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Selected Fertilizers Used in Turfgrass Fertilization¹

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Due to low nutrient reserves in most of Florida's sandy soils, fertilization is often required for optimum turfgrass growth. Turfgrasses have unique nutritional requirements and thus special consideration should be exercised when selecting a fertilizer. Turfgrass fertilizers can be grouped in two categories, soluble and slow-release. In this fact sheet we will discuss the chemical and nutrient release properties of a number of fertilizers which are typically used in turfgrass fertilization.

Soluble Fertilizer Sources

Nitrogen Materials

The three primary soluble N sources used in turfgrass fertilization are ammonium sulfate, ammonium nitrate, and urea. Potassium nitrate is used in lesser quantities, but is no less important in the overall turfgrass fertility management program. According to current recommendations, soluble forms of N should not be applied at more than 0.5 pounds of N per 1000 square feet per application (SL-21 General Recommendations for Fertilization of Turfgrasses on Florida Soils.)

- **Ammonium Sulfate** is a white crystalline material containing 20-21% N and 24% S. If produced in the pure crystalline form it is

rice-like in appearance, but the pure form is seldom marketed. The marketed product may be grayish in color due to carbon contamination during manufacture. Nitrification of ammonium sulfate produces acidity in the soil. Upon conversion to nitrate, the ammonium ion produces 5.35 pounds of acidity per pound of N applied, thus making ammonium sulfate the most acidifying N source available. This acidifying property makes ammonium sulfate the desired N source on alkaline turfgrass soils. When applied on high pH soils, particularly those containing free calcium carbonate, ammonium sulfate should always be watered in to limit volatile loss of N. Ammonium sulfate has a high burn potential with a salt index of 3.25, therefore, it should not be applied at high rates to avoid potential turfgrass burn. Due to limited solubility ammonium sulfate is not often applied in solution form. Ammonium sulfate imparts a dark green color in turfgrasses which tends to last for at least 30 days when applied at recommended rates. Turfgrass responses to ammonium sulfate tend to last for a longer period than for the other soluble N sources, and for this reason ammonium sulfate tends to be the preferred soluble N source of many turfgrass managers.

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Ammonium Sulfate



- 21% N $(\text{NH}_4)_2\text{SO}_4$
- Highly soluble and leachable
- Subject to volatilization
- Very acidifying
- High salt index (3.25)

Ammonium Nitrate



- 33.5% N NH_4NO_3
- Very soluble
- Highly leachable
- Subject to volatilization
- Low acidity
- High salt index (2.99)

- **Ammonium Nitrate** is typically marketed in prilled form containing 33-34% N. It is highly soluble and is also marketed in solution form; generally it will be offered in combination with urea containing 28, 30 or 32% N. Prilled ammonium nitrate may be bright white in color, indicating that the prill has been coated with magnesium chloride, or beige in color, indicating that the product has been coated with a mixture of clays. Both of these coatings reduce the hygroscopicity of the product and improve handling properties. Ammonium nitrate and urea cannot be mixed together in dry form because of severely reduced handling properties.

Ammonium nitrate produces only 1.8 pounds of acidity per pound of N applied upon nitrification, and thus is not as acidifying as ammonium sulfate. The salt index of ammonium nitrate, 2.99, is less than that of ammonium sulfate and thus there is less potential for turfgrass burn immediately after application. Ammonium nitrate generally does not impart as dark green a color as does ammonium sulfate and the longevity of the response is not as great.

- **Urea** is a white crystalline solid, generally marketed in prill form, containing 45-46% N. It has good physical properties and is not as hygroscopic as ammonium nitrate. It produces 1.8 pounds of acidity per pound of N and has a salt index of 1.62; thus it can be applied to turfgrass with little threat of burn when applied at recommended rates. If left on the soil surface, significant quantities of N may be lost by volatilization. Therefore, urea should always be watered in with the proper amount of water. Urea is a non-ionic compound when placed into

solution and will leach rapidly through the soil profile if excess water is applied. Remember that one inch of water will effectively wet the top ten inches of a Florida sand soil profile. Urea is highly soluble and one of the materials of choice in N solution fertilizers. Generally speaking urea does not produce as good a turfgrass response as does ammonium sulfate or ammonium nitrate, but because of its ease of application in solution form, its high solubility, its low burn potential and low cost per pound of N, it is a popular soluble N source, particularly by lawn care maintenance personnel.

