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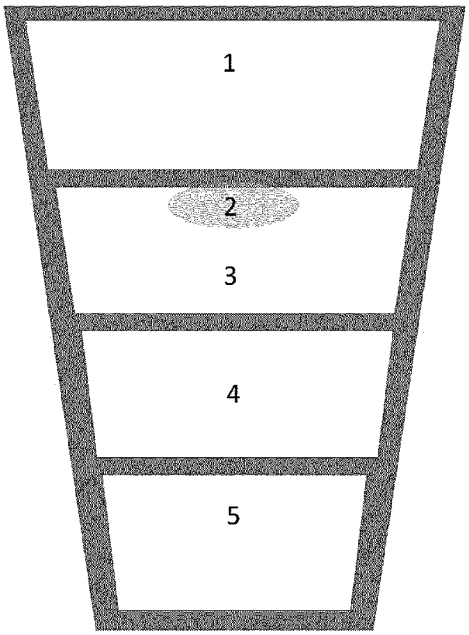
Figure 1.



(57) Abstract: The present invention relates to a method for production of a biodegradable growth plug for soilless plant cultivation. The present invention further relates a biodegradable growth plug for soilless cultivation and the use of the biodegradable growth plug. The biodegradable growth plug comprises vegetative fibers to provide an alternative soil which is eco-friendly and efficient for in- door agriculture and suitable for a variety of crops. The biodegradable growth plug also improves and simplifies the overall sustainability of the cultivation process.

WO 2024/213636 A1

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A BIODEGRADABLE GROWTH PLUG FOR SOILLESS CULTIVATION

Description

The present invention relates to a method for production of a biodegradable growth plug for soilless plant cultivation. The present invention further relates to a biodegradable growth plug for soilless plant cultivation and use thereof.

Due to increases in population, the world has an increase in food demand. To keep up and provide enough supply, excessive water, soil and pesticides are mandatory in cultivation and production of crops in the current food production system. Agriculture has become considerably more efficient, improving production systems, enhancing crop efficiency and disease resistance that has resulted in significant increases in food production. However, the overactive production developed in the last decade imposes a lot of pressure on the environment as agriculture has become highly resource intensive, even fully depleting resources locally with increasing damage to flora and fauna worldwide, decline in soil quality, water scarcity and water pollution due to chemicals present in pesticides, barren ground, salinity, and loss of biodiversity. To protect the environment a reduction of our carbon footprint is obligatory.

As a response and to protect the environment, a greener and healthier type of agriculture, more specifically horticulture, is an increasingly upcoming field and in continuous development. Horticulture incorporates a controlled-environment agriculture, which isolates growing plants from threatening factors such as pests, disease and drought. Inside this controlled environment the crops may be stacked vertically, thereby rendering locations that have a limited space suitable for highly productive cultivation. An environmentally friendly way to keep pace with the population growth.

A type of horticulture is hydroponics that involves growing crops without soil by organic substrates and the use of water-based mineral nutrient solution. The alternatives to soil have shown to be fit for large-scale agriculture and are under rapid development. Organic substrates that are light-transportable and CO2 neutral are a clean alternative to the often polluted and exhausted soil.

In horticulture, cultivation of plants and especially young plants is performed on a confined substrate shaped in mats, blocks or plugs. The confined substrate is ideal for stacking in vertical farming in a variety of layered shapes, without contaminated soil falling from the top floors. Normally, expertise is needed to select the right seeds suitable for horticulture and to sow said seeds to recommended depth. Sowing seeds in the growth substrate is done by seed drum or by hand and is very labour intensive. Furthermore, sown seeds on bio-mats or -plugs easily detach and many fall off the growth substrate and get lost in the process. At present, the materials used for the production of growth plugs or bio-mats comprise long curly fibers of at least 10 cm to 50 cm interlaced and mixed with numerous ingredients such as coconut fiber, latex, biochar, ground bark, peat moss, worm castings etc., to produce long stretches of organic boards and mattresses. The

pressed material is held in formed shapes, which have to be trimmed individually if smaller sizes are desired.

The alternative to soil is most preferably reused. Otherwise the alternative soil should be degradable and recyclable. Degradable organic material is broken down by microorganisms within 6 to 12 weeks. In greenhouse conditions such as high humidity and effected by microorganisms such as mold and yeast, are alternative soils susceptible for too early degradation, turning the alternative soil into rotting compost. Therefore, inorganic substrates such as mineral wool are often being used for soilless plant cultivation, that offer high water retention and resistance to decay and rotting. Unfortunately, mineral wool is an inorganic composite which is hard to recycle and knows an extremely energy-intensive production. An alternative soil is sought which is biological and has the right degradability, preferably to be used in horticulture.

Apart from a biodegradable material the alternative soil should provide a balanced water household against waterlogging and dehydration. Waterlogging refers to roots unable to respire. The resulting accumulated gasses are detrimental to root growth and induce rot. Dehydration on the other hand, causes stress and disable the root to absorb nutrients. A material should therefore have the right moisture and air mixture. However, not only the material but also its volume affects the evaporation and consequently the overall water management of the alternative soil. Moreover, a material which regulates a water balance suited for optimal plant growth is preferably a material efficient in water usage and irrigation.

Considering the above, there is a need in the art for a method that produces a biodegradable growth plugs for soilless plant cultivation, wherein the method does not comprise further processing steps, such as transplanting seedlings, before use of the plant plug. Moreover, the method does not comprise addition of numerous materials per processing step. In addition, there is a need in the art for a biodegradable growth plug suitable for plant soilless cultivation of plants which manages optimal water usage and requires little space by filling otherwise useless gaps. Respectively reducing wasted water and wasted space in green-houses. There is a need for a biodegradable growth plug suitable for soilless plant cultivation that provides an environment for plant growth in hydroponic or other soil-free systems, which is made from sustainable materials which can be broken down over time without leaving any harmful residue. Additionally, a biodegradable growth plug can also improve and simplify the overall sustainability of the cultivation process.

It is an object of the present invention, amongst other objects, to address the above need in the art. The object of present invention, amongst other objects, is met by the present invention as outlined in the appended claims.

