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(54) Title: DELIVERY OF BIOACTIVE MOLECULES IN COATINGS OR SURFACE LAYERS OF ORGANICALLY ENHANCED INORGANIC FERTILIZERS

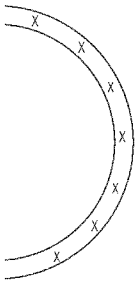


FIG. 1A

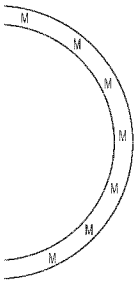


FIG. 1B

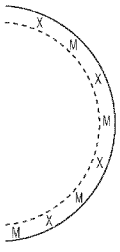


FIG. 1C

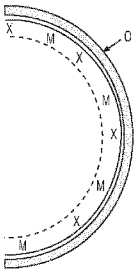


FIG. 1D

(57) Abstract: The invention is directed to coated fertilizer granules and methods for manufacturing granules and using organically enhanced inorganic fertilizer granules, which incorporate a coating of one or more concentric layers over a core such that the coating contains a bioactive agent such as a herbicide, pesticide, plant growth regulator, microorganism, or beneficial element. Application of the coating to the fertilizer granule preferably involves binding of the bioactive agent to the surface of granule or to the organic components within the granule. The release of the bioactive agent from the coating and or the surface of the granule preferably results in a two-phased release, a first fast release and a second extended or slow-release of the bioactive agent into the soil metering the bioavailability of the bioactive agent for crop growth or protection, and/or for controlling unwanted vegetation or pests.

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DELIVERY OF BIOACTIVE MOLECULES IN COATINGS OR SURFACE LAYERS OF ORGANICALLY ENHANCED INORGANIC FERTILIZERS

Reference to Related Applications

This application claims priority to U.S. Application No. 62/767,172 filed November 14, 2018, the entirety of which is incorporated by reference.

Background

1. Field of the Invention

This invention is directed to organic-containing inorganic fertilizers and, in particular, to the incorporation of bioactive substances such as, for example, herbicides and pesticides into fertilizer layers or coatings such that the treated fertilizer can be used as an effective inhibitor or killing agent for unwanted vegetation or pests, or to provide nutrients or other beneficial elements to crops. The organic-containing inorganic complex fertilizer may include salts of potassium, ammonium, phosphate, and sulfate, or combinations thereof.

2. Description of the Background

Most fertilizers, such as those that consist of or comprise ammonium sulfate, urea, diammonium phosphate, monoammonium phosphate or calcium phosphate are not manufactured specifically to have concentric layers. Some fertilizer granules are however made with specific coatings. These coatings can help control the rate of nutrient release to treated soil and help prevent dusting of the granule itself. For example, U.S. Patent No. 6,165,550 relates to the production of symmetrical fertilizer granules that are coated with polyurea-urethane to slow leaching of the granule nutrients into the soil. Other granules, as found in U.S. Pat. Nos. 5,679,129; 6,176,891 and 5,993,505, relate to a synthetic resin or polymer film on the surface of the granule to control the release of plant nutrients from the interior of the granule. Similarly, U.S. Patent No. 6,187,074 relates to a coating of carboxyl-carrying ethylene copolymer to contain inorganic or organic fertilizer such that it is released slowly over time to the target crops.

These coatings can be expensive as raw materials and expensive and involved to apply to the fertilizer material. In addition, upon application to crops, the coatings of these granular fertilizers may introduce harmful or unwanted substances into the soil. A fertilizer product and method of production are needed that does not result in harmful or unwanted substances entering the soil.

Summary of the Invention

The present invention overcomes the problems and disadvantages associated with current strategies and designs and provides new fertilizers and methods of preparing fertilizers and, in particular, coating granules of fertilizer.

One embodiment of the invention is directed to methods of coating fertilizer granules comprising: providing fertilizer granules comprised of organic material; contacting the fertilizer granules with a bioactive agent that chemically reacts with the surfaces of the fertilizer granules; and drying the fertilizer granules forming dried fertilizer granules. Preferably the organic material is sulfate-based and/or phosphate-based, and granules are contacted with a coating agent that comprises a tall oil (also called liquid rosin or tallol), latex, an amide-linked hydrocarbon compound, urethane or polyurethanes, acrylics or polyacrylics) or crystalline and or non-crystalline paraffin waxes. Preferably the fertilizer granules contain one or more of sulfate or phosphate molecules, organic molecules, or iron or aluminum molecules, which bind to the agent. Preferably the bioactive agent comprises an herbicide, a pesticide, a microbe, a plant growth regulator such as, for example, bioactive agents that are anionic, cationic, nonionic and/or lipophilic. Preferably the coated fertilizer granules further contain a refined paraffin wax coating, and further contain a surfactant that facilitates adherence of the coating and the active agent to the granule. Preferably the coating comprises from about 5 to about 40 pounds per ton of dried fertilizer granules, or from about 10 to about 25 pounds per ton of dried fertilizer granules. Preferably the dried fertilizer granules comprise from about 92% to about 100% solids, from about 96% to about 99% solids, or from about 98% to about 99% solids. Preferably the dried fertilizer granules have an increased hardness and/or crush strength as compared to fertilizer granules that have not been contacted with the agent, a reduced dust formation as compared to fertilizer granules that have not been contacted with the agent, are less absorbent as compared to fertilizer granules that have not been contacted the agent, a reduced odor as compared to fertilizer granules that have not been contacted with the agent, and/or a slow-release nutrient profile.

Another embodiment of the invention is directed to dried fertilizer granules containing the coatings and/or bioactive agents disclosed and described herein that are made by the methods disclosed and described herein.

Another embodiment of the invention is directed to the system of manufacturing fertilizer granules comprising a granulator and a coater for forming fertilizer granules as disclosed and described herein.

Other embodiments and advantages of the invention are set forth in part in the description, which follows, and in part, may be obvious from this description, or may be learned from the practice of the invention.

Description of the Figures

Figure 1A. Schematic of a portion of a fertilizer granule with bioactive molecules (X) distributed around a core.

Figure 1B. Schematic of a portion of a fertilizer granule with viable microorganisms (M) distributed around a core.

Figure 1C. Schematic of a portion of a fertilizer granule with bioactive molecules (X) and viable microorganisms (M) distributed around a core.

Figure 1D. Schematic of a portion of a fertilizer granule with bioactive molecules (X) and viable microorganisms (M) distributed around a core with a protective outer coating (O).

Figure 2. Basic reaction between secondary amine on a bioactive molecule and a bisulfate molecule present in or on a fertilizer surface.

Figure 3. Diagram of a pesticide or a plant growth regulator example – the herbicide (Atrazine) binding to a bisulfate group on surface of a fertilizer granule.

Figure 4. Diagram of herbicide (Dinitroaniline) primary amine binding to the organic matrix contained in the outer zone of the organically-enhanced, ammonium sulfate fertilizer granule.

Figure 5. Atrazine bound ionically to granule bisulfate surface reacts with calcium chloride or other cationic salt to form free Atrazine and either a precipitate or a bicarbonate salt on the surface of the granule.

Figure 6. Graph showing the release of bioactive molecules, nitrogen and ammonium sulfate from fertilizers prepared as described herein over a period of days after application to soil.

Description of the Invention

Fertilizers are and have been utilized throughout the world for many years and are applied to crops routinely. Often a particular crop will require herbicides or pesticides to control unwanted weeds or pests, requiring additional applications to the crop. In addition, fertilizers are typically granular in form and thereby create significant dust that reduces the

amount of fertilizer that reaches the intended target – the plant. Coated fertilizers are available, but these coating introduce harmful or unwanted substances into the soil.