Urea



- 45% N $\text{CO}(\text{NH}_2)_2$
- Soluble synthetic organic
- Nonionic, highly leachable
- Subject to volatilization
- Low acidity
- Low salt index (1.62)

- **Potassium Nitrate** is marketed in prill form and contains both N and K (13-0-44). It has good handling properties and is moderately soluble. The overall salt index of potassium nitrate is approximately 4.25. Thus, it should always be removed from the turfgrass surface by proper irrigation following application. Nitrate forms of N tend to be highly mobile, particularly in a sandy soil, so N uptake efficiency from potassium nitrate can be improved by applying small levels of N frequently. Potassium nitrate is

not acidifying, in fact it produces a slight alkaline reaction. One of the typical uses of potassium nitrate is a foliar application to putting greens during transition from cool- to warm-season turfgrasses. Its high K content along with low N content is thought to promote establishment and rooting of the warm-season turfgrass.

Potassium Nitrate



- 13% N, 44% K₂O or 37%K KNO₃
- Moderately soluble with good handling characteristics
- High salt index (4.25)
- Thought to promote establishment and rooting of turf

Phosphorus Sources

In general, phosphorus does not induce the visible response in turfgrasses that is observed with the application of N materials. When responses are obtained they are generally during the establishment phase of the turfgrass. Only at extremely low soil test P levels would a P response be observed.

Cool-season turfgrasses have been shown to respond positively in P application to soils testing high in P, whereas warm-season bermudagrass actually exhibited a reduction in growth in response to P application. Phosphorus is known to influence the rooting characteristics of turfgrasses and most of the response, especially during establishment, is related to root proliferation.

Elevated levels of P in surface waters contribute to eutrophication. Improper soil P fertilization can increase the potential for the movement of P offsite to surface water bodies. Thus, one should only apply P when it is recommended based on a soil test. Typically, P is not known as a mobile ion but in certain acid uncoated sands and organic soils in Florida P will leach. It is not uncommon for turfgrasses to be grown on these types of soils; therefore, we should insure that P fertilizers are applied at the recommended rate based on a soil test.

- **Concentrated Superphosphate** also known as triple superphosphate, is gray granular material containing 46% water and citric acid soluble phosphate (P₂O₅) of which the water-soluble portion is generally around 85%. This material has very good physical properties and is often used as a conditioner in complete mix fertilizers. The salt index is very low (0.21) and there is no overall effect on soil reaction. Because of its chemical nature it is a good P source for use on calcareous soils. Concentrated superphosphate granules are large and are not typically used in golf green fertilizers, but may be found in lawn and fairway grade fertilizers. In most tests with fertilizer P sources, no turfgrass response differences have been observed between sources.

Concentrated Super Phosphate Triple Super Phosphate



- 46% P₂O₅ or 20% P
- Ca(H₂PO₄)₂
- 85-90% water soluble phosphorus
- Reaction immediately around granule is acidic – pH 1.47
- Good for use on calcareous soil

- **Monoammonium Phosphate** is gray granular material containing a range of N and P₂O₅ levels, from 11-48-0 to 13-54-0. The most typical analysis is an 11-48-0. This material has very good physical properties and a salt index of 0.49. The phosphate portion of this product is almost 100% water soluble. Because of its ammoniacal N content, this product acidifies the soil upon nitrification. Therefore, it can be used on calcareous soils, but if surface applied it should be watered in to reduce the threat of volatile ammonia loss. This material is produced in small granular form and can be used as a P source in golf green fertilizers.
- **Diammonium Phosphate** is a gray granular material whose most typical analysis is an 18-46-0. The P in this material is almost 100% water soluble and its salt index is 0.64. Upon initial hydrolysis in the soil the solution moving out of the granule is alkaline; therefore, this

Monoammonium phosphate (MAP)



- 11% N, 48% P₂O₅ or 21% P
- NH₄H₂PO₄
- Very soluble
- Subject to leaching and volatilization
- Acid reaction
- Low salt index (0.49)
- Green's grade available

material is not recommended for use on alkaline soils. This material is almost as acidifying as ammonium sulfate, but it is not as widely used in turfgrasses as ammonium sulfate because the granules tend to be large and does not contain S.