Specifically, the above object, amongst other objects, is met, according to a first aspect, by a method for production of a biodegradable growth plug for soilless plant cultivation, wherein the method comprises the steps of

a) providing vegetative fibers having a size of at most 3 cm, preferably at most 2 cm, more preferably at most 1.5 cm, most preferably at most 1 cm,

b) preparing at least two distinct fiber mixtures, at least one fiber mixture A and at least one fiber mixture B, of which fiber mixture A consists of said vegetative fibers, and fiber mixture B comprises said vegetative fibers mixed with Poly Lactic Acid (PLA) and/or a bio-stimulant,

c) providing the at least one fiber mixture A into one or more moulds for production of the biodegradable growth plug, providing a first fiber layer of the biodegradable growth plug,

d) providing the at least one fiber mixture B on top of said first fiber layer in said one or more moulds, providing a second or further fiber layer of the biodegradable growth plug, optionally followed by providing the mixture A on top of said second or further fiber layer, providing a top fiber layer of the biodegradable growth plug,

e) tamping the fiber layers into said one or more moulds, thereby providing the biodegradable growth plug, wherein the total weight of said vegetative fibers per biodegradable growth plug is at most 2 gram, preferably at most 1.6 gram, most preferably at most 1.3 gram.

The fiber mixture A, comprised in the growth plug of present invention, is characterized in its ability to retain 20 to 50 % water, preferably 30 to 40 % moisture, more specifically water. The percentage moisture is measured 1 hour after watering. After watering, mixture A is a relatively dry layer compared to Mixture B and is used for the first fiber layer and preferably also the top fiber layer or the outer layers of the biodegradable growth plug. The first fiber layer or the bottom layer, is on purpose drier to stimulate downward growth of the roots of the plant/seed. The bottom layer also acts to prevent leaching of nutrients from the growth plug. The top layer is too comprised of mixture A and relatively dry in contrast to the middle layers (second and further layers) which are comprised of fiber mixture B, this to prevent attracting insects such as fly and/or worm-like organisms that live in moist soil. A dry top layer reduces the likelihood of parasitises, which puncture roots and inject toxins into plant cells, within the biodegradable growth plug.

The layer(s) that comprise mixture B are characterized in a water retainment capability of 40 to 90 % water, preferably 50 to 80 % water. Because mixture B comprises PLA, which increases osmotic pressure, the resulting moisture content after watering is higher than mixture A,

providing the roots of the plants with sufficient water. The percentage water retainment is measured 1 hour after watering.

After the step of preparing the specific fiber mixtures (i.e. mixture A and B), these mixtures may be collected into a container, comprising the initial batch of fiber mixture preferably weighting 100 to 300 gram, more preferably 120 to 200 gram. The method optionally comprises the step of dividing the fiber mixture into one or more collecting chambers. Each collecting chamber comprise at most 2 gram, preferably at most 1.6 gram, most preferably at most 1.3 gram of the fiber mixture. Thereafter, the collected fiber mixture is transferred from the collecting chamber to a mould. To ensure a clean transfer to the mould, an arm strikes off the remnant fibers. By exceeding a fiber length of 3 cm the succession of efficient striking off remnant fibers is decreased. Moreover, longer fibers strongly affect proper filling of the mould (as is demonstrated in Figure 3, wherein long (>3cm fibers) were used). Thus, each individual mould comprises the fiber mixtures for one individual biodegradable growth plug of at most 2 gram, preferably at most 1.6 gram, most preferably at most 1.3 gram.

Processing the vegetative fibers into shorter lengths resulted in short and straight fibers, wherein the length of the vegetative fibers is convenient for production of smaller shaped soil substrates, such as the biodegradable growth plug of present invention. The growth plug of present invention comprises straight fibers that allow for a high fiber density within the plug and do not fall apart upon water absorption. Moreover, a low fiber density, which is a result of long fibers stimulate the growth of thick roots, while short fibers pressed into a dense plug stimulate the formation of a network of small thin roots. Tamping can be performed by many means including the use of a tamping machine, wherein the fiber mixture is tamped and pressed in said mould and shaped into the biodegradable growth plug.

According to a preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the at least one fiber mixture B is comprised of two distinct fiber mixtures B1 and fiber mixture B2, wherein the fiber mixture B1 comprises said vegetative fibers mixed with PLA, and the fiber mixture B2 comprises said vegetative fibers mixed with the bio-stimulant. B2 is characterized in that the fiber mixture retains 40 to 60 % water, preferably 40 to 50 % water. The percentage water retainment is measured 1 hour after watering. The moisture content of B2 is lower than of B1. The bio-stimulant is very effective for successful germination and is blue in colour.

According to a preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein in step d, fiber mixture B1 is provided directly on top on said first fiber layer providing the second fiber layer, followed by mixture B2 on top of said second fiber layer, providing said further fiber layer.

Thereby creating a layered biodegradable growth plug. Each layer endows the plant the right conditions to grow.

There is a need for a method that produces a biodegradable and water regulating growth plugs which are small in size. However, small volumes are susceptible to environmental conditions, meaning that they are likely to dry out due to a high evaporation rate and be over-watered quickly, due to a high saturation rate. The roots experience drought or waterlogging, respectively, which negatively affects the germination and growth of a plant. The biodegradable growth plug of present invention proposes a solution by the multiple layers that vary in water retainment capability and density. Each layer of the multi-layered biodegradable grow plug manages a different water household leading to an overall ideal condition for (roots of) plants.

According to yet another preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the fiber mixture B or B1 comprising PLA has a ratio of vegetative fibers to PLA of between 5:1 to 3:1, preferably between 4:1 to 2:1, more preferably between 3:1 to 1:1. At any given air humidity level, the moisture is kept within the biodegradable growth plug due to the PLA. Per climate ruling within a green-house, the ratio vegetative fibers to PLA can be optimized within the claimed ranges.

According to another preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the fiber mixture B or B2 comprises between 1 to 6 mg, preferably 2 to 5 mg, more preferably 3 to 4 mg of the bio-stimulant.

According to a preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the bio-stimulant is a plant growth bio-stimulant composition extracted from algae, preferably compound BYAS-A601.