A coated fertilizer has been surprisingly discovered that does not result in harmful or unwanted substances entering the soil, but instead provides multiple advantages. As disclosed and described herein, methods of coating fertilizer granules and the coated granules themselves incorporate bioactive agents. These agents preferably are incorporated into a coating or contain reactive chemical groups that interact with the fertilizer granules such that the bioactive compounds bind to components of the coating and/or diffuse within the core fertilizer granule. Preferably, the bioactive agent employed in the coating exhibits a combination of chemical functional characteristics as anionic or cationic, or suitable solubility in the organic coating and organic matrix of the granule. Coated fertilizers as described herein provide direct and/or indirect benefit to plants which include killing, inhibiting and/or controlling unwanted vegetation, pests such as insects or parasites, and preventing or controlling diseases (e.g., as may be caused by bacterial or fungal infections, or other microorganisms). Also disclosed and described herein are methods for the production and use of coated granular fertilizers and the incorporation of bioactive agents within the coatings.

The manufacture of fertilizer is well known, with most solid fertilizers manufactured in granular form. Although any fertilizer granules can be coated as described herein, preferred fertilizer granules for coating include fertilizers made from organic materials such as organically-enhanced inorganic fertilizers (e.g., see U.S. Patent Nos. 7,513,927; 7,662,205; 7,662,206; 7,947,104; 8,105,413; 8,557,013; 8,992,654and 9,856,178). Many desirable procedures for generating the core for the fertilizer involve high heat that kill organisms (e.g., see U.S. Patent Nos. 6,841,515, 8,992,654, and 9,856,178) For example, many organic materials may be brought to a high temperature to achieve the USEPA's Class A standard for treatment of pathogens and then cooled. The bioactive agents can be incorporated into and/or onto the granules during the manufacturing process and preferably after the application of high heat that would otherwise destroy or damage the bioactive agent.

One embodiment of the invention is directed to coated fertilizer granules wherein the coating of the fertilizer granule contains one or more bioactive agents. Coating agents may be applied as liquids or solids (e.g., powder coatings), and include, for example, oil-based agent, alcohol-bases agents, waxes, polymers, urethanes including polyurethanes, crystalline and non-

crystalline paraffins, tall oil (also called liquid rosin or tallol), calcium-containing compounds, sulfur-containing compounds, phosphate-containing compounds, silicon-containing compounds, metal-containing compounds (e.g., ferrous or ferric iron, salts of boron, magnesium, or manganese), latex compounds, fatty acids, lipids, proteins, saccharides and polysaccharides, and combinations thereof. Coatings may form hard surfaces, or be porous or non-porous surfaces. Various coatings and method and systems of coating that may be employed include, for example, those disclosed in U.S. Patent No. 10,266,620 (issued April 23, 2019), U.S, Patent No. 10,207,284 (issued February 19, 2019), U.S, Patent No. 9,844,793 (issued December 19, 2017), U.S, Patent No. 9,539,371 (issued January 10, 2017), and U.S, Patent No. 9,267,052 (issued February 23, 2016). Coating agents may be mixed with bioactive agents and together applied to granules or applied individually but separately. When applied separately, generally the bioactive agent would be applied to the granules and the coating agent after thereby encompassing the bioactive agent and granule.

Bioactive agents may be fluids, liquids or solids, such as dry powder (e.g., freeze dried material). Preferably a liquid bioactive agent is mixed with an agent that adheres to the fertilizer granules during processing, or a solid bioactive agent is mixed with a liquid adhering agent and applied to the fertilizer granules. Preferably incorporation involves amide based and/or wax-based coatings that are applied to the fertilizer including the utilization of specific surfactants when necessary. A bioactive agent may also serve as part or all of a coating agent.

Bioactive agents include substances e.g., (synthetic or natural chemicals, compounds, chemical constructions, enzymes, and/or microbes) that directly or indirectly benefit the soil or fauna where the fertilizer is to be applied. Examples of agents that are directly beneficial include, for example, nutrients, and plant growth regulators (e.g., plant hormones). Plant growth regulations are chemical substances that influence the growth and/or differentiation of plant cells, tissues and organs. Plant growth regulators function as chemical messengers for intercellular communication in the plant. Plant growth regulators include, for example, auxins, gibberellins, cytokinins, abscisic acid, and derivative and variations thereof. Bioactive agents that provide indirect benefits include, for example, herbicides, insecticides, and fungicides that kill off or control the growth of invasive plants or infections organisms. Additional bioactive agents include microorganism, such as microorganism that fix nitrogen from the air and other sources for the benefit of plants, or beneficial microorganisms that kill or otherwise control the

proliferation of harmful organisms or other microbes. In addition, preferred bioactive agents are: (a) anionic; (b) cationic; or (c) nonionic or lipophilic that are applied though the mediation of a surfactant contained in the fertilizer coating.

Examples of herbicides that can be effectively contained coatings are members of the herbicide classes of triazines, glyphosates, aryloxyphenoxy compounds, imidazolinones, isoxazolidinones, sulfonylureas, triazolpyramidines, dinitroanilines and benzoic acid herbicides among others. An example of a pesticide for these coatings is phenyl pyrazole (Fipronil) with its high solubility in wax materials and its amine binding to the fertilizer granule. Examples of such are auxins, gibberellins, cytokinins, and abscisic acid as well as growth inhibitors, growth retardants and growth stimulators. Various chemicals that can be used to coat the fertilizer granule, for example, are described in Ullmann's Encyclopedia of Industrial Chemistry, published by Wiley-VCH Verlag GmbH & Co. KGaA (2002), in particularly the chapters discussing fertilizer granulation. Bioactive agents may comprise detergents (e.g., ionic or non-ionic), enzymes, and/or natural products (e.g., Diatomaceous earth).

Coatings of the fertilizer may contain the bioactive agent or encompass the bioactive agent such that no or substantially no bioactive agents are present on granule surfaces. Coating agents include, for example, a latex, a paraffin (e.g., crystalline or non-crystalline paraffin), an acrylamide (e.g., polyacrylamide), a urethane (e.g., polyurethane), a tall oil, a calcium-containing compound, a silicon-containing compound, or a combination thereof.

Preferably the core fertilizer granule contains a matrix comprised of organic molecules (e.g., biomass), especially amphoteric molecules. The positive and negative charges of the molecules bind to inorganic nutrient components such as the ammonium ion or sulfate ion as in the case of an ammonium sulfate fertilizer. The outer zones of this matrix with its amphoteric charges can be a binding mechanism for the bioactive agent such as a microbe, pesticide or plant growth regulator. A layer or coating material is processed to a) form a barrier to rapid dissolution of the granule components including the incorporated bioactive agent, b) to bind up nutrients and micronutrients as needed, and c) to protect the granule as from humidity and handling, and reduce dust formation. The coated fertilizer granules preferable contain substantially none or none of the bioactive agent on granule surfaces. Molecular binding of the bioactive agent to the granule may be to the sulfate or phosphate groups that are exposed in and/or on the surface of granules especially in the outer zone of

the core or on the core surface. The bioactive agent binding to the sulfate and phosphate groups can be ionic in nature (see Figure 2). Similarly, the binding of these agents to the organics or organic matrix can be electrostatic/ionic bonding. When the bioactive agent binds to the amide bond contained in the coating material it is also of an ionic nature.

Release of the bioactive agent from the fertilizer granule can occur in one, two or more phases. A first release phase can be anytime from an immediate release to release over a period of approximately two weeks following application of the fertilizer. Release rates can depend on rate of dissolution of the bound biological agent, which may be in the form of a salt (e.g., ammonium or sulfate salts from granules). Delayed release of the bioactive agent can occur as a bolus over multiple phases or gradually over time. For example, bioactive agents can bind to amphoteric organic molecules in the outer regions of the core fertilizer granules and be slowly released into the soil depending on the amount of moisture in the soil, or when moisture is applied to the soil. Alternatively, the bioactive agents can be applied as a layer and or concentrically-constructed layer on a fertilizer granule such that there are at least two components to the granule including a core with a surrounding layer or a core with one or more concentric outer layers that are distinguishable from the core with respect to nutrient content, density, hardness, solubility, composition, microbial content and or permeability or a combination of these. The outer of these layers are the coating for the fertilizer which can occupy up to the outer approximately 200 μm of the granule structure as seen when the granule is cross-sectioned and observed under a microscope. The bioactive agent can be contained in one or more of these concentric layers or coatings of fertilizer granules (see Figures 1A-1D).