Diammonium phosphate (DAP)



- 18% N, 46% P₂O₅ or 20% P
- (NH₄)₂HPO₄
- Very soluble
- Subject to volatilization on high pH soils
- Subject to leaching
- Initial basic reaction, then acidifying
- Low salt index (0.64)

- **Solutions** containing either 10-34-0 or 11-37-0 are commercially available. These solution fertilizers are used mostly in agronomic crops in the mid-west, and little is used on turfgrasses. When made with polyphosphoric acid these solutions can be used to produce 'complete' mix solutions containing elevated levels of N, P₂O₅ and K₂O.

Potassium Sources

- **Potassium Chloride**, also known as Muriate of Potash, is a mined crystalline material of various colors depending on contamination and mining source. It contains 60 to 63% K₂O equivalent and is completely water soluble. The material has a salt index of 2.19 and can cause burn if

applied at high rates and not watered in. Muriate of Potash makes up over 95% of the potassium fertilizer market due to its low cost relative to other K sources. Potassium chloride is a neutral salt and as such does not influence the soil reaction. Some crops, such as tomato, tobacco and potato, are sensitive to chlorine and K sources other than Potassium Chloride are used. Turfgrasses are not sensitive to chlorine.

Potassium Chloride Muriate of Potash



- KCl (60% K₂O or 50% K)
- Completely soluble
- High salt index (2.29)

- **Potassium Sulfate**, also known as Sulfate of Potash, is a crystalline mined product containing 50% K₂O and 17% S. It has a salt index of 0.84, which is approximately one-third that of Muriate of Potash. Thus potassium sulfate should be used in situations where salinity is a problem. In soils containing iron or aluminum coating, potassium sulfate leaches less than potassium chloride, but in most sandy Florida soils large differences in leaching characteristics of the two materials have not been observed. Potassium sulfate is mostly used on crops which are sensitive to chlorine.

Potassium Sulfate



- K₂SO₄ (50% K₂O or 41% K; 17% S)
- Good source of K and S
- Leaches less rapidly than KCl in coated soils

- **Potassium-Magnesium Sulfate**, also known as Sulfate of Potash Magnesia, is a crystalline mined material containing 22% K_2O , 11% Mg and 22% S. It is mainly used in cases where both K and Mg are deficient. Research has shown that in Florida soils Mg is held preferentially to K and soil K levels tend to decline when this material is used. If the soil tests low in Mg (less than 20 ppm) and the soil pH is less than 6.0, dolomitic lime is a much more economical source of Mg than potassium-magnesium sulfate. The salt index of potassium-magnesium sulfate is 1.97, comparable to that of Muriate of Potash. Therefore, attention should be given to application rate and irrigation following application to avoid salt burn.

Potassium-Magnesium Sulfate



- $K_2SO_4 \cdot MgSO_4$
- 22% K_2O or 18% K; 11% Mg; 22% S
- Good for soils low in K and Mg
- Moderate salt index (1.97)

- **Potassium Nitrate** - Properties of this material were discussed under N sources above.

Controlled or Slow-Release Fertilizer Sources

The terms controlled-release and slow-release fertilizer sources have slightly different meanings to selected individuals, but for purposes of this discussion the two terms are synonymous. Except for a few slow-release K sources, almost all slow-release fertilizers are N sources. While representing a relatively small segment of the total fertilizer industry (3-4%), slow-release materials are growing in utilization faster than the soluble materials. Because of reduced overall environmental impact, use of slow-release N materials is now being mandated in best management practices.

- **Ureaformaldehyde Reaction Products**, also known as **Nitroform**, Ureaform, UF, Methylene Urea, Blue Chip, **Nutralene** or Methex, represent one of the oldest controlled-release nitrogen technologies, having been first produced in 1936 and commercialized in 1955.

Ureaform is the oldest class of UF reaction products. Ureaform is sparingly soluble. It contains at least 35% total nitrogen with at least 60% of the total nitrogen as cold water-insoluble nitrogen (CWIN). Further, it must have an Activity Index (AI), i.e., the percent of CWIN that is soluble in hot (100°C) water, of not less than 40%. Ureaform is composed largely of longer-chained UF polymers, primarily tetramethylene pentaurea (TMPU) and longer. Unreacted urea nitrogen content is usually less than 15% of the total nitrogen. This product is commonly marketed under the following names: **Nitroform**, UF, Blue Chip, Powder Blue or Methex.