According to another preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the vegetative fibers are substantially straight fibers. The straight fibers are easily tamped into a mould. The vegetative fibers are firmly pressed yet allowing enough air in for optimal root growth.

According to a preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the PLA are PLA flakes of at most 50 mm2 in size, preferably at most 40 mm2 in size, most preferably at most 30 mm2 in size. Preferably, PLA is mixed as flakes with the fiber mixture. An optimum size of the flakes was sought to have a firmly pressed and airy biodegradable growth plug.

According to a preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the method

further comprises the step of attaching at most 25 seeds, preferably at most 15 seeds, preferably at most 10 seeds, more preferably at most 5 seeds to the biodegradable growth plug. The maximum number of the seeds depends on the seed length of the seed, wherein the seed length of a large seed is at least 5 mm, the seed length of a medium seed is between 1 to 5 mm and the seed length of a small seed is at most 0,5 mm. The seed length is defined as the maximum seed length of a seed under measurement, usually the longest axis of the seed. As a standard the size range is chosen of mature and normal seeds of a species. As such, only 1 large seed is adhered for species such as pumpkin and melons. Medium sized seeds, e.g., corn, onions, peas, cucumbers, radish, spinach, sweet corn and onions, are adhered per 2 to 3. Small sized seeds are adhered per 5 to 20. Species with small sized seeds are among others lettuce, basil, spirulina, cabbage, pepper, celery, radish, mint, thyme and carrot.

According to yet another preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the step of attaching the seed to the biodegradable growth plug is achieved by adhering to or injecting said seed directly below the surface of the biodegradable growth plug, preferably between 5 to 20 mm, more preferably 8 mm to 18 mm, most preferably 10 to 15 mm below the surface of the biodegradable growth plug. The seed is adhered or injected directly below the top layer, as is depicted in Figure 1. Preferably the seed is in-between layer B2 and the top layer. Normally expertise is needed to select the right seeds and to sow said seeds to recommended germination depth. The seed depth of present invention is dependent on the type of seed, and not a fixed depth. The pre-attached seed to the biodegradable growth plug saves the breeder time since sowing by hand into plugs is labour intensive. Furthermore, pre-attached seeds do not fall off the growth substrate and are thus ideal for vertical farming purposes.

According to a preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the method comprises the step of attaching the seed to the biodegradable growth plug by gluing or by a seed dispenser. The seeds that have been glued just below the surface of the biodegradable growth plug are left to dry for at most 30 seconds at a temperature of at most 40 °C, to ensure optimal adhesion of the seeds to the biodegradable growth plug. The seed dispenser is a rotating pressurized drum with openings for seeds to shoot towards the biodegradable growth plugs placed inside the drum. Adhesion follows the induction of high air pressure moving the seeds towards the inside of the drum at high speed, injecting the one or more seed(s) in the biodegradable growth plug.

According to another preferred embodiment, the present invention relates to the method for production of a biodegradable growth plug for soilless plant cultivation, wherein the vegetative fibers is one or more selected from the group consisting of jute fiber, elephant grass, flax fiber,

bamboo fiber, hemp fiber, coconut fiber, palm fiber and wood fiber, preferably jute fiber, elephant grass and flax fiber.

The present invention, according to a further aspect, relates to a biodegradable growth plug for soilless cultivation produced by the method described above, wherein said biodegradable growth plug is comprised of vegetative fibers having a size of at most 3 cm, preferably at most 2 cm, more preferably at most 1.5 cm, most preferably at most 1 cm, and wherein the biodegradable growth plug is comprised of a at least two distinct layers of fiber mixtures, at least one fiber mixture A providing a first fiber layer and optionally a top fiber layer, and at least one fiber mixture B providing a second and/or further fiber layer, of which fiber mixture A consist of said vegetative fibers, and fiber mixture B comprises said vegetative fibers mixed with PLA and/or a bio-stimulant, and wherein the biodegradable growth plug comprises at least one seed, wherein the biodegradable growth plug has a weight of at most 2 gram, preferably at most 1.6 gram, most preferably at most 1.3 gram. The biodegradable growth plug is environmentally friendly and biodegradable (100% compostable). Currently, the length of the curly strands of raw fibers limits the size of the plugs. Moreover, tamping fibers of a length of more than 3 cm result in a growth plug with empty gaps and makes the production process cumbersome. The vegetative fibers of present invention are short and preferably substantially straight which facilitate production of small plugs because the straight fiber is easily tamped in a mould to achieve high-fiber-density plugs without gaps. The biodegradable growth plug is small in size which makes optimal space use easy and increases the value of every square cm2 in the horticulture.

The biodegradable growth plug of present invention comprises multiple distinct layers of fiber material to cope with specific green-house environmental factors, such as the air-moisture content and air circulation. Each layer or phase of the multi-layered biodegradable grow plug manages a different water household, leading to an overall ideal condition for (roots of) plants. The overall surface tension of the biodegradable growth plug employs the high air-moisture, and in total a less frequent irrigation requirement compared to other plugs, as shown in Example 2. Accordingly, the biodegradable growth plug of present invention needs to be watered at most every day, preferably at most every two days, more preferably at most every 3 days most preferably at most every 7 days. In comparison: current irrigation in green house systems have a watering-frequency up to 12 times a day. The biodegradable growth plug of present invention not only save incredible amounts of water, but it also spares nutrients that would otherwise be washed away.

According to a preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the at least one fiber mixture B is comprised of two distinct fiber mixtures B1 and fiber mixture B2, wherein the fiber mixture B1 comprises said vegetative fibers mixed with PLA, and the fiber mixture B2 comprises said vegetative fibers mixed with the bio-stimulant. B2 is relatively drier compared to B1 and situated on top of B1.

According to another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the biodegradable growth plug is comprised of the first fiber layer comprised of fiber mixture A, followed by fiber mixture B1 provided directly on top of said first fiber, providing the second fiber layer, followed by mixture B2 on top of said second fiber layer, providing said further fiber layer, optionally followed by the top fiber layer comprised of the mixture A provided on top of the further fiber layer.

