

PLANTER AND METHOD FOR GROWING PLANTS WITH AIR PRUNING

Cross Reference to Related Application(s)

- 5 The present disclosure claims the benefit of Singapore Patent Application No. 10202112128V filed on 1 November 2021, which is incorporated in its entirety by reference herein.

Technical Field

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The present disclosure generally relates to a planter and a method for growing plants with air pruning.

Background

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Existing planters for growing plants are usually in the form of rigid containers or pots that are made of plastics or ceramics. For example, planters are used for nursery production of woody tree species, but these often result in plants with severely deformed roots and circling roots at the base, especially if the plants remain in the
20 containers for extended periods of time. Quality of the root morphology and function following transplanting may be impaired over time. Root morphology is affected by various environmental conditions such as water availability, nutrient status, physical obstacles, and biological damages, and is crucial for plant adaptation to unexpected environmental changes. To address the disadvantages of existing planters,
25 techniques such as root pruning, chemical pruning, and air pruning have been used to improve plant quality. These techniques can improve plant growth and yield, and they have been generally demonstrated in a wide range of woody plant species.

Root pruning by undercutting is a common agricultural technique for woody plants and
30 stimulates the emergence of new roots with more lateral roots. Root pruning has shown to be an effective tool to encourage lateral root formation, create a high root density, and enhance shoot growth ratio. Various reports have demonstrated the efficacy of root pruning in various plant species. For example, root pruning improves

root regeneration in the aerial roots of tropical grapes. For example, root pruning of wheat increases the number of lateral roots and amount of auxin content. For example, root cutting induces production of cyclin B1 protein in potato lateral root primordium and this occurs through the activation of auxin signalling. However, one disadvantage of root pruning by undercutting is that it is both time and labour intensive since roots need to be individually cut. Another disadvantage is that the cut roots are exposed to the environment, making the roots and other parts of the plants vulnerable to attacks by environmental pathogens.

- 10 Chemical pruning can be done using specially designed chemical pruning horticulture nursery containers. The chemical pruning is achieved by coating the inner walls of the containers with various materials. These materials contain copper as copper can inhibit root tip growth, increase secondary root branching, reduce root circling, reduce root to shoot ratio, and promote root regeneration after transplanting. Containers coated with copper hydroxide on its inner walls is a common commercial product to stop root elongation through the chemical pruning approach.

Air pruning of roots is a natural phenomenon in which the growing root tips dry out and stop growing upon exposure to air. Air pruning is different from aeroponics which is a technique of growing plants in a soilless environment wherein the roots are always exposed to air and sprayed with nutrient-rich mist. Air pruning of roots has been shown to effectively improve root vitality and proportion, and growth of aboveground part in woody plants. Specifically, plants respond to air pruning of roots by producing more lateral roots and root hairs, resulting in a healthier plant with a younger and denser root system. Air pruning of roots has now evolved into an effective method of reducing root malformation and regulating root growth. Commercial air pruning containers are designed with holes on the sides of the container. Air pruning can also be done by wrapping a perforated sheet around the soil instead of using a container. The roots will be exposed to air via the holes on the sides of the container or the sheet perforations. Root tip elongation is inhibited when the roots get exposed to air through these holes and perforations. However, the holes and perforations also expose large areas of the soil to the air, resulting in the soil drying out and increased water consumption.

Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved planter and method for growing plants with air pruning.

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Summary

According to a first aspect of the present disclosure, there is a planter for growing plants with air pruning, the planter comprising: an outer container for containing a planting material to grow the plants; and an inner container disposed in the outer container to reduce a volume of the outer container for containing the planting material, the inner container comprising an inner space, wherein the inner container comprises holes to expose roots of the plants grown in the planting material to air in the inner space and thereby air prune the exposed roots.

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According to a second aspect of the present disclosure, there is a method for growing plants with air pruning, the method comprising: providing a planter comprising an outer container and an inner container, the inner container disposed in the outer container to reduce a volume of the outer container for containing the planting material, the inner container comprising an inner space; filling the outer container with a planting material, the inner space absent of the planting material; growing the plants in the planting material until roots of the plants reach the inner container; and exposing the roots of the plants grown in the planting material to air in the inner space via holes in the inner container, thereby air pruning the exposed roots.

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According to a third aspect of the present disclosure, there is a kit for making a planter for growing plants with air pruning, the kit comprising: an outer container for containing a planting material to grow the plants; and an inner container for assembling into the outer container, the inner container comprising an inner space, wherein when the inner container is assembled into the outer container, the inner container reduces a volume of the outer container for containing the planting material; and wherein the inner container comprises holes to expose roots of the plants grown in the planting material to air in the inner space and thereby air prune the exposed roots.

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According to a fourth aspect of the present disclosure, there is use of one or more of the planter, the method, and the kit for growing plants in an indoor farm system.

- 5 A planter and method for growing plants with air pruning according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

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Brief Description of the Drawings

Figures 1A to 1E are illustrations of a planter for growing plants with air pruning.

- 15 Figures 2A to 2C are illustrations of a planter for growing plants without air pruning.

Figures 3A to 3D are illustrations of experiments to investigate root morphology of *Arabidopsis* and *arf7/arf19* double mutant plants grown using the planters with and without air pruning.

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Figures 4A to 4C are illustrations of experiments to investigate root morphology of Choy Sum plants grown using the planters with and without air pruning.

- Figures 5A to 5C are illustrations of experiments to investigate root morphology of Pak
25 Choi plants grown using the planters with and without air pruning.

Figures 6A to 6G are illustrations of experiments to investigate plant growth and nutrient content of Choy Sum plants grown using the planters with and without air pruning.

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Figures 7A to 7E are illustrations of experiments to investigate plant growth and nutrient content of Pak Choi plants grown using the planters with and without air pruning.

Figures 8A and 8B are illustrations of experiments to investigate total chlorophyll content of Choy Sum and Pak Choi plants grown using the planters with and without air pruning.