Nitroform



- Urea formaldehyde
- Insoluble organic
- 38% N; 65-71% WIN
- Biological N release
 - Rate influenced by soil temperature

Methylene Ureas are a class of sparingly soluble products which evolved during the 1960s and 1970s. These products contain predominantly intermediate chain-length polymers, primarily trimethylene tetraurea (TMTU) and tetramethylene pentaurea (TMPU). The total nitrogen content of these polymers is 39 to 40%, with between 25 and 60% of the nitrogen present as CWIN. The unreacted urea content generally is in the range of 15 to 30% of the total nitrogen. This product is typically marketed under the trade name **Nutralene**.

Nutralene



- Methylene urea
- 40% N; 38% WIN
- Biological N release
- More rapidly available than UF
- Not as adversely influenced by cool temperatures

UF solutions are clear water solutions. They contain only very low molecular-weight, water soluble UF reaction products plus unreacted urea. Various combinations of the UF solutions are produced. They contain a maximum of 55% unreacted urea with the remainder as one or more of methylolureas, methylolurea ethers, MDU, DMTU, or triazone. One of the commercial names under which this product is currently marketed as **CoRon**.

CoRon



- 28% N solution
- Polymethylene ureas and amine modified polymethylene ureas
- N release dependent upon microbial action

Agronomic Properties and Nutrient Release Mechanism of UF Products

The conversion of UF reaction products to plant available N is a multistep process, involving dissolution and microbial decomposition. Once in the soil solution, UF reaction products are converted to plant available N through either microbial decomposition or hydrolysis.

Microbial decomposition is the primary mechanism of N release with the carbon in the methylene urea polymers providing the site for

microbial activity. Environmental factors such as soil temperature, moisture, pH and aeration affect the rate of N release.

The rate of N release from UF reaction products is directly affected by polymer chain length. The longer the methylene urea polymer, the longer it takes for the N to become available. For ureaform and methylene urea products, the rate of mineralization is reflected by the cold water insoluble N (CWIN) content and its Activity Index. It is questionable if the very long methylene urea polymers are effectively used by the plant.

- **Isobutylidene Diurea (IBDU)**. Unlike the condensation of urea and formaldehyde, which forms a distribution of different UF polymer chain lengths, the reaction of urea with isobutyraldehyde forms a single oligomer. Although similar in chemical structure to methylene diurea (MDU), its physical properties are quite different.

Isobutylidene diurea (IBDU) is a non-hygroscopic white crystalline solid available in fine (0.5-1.0mm), coarse (.7-2.5mm) and chunk (2.0-3.0mm) particle sizes. The product contains a minimum of 30% N with 90% of the N in water-insoluble form. The typical commercialized product contains 31% N.

IBDU



- 31% N -90% WIN
- N released by hydrolysis
- Relatively unaffected by
 - Temperature
 - pH
- Particle size important
- Excellent cool season response

Nitrogen from IBDU becomes available to plants through hydrolysis. In the presence of water, the compound will hydrolyze to urea and isobutyraldehyde. The rate of hydrolysis is accelerated by low pH and high temperature. Unlike UF polymers that rely on soil microbial

populations to make the N available, IBDU is primarily dependent on water as the critical element in N availability. Its low water solubility controls the transport of the product into the soil solution. Once in the soil solution, the rate of hydrolysis is affected by both soil pH and temperature. The rate of dissolution is affected by particle size and amount of water available. The powder form is mineralized much more rapidly than large particles under the same field conditions. Because the release is not microbe-dependent, N can become available at low temperatures; thus IBDU is one of the preferred products for cool-season application. This attribute and the dependency on moisture are the distinguishing characteristics of IBDU.

IBDU is used on turfgrasses, in commercial nurseries, and in landscaping, forestry, and speciality agriculture. Although some fine-size IBDU (31-0-0) is used for direct application to golf course greens, most of the turfgrass use is in the form of blended fertilizers, often in combination with other types of controlled release fertilizers.

- **Sulfur-Coated Fertilizers. Sulfur-coated urea (SCU)** technology was developed in the 1960s and 1970s by the Tennessee Valley Authority. Sulfur was chosen as the principal coating material because of its low cost and its value as a secondary nutrient.

Sulfur-coated ureas (SCUs) are typically brown to tan to yellow depending on the source of urea, whether or not a sealant is used, and the type sealant employed. Soft sealants are typically used as a secondary coating over the sulfur coating to fill in imperfections in the sulfur coating and to provide handling integrity to the brittle sulfur coat. The total N content of SCUs varies with the amount of coating applied. SCUs available in the early 1990s ranged from 30 to 40% N.

