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(71) Applicant: **SABIC GLOBAL TECHNOLOGIES B.V.** [NL/NL]; Plasticslaan 1, 4612 PX Bergn Op Zoom (NL).

(72) Inventors: **AL-ROHILY, Khalid**; Saudi Basic Industries Corporation, P.O. Box 5101, Riyadh, 11422 (SA). **KELLS, Andrew**; SABIC UK Petrochemical Ltd., The Wilton Centre, Redcar and Cleveland, Wilton TS104RF (GB).

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(54) **Title:** METHODS AND FERTILIZER COMPOSITIONS FOR TREATING A PLANT AND PLANT GROWTH MEDIUM

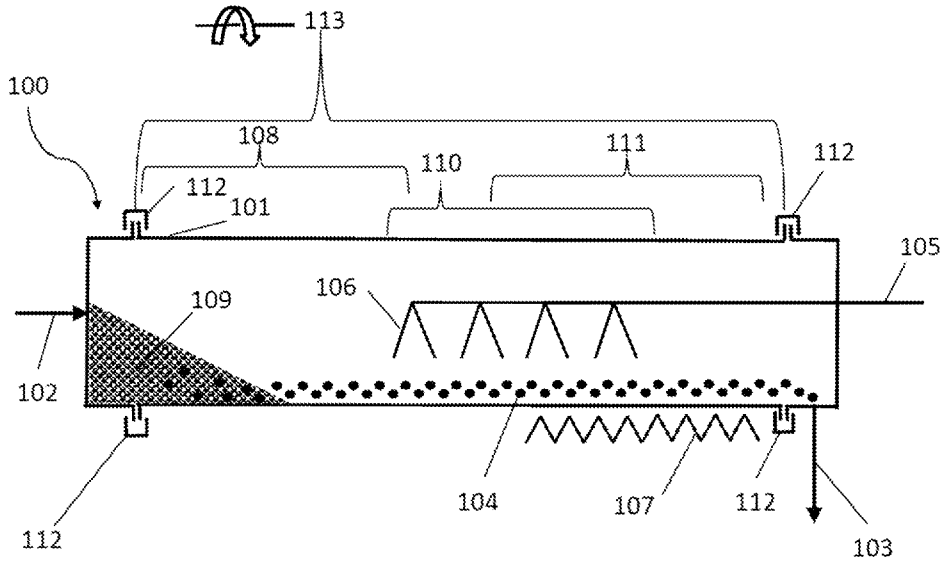


FIG. 1

(57) **Abstract:** A nitrogen, phosphorous, potassium, and sulfur fertilizer (NPKS) and methods for making and using the same are disclosed. The NPKS fertilizer can contain 12 to 15 wt. % elemental nitrogen, 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur. The NPKS fertilizer can be used for or formulated to fertilize rice.

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METHODS AND FERTILIZER COMPOSITIONS FOR TREATING A PLANT AND PLANT GROWTH MEDIUM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 62/772,990, filed November 29, 2018, the contents of which is incorporated into the present application by reference in its entirety.

BACKGROUND OF THE INVENTION

A. Field of the Invention

[0002] The invention generally concerns a nitrogen, phosphorus, potassium, and sulfur containing fertilizer. The fertilizer can contain 12 to 15 wt. % elemental nitrogen (N), 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur (S). In a particular embodiment, the fertilizer can be used to help grow rice.

B. Description of Related Art

[0003] Soil nutrients, such as nitrogen, phosphorus, potassium, and sulfur, as well as trace elements such as iron, zinc, copper, and magnesium, are useful for achieving thriving agriculture and growth of plants. Upon repeated planting cycles, the quantity of these nutrients in the soil may be depleted, resulting in inhibited plant growth and decreased production. To counter this effect, fertilizers have been developed to help replace the depleted vital nutrients. Single-nutrient fertilizers and multi-nutrient fertilizers, such as fertilizer blends, have been developed to meet the varied needs of crop production worldwide.

[0004] Rice (*Oryza sativa*) is a major food crop for nearly half of the world's population. It is also one of the most widely grown cereals in the world, along with corn and wheat in terms of production and trading. The total rice-cropped area worldwide is estimated to be over 146 million hectares, producing over 674 million tons of grain yearly. Average yearly yield is approximately 4,610 tons per hectare. However, average production per hectare is considered low and has been declining globally.

[0005] Some have attempted to address low production by producing regional or condition specific fertilizers. For example, multiple NPK or NPKS fertilizers have been tested and shown to be beneficial over no fertilizer at all (WO2014/009920; CN102701853; Krishnakumar *et al.*, Asian J. Plant Sci. 2005; 4(6):574-576; Rice production, Training and Development, United States Peace Corps Information Collection & Exchange Reprint R0040 (Peace Corps) Chapter 9).

[0006] While these attempts have provided some benefits to growing grains generally, they are not specifically tailored to the growth of rice.

SUMMARY OF THE INVENTION

[0007] A discovery has been made that addresses at least some of the problems associated with inefficient rice crop growth. The discovery is premised on providing ratios of nutrients in a fertilizer that is based on nutrient uptake in this crop. The fertilizer can contain 12 to 15 wt. % elemental nitrogen, 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur. This fertilizer can be beneficial to provide sufficient nutrients for growth and grain production, for maximizing yield, and to avoid over fertilization. This can be beneficial in reducing costs associated with applying unnecessary fertilizers and in reducing the burdens and costs of purchasing and distributing multiple fertilizers or creating or purchasing specialty blends.