Coatings may be amide-based as in amide linked hydrocarbons or may be wax or wax-based and these coatings may be utilized with surfactants to assist with spread ability and bridging of the coating and contained herbicide with the outer components of the granule. Surfactants of virtually any class may be used. One advantage of a surfactant is that surfactants can be employed without regard to their physical properties. However, benefits can be realized when the surfactants chosen are supplied as liquids at ambient temperature. An example of surfactant is N-oleyl 1,3 diamino propane. Herbicides and pesticides are often available/dissolved as solvents in that they are dispersed in slightly polar solvents such as mineral spirits. These absorb into the coating and granule but when the surfactant(s) are utilized these can especially assist in the linking of the active agent to the organics and the organic matrix present in organically-

enhanced, inorganic fertilizers.

Coating material of coated fertilizer granules comprise from about 5 to about 30 pounds per ton of the dry mass of the fertilizer granule. Preferably the coating composition represents preferably at least about 8 to about 10 pounds per ton, even more preferably least about 15 to about 20 pounds per ton relative to the total dry weight of the granule.

A particularly advantageous coated fertilizer comprises a fertilizer core coated with a material such as a polymer that binds or contains one or more microorganisms selected for a particular end uses in beneficiating the target plant crop or is used in a bioremediation strategy for improving soil.

In a manufacturing step one or more layers of material, such as polymer, polymer precursors, smaller clay particles, biosolid or other organic material, may be applied to the core particle. A wide variety of materials and methods of their use are suitable for forming a layer. Embodiments of the invention further include adding a chemically durable (polymer or chemical coating) or mechanically durable (colloidal attachment and the like) coating to the core that, variously may incorporate one or more types of bacteria in the coating to add value as a bioremediation material or tool, a pesticide management material or tool or other use where a bacteria with nutrient desirably may be distributed, such as a farm or waste site. In advantageous embodiments, bioactive molecules and or a microorganism in a coating may be combined with a plant micronutrient such as magnesium, boron, manganese, and or zinc; and applied over a granule core.

Coatings applied to a fertilizer granule promote the maintenance of good physical conditions, like the flowability, during storage and handling. Caking is the agglomeration of fertilizer particles by adhesion at their point of contact to form a compact mass that is difficult to break up. Caking has a negative influence on the flowability of a fertilizer, and thus, the coating minimize or eliminate caking upon storage.

The coated fertilizers described herein provide compositions for organic containing fertilizers that can be used for soil remediation, or pasture and/or crop fertilization. Coating of a fertilizer core with one or more outer layers as described herein adds significant value by providing several advantages over uncoated fertilizers. One advantage is that the layered fertilizer physically carries the bioactive agent with the fertilizer, which can reduce the number of applications needed for a particular crop. A second advantage is that the layer or

coating can control or limit the release of active molecules from the fertilizer surface and or the structure of the coating itself. A third advantage is that the bioactive molecules can attach to the granules as the coating or to organic molecules, moieties, or matrices of the fertilizer core. The bioactive agents may penetrate the core to a depth of from about 50 to about 1,000 μm, may penetrate the entire granule, or penetrate in different layers that are applied during manufacturing. Preferably the bioactive agents penetrate to within about 50 μm of the granule surface, within about 100 μm of the granule surface, within about 200 μm of the granule surface, within about 300 μm of the granule surface, within about 400 μm of the granule surface, or within about 500 μm of the granule surface. The depth of penetration can be used to provide controlled release of the bioactive agent, such as delaying release for about 2 to about 15 weeks, preferably from about 3 to about 12 weeks, and more preferably from about 3 to about 8 weeks. This release of the bioactive agent is an advantage to the grower in that drift of the bioactive agent on application is eliminated or at least minimized. A fourth advantage is that temperature-sensitive agent s (heat or cold sensitive) may be added to the coating or outer regions of the granule after the fertilizer core has been formed in manufacture thereby protecting the agents from the high or low temperatures (e.g., greater than about 150°C (302°F) or less than about 0°C (32°F)) that may exist in the area or during manufacture or shipping. A fifth advantage is that the bioactive agent within the coating is protected from photo-degradation. A sixth advantage is that additional application trips across the crop fields are eliminated thereby saving cost and energy. A seventh advantage is that exposure to the active agent that may be harmful to animals or persons, is limited during application by the coating. An eighth advantage is that insertion of bioactive agent directly with the fertilizer granule provides additional enhancement of the target crop dependent on the beneficiating property of the inserted agents, such as microorganisms. For example, microbes will be benefited by being carried on organically enhanced inorganic (sulfur or phosphate based) granule cores as opposed to being on traditional inorganic cores with no microbial nutrients.

Coated fertilizers as described herein can provide nutrient and/or microbial control to meet crop needs effectively and economically, thereby increasing yields and fertilizer costs (as in multiple applications) as to increase profits for the farmer. The amount of coating to be applied to the fertilizer core structure ranges from about 5 pounds per ton to about 100 pounds per ton of fertilizer, preferably from about 15 pounds to about 75 pounds per ton, preferably

from about 25 pounds to about 50 pounds per ton, and preferably from about 15 pounds to about 40 pounds per ton. Previously heated or sterilized fertilizer particles may be subsequently coated with coatings that contain viable organisms. Such viable organisms can be in a dormant form or may be physically viably preserved as with freeze dried technologies.

Coated fertilizer granules may have one, two, three or more concentric layers and a central core. The core preferably contains organics that are bound to inorganics as described in U.S. Patent No. 8,992,654 (e.g., ammonium sulfate molecules bound to organics obtained from municipal wastes such as biosolids, digested or undigested food wastes and or digested or undigested animal manures). Similarly, the fertilizer can be ammonium phosphate based as in diammonium phosphate or monoammonium phosphate with the organics similarly bound with the ammonium or phosphate charged molecules.

A coated fertilizer may contain microorganisms in an outer zone of the granule core in in one or more concentric layers applied to a core. Microorganisms that can be included in the coating include bacteria, algae, yeast, fungi, and/or combinations thereof (e.g. such as mixtures of microorganisms present in and isolated from natural flora, soil, water and within or on other organisms and genetically engineered microorganisms). Preferably, the microorganisms incorporated metabolize toxic chemicals or compounds, replenish depleted soil microflora, and/or enhance the transfer of nutrients to a target crop. Examples of microorganisms that can be incorporated include, but are not limited to *Pseudomonas stutzeri* strain KC, *Nocardia salmonicolor, Nocardia globerula, Nocardia paraffinae, Nocardia poaca, Pseudomonas putida, Pseudomonas oleovorans, Pseudomonas aeruginosa, Pseudomonas fluoroscens, Mycobacterium phlei, Mycobac- terium lacticola, Mycobacterium paraffinicum, Aerobacter aerogenes, Bacillus subtilis, Bacillus lichiniformis, Bacillus circulans, Bacillus polymyxa, Bacillus coagulans, Bacillus macerans, Bacillus azotofixans, Sacharomyces cereviseae, Bacterium acidipropionci, Bacterium aliphaticium liquifaciens, Arthrobacter paraffinens, Rhodococcus rhodochrous, Acinetobacter calcoaceticus, Clostridium cellulolytican, Clostridium aerotolerans, Clostridium acetobutylican, Clostridium pasturianum,* the various *Azotobacter* sp., *Bacillis* sp., *Clostridium* sp., *Fusarium* sp., *Candida* sp., *Flavobacterium* sp., *Corynebacterium* sp., *Achromobacter* sp. *Acinetobacter* sp., *Rhodococcus* sp., *Pseudomonas* sp., *Mycobacterium, Nocardia* sp., *Rhodot- orula* sp., filamentous fungi such as *Penicillium* sp. and *Phycomyces* sp., and

Apergillus sp., *Streptomyces griseus,* among others. Genetically engineered microorganisms are preferably engineered to produce enhancement of the target crop growth and fruit production or to improve the ability of the microorganism to metabolize toxic chemicals and compounds present in the soil to which the fertilizer is applied.

