



(51) International Patent Classification:

A01C 1/06 (2006.01) *A01N 25/26* (2006.01)
A01H 4/00 (2006.01) *A01P 21/00* (2006.01)

(21) International Application Number:

PCT/US2015/041480

(22) International Filing Date:

22 July 2015 (22.07.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/028,001 23 July 2014 (23.07.2014) US

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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,

HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: PLANT PROPAGATION COMPRISING AN AGRICULTURAL CHEMICAL

(57) Abstract: The present invention relates to coatings for the propagation of vegetatively reproducing plants comprising an agricultural chemical. The present invention also provides a biodegradable polymer for the coating of a propagule or capsule and propagules or capsules coated in the same. The present invention also provides for an apparatus for encapsulating mini rhizomes and mini stem cuttings, which are collectively referred to herein as "capsules". The encapsulation material comprising such capsules may advantageously any plant growth medium, such as compost, potting mix, peat, hydrogel, soil, rock wool, perlite, vermiculite, foam, syrofoam, pumice, coir, expanded clay pellets etc. The resulting capsule for encapsulating such mini rhizomes or mini stem cuttings is a capsule of less than about 50 grams and is in a form ready for precision planting using minimally adapted conventional farming equipment or ready for storage until required.



PLANT PROPAGATION COMPRISING AN AGRICULTURAL CHEMICAL

The present application relates generally to the field of plant propagation. In particular, the present invention relates methods for treating plant propagation material with agricultural chemicals. The plant propagation material of the present technology generally refers to the plant
5 propagation material described herein and that described in the International Application Published under the Patent Cooperation Treaty (PCT) having the International Publication Number WO 2013/186558 A1.

Agricultural chemicals may include, for examples pesticides, safeners, fertilizers, hormones and other chemical growth agents. Pesticides, for example, include insecticides,
10 nematocides, fungicides, and herbicides. Chemical growth agents may include, for example plant growth regulators and plant growth activators.

Agricultural chemicals can be applied directly to plant propagation materials (such as seeds) prior to sowing and/or are used in foliar or furrow applications. A seed treatment is any material applied to a seed. Examples of seed treatments include, *inter alia*, pesticides, non-
15 pesticide formularies, and mixtures thereof. Non-pesticide formularies generally include material such as surfactants, humectants, fillers, and polymers that influence the treated seed characteristics. Seed treatments are generally used on a large variety of crops to control a large variety of pests. Seed treatments are commonly used to ensure uniform stand establishment by protecting against soilborne diseases and insects. Systemic seed treatments may provide an
20 alternative to traditional broadcast sprays of foliar fungicides or insecticides for certain early season airborne diseases and insects. The term "seed" or "seed treatment" as used herein is synonymous with "plant propagation material" or "plant propagation material treatment."

The term "pesticide" as used herein is intended to cover compounds active against pests which are intended to repel, kill, or control any species designated a pest including weeds,
25 insects, rodents, fungi, bacteria, or other organisms.

Agricultural chemicals are known in the art and include, for example and among others, insecticides, nematocides, fungicides, plant growth regulators, acaricides, microorganisms, bactericides and plant activators. Lists of such agricultural chemicals can be found at Alan

Wood's website, <www.alanwood.net/pesticides>, and/or in Tomlin, CDS, ed. (2009), and/or *The Pesticide Manual*, 15th Edition, British Crop Protection Counsel, (ISBN: 9781901396188).

Examples of pesticides include those selected from, for example and not for limitation, insecticides, acaricides, bactericides, fungicides, nematocides and molluscicides.

5 Suitable additions of fungicidally active ingredients are, for example and not for limitation, representatives of the following classes of active ingredients: strobilurins, triazoles, ortho-cyclopropyl-carboxanilide derivatives, phenylpyrroles, and other systemic fungicides. In one embodiment the crop protection chemical is a strobilurin fungicide such as azoxystrobin, trifloxystrobin, pyraclostrobin, picoxystrobin or fluoxastrobin. In another embodiment the crop
10 protection chemical is a fungicide such as difenoconazole, fludioxonil, thiabendazole, tebuconazole, metalaxyl, mefenoxam, myclobutanil, sedaxane, boscalid, bixafen, or penflufen.

 Suitable additions of insecticidally, acaricidally, nematocidally, or molluscicidally active ingredients are, for example and not for limitation, representatives of the following classes of active ingredients: organophosphorus compounds, nitrophenols and derivatives, formamidines,
15 triazine derivatives, nitroenamine derivatives, nitro- and cyanoguanidine derivatives, ureas, benzoylureas, carbamates, pyrethroids, chlorinated hydrocarbons and *Bacillus thuringiensis* products. In one embodiment the crop protection chemical is a neonicotinoid insecticide such as thiamethoxam, clothianidin, imidacloprid or thiacloprid. In another embodiment the crop
20 protection chemical is an insecticide such as abamectin, acetamiprid, thiodicarb, nitenpyram, dinotefuran, fipronil, lufenuron, pyriproxyfen, fluxofenim, chlorantraniliprole, cyantraniliprole, beta-cyfluthrin, lambda-cyhalothrin, fenoxycarb, diafenthiuron, pymetrozine, diazinon, disulphate, profenofos, furathiocarb, cyromazine, cypermethrin, tau-fluvalinate, tefluthrin or
Bacillus thuringiensis products.

 Plant regulators are also suitable additions in the present technology. Plant growth
25 regulators are any substances or mixtures of substances intended to alter the germination, growth, maturation, or development of plants or their produce. Plant growth regulators may be classified into subcategories including, but not limited to antiauxins (clofibric acid, 2,3,5-triiodobenzoic acid), auxins (4-CPA, 2,4-D, 2,4-DB, 2,4-DEP, dichlorprop, fenoprop, IAA, IBA,

naphthaleneacetamide, α -naphthaleneacetic acid, 1-naphthol, naphthoxyacetic acid, potassium naphthenate, sodium naphthenate, 2,4,5-T), cytokinins (2iP, benzyladenine, kinetin, zeatin), defoliants (calcium cyanamide, dimethipin, endothal, ethephon, merphos, metoxuron, pentachlorophenol, thidiazuron, tribufos), ethylene inhibitors (aviglycine, 1-methylcyclopropene), ethylene releasers (ACC, etacelasil, ethephon, glyoxime), gibberellins (gibberellic acid, gibberellins, including non-cyclopropene compounds that show gibberellin-like activity, such as, for example, helminthosporic acid, phaseolic acid, kaurenoic acid, and steviol), growth inhibitors (abscisic acid, ancymidol, butralin, carbaryl, chlorphonium, chlorpropham, dikegulac, flumetralin, fluoridamid, fosamine, glyphosine, isopyrimol, jasmonic acid, maleic hydrazide, mepiquat, piproctanyl, prohydrojasmon, propham 2,3,5-tri-iodobenzoic acid), morphactins (chlorfluren, chlorflurenol, dichlorflurenol, flurenol), growth retardants/modifiers (chlormequat, daminozide, flurprimidol, mefluidide, paclobutrazol, cyproconazole, tetcyclacis, uniconazole, ancymidol, trinexapac-ethyl, and prohexadione-CA), growth stimulators (brassinolide, forchlorfenuron, hymexazol, 2-amino-6-oxypurine derivatives, as described below, indolinone derivatives, as described below, 3,4-disubstituted maleimide derivatives, as described below, and fused azepinone derivatives, as described below). The term additionally includes other active ingredients such as benzofluor, buminafos, carvone, ciobutide, clofencet, cloxyfonac, cyclanilide, cycloheximide, epocholeone, ethychlozate, ethylene, fenridazon, heptopargil, holosulf, inabenfide, karectazan, lead arsenate, methasulfocarb, prohexadione, pydanon, sintofen, triapenthenol, and trinexapac. Preferred plant growth regulators include growth retardants, the class of gibberellins, including gibberellic acid, growth inhibitors, and growth stimulators. Particularly preferred plant growth regulators include growth retardants, particularly paclobutrazol, cyproconazole, flurprimidol, trinexapac, and uniconazole and the class of gibberellins, including gibberellic acid, especially GA₃. Particularly preferred are paclobutrazol, cyproconazole, uniconazole, trinexapac and gibberellic acid.

Agricultural chemicals may also include herbicidal safeners. Suitable safeners can be benoxacor, cloquintocet-mexyl, cyometrinil, cyprosulfamide, dichlormid, dicyclonon, dietholate, fenchlorazole-ethyl, fenclorim, flurazole, fluxofenim, furilazole and the corresponding R isomer, isoxadifen-ethyl, jiecaowan, jiecaoxi, mefenpyr-diethyl, mephenate, naphthalic anhydride,

oxabetrinil, TI-35, and 2-methoxy-*N*-[[4-[[[(methylamino)carbonyl]amino]phenyl]sulfonyl]-benzamide.

