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(71) Applicant: **OSTARA NUTRIENT RECOVERY TECHNOLOGIES INC.** [CA/CA]; 690 - 1199 West Pender Street, Vancouver, British Columbia V6E 2R1 (CA).

(72) Inventors: **CLARK, Donald R.**; 19705 Sea Rider Way, Lutz, Florida 33559 (US). **FROEHLICH, Dan Michael**; 5875 Red Pine Blvd, White Bear Lake, Minnesota 55110

(US). **BRITTON, Ahren Thomas**; 5811 Dunlinwood Ln, Lithia, Florida 33547 (US).

(74) Agents: **MANNING, Gavin N.** et al.; c/o Oyen Wiggs Green & Mutala LLP, 480 - The Station 601 West Cordova Street, Vancouver, British Columbia V6B 1G1 (CA).

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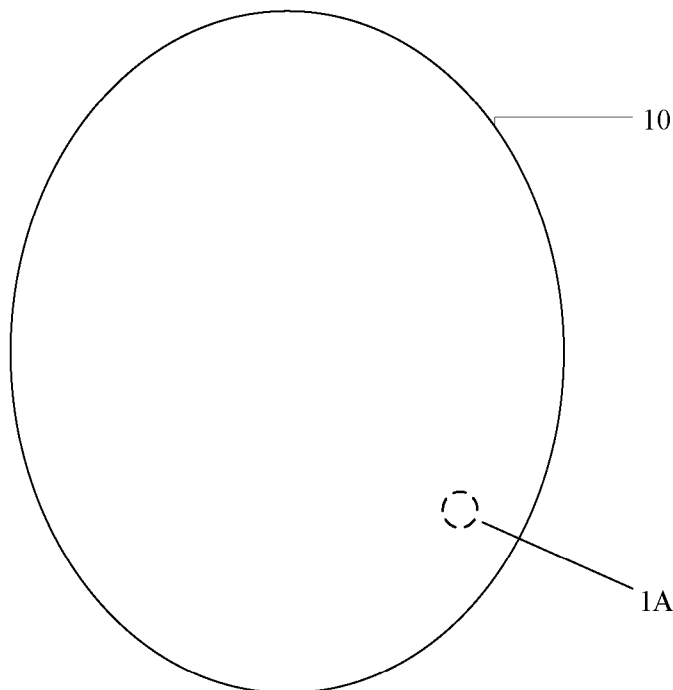


FIG. 1

(57) Abstract: A homogeneous fertilizer granule comprises slow-release (e.g. struvite) and fast release sources of phosphorus (P). The homogeneous fertilizer granule may further contain other essential nutrients and micronutrients required by plants. A number of methods may be used to make such granules. One method includes introducing a struvite slurry or fines and a liquid supply of water soluble P into a granulator. Alternatively, dry raw materials can be mixed with water/steam and/or another binder prior to being fed into a granulator. In another embodiment, pre-mixed dry raw materials are mechanically compacted and crushed to yield homogeneous fertilizer particles.

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**SLOW AND FAST RELEASE FERTILIZER COMPOSITION AND METHODS
FOR MAKING SAME**

Cross-Reference to Related Applications

5 [0001] This application claims priority from United States Application No. 61/835476 filed 14 June 2013. For purposes of the United States, this application claims the benefit under 35 U.S.C. §119 of United States Application No. 61/835476 filed 14 June 2013 and entitled SLOW AND FAST RELEASE FERTILIZER COMPOSITION AND METHODS FOR MAKING SAME which is hereby incorporated herein by reference for all purposes.

Technical Field

10 [0002] The invention relates to fertilizers for plants. Some embodiments of the invention provide granular fertilizers that provide both slow and fast release of nutrients. Some embodiments of the invention provide methods for making fertilizer particles.

Background

15 [0003] The growth and health of plants relies on a variety of nutrients. Three nutrients in particular are common components of fertilizer: nitrogen (N), phosphorus (P), and potassium (K). Fertilizers may additionally contain other active materials including macronutrients, such as magnesium (Mg), calcium (Ca), sulfur (S), micronutrients, such as boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), and nickel (Ni), pesticides, herbicides, etc.

20 [0004] A problem with many fertilizer compositions is the lack of sustained and simultaneous availability to plants of the component nutrient sources in the fertilizer. Typically, water-soluble components rapidly permeate the soil and may be lost via leaching, run-off or chemical binding with soil minerals. Water-insoluble components may be released over longer time scales.

25 [0005] Availability and retention of the nutrients and other active materials within the fertilizer will also be influenced by other factors. For instance, the pH level of soil and water hardness affect the bioavailability of phosphorus because phosphorus forms

insoluble precipitates when sequestered by calcium within alkaline soils and aluminum or iron within acidic soil. Irrigation with hard water is another factor that can limit the effectiveness of fertilizers to deliver phosphorus since hard water has high calcium content. A fertilizer that releases phosphorus at a lower rate (a slow-release fertilizer) can provide plants with a better opportunity to uptake this nutrient. Improved nutrient uptake increases nutrient use efficiency and decreases the amount of fertilizer required for optimum plant growth over a growing season. Furthermore, by decreasing the amount of fertilizer used and increasing the efficiency of nutrient uptake, less fertilizer may be used, and this may reduce the impact on the environment.

10 [0006] Various controlled or slow release fertilizers are described in the literature. These include: Agrotain™, Environmentally Smart Nitrogen (ESN™), Osmocote™, Nutricote™, and Polyon™.

[0007] Another issue of importance is the cost of fertilizers. It would be desirable to produce a fertilizer from low-cost raw materials. Struvite is a material that can be obtained as a by-product of waste water treatment processes. Harvesting struvite from wastewater is described for example in US patent Nos. 7622047 and 8444861. Struvite has the formula $MgNH_4 PO_4 \cdot 6H_2O$ and is also known as magnesium-ammonium-phosphate. Due to its low solubility in water, the slow-release nature of struvite can provide a sustained source of phosphorus over a growing season. The slow release of phosphorus also minimizes the sequestration of phosphorus by soil-borne cations as the phosphorus will only be made available by dissolution when there are plant roots present to take up the phosphorus; thus, by reducing the time phosphorus is present in the soil, the amount of sequestration by soil-borne cations is reduced. Furthermore, the presence of magnesium within struvite alleviates concerns over ineffectual phosphorus uptake by plants grown in alkaline soils or irrigated with hard water. Thus, struvite is an abundant, renewable source of water-insoluble phosphorus that may be used in the production of fertilizers.

[0008] Patent publications relating to fertilizers include:

- US20060230798 discloses a fertilizing material comprising a phosphate fertilizer and a phosphate binder of a bauxite refinery residue known as red mud,

- US20130104612 describes a phosphate fertilizer compound prepared from an insoluble source of phosphorus and preferably phosphate rocks in the presence of complexing compounds extracted from organic matter, and in particular the presence of humic substances to yield organo-calcium-phosphate complexes.
- 5 • US 8262765 discloses methods of producing a controlled release fertilizer that include intentional formation of magnesium ammonium phosphate within amino acid fermentation byproduct liquors.
- US20100326151 discloses an agglomerated fertilizer product comprising of nutrients and inert solids derived from a source material such as manure or
10 effluent.
- US20110314882 discloses A fertiliser composition in the form of pellets or granules comprising an organic fertiliser in admixture with a water absorbent polymer.
- WO2012020427 discloses a fertilizer comprising a water-insoluble, dilute acid-
15 soluble polyphosphate composition.
- WO2012053907 discloses a mixed release rate fertilizer composition comprising an acidulated phosphate together with a source of both slow release cobalt and quick release cobalt.

[0009] There is a need for fertilizers that can supply plants with nutrients, especially
20 phosphorus, on both an immediate and ongoing basis.

