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The development of fertilizer from the early years to today

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A BRIEF HISTORY OF FERTILIZER

Scottish physician, chemist, and botanist Daniel Rutherford is credited for the discovery of nitrogen through a series of experiments handed to him by his mentor and teacher, Joseph Black, working with what they called “noxious air, fire air, and foul air.” Once isolated, nitrogen was determined to be one of the most abundant elements in the atmosphere. Nitrogen is an inert gas and forms many inorganic compounds used as fertilizers and gases. Nitrogen is a precursor for ammonia, which is a commercially used compound.

Nicolas-Theodore de Saussure, a Swiss chemist and plant physiologist, was a major pioneer in the study of photosynthesis. He discovered in 1804 that nitrogen was an essential nutrient for plant growth. He discovered that nitrogen is vital because it is a major component in chlorophyll. Chlorophyll is the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide.

Urea was first found in human urine in 1773 by H.M. Roelle, and Friedrich Wohler first synthesized urea in 1828, with urea being the first organic compound to be synthesized from inorganic starting materials. This discovery was an accident, as Wohler was attempting to synthesize ammonium cyanate by treating silver cyanate with ammonium chloride. The result was a white crystalline material which proved to be identical to urea found in urine. Urea is produced commercially by reacting carbon dioxide with anhydrous ammonia under high pressure and high temperature. 140 million tons of urea are currently produced annually throughout the world.

Urea was found to have many uses. Adolf Bayer discovered in 1864 that urea and malonic acid form barbiturates. Also, the resin material melamine is formed by dehydration of urea, and is still used in adhesives, laminates, and various coatings. In agriculture, urea is used as a nitrogen fertilizer.

In 1842, Sir John Bennet Lawes created the first commercial fertilizer by treating phosphates with sulfuric acid, creating single super phosphate, the first patented fertilizer. This English entrepreneur experimented with manure and its effects on plant growth of potted and field crops, as well as the relationship between plant nutrition and animal feed quality. He also founded the Rothamsted Experiment Station, the oldest agricultural research station in the world.

Urea formaldehyde was first synthesized by Dr. Holzer in 1884. Then, in 1919, Hanns John of Prague, Czechoslovakia, patented the first urea formaldehyde resin. In addition to its use as fertilizer, urea formaldehyde is used in laminates, textiles, wrinkle-resistant fabrics, cotton blends, rayon, and as a bonding agent for particleboard, fiberboard, and plywood.

In the early 1900s, there were two major advances. In 1910, the Haber production process was invented. This process, which produces ammonia, was found by German chemists Fritz Haber and Carl Bosch. The process was later purchased by German company BASF. Ammonia was mainly used as a fertilizer but, during World War I, it was used to manufacture German explosives. The Haber process is an artificial nitrogen fixation process and is the main industrial process for the production of ammonia. The process converts atmospheric nitrogen (N₂) to ammonia (NH₃) by a reaction with hydrogen (H₂) using a metal catalyst under high temperature and pressure. Wilhelm Ostwald invented a process which converts ammonia into nitric acid (HNO₃). Without the Haber process, we would not have commercially available ammonium nitrate or urea.

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In 1955, Nitroform slow-release urea formaldehyde was first offered for sale, with many additional short chain of methylene urea products following. In 1956, a research study was conducted on loblolly pine seedlings at Auburn University. The study concluded that one application of UF 38-0-0 (632 lbs. per acre, 240 lbs. of N) resulted in seedling heights equivalent to those of seedlings receiving 8 separate applications of straight ammonium nitrate 34-0-0 (1,141 lbs. per acre, 388 lbs. of N). Nitroform was thus the first true slow-release fertilizer.

A BRIEF HISTORY OF CONTROLLED-RELEASE FERTILIZER (CRF)

The first CRF, Osmocote, was created in 1960 by the Archer Daniels Midland Company. Thirty-one years later, Purcell Technologies perfected and commercialized Polyon in 1991. The company also included the green color of the product in the product's patent. In-the-mid-1990s, Haifa began selling Multicote in the U.S. Today multiple technologies are available from multiple companies in such products as Polyon, Osmocote, Nutricote, Multicote, Florikote, and Gal-Xe One.