The safeners of the compound of formula I may also be in the form of esters or salts, as mentioned e.g. in The e-Pesticide Manual, version 5.2 (BCPC), 2011. The reference to
5 cloquintocet-mexyl also applies to cloquintocet, and the reference to fenchlorazole-ethyl also applies to fenchlorazole, etc.

Example of microorganisms include those, such as, mycorrhiza, rhizobia, *bacillus* spp., *trichoderma* spp., and *pasteuria* spp..

BACKGROUND

10 Recently, there has been much interest in alternative energy sources that can reduce our reliance on traditional energy sources such as coal, oil and nuclear power. One such alternative energy source is bio-fuels, which is fuel derived from crops (energy crops) which can be burned to produce heat and electricity or treated with enzymes to produce sugars that can be used to produce ethanol or hydrogen.

15 Miscanthus is an example of a perennial grass that has been identified as an energy crop due to its high biomass yields. Miscanthus is a seed-bearing grass but the hybrid *M. x giganteus* is a triploid which is therefore sterile and does not produce seed. It can therefore only be multiplied by vegetative means which has severely restricted its commercial introduction. The main concern with seeded varieties of Miscanthus is their potential to become invasive, however
20 the alternative to seeded varieties is to rely on vegetative propagation which is largely inefficient. Conventional means for the vegetative propagation of Miscanthus involves planting rhizome cuttings produced from dedicated multiplication crops, rhizomes being underground stems. These conventional rhizomes are uneven in shape and can often have numerous root hairs and adventitious roots making them difficult to process using conventional farming equipment and
25 difficult to store and handle due to the tangling of the root hairs and due to their large, uneven and bulky nature. Rhizome cuttings are obtained from these "root complexes", which are usually about 12-15cm long and weigh about 50g including the surrounding soil. Although these rhizomes look robust, they are rather sensitive to dehydration and therefore require careful

storage and handling. The aforementioned factors make the multiplication of Miscanthus relatively expensive compared to other crops. For example, under typical growing conditions in Europe, the multiplication ratio of Miscanthus rhizomes is around 3-5 fold in one growing season, meaning that one rhizome will produce a maximum of five rhizomes after one year's growth. This is in contrast to cereals with a multiplication ratio of up to 80 fold and oilseed rape which has a multiplication rate of over 5,000 fold. Similarly, the costs of planting conventional Miscanthus rhizomes are also high compared with the costs of cleaning, processing and planting seeded crops.

Many of the crops (perennial grasses) required for producing feedstock for fuel, feed and fiber do not possess rhizomes at all or not in sufficient quantities and therefore require stem propagation. However, similar problems exist with plant propagation based on stem cuttings. For example, sugarcane is an economically important crop for sugar production and for bio-fuel production, but production of sugarcane is labor-intensive and reliant on the use of specialist machinery. Cultivation of sugarcane involves a fairly lengthy process of about 2 years for the production of cane seed using micro-propagation techniques, followed by testing and breeding to develop new sugarcane cultivars. With high disease pressure, it can take up to five years for new cultivars to reach the market. The multiplication of sugarcane from seed cane then begins, a process which typically takes about 3 years before commercial production can begin. Typically, about 20% of the total growing area is reserved for multiplication, meaning that about 20% of the land is tied up for at least 3 years, if not continuously, for successive cycles of multiplication. The multiplication ratios over the 3 year period are also relatively inefficient showing around an 8-fold increase.

One of the major obstacles preventing wider cultivation of sugar cane and Miscanthus and other such crops is the inefficient propagation discussed above due, at least in-part, to its vegetative means for reproduction. There therefore remains a need for increased efficiency and production of vegetative propagules.

DETAILED DESCRIPTION OF THE INVENTION

The efficiency gains described in WO 2013/186658 give an improvement, depending on the plant in question, of between about 50-fold to about 200-fold compared to the prior art methods, which may show, for example, an improvement of about seven-fold compared to
5 conventional techniques.

The terms "plantlet", "plug plant" and "bare root cutting" are used interchangeably herein and are taken to mean small plants produced following known micro-propagation and multiplication techniques. The size of the plantlet will vary depending on the plant being propagated, and a skilled person will have at his or her disposal suitable means for generating
10 plantlets from any given plant. In the case of Miscanthus, for example, the plantlets are typically in the range of at least 2-5cm in length.

The term "rhizome" as used herein is used in its conventional sense to refer to an underground stem of a plant, which typically produces roots and shoots. The term "rhizomatous" plant as used herein refers to any plant capable of producing a rhizome. The term "mini-rhizome"
15 is a term known in the art and refers to a whole rhizome from any given plant species which is about 10% of the size of a typical whole rhizome for that plant species, preferably about 5% of the size of a typical whole rhizome for that plant species. For example, a typical whole rhizome from Miscanthus is about 50g in weight and between about 12 to 15 cm in length, whereas a mini-rhizome from the same plant species is typically about 5g in weight, preferably about 4g or
20 3g or 2g in weight and between about 2 to 5 cm in length, preferably between about 1 to 2 cm in length.

The term "stem cutting" as used herein is used in its conventional sense where a piece of any given parent plant is removed and encouraged to grow as an independent plant by placing the removed plant piece on a suitable growth medium, such as one or more of the following: soil,
25 compost, potting mix, rock wool, perlite, vermiculite, coir, expanded clay pellets, hydrogel and water, which facilitates the growth of new roots and/or stems, which enable the stem cutting to become a plant independent of the source plant. The term "mini stem cutting" as used herein refers to a stem cutting from any given plant species which is about 10% of the size of a typical

stem cutting for that plant species, preferably about 5% of the size of a typical stem cutting for that plant species. For example, a typical stem cutting from *Arundo donax* is about 100g in weight and between about 40 to 60cm in length, whereas a mini stem cutting from the same plant species is typically about 10g in weight, preferably about 4g or 3g or 2g in weight and between
5 about 2 to 4cm in length. In the case of sugarcane, a conventional stem cutting is 30 to 40 cm in length, whereas a mini stem cutting from the same sugarcane species is typically between about 2 to 4cm in length.

Micropropagation and Multiplication

Micro-propagation is a standard, well known horticultural technique used for the rapid
10 bulking up of large numbers of plantlets. Micro-propagation described in stage (i) of the method aims at producing large quantities of material suitable for entering stage (ii) of the method. The micro-propagation techniques used may be any conventional micro-propagation technique, such as tissue culture or rooted stem cuttings.

The micro-propagation results in plantlets which are ready to be multiplied, typically in a
15 greenhouse. Conventional means for plant multiplication are used for this stage of the method. The greenhouse multiplication of the plantlets typically results in a 20-30 fold increase every 2-3 months. In the case of *Miscanthus* and *Arundo donax*, the micropropagation and multiplication results in every one plant generating about 10 plants in about an 8 week cycle; those 10 plants can then in turn generate about 100 plants in a further cycle of about 8 weeks.

20 Advantageously, micro-propagation followed by multiplication can result in every 1 (one) plant generating 10 million plantlets, plug plants or bare root cuttings (which refer to individual stems which can be separated from larger plants) in less than 6 months or in less than 8 months or in less than 10 months or in less than 12 months or in less than 14 months or in less than 16 months or in less than 18 months, depending on the plant in question.

25 Advantageously, micro-propagation followed by multiplication results in a decreased rate of mutation compared to conventional micropropagation, which again contributes to the overall efficiency gains brought about by performing the methods of the invention.

According to the present invention, there is therefore provided a method for the propagation of a vegetatively reproducing plant, comprising the steps of:

(i) micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication to produce plantlets;

5 (ii) contacting the plantlets or a part thereof from step (i) with at least one plant hormone and growing the plantlets and harvesting mini rhizomes or mini stem cuttings therefrom;

(iii) substantially encapsulating the mini rhizomes or mini stem cuttings produced from step (ii) in a plant growth medium; and

10 (iv) treating the plant growth medium with an agricultural chemical prior to, during, or after, the encapsulation of step (iii).

The present invention also provides encapsulated mini rhizomes and encapsulated mini stem cuttings comprising an agricultural chemical, which are collectively referred to herein as "encapsulated propagules".

15 The present invention also provides a biodegradable polymer for the coating of a propagule or capsule and propagules or capsules coated in the same.