Sulfur Coated Urea



- 32-38% N
- Release depends upon
 - Thickness of sulfur coating
 - Biological activity
 - Soil environment
 - Temperature
 - pH
- Cool season response erratic
- Coating fragile

Agronomic Properties and Nutrient Release Mechanisms of SCU

The mechanism of N release from SCU is by water penetration through micropores and imperfections, i.e., cracks or incomplete sulfur coverage, in the coating. This is followed by a rapid release of the dissolved urea from the core of the particle. When wax sealants are used, a dual release mechanism is created. Microbes in the soil environment must attack the sealant to reveal the imperfections in the sulfur coating. Because microbial populations vary with temperature, the release properties of the wax-sealed SCUs are also temperature dependent.

The release rate of a SCU particle is directly affected by the coating thickness and the coating quality. Particles with higher sulfur loads, i.e., thick sulfur coatings, typically show fewer imperfections than particles with lighter coatings.

There is a risk, however, that particles with too-thick sulfur coatings will exhibit lock-off, i.e., they may never effectively release their N.

Depending on the coating weight, N application rate, and environmental conditions, SCUs can have residual characteristics which provide agronomic response from 6 to 16 weeks in turfgrass applications. Because of the differential release of N due to the lack of uniformity in coating thickness and the influence of temperature on N release, severe mottling has been observed in turfgrass when SCU was applied during the cool-season growth period.

• **Polymer-Coated Fertilizers (PCFs)** represent the most technically advanced state of the art in terms of controlling product longevity and providing nutrient efficiency. Because most polymer-coated products release by diffusion through a semipermeable membrane, the rate of release can be altered by composition of the coating and the coating thickness. In recent research, the fertilizer N source being coated has also been shown to influence the rate of N release. Polymer coatings can be categorized as either thermoset resins or thermoplastic resins. Because of the relatively high costs of the coatings on most polymer-coated products, their use has been restricted mostly to high-value applications.

Osmocote. Production of Osmocote involves the coating of a soluble fertilizer core with a thermoset copolymer of dicyclopentadiene and a glycerol ester (linseed oil) dissolved in an aliphatic hydrocarbon solvent. Nutrient release patterns vary with the amount of coating applied and the substrate used. Coating weights vary from 10 to 20%. Typically, commercial products are blends of different coating weights. Coating substrates include, but are not limited to, urea, potassium sulfate, and ammonium nitrate. Product longevities range from 5 to 16 months, depending on the temperature.

Osmocote



- Usually a coated NPK fertilizer
- N release by diffusion
 - Temperature sensitive
 - Release rates vary; 6-8, 9-10, and 11-12 months
- Once coating hydrated material must remain moist or coating cracks eliminating control release properties

Osmocote products, like most polymer-coated products, release by diffusion through a semipermeable membrane. Water vapor penetrates the resin coating and dissolves the water-soluble fertilizer core. The dissolved nutrients then diffuse back through the coating

to the environment. Since temperature influences the rate of diffusion, temperature plays a big role in the nutrient release. The Osmocote market has been mainly limited to commercial ornamental horticulture production, such as nurseries and greenhouses, citrus production, and strawberry production.

Meister products. Meister products are produced by using thermoplastic resins, such as polyolefins, polyvinylidene chloride, and copolymers as coating materials. The coatings are dissolved in fast-drying chlorinated hydrocarbon solvents and are applied to a variety of substrates including urea, diammonium phosphate, potassium sulfate, potassium chloride, and ammonium nitrate. Because the thermoplastic polymers used are highly impermeable in water, release controlling agents such as ethylene-vinyl acetate and surfactants are added to the coating to obtain the desired diffusion characteristics. Coating thicknesses are essentially the same for all products with the release pattern being controlled by the level of release-controlling agent. Release rates can also be altered by blending talc resin into the coating.

Meister Product



- Thermoplastic resin applied to
 - Urea
 - Diammonium phosphate
 - Potassium sulfate
 - Potassium chloride
 - Ammonium nitrate
- Release by diffusion dependant upon soil temperature and moisture

As with other polymer-coated fertilizers, nutrients are released by diffusion through the coating. The various releasing agents incorporated into the coating change the permeability characteristics, while the amount of release agent contained in the coating

determines how fast the nutrients will diffuse. As with most polymer-coated fertilizers, the release is largely controlled by temperature.