According to a preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the fiber mixture B or B1 comprising PLA has a ratio of vegetative fibers to PLA of between 5:1 to 3:1, preferably between 4:1 to 2:1, more preferably between 3:1 to 1:1.

According to yet another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the fiber mixture B or B2 comprises 1 to 6 mg, preferably 2 to 5 mg, more preferably 3 to 4 mg of the bio-stimulant. The biodegradable growth plug of present invention is comprised of a bio stimulatory compound. The bio stimulatory compound is a plant growth bio-stimulant composition extracted from algae, preferably compound BYAS-A601. BYAS-A601 from Back of the Yards algae sciences Inc. is a potent microalgae-based bio stimulant that acts on cellular level which accelerates plant growth, improves plant biomass yield. BYAS has been tested in comparative trials on lettuce, basil, pepper and tomato. It is a proven natural accelerator of plant growth and phytochemical production and is very suitable for vertical farming purposes, both indoor and outdoor.

According to a preferred embodiment, the present invention relates to the biodegradable growth plug, wherein

- the first layer comprises a fiber density between 2400 g/m2 to 3800 g/m2, preferably between 2600 g/m2 to 3600 g/m2, most preferably between 2800 g/m2 to 3400 g/m2 and
- the second or further fiber layer has a fiber density between 1800 g/m2 to 3200 g/m2, preferably between 2000 g/m2 to 3000 g/m2, most preferably between 2200 g/m2 to 2800 g/m2.

The fiber density in the biodegradable growth plug acts as counter-pressure which is defined as a positive pressure stimulating development of stronger roots in plants, thereby maximizing the total root surface in each biodegradable growth plug, therefore, the first layer or bottom layer has a higher density than the other layers of the biodegradable growth plug of present invention.

According to a preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the at least one seed is located directly below the surface of the biodegradable growth plug, preferably between 5 to 20 mm, more preferably 8 mm to 18 mm, most preferably 10 to 15 mm below the surface of the biodegradable growth plug. The seed is adhered or

injected preferably directly below the top layer of the plug, as is depicted in Figure 1. Preferably the seed is in-between layer comprised of fiber mixture B2 and the top layer.

According to another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the at least one seed is in the second or further fiber layer of the biodegradable growth plug. The seed may be adhered or injected directly below the top layer, as is depicted in Figure 1. Preferably the seed is in-between layer B2 and the top layer. The pre-attached seed to the biodegradable growth plug saves the breeder time since sowing by hand into plugs is in general more labour intensive. Furthermore, pre-attached seeds do not fall off the growth substrate and are thus ideal for vertical farming purposes and saving costs of labour.

According to a preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the vegetative fibers is one or more selected from the group consisting of jute fiber, elephant grass, coconut fiber, hemp fiber, bamboo fiber, palm fiber and wood fiber, preferably jute fiber, elephant grass and/or hemp fiber An optional embodiment of the biodegradable growth plug of the present invention has a top layer comprised of elephant grass and the remainder of layers comprised of vegetative fibers

According to another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the vegetative fibers are jute fiber derived from *Corchorus capsularis* and/or *Corchorus olitorius.* The biodegradable growth plug of the present invention consists of fiber derived from cultivated jute, wherein cultivated jute is *Corchorus capsularis* and/or *Corchorus olitorius*. Jute fibers are 100% compostable once the growth substrate has been used. It can end up in the green waste without any problems and can be given a second life as a fertilizer product by composting it, providing a ready-to-use ecosystem to complement and enhance soil biology. Jute fibers are composed of the plant materials cellulose and lignin. The high hydroxyl content of cellulose bestows hydrophilicity upon the jute fiber, responsible for the high absorbability and retainment of water, to maintain the right moisture for optimal plant growth. Hydrophobic lignin offers protection to the cellulosic fraction of the fiber and is the most resistant constituent of jute. The characteristics of the cultivated jute make it a well-suited soil alternative.

According to yet another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein said one or more seeds is at most 25 seeds, more preferably at most 20 seeds, more preferably at most 10 seeds, most preferably at most 5 seeds. Seeds differ in size per species. The seeds sizes can be categorized as large, medium or small. The number of seeds pre-attached to the biodegradable growth plug may depend on the category of the seed size. Biodegradable grow plugs allow for versatile working methods in hydroponics, combining various crops in different compositions and locations. Comprising pre-attached seed(s), the present invention subjugates sowing by hand or expensive machinery (80% downtime machine), thereby reducing costs.

According to another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the biodegradable growth plug has a shape is selected from the group cylindrical, cuboidal, pentagonal and hexagonal, preferably cylindrical shaped. A cylindrical shaped plug guides itself into the destined surface taking only a limited push to engage the plug. This shape enables also tamping a maximal number of vegetative fibers to fit the mould.

According to a preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the PLA are PLA flakes of at most 50 mm2 in size, preferably at most 40 mm2 in size, most preferably at most 30 mm2 in size. The right size of the PLA flakes allows for a balanced water to air content within the biodegradable growth plug.

According to yet another preferred embodiment, the present invention relates to the biodegradable growth plug, wherein the one or more seeds are from at least one species selected from the group consisting of lettuce, cilantro, sweet corn, onions, spirulina, cauliflower, cabbage, pepper, spirulina, celery, melons, peas, cucumbers, carrots, radish, spinach, thyme, mint, and basil, preferably lettuce, cilantro, sweet corn onions and/or spirulina. Especially herbs are well suited for the horticulture industry and used in the biodegradable plug of present invention.

The present invention, according to a further aspect, relates to the use of a biodegradable growth plug according the second aspect of the invention in vertical indoor farming, soilless plant cultivation, vertical hydroponic and aquaponic or controlled environment agriculture.