20 The present invention also provides for an apparatus for encapsulating mini rhizomes and mini stem cuttings, which are collectively referred to herein as "capsules". The encapsulation material comprising such capsules may advantageously any plant growth medium, such as compost, potting mix, peat, hydrogel, soil, rock wool, perlite, vermiculite, foam, syrofoam, pumice, coir, expanded clay pellets etc. The resulting capsule for encapsulating such mini rhizomes or mini stem cuttings is a capsule of less than about 50 grams and is in a form ready for precision planting using minimally adapted conventional farming equipment or ready for storage until required.

The encapsulation material may also comprise compounds, such as plant hormones (such as cytokinins or auxins), plant growth regulators, mycorrhiza, endophytic organisms, symbiotic organisms or other beneficial organisms, surfactants, gels, organic and inorganic nutrients, water, polymer and organic-based super absorbents and stabilization compounds etc. to aid the storage
 5 of the mini rhizomes and mini stem cuttings so as to prevent any loss of material due to deterioration and to enhance the survival and performance of the propagules once they are planted in the field.

The encapsulation material may also comprise pesticides include those selected from, for example and not for limitation, insecticides, acaricides, bactericides, fungicides, nematocides and
 10 molluscicides. The encapsulation material may also comprise chemical growth agents may include, for example plant growth regulators and plant growth activators.

The term “insecticide” as used herein means a compound that controls or modifies the growth of insects. The term “insecticidally effective amount” means the quantity of such a compound or combination of such compounds that is capable of killing, controlling, or infecting
 15 insects, retarding the growth or reproduction of insects, reducing an insect population, and/or reducing damage to plants caused by insects.

Suitable insecticide of the following chemicals classes may include benzoylureas, carbamates, chloronicotinyls, diacylhydrazines, diamides, fiproles, macrolides, nitroimines, nitromethylenes, organochlorines, organophosphates, organosilicons, organotinins,
 20 phenylpyrazoles, phosphoric esters, pyrethroids, spinosyns, tetramic acid derivatives and tetrionic acid derivatives.

Suitable, specific, insecticides may include, but are not limited to, for example: 4-[(5S)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-(thietan-3-yl)benzamide, 4-[(5R)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-(thietan-3-yl)benzamide, 4-[(5S)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-(cis-1-oxo-thietan-3-yl)benzamide, 4-[(5R)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-(cis-1-oxo-thietan-3-yl)benzamide, 4-[(5S)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-(trans-1-oxo-thietan-3-yl)benzamide, 4-[(5R)-5-

(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-(trans-1-oxo-thietan-3-yl)benzamide, 4-[(5S)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-N-(1,1-dioxothietan-3-yl)-2-methyl-benzamide, 4-[(5R)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-N-(1,1-dioxothietan-3-yl)-2-methyl-benzamide, 4-[(5S)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-[2-oxo-2-(2,2,2-trifluoroethylamino)ethyl]benzamide, 4-[(5R)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-methyl-N-[2-oxo-2-(2,2,2-trifluoroethylamino)ethyl]benzamide, 5-[(5S)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-(1,2,4-triazol-1-yl)benzonitrile, 5-[(5R)-5-(3,5-dichlorophenyl)-5-(trifluoromethyl)-4H-isoxazol-3-yl]-2-(1,2,4-triazol-1-yl)benzonitrile, abamectin, acephate, acequinocyl, acetamiprid, acetoprole, acrinathrin, alanycarb, aldicarb, aldoxycarb, aldrin, allethrin, allyxycarb, alphamethrin, aminocarb, amitraz, anisopliae, azadirachtin, azamethiphos, azinphos-ethyl, azinphos-methyl, azocyclotin, , *Bacillus thuringiensis*, bendiocarb, benfuracarb, bensultap, beta-cyfluthrin, bifenazate, bifenthrin, binapacryl, bioallethrin, bioallethrin (S)-cyclopentenyl isomer, bioethanomethrin, biopermethrin, bioresmethrin, bromfenvinfos, bromophos, bromophos-ethyl, bufencarb, buprofezin, bistrifluron, butacarb, butathiofos, butocarboxim, butoxycarboxim, byfenthrin, cadusafos, calcium polysulphide, camphechlor, carbaryl, carbofuran, carbophenothion, carbosulfan, cartap, chlordane, chlorethoxyfos, chlorfenapyr, chlorfenvinphos, chlorfluazuron, chlormephos, chloropicrin, chlorpyrifos, chromafenozide, clothianidin, cis-cypermethrin, cis-resmethrin, cis-permethrin, clocythrins, cloethocarb, clofentezine, coumaphos, cryolite, cyanofenphos, cyanophos, cycloprothrin, cyenopyrafen, cyflumetofen, cyfluthrin, beta-cyfluthrin, cyhalothrin, cyhexatin, alpha- cyphenothrin, cypermethrin, cyphenothrin, cyromazine, dazomet, DDT, decamethrin, deltamethrin, demeton, demeton-S-methyl, demeton-S-methylsulphone, deoxabenzofos, diafenthiuron, dialifos, diazacarb, diazinon, dichlofenthion, dichlorvos, dicrotophos, diflubenzuron, dimethoate, dimethylvinphos, dimetilan, dinobuton, dinocap, dinoseb, dinotefuran, diofenolan, dioxabenzofos, disulfoton, eflusilanat, emamectin, emamectin benzoate, empenthrin, endosulfan, EPN, epofenonane, esfenvalerate, ethiofencarb, ethion, ethiprole, ethoate, ethoprophos, etofenprox, etoxazole, etrimfos, famphur, fenamiphos, fenazaquin, fenbutatin oxide, fenfluthrin, fenitrothion, fenobucarb, fenothiocab, fenoxycarb, fenpropathrin, fenpyrithrin, fenpyroximate, fensulfothion, fenthion, fenvalerate, fipronil, flonicamid, fluacrypyrim, fluazuron, flubendiamide, flubrocycythrinate, flucycloxuron,

flucythrinate, flufenoxuron, flufenprox, flumethrin, flupyrzofos, fluvalinate, fonofos, formetanate, formothion, fosmethilan, fosthiazate, fubfenprox, fufenozide, furathiocarb, gamma-cyhalothrin, halofenozide, heptachlor, heptenophas, heptenophos, hexaflumuron, hexythiazox, hydramethylnon, hydrogen cyanide, hydroprene, imicyafos, imidacloprid, imidaclothiz, imiprothrin, indoxacarb, iodfenphos, iprobenfos, IPSP, isazofos, isofenphos, isoprocab, isopropyl, isoprothiolane, isoxathion, ivermectin, kadethrin, kinoprene, lambda-cyhalothrin, lepimectin, lindane, lufenuron, malathion, mecarbam, mephosfolan, mercurous chloride, metaflumizone, metam, metam-sodium, metarthizium, methacrifos, methamidophos, methidathion, methiocarb, methomyl, methoprene, methoxychlor, methoxyfenozide, methyl bromide, methyl isothiocyanate, metholcarb, metofluthrin, mevinphos, milbemectin, monocrotophos, naled, nicotine, nitenpyram, nithiazine, novaluron, noviflumuron, omethoate, O-salicylate, oxamyl, oxydemeton-methyl, parathion, parathion-methyl, penfluron, permethrin, pentachlorophenol, petroleum oils, phenothrin, phenthoate, phorate, phosalone, phosmet, phosphamidon, phosphine, phosphocarb, phoxim, pirimicarb, pirimiphos, pirimiphos-ethyl, pirimiphos-methyl, poxim, prallethrin, profenofos, profluthrin, promecarb, propaphos, propargite, propetamphos, propoxur, prothiofos, prothoate, protrifenbute, pymetrozine, pyraclofos, pyrafluprole, pyrethrin, pyrethrum, pyridaben, pyridafenthion, pyridathion, pyrifluquinazon, pyrimidifen, pyriprole, pyriproxifen, quinalphos, quinomethionate, resmethrin, rotenone, silafluofen, sebufos, sodium fluoride, sodium hexafluorosilicate, spinosad, spinetoram, spirotetramat, sulfotep, sulfuryl fluoride, sulprofos, tar oils, taufluvalinate, tebufenozide, tebufenpyrad, tebupirimfos, teflubenzuron, tefluthrin, temephos, terallethrin, terbufos, tetrachlorvinphos, tetradifon, tetramethrin, thiacloprid, thiamethoxam, thiocylam, thiodicarb, thiofanox, thiometon, thiosultap-sodium, tralomethrin, transfluthrin, triazophos, trichlorphon, triflumuron, trimethacarb, triprene, tolfenpyrad, vamidothion, Verticillium lacanii, vaniliprole, and xylylcarb.