[0008] In one aspect of the invention, NPKS fertilizers are described. The NPKS fertilizer can include 12 to 15 wt. % elemental nitrogen (N), 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur (S). The nitrogen, P_2O_5, K_2O, and sulfur contained therein can be any amount within these ranges. The NPKS fertilizer can include 12, 13, 14, or 15 wt. % N, 14, 15, 16, 17, or 18 wt. % P_2O_5, 16, 17, 18, 19, or 20 wt. % K_2O, and 4, 5, 6, 7, 8, 9, or 10 wt. % S. In some instances, the NPKS fertilizer contains 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S. In some particular instances, the NPKS fertilizer contains 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

[0009] The fertilizer can contain additional nutrients. In some instances, the fertilizer contains one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

[0010] In some aspects, the fertilizer is a fertilizer granule or a coated fertilizer. The fertilizer granule can contain one or more particles. The particles or coated fertilizer can contain a core and one or more layers covering at least a portion of the core. A first portion of the fertilizer can form a core that contains all or a majority of the N, P_2O_5, K_2O, and S, and a second portion of the fertilizer can form a layer that covers at least a portion of the core (e.g., at least 50, 60, 70, 80, 90, 0r 100 % of the surface area of the core). In some instances, the layer is a water repellant layer. The layer can be a coating oil. The coating oil can be an amine based coating oil. The layer can self-assemble during the manufacture of the particle, coated fertilizer, or granule. In some embodiments, the particle, coated fertilizer, or granule can be elongated or can be substantially spherical or can be another shape or combinations of shapes.

[0011] In some aspects, the fertilizer is formulated to fertilize a specific crop. In some instances, the fertilizer is formulated to fertilize rice. The crop can be fertilized by addition of the fertilizer to the medium, water, or soil surrounding the crop or by application directly to the plant. The crop can be fertilized by addition of the fertilizer as a solid fertilizer or a liquid fertilizer. The fertilizer can be added to a liquid medium for application of the fertilizer.

[0012] In some aspects, the nitrogen, phosphorus, potassium, and sulfur content are provided by one or more nutrient sources in the fertilizer. In some instances, the nitrogen source is urea, an ammonium, monoammonium phosphate (MAP), diammonium phosphate (DAP), and/or ammonium sulfate. In some instances, the phosphorus source is MAP and/or DAP. In some instances, the potassium source is sulfate of potash (SOP) and/or muriate of potash (MOP). In some instances, the sulfur source is a sulfate, such as ammonium sulfate.

[0013] In some aspects, the fertilizer is combined in a composition to form a blended fertilizer or a compounded fertilizer. The compositions can include a plurality of the NPKS fertilizer of the present invention mixed with other fertilizers, micronutrients, secondary nutrients, or organic additives. The fertilizers can be particulate in form (e.g., urea, monoammonium phosphate (MAP), diammonium phosphate (DAP), muriate of potash (MOP), and/or sulfate of potash (SOP)). Preferably, the NPKS fertilizers and additional fertilizers are compatible with each other (e.g., can contact each other without having a chemical reaction take place). The blended or compounded fertilizer can contain in addition to the NPKS fertilizer, a nitrogen based fertilizer, a phosphate-based fertilizer, a potassium-

based fertilizer, a urea-based fertilizer, a fertilizer providing nitrogen, phosphorus, and potassium (NPK), diammonium phosphate (DAP), monoammonium phosphate (MAP), single superphosphate (SSP), triple superphosphate (TSP), urea, potassium chloride, potassium sulfate, magnesium sulfate, superphosphates, phosphate rocks, potash, sulfate of potash (SOP), muriate of potash (MOP), kieserite, carnallite, magnesite, dolomite, boric acid, B, Cu, Fe, Mn, Mo, Zn, Se, Si, Ca, Mg, S, neem oil, seaweed extract, bio-stimulants, char, ashes from incineration of animal waste or animal tissues, etc., or any combination thereof.

[0014] In yet another aspect of the invention, processes to produce the NPKS fertilizer of the present invention are described. A process can include (a) combining one or more sources of nitrogen, phosphorous, potassium, and sulfur in a ratio sufficient to produce a fertilizer composition with a fertilizer grade of 12 to 15 wt. % elemental nitrogen (N), 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur (S); and (b) mixing the one or more sources under conditions sufficient to produce the fertilizer composition. The method can include granulating one or more of the sources or the NPKS fertilizer to form a granulated fertilizer. The method can include coating one or more of the sources and/or coating the NPKS fertilizer to form a coated fertilizer. The method can also include drying the fertilizer, granulated fertilizer, and/or coated fertilizer. In some instances, the method can further include combining the NPKS fertilizer with one or more additional fertilizers to form a blended or compounded fertilizer.

[0015] In some aspects, the process to produce the NPKS fertilizer of the present invention includes use of drum granulation technology. The temperature used to dry and/or granulate the fertilizer can be in the range of 60 to 100 °C. The temperature can be 60, 65, 70, 75, 80, 85, 90, 95, and/or 100 °C, or any temperature between 60 and 100 °C. The moisture content of the mixture and/or granulated material can be in the range of 2 to 4 wt. %. The moisture can be 2, 2.5, 3, 3.5, and/or 4 wt. %, or any wt. % therein. If the fertilizer, coated fertilizer, mixture, and/or granulated material is dried, the moisture content can be reduced to at or below 1 wt. %. The moisture content can be 1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.05, 0.01, 0.005, and/or 0.001, wt. %, or any wt. % therein or below. The NPKS fertilizer, granulated fertilizer, coated fertilizer, or dried fertilizer can have an average mean size range of 2 to 4 mm. The average mean size range can be 2, 2.5, 3, 3.5, and/or 4 mm, or any size therein. The NPKS fertilizer, granulated fertilizer, coated fertilizer, or dried fertilizer can have an average mean crush strength of or more than 2 kg/granule. The average

mean crush strength can be 2, 2.5, 3, 3.5, 4, 4.5, and/or 5, or any crush strength therein or more.

[0016] In another aspect of the present invention, methods of fertilizing are described. A method can include applying a plurality of NPKS fertilizers of the present invention to a portion of a soil, water, a crop, or a combination of any of the soil, water, and the crop. The crop can be rice. In some instances, the fertilizer is added to a liquid medium for application to the crop. In some embodiments, the soil is at least partially or fully submerged under water (e.g., rice paddy crops) and the fertilizers sink in the water to contact the soil. This can allow for homogenous distribution of the fertilizers to the soil rather than having the fertilizers coalesce together in or on the surface of the water.