The coatings of coated fertilizer granules may contain micronutrients beneficial to the viability and physiological activity microorganisms, especially when reactivated upon application to soils. Micronutrients and/or the microorganisms may be in one or more of the outer zones of the granules, and/or in one or more layers around the core granule. Preferably granules containing microorganisms are coated in a manufacturing step subsequent to heating to avoid thermal destruction of the microorganisms. In such granules, release of microorganism may be preferably stimulated under predetermined environmental conditions which would activate or dissolve the outer protective layer of the granule. The microorganisms upon their release, are then able to utilize growth-stimulating nutrients derived from other components of the organically-enhanced granule.

Another embodiment of the invention is directed to method of contacting bioactive agents to fertilizers. Preferably the fertilizer contains organic material and is initially prepared as described in U.S. Patent Nos. 7,947,104; 8,557,013 or 8,992,654. During or after the granulation process, the bioactive agent is contacted with the fertilizer forming coated granules. The bioactive agent may be combined with an agent that adheres to the fertilizer granules forming a coating. Contacting may be performed by spray the bioactive agent as a liquid onto the surfaces of granules, or by immersing the granules in a fluid. Additional coatings can be applied contained the same or different bioactive agents or combinations of agents. Preferably the final coating produces a smooth surface on the granules. The now coated fertilizer granules are dried to the desired level of dryness and sized for sorting and eventual shipping. Because the granules are coated, exposure to harmful chemicals and other substances within the granules is reduced or eliminated.

In conventional coating processes, the inclusion and ionic reactions between the added substance and the coating molecules is carried out prior to the application of the coating to the fertilizer granule. In a preferred method of coating, materials such as, for example, amide linked hydrocarbons or waxes (e.g., paraffin) are solids at ambient temperatures. The interactive reactions between the bioactive agent and the coating material take place at temperatures of

between about 49°C (120°F) and 66°C (150°F) over a period of at least one hour, more preferably at least 12 hours, even more preferably at least 24 hours. There is no required upper limit as the bioactive agent may be stored with the coating for several months prior to its actually being applied to the fertilizer core.

Methods for applying the coated fertilizer granules include in-situ remediation which provides a low-cost treatment for environments contaminated with hazardous wastes. Environments that can be treated include contaminated areas of land (e.g. landfills, contaminated fields, pastures) and areas that have undesired hydrocarbon contaminants. The utilization of fertilizers containing microorganisms that can digest unwanted contaminants provide a means of treating hazardous materials without the need for extraction or evacuation of contaminated materials. In addition, bioremediation, both biostimulation and bioaugmentation, requires periodic or continuous introduction of nutrients or buffers to sustain active populations of bacteria, capable of degrading hazardous wastes in situ. For treatment of many sites, delivery of nutrients or other environmental modifiers may be needed over sustained periods of time. The coated fertilizer granules described herein provide an inexpensive means of delivering micronutrients (e.g. controlled levels of nutrients to maintain active microorganism populations), microorganisms, or chemical reactants to effect degradation over extended periods of time. This is accomplished by delivering a solid phase fertilizer granule capable of delivering via dissolution the nutrients, microbial environmental modifiers and/or reactants capable of biologically remediating an environment contaminated with hazardous materials. In addition, coating slow-release or delayed release fertilizer granules allow additional control of nutrient release in a growth season.

The following examples illustrate embodiments of the invention but should not be viewed as limiting the scope of the invention.

EXAMPLES

Example 1.

For an amide-based coating, the material is an amide composed of a fatty acid esterified to a C18 stearyl amine. The fatty acid may be of different carbon lengths, optimally at C12 or C14 carbons, but more preferably at C16 or C18 carbons. This amide is solid at ambient temperatures below 52°C (125°F). In an embodiment using this amide compound, the coating will permit some binding of the amide with the active group on the bioactive

molecule. The primary binding occurs between the bioactive molecule and the sulfate components both on the surface of and within the outer 100 μm of the granule. The bioactive substance (e.g., herbicide and/or pesticide) also binds with organics or matrix containing negative charges that are in the granule core as the herbicide or pesticide migrates from the coating into the granule surface and core structure. The bioactive molecule also binds with iron and aluminum molecules that are also on the granule surface and core structure.

Coatings may comprise an oil or a paraffin wax with a melting point of 49°C (120°F) to 63°C (145°F) and preferably between 52°C (125°F) and 57°C (135°F). The wax coating is used to contain and apply the bioactive molecule to the fertilizer granule core. The wax is a solid at ambient temperatures and at temperatures below 54°C (130°F). To facilitate the distribution and adherence of the bioactive substance to the coating molecules a surfactant is mixed with the molten wax prior to application to the granular fertilizer. The surfactant is N-oleyl 1-1,3, diamino propane and the hydrocarbon end interacts with the wax and permits a binding with an herbicide or pesticide. The diamine surfactant can serve as a bridge between the carboxylic acid and the granule surface, anchoring the herbicide to the granule surface until the fertilizer is dissolved and the herbicide releases to the soil.

The procedure for the addition of the bioactive substance to the coating is to warm the coating formulation of wax and surfactant to a temperature of 60°C (140°F) and add the correct amount of warmed herbicide to this warm liquid coating. Preferably the mixing container is heated and insulated to prevent solidification of the coating either during addition of the bioactive agent and or during storage prior to transport or use. The amount of bioactive agent to be added to the coating varies as to the recommendations for the specific herbicide to be applied. As the coating is applied between 2# and 30# per ton of the dry mass of the fertilizer it should contain sufficient herbicide, pesticide, plant growth agent, or microbe such that agronomic application rates of the fertilizer will yield sufficient herbicide or pesticide into the treated soil to inhibit or kill the unwanted vegetation or allow effective action. Bioactive substances such as an herbicide (e.g., Atrazine) may be added in a separate coating step, as in a spray, to be applied prior to the final coat of amide or wax such that the herbicide would then reside in the outer approximate 100 μm of the granule structure underneath either the outer coating.

As disclosed in U.S. Patent Nos. 8,992,654 and 9,856,178, some of the herbicide or

pesticide directly bind with the sulfate groups on the surface of the granule as the fertilizer is an organically enhanced ammonium sulfate. On application of the fertilizer to the soil of the target crop as per agronomic rates the herbicide or pesticide will be slowly released on dissolution of the granular fertilizer as a salt, e.g., a sulfate salt, and be available in the soil to inhibit unwanted vegetation, e.g., weeds or pests. Similarly, release of contained microbes will occur on dissolution of the granular fertilizer components.

Average application amounts for the referenced fertilizers of this invention, as, for example, set forth in U.S. Patent Nos. 8,992,654, and 9,856,178, are 1 to 2 pounds of nitrogen content per 100 square feet of turf, and on average, 150 to 400 pounds of product per acre for row crops such as corn, cotton, rice and wheat. When the fertilizer containing the bioactive molecules are applied to the target crops the herbicide or pesticide is released as a free molecule leaving a salt (e.g., calcium salt or bicarbonate) as a precipitate on the fertilizer granule surface. This release mechanism is very advantageous in the control of unwanted vegetation in that the release occurs in two phases following the release of nutrients (e.g, nitrogen) from the granule. The majority of the bioactive molecule will be released within the first two weeks following application of the fertilizer (see Figure 6) with the remainder being slowly released over the next three to twelve weeks and more preferably being released slowly over the period of three weeks to 8 weeks.

Example 2.

