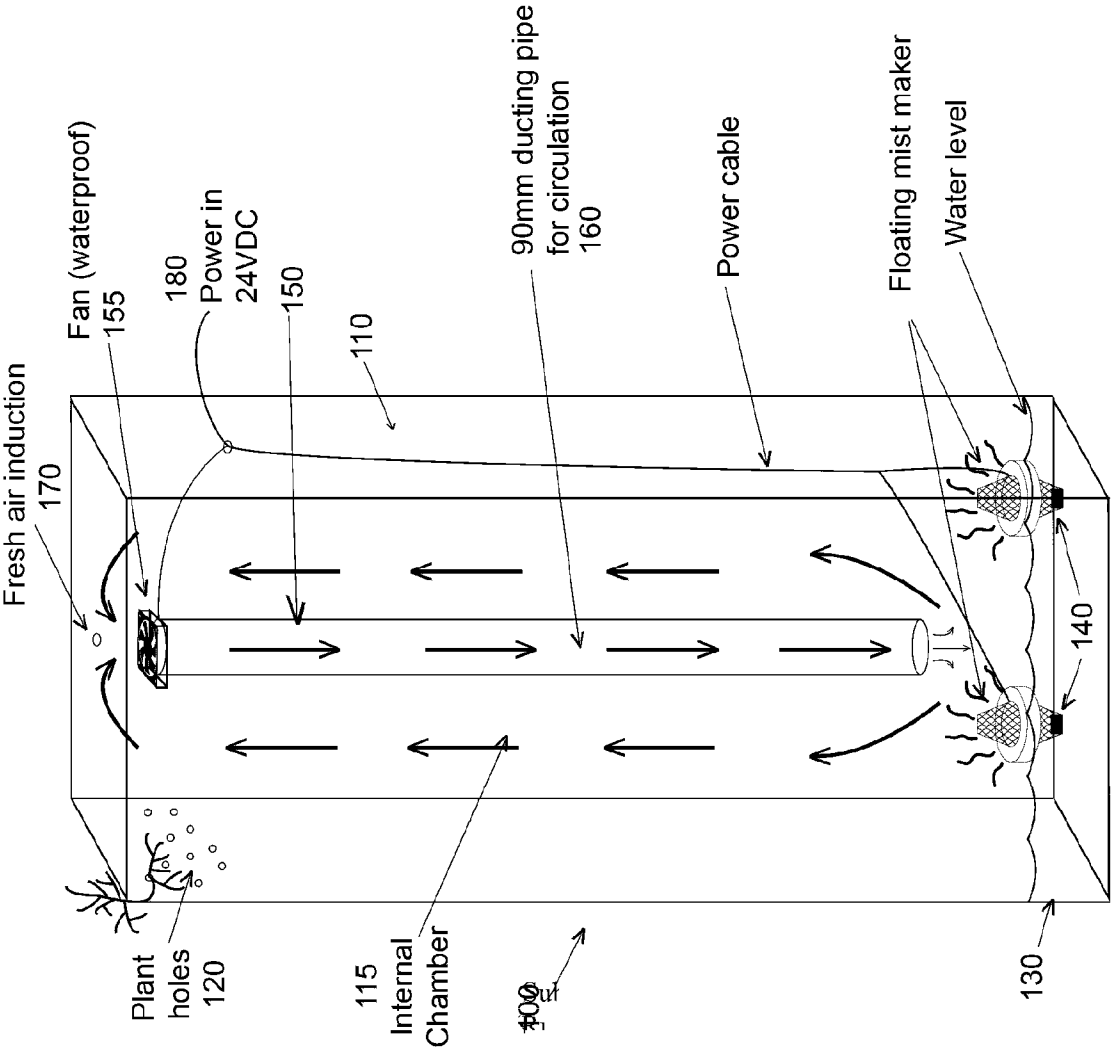
16. The vertical plant cultivation system as claimed in claim 14 wherein the support structure includes a seed encapsulated with nutrient and growing media.

17. The vertical plant cultivation system as claimed in claim 1 wherein the shell includes at least one fresh air intake aperture located in an upper portion of the shell proximate the mist circulation module.

15

18. The vertical plant cultivation system as claimed in claim 1 wherein the shell is configured to be modular and allow interconnection of two or more shells.