[0017] Also disclosed are the following Aspects 1 to 20 of the present invention.

[0018] Aspect 1 is a method of fertilizing rice, the method comprising applying a fertilizer composition to at least one of a soil, or a rice organism, or a combination thereof, wherein the fertilizer composition has a fertilizer grade of 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S).

[0019] Aspect 2 is the method of aspect 1, wherein the fertilizer grade comprises 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S.

[0020] Aspect 3 is the method of aspect 1, wherein the fertilizer grade comprises 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

[0021] Aspect 4 is the method of any one of aspects 1 to 3, wherein the soil comprises the rice organism.

[0022] Aspect 5 is the method of any one of aspects 1 to 4, wherein the fertilizer composition is a blended or compounded fertilizer.

[0023] Aspect 6 is the method of any one of aspects 1 to 4, wherein the fertilizer composition is a granulated fertilizer or coated fertilizer.

[0024] Aspect 7 is the method of any one of aspects 1 to 6, wherein the fertilizer composition further comprises one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

[0025] Aspect 8 is a method of making a fertilizer composition with a fertilizer grade comprising 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S), the method comprising: combining one or more source of nitrogen, phosphorous, potassium, and sulfur in a ratio sufficient to produce a fertilizer composition with a fertilizer grade of 12-15 wt. % N, 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % S; and mixing the sources under conditions sufficient to produce the fertilizer composition.

[0026] Aspect 9 is the method of aspect 8, wherein the fertilizer grade comprises 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S.

[0027] Aspect 10 is the method of aspect 8, wherein the fertilizer grade comprises 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

[0028] Aspect 11 is the method of any one of aspects 8 to 10, wherein the fertilizer composition produced is a blended or compounded fertilizer.

[0029] Aspect 12 is the method of any one of aspects 8 to 10, wherein mixing the sources further comprises granulating one or more of the sources to form a granulated fertilizer, and the method further comprises drying the granulated fertilizer.

[0030] Aspect 13 is the method of any one of aspects 8 to 10, wherein mixing the sources further comprises coating one or more of the sources to form a coated fertilizer, and wherein the method further comprises drying the coated fertilizer.

[0031] Aspect 14 is the method of any one of aspects 8 to 13, wherein the fertilizer composition further comprises one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

[0032] Aspect 15 is a fertilizer composition with a fertilizer grade comprising 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S).

[0033] Aspect 16 is the fertilizer composition of aspect 15, wherein the fertilizer composition is formulated to fertilize rice.

[0034] Aspect 17 is the fertilizer composition of any one of aspects 15 to 16, wherein the fertilizer grade comprises 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S.

[0035] Aspect 18 is the fertilizer composition of any one of aspects 15 to 17, wherein the fertilizer grade comprises 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

[0036] Aspect 19 is the fertilizer composition of any one of aspects 15 to 18, wherein the fertilizer composition is one or more of a blended fertilizer, a compounded fertilizer, a granulated fertilizer, or a coated fertilizer.

[0037] Aspect 20 is the fertilizer composition of any one of aspects 15 to 19, wherein the fertilizer composition further comprises one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

[0038] The following includes definitions of various terms and phrases used throughout this specification.

[0039] The term "fertilizer" is defined as a material applied to soils, water, or to plant tissues to supply one or more plant nutrients essential or beneficial to the growth of plants and/or stimulants or enhancers to increase or enhance plant growth. Non-limiting examples of fertilizers include materials having one or more of urea, ammonium nitrate, calcium ammonium nitrate, one or more superphosphates, binary NP fertilizers, binary NK fertilizers, binary PK fertilizers, NPK fertilizers, molybdenum, zinc, copper, boron, cobalt, and/or iron. In some aspects, fertilizers include agents that enhance plant growth and/or enhance the ability for a plant to receive the benefit of a fertilizer, such as, but not limited to biostimulants, urease inhibitors, and nitrification inhibitors. In some particular instances, the fertilizer is urea.

[0040] The term "micronutrient" is defined as a chemical element or substance that can be used in trace amounts for the normal growth and development of a plant. Non-limiting examples of micronutrients include B, Cu, Fe, Mn, Mo, Zn, Se, and Si.

[0041] The term "secondary nutrient" is defined as a chemical element or substance that can be used in moderate amounts for plant growth and are less likely to limit crop growth in

comparison to N, P, and K. Non-limiting examples of secondary nutrients include Ca, Mg, and S.

[0042] The term "organic agent" is defined as a substance that is produced by or part of an organism. Non-limiting examples of organic agents suitable for a fertilizer include neem oil, seaweed extract, bio-stimulants, char, ashes from incineration of animal waste or animal tissues, and diatomaceous earth.

[0043] The term "granule" can include a solid material. A granule can have a variety of different shapes, non-limiting examples of which include a spherical, a puck, an oval, a rod, an oblong, or a random shape.

[0044] The terms "about" or "approximately" are defined as being close to as understood by one of ordinary skill in the art. In one non-limiting embodiment, the terms are defined to be within 10%, preferably within 5%, more preferably within 1%, and most preferably within 0.5%.

[0045] The terms "wt.%," "vol.%," or "mol.%" refers to a weight percentage of a component, a volume percentage of a component, or molar percentage of a component, respectively, based on the total weight, the total volume of material, or total moles, that includes the component. In a non-limiting example, 10 grams of component in 100 grams of the material is 10 wt.% of component.

[0046] The term "substantially" and its variations are defined to include ranges within 10%, within 5%, within 1%, or within 0.5%.

[0047] The terms "inhibiting" or "reducing" or "preventing" or "avoiding" or any variation of these terms, when used in the claims and/or the specification includes any measurable decrease or complete inhibition to achieve a desired result.

