

A Review

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Polymer coated fertilizers as advance technique in nutrient management

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Control release fertilizers (CRF's) are coated fertilizers that release nutrients over an extended period of time at a rate driven primarily by temperature and moisture of the root zone. Polymer coated fertilizers (PCF's) were also a type of CRF's, which are solid or other nutrient core, coated with various polymers ("plastics"). Fertilizer use efficiency can be increased by application of polymer coated fertilizer compared to common fertilizers due to very less nutrient losses. Most common three marketed products are Nutricote, Osmocote and Polyon. Coatings are tough, resist to damage and thin. Nutrient release is due to controlled diffusion, which is fairly constant over time. Release depends on coat thickness, chemistry, temperature and moisture.

It has been estimated that slow-release fertilizers comprise only 8–10 per cent of the total fertilizers used in Europe, 1 per cent in the USA and only 0.25 per cent in the World. In Japan 70 per cent of polymer coated controlled-release fertilizers are used in rice. Polymer

coated fertilizers are used for high value applications. Controlled-release is one of the modern application that has enhanced nutrient use efficiency. Fertilizer use efficiency can be increased by modification of fertilizer products. e.g. coated encapsulation. Controlled release fertilizers (CRFs) will bring revolution in agricultural industry in near future.

Standard sulphur coated urea (SCU) and polymer coated sulphur coated urea (PCSCU) have dominated in the market for several years. However, the horticultural and garden-lawn markets in particular require a more sophisticated nitrogen release pattern. Thus, many new controlled-release fertilizers with modified coatings have been developed. Polymer coatings may either be semi-permeable or impermeable membranes with tiny pores. The main problems in the production of polymer-coated fertilizers are the choice of the coating material and the process used to apply it. The nutrient release through a polymer membrane is not significantly affected by soil properties, such as pH,

salinity, texture, microbial activity, redox-potential, ionic strength of the soil solution, but rather by temperature and moisture permeability of the polymer coating. Thus, it is possible to predict the nutrient release from polymer-coated fertilizers for a given period of time much more reliably than, for instance, from SCU. Nutrient release from Osmocote (an alkyd-resin-coated fertilizer) follows water entering the microscopic pores in the coating. This increases the osmotic pressure within the pore, which is enlarged and nutrients are released through the enlarged micropore. The alkyd-resin-type coating makes it possible to satisfactorily control the release rate and timing. Polyurethane-like coatings also provide a good control over rate and duration of release. The rate of nutrient release from a polymer coated product, can to a reliable extent be controlled by varying the characteristics and types, thickness of the coating, as well as by changing the ratio of different coating materials. The moisture permeability of the capsule can be controlled by changing the composition of the polymeric coating material used. For instance, with the Chissoasahi process, the ratio of ethylene-vinyl-acetate (EVA—high moisture permeability) to polyethylene (PE – low moisture permeability) is changed. The nutrient release pattern is then determined by a water-leaching test at 25°C.

Polymer-coated fertilizer technologies vary greatly between producers depending on the choice of the coating material and the coating process. The Pursell Reactive Layers Coating (RLCTM) uses polymer technology, while Polyon uses a polyurethane as does Haifa (Multicote) and Aglukon (Plantacote). Chissoasahi polymer technology (Meister), Nutricote is a polyethylene; while Scotts polymer technology (Osmocote) is an alkyd-resin.

The quantity of coating material used for polymer coatings of conventional soluble fertilizers depends on the geometric parameters of the basic core material (granule size to surface area, roundness etc.) and the longevity target. In general, the coating material represents 3-4 per cent (RLCTM) to 15 per cent (conventional coating with polymers) of the total weight of the finished product. For example, the capsule or coating film of Meister (encapsulated urea) is 50 to 60 µm in thickness and approximately 10 per cent in weight. The longer the need to supply the nutrients, the smaller is the amount released per unit of time. The producers indicate the period of release, e.g. 70, 140, upto 400 days release at constant 25°C. However, if the polymer-

coated fertilizers are not straight nitrogen but NPK fertilizers, particularly when containing secondary and micronutrients, the rate of release of the different nutrients, N, P, K, S, Ca, Mg and micronutrients, are generally Slow- and controlled-release and stabilized fertilizers not stated.