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Figure 9 is an illustration of experiments to investigate postharvest leaf senescence of Choy Sum plants grown using the planters with and without air pruning.

Detailed Description

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For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a planter and method for growing plants with air pruning, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith. References to "an embodiment / example", "another embodiment / example", "some embodiments / examples", "some other embodiments

/ examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore,
5 repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of
10 certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment. The terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The recitation of a particular numerical value or value range herein is
15 understood to include or be a recitation of an approximate numerical value or value range. The terms “first”, “second”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms.

Planter

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In representative or exemplary embodiments of the present disclosure, as shown in Figures 1A to 1C, there is a planter 100 for growing plants 200 with air pruning. The planter 100 comprises an outer container 110 and an inner container 120. The outer container 110 is for containing a planting material 210 to grow the plants 200. The
25 planting material is preferably soil, such as potting soil or garden soil, but it will be appreciated that it can be other suitable material such as a potting mix that includes constituents like compost and fertilizers. The outer container 110 comprises a side area 112 and a bottom area 114. The inner container 120 is disposed in the outer container 110 to reduce a volume of the outer container 110 for containing the planting
30 material 210. For example, the inner container 120 reduces about 10% to 90%, but not limited to this range, of the volume of space in the outer container 110. For example, the inner container 120 occupies a footprint of about 10% to 90%, but not limited to this range, of the bottom area 114 of the outer container 110. For example, the inner

container 120 has a height of about 10% to 90%, but not limited to this range, of the height of the outer container 110.

In some embodiments, the inner container 120 is removably joined to or assembled
5 with the outer container 110 to bring both containers 110,120 together in a functional relationship. The joint between the containers 110,120 may be permanent or temporary which would enable the inner container 120 to be removed or detached from the outer container 110. For example, the inner container 120 is removably joined to the outer container 110 using suitable fastening elements such as string, ribbon,
10 cable tie, snap-fit and/or threaded fasteners. In some other embodiments, the inner container 120 is integrally formed with or joined to the outer container 110 as a unitary or monolithic unit, such as by welding or moulding.

The inner container 120 comprises an inner space 130 in the inner container 120. The
15 inner container 120 is disposed in the outer container 110 such that the volume of the outer container 110 is reduced by occupancy of the inner container 120 and this reduces the amount of planting material needed to fill the planter 100. More particularly, when the outer container 110 is filled with the planting material 210, the inner space 130 creates a volume of air or an air pocket that is absent of the planting material 210.
20 The inner container 120 comprises holes to expose roots 202, particularly the primary roots, of the plants 200 grown in the planting material 210 to air in the inner space 130 and thereby air prune the exposed roots 202.

In some embodiments, the inner container 120 comprises a side area 122 and a top
25 area 124 that define the inner space 130. In one embodiment, at least one of the side area 122 and top area 124 comprises the holes to expose the roots 202 of the plants 200 to air in the inner space 130. For example, the side area 122 comprises holes 132 and/or the top area 124 comprises holes 134. In another embodiment, all areas or surfaces of the inner container 120 comprise the holes to expose the roots 202 of the
30 plants 200 to air in the inner space 130.

In some embodiments as shown in Figure 1A, the inner container 120 is integrally formed with or joined to the bottom area 114 of the outer container 110, wherein the

top area 124 of the inner container 120 is opposite to the bottom area 114 of the outer container 110. In some other embodiments, the inner container 120 is integrally formed with or joined to the side area 112 of the outer container 110, wherein the top area 124 of the inner container 120 is opposite to the side area 112 of the outer container 110. The side area 112 of the outer container 110 is preferably closed and does not have holes or perforations like the inner container 120.

Figure 1E illustrates suitable dimensions of the outer container 110 and inner container 120 for an exemplary embodiment of the planter 100. Depending on the plant species and plant root types, such as taproot and fibrous root, the dimensions of the outer container 110 and inner container 120, as well as the holes 132 / 134, can be adjusted accordingly.

Method

In embodiments of the present disclosure, there is a method for growing plants 200 with air pruning. The method may be performed using various planters, containers, or pots, including the planter 100 as described herein. The method includes a step of providing the planter 100 as described herein. The method further includes a step of filling the outer container 110 with the planting material 210, the inner space 130 is absent of the planting material 210. The method further includes a step of growing the plants 200 in the planting material 210 until the roots 202 of the plants 200 reach the inner container 120. The method further includes a step of exposing the roots 202 of the plants 200 grown in the planting material 210 to air in the inner space 130, such as via the holes 132 / 134, thereby air pruning the exposed roots 202.

For example, the side area 122 comprises the holes 132 and the top area 124 comprises the holes 134. The roots 202 would grow and reach the top area 124 first and continue to grow into the inner space 130 via the holes 134. Outside of the inner container 120, the roots 202 would also keep growing and reach the side area 122 and continue to grow into the inner space 130 via the holes 132. The roots 202 that are exposed to the air pocket in the inner space 130 via the holes 132 / 134 would be air pruned.

Kit

In embodiments of the present disclosure, there is a kit for making the planter 100 for
5 growing plants 200 with air pruning. For example, a home user may purchase this kit
and make the planter 100 for their home gardening hobby. The kit comprises the outer
container 110 and the inner container 120 for assembling into the outer container 110.
Particularly, the inner container 120 is joinable or attachable to the bottom area 114
or side area 112 of the outer container 110. Suitable attachment or fastening elements
10 may be provided at the outer container 110 and inner container 120 to enable them to
assemble together. These fastening elements may include strings, ribbons, cable ties,
snap-fit fasteners and/or threaded fasteners. The inner container 120 is removable
from the outer container 110, such as to clean the holes 132 / 134 and to remove fallen
roots 202.