Summary

[0010] The present invention has a number of aspects. One aspect provides a fertilizer that comprises a plurality of nutrient sources in granules that are macroscopically
homogeneous. The fertilizer may comprise granules made up of small particles of struvite
25 intermixed with small particles of a fast-release phosphorus-containing material. The particles may be held together in the granules with or without a separate binder material.

[0011] Another aspect provides a granular fertilizer comprising granules having a size of at least SGN 100. The granules comprise particles of struvite having sizes of about SGN 10 or less and particles of a water-soluble phosphorus-containing material having sizes of

about SGN 10 or less. The struvite particles contain in the range of 6% to 18% (in some embodiments 7% to 17% or 8% to 16%) of total phosphate in the granules.

[0012] In some embodiments the water-soluble phosphorus-containing material is acidic in aqueous solution. For example, a saturated solution of the water-soluble phosphorus-containing material may have a pH of 5.5 or less. In some embodiments the water-soluble phosphorus-containing material comprises a material selected from the group consisting of single superphosphate, triple superphosphate, monoammonium phosphate and combinations thereof. In some embodiments the fertilizer granules consist essentially of struvite and the water-soluble-phosphorous-containing material. In some embodiments the particles of struvite are uniformly distributed in the granules within $\pm 7\%$.

[0013] In some embodiments the particles of struvite and the particles of water-soluble phosphorus-containing material are exposed on outer surfaces of the granules. The particles of struvite and the particles of water-soluble phosphorus-containing material may be uniformly distributed on outer surfaces of the granules.

[0014] In some embodiments the granules have a struvite content in the range of 12 to 28 % by weight. In some embodiments substantially all phosphate in the granules is in the form of struvite or the water-soluble phosphorus-containing material. In some embodiments the water-soluble phosphorus-containing material is monoammonium phosphate.

[0015] A fertilizer according to this aspect may optionally comprise a binder which may, for example, comprise monoammonium phosphate, calcium lignosulphonates, starch or molasses.

[0016] An example embodiment provides a fertilizer comprising granules that consist essentially of struvite and monoammonium phosphate.

[0017] Another aspect of the invention provides the use of a fertilizer as described herein for growing any of a wide range of plants. For example, the use of a fertilizer for growing tuber plants such as potatoes or leafy plants such as lettuce.

[0018] Another aspect provides a granular fertilizer having granules that comprise a mixture of struvite and a relatively fast-release phosphorus-containing material homogeneously distributed within the granules. The non-struvite fraction of the granules may comprise water-soluble sources of phosphorus derived, for example, from phosphoric acid; single super phosphate (SSP); double super phosphate (DSP); triple super phosphate (TSP - $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$); monoammonium phosphate (MAP); diammonium phosphate (DAP); or dicalcium phosphate. Fertilizers according to these aspects of the invention may optionally include other nutrients such as additional sources of nitrogen, potassium, sulfur, or any other nutrient or micronutrient useful for plant growth or health and/or other active materials such as pesticides, selective herbicides, and the like.

[0019] Fertilizer granules according to different embodiments comprise varied proportions of slow- and fast-release phosphorus. Embodiments having different proportions of slow- and fast-release phosphorus may be used in different applications based on phosphorus demand from targeted plants. Some preferred embodiments comprise struvite in the range of 12% by weight to 28% by weight.

[0020] Other aspects of the invention provide methods for making granular fertilizers. The methods involve granulating a mixture of struvite fines and water soluble material containing phosphorus. The methods of different aspects differ in regard to the manner of introduction of the water-soluble material containing phosphorus. In one example embodiment, the water-soluble material containing phosphorus has a liquid phase and, in the liquid phase is combined with struvite fines to form a slurry which is processed to yield granules in a granulator. Other plant nutrient sources can be added to yield a homogeneous fertilizer particle of various compositions.

[0021] Another example embodiment utilizes water and/or steam and/or a binder to produce a slurry comprising desired proportions of struvite and a water-soluble material containing phosphorus, and the slurry is processed in a granulator to yield granules.

[0022] Another example embodiment pre-mixes small particles or powders of dry struvite and water-soluble material containing phosphorus. The mixture is compacted to yield a

dense form such as a sheet. The dense form is then crushed to produce homogeneous granules of fertilizer.

[0023] Further aspects and example embodiments are illustrated in the accompanying drawings and/or described in the following description.

5 Brief Description of the Drawings

[0024] The accompanying drawings illustrate non-limiting example embodiments of the invention.

[0025] Figure 1 shows a cross-section of a fertilizer granule according to an example embodiment.

10 [0026] Figure 1A is a further magnified view of a portion 1A of the fertilizer granule of Figure 1.

[0027] Figure 1B is a magnified view of a portion of a fertilizer granule according to another embodiment.

15 [0028] Figure 2 is a process diagram illustrating a first example method for making fertilizer granules.

[0029] Figure 3 is a process diagram illustrating a second example method for making fertilizer granules.

[0030] Figure 4 is a process diagram illustrating a third example method for making fertilizer granules.

20 Description

[0031] Throughout the following description specific details are set forth in order to provide a more thorough understanding to persons skilled in the art. However, well known elements may not have been shown or described in detail to avoid unnecessarily obscuring the disclosure. The following description of examples of the invention is not intended to

be exhaustive or to limit the system to the precise forms of any example embodiment. Accordingly, the description and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

[0032] Figure 1 is a magnified cross-section of an example fertilizer granule 10. Figure 5 1A is a further magnified view of a portion 1A of granule 10. Figure 1B is a magnified view of a portion of granule 10 according to another embodiment. As can be best seen in Figure 1A, granule 10 comprises small particles of struvite 12 evenly intermixed with small particles of a water-soluble phosphorus-containing material 14. Water-soluble phosphorus-containing material 14 is preferably a material that, when dissolved in water, 10 liberates phosphorus in a form that can be taken up efficiently by plants (for example, in the form of ions of H_2PO_4^- and HPO_4^{2-}). In some embodiments, water-soluble phosphorus-containing material 14 is monoammonium phosphate (MAP), diammonium phosphate (DAP), a combination of both, or other suitable phosphates as would be known to a person skilled in the art in light of the present disclosure.

15 [0033] The applicant has found that phosphorus is released more quickly from struvite particles 12 when struvite particles 12 are in an acidic environment. This may be achieved, for example, by selecting a water-soluble phosphorus-containing material 14 that is acidic. For example, water-soluble phosphorus-containing material 14 may comprise one or more 20 of single superphosphate, triple superphosphate or monoammonium phosphate, all of which are acidic. A solution of single superphosphate typically has a $\text{pH} \leq 2$. A solution of triple superphosphate typically has a pH in the range of about 1 to 3. A solution of monoammonium phosphate typically has a pH in the range of 4 to 4.5. In some 25 embodiments, dissolution in water of those parts of a granule 10 that dissolve readily in water yields an acidic solution. In some embodiments, the pH of such a solution, when saturated, does not exceed 5.5 and does not exceed 5 in some embodiments. Varying the composition of granules 10 to adjust the acidity of those parts of a granule 10 that dissolve readily in water is one way to adjust a period over which phosphorus from struvite particles 12 is made available for uptake by plants.

[0034] Making those parts of a granule 10 that dissolve readily in water less acidic can 30 make release of phosphorus from struvite particles slower while making those parts a

granule 10 that dissolve readily in water more acidic can make release of phosphorus from struvite particles 12 occur more rapidly once granules 10 become dampened by contact with soil.

[0035] Combining struvite with a water soluble source of phosphorus allows immediate and sustained delivery of phosphorus to plants. The presence of struvite 12 throughout granule 10 prevents the water-soluble phosphorus-containing material 14 that is not on the surface of granule 10 from being able to contact any surrounding water. Particles of water-soluble phosphorus-containing material 14 inside granule 10 are protected until outer layers of granule 10 are eroded to the point that particles of water-soluble phosphorus-containing material 14 inside granule 10 are exposed to water.