Apparently, it is very difficult to determine exactly the release mechanism, particularly for secondary and micronutrients. The problem is that, in order to guarantee the longevity of nutrient release from a polymer-coated product, there should be no (or an extremely slow) biodegradation, chemical-degradation or mechanical destruction of the coating during the period of nutrient release. Only after the nutrient supply of the product has ceased should microbial attack and mechanical destruction of the empty shell occur.

Some polymer-coated fertilizers still present a problem with the persistence in the soil of the synthetic material used for encapsulation; there is much research on this topic. Agrium indicates that the polymer coating of their polymer-coated urea (ESN) degrades in a two-step process to CO₂, ammonia and water. Coating material made from a photo-degradative polymer is easily decomposed by photochemical process in the soil. Recently, 'UBER', a new type of controlled-release fertilizer without a polymer coating has been developed by Chissoasahi. It is produced using CDU and two additives that control the pattern and rate of nutrient release. Three formulations are available with short to long release patterns. It is mainly used for high value plants and is especially helpful for 'eco-farmers' practicing environment-friendly farming because it has no polymer coating. Several companies have marketed thin PCU products as controlled release N sources (e.g., "POLYON" coated urea by Pursell, "ESN" by Agrium, "Osmocote" by Scotts, Meister by Chisso-Asahi, and many others). The coatings are usually resins or thermoplastic materials and their weight can be as low as <1% of the granule mass without significantly reducing the N content. Unlike SCU which releases urea through small pinholes that can result in a more difficult controlled-N release pattern, PCU releases N by diffusion of urea through the swelling polymer membrane. The release pattern is related to the coating composition and usually depends on soil moisture and temperature, although some products are reported to be affected little by soil moisture content, pH, soil microbial activity, and even by temperature. It is possible, by changing or combining

coatings, to formulate fertilizers which release 80 per cent of their nutrients in pre-established time intervals such as 80, 120, 180, or even 400 days. There are many reports of favourable, as well as not so encouraging, results for the coated N fertilizers in the literature.

In field trials, reported that grain yield of lowland rice from a single application of PCU was equivalent to or better than 3–4 well-timed split urea application. Fertilizer recovery with PCU was 70–75 per cent compared with 50 per cent with prilled urea (PU). The higher recovery of N from two PCU products was related to N release and subsequent N uptake by rice during the post anthesis stage. A one-time application of PCU may have distinct advantages over prilled urea, not just in terms of labour saving, but also because PCU may provide a more stable and sustained N release in *rainfed* crop systems where well-timed split N applications may not be feasible due to variability in rainfall and soil moisture. Coated urea also performed better than regular fertilizers by promoting increased grain yield and N uptake in rice in Spain, winter wheat in China, peanuts in Japan, potatoes in the USA, and maize in Japan.

Controlled release fertilizer (CRF) :

Controlled released fertilizers (CRF's) are coated fertilizers that release nutrients over an extended period of time at a rate driven primarily by temperature and moisture of the root zone. At soil temperatures under 25°C, a controlled release fertilizer must meet three criteria:-

- Less than 15 per cent of the CRF nutrients should be released in 24 hours,
- Less than 75 per cent should be released in 28 days and
- At least 75 per cent should be released by the stated release time (40–360 days).

Types of coating technology of CRFs :

- Polymer (polyethylene, polyesters)
- Sulphur
- Sulphur plus polymer.

Polymer coated fertilizers (PCFs) :

Polymer coated fertilizers (PCFs) are solid or other nutrient core, coated with various polymers (“plastics”). Coatings are tough, resist to damage and thin. Coating chemistry affect release rate. Release is due to controlled diffusion, which is fairly constant over time. Release

depends on coat thickness, chemistry, temperature, moisture.