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In one embodiment as shown in Figures 2A and 2B, the bottom area 114 of the outer
container 110 that is covered by the inner container 120 may comprise holes 116 to
fasten the inner container 120 to the bottom area 114 of the outer container 110, such
as by a string or ribbon 140. The bottom area 114 of the outer container 110 may be
20 raised or comprise raised features such as raised ridges 142 to facilitate airflow into
the inner space 130. In one embodiment, a bottom area 126 of the inner container 120
is open such that the periphery of the bottom area 126 is joined to or integrally formed
with the bottom area 114 of the outer container 110. The bottom area 114 of the outer
container 110 may further comprise holes 118 to facilitate airflow into the inner space
25 130. More specifically, the periphery of the bottom area 126 is joined to or integrally
formed with the raised ridges 142 at the bottom area 114 so that the periphery is not
completely sealed and is exposed to gaps 144 between the raised ridges 142. Air can
flow from the external environment through the holes 118 and gaps 144 into the inner
space 130. In another embodiment, the bottom area 126 of the inner container 120 is
30 closed and comprises holes that may be fluidically communicative with the holes 118
at the bottom area 114 of the outer container 110.

In some embodiments, the inner container 120 is integrally formed with or joined to the outer container 110, such as by welding at the bottom area 114 of the outer container 110. The outer container 110 may comprise an opening for accessing the inner space 130. For example, the opening is disposed at the bottom area 114 for
5 accessing the inner space 130 using suitable instruments to remove pruned roots and clean the inner space 130. This opening may also facilitate airflow into the inner space 130 and may optionally be closed by a cover.

The side area 122 of the inner container 120 may be straight, tapered, or curved. In
10 one embodiment as shown in Figure 1C, the side area 122 of the inner container 120 is tapered outwardly from the top area 124, thus making the bottom area 126 larger than the top area 124. Various examples of the inner container 120 having straight and tapered side areas 122 are shown in Figure 1D. For example, the side area 122 is vertically straight or perpendicular to the bottom area 114 of the outer container 110.
15 Alternatively, the side area 122 may be inclined to the bottom area 114 of the outer container 110. Further, the top area 124 of the inner container 120 may be horizontally flat (parallel to the bottom area 114 of the outer container 110) or curved, such as concave or convex shaped.

20 Experiments

Various experiments were performed to investigate the efficacy of the planter 100 in growing plants 200 with air pruning in comparison with growing the plants 200 without air pruning. Growing plants 200 with air pruning, i.e. under air pruning (AP) conditions,
25 were done using the planter 100 comprising the outer container 110 and inner container 120 with the inner space 130 forming the air pocket, as shown in Figures 1A to 1C. Growing plants 200 without air pruning, i.e. under non air pruning (NAP) conditions, were done using the outer container 110 alone, i.e. without any air pocket, as shown in Figures 2A to 2C. For distinction, the outer container 110 used for the
30 NAP conditions is referred to as the NAP planter 300 to differentiate from the AP planter 100 (having the outer container 110 and inner container 120). It will be appreciated that the NAP planter 300 can be any conventional flowerpots or containers.

Under NAP conditions, the roots 202 of the plants 200 grown in the NAP planter 300 grow continuously and form circles at the bottom area 114, as shown in Figure 2C. For plants 200 grown in the AP planter 100 under AP conditions, when the roots reach the inner container 120, the tips of first order lateral roots 202 are exposed to air in the inner space 130 via the holes 132 / 134. The roots 202 upon exposure to the air dry out and this leads to the formation of more lateral roots 202 as shown in Figure 1C.

An experiment was done to investigate the root morphology of some plants 200 grown under NAP and AP conditions. Two species of plants 200 were tested – *Arabidopsis thaliana* wild-type (WT) (Col-0) (plants 200A) and lateral root deficient *arf7/arf19* double mutants (plants 200B). Seeds of the *Arabidopsis* plants 200A and *arf7/arf19* plants 200B were germinated on 0.8% agar media containing Murashige and Skoog basal salt mixture (MS), 0.5% MES (free acid), and 10 g/L sucrose. As shown in Figures 3A and 3B, to create the NAP conditions, 5-days-old seedlings of the *Arabidopsis* plants 200A and seedlings of the *arf7/arf19* plants 200B were transferred to the NAP planters 300. To create the AP conditions, 5-days-old seedlings of the *Arabidopsis* plants 200A and seedlings of the *arf7/arf19* plants 200B were transferred to the AP planters 100 and 2/3 of the agar media was cut out. The arrows in Figures 3A and 3B represent the cutting plane of the agar media. The *Arabidopsis* plants 200A and *arf7/arf19* plants 200B were grown in growth chambers at 22 °C under white light at 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ with 60% relative humidity in long-day conditions (16 hours of light and 8 hours of darkness). The growth of the *Arabidopsis* plants 200A and *arf7/arf19* plants 200B were tested under NAP and AP conditions to test the importance of lateral roots 202 in response to air pruning.

The results of the growth comparison for the *Arabidopsis* plants 200A under NAP and AP conditions are shown in Figures 3C and 3D. The number of first order lateral roots 202 and root hairs 204 was higher under AP conditions than under NAP conditions, indicating that air pruning induces formation of lateral roots 202 and root hairs 204. The measurements of the plant growth parameters in Figure 3C were generated based on the mean $\pm$ SD (standard deviation) of 12 biological replicates of the *Arabidopsis* plants 200A. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-value was calculated as shown in Figure 3C. The

p-value 0.0128 is less than 0.05 which is statistically significant. It indicates strong evidence which corresponds a 95% confidence.

The results of the growth comparison for the *arf7/arf19* plants 200B under NAP and AP conditions are shown in Figure 3B. Although the *arf7/arf19* plants 200B appeared slightly smaller than the *Arabidopsis* plants 200A under NAP conditions, the growth of the *arf7/arf19* plants 200B were significantly affected under AP conditions, suggesting the importance of lateral roots in response to air pruning. Hence, this experiment showed that the lateral roots 202 and root hairs 204 play an important role in response to air pruning of roots 202 of plants 200.