The present invention will be further detailed in the following examples and figures wherein:

Figure 1:

Shows a biodegradable growth plug according to present invention comprised of different layers conferring variation in moisture content within the biodegradable growth plug. Number 1 indicates the top layer and is comprised of mixture A which is, after watering of the plug during plant/seed cultivation, a relative dry layer that prevents attraction of unwanted organisms. After watering, the top layer has a moisture content between 20 – 50 % and the vegetable fibers comprised of jute fiber, may be optionally and in addition be comprised of elephant grass. Number 2 illustrates the pre-attached seed within the further and/or optional layer indicated by number 3, following the top layer. The seed is attached just below the surface of the biodegradable growth plug. Pre-attachment of the seed omits the need to transplant seedlings. Layer number 3 has a moisture content between 40 – 60%, comprising of mixture B2. Number 4 represents the middle layer comprising mixture B1 with PLA, which comprises the highest moisture content after watering, around 60 – 80% thereby providing the plant/seed with sufficient water. The bottom layer is expressed by number 5 and is, similar to the top layer, a relative dry layer (comprising fiber mixture A)

with a moisture content of 20 – 50 %, which stimulates root growth and prevents leaching of nutrients from the growth plug.

Figure 2:

Shows a side view of a biodegradable growth plug of present invention, pulled lengthwise to demonstrate the distinct layers of the growth plug. Number 1 depicts the sprout, number 2 and 5 are the outer dry layers (with mixture A). Number 3 depicts the optional layer preferably mixture B2, below and adjacent to the top layer and comprises the bio-stimulant preferably BYAS-A601, colouring the layer blue. The middle layer is depicted by number 4 and comprises mixture B1 with the white PLA flakes. The various densities between the different layers within the growth plug is clearly visible.

Figure 3:

To illustrate, production of four plugs with long (>3cm) fibers. The four moulds are tamped with long curly fibers that stick out and obstruct correct filling of the moulds. Consequences are plugs with low fiber densities caused by gaps and a weight lower than 1.5 to 2 gram per plug.

Examples

Example 1: *Production of short jute fiber and producing a biodegradable plant plug*

The method for providing a biodegradable growth plug according to the present invention starts with collecting and preparing one or more fiber mixtures comprised of short jute fibers in a small container. Briefly, 1300 mg fibers that are about 2.5 cm in length are divided into three separate mixtures (A, B1 and B2). The first mixture (A) comprises 650 mg jute fiber, mixture (B1) comprises 325 mg fibers and 320 mg 40 mm2 PLA flakes (645 mg total) and the third mixture (B2) comprises 325 gram fibers and approximately 3 mg of (biostimulant) BYAS-A601.

First 325 gram of mixture A is collected in a funnel-shaped reservoir positioned and located on top of a biodegradable growth plug production machine. The fiber mixture is then divided over a tray comprised of multiple collecting chambers (160 total) to enable the production of multiple biodegradable growth plugs. The short fibers enable efficient division and spread over the collecting chambers. Moreover, fibers of more than 3 cm in length have shown to obstruct the small entrance of the plug or stick to the neighbouring plug and consequently disturbing the filling of the chambers with the fiber mixture. Furthermore, at a later stage, when the plant is germinated, difficulties have been encountered in pulling the plug as a whole, including roots, from the substrate to which the plug is initially attached. It is therefore important that the production of the

biodegradable growth plug of present invention, the fiber mixture must not contain fibers of more than 3 cm in length.

Next, the fiber mixtures per chamber are deposited in corresponding cylindric moulds of 2,2*2,2*3,5 cm positioned on a tray. Fiber mixture A1 is tamped within these moulds. Next, 645 mg of fiber mixture B1 is likewise collected and deposited, followed by 325 mg of B2 and lastly 325 mg of A.

Each growth plug weighing about 1,6 gram in total on average. The tamping machine, tamps and compresses the fiber mixture, shaping the cylindrical plugs. The short, straight fibers have a high density: 3307 g/m^2 for A2 (bottom) 2687 g/m2 for A1, B1 and B2.

The cylindrical moulded biodegradable growth plug is then provided with one or more plant seeds. These plant seeds are preferably attached directly under the surface of the biodegradable growth plug by injecting the seed with a seed drum dispenser device with vacuum air pressure.

Example 2: *Water sustainability of biodegradable growth plug*

Next, the bioplug being produced in example 1, is tested for their water retention capabilities. One of the main advantages of the biodegradable growth plug of the present invention is its prolonged water retention time and consequently improved moisture management, thereby contributing to water conservation. The improved water retention is measured over time and compared with two commercially available soil alternatives (which are trimmed in their dimensions to match with of the biodegradable growth plug of present invention).

Type A is composed of peat, coconut, and perlite.

Type B is composed of peat, waste pulp, vermiculite, and plasticizer (binding agent).

This embodiment of the biodegradable growth plug is composed of a top layer comprising 0.20 gram elephant grass, a middle layer comprising 0.60 gram of jute fiber and 0.30 gram PLA flakes of 50 mm2, the bottom layer of the plug comprises 0.30 gram jute fibers. The jute fibers are 2.5 cm in length.

The percentage moisture in the growth substrate (soil A, B, or plug) is measured and determined by weighing, after 1 hour our, after 24 hours and after 7 days. The environmental factors under which this experiment is performed are an average temperature of 25 degrees Celsius and relative humidity of about 70%.

Table 1. Percentage moisture content in growth substrate

	After 1h	After 24h	After 7d
Type A	60-70%	25-35%	5-10%
Type B	70-80%	35-45%	0-5%
The biodegradable growth plug	50-60%	40-50%	30-40%

The results show that 1 hour after watering, the biodegradable growth plug has the lowest percentage moisture content in comparison to Type A and B growth substrates; a percentage least likely to result in waterlogged roots. In contrast, Type A and Type B soil absorb higher levels of water compared to the biodegradable growth plug of present invention, consequently a higher risk of waterlogging. After 24 hours, the moisture content of Type A and B dropped to about 35%. A decrease of around 10% is measured for the biodegradable growth plug of present invention, remaining as high as 40 to 50%.

After 7 days Type B contains very little moisture. The moisture content percentage of alternative soil Type A is slightly better to B, but still is very low. Therefore, when using growth substrates of type A or B, it takes more effort (multiple times watering) to maintain sufficient levels of moisture content in plugs consisting of Type A or B growth substrate. The biodegradable growth plug of present invention however maintains a moisture percentage well above 30%, which is sufficient for healthy plant growth.

Taken together, the water moisture percentage of biodegradable growth plug manages the water household optimal over an expanded period of time, in contrast to known plant plug growth substrates used. Hence, the layers of the biodegradable growth plug of present invention retains water without overwatering. The top layer discourages damping-off. The biodegradable growth plug spares water and also nutrients are not easily washed away by watering.

