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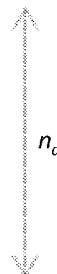
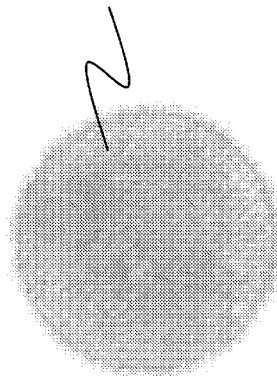


FIG. 1A

(57) Abstract: Systems and methods that use fiberglass as a soil-based additive to enhance seed germination and plant growth are disclosed. The fiberglass is used to deliver extended hydration through its ability to retain and slowly release water, deliver necessary plant chemistry that is carried on the glass fiber surface (e.g., pesticides, hormones), provide soil aeration, release nutrients (Na, Ca, Mg, B, Fe, K) into the soil, and perform pH buffering through the dissolution of the glass into the soil.

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FIBERGLASS DELIVERY SYSTEM TO AID SEED GERMINATION AND NUTRITION IN AGRICULTURAL CROP OR PLANT GROWTH

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to and any benefit of U.S. Provisional Application No. 63/049,076, filed July 7, 2020, the content of which is incorporated herein by reference in its entirety.

FIELD

[0002] The general inventive concepts relate to systems and methods that use fiberglass to promote seed germination and facilitate nutrient delivery for agricultural crop or plant growth.

BACKGROUND

[0003] Glass fibers have been widely used in building materials, biomaterials, and composite materials. A glass fiber has a manipulatable and controllable fiber diameter, aspect ratio (i.e., the ratio of the fiber's length to the fiber's diameter), and morphology, as well as chemistry and surface properties, depending on the process used to manufacture the glass fiber. These properties may allow glass fiber, including stone wool and slag wool, to be beneficial to agricultural applications. Glass fiber, when manufactured in a mat form, has been used to control the erosion of soil against heavy rain and slippage due to sandy soil, the success of which can be attributed to the high aspect ratio of the glass fiber. Also, glasses have been used as a controlled-release fertilizer in some applications. For example, fritted nutrients have been used to promote the growth of wasabi root in cold weather. Fritted nutrients are trace elements such as zinc, copper, manganese, boron, iron, potassium, or molybdenum that are contained within a finely ground glass powder. The glass ion exchanges with the proton in water and the hydroxide group breaks the Si-O-Si bond in the glass network, with these reactions releasing plant-beneficial nutrients and other trace elements. Other conventional materials (e.g., soil amendments) used to promote plant/crop growth include, for example, super absorbent polymers (SAPs), silicas, biochar, and mulch.

[0004] In view of the above, systems for and methods of using fiberglass to promote seed germination and facilitate nutrient delivery for agricultural crop or plant growth are disclosed. The inventive glass-based materials, including the systems and methods utilizing the

materials, achieve comparable or better results than conventional approaches and materials, and do so at a reduced cost, at a reduced dosage, and/or while avoiding one or more drawbacks associated with the conventional approaches and materials.

SUMMARY

[0005] The general inventive concepts relate to a fiberglass-based material functioning as a new delivery system to aid seed germination and nutrition in agricultural crop or plant growth due, at least in part, to the fiberglass media having a high surface-area-to-volume ratio and being soluble in an aqueous environment. These features enable several key benefits including, but not limited to, extended hydration, the transport of water-activated chemical enriching agents, soil aeration, nutrient supply, and pH balancing of the soil.

[0006] In this disclosure, a series of glass compositions, as well as auxiliary organic materials to enable various forms of glass fiber, are disclosed primarily focusing on agricultural applications. Agricultural use of fertilizers and water retention agents require the subject matter to be non-toxic to the plants. Furthermore, the subject matter must achieve a suitable release rate to avoid chemically burning the plant. This disclosure presents a series of materials that are considered beneficial to the growth of plants. These materials may achieve a slow-release of nutrients, organic matter, and the like, when in the soil environment. These materials may be suitable for agricultural use in different geographical conditions (climate, weather, soil type, etc.).

[0007] To further illustrate various aspects of the general inventive concepts, several exemplary embodiments of fiberglass materials (e.g., a nodule, a mat, a coating) for promoting seed germination and/or facilitating nutrient delivery are disclosed.

[0008] In one exemplary embodiment, a soil amendment for promoting the growth of a plant is disclosed. The soil amendment comprises: a plurality of discrete glass fibers; wherein the glass fibers comprise about 20 wt.% to about 75 wt.% of SiO_2 , about 1 wt.% to about 15 wt.% of Al_2O_3 , and about 2 wt.% to about 25 wt.% of Na_2O ; wherein the glass fibers have a ratio of Si to (Si+Al) greater than about 0.7; wherein the glass fibers have an average fiber diameter in the range of 1 μm to 10 μm ; wherein the soil amendment has a density in the range of 10 kg/m^3 to 50 kg/m^3 ; and wherein the soil amendment is operable to increase the plant-available-water level of the soil by about 30% to about 260% at a level of about 0.5 wt.% to 3.0 wt.% of the soil amendment.

[0009] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 20 wt.% of CaO. In some exemplary embodiments, the glass fibers have a ratio of Na to (Na+Ca) in the range of about 0.3 to about 0.9.

[0010] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of MgO.

[0011] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 15 wt.% of Fe₂O₃ or FeO.

[0012] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 30 wt.% of B₂O₃. In some exemplary embodiments, the glass fibers have a ratio of Na to (Na+B) less than about 0.6.

[0013] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of Li₂O.

[0014] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 25 wt.% of K₂O.

[0015] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of P₂O₅.

[0016] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 5 wt.% of CuO or Cu₂O.

[0017] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 3 wt.% of SeO₂.

[0018] In some exemplary embodiments, the glass fibers further comprise about 0.005 wt.% to about 5 wt.% of ZnO.

[0019] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 3 wt.% of Cl.

[0020] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of MnO or MnO₂.

[0021] In some exemplary embodiments, the glass fibers further comprise about 0.01 wt.% to about 3 wt.% of Mo.

[0022] In some exemplary embodiments, the glass fibers form a plurality of nodules having an average largest linear dimension in the range of about 1 mm to about 10 mm. In some exemplary embodiments, each of the nodules has a spherical shape and the largest linear dimension is a diameter of the spherical shape.

[0023] In some exemplary embodiments, the glass fibers form a non-woven mat having a width, a length, and a thickness. In some exemplary embodiments, the width is in the range of about 10 mm to about 1 m; the length is in the range of about 10 mm to about 1,000 m; and the thickness is in the range of about 1 mm to about 50 mm. In some exemplary embodiments, the width is about 10 mm, the length is about 10 mm, and the thickness is about 10 mm. In some exemplary embodiments, the width is about 50 mm, the length is about 1,000 m, and the thickness is about 10 mm. As noted above, the mat will typically have a density in the range of about 10 kg/m³ to about 50 kg/m³.

[0024] In some exemplary embodiments, the glass fibers of the mat are held together by a binder.

[0025] In some exemplary embodiments, the glass fibers of the mat are held together by mechanical entanglement.

[0026] In some exemplary embodiments, the glass fibers have an average half-life in the soil in the range of about six months to about eighteen months.

[0027] In some exemplary embodiments, the glass fibers have an average half-life in the soil of about twelve months.

[0028] In some exemplary embodiments, the soil amendment further comprises an additive applied to a surface of the glass fibers. In some exemplary embodiments, the additive is at least one of a herbicide, an insecticide, a nematicide, and a fungicide. In some exemplary embodiments, the additive is a hormone. In some exemplary embodiments, the additive is an agricultural biological. In some exemplary embodiments, the additive is a surfactant.

[0029] In some exemplary embodiments, the additive makes the glass fibers more hydrophilic. In some exemplary embodiments, the additive makes the glass fibers more hydrophobic.

[0030] In one exemplary embodiment, a system for promoting the growth of a plant is disclosed. The system comprises: a seed corresponding to the plant, wherein an outer surface of the seed is at least partially coated with a fiberglass media, and wherein a thickness of the coating is less than a largest thickness of the seed.

[0031] In one exemplary embodiment, a method of promoting the growth of a plant is disclosed. The method comprises: placing a seed corresponding to the plant within a quantity of a soil; and placing a soil amendment comprising a plurality of discrete glass fibers in the soil in proximity to the seed; wherein the soil amendment constitutes about 0.5 wt.% to 3.0 wt.% of the soil; wherein the glass fibers comprise about 20 wt.% to about 75 wt.% of SiO_2 , about 1 wt.% to about 15 wt.% of Al_2O_3 , and about 2 wt.% to about 25 wt.% of Na_2O ; wherein the glass fibers have a ratio of Si to (Si+Al) greater than about 0.7; wherein the glass fibers have an average fiber diameter in the range of 1 μm to 10 μm ; wherein the soil amendment has a density in the range of 10 kg/m^3 to 50 kg/m^3 ; and wherein the soil amendment increases the plant-available-water level of the soil by about 30% to about 260%.