20



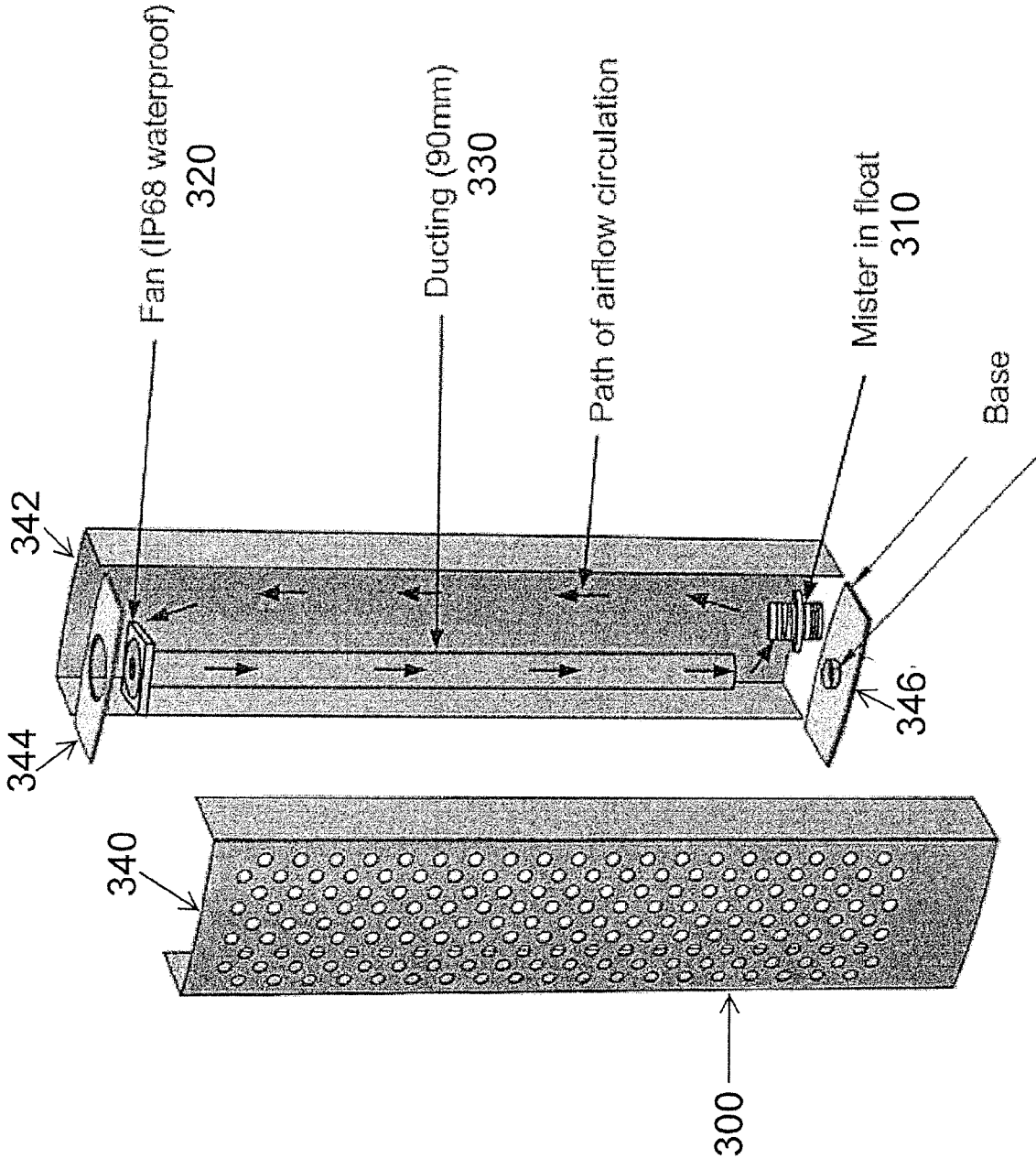


Figure. 3

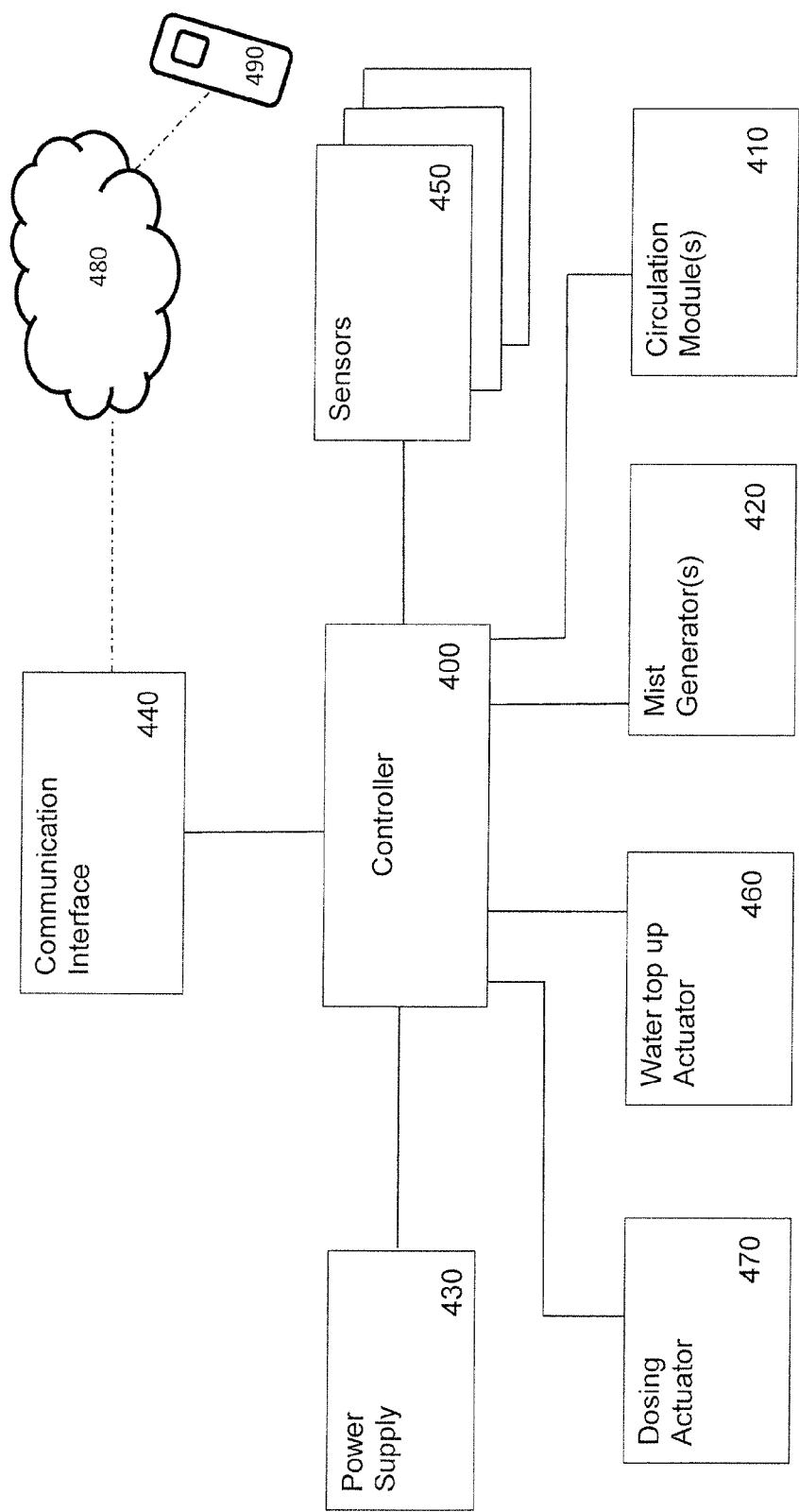


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2015/000094

A. CLASSIFICATION OF SUBJECT MATTER

A01G 31/02 (2006.01) A01G 27/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPIAP: IPC: A01G31 and A01G27 & Keywords: vertical, reservoir, float, buoy, mist, fog, ultrasonic, transducer, circulate, fan and other like terms.

GOOGLE, GOOGLE PATENTS, ESPACENET & Keywords: hydroponic, aeroponic, vertical, reservoir, float, buoy, mist, fog, ultrasonic, transducer, circulate, fan and other like terms.

GOOGLE, GOOGLE PATENTS, and ESPACENET applicant name search.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 27 April 2015		Date of mailing of the international search report 27 April 2015	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au		Authorised officer Ericson Salindo AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262256102	

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. PCT/AU2015/000094
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 103477966 A (JIANGSU UNIVERSITY) 01 January 2014 (Figs. 1-4, 8; paragraphs [0004], [0007], [0008], and [0025] of English language translation available from Espacenet.com	1-18
X	JP 2012034581 A (HONDA ELECTRONIC CO LTD) 23 February 2012 Figs. 1-3 and English language Abstract available from Espacenet.com	1-18