[0036] Phosphorus, usually as phosphate (P_2O_5), may be present in fertilizers in various different forms. The availability of phosphate in any particular fertilizer for take up by plants depends on the form in which the phosphate is present. This availability may be assessed by determining the solubility of the fertilizer in various solvents. For example, phosphate may be present in forms which are: water soluble; neutral ammonium citrate soluble or insoluble; citric acid soluble or insoluble; and acid soluble. “Available phosphorus” may be defined as the sum of the water soluble and citrate soluble fractions of a phosphate fertilizer. Plants are capable of utilizing both forms of the soluble sources.

[0037] Example methods for determining water soluble phosphate and citrate soluble phosphate are described in:

- AOAC: Official Methods of Analysis 15th Edition, 1990, which describes standard methods specified by the standards body AOAC International (ASSOCIATION of OFFICIAL ANALYTICAL CHEMISTS);
 - Guide to laboratory establishment for plant nutrient analysis; FAO Fertilizer and plant nutrition bulletin 19; FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, Rome, 2008 ISSN 0259-2495
- both of which are hereby incorporated herein by reference.

[0038] Water-soluble phosphate (P_2O_5) of a fertilizer sample may be determined, for example, by dissolving the sample in distilled water or by washing the sample successively with distilled water. For example, a 1g fertilizer sample may be placed on a filter paper fitted on a funnel. The sample may be washed with small portions of water until 250 ml of filtrate has been collected. The phosphate content of the filtrate may then be measured, for example using a gravimetric method such as the gravimetric quinolinium phosphomolybdate method or the volumetric ammonium phosphomolybdate method. The residue remaining on the filter paper contains the water-insoluble portion of P in the sample which can also be analyzed to determine the phosphate content.

[0039] Citrate soluble phosphate may be measured in a similar manner using as a solvent a neutral ammonium citrate solution.

[0040] In some embodiments, water-soluble phosphorus-containing material 14 has at least 80% water soluble phosphate content. In some embodiments, struvite particles 12 comprise 5% or less water soluble phosphate and at least 80% citrate soluble phosphate. Struvite typically has a water solubility of not more than about 1.0% and a citrate solubility on the order of 99%. MAP typically has a water solubility on the order of about 87% and a citrate solubility on the order of about 13%.

[0041] The relative amounts of struvite 12 and water-soluble phosphorus-containing material 14 can vary widely. In some embodiments, the struvite content of granules 10 is in the range of about 1% to about 99% struvite by weight. In other embodiments, the struvite content of granules 10 is in the range of about 5% to 50% by weight and the content of water-soluble phosphorus-containing material 14 is in the range of about 95% to 50% by weight. Applicant has discovered that a particularly advantageous relative amount of struvite for certain applications is in the range of 7% to 15% of total phosphate provided by struvite particles 12 and the remaining 93% to 85% of the total phosphate content being provided by the water-soluble phosphorus-containing material 14. In the case where the water-soluble-phosphorus-containing material 14 is MAP, this corresponds to about 12% to 28% by weight of the phosphate-containing components of the granules being struvite with the remaining 88% to 72% by weight being MAP.

[0042] Granule 10 may be homogeneous at a macroscopic level. In one embodiment, the small particles of struvite 12 and water-soluble phosphorus-containing material 14 are evenly dispersed throughout granule 10. In other embodiments, granule 10 is packed tightly with particles of struvite 12 and water-soluble phosphorus-containing material 14.

5 In other embodiment, granule 10 is packed loosely with particles of struvite 12 and water-soluble phosphorus-containing material 14. In yet other embodiments, the outer region of granule 10 has a higher concentration of water-soluble phosphorus-containing material 14 relative to the interior region. In further embodiments, particles of struvite 12 and water-soluble phosphorus-containing material 14 are exposed on the outer surface of granule 10.

10 In other embodiments, particles of struvite 12 and water-soluble phosphorus-containing material 14 are uniformly distributed on the outer surface of granule 10 $\pm 7\%$. In yet other embodiments, the outer region of granule 10 has a higher concentration of struvite 12 relative to the interior region. In some embodiments, the ratio of struvite 12 to water-soluble phosphorus-containing material 14 is constant to within $\pm 7\%$ throughout granule

15 10. In one embodiment, particles of struvite 12 are uniformly distributed in granule 10 within $\pm 7\%$. In another embodiment, particles of water-soluble phosphorus-containing material are uniformly distributed in granule 10 within $\pm 7\%$.

[0043] In example embodiments, granule 10 is characterized by a diameter or other characteristic dimension on the order of about 1 to 6 mm. Particle sizes may be described

20 by a size guide number (SGN). SGN is given by the diameter of the median granule size in millimeters multiplied by 100. For example, a SGN of 311 corresponds to a median particle size of 3.11 mm. In one embodiment, granules 10 have a size at or between about SGN 100 to SGN 600.

[0044] The particles of struvite 12 and water-soluble phosphorus-containing material 14

25 have characteristic dimensions that are 100 times or more smaller than the characteristic dimension of granule 10 (e.g. not exceeding about 0.1 mm (SGN 10 or passing 150 mesh size screen) in some embodiments and not exceeding about 75 μm (SGN 7.5/passing 200 mesh size screen) in other embodiments). In some embodiments, the particles of struvite 12 are about 100 μm or less (about SGN 10 or less). In other embodiments, the particles of

30 water-soluble phosphorus-containing material 14 are about 100 μm or less (about SGN 10 or less). The size of the particles of struvite 12 in granules 10 can be adjusted to modify

the dissolution rate of the struvite phase of granules 10. For instance, if slower dissolution of struvite 12 is needed, then the size of the particles of struvite 12 may be made larger. On the other hand, if faster dissolution of struvite 12 is needed, then the size of the particles of struvite 12 may be made smaller.

- 5 [0045] In one embodiment, particles of struvite 12 and particles of water-soluble phosphorus-containing material 14 are similar in size. In other embodiments, such particles are identical in size. In yet other embodiments, particles of struvite 12 and particles of water-soluble phosphorus-containing material 14 have different sizes.

[0046] Granule 10 may have a hardness/crush strength of about 4lbs or greater.

- 10 [0047] In one embodiment, granules 10 are spherical or substantially spherical in shape. In other embodiments, granules 10 are elliptical or substantially elliptical in shape. Granules 10 may have other shapes. Advantageously, granules 10 have shapes that allow bulk granules 10 to properly flow through equipment used to apply the granules such as fertilizer spreaders and/or fertilizer drills.

- 15 [0048] In one embodiment, granules 10 are substantially uniform in size. In another embodiment, there is heterogeneity to the size of granules 10. In yet other embodiments, fertilizers comprise mixtures of different sizes of granules 10. In other embodiments, fertilizers comprise mixtures of granules 10 having different compositions of struvite 12 and water-soluble phosphorus-containing material 14. In yet other embodiments, fertilizers
20 comprise mixtures of granules 10 having different distributions of struvite 12 and water-soluble phosphorus-containing material 14. Preferably, granules 10 are of sufficiently similar size so that granules 10 do not segregate during transport of granules 10.

- [0049] In one embodiment, struvite 12 and water-soluble phosphorus-containing material 14 are in the form of distinguishable particles within granules 10. In other embodiments,
25 as illustrated in Figure 1B, particles of water-soluble phosphorus-containing material 14 are in the form of a matrix surrounding particles of struvite 12. In other embodiments, granules 10 are formed of layers of particles of struvite 12 and particles of water-soluble phosphorus-containing material 14. In yet other embodiments, granules 10 are formed of

alternating layers of particles of struvite 12 and particles of water-soluble phosphorus-containing material 14. In further embodiments, such alternating layers of particles of struvite 12 and particles of water-soluble phosphorus-containing material 14 are concentric alternating layers.