[0032] Other aspects and features of the general inventive concepts will become more readily apparent to those of ordinary skill in the art upon review of the following description of various exemplary embodiments in conjunction with the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] The general inventive concepts, as well as embodiments and advantages thereof, are described below in greater detail, by way of example, with reference to the drawings in which:

[0034] Figure 1A is a front elevational view of a fiberglass nodule for promoting plant growth, according to one exemplary embodiment.

[0035] Figure 1B is a perspective view of a fiberglass mat for promoting plant growth, according to one exemplary embodiment.

[0036] Figure 1C is a perspective cut-away view of a fiberglass coating for promoting plant growth, according to one exemplary embodiment.

[0037] Figure 2 is a graph showing the relationship between the density of the fiberglass media density and the water holding capacity of the fiberglass media.

[0038] Figure 3 is a graph showing the relationship between the fiber diameter, the product of the nodule density and the nodule diameter, and the ratio of the fiber surface area to the nodule surface area of the fiberglass media.

[0039] Figure 4 is a diagram illustrating an extended hydration process and a chemical agent transport process, as the fiberglass media is hydrated and then dehydrated by diffusion of chemical-laden water to the soil, according to one exemplary embodiment.

[0040] Figure 5 is a diagram illustrating a hydrophobic region of the fiberglass media, surrounded by a hydrophilic region, where the hydrophobic region traps air for soil aeration.

[0041] Figure 6 is a diagram illustrating the nutrient delivery and pH balancing mechanisms of the fiberglass media, according to one exemplary embodiment.

DETAILED DESCRIPTION

[0042] Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs. All references, publications, patents, patent applications, and commercial materials mentioned herein are incorporated herein by reference for all purposes including for describing and disclosing the methodologies which are reported in the publications which might be used in connection with the invention. Nothing herein is to be construed as an admission that the invention is not entitled to antedate such disclosure by virtue of prior invention.

[0043] Several illustrative embodiments will be described in detail with the understanding that the present disclosure merely exemplifies the general inventive concepts. Embodiments encompassing the general inventive concepts may take various forms and the general inventive concepts are not intended to be limited to the specific embodiments described herein.

[0044] The general inventive concepts encompass a fiberglass-based media functioning as a new delivery system to aid seed germination and nutrition in agricultural crop or plant growth due, at least in part, to the fiberglass media having a high surface-area-to-volume ratio and being soluble in an aqueous environment. The fiberglass media can take any suitable form.

[0045] In one exemplary embodiment, the fiberglass media 100 is a nodule 102, as shown in FIG. 1A. The nodule 102 is generally an irregularly-shaped body. The irregularly-shaped body can have a string-like portion and/or a spherical-like portion. In some instances, the nodule 102 has a somewhat spherical shape. The nodule 102 has a nodule diameter n_d , which represents the largest length across or through the nodule. In some exemplary embodiments, the nodule diameter n_d is in the range of 1 mm to 10 mm. With a more irregularly shaped nodule (e.g., having a significant string-like portion), the nodule diameter n_d could be in the range of 10 mm to 38 mm or 10 mm to 51 mm. The nodule 102 is formed of glass fibers, which may or may not be held together with a binder (as described below). For example, the nodules could be formed in a manner similar to loosefill insulation product (using chopped/milled glass fibers).

[0046] In one exemplary embodiment, the fiberglass media 120 is a mat 122, as shown in FIG. 1B. The mat 122 is generally a planar-shaped body. The mat is generally a non-woven mat. For example, the mat could be formed in a manner similar to a fiberglass batt insulation product. The mat 122 may have any practical dimensions (i.e., thickness, width, and length). The mat 122 is typically cut (illustrated by dashed line 124) from a formed roll 126 of the fiberglass material. Because the dimensions of the fiberglass material are really only limited by its manufacturing and storing processes, the dimensions of the mat 122 can vary widely. In some exemplary embodiments, a thickness of the mat 122 is in the range of 1 mm to 50 mm. In some exemplary embodiments, a width of the mat 122 is in the range of 10 mm to 1 m. In some exemplary embodiments, a length of the mat 122 is in the range of 10 mm to 1,000 m. Often, the dimensions of the mat 122 will depend upon its intended application. For example, if the mat 122 is being used in a greenhouse to produce seedlings, the mat 122 might have dimensions of 10 mm x 10 mm x 10 mm (i.e., a pod). Alternatively, if the mat 122 is being placed into a furrow created by a piece of farm equipment, the mat 122 might have dimensions of 10 mm x 50 mm x 1,000 m.

[0047] In one exemplary embodiment, the fiberglass media 140 is a coating 142 applied to a seed 144, as shown in FIG. 1C. In this manner, the glass fibers are directly interfaced with or around a surface of the seed 144. In some exemplary embodiments, the coating 142 at least partially encapsulates the seed 144. In some exemplary embodiments, the coating 142 completely encapsulates the seed 144. Typically, a coating thickness c_t is less than or equal to the largest dimension of the seed 144.

[0048] The fiberglass media 140 may be applied to the seed 144 in any suitable manner. For example, conventional seed coating techniques include the use of a fluidized bed, a rotary coater, a rotating pan, etc. It may be the case that a slurry of glass fibers, a binder (as described below), and other ingredients (e.g., fillers) are applied to the seed 144 and allowed to cure or otherwise harden. In accordance with the general inventive concepts, any suitable technique for applying the fiberglass media 140 to or around the seed 144 can be used. By way of example, resonant acoustic mixing may be one such technique.

[0049] Notwithstanding these illustrative embodiments, the general inventive concepts contemplate that the fiberglass media 140 can assume any form suitable for use as a growth media given the intended application (e.g., agriculture, horticulture, etc.). By way of example, the fiberglass media 140 could simply be a quantity of loose glass fibers, a collection of entangled (e.g., needled) glass fibers, a quantity of texturized glass fibers (often referred to as “glass wool”), etc. Generally, the fiberglass media 140 will act as an inorganic soil amendment.

[0050] The fiberglass media (e.g., fiberglass media 100, 120, 140) encompassed by the general inventive concepts will typically comprise a glass formed from a composition including: 20 wt.% to 75 wt.% of SiO_2 ; 1 wt.% to 15 wt.% of Al_2O_3 ; and 2 wt.% to 25 wt.% of Na_2O .

[0051] In some exemplary embodiments, the glass composition includes one or more of CaO , MgO , Fe_2O_3 or FeO , B_2O_3 , Li_2O , K_2O , P_2O_5 , CuO or Cu_2O , SeO_2 , ZnO , Cl , MnO or MnO_2 , and Mo in oxide form. In some exemplary embodiments, the glass composition includes two or more of CaO , MgO , Fe_2O_3 or FeO , B_2O_3 , Li_2O , K_2O , P_2O_5 , CuO or Cu_2O , SeO_2 , ZnO , Cl , MnO or MnO_2 , and Mo in oxide form. In some exemplary embodiments, the glass composition includes three or more of CaO , MgO , Fe_2O_3 or FeO , B_2O_3 , Li_2O , K_2O , P_2O_5 , CuO or Cu_2O , SeO_2 , ZnO , Cl , MnO or MnO_2 , and Mo in oxide form. In some

exemplary embodiments, the glass composition includes four or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes five or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes six or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes seven or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes eight or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes nine or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes ten or more of CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In some exemplary embodiments, the glass composition includes CaO, MgO, Fe₂O₃ or FeO, B₂O₃, Li₂O, K₂O, P₂O₅, CuO or Cu₂O, SeO₂, ZnO, Cl, MnO or MnO₂, and Mo in oxide form. In general, intentional inclusion of any of these constituents will be at a level greater than a trace amount or an impurity.

[0052] In some exemplary embodiments, the glass composition includes 0 wt.% to 20 wt.% of CaO. In some exemplary embodiments, the glass composition includes 0 wt.% to 10 wt.% of MgO. In some exemplary embodiments, the glass composition includes 0 wt.% to 15 wt.% of Fe₂O₃ or FeO. In some exemplary embodiments, the glass composition includes 0 wt.% to 30 wt.% of B₂O₃. In some exemplary embodiments, the glass composition includes 0 wt.% to 10 wt.% of Li₂O. In some exemplary embodiments, the glass composition includes 0 wt.% to 25 wt.% of K₂O. In some exemplary embodiments, the glass composition includes 0 wt.% to 10 wt.% of P₂O₅. In some exemplary embodiments, the glass composition includes 0 wt.% to 5 wt.% of CuO or Cu₂O. In some exemplary embodiments, the glass composition includes 0.01 wt.% to 3 wt.% of SeO₂. In some exemplary embodiments, the glass composition includes 0.005 wt.% to 5 wt.% of ZnO. In some exemplary embodiments, the glass composition includes 0 wt.% to 3 wt.% of Cl. In some exemplary embodiments, the glass composition includes 0 wt.% to 10 wt.% of MnO or MnO₂. In some exemplary embodiments, the glass composition includes 0 wt.% to 3 wt.% of Mo.