The term “fungicide” as used herein means a compound that controls, modifies, or prevents the growth of fungi. The term “fungicidally effective amount” means the quantity of such a compound or combination of such compounds that is capable of producing an effect on the growth of fungi. Controlling or modifying effects include all deviation from natural

development, such as killing, retardation and the like, and prevention includes barrier or other defensive formation in or on a plant to prevent fungal infection.

Suitable fungicides of the following chemicals classes may include acycloamino acid fungicides, aliphatic nitrogen fungicides, amide fungicides, anilide fungicides, antibiotic
 5 fungicides, aromatic fungicides, arsenical fungicides, aryl phenyl ketone fungicides, benzamide fungicides, benzanilide fungicides, benzimidazole fungicides, benzothiazole fungicides, botanical fungicides, bridged diphenyl fungicides, carbamate fungicides, carbanilate fungicides, conazole fungicides, copper fungicides, dicarboximide fungicides, , dinitrophenol fungicides, dithiocarbamate fungicides, dithiolane fungicides, furamide fungicides, furanilide fungicides,
 10 hydrazide fungicides, imidazole fungicides, mercury fungicides, morpholine fungicides, organophosphorous fungicides, organotin fungicides, oxathiin fungicides, oxazole fungicides, phenylsulfamide fungicides, polysulfide fungicides, pyrazole fungicides, pyridine fungicides, pyrimidine fungicides, pyrrole fungicides, quaternary ammonium fungicides, quinoline fungicides, quinone fungicides, quinoxaline fungicides, strobilurin fungicides, sulfonanilide
 15 fungicides, thiadiazole fungicides, thiazole fungicides, thiazolidine fungicides, thiocarbamate fungicides, thiophene fungicides, triazine fungicides, triazole fungicides, triazolopyrimidine fungicides, urea fungicides, valinamide fungicides, and zinc fungicides.

Suitable, specific, fungicides may include, but are not limited to, for example: (E)-N-methyl-2-[2-(2,5-dimethylphenoxy)methyl]phenyl]-2-methoxy-iminoacetamide, 4-bromo-2-
 20 cyano-N,N-dimethyl-6-trifluoromethylbenzimidazole-1-sulphonamide, a-[N-(3-chloro-2,6-xylyl)-2-methoxyacetamido]-γ-butyrolactone, 4-chloro-2-cyano-N,N-dimethyl-5-p-tolylimidazole-1-sulfonamide, N-allyl-4,5,-dimethyl-2-trimethylsilylthiophene-3-carboxamide, N-(1-cyano-1,2-dimethylpropyl)-2-(2,4-dichlorophenoxy)propionamide, N-(2-methoxy-5-pyridyl)-cyclopropane carboxamide, (+,-)-cis-1-(4-chlorophenyl)-2-(1H-1,2,4-triazol-1-yl)-
 25 cycloheptanol, 2-(1-tert-butyl)-1-(2-chlorophenyl)-3-(1,2,4-triazol-1-yl)-propan-2-ol, 2',6'-dibromo-2-methyl-4-trifluoromethoxy-4'-trifluoromethyl-1,3-thiazole-5-carboxanilide, 1-imidazolyl-1-(4'-chlorophenoxy)-3,3-dimethylbutan-2-one, methyl (E)-2-[2-[6-(2-cyanophenoxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(2-thioamidophenoxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(2-
 30 fluorophenoxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(2,6-

difluorophenoxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[3-(pyrimidin-2-yloxy)phenoxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[3-(5-methylpyrimidin-2-yloxy)-phenoxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[3-(phenyl-sulphonyloxy)phenoxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[3-(4-nitrophenoxy)phenoxy]phenyl]-3-methoxyacrylate,
 5 methyl (E)-2-[2-phenoxyphenyl]-3-methoxyacrylate, methyl (E)-2-[2-(3,5-dimethyl-benzoyl)pyrrol-1-yl]-3-methoxyacrylate, methyl (E)-2-[2-(3-methoxyphenoxy)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(2-phenylethen-1-yl)-phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(3,5-dichlorophenoxy)pyridin-3-yl]-3-methoxyacrylate, methyl (E)-2-(2-(3-(1,1,2,2-tetrafluoroethoxy)phenoxy)phenyl)-3-methoxyacrylate, methyl (E)-2-(2-[3-(alpha-
 10 hydroxybenzyl)phenoxy]phenyl)-3-methoxyacrylate, methyl (E)-2-(2-(4-phenoxy)pyridin-2-yloxy)phenyl)-3-methoxyacrylate, methyl (E)-2-[2-(3-n-propyloxy-phenoxy)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(3-isopropyloxyphenoxy)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[3-(2-fluorophenoxy)phenoxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(3-ethoxyphenoxy)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(4-tert-butyl-pyridin-2-
 15 yloxy)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[3-(3-cyanophenoxy)phenoxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(3-methyl-pyridin-2-yloxymethyl)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(2-methyl-phenoxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(5-bromo-pyridin-2-yloxymethyl)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(3-(3-iodopyridin-2-yloxy)phenoxy)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(2-chloropyridin-
 20 3-yloxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E), (E)-2-[2-(5,6-dimethylpyrazin-2-ylmethyloximinomethyl)phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(6-methylpyridin-2-yloxy)pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E), (E)-2-[2-(3-methoxyphenyl)methyloximinomethyl]-phenyl]-3-methoxyacrylate, methyl (E)-2-[2-(6-(2-azidophenoxy)-pyrimidin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E), (E)-2-[2-[6-
 25 phenylpyrimidin-4-yl)-methyloximinomethyl]phenyl]-3-methoxyacrylate, methyl (E), (E)-2-[2-[(4-chlorophenyl)-methyloximinomethyl]-phenyl]-3-methoxyacrylate, methyl (E)-2-[2-[6-(2-n-propylphenoxy)-1,3,5-triazin-4-yloxy]phenyl]-3-methoxyacrylate, methyl (E), (E)-2-[2-[(3-nitrophenyl)methyloximinomethyl]phenyl]-3-methoxyacrylate, 3-chloro-7-(2-aza-2,7,7-trimethyl-oct-3-en-5-ine), 2,6-dichloro-N-(4-trifluoromethylbenzyl)-benzamide, 3-iodo-2-
 30 propinyl alcohol, 4-chlorophenyl-3-iodopropargyl formal, 3-bromo-2,3-diiodo-2-propenyl ethylcarbamate, 2,3,3-triiodoallyl alcohol, 3-bromo-2,3-diiodo-2-propenyl alcohol, 3-iodo-2-

propinyl n-butylcarbamate, 3-iodo-2-propinyl n-hexylcarbamate, 3-iodo-2-propinyl cyclohexylcarbamate, 3-iodo-2-propinyl phenylcarbamate; phenol derivatives, such as tribromophenol, tetrachlorophenol, 3-methyl-4-chlorophenol, 3,5-dimethyl-4-chlorophenol, phenoxyethanol, dichlorophene, o-phenylphenol, m-phenylphenol, p-phenylphenol, 2-benzyl-4-chlorophenol, 5-hydroxy-2(5H)-furanone; 4,5-dichlorodithiazolinone, 4,5-benzodithiazolinone, 4,5-trimethylenedithiazolinone, 4,5-dichloro-(3H)-1,2-dithiol-3-one, 3,5-dimethyl-tetrahydro-1,3,5-thiadiazine-2-thione, N-(2-p-chlorobenzoyl-ethyl)-hexaminium chloride, acibenzolar, acypetacs, alanycarb, albendazole, aldimorph, allicin, allyl alcohol, ametoctradin, amisulbrom, amobarn, ampropylfos, anilazine, asomate, aureofungin, azaconazole, azafendin, azithiram, azoxystrobin, barium polysulfide, benalaxyl, benalaxyl-M, benodanil, benomyl, benquinox, bentalluron, benthialdicarb, benthiazole, benzalkonium chloride, benzamacril, benzamorf, benzohydroxamic acid, berberine, bethoxazin, biloxazol, binapacryl, biphenyl, bitertanol, bithionol, bixafen, blasticidin-S, boscalid, bromothalonil, bromuconazole, bupirimate, buthiobate, butylamine, calcium polysulfide, captafol, captan, carbamorph, carbendazim, carbendazim chlorhydrate, carboxin, carpropamid, carvone, CGA41396, CGA41397, chinomethionate, chitosan, chlobenthiazole, chloraniformethan, chloranil, chlorfenazole, chloroneb, chloropicrin, chlorothalonil, chlorozolate, chlozolate, climbazole, clotrimazole, clozylacon, copper containing compounds such as copper acetate, copper carbonate, copper hydroxide, copper naphthenate, copper oleate, copper oxychloride, copper oxyquinolate, copper silicate, copper sulphate, copper tellate, copper zinc chromate and Bordeaux mixture, cresol, cufraneb, cuprobam, cuprous oxide, cyazofamid, cyclofuramid, cycloheximide, cyflufenamid, cymoxanil, cypendazole, cyproconazole, cyprodinil, dazomet, debacarb, decafentin, dehydroacetic acid, di-2-pyridyl disulphide 1, 1'-dioxide, dichlofluanid, diclomezine, dichlone, dicloran, dichlorophen, dichlozoline, diclobutrazol, diclocymet, diethofencarb, difenoconazole, difenzoquat, diflumetorim, O, O-di-iso-propyl-S-benzyl thiophosphate, dimefluazole, dimetachlone, dimetconazole, dimethomorph, dimethirimol, diniconazole, diniconazole-M, dinobuton, dinocap, dinocton, dinopenton, dinosulfon, dinoterbon, diphenylamine, dipyrithione, disulfiram, ditalimfos, dithianon, dithioether, dodecyl dimethyl ammonium chloride, dodemorph, dodicin, dodine, doguadine, drazoxolon, edifenphos, enestroburin, epoxiconazole, etaconazole, etem, ethaboxam, ethirimol, ethoxyquin, ethilicin, ethyl (Z)-N-benzyl-N ([methyl (methyl-thioethylideneamino-oxycarbonyl) amino] thio)-β-alaninate, etridiazole, famoxadone,