- 5 [0050] Granules 10 may optionally comprise a binder for use in binding together particles of struvite 12 and particles of water-soluble phosphorus-containing material 14. In one embodiment, the binder is calcium lignosulphonates. In other embodiments, the binder is starch. In yet other embodiments, the binder is molasses. In a further embodiment, the binder is MAP.
- 10 [0051] Granules 10 may further optionally be coated with a coating. In one embodiment, the coating is a biological agent. In yet other embodiments, the coating comprises plant-growth promoting rhizobacteria, such as rhizobium, azotobacter, azospirillum, and/or cyanobacteria. In further embodiments, the coating comprises other materials that may enhance plant growth. In other embodiments, the coating comprises one or more materials
- 15 that may assist in the controlled release of phosphorus, such as a thermoplastic.

- [0052] In one embodiment, upon placement of granules 10 in an area having moisture, such as soil-laden areas, particles of water-soluble phosphorus-containing material 14 are the first to dissolve upon contact with moisture. Upon such dissolution, granules 10 would then contain cavities through which moisture can penetrate. Moisture penetrating granules
- 20 10 through these cavities will encourage dissolution of particles of water-soluble phosphorus-containing material 14 within the unexposed portions of granules 10.

- [0053] An initial greenhouse study grew lettuce for 9 weeks. Fertilizer as described herein comprising granules of struvite co-granulated with MAP in different proportions was applied at a P_2O_5 application rate of 80 lbs P_2O_5 /acre equivalent. Soil was a sandy loam.
- 25 Greenhouse lighting provided 16 hours of sunlight/day. This study showed that fertilizer comprising 15% struvite by weight was 3.7% higher yielding and fertilizer containing 25% struvite by weight was 3.0% higher yielding than a comparison plot fertilized with mono-ammonium phosphate. Tested fertilizer compositions which included more than 25% struvite or less than 15% struvite by weight provided poorer yields of lettuce. A

follow-up greenhouse experiment found that the fertilizer containing 15% by weight struvite was 1.7% higher yielding than a comparison plot fertilized with mono-ammonium phosphate.

5 [0054] In a greenhouse study one plot was fertilized with a fertilizer comprising a blend of struvite granules and MAP granules. A comparison plot was fertilized with a fertilizer comprising a blend of struvite particles with di-ammonium phosphate (DAP) granules. It was found that the struvite -MAP blend generated a 15.9% higher yield than the struvite-DAP blend. The total amount of phosphate and the amount of phosphate provided in the form of struvite were the same in both cases.

10 [0055] In a field trial growing lettuce, fertilizer as described herein comprising pellets of struvite co-granulated with MAP in different proportions was applied at a P_2O_5 application rate of 80 lbs P_2O_5 /acre equivalent. Soil was a sandy loam. For comparison a plot was fertilized with a co-blended fertilizer comprising 25% by weight struvite in which struvite and MAP were provided by separate granules. The field trial found that the fertilizer
15 containing 15% struvite by weight and the fertilizer containing 25% struvite by weight performed equally and were 29.9% higher yielding than the co-blended fertilizer.

[0056] These trials found that a co-granulated product (i.e. a homogeneous product with water soluble and slow release P in each granule) was more effective at lower slower release P content than a comparable co-blended fertilizer in which water soluble phosphate
20 and slow-release phosphate were provided in individual separate granules.[0057] One application of a fertilizer as described herein is in growing potatoes or other similar plants. Such a fertilizer may be applied in an amount sufficient to provide a desired level of water -soluble phosphate to induce formation of many potatoes during the early tuber initiation phase. The same fertilizer can then provide sufficient slow-release phosphate to
25 support the filling out of those many small potatoes during the potato bulking phase later in the season. This may improve both potato yield and grade. By contrast, applying a fertilizer comprising phosphate that is entirely in a water-soluble form according to typical current farming practices can result in a large number of potatoes being initiated and then growing slowly due to a non-optimally low concentration of available phosphate in the

soil later in the season. The potatoes then remain too small (or of lesser value small-size grades).

[0058] Granules like granule 10 may be made in various ways. The following are some non-limiting example processes for making fertilizer granules. Any of these processes may be applied to make fertilizer granules like granule 10 described above. In preferred 5 embodiments, the fertilizer granules include small particles of struvite. The processes differ in terms of the manner in which the struvite particles are processed to yield fertilizer granules.

[0059] Figure 2 illustrates a process 20 according to one example embodiment. Process 20 10 involves chemical granulation. In process 20, granules may be formed by accretion. In process 20, struvite 22 is powdered, for example by crushing or grinding in a suitable mill 23 (unless the struvite 22 is already in the form of suitably small particles). Liquid phase material 26 is obtained by reacting ammonia 24 with a water-soluble phosphate 25 such as phosphoric acid or other soluble phosphates known to a person skilled in the art. This 15 reaction may be performed in a suitable reactor such as a suitable tank-type pre-neutralizer or a pipe-type reactor.

[0060] Powdered struvite 22 and liquid-phase material 26 are introduced into a granulator 28. This may be done by mixing the powdered struvite 22 and liquid phase material 26 to form a slurry in the reactor 27 and then introducing the slurry into granulator 28. Fines of 20 struvite 22 may also be introduced into granulator 28 directly from mill 23 or by a recycle path, where struvite 22 may be mixed with dried recycle material (e.g. a material comprising recycle dry product and/or crushed oversize material and/or undersized material), for example. In some embodiments a pug mill or other mechanical mixing device may be used to premix dry solids (e.g. struvite) and liquid prior to introduction to 25 granulator 28. Where struvite 22 is introduced directly into granulator 28 as fines, in some embodiments, the struvite particles 22 may have sizes of about 1 mm diameter or less. In other embodiments, the struvite particles 22 may have a size of less than 100 μm in diameter.

[0061] Optionally a binder is added to granulator 28 to enhance granule strength and cohesiveness. Calcium lignosulphonate, starch or molasses binders may be used to help improve granulation. MAP may also be used as a binder.

[0062] In some embodiments the material entering granulator 28 has a struvite content in the range of up to 25% by weight (e.g. 1% to 25%). In some embodiments the material entering granulator 28 has a struvite content in the range of about 12% to about 28% by weight. In some embodiments the proportion of the total phosphate in the material entering granulator 28 provided by the phosphate in the struvite is in the range of 6% to 18% (7% to 15% in some embodiments). Preferably, the struvite content of materials entering granulator 28 is of such a proportion that granule 10 will remain cohesive and have sufficient struvite to make the product economically attractive. Struvite particles 22 may be injected as fines into the recycle stream of the granulation plant or as a slurry into granulator 28. The particular makeup of the solid and liquid raw materials delivered to granulator 28 will depend on the specific formulation of the fertilizer being produced according to non-exhaustive variables including 1) desired nutrient ratios, 2) nutrient solubility requirements, 3) heat of reaction, 4) temperature limitations to limit thermal breakdown of struvite, 5) pH, and 6) process plant and equipment limitations.

[0063] Granulator 28 may, for example, comprise a rotary drum, fluidized bed, pug mill, pipe reactor, or Spherodizer®. Steam, water, scrubber liquor, and/or additional ammonia and acid may optionally be fed into granulator 28 in order to optimize granulation characteristics of each particular formulation.

[0064] In addition to phosphorus, granule product produced by process 20 may also contain water-soluble forms of nitrogen, a macronutrient in fertilizers. In one embodiment, nitrogen in products originate from MAP and DAP, both of which contain water soluble nitrogen in ammonia form.

[0065] Granule products produced by process 20 may also contain magnesium, another macronutrient. In one embodiment, magnesium in the product originates from thermal breakdown of struvite 22 that is fed into granulator 28. In some embodiments, the temperature range of the product bed leading to breakdown of struvite 22 is 55°C to 75°C.

[0066] Granules output by granulator 28 are dried and screened at 29 to yield product size material. The product may be cooled and coated to reduce caking. Granules of sizes outside of a desired range (oversize and/or undersize) may be crushed and returned to granulator 28. Such oversized or undersized granules may help to absorb the excess
5 moisture in granulator 28 and to control product size.