[0053] The glass composition used to form the fiberglass media (e.g., fiberglass media 100, 120, 140) is typically suitable for melting using various types of furnaces (e.g., electric, gas, a combination of both) in both laboratory and manufacturing scale. The liquidus temperature and rheological working range of glasses for different manufacturing processes can be adjusted via the manipulation of the glass chemistry in the given range. A typical melting temperature for the glass composition ranges from 2,100 °F to 2,800 °F, depending on the glass chemistry. The glass composition can be melted at a given temperature for 30 mins to several hours depending on the rheological properties and spatial-composition of the glass melts inside the furnace.

[0054] The fiberizing process (i.e., the process of forming fibers from the molten glass) can be performed by continuous and discontinuous methods including drawing from a precious metal bushing, a rotary process utilizing internal centrifuge, a cascade process using external centrifuge, a flame attenuation process, or a combination of one or more of these fiberizing techniques. For example, the fiberizing process can involve both the flame attenuation process and the rotary process to achieve a desirable fiber diameter, morphology, and surface area, as well as other physical properties and appearance of interest.

[0055] The glass fibers are attenuated from the device and are blown generally downwardly within a forming chamber so as to be deposited onto a forming conveyor. A chemical agent (e.g., a sizing composition) is applied to an outer surface of the glass fibers, as they are being formed, by means of suitable spray applicators to result in a uniform distribution of the chemical agent throughout a glass fiber mass. The chemical agent may be applied to the fibers as a solution or dispersion in an organic or aqueous medium. Often, the composition is applied to the fibers as an aqueous solution. The temperature of the glass and the surrounding forming area is usually high enough to evaporate the water from the aqueous solution before the fibers have been collected. A chemical agent could also be applied to the surface of a glass fiber at a subsequent step in the manufacturing process, after the fibers have been initially collected.

[0056] A chemical agent (e.g., a binder composition), such as a resin, could also be applied to the glass fibers during this manufacturing process to hold the fibers (i.e., the glass fiber mass) together. The necessity, as well as the type and amount, of the binder composition will

typically depend on the form of the fiberglass media, for example, the nodule 102, the mat 122, or the coating 142.

[0057] Alternatively, in some exemplary embodiments, a binder is not used to hold the glass fibers together. As one example, the glass fibers could be held together by mechanical entanglement (e.g., needling).

[0058] Should the fiberglass media be bonded with a binder, any suitable binder may be used. In some exemplary embodiments, the binder is based on a thermosetting binder. The binder may be a PUF (phenol-urea-formaldehyde), a PF (phenol-formaldehyde), or a non-added formaldehyde binder. Examples of non-added formaldehyde binders include, but are not limited to, polyesters, polyamides, and melanoidin-based binders. Polyester and polyamide-based binders may comprise monomeric or polymeric carboxylic acids; monomeric or polymeric polyols; and monomeric or polymeric amines, preferably primary or secondary amines. The melanoidin-based binder may be based on a reducing sugar and an amine or ammonia component. In some exemplary embodiments, the binder is based on a thermoplastic binder. Optionally, the binder may be mainly water-insoluble or mainly water-soluble. The binder may comprise processing aides like oils, silanes, silicones, and surfactants. Alternatively, the fiberglass media may be mainly free of a binder and only contain processing aides, wherein the processing aides may comprise oils, silanes, silicones, and surfactants.

[0059] In some exemplary embodiments, one or more additives (e.g., functional components) can be incorporated into the sizing and/or the binder or the processing aides associated therewith. In this case, the sizing and/or the binder function as a release agent for the additives. Indeed, certain additives could be used to control the rate of release of other additives.

[0060] In some exemplary embodiments, the additives include protective additives for the plant that leach into the seed or soil when hydrated, such as herbicides, insecticides, nematocides, and/or fungicides.

[0061] In some exemplary embodiments, the additives include plant growth additives, such as nutrients or hormones.

[0062] In some exemplary embodiments, the additives include one or more agricultural biologicals.

[0063] In some exemplary embodiments, the additives include soil enrichening additives such as surfactants that enhance the water holding capacity of the soil (also known as “moisturizers” or “soil loosening agents” or “humectants”).

[0064] In some exemplary embodiments, the additives include an additive (e.g., a surfactant) that makes the glass fibers more hydrophilic, which in turn enhances the water holding capacity and subsequent water release ability of the fiberglass media.

[0065] In some exemplary embodiments, the additives include an additive (e.g., a silicone oil) that makes the glass fibers more hydrophobic, which in turn creates regions within the fiberglass media where air can be trapped to provide enhanced soil aeration despite the presence of hydration (i.e., exposure of the fiberglass media to water, such as water passing through or around the fiberglass media).

[0066] Regarding the hydrophilic and hydrophobic characteristics of the glass fibers, these properties can be achieved within the same product form (i.e., fiberglass media) by having the hydrophilic fiber bundles created in one part of the process, having the hydrophobic fiber bundles created in another part of the process, and then having them intermixed in desired proportions downstream in the process. By controlling the ratio of hydrophilic fibers and hydrophobic fibers, it is possible to tune the fiberglass media to provide more or less aeration versus extended hydration, as desired for a particular application. It is to be understood that other substances, such as a de-dusting oil, a lubricant, a dye, etc., may also be applied to the glass fibers together with the aforementioned additives.

[0067] The average surface area of the glass fibers can range from 0.01 m²/g to 20 m²/g depending on the forming process and the glass chemistry that enables that process. Also, the morphology of the resultant fibers or bundles of fibers can be aligned, tortured, cross-linked, and woven depending on the post-fiberizing processing technology and the desired product form. The glass fibers will typically have a relatively large fiber diameter distribution ranging from 0.1 microns to 40 microns. However, the glass fibers used in the fiberglass media will generally have an average fiber diameter in the range of 1 microns to 10 microns (or in the range of 3 microns to 10 microns), which is controlled by the fiberizing process and glass rheological properties at the designated operating temperature.

[0068] The high surface-area-to-volume ratio enables deposition of functional chemistry (e.g., nutrients, pesticides [weed, insect, fungus]) on the glass surface that would be released/activated by the infusion of water upon hydration. The surface-area-to-volume ratio of the fiberglass media is a function of its density. The fiberglass media will typically have a density in the range of 10 kg/m^3 to 50 kg/m^3 , which corresponds to a surface-area-to-volume ratio in the range of $5,000 \text{ m}^{-1}$ to $27,000 \text{ m}^{-1}$.

[0069] Due to its high porosity (e.g., $> 95\%$ open volume in some instances), the fiberglass media is able to hold a significant amount of liquid water within its volume when saturated. Likewise, the porosity of the fiberglass media is a function of its density. As noted above, the fiberglass media will typically have a density in the range of 10 kg/m^3 to 50 kg/m^3 , which corresponds to a porosity in the range of $20 \text{ cm}^3/\text{gm}$ to $100 \text{ cm}^3/\text{gm}$. The porosity of the fiberglass media can be readily controlled, at least for those embodiments where a binder is used to hold the glass fibers together.

[0070] The fiberglass media is hydrated upon placement within the soil and slowly releases the water (extended hydration) and intended chemistry (transport) to the soil, at the soil-media interface, initially and with repeated cycles of re-hydration.

[0071] The efficacy of this release of water from the fiberglass media could be assessed, for example, by measuring the plant available water (PAW). The PAW is the difference between the field capacity (i.e., the maximum amount of water the soil can hold) and the wilting point (i.e., the point at which a plant can no longer extract water from the soil). Field capacity is determined by mass and measures the total % water content after thorough saturation followed by freely draining for 24 hours. The permanent wilting point is determined by the Sunflower Method for Permanent Wilting Point. This method is designed to measure the moisture content of soils when a plant reaches the permanent wilting point (PWP). This point is where a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours. This method uses a dwarf sunflower bioassay. The assessment could involve multiple samples and encompass different amounts of fiberglass media (e.g., 0%, 15%, 30%, and 50% by volume), different soil types (e.g., high clay, high organic matter, high sand/silt), etc. Such PAW levels for an exemplary fiberglass media (in the form of nodules) by soil type, dosage, and relative to control (i.e. unamended soil) are shown in Table 1.

Soil Type	Volume Fraction	Mass Fraction	PAW	PAW (relative to control)
	%	%	%	%
High Clay (silty clay)	0	0.0	33.5	
	15	0.8	43.3	129
	30	1.6	53.6	160
	50	2.6	69.7	208
High Sand (sandy loam)	0	0.0	26.7	
	15	0.8	35.5	133
	30	1.6	50.8	190
	50	2.6	68.3	256
High Organic Matter (silt loam)	0	0.0	40.5	
	15	0.8	52.2	129
	30	1.6	63.0	156
	50	2.6	87.8	217

Table 1

[0072] In some exemplary embodiments, the fiberglass media can achieve comparable or better levels of PAW at a lower dosage than some conventional soil amendments (e.g., silicas, biochar, mulch).