An experiment was done to investigate the root morphology of some other plants 200 grown under NAP and AP conditions. Two species of leafy vegetable plants 200 were tested – Choy Sum (*Brassica rapa* var. *Parachinensis*) (plants 200C) and Pak Choi (*Brassica rapa* var. *chinensis*) (plants 200D). Seeds of the Choy Sum plants 200C and Pak Choi plants 200D were germinated on 0.8% agar media containing Murashige and Skoog basal salt mixture (MS), 0.5% MES (free acid), and 10 g/L sucrose. Seedlings of 1-week-old Choy Sum plants 200C and Pak Choi plants 200D were transferred to the NAP planters 300 and AP planters 100 filled with planting material 210 (soil). The Choy Sum plants 200C and Pak Choi plants 200D were grown in growth chambers at 22 °C under white light at 100 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ with 60% relative humidity in long-day conditions (16 hours of light and 8 hours of darkness).

The comparison for the roots 202 of 5-weeks-old Choy Sum plants 200C grown under NAP and AP conditions are shown in Figures 4A to 4C. Figure 4A compares the root phenotype or appearance (the scale bar represents a 5 cm dimension), Figure 4B compares the root length, and Figure 4C compares the root fresh weight. Notably, the root length under AP conditions was significantly shorter than under NAP conditions, but the root fresh weight under AP conditions was much higher than under NAP conditions. The measurements of the plant growth parameters in Figures 4B and 4C were generated based on the mean $\pm$ SD of 18 biological replicates of the Choy Sum plants 200C. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in the respective

Figures 4B and 4C. Figures 4B and 4C show p-values that are less than 0.001 and 0.05, respectively, and are statistically significant. They indicate strong evidence which corresponds a 99.9% and 95% confidence, respectively.

- 5 The comparison for the roots 202 of 5-weeks-old Pak Choi plants 200D grown under NAP and AP conditions are shown in Figures 5A to 5C. Figure 5A compares the root phenotype or appearance (the scale bar represents a 5 cm dimension), Figure 5B compares the root length, and Figure 5C compares the root fresh weight. Like the Choy Sum plants 200C, the root length under AP conditions was shorter than under
- 10 NAP conditions, and the root fresh weight under AP conditions was higher than under NAP conditions. The measurements of the plant growth parameters in Figures 5B and 5C were generated based on the mean $\pm$ SD of 18 biological replicates of the Pak Choi plants 200D. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in the
- 15 respective Figures 5B and 5C. Both Figures 5B and 5C show p-values that are less than 0.05 and are statistically significant. They indicate strong evidence which corresponds a 95% confidence.

- An experiment was done to investigate the plant growth and nutrient content,
- 20 specifically the vegetable yield and macronutrient and micronutrient levels, of the 5-weeks-old Choy Sum plants 200C grown under NAP and AP conditions. Figures 6A and 6B show the whole plant and leaf arrangement of 5-weeks-old Choy Sum plants 200C grown under NAP and AP conditions. The scale bar represents a 5 cm dimension. As shown in Figures 6C and 6D, the Choy Sum plants 200C grown under
- 25 AP conditions were visibly larger, had 29.2% higher shoot fresh weight or biomass, and had a 46.3% increase in the number of leaves than under NAP conditions. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in the respective Figures 6C and 6D. Both Figures 6C and 6D shows p-values that are less than 0.001 and are
- 30 statistically significant. They indicate strong evidence which corresponds a 99.9% confidence.

Quantitative analysis of 10 macronutrients and micronutrients was done on 150 g of freshly harvested leaves of the Choy Sum plants 200C. The macronutrients include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). The micronutrients include copper (Cu), manganese (Mn), iron (Fe), zinc (Zn), and boron (B). All the macronutrients and micronutrients except nitrogen were analysed using inductively coupled plasma - optical emission spectrometry (ICP-OES), and nitrogen was analysed using a CHNS analyser. As shown in Figure 6E, the quantitative analysis showed that the levels of the macronutrients nitrogen, potassium, calcium, and magnesium were lower in the leaves grown under AP conditions than under NAP conditions. Total nitrogen content as shown in Figure 6E shows a p-value that is less than 0.05 and is statistically significant. It indicates strong evidence which corresponds a 95% confidence. As shown in Figure 6F, the quantitative analysis showed that the levels of the micronutrients manganese, iron, and zinc were higher in the leaves grown under AP conditions than under NAP conditions. Total iron content as shown in Figure 6F shows a p-value that is less than 0.001 and is statistically significant. It indicates strong evidence which corresponds a 99.9% confidence.

The Choy Sum plants 200C were divided into 2 groups – first group for plants 200C with 1 to 5 leaves and second group for plants 200C with 6 or more leaves (numbered from the bottom) – and the antioxidant activity of the plants 200C was measured for both groups. As shown in Figure 6G, the antioxidant activity was significantly higher for the Choy Sum plants 200C grown under AP conditions than under NAP conditions. The antioxidant activity was measured based on the DPPH (organic chemical compound 2,2-diphenyl-1-picrylhydrazyl) inhibition activity. Leaf discs were extracted using 80% acetone at 4 °C in darkness for 24 hours. 20 µL of acetone extract was mixed with 180 µL of 0.3 mM DPPH in acetone and incubated at room temperature for 2 hours. Absorbance at 517 nm was then measured using a spectrophotometer and the DPPH inhibition activity was calculated using the equation below. $Abs_{control}$ represents the absorbance of DPPH radicals and acetone, and Abs_{sample} represents the absorbance of DPPH radicals and sample extract. Figure 6G shows p-values that are less than 0.05 (1 to 5 leaves) and 0.01 (6 or more leaves) and are statistically significant. They indicate strong evidence which corresponds a 95% and 99% confidence, respectively.

$$DPPH\ Inhibition\ (\%) = \frac{Abs_{control} - Abs_{sample}}{Abs_{control}} \times 100\%$$

The measurements of the plant growth parameters in Figures 6C and 6D were generated based on the mean $\pm$ SD of 18 biological replicates of the Choy Sum plants 200C. The measurements of the plant growth parameters in Figures 6E to 6G were generated based on the mean $\pm$ SD of 3 biological replicates of the Choy Sum plants 200C. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in the respective Figures 6C to 6G.