[0067] In one embodiment, granule products are screened at 29 for size using screeners. In other embodiments, granule products are separated by weight.

[0068] Figure 3 illustrates a process 30 according to another example embodiment which produces fertilizer granules by steam/water granulation. In process 30, the addition of
10 steam and/or water 37 to a granulator 34 provides all or most of the liquid needed for granulation.

[0069] In process 30, struvite 32 is powdered, for example by crushing or grinding in a suitable mill 33 (unless the struvite 32 is already in the form of suitably small particles). It can be convenient to provide struvite 32 as a slurry with a moisture content of up to 25%
15 by weight. In one embodiment, particles of struvite 32 have a diameter of up to 1 mm. In other embodiments, particles of struvite 32 have a diameter of up to 100 μm . Struvite 32 and other powdered raw materials 33 (e.g. one or more of a water-soluble phosphorus-containing material, other nutrients, a binder 35 (e.g. MAP, calcium lignosulphonates, starch or molasses etc.)) are proportioned and fed into granulator 34. The materials may
20 enter granulator 34 together or in two or more separate streams. Optionally, raw materials which may optionally include one or more liquids, are premixed, for example in a pug mill or similar device (not shown) prior to being fed into granulator 34. Struvite 32 may also be added into granulator 34 by a recycle path (the recycle path may carry, for example, recycle dry product and/or crushed oversize material and/or undersized material).

[0070] Granulator 34 may comprise, for example a, rotary drum, pug mill, or pan
25 granulator. Steam and/or water 37 is introduced into granulator 34 in an amount sufficient to cause the dry raw materials to agglomerate into granules having the desired size and properties.

[0071] Granules are dried at a drier 36 and screened at a screen 38 or other size selector to separate product size granules from granules that are oversize or undersize. Oversized and undersized granules may be crushed and recycled to granulator 34. In one embodiment, granules are screened at screen 38 by weight. Product size material may also be recycled and re-introduced into granulator 34 as part of the recycle process to absorb the excess moisture in the granulator and to control product size. If required, the product may be cooled and coated to reduce caking.

[0072] Figure 4 is a process diagram depicting a process 40 according to another example embodiment in which fertilizer granules are formed from dry raw materials by compaction.

[0073] In process 40, fine, non-granular sources of struvite 42, water-soluble phosphorus-containing material 43, and any other nutrient to be incorporated into the homogeneous fertilizer product particles are proportioned and thoroughly mixed at a mixer 44 . Advantageously, the size of particles of struvite 42 is about 100 μm or below (about SGN 10 or less). Advantageously, the size of particles of water-soluble phosphorus-containing material is about 100 μm or below (about SGN 10 or less). Optionally, suitable material (as described herein for example) may be added to the mixture as binder 41 to enhance product characteristics. Other fertilizer ingredients that are desired to achieve the desired nutrient ratios, mixture of water soluble and slow release components, product characteristics and/or micronutrients may optionally be added to the mixture.

[0074] The mixture is pressed into a compact form by a suitable press 45. For example, in one embodiment, the mixture may be formed into a dense hard sheet, which in some embodiments is approximately 2 – 3 cm thick, by the addition of mechanical force. Press 45 may comprise, for example, a number of horizontally-opposed rollers that counter-rotate. The mixture is then compressed in passing between the rollers.

[0075] The resulting sheet of fertilizer may then be crushed in a controlled manner, for example by a crusher 47 to yield smaller granules. The crushed material may then be screened at a screen or other size selector 48 to obtain granules of a desired product size

range. In some embodiments, size selector 48 selects granules by weight. Oversize and undersized particles may be crushed and returned to press 45.

[0076] Granules of granular fertilizers prepared by compaction will typically have shapes that are more irregular as compared to granules produced by the other granulation
5 processes discussed above.

[0077] The granules produced by any of the methods described herein may have struvite (1% to 99% by weight) and soluble phosphorus (99% to 1% by weight) as required for a desired application. In some embodiments the granules comprise struvite in the range of 12% to 28% by weight. In some embodiments the proportion of the total phosphate in the
10 granules provided by the phosphate in the struvite is in the range of 6% to 18% (7% to 15% in some embodiments). Substantially all of the remainder of the phosphate is in the form of soluble phosphorus in some embodiments.

[0078] Product granules similar to granules 10, which may be produced by any of the production processes disclosed above, may be used to fertilize plants in different ways.
15 For example, the product granules may be applied as a banded fertilizer by placement of the product granules below the surface of the soil. In some embodiments, the product granules are placed at least 2 cm below the surface. In other embodiments, the product granules may also be applied by incorporation into the soil.

[0079] Specific examples of systems, methods and apparatus have been described herein
20 for purposes of illustration. These are only examples. The technology provided herein can be applied to systems other than the example systems described above. Many alterations, modifications, additions, omissions, and permutations are possible within the practice of this invention. This invention includes variations on described embodiments that would be apparent to the skilled addressee, including variations obtained by: replacing features,
25 elements and/or acts with equivalent features, elements and/or acts; mixing and matching of features, elements and/or acts from different embodiments; combining features, elements and/or acts from embodiments as described herein with features, elements and/or acts of other technology; and/or omitting combining features, elements and/or acts from described embodiments.

[0080] In addition, while elements are at times shown as being performed sequentially, they may instead be performed simultaneously or in different sequences. It is therefore intended that the following claims are interpreted to include all such variations as are within their intended scope.

- 5 [0081] It is therefore intended that the following appended claims and claims hereafter introduced are interpreted to include all such modifications, permutations, additions, omissions, and sub-combinations as may reasonably be inferred. The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

What is claimed is:

1. A granular fertilizer comprising:
granules having a size of at least SGN 100, the granules comprising
particles of struvite having sizes of about SGN 10 or less and particles of a water-
soluble phosphorus-containing material having sizes of about SGN 10 or less;
5 wherein the struvite particles contain in the range of 6% to 18% of total
phosphate in the granules.
2. A fertilizer according to claim 1 wherein the water-soluble phosphorus-containing
10 material is acidic in aqueous solution.
3. A fertilizer according to claim 2 wherein a saturated solution of the water-soluble
phosphorus-containing material has a pH of 5.5 or less.
- 15 4. A fertilizer according to claim 2 wherein the water-soluble phosphorus-containing
material comprises a material selected from the group consisting of single
superphosphate, triple superphosphate, monoammonium phosphate and
combinations thereof.
- 20 5. A fertilizer according to any one of claims 1 to 4 wherein the particles of struvite
are uniformly distributed in the granules within $\pm 7\%$.
6. A fertilizer according to any one of claims 1 to 5 wherein the particles of struvite
and the particles of water-soluble phosphorus-containing material are exposed on
25 outer surfaces of the granules.
7. A fertilizer according to claim 6 wherein the particles of struvite and the particles
of water-soluble phosphorus-containing material are uniformly distributed on outer
surfaces of the granules.

8. A fertilizer according to any one of claims 1 to 7 wherein the granules have a struvite content in the range of 12 to 28 % by weight.
9. A fertilizer according to any one of claims 1 to 8 wherein substantially all phosphate in the granules is in the form of struvite or the water-soluble phosphorus-containing material.
10. A fertilizer according to claim 9 wherein the water-soluble phosphorus-containing material is monoammonium phosphate.
11. A fertilizer according to any one of claims 1 to 10 comprising a binder.
12. A fertilizer according to claim 11 wherein the binder comprises monoammonium phosphate, calcium lignosulphonates, starch or molasses.
13. A fertilizer according to any of claims 1 to 9 wherein the granules consist essentially of struvite and monoammonium phosphate.
14. A fertilizer according to any one of claims 1 to 13 wherein the granules are substantially spherical in shape or substantially elliptical in shape.
15. A fertilizer according to claim 1 wherein the water-soluble phosphorus-containing material comprises one or more of: phosphoric acid; single super phosphate; double super phosphate; triple super phosphate; monoammonium phosphate; diammonium phosphate; and dicalcium phosphate.
16. Use of a fertilizer according to any one of claims 1 to 15 for growing tuber plants.
17. A use according to claim 16 wherein the plants comprise potatoes.
18. A use according to claim 16 or 17 comprising applying the fertilizer prior to a tuber initiation phase.