[0048] The term "effective," as that term is used in the specification and/or claims, means adequate to accomplish a desired, expected, or intended result.

[0049] The use of the words "a" or "an" when used in conjunction with any of the terms "comprising," "including," "containing," or "having" in the claims, or the specification, may mean "one," but it is also consistent with the meaning of "one or more," "at least one," and "one or more than one."

[0050] The words "comprising" (and any form of comprising, such as "comprise" and "comprises"), "having" (and any form of having, such as "have" and "has"), "including" (and any form of including, such as "includes" and "include"), or "containing" (and any form of containing, such as "contains" and "contain") are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

[0051] The NPKS fertilizers of the present invention can "comprise," "consist essentially of," or "consist of" particular ingredients, components, compositions, etc. disclosed throughout the specification. With respect to the transitional phase "consisting essentially of," in one non-limiting aspect, a basic and novel characteristic of the NPKS fertilizer of the present invention is the presence of 12 to 15 wt. % elemental nitrogen, 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur and in some instances, 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S. Further, the NPKS fertilizer can be formulated and/or used to fertilize rice.

BRIEF DESCRIPTION OF THE DRAWINGS

[0052] Advantages of the present invention may become apparent to those skilled in the art with the benefit of the following detailed description and upon reference to the accompanying drawings.

[0053] **FIG. 1** is a schematic of a system that can be used to produce NPKS fertilizers of the present invention.

[0054] **FIG. 2** is graph of the grain yield for rice treated with no fertilizer (T1), standard recommended dose of fertilizer (SRD) (T2), and varying amounts of a NPKS fertilizer of the present invention (Test Grade) (T3 through T7).

[0055] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings. The drawings may not be to scale.

DETAILED DESCRIPTION OF THE INVENTION

[0056] The NPKS fertilizer of the present invention can include 12 to 15 wt. % elemental nitrogen, 14 to 18 wt. % P_2O_5, 16 to 20 wt. % K_2O, and 4 to 10 wt. % elemental sulfur. This fertilizer can be particularly beneficial for the specific nutrient uptake of rice and can be used or formulated for rice. However, the fertilizer can be used for other plants as well. The

fertilizer can be beneficial to provide sufficient nutrients for growth and grain production, for maximizing yield, and/or to avoid over fertilization. This can be beneficial in reducing costs associated with applying unnecessary fertilizers and in reducing the burdens and costs of purchasing and distributing multiple fertilizers. The NPKS fertilizer can be produced by using any nitrogen, phosphorus, potassium, and/or sulfur source that is suitable as a fertilizer. The NPKS fertilizer is stable and can be a solid or liquid when applied to a crop. In particularly preferred embodiments, NPKS fertilizer compositions are granules and/or coated fertilizers.

[0057] For example, NPKS fertilizers of the present invention can include 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S. In some particular instances, the fertilizer contains 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S. This can be beneficial where a rice plant is fertilized and can reduce the amount of material needed to provide nutrients to this crop.

[0058] In some instances, the surface of the NPKS fertilizer can comprises a water repellant layer or a layer having another fertilizer or any combination thereof. By way of example, the layer can be formed on at least a portion of the outer surface of the NPKS fertilizer, and the layer can include an oil, such as an amine based coating oil. The layer can be applied to a NPKS fertilizer core or self-form or self-assemble during the production process of the NPKS fertilizer. The layer can contain a fertilizer in particulate form.

[0059] These and other non-limiting aspects of the present invention are discussed in further detail in the following sections.

A. Process to Produce NPKS Fertilizer

[0060] The NPKS fertilizer of the present invention can be made using a granulation system shown in FIG. 1. FIG. 1 is a non-limiting, simplified schematic of a granulator/coating apparatus 100 for producing a NPKS fertilizer granule 104 or a NPKS coated fertilizer 104 and drying the NPKS fertilizer 104 using a heat source 107. The materials of construction, size, and shape of apparatus 100 can be determined using standard engineering practice and/or modeling programs to achieve the maximum flow rates and appropriate contact time. Apparatus 100 can include a rotating drum 113. Container 101 can include source material inlet(s) 102 for introduction of the source material 109 and fertilizer outlet 103. Apparatus 100 may be adapted to move source material 109 and NPKS fertilizer

104 between source material inlet(s) 102 and fertilizer outlet 103. For example, in embodiments of the invention, container 101 may include a rotatable section 113 rotatably coupled to the apparatus through large mechanical seals 112, for moving source material 109 and/or fertilizer 104 through a mixing/granulating zone 108, an optional coating zone 110, and/or optional drying zone 111. In some embodiments, container 101 is capable of agitating and/or mixing the source material 109 or fertilizer 104, and/or includes an apparatus that can cause such agitation. For example, container 101, may include a rotatable section 113, a rotatable internal container, and/or a section that vibrates. In some instances, the rotatable section 113 and/or rotatable internal container may contain internal flights and/or be rotated to induce movement of the source material 109 and/or fertilizer 104. Optional coating material can be introduced through the coating material inlet 105. In some embodiments, the coating material can be distributed onto the fertilizer 104 by sprayers 106. In some embodiments the source material 109 can be used or designed to produce a fertilizer grade comprising 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S). The source material 109 can in some instances be a single source or can be more than one source of nitrogen, phosphorous, potassium, and sulfur. The N source can be urea, an ammonium, monoammonium phosphate (MAP), diammonium phosphate (DAP), and/or ammonium sulfate. The P_2O_5 source can be MAP and/or DAP. The K_2O source can be sulfate of potash (SOP) and/or muriate of potash (MOP). The S source can be a sulfate, such as ammonium sulfate.

[0061] The conditions of the material exiting the mixing/granulating zone 108 or coating zone 110 can be a semi-wet material or granule, which easily forms "balls when compresses with the hands." If the material is too dry, then granulation is decreased leading to smaller product fraction in the material exiting the apparatus. If the material is too "wet" (tending towards mud) then there is a risk that the "mud" material will stick to the surfaces of the container, leading to building up on the container surface.