A similar experiment was done to compare the plant growth and nutrient content of the 5-weeks-old Pak Choi plants 200D grown under NAP and AP conditions. Figures 7A and 7B show the whole plant and leaf arrangement of 5-weeks-old Pak Choi plants 200D grown under NAP and AP conditions. The scale bar represents a 5 cm dimension. As shown in Figures 7C and 7D, the Pak Choi plants 200D grown under AP conditions were visibly larger, had a significant increase of 86.7% in shoot fresh weight or biomass, and had a 14.2% increase in the number of leaves than under NAP conditions. As shown in Figure 7E, measurement of the leaf area showed that leaf number 5 and leaf number 7 (counted from the bottom) of the Pak Choi plants 200D grown under AP conditions were significantly larger than under NAP conditions.

The measurements of the plant growth parameters in Figures 7C to 7E were generated based on the mean $\pm$ SD of 18 biological replicates of the Pak Choi plants 200D. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in the respective Figures 7C to 7E. Figures 7C and 7D show p-values that are less than 0.05 and are statistically significant. They indicate strong evidence which corresponds a 95% confidence. Figure 7E shows p-values that are less than 0.01 (leaf number 5) and 0.001 (leaf number 7) and are statistically significant. They indicate strong evidence which corresponds a 99% and 99.9% confidence, respectively.

An experiment was done to compare the total chlorophyll content of the 5-weeks-old Choy Sum plants 200C grown under NAP and AP conditions. The total chlorophyll content was measured spectrophotometrically, and the measurements were expressed in mg per g of fresh weight. The Choy Sum plants 200C were divided into 2 groups – first group for the older plants 200C with 1 to 5 leaves (as the leaves are aging and falling) and second group for the younger plants 200C with 6 or more leaves. As shown in Figure 8A, the older Choy Sum plants 200C in the first group grown under AP conditions had slightly higher total chlorophyll content than under NAP conditions. The younger Choy Sum plants 200C in second group had similar total chlorophyll content for both AP and NAP conditions. The measurements were generated based on the mean $\pm$ SD of 3 biological replicates and 3 technical replicates of the Choy Sum plants 200C. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in Figure 8A. Figure 8A shows p-values that are more than 0.05 and are statistically not significant. They indicate weak evidence which corresponds to less than 95% confidence.

A similar experiment was done to compare the total chlorophyll content of the 5-weeks-old Pak Choi plants 200D grown under NAP and AP conditions. The Pak Choi plants 200D were divided into 3 groups – first group for the oldest plants 200D with 1 to 6 leaves, second group for plants 200D with 7 to 12 leaves, and third group for the youngest plants 200D with 13 or more leaves. As shown in Figure 8B and like the Choy Sum plants 200C, the older Pak Choi plants 200D in the first and second groups grown under AP conditions had slightly higher total chlorophyll content than under NAP conditions. The measurements were generated based on the mean $\pm$ SD of 3 biological replicates of the Pak Choi plants 200D. The statistical significance of the measurements was determined by the two-tailed Student's t-test and the p-values were calculated as shown in Figure 8B. For the group with 13 or more leaves, the p-value is less than 0.01 and is statistically significant. It indicates strong evidence which corresponds a 99% confidence.

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An experiment was done to investigate postharvest leaf senescence of the 5-weeks-old Choy Sum plants 200C grown under NAP and AP conditions. 6 biological replicates of the Choy Sum plants 200C were stored in plastic boxes in darkness at

22 °C for 2 weeks. Figure 9 shows the visual appearances of the Choy Sum plants 200C at selected days from Day 0 (D0) to Day 14 (D14). The scale bar represents a 5 cm dimension. Initially before storage in darkness (at D0), the Choy Sum plants 200C grown under NAP conditions had yellow leaves whereas no visible senescence phenotype was observed for the Choy Sum plants 200C grown under AP conditions. After 6 days of storage in darkness (at D6), the oldest leaves started to turn yellow for the Choy Sum plants 200C grown under AP conditions. Hence, Choy Sum plants 200C grown under AP conditions showed delayed postharvest leaf senescence or leaf yellowing compared to those grown under NAP conditions.

Embodiments herein describe the AP planter 100 and method for growing plants 200 with air pruning using an air pocket (inner space 130) in the AP planter 100. The AP planter 100 can be used in various settings, such as indoor farming for growing leafy vegetables. More particularly, one or more of the disclosed AP planter 100, method for growing plants 200 with air pruning and the kit for making the AP planter 100 can be used in an indoor farm system for growing plants 200, wherein the indoor farm system may be soil-based. When the plants 200 are grown using the AP planter 100, the plant roots 202 exposed to and growing inside the air pocket dry out and die off, thereby encouraging lateral root formation, creating a higher root density and a higher shoot growth.

The AP planter 100 thus provides advantages as compared to growing plants 200 without air pruning, such as improved shoot growth, higher antioxidant activity, and better shelf-life through a denser and healthier root system. The roots 202 are air pruned naturally in the air pocket without requiring manual intervention. Furthermore, as the inner container 120 occupies a volume of space in the outer container 110, the total volume of the outer volume 110 is reduced and less planting material 210 would be needed to fill the AP planter 100. As the side area 112 of the outer container 110 is closed, i.e. does not have holes or perforations like current air pruning methods using a perforated sheet wrapped around the soil, less areas of the soil are exposed to the air. This mitigates drying out of the soil, helps to retain moisture within the soil, and reduces water consumption. With less areas of the soil exposed to the environment, the roots 202 are less vulnerable to attacks by environmental pathogens.

The experiments described above have evaluated the advantages of growing plants 200 with air pruning using the AP planter 100 compared to without air pruning. For example, air pruning of plant roots 202 has been shown to produce higher shoot and root biomass in the plants 200. Lateral roots 202 and root hairs 204 produced as response to air pruning increase the root surface area and aid nutrient uptake. As root morphology is highly correlated with root functions such as anchoring, nutrient and water uptake, and response to environmental cues. Plants 200 with well-developed, denser, and healthier root systems are more efficient in nutrient and water absorption and have higher photosynthetic rates.

