Controlled-Release Fertilizers (CRFs)

Benefits & Developments

The issue
Fertilizers and innovative plant nutrition solutions play a critical role for nutrition and food security as they are estimated to help produce about half of the world’s current food supply. They contribute to limiting further deforestation, other land use changes, and related climate change and biodiversity impacts because the use of fertilizers increase yields significantly compared to unfertilized fields.

Plants need nutrients: Tailoring the use of fertilizers to the individual needs of agricultural crops not only results in increased production (and thus an increase of the total supply of food) but also contributes to the quality of plant- and animal-based food and its content of essential nutrients. Nitrogen is necessary to support microorganisms’ activities, mineralize crop residues and organic matter.

Mineral (and organic) fertilizers are naturally prone to losses and leakages: According to the FAOSTAT, on average globally, 55% of the nitrogen input is recovered by the crop grown, whereas the remaining 45% may be stored in the soil or lost through leaching, runoff or gaseous emissions. Microbial activity in soils, heavy rainfalls, excessive irrigation water, poor agronomic management, wrong amount, source, timing or placement of fertilizer can increase such losses. While zero losses is impossible for these reasons, the crop can recover up to 80% of the applied N with very precise management.

Nutrient Use Efficiency (NUE) is defined as the proportion of the nutrients applied (from all sources) that is removed from the same field with the harvested crop. In general, achieving a high Nutrient Use Efficiency requires synchronizing nutrient supply from soil, fertilizer and other sources with crop nutrient requirements during the key stages of crop growth and development. Improving NUE is critical to increasing agricultural productivity while reducing its environmental impacts. In practice, this can be achieved through the adoption of:

- fertilizer best management practices following the 4R Nutrient Stewardship principles (applying the right nutrient source, at the right rate, at the right time, in the right place),
- enhanced-efficiency fertilizers, such as CRFs, and
- other technologies that aim to deliver nutrients precisely when they are required by the crop.

The benefit of CRFs: Combining food security goals with environmental protection and greenhouse gas emission reductions
CRFs release nutrients over time through a polymer coating as thin as hair. They regulate the release of nitrogen or other nutrients according to the requirements of the plant and depending on external conditions: Soil moisture is necessary to activate the release, and temperature drives the speed of the release.

This means that the farmer can tailor fertilizer applications to crops with differentiated growing cycles, taking into account weather and early or late seasonal applications. The nutrient release duration of these fertilizers depends on the coating chemistry and the environmental conditions; release duration typically ranges from 2 to 18 months depending on the products.
CRFs are an integrated solution because they:

- **Increase nutrient use efficiency by offering consistent and predictable nutrient release** over much longer periods of time vs conventional fertilizers;
- **Improve crop quality as the nutrients get released when the plant needs them**;
- **Reduce nutrient losses and greenhouse gas emissions**: Scientific research has shown that CRFs can reduce nitrate leaching in cropland by about 20-40%, ammonia volatilization by 40-70%, nitrous oxide emissions by 10-40% (Lam et al, 2022¹).
- **Reduce the frequency of applications**: A single application can meet crop nutrient requirements over the entire growing season, which, in turn, contributes to reduce labor and application costs.
- **It is an efficient way to improve nutrient use efficiency, when labor shortage is a key constraint** to broader adoption of split fertilizer applications or when it is technically complicated to apply a fertilizer in the field for different reasons (e.g. related to the crop itself or to weather conditions).

**Mode of action**

CRFs are granular fertilizers containing water-soluble nutrients (mostly nitrogen fertilizers, and multi-nutrient fertilizers containing also phosphorus and/or potassium, combined sometimes with sulphur, calcium, magnesium and micronutrients to address deficiencies).

The granules are typically coated with a polymeric coating, which acts as a barrier or membrane.

The CRFs are activated through soil moisture penetrating the coating and dissolving the nutrients within the granule. The nutrients will be progressively released through diffusion in response to temperature for a predetermined period of time.