When Osmocote was first introduced in the mid-1960s, it was intended to be used on cereal crops, but proved to be too expensive for those crops. Shortly after, the Osmocote know-how was sold to Sutter Hill, who formed Sierra Chemical. In the early 1970s, Sierra Chemical was sold off to private investors. New processes and procedures were created to make a better, more consistent product. Marketing began to focus on higher value crops. In the late 1980s, Sierra Chemical was sold to W.R. Grace and became Grace-Sierra. In 1994, Grace-Sierra was sold to the Scotts Miracle-Gro Company. In 2011, Israel Chemicals Ltd. purchased the Global Professional business of the Scotts Miracle Gro Company.

In the 1970s, sulfur-coated urea was created for the first time. The Tennessee Valley Authority created the technology which involves spraying sulfur and a layer sealant onto urea. Several companies built plants to manufacture sulfur-coated urea: CIL (now Agrium) in 1975, Lesco (now Turf Care Supply) in 1980, Scotts Company in 1982, and Purcell Technologies in 1985.

In the early 1990s, Purcell Technologies came out with Polyon CRF. In 2007, the Purcell family sold the Polyon technology to Agrium Advanced Technologies. Since 2014, Koch Agronomics has owned Polyon. Harrell's was the exclusive formulator and sales and marketing arm for Polyon east of the Rocky Mountains, whereas Simplot held the exclusivity west of the Rocky Mountains (and marketed the product under the Apex brand). Since 2014, Polyon has been formulated and marketed exclusively by Harrell's across the U.S. All Polyon green products are now formulated, manufactured, and marketed under the Harrell's brand. Poly is currently distributed in the Pacific Northwest under an agreement with Marion Ag Services. In 2014, Simplot parted ways with Polyon and began making Apex brand fertilizer with Gal-Xe.

No matter which brand we are talking about, there are multiple reasons to use CRFs. Nursery best management practices manuals (such as the BMP manual from the Southern Nursery Association) state that CRFs should be used and applied at the manufacturer's recommended rates. Reapplication should occur only when substrate solution nutrient status is below the desired level for the specific crop. The nutrients are released over a specific time frame, often matching the nutrient demand of the crop. Also, there is reduced nutrient leaching and run-off due to gradual release of nutrients into the growing substrate. In addition, they offer reduced volatilization of ammonia, with only small amounts being released. CRFs also reduce soluble salt injury, reduce potential contamination of surface water in nearby waterways, and increase irrigation efficiency (no "feeding when raining").

CRFs simply work! Multiple studies show that plants grown with CRFs produce plants of equal size to those grown with soluble fertilizers. Labor and energy use is also reduced; in certain operations, the time it takes to continually mix soluble fertilizer can be considerable. CRFs also have extended shelf life for the retailer.

WHAT ARE CONTROLLED-RELEASE FERTILIZERS?

Slow-release fertilizers and controlled-release fertilizers are not the same thing! Slow-release fertilizers are defined by AAPFCO as fertilizers containing a plant nutrient in a form which either (a) delays its availability for plant uptake and use after application, or (b) is available to the plant significantly longer than a reference “rapidly available nutrient fertilizer,” such as ammonium nitrate or urea, ammonium phosphate, or potassium chloride. Slow-release fertilizers have release mechanisms that are not controlled, contain unavailable nutrients, and are less efficient than CRFs. Their release mechanisms are hydrolysis (involving water and particle size), mineralization (involving microbial activity, soil temperature, moisture level, and oxygen), and catastrophic release (e.g., coating breakdown). Slow-release fertilizers include natural organics (e.g., Milorganite), synthetic organics (e.g., IBDU and Nitroform), and sulfur-coated products (e.g., Poly S and TriKote).

Conventional water-soluble fertilizer materials (substrates) are given a protective coating or encapsulation (water insoluble, semipermeable, or impermeable with pores) that controls water penetration and the rate of nutrient dissolution and nutrient release. Factors that play a role in CRF performance are coating, moisture, temperature, substrate (that is being coated), and the nursery manager.