In the experiments performed on leafy vegetable (Choy Sum plants 200C and Pak Choi plants 200D), the root density was found to have increased when they are grown under AP conditions. The results also demonstrated that shoot growth and nutrient uptake activity can be improved with a healthier root system. Furthermore, higher nutrient uptake activity led to increased micronutrient content, regulating of antioxidant activity, and indicating higher antioxidant activity in plants 200 grown under AP conditions than under NAP conditions.

Plants 200 grown under AP conditions also exhibited late senescence phenotype, which in previous research has found to be accompanied by increased yield and improved quality. Previous research also found that plants 200 with delayed onset of postharvest senescence have shown to have a higher nitrogen-use efficiency than the conventional plants 200 with normal onset of senescence. Thus, for plants 200 grown under AP conditions, delayed postharvest senescence of the plant leaves may not only prolong the lifespan of the leaves but may also improve nutrient use efficiency.

The morphological manifestation of postharvest senescence seems to depend on pervasive nutrient content in plant tissue. Nutrient limitation is one of the factors that induce the onset of senescence in older leaves, which dismantles the functional structures of leaves and generates nutrients that are remobilized to develop young leaves in apical meristem. Moreover, as the delayed senescing phenotype is indicative

of plant health, plants 200 grown under AP conditions are likely to have increased tolerance to abiotic and biotic stress.

5 The AP planter 100 and the experiments done to evaluate its performance have provided new insights to implement air pruning of plant roots 202. It will be appreciated that growth of plants 200 under AP conditions may be affected by factors such as design of the AP planter 100, plant species, root growth pattern, developmental stage of the plants 200, and environmental conditions. For example, the size and/or shape of the air pocket may be related to nutrient usage of the plants 200 and the
10 configuration of the air pocket can be designed to optimize plant growth, especially for farming vegetable crops.

Additive Manufacturing

15 The planter 100 and parts thereof can be fabricated by various manufacturing methods, such as casting, injection moulding, laser cutting, and CNC machining. In some embodiments, the planter 100 or parts thereof or a product comprising the planter 100 or parts thereof may be formed by a manufacturing process that includes an additive manufacturing process. A common example of additive manufacturing is three-
20 dimensional (3D) printing; however, other methods of additive manufacturing are available. Rapid prototyping or rapid manufacturing are also terms which may be used to describe additive manufacturing processes.

As used herein, “additive manufacturing” refers generally to manufacturing processes
25 wherein successive layers of material(s) are provided on each other to “build-up” layer-by-layer or “additively fabricate”, a 3D component. This is compared to some subtractive manufacturing methods (such as milling or drilling), wherein material is successively removed to fabricate the part. The successive layers generally fuse together to form a monolithic component which may have a variety of integral sub-
30 components. In particular, the manufacturing process may allow an example of the disclosure to be integrally formed and include a variety of features not possible when using prior manufacturing methods.

Additive manufacturing methods described herein enable manufacture to any suitable size and shape with various features which may not have been possible using prior manufacturing methods. Additive manufacturing can create complex geometries without the use of any sort of tools, moulds, or fixtures, and with little or no waste material. Instead of machining components from solid billets of plastic or metal, much of which is cut away and discarded, the only material used in additive manufacturing is what is required to shape the part.

Suitable additive manufacturing techniques in accordance with the present disclosure include, for example, Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS), 3D printing such as by inkjets and laserjets, Stereolithography (SLA), Direct Selective Laser Sintering (DSLS), Electron Beam Sintering (EBS), Electron Beam Melting (EBM), Laser Engineered Net Shaping (LENS), Electron Beam Additive Manufacturing (EBAM), Laser Net Shape Manufacturing (LNS), Direct Metal Deposition (DMD), Digital Light Processing (DLP), Continuous Digital Light Processing (CDLP), Direct Selective Laser Melting (DSLML), Selective Laser Melting (SLM), Direct Metal Laser Melting (DMLM), Direct Metal Laser Sintering (DMLS), Material Jetting (MJ), NanoParticle Jetting (NPJ), Drop On Demand (DOD), Binder Jetting (BJ), Multi Jet Fusion (MJF), Laminated Object Manufacturing (LOM), and other known processes.

The additive manufacturing processes described herein may be used for forming components using any suitable material. For example, the material may be metal, plastic, polymer, composite, or any other suitable material that may be in solid, liquid, powder, sheet material, wire, or any other suitable form or combinations thereof. More specifically, according to exemplary embodiments of the present disclosure, the additively manufactured components described herein may be formed in part, in whole, or in some combination of materials suitable for use in additive manufacturing processes and which may be suitable for the fabrication of examples described herein.

As noted above, the additive manufacturing process disclosed herein allows a single component to be formed from single or multiple materials. Thus, the examples described herein may be formed from any suitable mixtures of the above materials.

For example, a component may include multiple layers, segments, or parts that are formed using different materials, processes, and/or on different additive manufacturing machines. In this manner, components may be constructed which have different materials and material properties for meeting the demands of any particular application.

- 5 In addition, although the components described herein are constructed entirely by additive manufacturing processes, it should be appreciated that in alternate embodiments, all or a portion of these components may be formed via casting, machining, and/or any other suitable manufacturing process. Indeed, any suitable combination of materials and manufacturing methods may be used to form these
10 components.

- Additive manufacturing processes typically fabricate components based on 3D information, for example a 3D computer model (or design file), of the component. Accordingly, examples described herein not only include products or components as
15 described herein, but also methods of manufacturing such products or components via additive manufacturing and computer software, firmware or hardware for controlling the manufacture of such products via additive manufacturing.

- The structure of the product may be represented digitally in the form of a design file.
20 A design file, or computer aided design (CAD) file, is a configuration file that encodes one or more of the surface or volumetric configuration of the shape of the product. That is, a design file represents the geometrical arrangement or shape of the product.