fenamidone, fenaminosulf, fenapanil, fenarimol, fenbuconazole, fenfuram, fenhexamid, fenitropan, fenoxanil, fempiclonil, fenpropidin, fenpropimorph, fenpyrazamine, fentin acetate, fentin hydroxide, ferbam, ferimzone, fluazinam, fludioxonil, flumetover, flumorph, flupicolide, fluopyram, fluoroimide, fluotrimazole, fluoxastrobin, fluquinconazole, flusilazole, flusulfamide,

5 flutanil, flutolanil, flutriafol, folpet, formaldehyde, fosetyl, fuberidazole, furalaxyl, furametpyr, furcarbanil, furconazole, furfural, furmecyclox, furophanate, glyodin, griseofulvin, guazatine, halacrinat, hexa chlorobenzene, hexachlorobutadiene, hexachlorophene, hexaconazole, hexylthiofos, hydrargaphen, hydroxyisoxazole, hymexazole, imazalil, imazalil sulphate, imibenconazole, iminoctadine, iminoctadine triacetate, inezin, iodocarb, ipconazole, iprobenfos,

10 iprodione, iprovalicarb, isopropanyl butyl carbamate, isoprothiolane, isopyrazam, isotianil, isovalledione, izopamfos, kasugamycin, kresoxim-methyl, LY186054, LY211795, LY248908, mancozeb, mandipropamid, maneb, mebenil, mecarbinzid, mefenoxam, mepanipyrim, mepronil, mercuric chloride, mercurous chloride, meptyldinocap, metalaxyl, metalaxyl-M, metam, metazoxolon, metconazole, methasulfocarb, methfuroxam, methyl bromide, methyl iodide,

15 methyl isothiocyanate, metiram, metiram-zinc, metominostrobin, metrafenone, metsulfovax, milneb, moroxydine, myclobutanil, myclozolin, nabam, natamycin, neosozin, nickel dimethyldithiocarbamate, nitrostyrene, nitrothal-iso- propyl, nuarimol, octhilinone, ofurace, organomercury compounds, orysastrobin, osthol, oxadixyl, oxasulfuron, oxine-copper, oxolinic acid, oxpoconazole, oxycarboxin, parinol, pefurazoate, penconazole, pencycuron, penflufen,

20 pentachlorophenol, penthiopyrad, phenamacril, phenazin oxide, phosdiphen, phosetyl-Al, phosphorus acids, phthalide, picoxystrobin, piperalin, polycarbamate, polyoxin D, polyoxrim, polyram, probenazole, prochloraz, procymidone, propamidine, propamocarb, propiconazole, propineb, propionic acid, proquinazid, prothiocarb, prothioconazole, pyracarbolid, pyraclostrobin, pyrametrostrobin, pyraoxystrobin, pyrazophos, pyribencarb, pyridinitril,

25 pyrifenoxy, pyrimethanil, pyriofenone, pyroquilon, pyroxychlor, pyroxyfur, pyrrolnitrin, quaternary ammonium compounds, quinacetol, quinazamid, quinconazole, quinomethionate, quinoxifen, quintozone, rabenzazole, santonin, sedaxane, silthiofam, simeconazole, sipconazole, sodium pentachlorophenate, spiroxamine, streptomycin, sulphur, sultropen, tebuconazole, tebfloquin, tecloftalam, tecnazene, tecoram, tetraconazole, thiabendazole, thiadifluor, thicyofen,

30 thifluzamide, 2- (thiocyanomethylthio) benzothiazole, thiophanate-methyl, thioquinox, thiram, tiadinil, timibenconazole, tioxyimid, tolclofos-methyl, tolylfluanid, triadimefon, triadimenol,

triamiphos, triarimol, triazbutil, triazoxide, tricyclazole, tridemorph, trifloxystrobin, triflumazole, triforine, triflumizole, triticonazole, uniconazole, urbacide, validamycin, valifenalate, vapam, vinclozolin, zarilamid, zineb, ziram, and zoxamide.

According to the present invention, there is therefore provided a method for the
5 propagation of a vegetatively reproducing plant, comprising the steps of:

(i) contacting plantlets produced from micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication or a part thereof with at least one plant hormone and growing the plantlets and harvesting mini-rhizomes or mini stem cuttings therefrom;

10 (ii) substantially encapsulating the mini-rhizomes or mini stem cuttings produced from step (i) in a plant growth medium; and

(iii) treating the plant growth medium with an agricultural chemical prior to, during, or after, the encapsulation of step (ii).

The plantlets produced in stage (i) of the process are then subjected to hormonal
15 treatment of the plantlets with cytokinin(s) and/or auxin(s). Any one given plant hormone is applied at a rate of less than about 1000 ppm, less than about 900ppm, less than about 800ppm, less than about 700ppm, less than about 600ppm, less than about 500ppm, less than about 400ppm, less than about 300ppm, less than about 200ppm, less than about 100ppm, less than about 90ppm, less than about 80ppm, less than about 70ppm, less than about 60ppm, less than
20 about 50ppm, less than about 40ppm, less than about 30ppm, less than about 20ppm or less than about 10ppm.

The cytokinin may be selected from the group consisting of kinetin, zeatin, 6-benzylaminopurine, diphenyl urea and thidiazuron (TDZ). The auxin may be selected from the group consisting of indole-3-acetic acid (IAA), 4-chloroindole-3-acetic acid (4-CI-IAA), 2-phenylacetic acid (PAA) and indole-3-butyric acid (IBA). A combination of benzylaminopurine, TDZ and IAA is preferred in the case of Miscanthus propagation. Preferably, the
25 benzylaminopurine, TDA and IAA are each applied at a rate of less than about 1000ppm, less

than about 900ppm, less than about 800ppm, less than about 700ppm, less than about 600ppm, less than about 500ppm, less than about 400ppm, less than about 300ppm, less than about 200ppm, less than about 100ppm, less than about 90ppm, less than about 80ppm, less than about 70ppm, less than about 60ppm, less than about 50ppm, less than about 40ppm, less than about 30ppm, less than about 20ppm or less than about 10ppm. The combinations and concentrations of plant hormones may readily be optimized, if necessary, by one skilled in the art depending on the plant to be propagated.

According to a preferred feature of the present invention, after or during the hormone treatment of stage (i), but before the harvesting of mini rhizomes or mini stem cuttings, the plants may be subjected to a temporary abiotic or mechanical stress.

The abiotic stress may comprise subjecting the growing plant to any temporary environmental change compared to the normal growth conditions for the plant in question. For example, the stress may be any one or more of: (i) an osmotic stress (which may be caused by limited or excess salt or water compared to the normal levels of salt or water); (ii) a temperature stress (which may be caused by exposure of the plant to excessive heat or cold compared to normal growth conditions for the plant in question); (iii) a nutrient stress (which may be caused by a lack of nitrogen, phosphorous, sulphur etc.); or (iv) an oxidative stress. The exposure of the plants to the temporary abiotic and/or mechanical stress serves to encourage more bud formation.