[0062] Drying the fertilizer can enable agglomeration to form a solid such as a granule or coated fertilizer. In some embodiments the fertilizer 104 is dried or further dried in a drying zone 111. The fertilizer 104 can enter a dryer (dryer) (*e.g.*, a rotating dryer) to reduce the amount of moisture in the material. The formation of granules can also occur or continue during the drying of the material.

B. Blended or Compounded Fertilizer Compositions

[0063] The NPKS fertilizer of the present invention can also be included in a blended or compounded fertilizer composition comprising other fertilizers, such as other fertilizer granules or coated fertilizers. Additional fertilizers can be chosen based on the particular needs of certain types of soil, climate, or other growing conditions to maximize the efficacy of the NPKS fertilizer in enhancing plant growth and crop yield. The other fertilizer granules or coated fertilizers can be or can contain urea, Single Super Phosphate (SSP), Triple Super Phosphate (TSP), ammonium sulfate, monoammonium phosphate (MAP), diammonium phosphate (DAP), muriate of potash (MOP), and/or sulfate of potash (SOP), and the like.

C. Method of Using the NPKS Fertilizer

[0064] The NPKS fertilizers of the present invention can be used in methods of increasing the amount of nitrogen, phosphorus, potassium, and/or sulfur in soil and/or water and of enhancing plant growth and/or yield. Such methods can include applying to the soil, to a plant organism and/or to water an effective amount of a composition comprising the NPKS fertilizers of the present invention. The method may include increasing the growth and yield of crops, trees, ornamentals, etc. such as, for example, rice, palm, coconut, wheat, corn, barley, oats, and soybeans. The method can include applying NPKS fertilizers of the present invention to at least one of a soil, water, an organism, a liquid carrier, a liquid solvent, etc.

[0065] Non-limiting examples of plants that can benefit from the fertilizer of the present invention include vines, trees, shrubs, stalked plants, ferns, etc. The plants may include orchard crops, vines, ornamental plants, food crops, timber, and harvested plants. The plants may include Gymnosperms, Angiosperms, and/or Pteridophytes. The Gymnosperms may include plants from the Araucariaceae, Cupressaceae, Pinaceae, Podocarpaceae, Sciadopitaceae, Taxaceae, Cycadaceae, and Ginkgoaceae families. The Angiosperms may include plants from the Aceraceae, Agavaceae, Anacardiaceae, Annonaceae, Apocynaceae, Aquifoliaceae, Araliaceae, Arecaceae, Asphodelaceae, Asteraceae, Berberidaceae, Betulaceae, Bignoniaceae, Bombacaceae, Boraginaceae, Burseraceae, Buxaceae, Canellaceae, Cannabaceae, Capparidaceae, Caprifoliaceae, Caricaceae, Casuarinaceae, Celastraceae, Cercidiphyllaceae, Chrysobalanaceae, Clusiaceae, Combretaceae, Cornaceae, Cyrillaceae, Davidsoniaceae, Ebenaceae, Elaeagnaceae, Ericaceae, Euphorbiaceae, Fabaceae,

Fagaceae, Grossulariaceae, Hamamelidaceae, Hippocastanaceae, Illiciaceae, Juglandaceae, Lauraceae, Lecythidaceae, Lythraceae, Magnoliaceae, Malpighiaceae, Malvaceae, Melastomataceae, Meliaceae, Moraceae, Moringaceae, Muntingiaceae, Myoporaceae, Myricaceae, Myrsinaceae, Myrtaceae, Nothofagaceae, Nyctaginaceae, Nyssaceae, Olacaceae, Oleaceae, Oxalidaceae, Pandanaceae, Papaveraceae, Phyllanthaceae, Pittosporaceae, Platanaceae, Poaceae, Polygonaceae, Proteaceae, Punicaceae, Rhamnaceae, Rhizophoraceae, Rosaceae, Rubiaceae, Rutaceae, Salicaceae, Sapindaceae, Sapotaceae, Simaroubaceae, Solanaceae, Staphyleaceae, Sterculiaceae, Strelitziaceae, Styracaceae, Surianaceae, Symplocaceae, Tamaricaceae, Theaceae, Theophrastaceae, Thymelaeaceae, Tiliaceae, Ulmaceae, Verbenaceae, and/or Vitaceae family. In one particular embodiment, the plant benefited is rice.

[0066] The effectiveness of compositions comprising the NPKS fertilizers of the present invention can be ascertained by measuring the amount of nitrogen, phosphorus, potassium, and/or sulfur in the soil and/or water at various times after applying the fertilizer composition to the soil, the plant organism, and/or to water. It is understood that different soils and/or waters have different characteristics, which can affect the stability of the nutrients in the soil and/or water. The effectiveness of a fertilizer composition can also be directly compared to other fertilizer compositions by doing a side-by-side comparison in the same soil and/or water under the same conditions.

[0067] As discussed above, one of the unique aspects of the NPKS fertilizer of the present invention is that they can be formulated to meet the nutrient uptake needs of rice. This can allow the fertilizer to be used for this crop more versatilely in various regions of the world and under a wider range of soil/environment conditions than other fertilizers. This can be especially beneficial to reduce or eliminate the need to test the soil and/or water and to reduce or eliminate the need to purchase or create specialty fertilizer blends.

D. Compositions

[0068] The NPKS fertilizer can comprise other fertilizer actives and micronutrients. These could be added with the sources of N, P_2O_5, K_2O, and/or S at the beginning of the production process or can be added at any later stage.