Wet community waste organics comprised of digested food waste and manures (also referred to as biosolids) are received at a fertilizer manufacturing facility with a percent solids of about 17.0 percent. The plant is set up to operate at an organics processing rate of 220 wet tons per day. In this example, the material is mixed with previously dried organic materials to yield a preferred percent solids of about 20% to 26%, or more preferably about 22% to 24% solids. This conditioned organic mix is pumped into the first vessel for hydrolysis. At the orifice of the first vessel, the conditioned organic mix is further mixed with 93% sulfuric acid in an amount pre-calculated to yield a degree of heat of hydration of about 110°C (230°F) and a total of about 17% sulfur in the finished fertilizer. The contents of the vessel are mixed vigorously at a rate of 360 RPM for between about 30 seconds and ten minutes or, preferably for between about two minutes and six minutes. Within the vessel, the acidified mix gradually is forced to the upper quarter of the vessel where it is discharged after the reaction. In this first vessel, proteins from the organics

are hydrolyzed to various length of polypeptides or, preferably, to monomeric amino acids. Other macro-organic compounds that are present are also hydrolyzed to smaller molecular forms. Hydrolysis increases the fluidity of the contents of the vessel, preferably to less than 1000 cP. This now fluidized, acidified mix is then transferred under pressure to the bottom orifice of a second pressure vessel for ammoniation, wherein it is mixed with vaporized anhydrous ammonia sufficient to raise the temperature of the mix to over 150°F (65°C) (or alternatively over 300°F (149°C)). The internal pressure of the second vessel can equal or exceed 35 psi and is sufficient to cause the concentration of nitrogen (N) in the final formulation of the resultant fertilizer to between about 16% to 17% nitrogen by dry weight of the finished product. The ammoniated mix is maintained in the second pressure vessel for six minutes of reaction time before it is discharged through an orifice to the granulator. The discharged mix (also referred to as a melt) is slightly increased in viscosity compared to the discharge of the first pressure vessel, but preferably has a viscosity of less than about 1200 cP. This discharged melt is under pressure and therefore enters the granulator to be sprayed onto a receiving bed of recycled fertilizer granules (e.g., crushed fertilizer material or undersized fertilizer material or fertilizer dust material collected from the various dust collectors contained in the process air treatment system). The spray coats the receiving fertilizer granules and gradually builds up a series of coatings or agglomerated material, such that the granular fertilizer is produced in which the majority of the material is of the desired product size. Desired sizes may be, for example, about 1.7 mm to 3.5 mm (170 sgn to 350 sgn; "size guide number") diameter granules, suitable for use in commercial agriculture. Subsequent or simultaneously with application of the sprayed coating, an amount of a hardener is applied to the granules in the granulator. Preferably, the hardener amount is sufficient for the hardness of the finished granules to reach a range of about 5 lbs. to 8 lbs. crush strength. This material is then dried to about 98% or more solids, for example in a rotary drum dryer, and then screened to one of three commercial sizes of about 1.7 mm to 1.9 mm, about 1.2 mm to 1.4 mm, and to about 2.6 mm to 3.5 mm. Smaller material is returned to the granulator as part of the recycle bed. All larger material is crushed in a chain mill and also returned to the granulator as part of the recycle bed. A portion of the proper sized product, preferably about 2.4 mm to 3.0 mm for commercial product size, may also be returned to the recycle bed to maintain the mass balance of the production process. The steps of this process were performed under negative pressure to minimize dust and to prevent odors being released into the manufacturing environment. Process air was treated

through a robust odor control system such that no noxious odors were perceived at the fence line of the manufacturing property. Scrubbed nutrients such as ammonium ion, in this example--ammonium sulfate, were returned to a process water tank wherein it was added to the first mixer to help control the solids content and the fluidity of the conditioned mix entering the first pressure vessel. This maximizes the efficiency of the manufacturing process so that the only discharges from the fertilizer manufacturing process are treated condensed water (from the municipal organic material and any cooling water that may need to be discharged from the cooling system) along with the treated process air. In the fertilizer manufactured in this example the slow release percentage of nitrogen was about 30% of the total nitrogen in the product. This slow release nitrogen is in the form of an organic matrix in which the positive charged ammonium ion is electrostatically bound to a negative charge on the organic compounds such as polypeptides and amino acids that comprise the core of the matrix. After exiting the rotary dryer, the product is passed through a product cooler to reduce the temperature of the product to between about 115°F (46°C) and 160°F (71°C), and more preferably between about 130°F (54°C) and 150°F (65°C). This cooled product is coated with 5 to 10 pounds per ton of an amide hydrocarbon coating initially at an average granule temperature of 135°F (57°C) with the coating temperature set to 160°F (71°C). The product then is transported to the warehouse pending shipment. When shipping is scheduled the product is coated a second time with an additional 10 to 20 pounds per ton product. The herbicide will be contained in this coating or may be applied as a spray prior to the application of the final coat layer as in a shipping coat. In this example Atrazine is used (see Figures 3, 4 and 5). Atrazine is a herbicide of the triazine class. Atrazine is used to prevent pre- and post-emergence broadleaf weeds in crops such as maize (corn) and sugarcane and on turf, such as golf courses and residential lawns. It is one of the most widely used herbicides in U.S. and Australian agriculture. The Atrazine is added to the amide coating as a lipid soluble blend. Upon being applied to the fertilizer granule the coating with Atrazine solidifies and forms a very dust resistant, handling resistant surface coating. The Atrazine located at the interface with the coating will bind to the exposed bisulfate anions in the outer approximate 100 μm of granule structure (see Figures 1 and 3). The Atrazine that is carried in the body of the solidified amide coating will slowly migrate and find additional bisulfate molecules to bind to. The Atrazine is contained in the organically enhanced ammonium sulfate fertilizer such that the dry mass of the herbicide is between 0.25% and 0.75% of the mass of the product. This means that between 5# to 15# of

herbicide needs to be included in a ton of the molten coating prior to application to the granules. This quantity may require a separate embodiment in which the Atrazine or other herbicide to be added in a separate coating step to be applied prior to the final coat of amide or wax such that the herbicide would then reside in the outer approximate100 µm of the granule structure underneath either the outer amide coating or the wax coating.

The result is a smooth coated granular fertilizer with enhanced protection against dusting and handling in warehouse storage and for transport and handling by the intermediate fertilizer distributor and finally by the end-user—the grower farmer. The product of this example contained a 98% dry granular fertilizer with a nutrient formulation of 16-1-0-20-1-16 (N-P-K-S-Fe-Organic) by dry weight of the finished granules containing sufficient Atrazine (0.5% to 1.5% w/w) to inhibit unwanted vegetation.

Example 3.

In granules formed as in Examples 1 and 2, a coating is applied containing the herbicide 2,4-D, is applied as lipid soluble herbicide in a refined paraffin wax that has a melting point of about 131°F (55°C). Again between 5 and 30 pounds of coating per ton of product are used. The 2,4-D again binds to the sulfur and organic molecules on the surface of the granule and in the outer 100 µm of the granule. This binding increases over time as the 2,4-D in the solidified wax coating migrates to the surface of the granule and finds more sulfate to ionically bind to. The concentration of the 2,4-D in the finished fertilizer is usually between 0.05% and 0.5% as based on agronomist recommendations.

Example 4.

In fertilizer granules formed as in Examples 1 and 2, a refined wax coating containing a surfactant is applied at 25# per ton and which coating containing a herbicide from the sulfonylurea class. This is an effective herbicide class that kills broadleaf weeds and some annual grasses. One of its active forms is sold as Metsulfuron-methyl, which is a systemic compound with foliar and soil activity that inhibits cell division in shoots and roots that has excellent compatibility with a paraffin wax coating with its aromatic rings and binds well to the sulfate and organic molecules in the outer 100 µm of the fertilizer at a fertilizer pH of between 4.5 and 6.0. This binding enhances the stability of the herbicide becoming an advantage over other methods of application.

Example 5.

In fertilizer granules made similarly to the method of Example 1 however, with the difference that a diammonium phosphate-based fertilizer was manufactured. This fertilizer was coated with 25 pounds of a refined paraffin wax. The nutrient formulation of this fertilizer is 16-34-0-7-1-12 (N-P-K-S-Fe-Organic by dry weight). A dinitroaniline class herbicide was added to the hydrocarbon amide coating. This herbicide has an excellent compatibility to the wax coating because of its lipophilic nature and binds well to the phosphate and organic components, especially the organic matrix in this fertilizer, in the outer range of the granule core and surface area. The tight organic binding exhibited by the nitroaniline contributes to the slow release of this herbicide in the field thereby extending weed control.