[0073] In some exemplary embodiments, the fiberglass media can achieve comparable or better levels of PAW at a lower cost than some conventional soil amendments (e.g., SAPs).

[0074] In some exemplary embodiments, the fiberglass media can avoid various drawbacks associated with conventional soil amendments, such as soil pH sensitivity (e.g., SAPs) and high material variability (biochar).

[0075] Furthermore, hydration creates a water film around and throughout the nodule/mat/coating, allowing ionic exchange between the H⁺ of water and the alkaline ions present in the glass fibers. This film is rich in alkaline oxides (that diffuse into the soil, providing nutrients (e.g., Na, Ca, Mg, B, Fe, K) and elevating the pH). In some exemplary embodiments, the fiberglass media is operable to release one or more of Na, Ca, Mg, B, Fe, K, P, Se, Zn, Cl, and Mo into the soil to provide necessary nutrient and micronutrients to a plant. The release of these oxides will be time-delayed because the solubility of glass is a function of the surrounding conditions (temperature, moisture content, etc.). This delayed release could extend over the life of the plant (i.e., from planting to harvesting) or some portion thereof.

[0076] The rate of release of ions (nutrients) from the glass fibers, as the glass dissolves, can be engineered (ignoring environmental factors, such as soil temperature, soil pH, etc.) to be regulated by multiple factors including, for example, the surface area of the glass fibers, the surface area of the nodule, and the glass chemistry.

[0077] The fiberglass media can effectively dissolve in soil. The dissolution over time is such that the fiberglass media essentially turns into a powder (e.g., having particle sizes in the range of 10 nm to 40 μ m) and becomes part of the soil, as opposed to a visibly discernable additive. As described herein, the rate of dissolution of the fiberglass media is impacted, at least in part, by various properties of the fiberglass media (including its form) and, thus, can be controlled to a certain extent. This ability to control the rate of dissolution of the fiberglass media can be important given the variability of the applicable plant life, the geographical and seasonal differences in environmental factors, the different types of soil (e.g., sand, clay, silt, blended) to be amended, etc.

[0078] In some exemplary embodiments, the fiberglass media has a half-life in the range of six months to eighteen months. In some exemplary embodiments, the fiberglass media has a half-life of twelve months.

[0079] The dissolution process begins at the surface of the glass fiber and is therefore proportional to the fiber surface area. The fiber surface area is a function of the fiber diameter, nodule diameter, glass density, and nodule density, all of which are controllable to varying degrees. In the case of the nodule form of the fiberglass media, once the ion/nutrient departs the glass surface, it must then diffuse to the nodule-soil interface, where the rate of diffusion into the soil is a function of the nodule surface area and therefore the nodule diameter. The glass chemistry impacts the overall rate of dissolution of the glass fibers, as certain constituents may have a faster rate of dissolution than other constituents.

[0080] In some exemplary embodiments, the dissolution rate of the fiberglass media is attributable, at least in part, to having a ratio of Si to (Si+Al) greater than 0.7.

[0081] In some exemplary embodiments, the dissolution rate of the fiberglass media is attributable, at least in part, to having a ratio of Na to (Na+B) less than 0.6.

[0082] In some exemplary embodiments, the dissolution rate of the fiberglass media is attributable, at least in part, to having a ratio of Na to (Na+Ca) in the range of 0.3 to 0.9.

[0083] As noted above, various forms of fiberglass media (e.g., fiberglass media 100, 120, 140) can be achieved downstream of the fiberizing section, including a nodule (see FIG. 1A), a mat (see FIG. 1B), and a seed coating (see FIG. 1C).

[0084] The glass fibers can be blown into a forming chamber where they are deposited with little organization, or in varying patterns, onto a traveling conveyor so as to form a mat. Subsequently, the coated fibrous mat, which would include a binder as a chemical agent, is transferred out of the forming chamber to a transfer zone where the mat vertically expands due to the resiliency of the glass fibers. The coated mat is then transferred to a curing oven, where heated air is blown through the mat, or to a curing mold, where heat may be applied under pressure, to cure the binder and rigidly attach the glass fibers together. This mat product can then be used as a planting media, as described herein.

[0085] Other types of fiberglass products include glass fibers that are not bound or held together by a binder. In this case, the fibers are blown into a forming chamber where they are deposited with little organization, or in varying patterns, onto a traveling conveyor (so as to form a mat) or into a duct for transport. Subsequently, the fibrous mat is transferred out of the forming chamber to a transfer zone where the fibers may expand due to their resiliency.

[0086] The expanded glass fibers can then be sent through a mill (e.g., a hammermill) to be cut apart where chemical agents could also be added. The fibers once formed, may be pulverized, cut, chopped or broken into suitable lengths for the plant growth application. Several devices and methods are available to produce short pieces of fibers and are known in the art. The resulting glass fiber products could take the form of nodules, which are roughly spherical in shape and have a diameter that ranges from 1 mm to 10 mm. These nodules could be used directly as a soil additive or could be used in a subsequent seed coating operation, for example, employing conventional seed coating technology (e.g., fluidized bed, rotary coater, rotating pan).

[0087] This fiberglass media, independent of whether it is in the form of a nodule, mat, or coating, can deliver multiple benefits to soil-based plant growth, including extended hydration, the transport of water-activated chemical enriching agents, soil aeration, nutrient

supply, and pH balancing of the soil. The fiberglass media may be used in any suitable soil-based agriculture or plant application, including for turf and lawn grasses.

[0088] Extended hydration depends on the water holding capacity of the fiberglass media (grams of water per grams of fiberglass), which is a function of the density of the fiberglass media. The graph 200 of FIG. 2 shows this relationship by plotting a water holding capacity range from 6 to 200 for the density range of 5 kg/m^3 to 150 kg/m^3 . The transport of chemical agents depends on the ratio of the surface area of the glass fibers where the agents are deposited to the outer surface area of the fiberglass media consuming space in the soil (e.g., nodule outer surface area), which is a function of the fiber diameter, the nodule diameter, and the media density. The higher the surface area ratio, the more chemical agents that could conceivably be contained within a fixed soil volume. The graph 300 of FIG. 3 shows this relationship by plotting a surface area ratio range from 7 to 400 for the fiber diameter range of $1 \text{ }\mu\text{m}$ to $20 \text{ }\mu\text{m}$ and the range of the product of the nodule density and the nodule diameter from 0.5 kg/m^2 to 1.5 kg/m^2 .

[0089] The extend hydration mechanism is illustrated via the diagram 400 of FIG. 4. Initially, the fiberglass media (e.g., nodule, mat, coating) is hydrated upon placement within the soil from an available water supply or a rain event. The fiberglass media then slowly releases the water (extended hydration) and chemistry (transport) to the soil by diffusion, initially and with repeated cycles of re-hydration.

[0090] The soil aeration mechanism is illustrated via the diagram 500 of FIG. 5. Initially, the fiberglass media (e.g., nodule, mat, coating) is formed to have regions of hydrophobicity. These regions are formed during the manufacturing process by applying a non-wetting chemistry (e.g., silicone) to those glass fibers or resulting fiberglass media (e.g., nodules). Any fibers or nodules with the non-wetting chemistry would later become a source of soil aeration, whereas any nodules without the chemistry would later become a source of water-holding. The general inventive concepts encompass controlling the manufacturing process such that a certain percentage of the fibers/nodules are hydrophobic (aerators) and the balance are hydrophilic (hydrators). In the case of nodules, the air entrainment capability of the fiberglass media is linked to the quantity and size of the nodules. The volume of aeration would then be the number of hydrophobic nodules times average nodule volume.

[0091] The nutrient delivery and pH balancing mechanisms are illustrated via the diagram 600 of FIG. 6. As noted above, the fiberglass media (e.g., fiberglass media 100, 120, 140), when applied in the field, interacts with water through an ionic exchange process. Glass network modifiers (such as FeO, CaO, MgO, Na₂O, and K₂O; termination of -Si-O-Si-network) ion-exchanges with H⁺ to form silicic acid -Si-OHs, which is soluble in aqueous conditions and enables the dissolution of the glass fibers inside soil. In addition, -OH groups at pH larger than 7 react with -Si-O-Si- to break the bond and form additional silicic acid. This process is controlled by surface reaction as well as diffusion process, and thus allowing the nutrients to be slowly released into the soil to avoid any harmful chemical burning of plants. In addition, the release rate can be manipulated or engineered, for example, via the adjustment of the glass chemistry, the mixture of organic matter applied onto the glass fibers, or a combination of both, as well as other suitable techniques. A typical life span of soda-lime-silicate glass fiber inside soil can be as long as a year. Therefore, the fiberglass media products disclosed herein can provide nutrition to plants on a year- or season-long basis.