The mechanical stress refers to any non-environmental stress resulting from a physical action to a plant, such as cutting parts of the plant. Preferably, the aboveground parts of the plant are cut back to a point just above a node.

Reference herein to a "temporary" stress is taken to mean exposure to a non-continuous stress, which may involve exposure of the plant to any one or more given stresses at intermittent periods. For example, the intermittent periods of stress may be 1, 2, 3, 4 or 5 or more separate occasions of exposure of the plant to a stress in between non-stress periods.

The process of contacting the plantlets with at least one plant hormone, which may or may not comprise exposure of the plants to an abiotic and/or mechanical stress, can last from

between about 12 and 24 weeks depending on the plant in question and depending on whether sufficient buds have formed.

The contacting of the plantlets to at least one plant hormone may occur before, after or during exposure of the plants to a temporary abiotic or mechanical stress. Preferred plant
5 hormones include benzylaminopurine, TDA and IAA, one or more of which may be applied at a rate of <1000ppm (less than one thousand parts per million).

Therefore, a preferred method for the propagation of a vegetatively reproducing plant comprises the steps of:

(i) contacting the plantlets produced from micro-propagation of plant material from a
10 vegetatively reproducing plant followed by multiplication or a part thereof with at least one plant hormone;

(ii) exposing the plantlets before, after or during step (i) above to an abiotic or mechanical stress;

(iii) growing the plantlets and harvesting mini rhizomes or mini stem cuttings therefrom;

15 (iv) substantially encapsulating the mini rhizomes or mini stem cuttings produced from step (iii) in a plant growth medium; and

(v) treating the plant growth medium with an agricultural chemical prior to, during, or after, the encapsulation of step (iv).

The hormone-treated plants are then grown in a field or greenhouse setting under optimal
20 growth conditions. In the case of *Arundo donax*, sugar cane, or other plants produced from stem cuttings, this growth phase may span a period of about 12 months. Shoots emerging from the new buds are removed and cut (by machine or hand) into short lengths resulting in mini stem cuttings.

In the case of *Miscanthus*, this growth phase may span a period of about 12 months or until the size of the plant is about 20cm in length and the rhizomes are between about 2 to 5g in weight and/or until the bud capacity of the rhizomes is around 20 buds per rhizome.

5 The hormonal treatment followed by the growth cycle in the field or greenhouse leads to the generation of mini rhizomes from the plantlets of stage (i).

Advantageously, in the case of *Miscanthus* propagation, the mini rhizomes are around 2 to 5g in weight compared to the about 30 to 50g weight of rhizomes produced by conventional production methods.

10 The small, uniformly-shaped mini rhizomes or mini stem cuttings resulting from stage (ii) of the method are then in a form ready for encapsulation. The encapsulation process may advantageously be automated. The combined automation of the shredding (in the case of rhizomatous plants) and encapsulation processes will contribute towards further efficiency gains.

15 According to a preferred feature of the present invention, the encapsulated material is then substantially coated in a biodegradable polymer, which preferably has a melting point of between 30 to 65°C.

Preferably the polymer is selected from one or more of wax, polyester, petroleum-based paraffin or plastic, polysaccharide or any plant-based plastic.

20 Preferably, the coating also comprises a fiber component comprising at least up to 20%, at least up to 30%, at least up to 40%, at least up to 50%, at least up to 60%, at least up to 70%, at least up to 80% or at least up to 90% of the coating.

The fiber may be one or more of the following: (i) fiber from agricultural biomass residue (for example, cereal straw, cotton, peanut hulls, soy straw, corn fodder); (ii) dedicated fiber (for example, *Miscanthus*, *Arundo*, sugarcane, bagasse, hemp, Kenaf); (iii) processed fibers (for example, paper, recycled cardboard, wood flour, wood saw dust); and (iv) artificial or processed
25 fibers (for example, nylon, polyester, cotton).

The coating may also comprise fungicides, insecticides, nematocides, endophytic organisms, plant nutrients, hormones, dyes or other means for identification, such as barcodes or transponders or the like, to aid sorting.

5 The coating is applied to the encapsulated propagule by dipping (at least once) or by co-extrusion or by thermally forming the coating around the propagule. The coating covering the propagule is less than 1 mm (millimeter) thick, preferably less than 0.5mm thick.

10 In another aspect of the present technology, the agricultural chemical may be applied to the capsule after the coating is applied. Therefore, an agricultural chemical may present within or on the encapsulation material only, applied to the coating only, or applied to the encapsulation material and the coating. Such option gives the flexibility of utilizing agricultural chemicals where best suited based on the chemical properties, desired effect, and pest to be controlled.

According to a preferred embodiment of the present technology, there is therefore provided a method for the propagation of a vegetatively reproducing plant, comprising the steps of:

15 (i) contacting the plantlets produced from micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication or a part thereof with at least one plant hormone and growing the plantlets and harvesting mini-rhizomes or mini stem cuttings therefrom;

20 (ii) substantially encapsulating the mini-rhizomes or mini stem cuttings produced from step (i) in a plant growth medium;

(iii) treating the plant growth medium with an agricultural chemical prior to, during, or after, the encapsulation of step (ii).

(iv) substantially coating the encapsulated mini rhizome or mini stem cutting of step (iii) in a biodegradable polymer.

25 According to a further preferred embodiment of the present invention, there is provided a method for the propagation of a vegetatively reproducing plant, comprising the steps of:

(i) micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication to produce plantlets;

(ii) contacting the plantlets or a part thereof from step (i) with at least one plant hormone;

5 (iii) exposing the plantlets before, after or during step (ii) above to an abiotic or mechanical stress;

(iv) growing the plantlets and harvesting mini rhizomes or mini stem cuttings therefrom;

(v) substantially encapsulating the mini rhizomes or mini stem cuttings produced from step (iv) in a plant growth medium;

10 (vi) treating the plant growth medium with an agricultural chemical prior to, during, or after, the encapsulation of step (v).

(vii) substantially coating the encapsulated mini rhizome or mini stem cutting of step (vi) in a biodegradable polymer.

15 According to another preferred embodiment of the present technology, there is therefore provided a method for the propagation of a vegetatively reproducing plant, comprising the steps of:

(i) contacting the plantlets produced from micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication or a part thereof with at least one plant hormone and growing the plantlets and harvesting mini-rhizomes or mini stem cuttings therefrom;

20 (ii) substantially encapsulating the mini-rhizomes or mini stem cuttings produced from step (i) in a plant growth medium;

(iii) optionally treating the plant growth medium with an agricultural chemical prior to, during, or after, the encapsulation of step (ii).

(iv) substantially coating the encapsulated mini rhizome or mini stem cutting of step (iii) in a biodegradable polymer; and

(v) optionally treating the biodegradable polymer with an agricultural chemical.

Advantageously, the methods of the invention may be applied to any plant capable of vegetative reproduction. In particular, the methods of the invention are particularly suited to rhizomatous and stem propagated plants. For example, the methods of the invention are particularly suited to energy grasses, such as sugar cane, *Miscanthus* (elephant grass), *Pennisetum purpureum* (napier grass), *Panicum virgatum* (switch grass), energy cane (the *Saccharum* complex), *Arundo donax* (Giant Reed), *Bambusa* (bamboo), *Curcuma*, *Humulus* (hop), asparagus, *Zingiber* (ginger), iris, genus *Erianthus*, *Faiiopia sac aiinensis* (Igniscum), *Ipomoea batatas* (sweet potato) and wasabi. In addition there are applications for other food and medicinal crops propagated using rhizomes or stems, such as strawberry (genus *Fragaria*), the medicinal herb nettle (genus *Urtica*) and turmeric.

Arundo donax (giant reed), *Pennisetum purpureum* (napier grass), energy cane, *Saccharum officinarum* (sugar cane), Hevea (rubber) and Manihot (cassava), for example, are more suited to multiplication using stem cuttings. When multiplying using stem cuttings, the plantlets, derived from micro-propagation are planted and grown to a suitable height and any aboveground growth is cut back to a point just above a node. This procedure encourages more bud formation which may be further stimulated by the application of cytokinins and auxins. The shoots emerging from the new buds are removed and cut up by machine into short lengths to form mini stem cuttings which are then ready to be encapsulated. Although not all of the stem cuttings that are produced will contain buds, the multiplication rate that is achieved is many times greater than would be achieved by conventional procedures.

According to another aspect of the present invention, there is provided a substantially encapsulated mini rhizome or substantially encapsulated mini stem cutting produced by the method according to the invention. The encapsulated mini rhizome or encapsulated mini stem cutting may be substantially coated in a biodegradable polymer.