19. Use of a fertilizer according to any one of claims 1 to 15 for growing lettuce.
20. A use according to claim 19 comprising applying the fertilizer at an application rate of at least 80 lbs P₂O₅/acre equivalent.
- 5 21. A granular fertilizer comprising a slow release low water-solubility source of phosphorus and a fast release water-soluble source of phosphorus bound together into granules.
- 10 22. The fertilizer of claim 21, wherein the slow release source of phosphorus comprises struvite.
23. The fertilizer of claim 21 or 22, wherein the fast release source of phosphorus comprises one or more of: phosphoric acid; single super phosphate; double super phosphate; triple super phosphate; monoammonium phosphate; diammonium phosphate; and dicalcium phosphate.
- 15 24. The fertilizer of any one of claims 21 to 23 further comprising other essential or non-essential nutrient and micro-nutrient sources.
- 20 25. The fertilizer of any one of claims 21 to 24 further comprising a binder.
26. The fertilizer of any one of claims 21 to 25 wherein the fast release source of phosphorus is in the form of a matrix surrounding particles of the slow release source of phosphorus.
- 25 27. The fertilizer of claim 22 wherein the struvite is in a particulate form.
28. The fertilizer of claim 27 wherein the particles of struvite have sizes of about 100 μm or less.
- 30 29. The fertilizer of claim 27 wherein the particles of struvite have sizes of about SGN10 or less.

30. The fertilizer of claim 27 wherein the particles of struvite pass screens with a mesh of 150 or greater.
- 5 31. The fertilizer of any one of claims 21 to 30 wherein the fast release source of phosphorus is a water-soluble phosphorus-containing material in particulate form.
32. The fertilizer of claim 31 wherein the particles of water-soluble phosphorus-containing material have sizes of about 100 μm or less.
- 10 33. The fertilizer of claim 31 wherein the particles of water-soluble phosphorus-containing material have sizes of about SGN10 or less.
34. The fertilizer of claim 31 wherein the particles water-soluble phosphorus-containing material pass screens with a mesh of 150 or greater.
- 15 35. The fertilizer of any one of claims 21 to 34 wherein the granules have sizes in the range of about 1mm to about 6mm.
- 20 36. The fertilizer of any one of claims 21 to 34 wherein the granules have sizes equal to or greater than about 1mm.
37. The fertilizer of any one of claims 21 to 34 wherein the granules have sizes equal to or less than about 6mm.
- 25 38. The fertilizer of claim 27 wherein particles of struvite are uniformly distributed in the granule within $\pm 7\%$.
39. The fertilizer of claim 31 wherein particles of the water-soluble phosphorus-containing material are uniformly distributed in the granules within $\pm 7\%$.
- 30 40. The fertilizer of claim 31 wherein the particles of water-soluble phosphorus-containing material are uniformly distributed within the granules.

41. The fertilizer of any one of claims 21 to 40 wherein struvite and water-soluble phosphorus-containing material are exposed on outer surfaces of the granules.
- 5 42. The fertilizer of claim 41 wherein particles of the struvite and particles of the water-soluble phosphorus-containing material are uniformly distributed on the outer surface of the granules.
43. The fertilizer of claim 22 wherein the struvite content by weight is in the range of
10 10% to 29%.
44. The fertilizer of claim 22 wherein the struvite content by weight is at or greater than 1%.
- 15 45. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 1% to about 9%.
46. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 10% to about 19%.
20
47. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 20% to about 29%.
48. The fertilizer of claim 22 wherein the struvite content by weight is in the range of
25 about 30% to about 39%.
49. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 40% to about 49%.
- 30 50. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 50% to about 59%.

51. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 60% to about 69%.
52. The fertilizer of claim 22 wherein the struvite content by weight is in the range of
5 about 70% to about 79%.
53. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 80% to about 89%.
- 10 54. The fertilizer of claim 22 wherein the struvite content by weight is in the range of about 90% to about 99%.
55. A method of producing a fertilizer, the method comprising:
mixing struvite with water-soluble phosphorus-containing material;
15 granulating the mixture into granules; and
selecting the granules based on size.
56. The method of claim 39 further comprising the step of grinding or crushing the struvite into powdered struvite.
20
57. The method of claim 39 wherein the granulation step comprises wet granulation.
58. The method of claim 39 wherein the granulation step comprises dry granulation.
- 25 59. The method of claim 39 wherein the granulation step comprises chemical granulation.
60. The method of any one of claims 55 to 59 wherein the water-soluble phosphorus-containing material comprises monoammonium phosphate (MAP), diammonium
30 phosphate (DAP), or a combination of both.
61. The method of any one of claims 55 to 59 wherein the water-soluble phosphorus-containing material is acidic in aqueous solution.

62. A method according to claim 61 wherein a saturated solution of the water-soluble phosphorus-containing material has a pH of 5.5 or less.
- 5 63. A method according to claim 61 or 62 wherein the water-soluble phosphorus-containing material comprises a material selected from the group consisting of single superphosphate, triple superphosphate, monoammonium phosphate and combinations thereof.
- 10 64. A method according to any one of claims 61 to 63 wherein the struvite contains in the range of 7% to 15% of total phosphate in the slurry.
65. A method according to any one of claims 61 to 64 wherein the struvite contains in the range of 7% to 15% of total phosphate in the granules.
- 15 66. The method of any one of claims 55 to 65 further comprising the step of collecting oversized and/or undersized granules and returning the oversized and/or undersized granules into the mixture for granulation.
- 20 67. The method of any one of claims 55 to 66 further comprising the step of mixing binder with struvite and water-soluble phosphorus-containing material prior to the step of granulating the mixture into granules.
68. The method of claim wherein the granules have a struvite content in the range of
25 12 to 28 % by weight.
69. The method of any one of claims 55 to 68 wherein the water-soluble phosphorus-containing material consists essentially of monoammonium phosphate.

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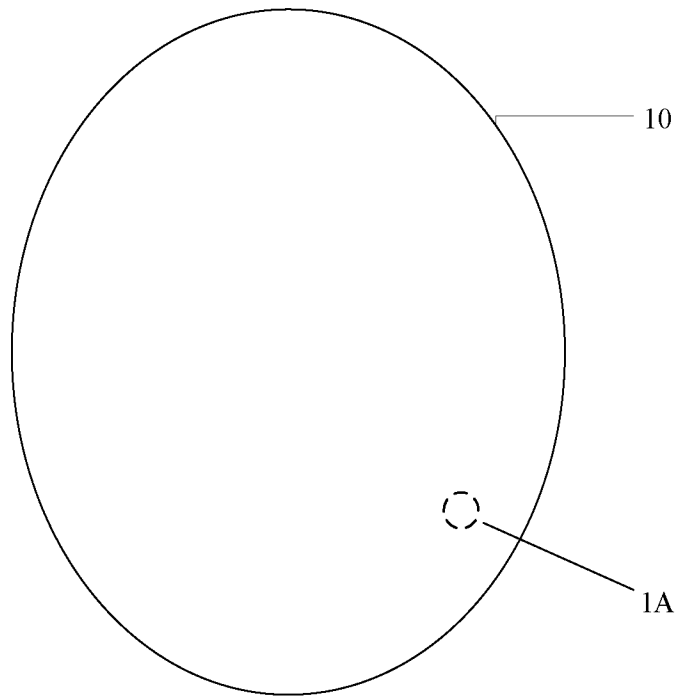