[0069] Non-limiting examples of additional additives can be micronutrients, primary nutrients, and/or secondary nutrients. A micronutrient is an inorganic or organometallic

compound such as boron, copper, iron, chloride, manganese, molybdenum, nickel, or zinc. A primary nutrient is a material that can deliver nitrogen, phosphorous, and/or potassium to a plant. Nitrogen-containing primary nutrients may include urea, ammonium nitrate, ammonium sulfate, diammonium phosphate, monoammonium phosphate, urea-formaldehyde, or combinations thereof. A secondary nutrient is a substance that can deliver calcium, magnesium, and/or sulfur to a plant. Secondary nutrients may include lime, gypsum, superphosphate, or a combination thereof. For example, in some instances the NPKS fertilizer can contain calcium sulfate, potassium sulfate, magnesium sulfate, or a combination thereof.

[0070] In one aspect, the NPKS fertilizer can comprise one or more inhibitors. The inhibitor can be a urease inhibitor or a nitrification inhibitor, or a combination thereof. In one aspect, NPKS fertilizers can comprise a urease inhibitor and a nitrification inhibitor. In one aspect, the inhibitor can be a urease inhibitor. Suitable urease inhibitors include, but are not limited to, N-(n-butyl) thiophosphoric triamide (NBTPT) and phenylphosphorodiamidate (PPDA). In one aspect, the NPKS fertilizer can comprise NBTPT or PPDA, or a combination thereof. In another aspect, the inhibitor can be a nitrification inhibitor. Suitable nitrification inhibitors include, but are not limited to, 3,4-dimethylpyrazole phosphate (DMPP), dicyandiamide (DCD), thiourea (TU), 2-Chloro-6-(trichloromethyl)-pyridine (Nitrapyrin), 5-Ethoxy-3-trichloromethyl -1, 2, 4-thiadiazol (Terrazole), 2-amino 4-chloro 6-methyl pyrimidine (AM), 2-mercaptobenzothiazole (MBT), or 2-sulfanilamidothiazole (ST), and any combination thereof. In one aspect, nitrification inhibitor can comprise DMPP, DCD, TU, Nitrapyrin, Terrazole, AM, MBT or ST, or a combination thereof. In one aspect, the NPKS fertilizer can comprise NBTPT, DMPP, TU, DCD, PPDA, Nitrapyrin, Terrazole, AM, MBT, or ST or a combination thereof.

EXAMPLES

[0071] The present invention will be described in greater detail by way of specific examples. The following examples are offered for illustrative purposes only, and are not intended to limit the invention in any manner. Those of skill in the art will readily recognize a variety of noncritical parameters which can be changed or modified to yield essentially the same results.

Example 1
(Crop Yield with NPKS Fertilizer)

[0072] Rice yield was tested for crops grown in fields fertilized with a NPKS fertilizer of the present invention containing 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S (test fields) and compared to crops grown in unfertilized fields and fields fertilized with recommended doses of N, P_2O_5, and K_2O (63 kg/ha N, 38 kg/ha P_2O_5, and 30 kg/ha K_2O) (SRD). See Table 1. All test fields and the SRD fields were treated with 63 kg/ha nitrogen total, additional nitrogen was added if needed in the test fields to reach 63 kg/ha nitrogen total. The field evaluation showed an increase in yield of rice for the fields treated with a fertilizer of the present invention by 24.8% and 10.13% compared with unfertilized and SRD treated fields, respectively. See FIG. 2.

[0073] Briefly, the study was conducted at a farm located in the Pathum Thani Province, Central Plain of Thailand. The soils at the experimental site belong to the Rangsit Series (Sulfic Tropaquepts) and are characterized as heavy clay, hydromorphic alluvial, with a pH of 4-5 (moderately acidic). Soil at the test site was tested at an accredited laboratory. It was found that the soil characteristics at this location is predominantly clay, as expected from a typical farm in the Central Thailand.

[0074] The experiment was conducted from April to August with rice variety, RD 57 (110 days). The layout of the experiment followed the Rondmise Complete Block Design (RCBD), with 7 treatments, 3 replications, and a total of 21 plots, each plot size was 9 m by 6m = 54 m^2.

Table 1 – Treatment Details

Treatment	Treatment Description	N-P_2O_5-K_2O (Kg/Hectacre) (Kg/Ha)
T_1	N_0 P_0K_0 (Without fertilizer)	(0-0-0)
T_2	SRD	63-38-30
T_3	Test Grade-150 kg/ha	21-25-25 + 10S (+ additional N to 63 kg/ha)
T_4	Test Grade- 200 kg/ha	28-34-34 + 14S (+ additional N to 63 kg/ha)
T_5	Test Grade- 250 kg/ha	35-42-42 + 17S (+ additional N to 63 kg/ha)
T_6	Test Grade- 300 kg/ha	42-51-51 + 21S (+ additional N to 63 kg/ha)
T_7	Test Grade- 350 kg/ha	49-59-59 + 24S (+ additional N to 63 kg/ha)

[0075] Harvesting was done manually. The harvesting sample area was 12 m^2/plot. At harvest, grain yield per plot was recorded for each treatment.

[0076] **Yield:** Plant yield varied between 3.96-4.9 ton/ha. See FIG. 2. The minimum yield harvested was from the T_1 non-fertilized control. The highest yield was achieved with T_3, Test Grade at 150 kg/ha. Treatment with all of the amounts of Test Grade tested produced greater yield than the non-fertilized control and the SRD treated crops. See FIG. 2.

Example 2 (Prophetic Example)
(Characterization of the NPKS Fertilizer)

[0077] Properties of the fertilizers disclosed herein can be tested. The purity of the components can be cross-checked by NMR, HPLC, and LCMS analysis. Crush strength can be measured for some of the samples using a crush strength analyzer to determine the strength of the fertilizers. The stability of any inhibitors in the fertilizers can be measured using HPLC and LCMS. The total moisture content of fertilizers can be measured using a moisture analyzer.

[0078] The stability in soil and/or water, release rates, nitrogen volatilization, and nitrogen transformation (nitrification) can be measured in different soils and/or water and compared to other NPKS fertilizers and to products on the market. A soil that is representative of a broader class of soil types can be used to measure the properties of the fertilizer. Greenville soil and Crowley soil are two such representative soils. Other soils may also be used for the experiments described herein.