- Design files can take any now known or later developed file format. For example,
25 design files may be in the Stereolithography or "Standard Tessellation Language" (.stl) format which was created for Stereolithography CAD programs of 3D Systems, or the Additive Manufacturing File (.amf) format, which is an American Society of Mechanical Engineers (ASME) standard that is an extensible markup-language (XML) based format designed to allow any CAD software to describe the shape and composition of
30 any 3D object to be fabricated on any additive manufacturing printer. Further examples of design file formats include AutoCAD (.dwg) files, Blender (.blend) files, Parasolid (.x_t) files, 3D Manufacturing Format (.3mf) files, Autodesk (3ds) files, Collada (.dae) files and Wavefront (.obj) files, although many other file formats exist.

Design files can be produced using modelling (e.g. CAD modelling) software and/or through scanning the surface of a product to measure the surface configuration of the product. Once obtained, a design file may be converted into a set of computer executable instructions that, once executed by a processor, cause the processor to control an additive manufacturing apparatus to produce a product according to the geometrical arrangement specified in the design file. The conversion may convert the design file into slices or layers that are to be formed sequentially by the additive manufacturing apparatus. The instructions (otherwise known as geometric code or “G-code”) may be calibrated to the specific additive manufacturing apparatus and may specify the precise location and amount of material that is to be formed at each stage in the manufacturing process. As discussed above, the formation may be through deposition, through sintering, or through any other form of additive manufacturing method.

The code or instructions may be translated between different formats, converted into a set of data signals and transmitted, received as a set of data signals and converted to code, stored, etc., as necessary. The instructions may be an input to the additive manufacturing system and may come from a part designer, an intellectual property (IP) provider, a design company, the operator or owner of the additive manufacturing system, or from other sources. An additive manufacturing system may execute the instructions to fabricate the product using any of the technologies or methods disclosed herein.

Design files or computer executable instructions may be stored in a (transitory or non-transitory) computer readable storage medium (e.g., memory, storage system, etc.) storing code, or computer readable instructions, representative of the product to be produced. As noted, the code or computer readable instructions defining the product that can be used to physically generate the object, upon execution of the code or instructions by an additive manufacturing system. For example, the instructions may include a precisely defined 3D model of the product and can be generated from any of a large variety of well-known CAD software systems such as AutoCAD®, TurboCAD®, DesignCAD 3D Max, etc. Alternatively, a model or prototype of the

product may be scanned to determine the 3D information of the product. Accordingly, by controlling an additive manufacturing apparatus according to the computer executable instructions, the additive manufacturing apparatus can be instructed to print out the product.

5

In light of the above, embodiments include methods of manufacture via additive manufacturing. This includes the steps of obtaining a design file representing the product and instructing an additive manufacturing apparatus to manufacture the product according to the design file. The additive manufacturing apparatus may
10 include a processor that is configured to automatically convert the design file into computer executable instructions for controlling the manufacture of the product. In these embodiments, the design file itself can automatically cause the production of the product once input into the additive manufacturing apparatus. Accordingly, in this embodiment, the design file itself may be considered computer executable instructions
15 that cause the additive manufacturing apparatus to manufacture the product. Alternatively, the design file may be converted into instructions by an external computing system, with the resulting computer executable instructions being provided to the additive manufacturing apparatus.

20 Given the above, the design and manufacture of implementations of the subject matter and the operations described in this specification can be realized using digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. For instance, hardware may include processors,
25 microprocessors, electronic circuitry, electronic components, integrated circuits, etc. Implementations of the subject matter described in this specification can be realized using one or more computer programs, i.e., one or more modules of computer program instructions, encoded on computer storage medium for execution by, or to control the operation of, data processing apparatus. Alternatively or in addition, the program
30 instructions can be encoded on an artificially generated propagated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal that is generated to encode information for transmission to suitable receiver apparatus for execution by a data processing apparatus. A computer storage medium can be, or be included in, a

computer-readable storage device, a computer-readable storage substrate, a random or serial access memory array or device, or a combination of one or more of them. Moreover, while a computer storage medium is not a propagated signal, a computer storage medium can be a source or destination of computer program instructions
5 encoded in an artificially generated propagated signal. The computer storage medium can also be, or be included in, one or more separate physical components or media (e.g., multiple CDs, disks, or other storage devices).

Although additive manufacturing technology is described herein as enabling
10 fabrication of complex objects by building objects point-by-point, layer-by-layer, typically in a vertical direction, other methods of fabrication are possible and within the scope of the present subject matter. For example, although the discussion herein refers to the addition of material to form successive layers, one skilled in the art will appreciate that the methods and structures disclosed herein may be practiced with
15 any additive manufacturing technique or other manufacturing technology.

In the foregoing detailed description, embodiments of the present disclosure in relation to a planter and method for growing plants with air pruning are described with reference to the provided figures. The description of the various embodiments herein
20 is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having
25 ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

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Claims

1. A planter for growing plants with air pruning, the planter comprising:
an outer container for containing a planting material to grow the plants;
5 and
an inner container disposed in the outer container to reduce a volume of
the outer container for containing the planting material, the inner container
comprising an inner space,
wherein the inner container comprises holes to expose roots of the
10 plants grown in the planting material to air in the inner space and thereby air
prune the exposed roots.
2. The planter according to claim 1, wherein the inner container is integrally
formed with the outer container.
15
3. The planter according to claim 1, wherein the inner container is removable from
the outer container.
4. The planter according to claim 3, wherein the inner container is removably
20 joined to the outer container by a string, ribbon, cable tie, snap-fit and/or threaded
fasteners.
5. The planter according to any one of claims 1 to 4, wherein the inner container
is integrally formed with or joined to a bottom area of the outer container, the inner
25 container comprising a top area and a side area defining the inner space, the top area
of the inner container opposite to the bottom area of the outer container.
6. The planter according to claim 5, wherein the side area of the inner container
is tapered outwardly from the top area.
30
7. The planter according to claim 5, wherein the side area of the inner container
is perpendicular to the bottom area of the outer container.