FIG. 1

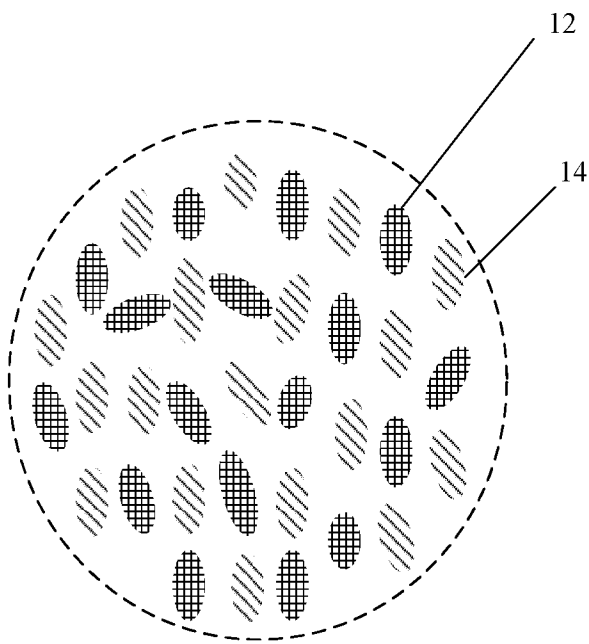


FIG. 1A

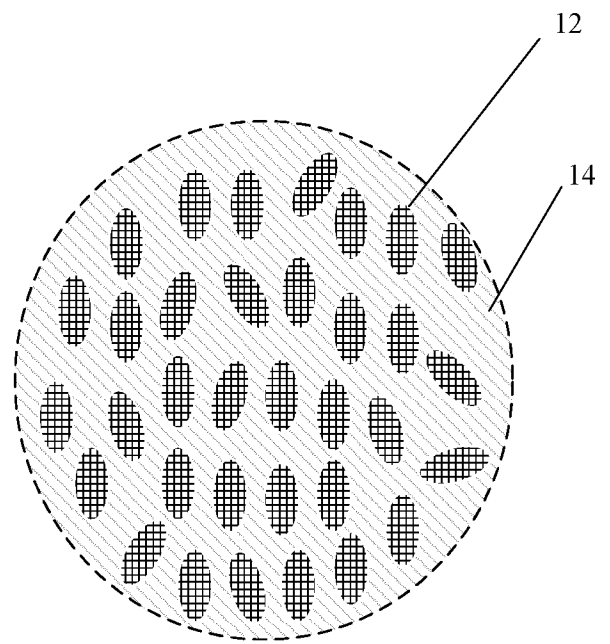


FIG. 1B

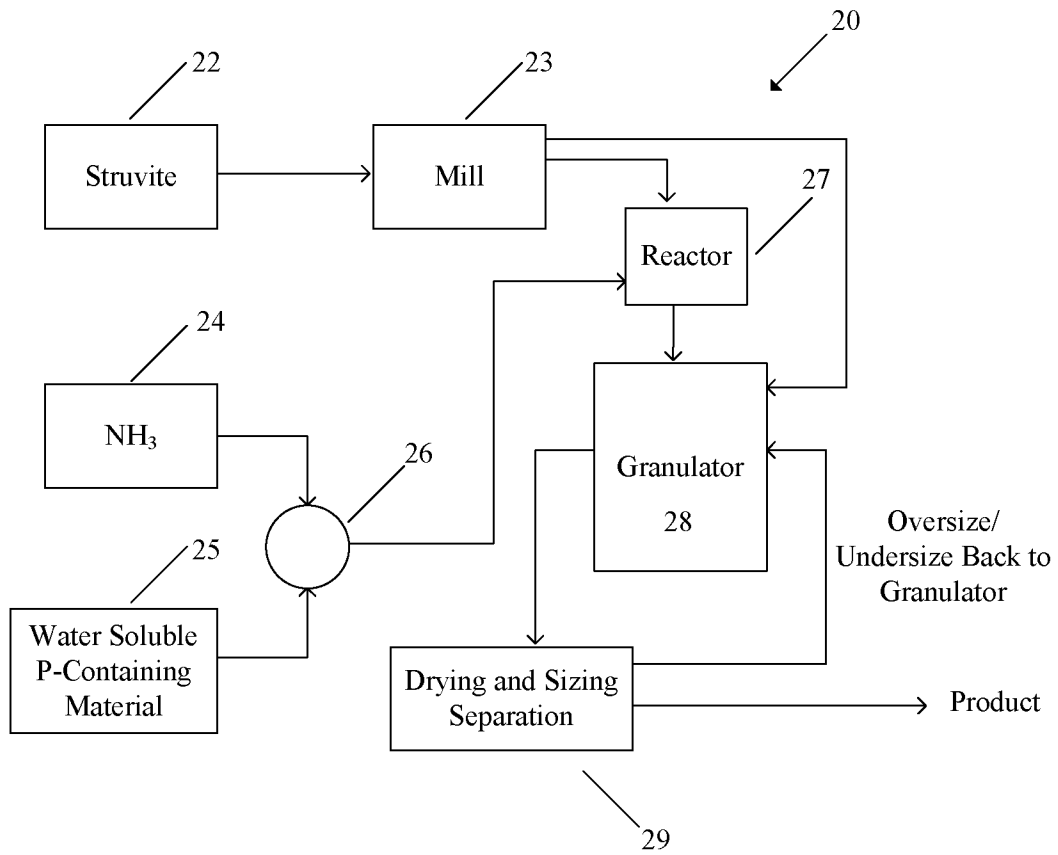


FIG. 2

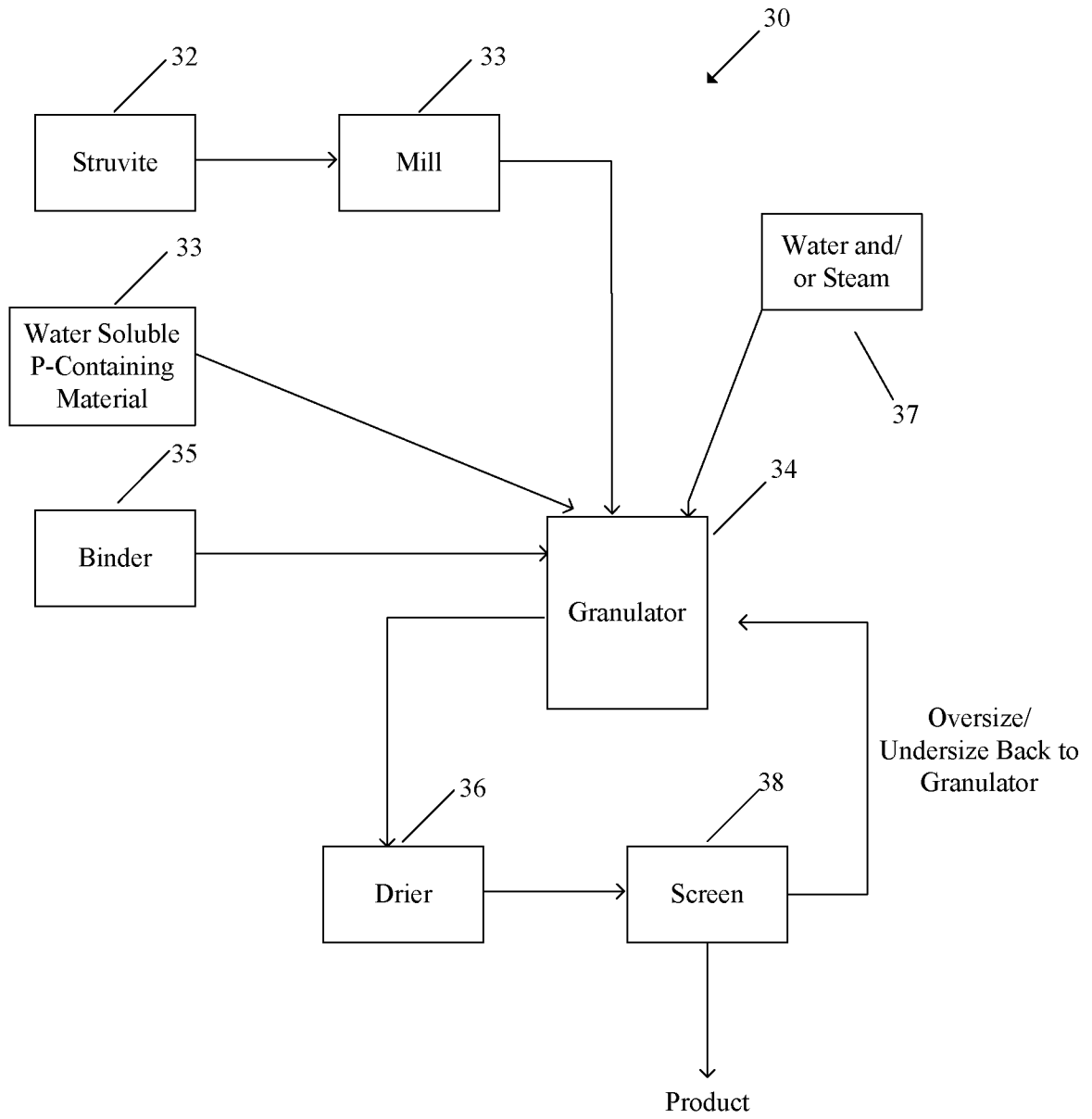


FIG. 3

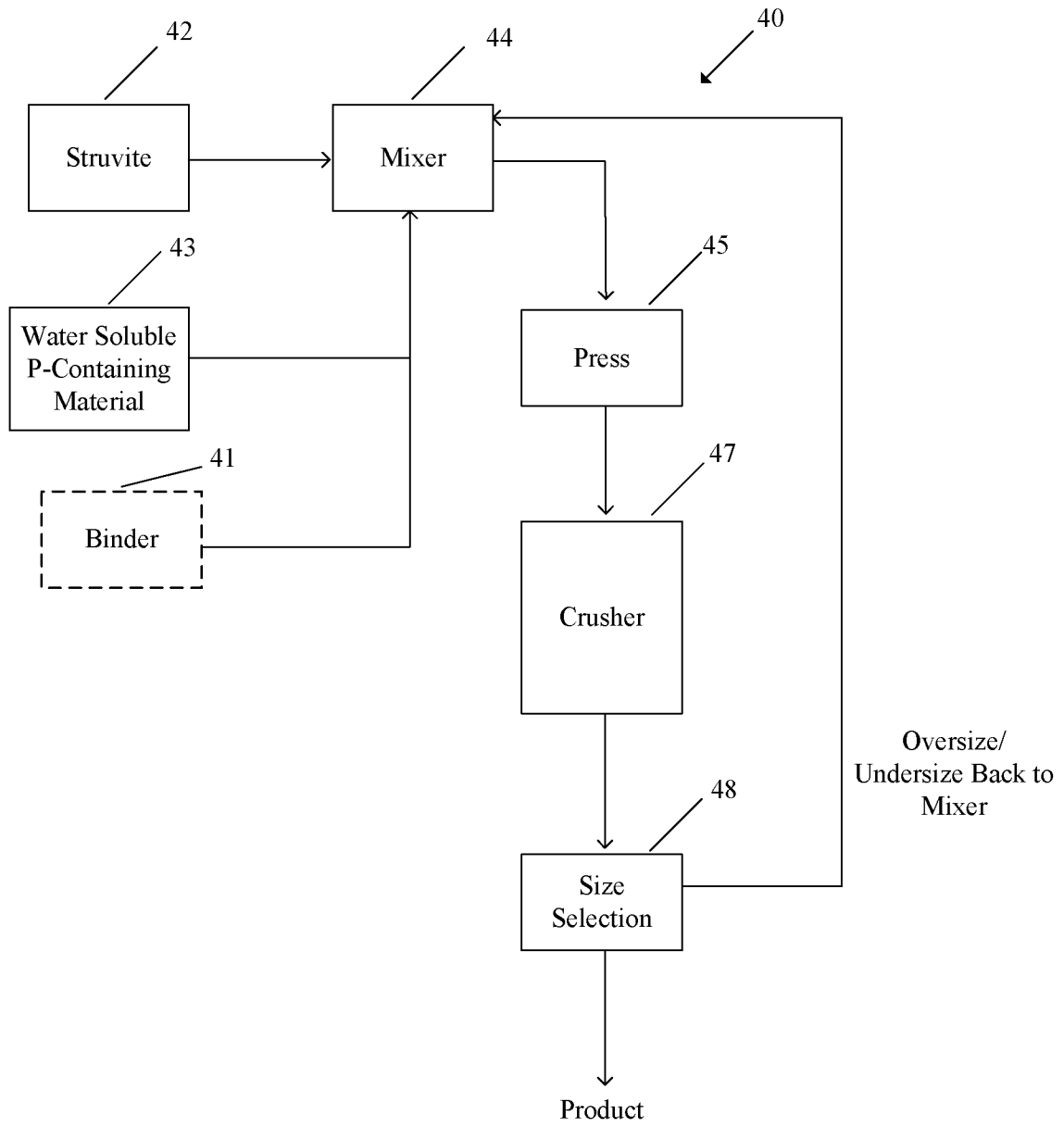


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CA2014/050558

A. CLASSIFICATION OF SUBJECT MATTER
 IPC: **C05B 19/00** (2006.01), **A01C 21/00** (2006.01), **C05B 1/00** (2006.01), **C05B 7/00** (2006.01),
C05B 9/00 (2006.01), **C05G 5/00** (2006.01)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 IPC: **C05B 19/00** (2006.01), **A01C 21/00** (2006.01), **C05B 1/00** (2006.01), **C05B 7/00** (2006.01),
C05B 9/00 (2006.01), **C05G 5/00** (2006.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Questel Orbit: Classifications: C05B, A01C, and C05G; with keywords: struvite, monoammonium, phosphate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| X | US20110230353, 22 September 2011 (22-09-2011), Anderson et al. *paragraphs:0002-0006, 0008, 0010-0015, 0019, 0033* | 1-69 |
| A | CA2770003, 02 December 2010 (02-12-2010), Goodwin *abstract; claims 1-10; page 1, lines 15-20; page 3, lines 10-20* | 1-69 |
| A | CA2506496, 03 June 2004 (03-06-2004), Clark et al. *abstract; claims 1-60* | 1-69 |

Further documents are listed in the continuation of Box C.

See patent family annex.

| | |
|---|--|
| * Special categories of cited documents: | “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 |
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| “P” document published prior to the international filing date but later than the priority date claimed | |

Date of the actual completion of the international search
 30 July 2014 (31-07-2014)

Date of mailing of the international search report
 12 August 2014 (12-08-2014)

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 Place du Portage I, C114 - 1st Floor, Box PCT
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 Toby Maurice (819) 997-2963

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CA2014/050558

| Patent Document Cited in Search Report | Publication Date | Patent Family Member(s) | Publication Date |
|--|--------------------------------|---|---|
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| CA2506496A1 | 03 June 2004 (03-06-2004) | AU2002952712D0 AU2003283057A1 BR0316381A CN1756726A EP1567463A1 US2006230798A1 WO2004046064A1 ZA200504383A | 28 November 2002 (28-11-2002) 15 June 2004 (15-06-2004) 04 October 2005 (04-10-2005) 05 April 2006 (05-04-2006) 31 August 2005 (31-08-2005) 19 October 2006 (19-10-2006) 03 June 2004 (03-06-2004) 22 February 2006 (22-02-2006) |