[0079] Greenville soil or Greenville clay-loam soil is typical of weathered tropical ultisols and is found in warm humid environments. The soil is classified as fine, kaolinitic, thermic Rhodic Kandiudults with a pH of 6.1-6. The soil has organic matter of 1.4%, total amount of nitrogen is about 0.06%, and the CEC is 5.2 cmol/kg. Accordingly, the soil has a low content of organic matter, and also low availability of sulfur and nitrogen. Thus, the soil is ideal for nitrogen and sulfur trials with fertilizers.

[0080] Crowley soil consists of very deep, somewhat poorly drained, very slowly permeable soils that formed in clayey fluviomarine deposits of the Pleistocene age. The soil exists in nearly level to very gently sloping soils and occurs on flat coastal plains terraces. The slope is dominantly less than 1 percent but ranges to up to 3 percent. Where the soil is found, the mean annual precipitation is about 1549 mm (61 in.) and the mean annual air temperature is about 20 ° C (68 °F). The soil is fine, smectitic, and thermic Typic Albaqualfs.

[0081] Nitrogen volatilization can be determined as the percentage of nitrogen loss via ammonia volatilization as compared to the amount of nitrogen applied or as the absolute mass of nitrogen lost via ammonia volatilization.

[0082] Compatibility and stability can be measured by combining the NPKS fertilizers of the present invention with other fertilizers such as urea, DAP, MAP, urea, MOP, and SOP. Compatible and stabile fertilizers can be used to provide a range of nitrogen-phosphorus-potassium-sulfur grades.

[0083] Benefits to crops, such as rice can be determined and compared to other NPKS fertilizers and to products on the market. Non-limiting properties of the crop that can be tested include growth rate, root mass, head and grain size, mass, and number, date to maturity, drought tolerance, heat and cold tolerance, yield, etc.

[0084] Surface and cross-sectional morphology of the NPKS fertilizer of the present invention can be carried out using a scanning electron microscope (SEM). These morphology studies can be used to determine the properties of a coated or uncoated NPKS fertilizer of the present invention.

CLAIMS

1. A method of fertilizing rice, the method comprising applying a fertilizer composition to at least one of a soil, or a rice organism, or a combination thereof, wherein the fertilizer composition has a fertilizer grade of 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S).

2. The method of claim 1, wherein the fertilizer grade comprises 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S.

3. The method of claim 1, wherein the fertilizer grade comprises 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

4. The method of claim 1, wherein the soil comprises the rice organism.

5. The method of claim 1, wherein the fertilizer composition is a blended or compounded fertilizer.

6. The method of claim 1, wherein the fertilizer composition is a granulated fertilizer or coated fertilizer.

7. The method of claim 1, wherein the fertilizer composition further comprises one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

8. A method of making a fertilizer composition with a fertilizer grade comprising 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S), the method comprising:

   combining one or more source of nitrogen, phosphorous, potassium, and sulfur in a ratio sufficient to produce a fertilizer composition with a fertilizer grade of 12-15 wt. % N, 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % S; and

   mixing the sources under conditions sufficient to produce the fertilizer composition.

9. The method of claim 8, wherein the fertilizer grade comprises 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S.

10. The method of claim 8, wherein the fertilizer grade comprises 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

11. The method of claim 8, wherein the fertilizer composition produced is a blended or compounded fertilizer.

12. The method of claim 8, wherein mixing the sources further comprises granulating one or more of the sources to form a granulated fertilizer, and the method further comprises drying the granulated fertilizer.

13. The method of claim 8, wherein mixing the sources further comprises coating one or more of the sources to form a coated fertilizer, and wherein the method further comprises drying the coated fertilizer.

14. The method of claim 8, wherein the fertilizer composition further comprises one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

15. A fertilizer composition with a fertilizer grade comprising 12-15 wt. % elemental nitrogen (N), 14-18 wt. % P_2O_5, 16-20 wt. % K_2O, and 4-10 wt. % elemental sulfur (S).

16. The fertilizer composition of claim 15, wherein the fertilizer composition is formulated to fertilize rice.

17. The fertilizer composition of claim 15, wherein the fertilizer grade comprises 13-15 wt. % N, 14-17 wt. % P_2O_5, 16-18 wt. % K_2O, and 5-9 wt. % S.

18. The fertilizer composition of claim 15, wherein the fertilizer grade comprises 14 wt. % N, 17 wt. % P_2O_5, 17 wt. % K_2O, and 7 wt. % S.

19. The fertilizer composition of claim 15, wherein the fertilizer composition is one or more of a blended fertilizer, a compounded fertilizer, a granulated fertilizer, or a coated fertilizer.

20. The fertilizer composition of claim 15, wherein the fertilizer composition further comprises one or more micronutrients, organic additives, additional secondary nutrients, or additional fertilizers.