[0092] Given the reaction between glass fibers and water, the fiberglass media products disclosed herein can slowly improve the soil quality by shifting the pH of soil into a desirable range of 5.5 to 7.5 depending on the chemistry of the glass. The rate of pH balance, as well as the associated improvement of soil quality, is subject to the chemistry of the glass fibers and the form of the fiberglass media product being used.

[0093] The form of the fiberglass media (e.g., nodule 102, mat 122, coating 142) being used will typically depend on the particular application. Some suitable applications include, but are not limited to, various agricultural applications, various landscaping applications, and various gardening applications.

[0094] For example, a nodule form of the fiberglass media could be used in transplanting or during seed planting. In the case of transplanting, particularly in arid climates, hydration must be present during the time immediately following the transplant or the plant will die. Hydrated nodules, likely in the form of a slurry, would be deposited in the soil along with the transplanted root ball. In the case of seed planting, nodules would be deposited in the furrow at seed depth in the seed line such that the nodules and seeds are in proximity to one another. The nodules could be pre-hydrated at the time of planting or could be naturally hydrated with rainfall.

[0095] A mat form of the fiberglass media could be used to grow seedlings, where the mat functions initially as the growing media at the seed stage (soil substitute) and later accompanies the seedling in the transplanting process. During the germination period, the mat is providing structure for root growth, hydration, and nutrition. During the transplanting, the mat is providing root support and hydration. After transplanting, the mat provides extended hydration from its water holding capacity and nutrition with pH balancing from its dissolution. Examples of suitable seedlings include, but are not limited to, sugarcane, tomatoes, and trees (reforestation).

[0096] A potential problem with applying the fiberglass media in the form of a nodule is that its effectiveness is a strong function of its proximity to the seed. This problem can be remedied by applying the fiberglass media to the seed in the form of a coating in a factory by adapting conventional methods for seed coating (e.g., fluidized bed, rotary coater, rotating pan). The fiberglass-coated seed can then be planted in the soil to enjoy the growth benefits described herein without the concern of the seed and the fiberglass media being separated in the planting process.

[0097] In some embodiments, it may be possible to utilize the various inventive concepts in combination with one another. Additionally, any particular element recited as relating to a particularly disclosed embodiment should be interpreted as available for use with all disclosed embodiments, unless incorporation of the particular element would be contradictory to the express terms of the embodiment. The scope of the general inventive concepts presented herein are not intended to be limited to the particular exemplary embodiments shown and described herein. From the disclosure given, those skilled in the art will not only understand the general inventive concepts and their attendant advantages, but will also find apparent various changes and modifications thereto. It is sought, therefore, to cover all such changes and modifications as fall within the spirit and scope of the general inventive concepts, as described and/or claimed herein, and any equivalents thereof.

CLAIMS

What is claimed is:

1. A soil amendment comprising a plurality of discrete glass fibers;

wherein the glass fibers comprise about 20 wt.% to about 75 wt.% of SiO_2 , about 1 wt.% to about 15 wt.% of Al_2O_3 , and about 2 wt.% to about 25 wt.% of Na_2O ;

wherein the glass fibers have a ratio of Si to (Si+Al) greater than about 0.7;

wherein the glass fibers have an average fiber diameter in the range of 1 μm to 10 μm ;

wherein the soil amendment has a density in the range of 10 kg/m^3 to 50 kg/m^3 ; and

wherein the soil amendment is operable to increase the plant-available-water level of the soil by about 30% to about 260% at a level of about 0.5 wt.% to 3.0 wt.% of the soil amendment.
2. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 20 wt.% of CaO .
3. The soil amendment of claim 2, wherein the glass fibers have a ratio of Na to (Na+Ca) in the range of about 0.3 to about 0.9.
4. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of MgO .
5. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 15 wt.% of Fe_2O_3 or FeO .
6. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 30 wt.% of B_2O_3 .
7. The soil amendment of claim 6, wherein the glass fibers have a ratio of Na to (Na+B) less than about 0.6.

8. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of Li_2O .
9. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 25 wt.% of K_2O .
10. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of P_2O_5 .
11. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 5 wt.% of CuO or Cu_2O .
12. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 3 wt.% of SeO_2 .
13. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.005 wt.% to about 5 wt.% of ZnO .
14. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 3 wt.% of Cl .
15. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 10 wt.% of MnO or MnO_2 .
16. The soil amendment of claim 1, wherein the glass fibers further comprise about 0.01 wt.% to about 3 wt.% of Mo .
17. The soil amendment of claim 1, wherein the glass fibers form a plurality of nodules having an average largest linear dimension in the range of about 1 mm to about 10 mm.
18. The soil amendment of claim 17, wherein each of the nodules has a spherical shape and the largest linear dimension is a diameter of the spherical shape.
19. The soil amendment of claim 1, wherein the glass fibers form a non-woven mat having a width, a length, and a thickness.

20. The soil amendment of claim 19, wherein the width is in the range of about 10 mm to about 1 m;

wherein the length is in the range of about 10 mm to about 1,000 m; and

wherein the thickness is in the range of about 1 mm to about 50 mm.

21. The soil amendment of claim 20, wherein the width is about 10 mm, the length is about 10 mm, and the thickness is about 10 mm.

22. The soil amendment of claim 20, wherein the width is about 50 mm, the length is about 1,000 m, and the thickness is about 10 mm.

23. The soil amendment of claim 19, wherein the glass fibers of the mat are held together by a binder.

24. The soil amendment of claim 19, wherein the glass fibers of the mat are held together by mechanical entanglement.

25. The soil amendment of claim 1, wherein the glass fibers have an average half-life in the soil in the range of about six months to about eighteen months.

26. The soil amendment of claim 1, wherein the glass fibers have an average half-life in the soil of about twelve months.

27. The soil amendment of claim 1, further comprising an additive applied to a surface of the glass fibers.

28. The soil amendment of claim 27, wherein the additive is at least one of a herbicide, an insecticide, a nematicide, and a fungicide.

29. The soil amendment of claim 27, wherein the additive is a hormone.

30. The soil amendment of claim 27, wherein the additive is an agricultural biological.

31. The soil amendment of claim 27, wherein the additive is a surfactant.

32. The soil amendment of claim 27, wherein the additive makes the glass fibers more hydrophilic.

33. The soil amendment of claim 27, wherein the additive makes the glass fibers more hydrophobic.

34. A system for promoting growth of a plant, the system comprising a seed corresponding to the plant, wherein an outer surface of the seed is at least partially coated with a fiberglass media, and wherein a thickness of the coating is less than a largest thickness of the seed.

35. A method of promoting plant growth, the method comprising:

placing a seed within a quantity of a soil; and

placing a soil amendment comprising a plurality of discrete glass fibers in the soil in proximity to the seed;

wherein the soil amendment constitutes about 0.5 wt.% to 3.0 wt.% of the soil;

wherein the glass fibers comprise about 20 wt.% to about 75 wt.% of SiO_2 , about 1 wt.% to about 15 wt.% of Al_2O_3 , and about 2 wt.% to about 25 wt.% of Na_2O ;

wherein the glass fibers have a ratio of Si to (Si+Al) greater than about 0.7;

wherein the glass fibers have an average fiber diameter in the range of 1 μm to 10 μm ;

wherein the soil amendment has a density in the range of 10 kg/m^3 to 50 kg/m^3 ; and

wherein the soil amendment increases the plant-available-water level of the soil by about 30% to about 260%.