According to another aspect of the present invention, there is provided a capsule for encapsulating mini-stem cuttings or min-rhizomes. Such capsule may further be substantially coated in a biodegradable polymer. The capsule may contain an agricultural chemical. Methods of applying to or treating the capsule, or encapsulated propagule, include dressing, spraying, coating, pelleting and soaking application methods. Conventional treating techniques and machines can be used, such as fluidized beds, roller mills, rotostatic seed treaters, drum coaters, and spouted beds. Also, using commercially available equipment (Van der Ende PHYTO-DRIP BV, NL) it is possible to perform a precise seed soaking application at the time of planting.

Even distribution of ingredients and good adherence are particularly desirable. Treatment can vary from a thin film or dressing of a formulation, to a soaking treatment, to incorporation with and throughout the encapsulation material. Such applications can be made prior to the formation of a capsule, during formation of the capsule, or after formation of the capsule.

The present invention also provides a planting unit comprising an agricultural chemical weighing less than about 50g, less than about 25g, or less than about 20g, or less than about 15g or less than about 10g, or less than about 5g, or less than about 2g, comprising a substantially uniformly-shaped mini rhizome or mini stem cutting substantially contained within a plant growth medium and optionally coated in a biodegradable polymer. The weight of the planting unit described above does not include the growth medium. In one embodiment of the present invention, the planting unit comprises a rhizome from a *Miscanthus* plant, energy cane, *Arundo donax* or sugarcane plant.

The present invention also provide for a capsule comprising an agricultural chemical weighing less than about 100g, less than about 50g, less than about 25g, or less than about 20g, or less than about 15g or less than about 10g, or less than about 5g, or less than about 2g, comprising a plant growth medium and an agricultural chemical and optionally coated in a biodegradable polymer. Such capsule volume is advantageously less than 27 cubic inches, less than 8 cubic inches, and less than 2 cubic inches. Preferably the volume is between 0.5 to 27 cubic inches, between 1 to 27 cubic inches, between 1 to 8 cubic inches, between 1 to 4 cubic inches, and between 1 to 2 cubic inches.

Advantageously, plants produced from the mini stem cuttings or mini rhizomes produced by the methods according to the present invention will have increased vigour and/or yield over their untreated counterparts.

According to the present invention, there is provided a capsule comprising and
5 agricultural chemical, or use of an encapsulated mini rhizome or mini stem cutting comprising and agricultural chemical, in increasing plant vigour and/or yield relative to an untreated encapsulated mini-rhizome or mini-stem cutting.

According to a further aspect of the present invention, there is provided a coating for a propagule comprising a biodegradable polymer, which preferably has a melting point of between
10 30 to 65°C. The invention also provides propagules coated with such a biodegradable polymer.

Preferably the propagule is encapsulated prior to being coated in the biodegradable polymer. The propagule may advantageously be encapsulated in any plant growth medium, such as compost, potting mix, peat, hydrogel, soil, rock wool, perlite, vermiculite, foam, syrofoam, pumice, coir, expanded clay pellets etc. The encapsulation material may also comprise
15 compounds, such as plant hormones (such as cytokinins or auxins), plant growth regulators, mycorrhiza, endophytic organisms, symbiotic organisms or other beneficial organisms, surfactants, gels, fungicides, nematicides, insecticides, organic and inorganic nutrients, water, polymer and organic based super absorbents and stabilization compounds etc. to aid the storage of the propagule so as to prevent any loss of material due to deterioration and to enhance the
20 survival and performance of the propagules once they are planted in the field.

Preferably the polymer is one or more of wax, polyester, petroleum-based paraffin or plastic, polysaccharide or any plant-based plastic.

The coating may comprise preferably, the coating also comprises a fibre, which may comprise at least up to 20%, at least up to 30%, at least up to 40%, at least up to 50%, at least up
25 to 60%, at least up to 70%, at least up to 80% or at least up to 90% of the coating.

The fibre may be one or more of the following (i) fibre from agricultural biomass residue (for example, cereal straw, cotton, peanut hulls, soy straw, corn fodder); (ii) dedicated fibres (for

example, Miscanthus, Arundo, sugarcane, bagasse, hemp, Kenaf); (iii) processed fibres (for example, paper, recycled cardboard, wood flour, wood saw dust); and (iv) artificial or processed fibres (for example, nylon, polyester, cotton).

The coating may also comprise fungicides, endophytic organisms, plant nutrients,
5 hormones, dyes or other means for identification, such as barcodes or transponders or the like, to aid sorting.

The coating is applied to the (encapsulated) propagule by, for example, dipping (at least once) or by co-extrusion or by thermally forming the coating around the propagule. The coating covering the (encapsulated) propagule is less than 1 mm (millimetre) thick, preferably less than
10 0.5mm thick.

According to a further aspect of the present invention, there is provided use of a biodegradable polymer, which preferably has a melting point of between 30 °C to 65°C, for the coating of a propagule.

The amount of agricultural chemical that is included with the capsule or encapsulated
15 propagule will vary depending upon the size of capsule, the type of active ingredients and pest to be controlled, but the capsule or encapsulated propagule will contain an amount of the combination of pesticides that is pesticidally effective. In general, the amount of an agricultural chemical present will range from about 0.005 to about 50 percent of the weight of the capsule or encapsulated propagule. A more preferred range for the agricultural chemical is from about 0.01
20 to about 40 percent; more preferred is from about 0.05 to about 20 percent.

A "propagule" as defined herein is any plant part which is capable of being grown or regenerated into a whole plant. A propagule may therefore comprise, rhizomes, mini rhizomes, stem cuttings, mini stem cuttings, tubers, seeds etc.

In the case where the propagule is a seed, any commercial or other seed variety may
25 optionally first be encapsulated as described above and then coated in a biodegradable polymer as described. The seed may be a transgenic or non-transgenic seed. Preferred seeds include melon and tomato seeds.

CLAIMS:

1. A method for the propagation of a vegetatively reproducing plant comprising:
 - (i) contacting plantlets produced from micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication or a part thereof with at least one plant hormone;
 - 5 (ii) exposing the plantlets before, after or during step (i) above to an abiotic or mechanical stress;
 - (iii) growing the plantlets and harvesting mini rhizomes or mini stem cuttings therefrom;
 - (iv) substantially encapsulating the mini rhizomes or mini stem cuttings produced from step (iii) in a plant growth medium; and
 - (v) treating the plant growth medium with an agricultural chemical prior to, during, or after, the
 - 10 encapsulation of step (iv).
2. The method according to claim 1, wherein said encapsulated mini rhizome or mini stem cutting is substantially coated in a biodegradable polymer.
3. The method according to claim 2, wherein said biodegradable polymer has a melting point of between 30 to 65°C.
- 15 4. The method according to claim 2 or 3, wherein said biodegradable polymer comprises one or more of wax, polyester, petroleum-based paraffin or plastic, polysaccharide or any plant-based plastic.
5. The method according to any of claims 2 to 4, wherein said coating comprises a fibre component of at least 20%, at least 30%, at least 40%, at least 50%, at least 60%, at least 70%, at
- 20 least 80% or at least 90% of the coating.
6. The method according to claim 5, wherein said fibre comprises one or more of the following:
 - (i) fibre from agricultural biomass residue; (ii) dedicated fibres; (iii) artificial or processed fibres.

7. The method according to any of claims 2 to 6, wherein said coating comprises one or more of the following: fungicides, endophytic organisms, plant nutrients, hormones, dyes or other means for identification, such as barcodes or transponders.

8. The method according to any preceding claim, wherein said vegetatively reproducing plant is
5 a rhizomatous plant or a plant propagated using a stem cutting.

9. The method according to claim 8, wherein said plant is selected from *Miscanthus* (elephant grass), *Pennisetum purpureum* (napier grass), *Panicum virgatum* (switch grass), energy cane (the *Saccharum* complex), *Arundo donax* (giant reed), sugarcane, *Bambusa* (bamboo), *Curcuma*, *Humulus* (hop), asparagus, *Zingiber* (ginger), iris, genus *Erianthus*, *Faiiopia sachahensis*
10 (*Igniscum*), strawberry (Genus *Fragaria*), herb Nettle (Genus *Urtica*), *Hevea* (rubber) and *Manihot* (cassava), turmeric, wasabi and *Ipomoea batatas* (sweet potato).

10. The method according to any preceding claim, wherein said mechanical stress comprises cutting back of aboveground parts.