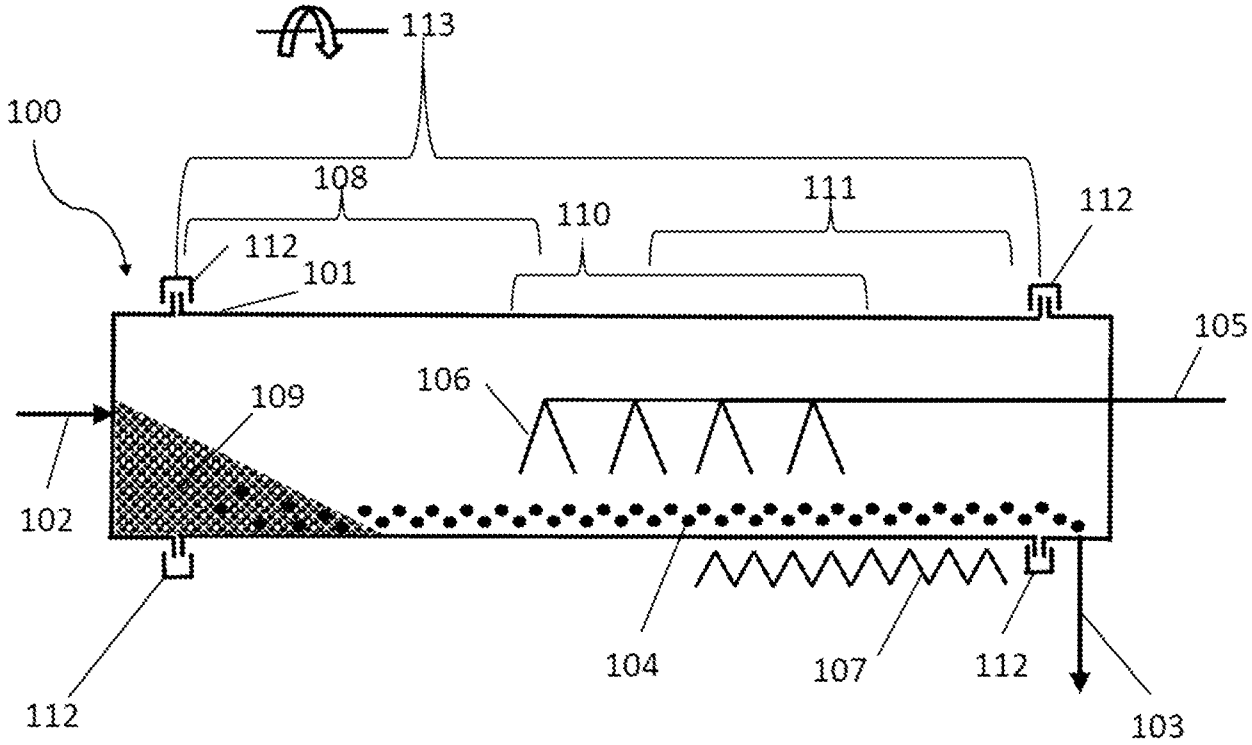

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FIG. 1

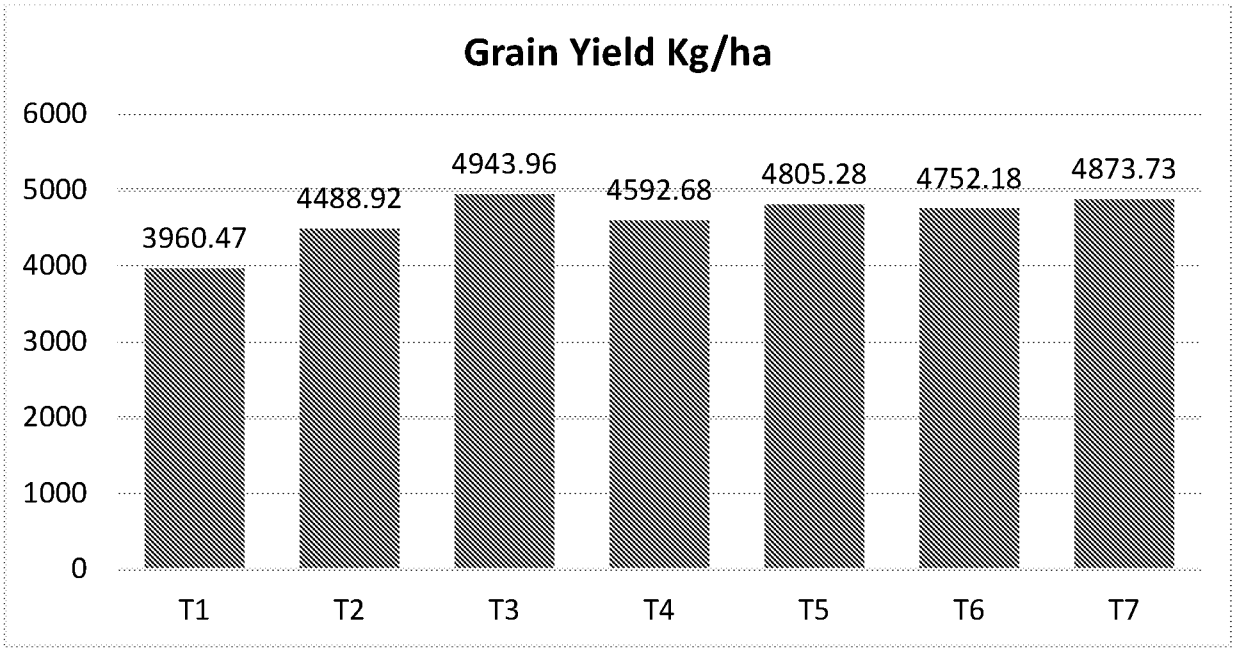

Grain Yield Kg/ha
6000
5000
4000
3000
2000
1000
0
3960.47
4488.92
4943.96
4592.68
4805.28
4752.18
4873.73
T1
T2
T3
T4
T5
T6
T7

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/060187

A. CLASSIFICATION OF SUBJECT MATTER
INV. C05C9/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C05C

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Anonymous: "Pioneering the Future Haifa Catalog Pioneering Products", , 18 November 2017 (2017-11-18), XP055666989, Retrieved from the Internet: URL:https://web.archive.org/web/20171118114809if_/http://www.haifa-group.com:80/files/Products/Haifa_Group_Catlog.pdf [retrieved on 2020-02-10] page 30	1-20

X	CN 1 907 919 A (HU CHUNXIN [CN]) 7 February 2007 (2007-02-07) the whole document examples claims	1-20

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 February 2020	18/02/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Cardin, Aurélie

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/060187

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RU 2 412 140 C2 (VOSKRESENSKIE MINERAL NYE UDOBRENIJA AOOT [RU]) 20 February 2011 (2011-02-20) the whole document -----	1-20

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2019/060187

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 1907919 A	07-02-2007	NONE	
RU 2412140 C2	20-02-2011	NONE	