Example 6.

In fertilizer granules made similarly to the method of Examples 1 and 2, with the difference that a diammonium phosphate-based fertilizer core was manufactured. The nutrient formulation of this fertilizer is 14-24-0-10-1-10 (N-P-K-S-Fe-Organic by dry weight). The first coating on the manufactured fertilizer core is a light-weight mineral oil-based coating which contains a suspension of freeze-dried *Acinetobacter calcoaceticus* applied to the granule cores are a rate of 12 pounds coating per ton of core. After drying, this core plus first coating is then further coated with a protective layer of 20 pounds per ton of a warmed paraffin wax or 20 pounds of a warmed oil-based amide coating, both of which are solids at about 75°F (24°C).

Example 7.

In fertilizer granules made similarly to the method of Examples 1 and 2, with the difference that a diammonium phosphate-based fertilizer core was manufactured. The nutrient formulation of this fertilizer is 14-24-0-10-1-12 (N-P-K-S-Fe-Organic by dry weight). The first coating on the manufactured fertilizer core is a modified tall oil-based coating which contains an amide linkage in the middle of a long hydrocarbon chain to assist in binding to the outer zone region of the granule core. This first coating is applied to the hot (about 130°F to about 160°F; or about 55°C to about 71°C) granule cores during manufacture at rate of 10 pounds coating per ton of core. After drying, this core plus first coating is then further coated, often at the time of shipping, with a protective layer of 22 pounds per ton of a similar tall oil coating containing 3% active Imidacloprid 2F by mass of coating. This is a good active agent for fertilizers that contain organics in their structure as Imidacloprid binds to organics making it possible for insecticide to be released slowly over time after application. Imidacloprid works well at a per acre application of 0.1 pounds

per acre of active compound. If the fertilizer of this example is applied at a typical application of 300 pounds per acre then each acre would be treated with 0.1 pound of active Imidacloprid 2F. This concentration would fit well in a 3 times a year application protocol as regulations limit the maximum amount of Imidaclosprid 2F to less than 0.4 pounds of active compound per acre. This is a particularly useful inclusion as imidacloprid is a systemic insecticide that acts as an insect neurotoxin and belongs to a class of chemicals called the neonicotinoids. Imidacloprid is widely used for pest control in agriculture.

Example 8.

Fertilizer granules are prepared basically as described in U.S. Patent No. 8,992,654, wherein liquid fertilizer is sprayed onto recycled fertilizer materials creating granules. The spray also contains an amount of a herbicide which together coat the fertilizer granules. A second liquid is introduced to the fertilizer granules through the same or a different nozzle, again via spraying, containing plant nutrients plus an amount of a hardener. Preferably, the hardener amount is sufficient for the hardness of the finished granules to reach a range of about 5 lbs. to 8 lbs. crush strength. This material is then dried to about 98% or more solids in a rotary drum dryer. The resulting fertilizer product is a smooth coated granular fertilizer with enhanced protection against dusting and handling in warehouse storage and for transport and handling by the intermediate fertilizer distributor and finally by the end-user, the grower farmer. The product contains multiple coating layers with sufficient Atrazine (0.5% to 1.5% w/w) to inhibit unwanted vegetation, and sufficient nutrients to promote plant growth and development.

Other embodiments and uses of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. All references cited herein, including all publications, U.S. and foreign patents and patent applications, and specifically the reference *Ullmann's Encyclopedia of Industrial Chemistry,* Published by Wiley-VCH Verlag GmbH & Co. KGaA (*2002*), are specifically and entirely incorporated by reference. It is intended that the specification and examples be considered exemplary only with the true scope and spirit of the invention indicated by the following claims. Furthermore, the term "comprising of" includes the terms "consisting of" and "consisting essentially of."

Claims

1. A method of coating fertilizer granules comprising:

providing fertilizer granules comprised of organic material;

contacting the fertilizer granules with a coating agent and a bioactive agent that chemically reacts with charged organic molecules of the surfaces and/or interior portions of the fertilizer granules forming a coating; and

drying the fertilizer granules forming dried and coated fertilizer granules.

2. The method of claim 1, wherein the organic material is sulfate-based and/or phosphate-based.

3. The method of claim 1, wherein the coating agent comprises an oil-based agent, alcohol-bases agents, waxes, polymers, urethanes including polyurethanes, crystalline and non-crystalline paraffins, tall oil, calcium-containing compounds, sulfur-containing compounds, phosphate-containing compounds, silicon-containing compounds, metal-containing compounds (e.g., ferrous or ferric iron, salts of boron, magnesium, or manganese), latex compounds, and combinations thereof .

4. The method of claim 3, wherein the fertilizer granules contain one or more of sulfate or phosphate molecules, organic molecules, iron molecules, or aluminum molecules, which bind to the coating agent.

5. The method of claim 1, wherein the coating diffuses within the outer 200 μm of cores of the fertilizer granules.

6. The method of claim 1, wherein the coating forms on cores of the fertilizer granules.

7. The method of claim 1, wherein the bioactive agent comprises an herbicide, a pesticide, a plant growth regulator, an enzyme, a natural product, a microbial agent, and/or a microorganism.

8. The method of claim 7, wherein the herbicide or pesticide is anionic, cationic, nonionic and/or lipophilic.

9. The method of claim 1, wherein contacting further includes a surfactant that facilitates adherence of the coating and the active agent to the fertilizer granule.

10. The method of claim 1, wherein the coating comprises from about 5 pounds to about 100 pounds per ton of dried fertilizer granules.

11. The method of claim 1, wherein the coating preferably comprises from about 10 to about 40 pounds per ton of dried fertilizer granules.

12. The method of claim 1, wherein the dried and coated fertilizer granules comprise from about 95% to about 100% solids.

13. The method of claim 1, wherein the dried and coated fertilizer granules have an increased hardness and/or crush strength as compared to fertilizer granules that have not been contacted with the coating agent.

14. The method of claim 1, wherein the dried and coated fertilizer granules have reduced dust formation as compared to fertilizer granules that have not been contacted with the coating agent.

15. The method of claim 1, wherein the dried and coated fertilizer granules are less moisture absorbent as compared to fertilizer granules that have not been contacted the coating agent.

16. The method of claim 1, wherein the dried and coated fertilizer granules have a two-phase release nutrient profile comprising a fast release over the first two weeks following application to the soil followed by a second phase of slow release.

17. The method of claim 1, wherein the bioactive agent comprises one or more microorganisms.

18. The method of claim 17, wherein the one or more microorganisms beneficiate a target crop by replenishing depleted soil microflora, enhance transfer of one or more nutrients to a target crop, and/or increase plant growth or plant production.

19. The method of claim 17, wherein the one or more microorganisms metabolize a toxic chemical or compound, and/or perform bioremediation.

20. Coated fertilizer granules comprising organic materials and a bioactive agent and a coating agent.

21. The granules of claims 20, wherein the organic material is sulfate-based and/or phosphate-based.

22. The granules of claims 20, further comprising an amide-linked hydrocarbon compound or a paraffin wax.

23. The granules of claims 20, wherein the bioactive agent is present or within the outer 200 μm of cores of the coated fertilizer granules.

24. The granules of claims 20, wherein the bioactive agent comprises an herbicide, a pesticide, a plant growth regulator, an enzyme, a natural product, a microbial agent, and/or a microorganism.

25. The granules of claims 20, wherein the bioactive agent is anionic, cationic, nonionic and/or lipophilic.

26. The granules of claims 20, wherein the bioactive agent is not present on the outer surface of granules.

27. Coated granules of fertilizer containing a bioactive agent within coatings.

28. The granules of claims 27, wherein the fertilizer comprises organic material.

29. The granules of claims 27, wherein the bioactive agent comprises an herbicide, a pesticide, a plant growth regulator, an enzyme, a natural product, a microbial agent, and/or a microorganism.