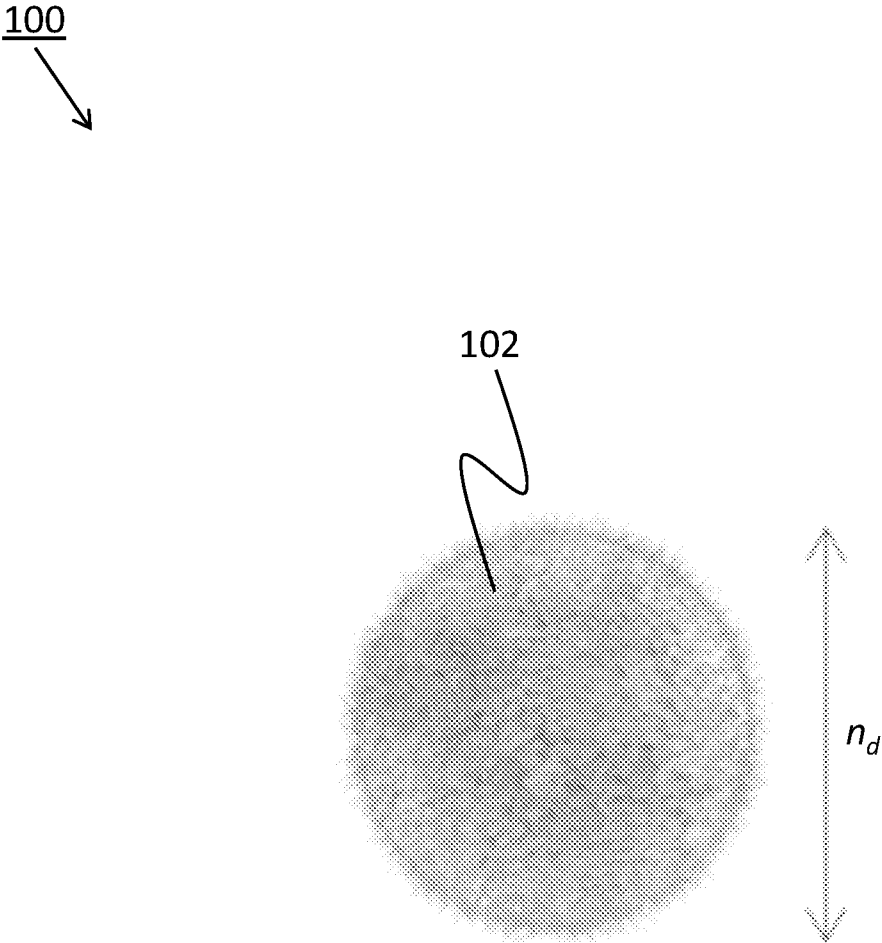


FIG. 1A

120
↓

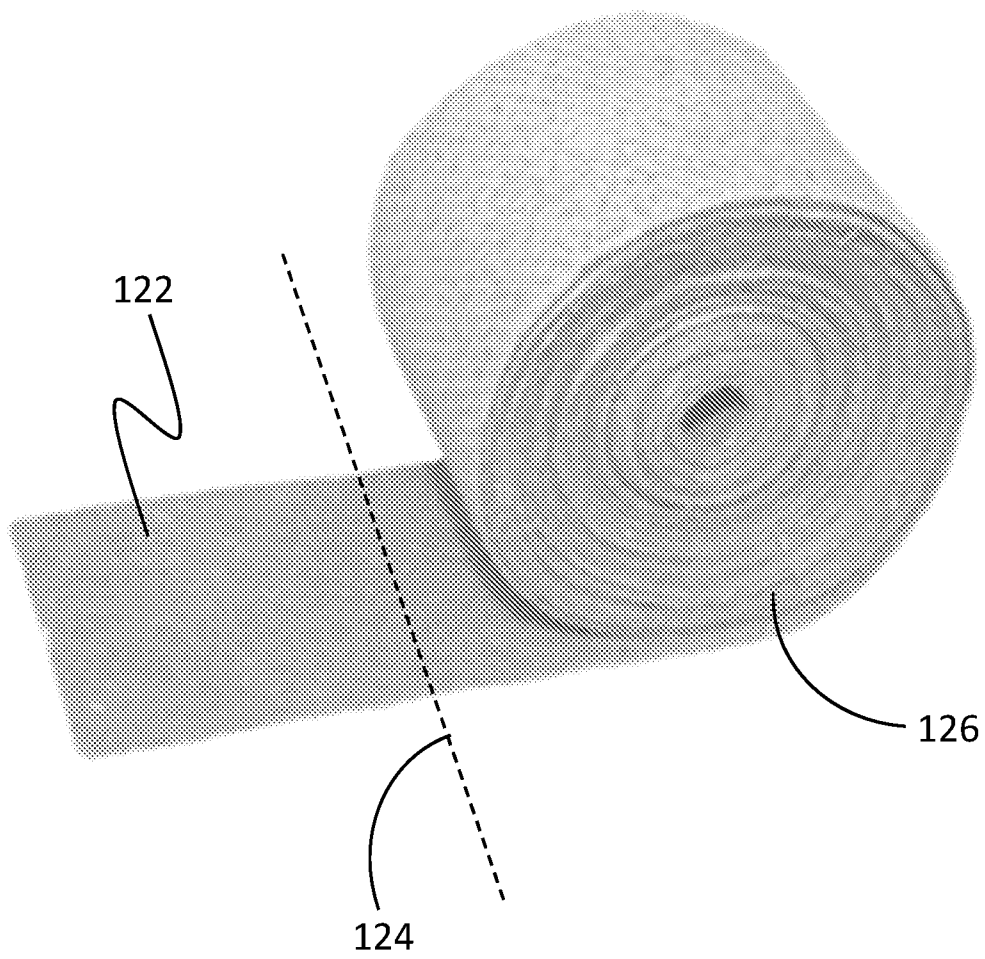


FIG. 1B

140
↓

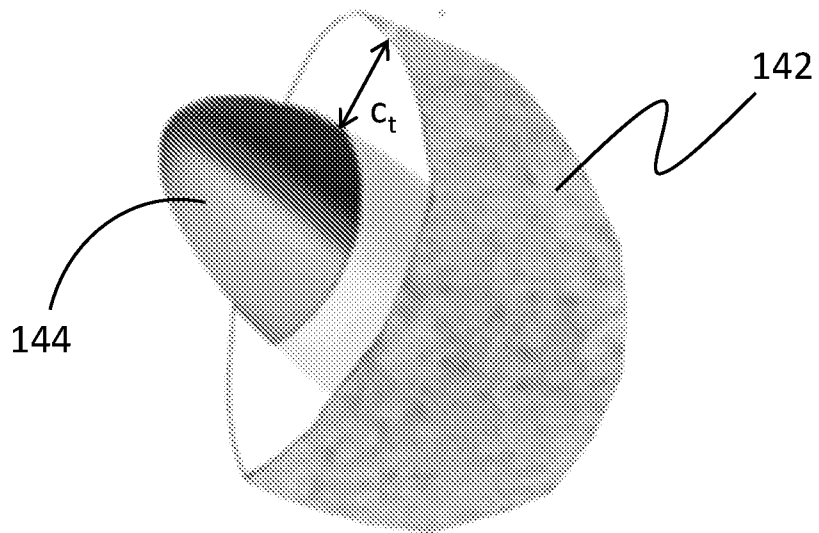


FIG. 1C

200

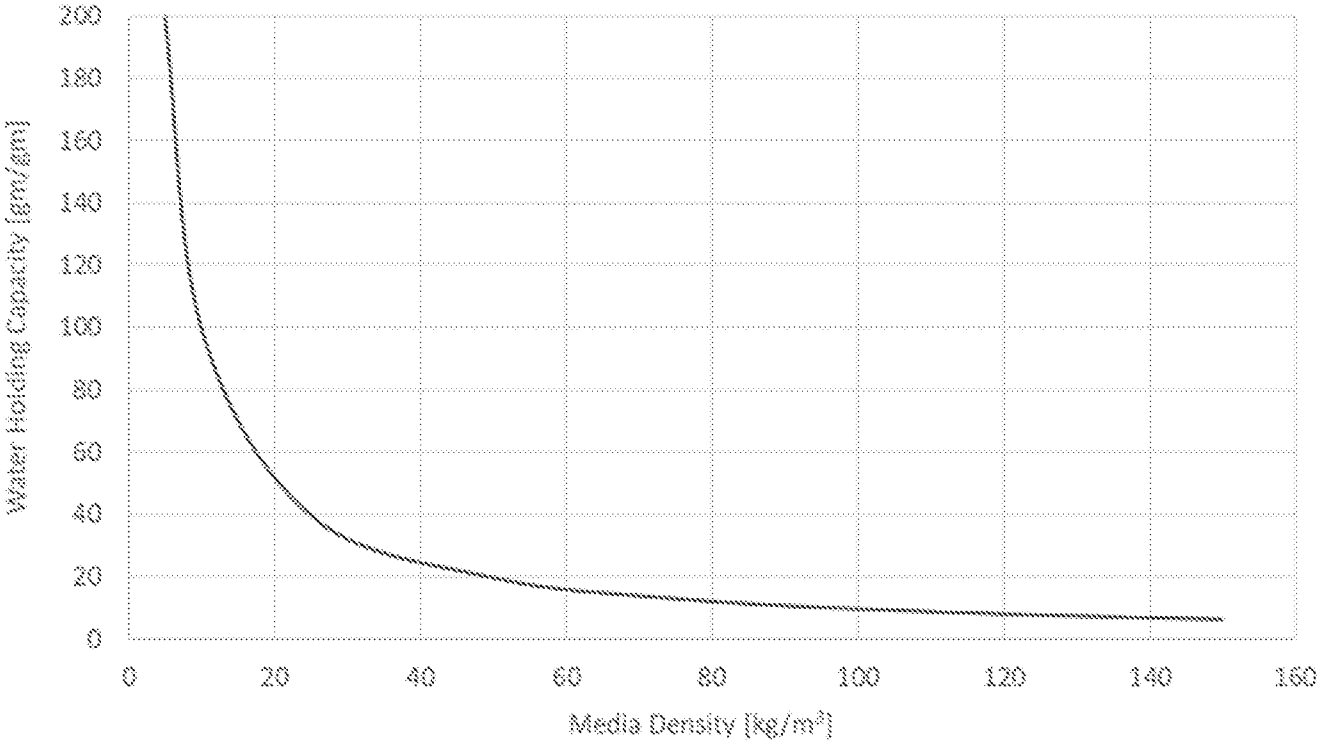


FIG. 2

300
↓

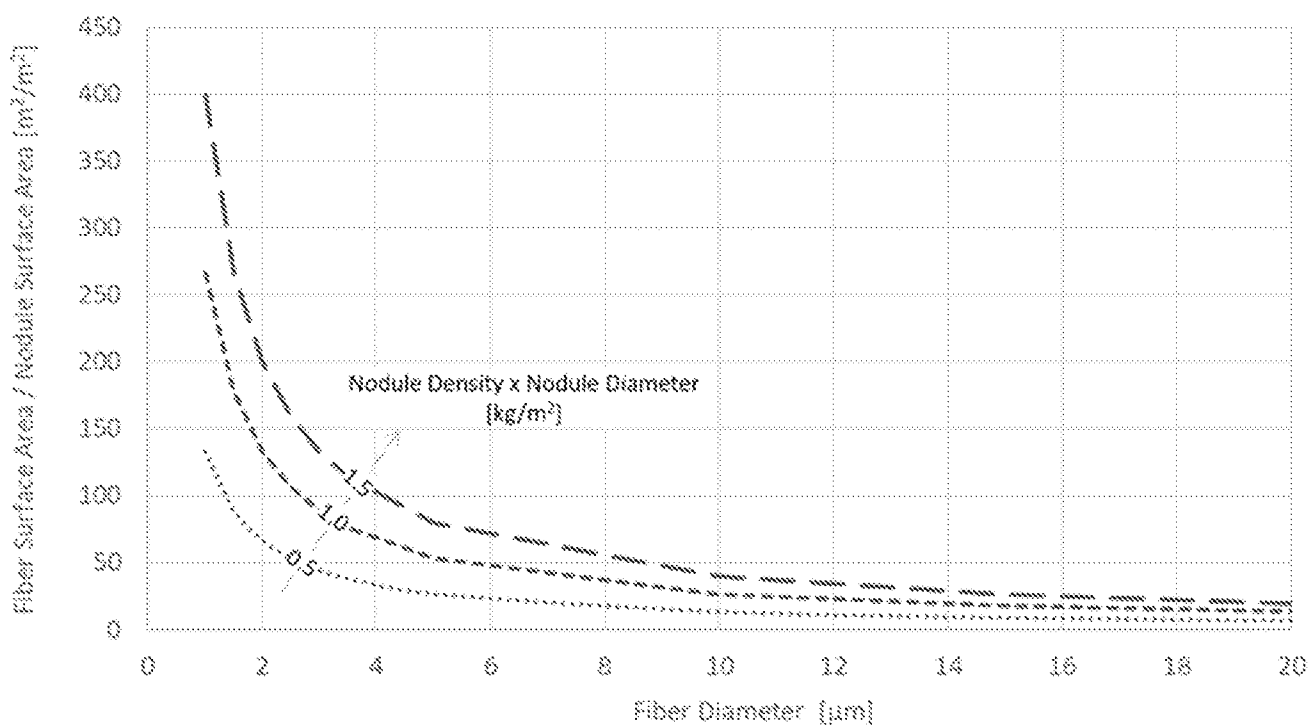


FIG. 3

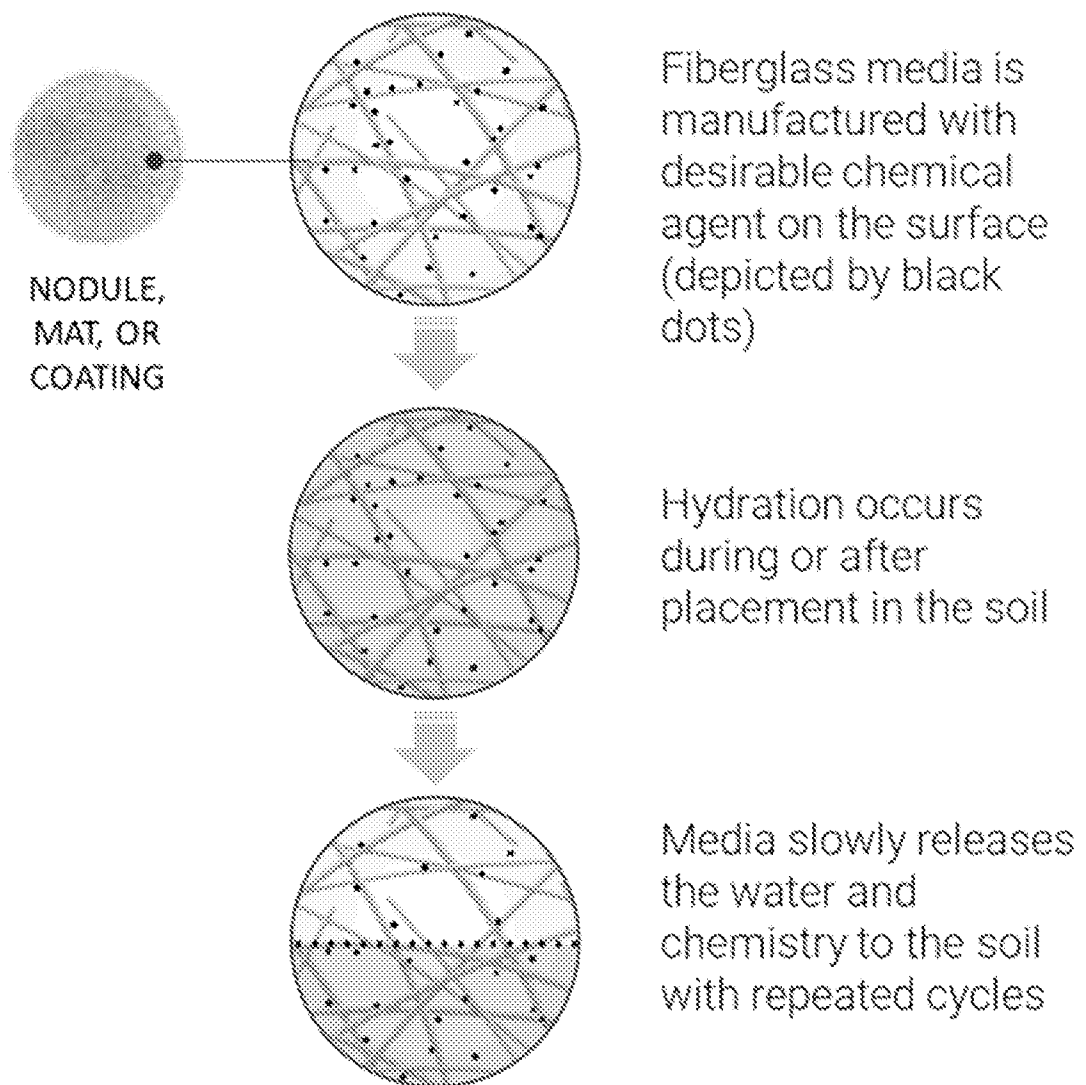
400
↓

FIG. 4

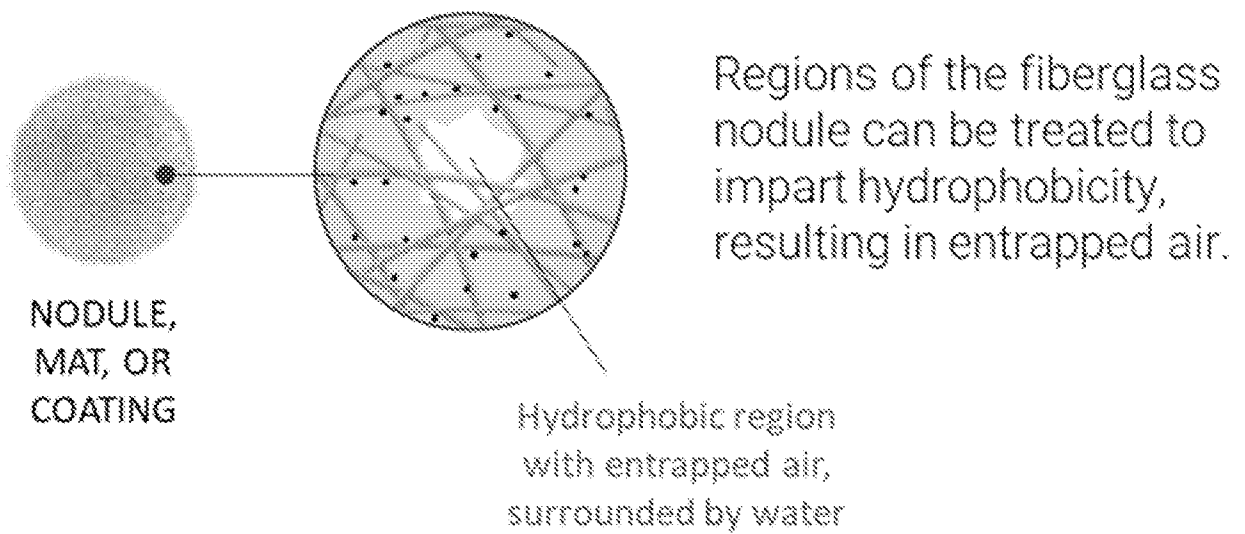
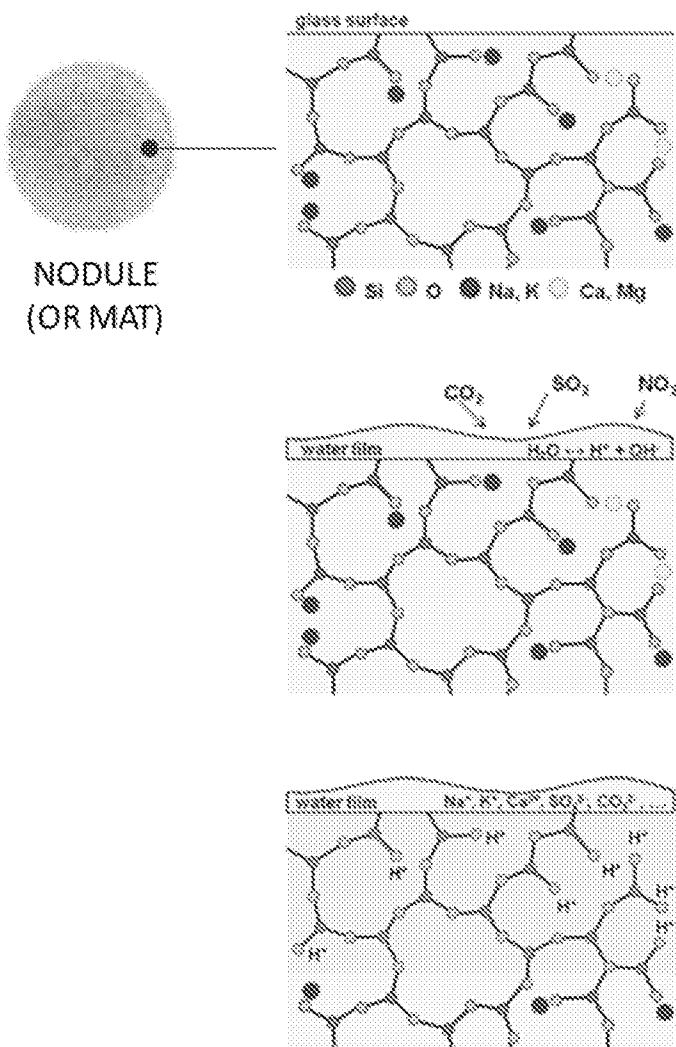
500

FIG. 5

600



- Fibers are manufactured with an un-corroded glass surface

- Hydration creates a water film, allowing ionic exchange between the H⁺ of water and the alkaline ions present in glass

- Film is rich in alkaline oxides that diffuse into the soil, providing nutrients and elevating the pH

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/40422

A. CLASSIFICATION OF SUBJECT MATTER

IPC - A01N 37/40; C05F 11/10; C05F 5/00 (2021.01)

CPC - A01N 37/40; A01N 43/16; A01N 63/32; C05F 11/00

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)

See Search History document

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

See Search History document

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 5,037,470 A (Matzen et al.) 06 August 1991 (06.08.1991) col 3, ln 15-68, col 4, ln 1-62, col 5, ln 22-31, col 6, ln 10-13, col 9, ln 29-38,	1-7, 9-11, 13, 15-23, 25-26, 35 ----- 8, 12, 14, 24, 27-33
Y	US 2009/312171 A1 (Tanaka) 17 December 2009 (17.12.2009) para [0015], para [0031], para [0055],	8, 14
Y	US 3,607,322 A (Brady et al.) 21 September 1971 (21.09.1971) col 2, ln 3-68, col 7, ln 20-22,	12
Y	US 2009/258776 A1 (Lecomte et al.) 15 October 2009 (15.10.2009) para [0001]-[0002], para [0008]	24
Y	US 2017/210677 A1 (Cool Planet Energy Systems) 27 July 2017 (27.07.2017) para [0002], para [0010]-[0011], para [0013], para [0064], para [0082], para [0162],	27-33
Y	US 5,917,110 A (Kust) 29 June 1999 (29.06.1999) col 1, ln 6-10, col 3, ln 13-57,	33
A	US 2018/230039 A1 (Jushi Group Co., Ltd) 16 August 2018 (16.08.2018) para [0009], para [0046],	8
A	US 2002/043019 A1 (Nakashima) 18 April 2002 (18.04.2002) para [0002], para [0020]	12
A	WO 2016/186906 A1 (Owens Corning Intellectual Capital, LLC) 24 November 2016 (24.11.2016) para [00100],	24

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14 September 2021