Y	US 4869019 A (EHRlich) 26 September 1989 Figs. 1-4 and the corresponding text description in columns 4-5	1-18
Y	US 2011/0061297 A1 (SIMMONS) 17 March 2011 Figs. 1-3 and the corresponding text description in paragraphs [0018]-[0043]	1-18
Y	AU 2013101430 A4 (DUGG, Christopher) 28 November 2013 Figs. 1-5	1-18
Y	US 8505238 B2 (LUEBBERS et al.) 13 August 2013 Figs. 1-5; column 2, line 13 to column 3, line 34	1-18
Y	CARRUTHERS, Steven, Aeroponics, Practical Hydroponics & Greenhouses, Issue 5, July/August 1992 [online], [retrieved from internet on 5 March 2015] <url: http://www.hydroponics.com.au/issue-05-aeroponics/ The text under the subheading "Aero-Gro System (AGS)"	1-18
Form PCT/ISA/210 (fifth sheet) (July 2009)		

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2015/000094	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
CN 103477966 A	01 January 2014		
JP 2012034581 A	23 February 2012		
US 4869019 A	26 September 1989	CA 1272884 A1	21 Aug 1990
US 2011/0061297 A1	17 March 2011	US 8250809 B2	28 Aug 2012
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		EP 2475241 A1	18 Jul 2012
		JP 2013504327 A	07 Feb 2013
		US 2011061296 A1	17 Mar 2011
		US 8225549 B2	24 Jul 2012
		US 2012279126 A1	08 Nov 2012
		US 8484890 B2	16 Jul 2013
		WO 2011031939 A1	17 Mar 2011
AU 2013101430 A4	28 November 2013		
US 8505238 B2	13 August 2013	US 8505238 B2	13 Aug 2013
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			