Claims

1. A method for production of a biodegradable growth plug for soilless plant cultivation, wherein the method comprises the steps of

a) providing vegetative fibers having a size of at most 3 cm, preferably at most 2 cm, more preferably at most 1.5 cm, most preferably at most 1 cm,

b) preparing at least two distinct fiber mixtures, at least one fiber mixture A and at least one fiber mixture B, of which fiber mixture A consist of said vegetative fibers, and fiber mixture B comprises said vegetative fibers mixed with Poly Lactic Acid (PLA) and/or a bio-stimulant,

c) providing the at least one fiber mixture A in one or more moulds for production of the biodegradable growth plug, providing a first fiber layer of the biodegradable growth plug,

d) providing the at least one fiber mixture B on top said first fiber layer in said one or more moulds, providing a second or further fiber layer of the biodegradable growth plug, optionally followed by providing the mixture A on top of said second or further fiber layer, providing a top fiber layer of the biodegradable growth plug,

e) tamping the fiber layers into said one or more moulds, thereby providing the biodegradable growth plug, wherein the total weight of said vegetative fibers per biodegradable growth plug is at most 2 gram, preferably at most 1.6 gram, most preferably at most 1.3 gram.

2. The method according to claim 1, wherein the at least one fiber mixture B is comprised of two distinct fiber mixtures B1 and fiber mixture B2, wherein the fiber mixture B1 comprises said vegetative fibers mixed with PLA, and the fiber mixture B2 comprises said vegetative fibers mixed with the bio-stimulant.

3. The method according to claim 2, wherein in step d, fiber mixture B1 is provided directly on top on said first fiber layer providing the second fiber layer, followed by mixture B2 on top of said second fiber layer, providing said further fiber layer.

4. The method according to any one of the claims 1 to 3, wherein the fiber mixture B or B1 comprising PLA has a ratio of vegetative fibers to PLA of between 5:1 to 3:1, preferably between 4:1 to 2:1, more preferably between 3:1 to 1:1.

5. The method according to any one of the claims 1 to 4, wherein the fiber mixture B or B2 comprises between 1 to 6 mg, preferably 2 to 5 mg, more preferably 3 to 4 mg of the bio-stimulant.

6. The method according to any one of the claims 1 to 5, wherein the bio-stimulant is a plant growth bio-stimulant composition extracted from algae, preferably compound BYAS-A601.

7. The method according to any one of the claims 1 to 6, wherein the vegetative fibers are substantially straight fibers.

8. The method according to any one of the claims 1 to 7, wherein the PLA are PLA flakes of at most 50 mm2 in size, preferably at most 40 mm2 in size, most preferably at most 30 mm2 in size.

9. The method according to any one of the claims 1 to 8, wherein the method further comprises the step of attaching at most 25 seeds, preferably at most 15 seeds, preferably at most 10 seeds, more preferably at most 5 seeds to the biodegradable growth plug.

10. The method according to any one of the claims 1 to 9, wherein the step of attaching the seed to the biodegradable growth plug is achieved by adhering to or injecting said seed directly below the surface of the biodegradable growth plug, preferably between 5 to 20 mm, more preferably 8 mm to 18 mm, most preferably 10 to 15 mm below the surface of the biodegradable growth plug.

11. The method according to any one of the claims 1 to 10, wherein the method comprises the step of attaching the seed to the biodegradable growth plug by gluing or by a seed dispenser.

12. The method according to any one of the claims 1 to 11, wherein the vegetative fibers is one or more selected from the group consisting of jute fiber, elephant grass, flax fiber, bamboo fiber, hemp fiber, coconut fiber, palm fiber and wood fiber, preferably jute fiber, elephant grass and flax fiber.

13. A biodegradable growth plug for soilless plant cultivation produced by a method according to any one of the claims 1 to 12, wherein said biodegradable growth plug is comprised of vegetative fibers having a size of at most 3 cm, preferably at most 2 cm, more preferably at most 1.5 cm, most preferably at most 1 cm, and

wherein the biodegradable growth plug is comprised of a at least two distinct layers of fiber mixtures, at least one fiber mixture A providing a first fiber layer and preferably a top fiber layer, and at least one fiber mixture B providing a second and/or further fiber layer, of which fiber mixture A consist of said vegetative fibers, and fiber mixture B comprises said vegetative fibers mixed with Poly Lactic Acid (PLA) and/or a bio-stimulant, and
wherein the biodegradable growth plug comprises at least one seed, wherein the biodegradable growth plug has a weight of at most 2 gram, preferably at most 1.6 gram, most preferably at most 1.3 gram.

14. The biodegradable growth plug according to claim 13, wherein the at least one fiber mixture B is comprised of two distinct fiber mixtures B1 and fiber mixture B2, wherein the fiber mixture B1 comprises said vegetative fibers mixed with PLA, and the fiber mixture B2 comprises said vegetative fibers mixed with the bio-stimulant.

15. The biodegradable growth plug according to claims 13 or 14, wherein the biodegradable growth plug is comprised of the first fiber layer comprised of fiber mixture A, followed by fiber mixture B1 provided directly on top of said first fiber, providing the second fiber layer, followed by mixture B2 on top of said second fiber layer, providing said further fiber layer, optionally followed by the top fiber layer comprised of the mixture A provided on top of the further fiber layer.

16. The biodegradable growth plug according to any one of the claims 13 to 15, wherein the fiber mixture B or B1 comprising PLA has a ratio of vegetative fibers to PLA of between 5:1 to 3:1, preferably between 4:1 to 2:1, more preferably between 3:1 to 1:1.

17. The biodegradable growth plug according to any one of the claims 13 to 16, wherein the fiber mixture B or B2 comprises between 1 to 6 mg, preferably 2 to 5 mg, more preferably 3 to 4 mg of the bio-stimulant.

18. The biodegradable growth plug according to any one of the claims 13 to 17, wherein the bio-stimulant is a plant growth bio-stimulant composition extracted from algae, preferably compound BYAS-A601.