Factors affecting nutrient release rate :

- Temperature
- Moisture
- Size
- Coating thickness
- Coating failure (cracks, abrasion).

Mechanisms of nutrient release :

In a recent assessment of polymer-coated materials, multiple mechanisms of release, including diffusion, osmotic pumping (apparently caused by changes in hydrostatic pressure and an osmotic gradient) and convective release by coating disruption. Release occurs mainly by diffusion when the water potential is at steady-state and the coating material is permeable to the solutes within. Release by diffusion yields a relatively steady release, subject mainly to changes in coating permeability and temperature. The authors indicated that osmotic pumping (mass flow) and diffusion of solutes is likely when the coating is semi-permeable to at least some solutes and cracks of limited volume are formed in the coating by the build up of hydrostatic pressure. If the coating is completely impermeable to the internal solutes, there is no solute release until cracks are formed. Impermeability to fertilizer salts may be associated with swelling of the prill, although swelling may not be easily detectable. Finally, convective solute transfer by coating disruption would occur when the build up of hydrostatic pressure causes coating rupture. This is the release mechanism for sulfur-coated urea, likely happens in most polymer coated fertilizers only due to coating failure.

Targeted experimentation must be done in order to correctly identify mechanisms of release and also that the mechanism may change with the phases of the release process. The dominant release mechanism depends on the physical properties of the polymer coating and internal solutes, and their interactions with environmental conditions. Polymer coated fertilizer (PCF) release nutrients purely by diffusion, mainly citing information from PCF manufacturers.

A conceptual model of nutrient release for individual PCF prills involving a three-phase process. The first of their proposed phases is a lag phase in which there is little to no nutrient release; during this phase water vapour diffuses into the prill and hydrates fertilizer salts. The

authors indicated that the duration of the lag phase may depend on the time to hydrate internal voids in the prill or on the establishment of a steady state between influx of water and efflux of solutes. Hydrostatic pressure is generated within the coating in response to water uptake/mass increase. The second phase is a period of linear release in which the driving gradient for nutrient release by diffusion remains constant; this is due to the presence of un-dissolved fertilizer salts that maintain nutrient-saturated conditions in the solution within the prill relative to dilute ion concentrations in solution surrounding the prill. The authors indicated that nutrient movement across the coating may also occur by mass flow due to a pressure gradient, but did not discuss the conditions under which this would occur.

Why to use PCFs :

- 70 per cent of conventionally applied fertilizer goes unutilized
- Loss of nutrients due to volatilization and leaching
- Fertilizer run-off in surface water leads to eutrophication process
- Negative environmental impacts
- Fertilizer waste through leaching increases ground water pollution
- Less fertilizer use efficiency.

Advantages :

- Minimize nutrient losses
- Increase Nutrient Use efficiency (NUE)
- Increased nutrient release timing
- Meet plant demand timely and efficiently
- Reduce labour requirement
- Reduction of the labour cost for the application of fertilizer
- To improve the yield and reduce the cost of production
- Reduction of plant toxicity
- Reduction in ground water pollution and water bodies
- Root burn can be avoided with the application of controlled release fertilizers even at the increased quantities of fertilizers supplied.
- Fertilizers are released at a slower rate throughout the season; so that plants could take up most of the nutrients without much waste.
- Reduced leaf burn from heavy rates of surface application

- More uniform growth response
- Flexibility of release periods from 40 to 360 days at 25° C
- Improved storage and handling properties of fertilizer materials.

Disadvantages :

- Very high cost.
- Applying sulphur coated urea almost always lowers soil pH.
- Prills can be damaged by abrasion.
- Only about 0.25 per cent of the total fertilizers consumption is such products
- Nutrient deficiencies may occur if nutrients are not released as predicted because of low temperatures, flooded or droughty soil, or poor activity of soil microbes

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