Date of mailing of the international search report

DEC 15 2021

Name and mailing address of the ISA/US

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Facsimile No. 571-273-8300

Authorized officer

Kari Rodriguez

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/40422

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

-----see supplemental box-----

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-33, 35

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 21/40422

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/094960 A1 (IPM Products Manufacturing, LLC) 06 April 2017 (06.04.2017) para [0007],	30

Bx. III (Lack of Unity)

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: Claims 1-33, and 35 is directed toward a soil amendment comprising a plurality of discrete glass fibers; wherein the glass fibers comprise about 20 wt.% to about 75 wt.% of SiO₂, about 1 wt.% to about 15 wt.% of Al₂O₃, and about 2 wt.% to about 25 wt.% of Na₂O; wherein the glass fibers have a ratio of Si to (Si+Al) greater than about 0.7; wherein the glass fibers have an average fiber diameter in the range of 1 μm to 10 μm; wherein the soil amendment has a density in the range of 10 kg/m³ to 50 kg/m³, and wherein the soil amendment is operable to increase the plant-available-water level of the soil by about 30% to about 260% at a level of about 0.5 wt.% to 3.0 wt.% of the soil amendment; and a method of promoting plant growth, the method comprising: placing a seed within a quantity of a soil; and placing the soil amendment in the soil in proximity to the seed.

Group II: Claim 34 is directed toward a system for promoting growth of a plant, the system comprising a seed corresponding to the plant, wherein an outer surface of the seed is at least partially coated with a fiberglass media, and wherein a thickness of the coating is less than a largest thickness of the seed.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features:

The invention of Group I includes the special technical feature of a soil amendment comprising a plurality of discrete glass fibers; wherein the glass fibers comprise about 20 wt.% to about 75 wt.% of SiO₂, about 1 wt.% to about 15 wt.% of Al₂O₃, and about 2 wt.% to about 25 wt.% of Na₂O; wherein the glass fibers have a ratio of Si to (Si+Al) greater than about 0.7; wherein the glass fibers have an average fiber diameter in the range of 1 μm to 10 μm; wherein the soil amendment has a density in the range of 10 kg/m³ to 50 kg/m³, and wherein the soil amendment is operable to increase the plant-available-water level of the soil by about 30% to about 260% at a level of about 0.5 wt.% to 3.0 wt.% of the soil amendment; and a method of promoting plant growth, the method comprising: placing a seed within a quantity of a soil; and placing the soil amendment in the soil, not required by Group II.

The invention of Group II includes the special technical feature of a system for promoting growth of a plant, the system comprising a seed corresponding to the plant, wherein an outer surface of the seed is at least partially coated with a fiberglass media, and wherein a thickness of the coating is less than a largest thickness of the seed, not required by Group I.

Shared Technical Features:

The inventions of Groups I-II share the technical features of promoting plant growth and a seed in proximity to a glass fiber material.

However, these shared technical features do not represent a contribution over prior art, because the shared technical feature is being anticipated by US 5,037,470 A to Matzen et al. (hereinafter "Matzen"). Matzen teaches a method of promoting plant growth (col 3, ln 15-21, The invention also relates to a method for plant growth and nutrition in accordance with which a substrate such as defined above is supplied with nitrogen), the method comprising: placing a seed in proximity to a glass fiber material (col 4, ln 40-41, As discussed above, the products of the invention can be glass fibers or glass powders; and col 9, ln 29-38, This time the culture medium comprised a cube of fibers whose composition is given in attached Table 1. These fibers were bound by means of a phenoplast binder, using 4% by weight of fibers which had a diameter of 6 micrometers. The cube formed had a density of 32 kg/m³ and the following dimensions: 100 mm x 100 mm x 60 mm. For this example, as well as for the following two examples, the cucumber seeds were sown under the same conditions as in Example 1).

As the common features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.