19. The biodegradable growth plug according to any one of the claims 13 to 18, wherein

- the first layer comprises a fiber density between 2400 g/m2 to 3800 g/m2, preferably between 2600 g/m2 to 3600 g/m2, most preferably between 2800 g/m2 to 3400 g/m2

and

- the second or further fiber layer comprises a fiber density between 1800 g/m2 to 3200 g/m2, preferably between 2000 g/m2 to 3000 g/m2, most preferably between 2200 g/m2 to 2800 g/m2.

20. The biodegradable growth plug to any one of the claims 13 to 19, wherein the at least one seed is located directly below the surface of the biodegradable growth plug, preferably between 5 to 20 mm, more preferably 8 mm to 18 mm, most preferably 10 to 15 mm below the surface of the biodegradable growth plug.

21. The biodegradable growth plug according to any one of the claims 13 to 20, wherein the at least one seed is under the top layer of the biodegradable growth plug.

22. The biodegradable growth plug according to any one of the claims 13 to 21, wherein the vegetative fibers is one or more selected from the group consisting of jute fiber, elephant grass, coconut fiber, hemp fiber, bamboo fiber, palm fiber and wood fiber, preferably jute fiber, elephant grass and/or hemp fiber.

23. The biodegradable growth plug according to any one of the claims 13 to 22, wherein the vegetative fibers are jute fiber derived from *Corchorus capsularis* and/or *Corchorus olitorius*.

24. The biodegradable growth plug according to any one of the claims 13 to 23, wherein said one or more seeds is at most 25 seeds, more preferably at most 20 seeds, more preferably at most 10 seeds, most preferably at most 5 seeds.

25. The biodegradable growth plug according to any one of the claims 13 to 24, wherein the biodegradable growth plug shape is selected from the group cylindrical, cuboidal, pentagonal and hexagonal, preferably cylindrical shaped.

26. The biodegradable growth plug according to any one of the claims 13 to 25, wherein the PLA are PLA flakes of at most 50 mm2 in size, preferably at most 40 mm2 in size, most preferably at most 30 mm2 in size.

27. The biodegradable growth plug according to any one of the claims 13 to 26, wherein the one or more seeds are from at least one species selected from the group consisting of lettuce, cilantro, sweet corn, onions, spirulina, cauliflower, cabbage, pepper, spirulina, celery, melons,

peas, cucumbers, carrots, radish, spinach, thyme, mint, and basil, preferably lettuce, cilantro, sweet corn onions and/or spirulina.

28. Use of a biodegradable growth plug according to any one of the claims 13 to 27 in vertical indoor farming, soilless plant cultivation, vertical hydroponic and aquaponic or controlled environment agriculture.

Figure 1.

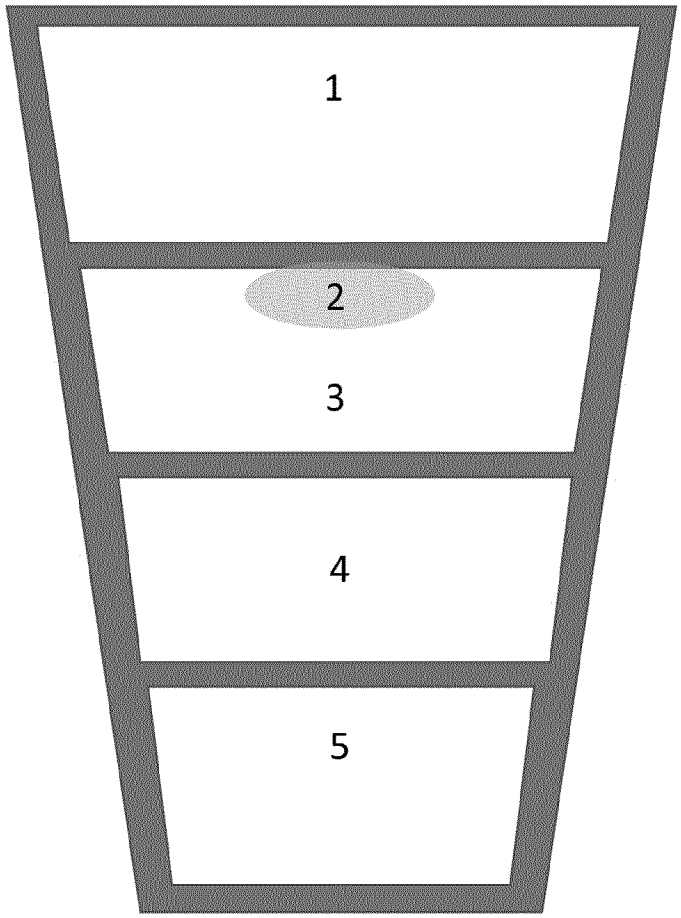


Figure 2.