Reactive Layer Coating. A relatively new coating technology known as reactive layer coating (RLC) polymerizes two reactive monomers as they are applied to the fertilizer substrate in a continuous coating drum. These *in situ* reactive layer polymerizations form an ultra-thin membrane coating which controls nutrient release by osmotic diffusion. A number of these products are being marketed under the trade name **Polyon**. These include coated basic fertilizer materials, i.e., urea, potassium nitrate, potassium sulfate, potassium chloride, ammonium sulfate, ammonium phosphate and iron sulfate, in various particle sizes. Coating weights on urea vary from 1.5 to 15%, depending on the release duration desired.

Polyon



- 40% N
- Polyurethane coated urea
- N release influenced by
 - Coating thickness
 - Diffusion rate
 - Soil temperature
- Good for both warm and cool season
- Coating is abrasion resistant

Nutrients are released from Polyon-coated fertilizers by osmotic diffusion. The RLC process permits application of ultra-thin, and hence lower cost, membrane coatings, which distinguishes this technology from many other polymer-coated fertilizers. The coating thickness determines the diffusion rate and the duration of release. Polyon-coated urea at 4% coating (44%N) will release at twice the rate and will have half the duration as an 8% coating (42% N).

During the manufacturing process two polymers react to form a polyurethane coating which is chemically bonded to the fertilizer core. The advantage of RLC technique is that the liquid coating materials can be applied and polymerized to the desired coating thickness in a continuous coating process drum without the need for solvents and associated recovery equipment. As a result, production costs are lower than many of the other commercial polymer-coated fertilizer technologies.

Multicote Products. In the production of multicote products, fertilizer granules are heated in a rotating pan and treated with fatty acid and metal hydroxide, such as stearic acid and calcium hydroxide. The two react to form a coating on the metal salt of a fatty acid, such as calcium stearate. Multiple layers of fatty acid salt are reacted *in situ*, followed by the application of a paraffin topcoat. Coating weights are relatively large compared to other technologies, but this problem is offset by the comparatively low cost of the coating materials. Substrates coated include potassium nitrate, urea, and triple superphosphate. The various coated components are blended together into different grades which are marketed under the **Multicote** name.

Multicote



- Relatively low analysis
- Release controlled by
 - Coating thickness
 - Soil moisture / temperature
- Substrates include
 - Potassium nitrate
 - Urea
 - Triple superphosphate

Polymer/Sulfur-Coated Fertilizers.

Polymer/sulfur coated fertilizers (PSCF) are hybrid products that utilize a primary coating of sulfur and a secondary polymer coat. These fertilizers were developed to deliver controlled- release performance approaching polymer-coated fertilizers, but at a much reduced cost. Sulfur is employed as the

primary coating because of its low cost. Low levels of a polymer surface-coat are used to control nutrient release rate. Unlike the soft wax sealants used to cover imperfections in the sulfur coatings of SCUs, the polymers in this case are chosen to provide a continuous membrane through which water and nutrients must diffuse. The water permeability characteristic of the polymer controls the rate of water diffusion into the particle. The combination of the two coatings permits a positive cost/benefit value over products with singular coatings of sulfur or polymer. They possess excellent abrasion resistance and handling integrity. Since the outer coating is a hard polymer, the products do not leave waxy residues on material handling and application equipment.

Poly-S



- Coated with sulfur and a polymer
 - Cheaper than regular polymer coated fertilizers
- Release dependent on
 - Temperature
 - Soil moisture

The nutrient release mechanism is a combination of diffusion and capillary actions. Water vapor must first diffuse through the continuous polymeric membrane layer. The rate of diffusion is controlled by the composition and thickness of the polymeric film. Once at the sulfur/polymer interface, the water subsequently penetrates the defects in the sulfur coat through capillary action and solubilizes the fertilizer core. The solubilized fertilizer then exits the particle in reverse sequence. This diffusion-controlled mechanism permits greater uniformity in nutrient release as compared to the typical matrix release of sulfur-coated fertilizers. The agronomic advantages of this material are reduced surge growth after application and longer residual of up to six months. In

addition, the combination coating renders the nutrient release much less temperature sensitive than most polymer-coated fertilizers.

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