30. The granules of claims 27, which contain substantially no bioactive agent on granule surfaces.

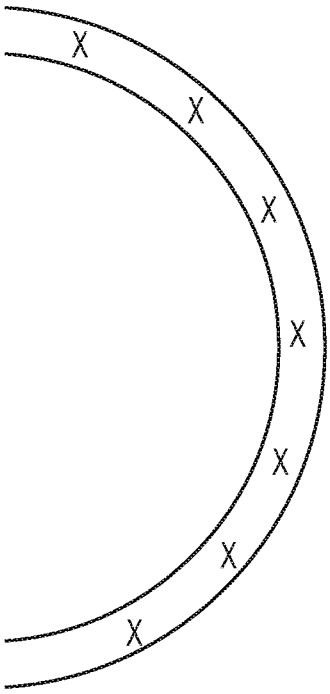


FIG. 1A

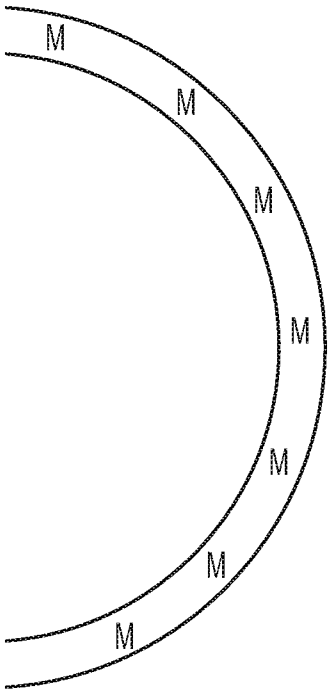


FIG. 1B

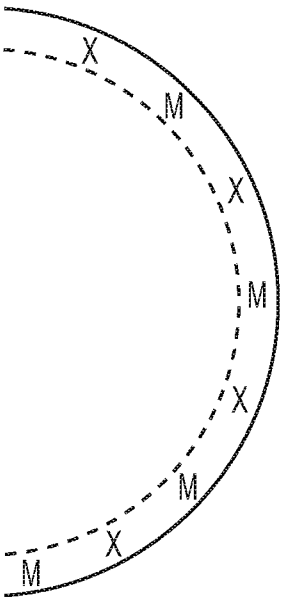


FIG. 1C

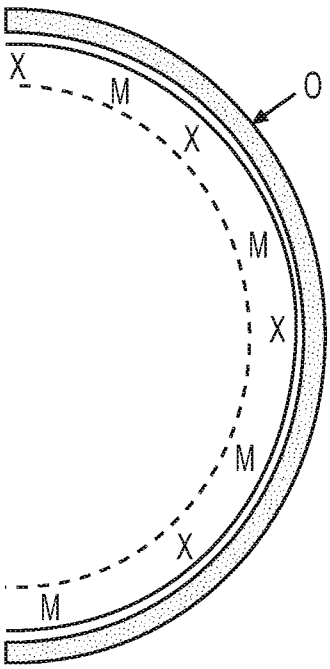


FIG. 1D

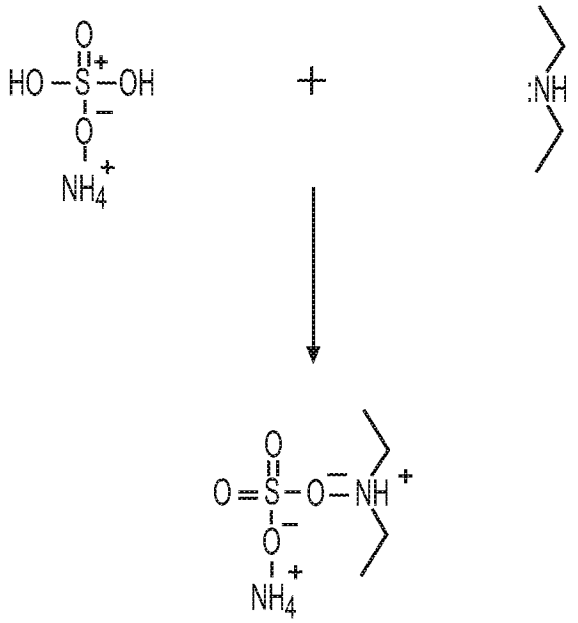


FIG. 2

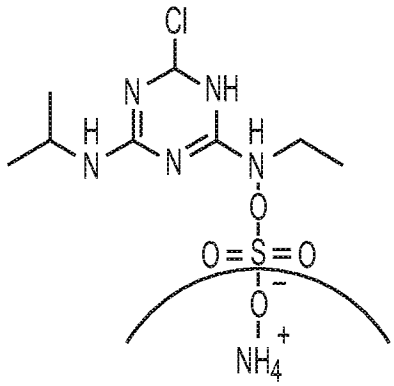


FIG. 3

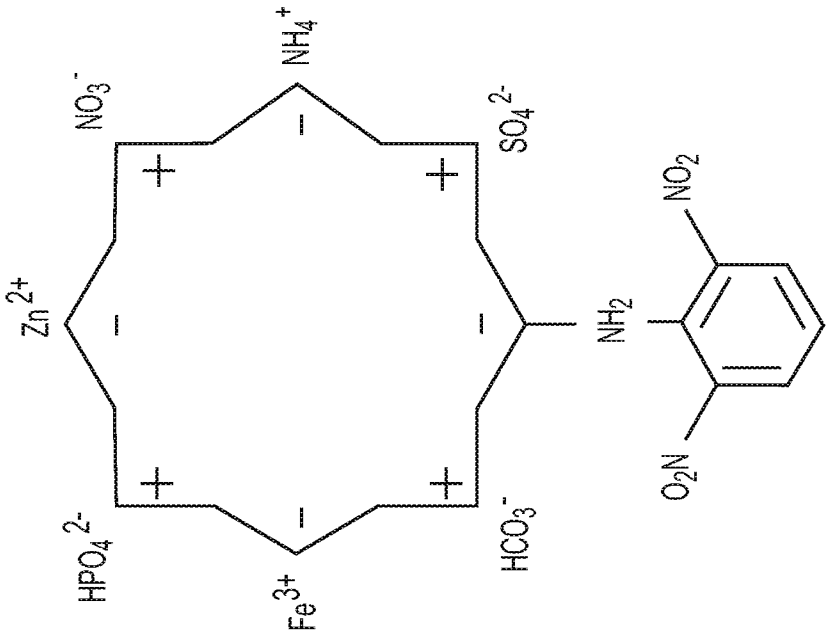


FIG. 4

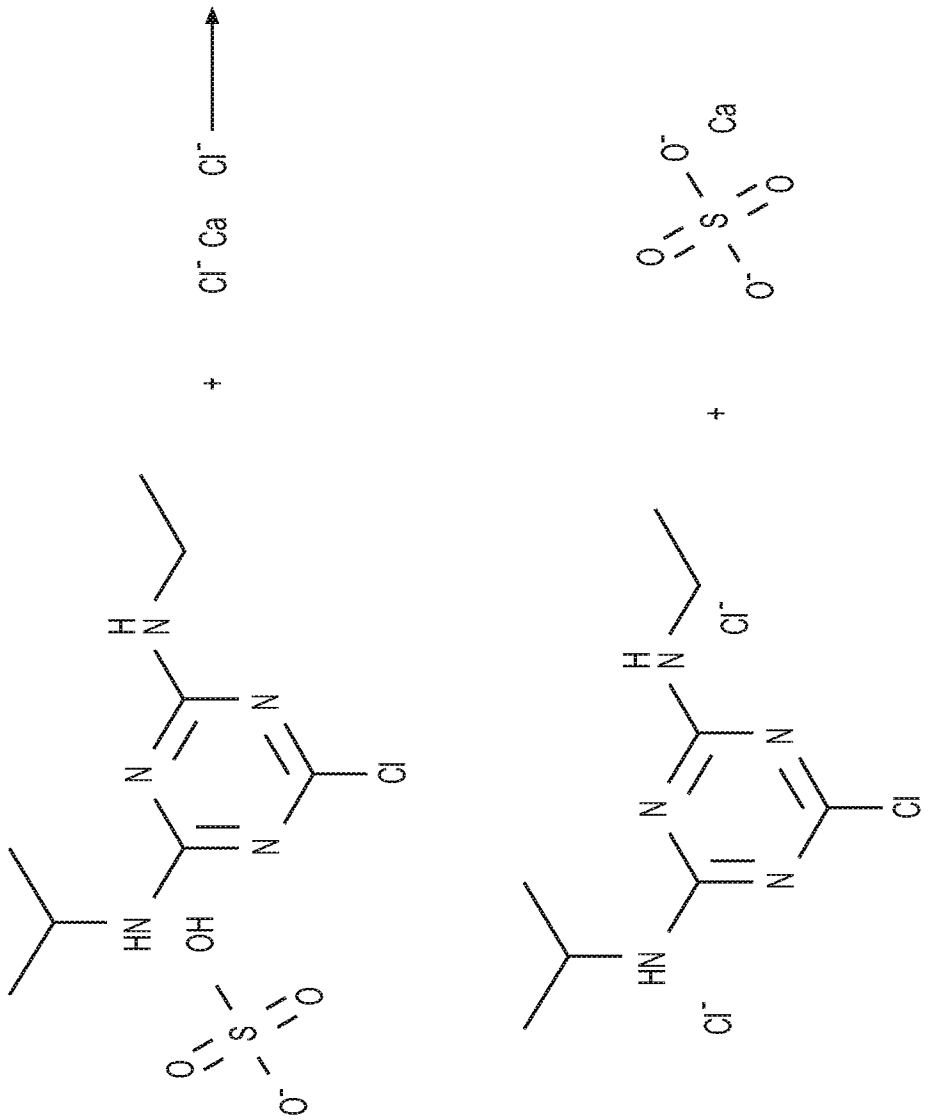


FIG. 5

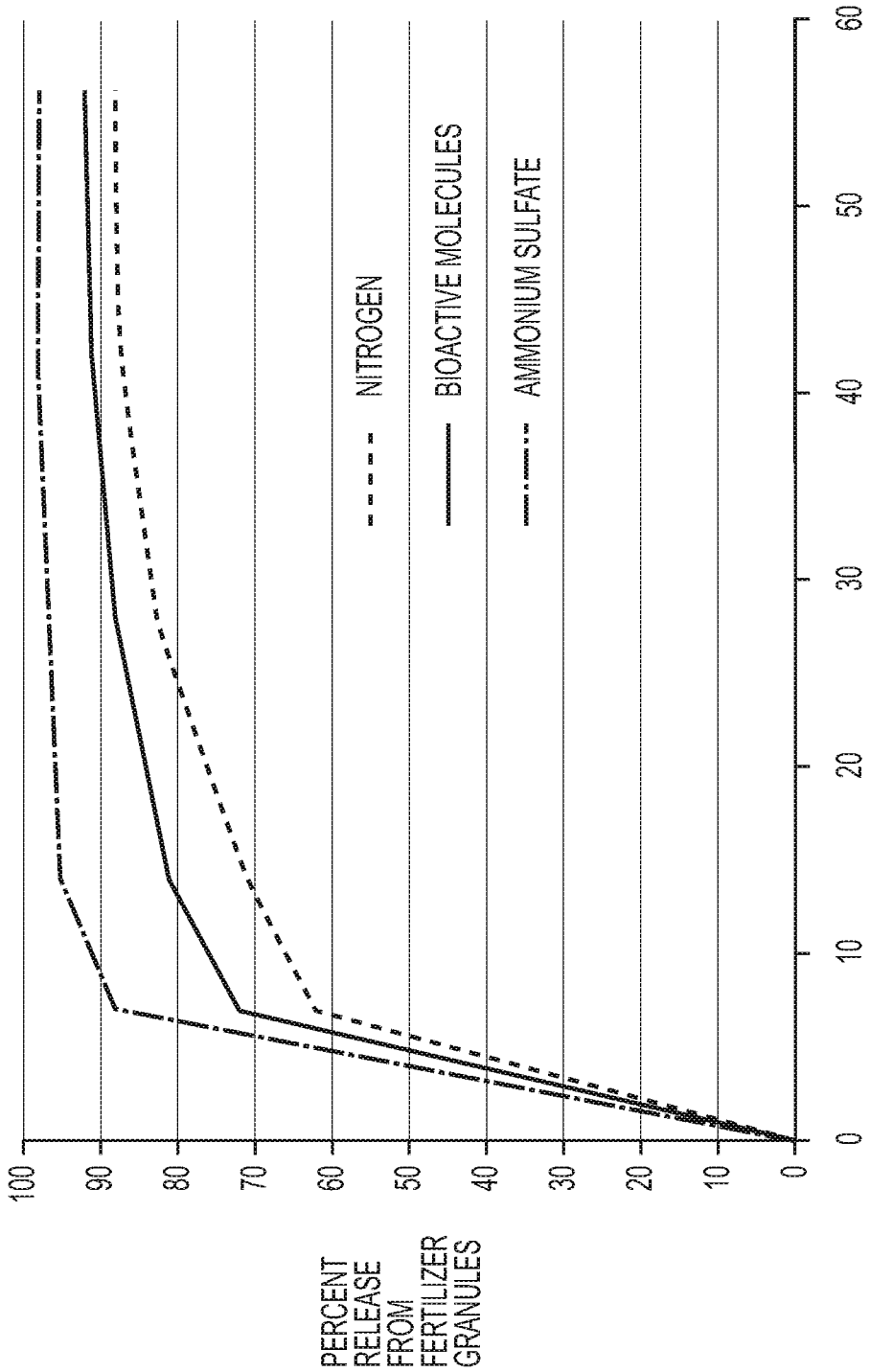

PERCENT RELEASE FROM FERTILIZER GRANULES
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
DAYS AFTER APPLICATION
NITROGEN
BIOACTIVE MOLECULES
AMMONIUM SULFATE

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US19/61276

A. CLASSIFICATION OF SUBJECT MATTER

IPC - C05B 19/00; C05F 11/08; C05G 3/02 (2019.01)

CPC - B01J 2/00; C05G 3/0005, 3/0041

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2010/0255050 A1 (LEONARD, JK et al.) 07 October 2010; paragraphs [0044], [0053]-[0056], [0060], [0073], [0076], [0106]	20, 22, 25, 27-28 ---------- 1-19, 21, 23-24, 26, 29-30