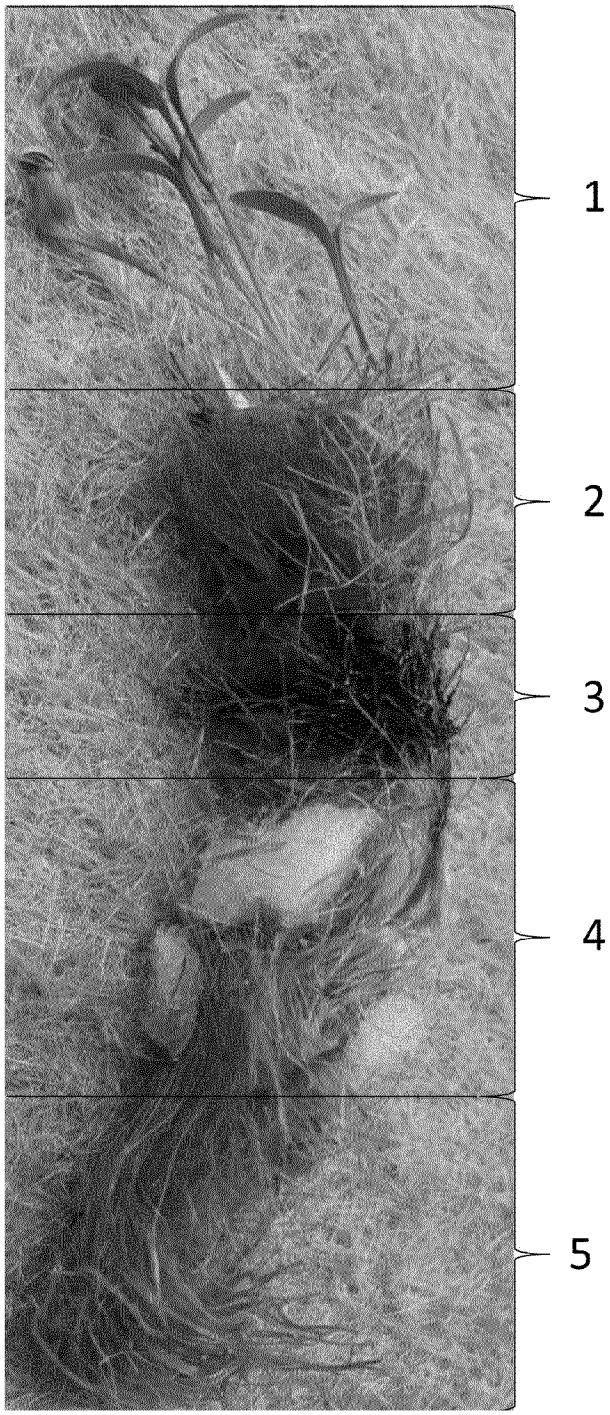
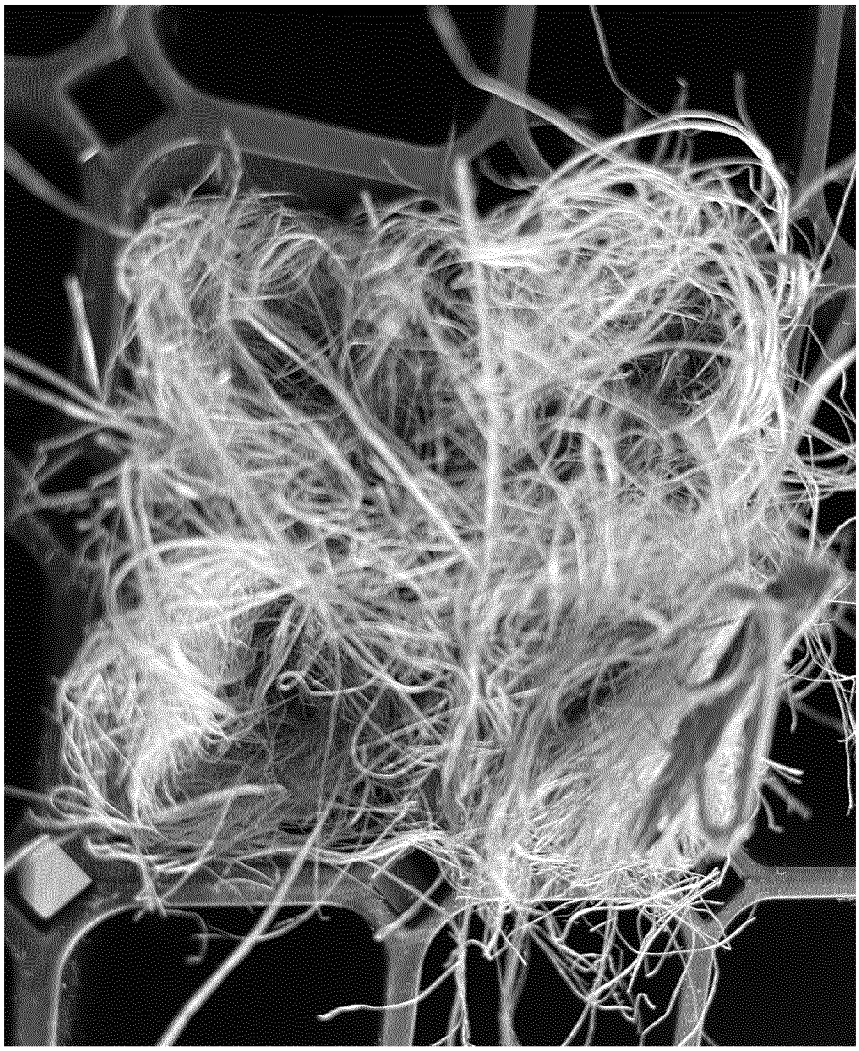


Figure 3.



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/059836

A. CLASSIFICATION OF SUBJECT MATTER

INV. A01G9/029 A01G24/44 A01G24/46 A01G24/25 A01G24/22
A01G24/23 A01G24/30

ADD.

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)

A01G A01C

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2018/037165 A1 (VAPO OY [FI]) 1 March 2018 (2018-03-01) paragraphs [0029] - [0030], [0039] - [0040], [0042] - [0043], [0051], [0060] - [0062]; claim 9	1-28
A	WO 2020/051681 A1 (BIOCOMPOSITES GROUP INC [CA]) 19 March 2020 (2020-03-19) abstract; claims 1-3, 7-16, 19	1,12,13, 22,28
A	US 2020/344960 A1 (VON RUNDSTEDT FRIEDERIKE [DE]) 5 November 2020 (2020-11-05) paragraphs [0026] - [0030]; claim 11	13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 June 2024	20/06/2024

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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2024/059836

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2018037165 A1	01-03-2018	CA 3034751 A1	01-03-2018
		EP 3503714 A1	03-07-2019
		FI 127883 B	30-04-2019
		US 2019208718 A1	11-07-2019
		WO 2018037165 A1	01-03-2018
WO 2020051681 A1	19-03-2020	CA 3107970 A1	19-03-2020
		US 2021144937 A1	20-05-2021
		WO 2020051681 A1	19-03-2020
US 2020344960 A1	05-11-2020	BR 112020013167 A2	01-12-2020
		CA 3087782 A1	18-07-2019
		CN 111629585 A	04-09-2020
		DE 102018100485 A1	11-07-2019
		EP 3737223 A1	18-11-2020
		PL 3737223 T3	19-04-2022
		US 2020344960 A1	05-11-2020
		WO 2019137981 A1	18-07-2019