This means that the nutrient release is controlled over time compared to conventional fertilizers. The nutrients are better maintained in the root zone and released according to plant needs.

The soil temperature and the thickness and type of the coating are the main determining factors for the speed of the release: The higher the soil temperature and the thinner the coating, the faster the release.

The thickness and type of the coating can be determined by the manufacturer before the production of the CRF. The farmer is advised to choose his controlled-release product with the support of the manufacturer, so that the manufacturer can provide the right solution, tailored to the specific needs of the farm.

**Green developments, new commercialization and future perspectives**

Coatings currently used in CRFs are mostly slowly degradable polymers.

For that reason, research has shifted towards new coating materials that are environmentally more benign, such as bio-oils or naturally occurring polymers.

¹ Lam et al (2022): Next Generation Enhanced-efficiency Fertilizers for Sustained Food Security. [https://www.nature.com/articles/s43016-022-00542-7](https://www.nature.com/articles/s43016-022-00542-7)
In line with new regulations, such as the European Fertilizer Products Regulation (EC 2019/1009), which lays out biodegradability criteria for polymers, fertilizer companies are developing coatings that decompose ultimately into carbon dioxide, biomass and water within a maximum period of 4 years, measured in a controlled environment after their “functionality period”. The functionality period refers to the time that the product is intended to release the nutrients to the plant. Good control over nutrient release can only be guaranteed if the biodegradation occurs after the CRF has released its nutrients.

Soil biodegradation testing methods are currently being proposed by independent research organizations.

Progress is being made in developing accelerated tests that will support development of new coating technologies in the future.

While fertilizer companies will offer different product formulations, it is expected that, within a decade, biodegradable coatings will be widely used for manufacturing CRFs. The ability to produce CRFs with release durations of more than 6 months using biodegradable coatings remains, however, scientifically challenging at this point.

**Market Outlook**

**CRFs account for about 0.4% of total nitrogen fertilizers consumed globally**, according to the data in the figure below. Available on the market as a premium product compared to commodity fertilizers, it is mainly consumed in mature markets or markets with challenging application conditions.

![Graph showing global consumption of CRFs vs. nitrogen fertilizers](image)

**Global consumption of CRFs vs. nitrogen fertilizers**
(Source: IFA consumption database 2023, and IFA special products assessment 2022)

Reviewing the landscape of 2021, the **North American** market dominated the consumption of CRFs, encompassing around 47% of the total usage. Notably, a substantial portion of CRF consumption was...
allocated to cereal production. On the other hand, the ornamentals market segment, estimated at 18%, experienced strong growth with increased use in turf, home gardens and ornamentals.

The **East Asia** region accounted for 44% of CRF consumption in 2021, with 70% going to China. It is a popular option for fertilizing rice in Japan, where labor shortage for fertilizer application is an important driver. The Asia-Pacific region is expected to dominate the medium-term market outlook (2023-2029), with China being expected to use an increasing amount for grains, fruits and vegetables.

**West and Central Europe** made up 6% of the total CRF market in 2021. 60% is consumed in the ornamentals market. Overall, demand has been stable, and it is expected to remain stable. However, there’s potential for growth in CRF demand for the agriculture market to align with EU’s Farm to Fork strategy, which aims to reduce nutrient losses while maintaining soil fertility.

The residual consumption occurred across global regions, with **Latin America** contributing a modest 1.8% to the global total. It experienced the fastest growth of about 12%, bringing consumption to 25,000mt in 2021. This increase was attributed to shift in demand for special products due to affordability and availability constraints impacting commodity fertilizers. There was a notable increase in the demand for CRFs for nurseries and plantations in **Brazil**.

The comparatively high production costs and retail prices are still limiting factors. Overall, prices depend on release duration. CRFs for field crops with a 2-6 months release time are cheaper than those used for nurseries with a release duration of 12-18 months.

Demand for biodegradable solutions is expected to increase CRFs’ share of the global fertilizer market. The CRF market may expand substantially in broadacre crops if more cost-effective coating technologies are developed.