8. The planter according to any one of claims 5 to 7, wherein the top area and/or side area of the inner container comprises the holes to expose the roots of the plants to the inner space.
- 5 9. The planter according to any one of claims 1 to 8, wherein all surfaces of the inner container comprise the holes to expose the roots of the plants to the inner space.
10. The planter according to any one of claims 1 to 9, wherein a bottom area of the outer container comprises raised features and/or holes to facilitate airflow into the
10 inner space.
11. The planter according to claim 10, wherein the inner container comprises a closed bottom area facing the bottom area of the outer container, the closed bottom area of the inner container comprising holes optionally fluidically communicative with
15 the holes in the bottom area of the outer container.
12. The planter according to any one of claims 1 to 4, wherein the inner container is integrally formed with or joined to a side area of the outer container, the inner container comprising a top area and a side area defining the inner space, the top area
20 of the inner container opposite to the side area of the outer container.
13. The planter according to any one of claims 1 to 12, wherein the inner container is integrally formed with the outer container and the outer container comprises an opening for accessing the inner space, wherein the opening is optionally closed by a
25 cover.
14. A method for growing plants with air pruning, the method comprising:
providing a planter comprising an outer container and an inner container,
the inner container disposed in the outer container to reduce a volume of the
30 outer container for containing the planting material, the inner container comprising an inner space;
filling the outer container with a planting material, the inner space absent of the planting material;

growing the plants in the planting material until roots of the plants reach the inner container; and

exposing the roots of the plants grown in the planting material to air in the inner space via holes in the inner container, thereby air pruning the exposed roots.

5

15. The method according to claim 14, wherein the inner container is integrally formed with the outer container.

10 16. The method according to claim 14, wherein the inner container is removable from the outer container.

17. The method according to claim 16, wherein the inner container is removably joined to the outer container by a string, ribbon, cable tie, snap-fit and/or threaded fasteners.

15

18. The method according to any one of claims 14 to 17, wherein the inner container is integrally formed with or joined to a bottom area of the outer container, the inner container comprising a top area and a side area defining the inner space, the top area of the inner container opposite to the bottom area of the outer container.

20

19. The method according to claim 18, wherein the side area of the inner container is tapered outwardly from the top area.

25 20. The method according to claim 18, wherein the side area of the inner container is perpendicular to the bottom area of the outer container.

25

21. The method according to any one of claims 18 to 20, wherein the top area and/or side area of the inner container comprises the holes to expose the roots of the plants to the inner space.

30

22. The method according to any one of claims 14 to 21, wherein all surfaces of the inner container comprise the holes to expose the roots of the plants to the inner space.

23. The method according to any one of claims 14 to 22, comprising facilitating airflow into the inner space via raised features and/or holes in a bottom area of the outer container.

5

24. The method according to claim 23, wherein the inner container comprises a closed bottom area facing the bottom area of the outer container, the closed bottom area of the inner container comprising holes, optionally fluidically communicative with the holes in the bottom area of the outer container.

10

25. The method according to any one of claims 14 to 17, wherein the inner container is integrally formed with or joined to a side area of the outer container, the inner container comprising a top area and a side area defining the inner space, the top area of the inner container opposite to the side area of the outer container.

15

26. The method according to any one of claims 14 to 25, wherein the inner container is integrally formed with the outer container and the outer container comprises an opening for accessing the inner space, wherein the opening is optionally closed by a cover.

20

27. A kit for making a planter for growing plants with air pruning, the kit comprising:
an outer container for containing a planting material to grow the plants;
and
an inner container for assembling into the outer container, the inner
25 container comprising an inner space,
wherein when the inner container is assembled into the outer container,
the inner container reduces a volume of the outer container for containing the
planting material; and
wherein the inner container comprises holes to expose roots of the
30 plants grown in the planting material to air in the inner space and thereby air
prune the exposed roots.

28. The kit according to claim 27, wherein the inner container is removably joinable to the outer container by a string, ribbon, cable tie, snap-fit and/or threaded fasteners.

29. The kit according to claim 27 or 28, wherein the inner container is removably
5 joinable to a bottom area of the outer container, the inner container comprising a top area and a side area defining the inner space, the top area of the inner container opposite to the bottom area of the outer container.

30. The kit according to claim 29, wherein the side area of the inner container is
10 tapered outwardly from the top area.

31. The kit according to claim 29, wherein when the inner container is assembled into the outer container, the top area of the inner container is opposite to the bottom area of the outer container and the side area of the inner container is perpendicular to
15 the bottom area of the outer container.

32. The kit according to any one of claims 29 to 31, wherein the top area and/or side area of the inner container comprises the holes to expose the roots of the plants to the inner space.
20

33. The kit according to any one of claims 27 to 32, wherein all surfaces of the inner container comprise the holes to expose the roots of the plants to the inner space.

34. The kit according to any one of claims 27 to 33, wherein a bottom area of the
25 outer container comprises raised features and/or holes to facilitate airflow into the inner space.

35. The kit according to claim 34, wherein the inner container comprises a closed bottom area comprising holes for optional fluid communication with the holes in the
30 bottom area of the outer container.

36. Use of one or more of the planter according to any one of claims 1 to 13, the method according to any one of claims 14 to 26, and the kit according to any one of

claims 27 to 35 for growing plants in an indoor farm system, the indoor farm system optionally being soil-based.

37. A computer program comprising computer executable instructions that, when
5 executed by a processor, cause the processor to control an additive manufacturing apparatus to manufacture a product comprising one or more of the planter according to any one of claims 1 to 13, and the kit according to any one of claims 27 to 35.

38. A method of manufacturing a product via additive manufacturing, the method
10 comprising:

obtaining an electronic file representing a geometry of the product wherein the product comprises one or more of the planter according to any one of claims 1 to 13, and the kit according to any one of claims 27 to 35; and

15 controlling an additive manufacturing apparatus to manufacture, over one or more additive manufacturing steps, the product according to the geometry specified in the electronic file.