11. The method according to any preceding claim, wherein said plant hormone comprises
15 cytokinins and auxins.

12. Method according to claim 11, wherein said plant hormones comprise benzylaminopurine, TDZ and IAA.

13. The method according to any of claims 1-12, wherein said agricultural chemical is a fungicide, insecticide, or nematicide.

20 14. The method according to any of claims 1-13 wherein said agricultural chemical is an insecticides chosen from thiamethoxam, clothianidin, imidacloprid, fipronil, abamectin, chlorantraniliprole, cyantraniliprole, flubendiamide, and combinations thereof.

15. The method according to any of claims 1-14 wherein said agricultural chemical is a fungicide chosen from tebuconazole, difenoconazole, fludioxonil, metalaxyl, azoxystrobin, thiabendazole,
25 benodanil, flutolanil, fluopyram, mepronil, isofetamid, fluopyram, fenfuram, oxycarboxin,

thiﬂuzamide, bixafen, ﬂuxapyroxad, furametpyr, isopyrazam, penﬂufen, penthiopyrad, sedaxane, boscalid, benzovindiflupyr, and combinations thereof.

16. The method according any of claims 1-12, wherein said agricultural chemical is a biological pesticide.

5 17. The method according to claim 14, wherein said agricultural chemical is thiamethoxam.

18. A capsule for encapsulating a mini rhizome or mini stem cutting, the capsule comprising:

(i) encapsulation material suitable for encapsulating a mini rhizome or mini stem cutting and which is formed into a capsule adapted for encapsulation of the mini rhizome or mini stem cutting;

10 (ii) an agricultural chemical; and

(iii) wherein the capsule weight is less than 50 grams and the capsule volume is less than 27 cubic inches.

19. The capsule of claim 18 wherein said capsule weight is less than 25 grams and the capsule volume is less than 8 cubic inches.

15 20. The capsule of any of claims 18 to 19 wherein the agricultural chemical is a fungicide, insecticide, or nematicide.

21. The capsule of any of claims 18-20, wherein the capsule is substantially coated in a biodegradable polymer.

20 22. The capsule of claim 18, wherein the biodegradable polymer has a melting point of between about 30 to about 65°C.

23. The capsule of any of claims 18 to 20, wherein said biodegradable polymer is selected from one or more of wax, polyester, petroleum-based paraffin or plastic, polysaccharide or any plant-based plastic.

24. The capsule according to any of claims 18 to 21 , wherein said coating comprises a fibre component of up to 20%, up to 30%, up to 40%, up to 50%, up to 60%, up to 70%, up to 80% or up to 90% of the coating.
25. The capsule of claim 22, wherein said fibre comprises one or more of the following: (i) fibre
5 from agricultural biomass residue; (ii) dedicated fibres (for example, Miscanthus, Arundo, sugarcane, bagasse, hemp, Kenaf); (iii) artificial or processed fibres.
26. The capsule according to any of claims 18-25 wherein said agricultural chemical is an insecticides chosen from thiamethoxam, clothianidin, imidacloprid, fipronil, abamectin, chlorantraniliprole, cyantraniliprole, flubendiamide, and combinations thereof.
- 10 27. The capsule according to any of claims 18-26 wherein said agricultural chemical is a fungicide chosen from tebuconazole, difenoconazole, fludioxonil, metalaxyl, azoxystrobin, thiabendazole, benodanil, flutolanil, fluopyram, mepronil, isofetamid, fluopyram, fenfuram, oxycarboxin, thifluzamide, bixafen, fluxapyroxad, furametpyr, isopyrazam, penflufen, penthiopyrad, sedaxane, boscalid, benzovindiflupyr, and combinations thereof.
- 15 28. The capsule according any of claims 18-19, wherein said agricultural chemical is a biological pesticide.
29. The capsule according to claim 26, wherein said agricultural chemical is thiamethoxam.
30. The capsule according to claims 18-19, wherein said agricultural chemical is a biological or chemical nematicide.
- 20 31. The capsule according to claims 30, where said chemical or biological nematicide is selected from abamectin, *Pasteuria spp.*, *Baccillus spp.*, thiodicarb, aldicarb, nemataphagous fungi and combination thereof.
32. The method of any of claims 2 to 7 further comprising the step of applying an agricultural chemical to the biodegradable polymer.

33. The capsule of 21-25 wherein said capsule further comprises an agricultural chemical applied to the biodegradable polymer.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/41480

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.: Note: Claims 5-17, 21, 23, 24, 26, 27, 29, 32, 33
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:

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 examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-4, drawn to a method for the propagation of a vegetatively reproducing plant.

Group II: Claims 18-20, 22, 25, 28, 30, and 31, drawn to a capsule for encapsulating a mini rhizome or mini stem cutting.

-- Please 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.:
1-4

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 15/41480

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A01C 1/06, A01C 21/00, A01H 4/00, A01N 25/26, A01P 21/00 (2015.01)

CPC - A01C 1/06, A01C 21/00, A01H 4/005, A01H 4/006, A01H 4/008, A01N 25/26, A01N 2300/00

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)

IPC(8)- A01C 1/06, A01C 21/00, A01H 4/00, A01N 25/26, A01P 21/00 (2015.01);

CPC- A01C 1/06, A01C 21/00, A01H 4/005, A01H 4/006, A01H 4/008, A01N 25/26, A01N 2300/00

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

USPC- 47/57.6, 47/DIG3, 424/408, 504/347, 514/645, 800/298, 800/FOR101;

Patents and NPL (classification, keyword; search terms below)

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

Pub West (US EP JP WO), Pat Base (AU BE BR CA CH CN DE DK EP ES FI FR GB IN JP KR SE TH TW US WO), Google Patent, Google Scholar, Free Patents Online; search terms: plantlet, rhizome, cutting, stem, micropropagate, propagate, vegetate, reproduce, biodegradable, polymer, propagule, microencapsulate, encapsulate, plant, growth, hormone

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/186558 A1 (NEW ENERGY FARMS LIMITED) 19 December 2013 (19.12.2013), pg 9, para 3 to pg 10, para 1; pg 10, para 4 to pg 11, para 2; pg 12, para 5 to pg 13, para 1	1-4
Y	US 2012/0329158 A1 (LAKSHMANAN et al.) 27 December 2012 (27.12.2012), para [0005]-[0216]	1-4
Y	US 2010/0064583 A1 (DUNDAS et al.) 18 March 2010 (18.03.2010), para [0003]-[0077]	1-4
Y	US 2002/0086425 A1 (GIELIS et al.) 04 July 2002 (04.07.2002), para [0012]-[0168]	1-4
Y	WO 93/19587 A1 (MICROCROP LIMITED) 14 October 1993 (14.10.1993), pg 2, ln 24 to pg 35, ln 19	1-4

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

* Special categories of cited documents:

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

"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

09 November 2015 (09.11.2015)

Date of mailing of the international search report

17 DEC 2015

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer:

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PCT OSP: 571-272-7774

Continued from Box No. III, Observations where unity of invention is lacking.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Special Technical Features

Group II does not require a method for the propagation of a vegetatively reproducing plant comprising:

- (i) contacting plantlets produced from micro-propagation of plant material from a vegetatively reproducing plant followed by multiplication or a part thereof with at least one plant hormone;
- (ii) exposing the plantlets before, after or during step (i) above to an abiotic or mechanical stress;
- (iii) growing the plantlets and harvesting mini rhizomes or mini stem cuttings therefrom;
- (iv) substantially encapsulating... produced from step (iii) in a plant growth medium; and
- (v) treating the plant growth medium with a chemical prior to, during, or after, the encapsulation of step (iv), as required by Group I.

Group I does not require a capsule, comprising:

- (i) encapsulation material suitable which is formed into a capsule adapted for encapsulation;
- (iii) wherein the capsule weight is less than 50 grams and the capsule volume is less than 27 cubic inches, as required by Group II.

Shared Common Features

The only feature shared by Groups I and II that would otherwise unify the groups is encapsulating a mini rhizome or mini stem cutting; and an agricultural chemical. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is anticipated by US 2011/0301036 A1 to Tank, et al. (hereinafter 'Tank').

Tank discloses encapsulating a mini rhizome or mini stem cutting; and an agricultural chemical (para [0026], [0038], [0043], applying microcapsule oil-in-water suspension to plant parts such as a cutting which is planted... stem... comprising an active compound such as a biocide.).

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

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

Note: Claims 5-17, 21, 23, 24, 26, 27, 29, 32, and 33 are dependent claims and not drafted in accordance with the second and third sentences of Rule 6.4(a).