Y	US 2014/0090430 A1 (NIHA CORP.) 03 April 2014; figure 1; paragraphs [0029], [0033]	2, 21
Y	WO 2015/075644 A1 (NBVD S.A.) 28 May 2015; page 3, lines 30-33; page 4, lines 1-16; page 5, lines 4-10, page 6, lines 1-11; page 8, lines 23-30	1-19, 23
Y	US 2003/0157247 A1 (CHIKAMI, Y et al.) 21 August 2003; paragraphs [0008], [0028]-[0029], [0071]	26, 30
Y	US 2017/0232419 A1 (ANUVIA PLANT NUTRIENTS CORPORATION) 17 August 2017; paragraphs [0024], [0028], [0030], [0079][0089]	1-19
Y	US 2012/0272700 A1 (NEVIN, JE) 01 November 2012; figure 1; paragraphs [0019], [0023], [0034], [0036], [0051]	9, 15
Y	US 2014/0137616 A1 (MOS HOLDINGS INC.) 22 May 2014; paragraph [0003], [0007], [0010]	10-11
Y	US 2016/0200634 A1 (AVALON ALLIANCE INC.) 14 July 2016; paragraphs [0022], [0027], [0034]-[0035], [0147]-[0148], [0155]	17-19

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 December 2019 (26.12.2019)	22 JAN 2020
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas Telephone No. PCT Helpdesk: 571-272-4300