The coating is the “control” in controlled-release fertilizers. The coating must have integrity to have longevity. Coating porosity must also be correct so that water can pass through the coating membrane and allow solutes and nutrients to pass back through the coating.

Moisture activates the CRF release mechanisms at a level below the wilting point. It thus becomes important to irrigate soon after potting into a CRF-containing substrate or after topdressing.

Temperature and nutrient release are directly correlated. All CRFs release nutrients faster with increasing temperature. In the plant, increasing temperature causes an increase in metabolic processes and demand for nutrients, and CRFs are able to match the demand. Coating integrity becomes especially important as temperature increases so that the product is not over-releasing (“dumping”) nutrients. Duration of nutrient release listed on product bags are based on testing at a certain temperature. Unfortunately, there is no industry standard temperature for this testing; each company makes its own decision (70°F for Osmocote, Multicote, Florikote, and Gal-Xe; 77°F for Nutricote; and 86°F for Polyon).

The fertilizer substrate characteristics that are of importance are prill vs. granule, shape (angular or round), surface smoothness, particle size, and water solubility (N, P, and K). At this time, all CRF manufacturers are all obtaining their substrate from the same source (Yara).

The nursery manager needs to give attention to the choice of appropriate product, use the product at the proper rate, use the proper method of application, and use proper placement. The growing medium components also affect what happens with the CRFs: bark (aged vs. fresh), peat (providing more cation exchange), or other amendments. Before our company makes product recommendations, we always take a sample of the medium. Irrigation concerns are type, water source, water quality, frequency, and salts monitoring. Regular use of an EC meter is critical for quality control.

Literature cited

Broschat, T.K. (1995). Nitrate, phosphate, and potassium leaching from container-grown plants fertilized by several methods. *HortScience* 30, 74-77.

Broschat, T.K. (2005). Rates of ammonium-nitrogen, nitrate-nitrogen, phosphorus, and potassium from two controlled-release fertilizers under difference substrate environments. *HortTechnology* 15, 332-335.

Cox, D.A. (1993). Reducing nitrogen leaching-losses from containerized plants: The effectiveness of controlled-release fertilizers. *J. Plant Nutrition* 16, 533-545.

Fain, G.B., Gilliam, C.H., Tilt, K.M., Olive, J.W., and Wallace, B. (2000). Survey of best management practices in container production nurseries. *J. Environ. Hort.* 18, 142-144.

Million, J., Yeager, T., and Albano, J. (2007). Effects of container spacing practice and fertilizer placement on runoff from overhead-irrigated sweet viburnum. *J. Environ. Hort.* 25, 61–72.

Owen, J.S., Warren, S.L., Bilderback, T.E., and Albano, J.P. (2008). Phosphorus rate, leaching fraction, and substrate influence on influent quantity, effluent nutrient content, and response of a containerized woody ornamental crop. *HortScience* 43, 906-912.

Southern Nursery Association (2013). *Best management practices: guide for producing nursery crops*. 3rd ed. Southern Nursery Association, Atlanta, Georgia.

QUESTIONS

Martin Stockton: With different companies using different reference temperatures to measure release, how do you correlate one to another?

Norman Lafaille: We do wish there were an industry standard, but unfortunately there is not. The 86°F temperature used to measure release of Polyon has served us well as, over time, we have worked to convert growers from Osmocote to Polyon, especially in the warmer growing climates.

Voice: Is there any research being conducted with CRFs on field stock?

Norman Lafaille: Yes, we work quite a bit with field growers. We take field samples over a large area. Often phosphorus is not needed; adequate amounts are already present in the soil. The “sticker shock” is often tough on the field growers who are accustomed to using agricultural grade fertilizers. We often recommend supplying about 30% of the nitrogen rate with controlled-release fertilizer (400 to 600 pounds per acre with one application) can allow trees to caliber-up just as well as they would with multiple applications. Plus, there are also labor savings.

Voice: Does the matrix of the coating remain stable or does it degrade over time?

Norman Lafaille: Coating integrity is important to permit controlled release over the specified period of time for the product. With time, microbial activity will take over and the coating will eventually be broken down.