Introduction

Nowadays, the use of nutrients from mineral fertilizers is necessary to ensure crops reach high productivities. Soil, plant, weather and crop management factors, can contribute to low efficiency of fertilizers. Some estimates show the Nutrient Use Efficiency (NUE) in the world are below 50%. This low efficiency may cause economic, environmental and social damage, affecting the sustainability of agricultural production [1]. In view of this problem, it is urgent to adopt strategies and technologies that promote NUE increase. In this sense, use of enhanced efficiency fertilizers appears an interesting option to help solve this important agricultural input. The use of enhanced efficiency fertilizers based on nanocomposites can help solve classic agricultural problems such as nutrient loss, and generate agronomic, economic and environmental benefits.

Enhanced Efficiency Fertilizers

The conventional fertilizers are sold in grain or dust form. One way to enhance efficiency of fertilizers, would be coating the grains with materials with ability to release nutrients in a controlled form (quantity a function of time), or, encapsulate the nutrients in an inorganic matrix that also has ability to control release. Some nanocomposites were studied to enhance fertilizers efficiency, among them stands out Layered Double Hydroxides (LDHs) [5-7], chitosan [8], carboxymethyl-cellulose [9], polyurethane [10], among others.

When input this technology in fertilizers, are generated products with release profile nutrient release similar of plant nutrient demand (Figure 1). This contributes to loss reduction and increases the agronomic efficiency of fertilizers.

1. Nitrogen (N)

One of the great problems of agriculture is the loss of N in fertilizers based on urea. This loss occurs by ammonia (NH₃) volatilization, as a result of fast urea hydrolysis in inadequate environmental conditions. The incorrect management of urea-based fertilizers can make N losses reach 70%. One way to solve this problem is to produce fertilizers that release urea gradually, this way the hydrolysis occurs slowly and N losses decrease.

In this sense, Pereira et al. [11] produced urea-based fertilizers from the mix of polymer (polyacrylamide), paraformaldehyde, and montmorillonite clay. The produced materials used in bioassays, where they evaluated the N volatilization and NUE in
the grass (test plant). The results showed when compared with conventional urea, the polymeric mix in a proportion of montmorillonite, urea, and paraformaldehyde 1:1:1 reduced volatilization 4.3 times. This same mix in proportion 1:4:0.5, increased grass production 53%, and NUE of N 60%.

Another usual problem in agriculture too N associated is nitrate (NO$_3^-$) leaching. The majority of soils have electronegativity character, due to this, some anions such as NO$_3^-$ tend to stay free in soil solution and be easily leached [12]. Beyond nutrient loss, the NO$_3^-$ generate environmental damages such as groundwater contamination and lake and rivers eutrophication. The use of slow-release fertilizers, to mitigate this problem, is a promising alternative. The application of nanocomposites to produce these fertilizers too presents good results. Olad et al. [13] produced a nanocomposite using sodium alginate, acrylic acid, acrylamide, and nanoparticles of silica obtained by carbonization rice husk; they used polymer as a slow-release fertilizer matrix. Testing nutrient release from fertilizer, in the soil, they found conventional fertilizers released all nutrients in first hours after application, while encapsulation in nanocomposites promoted a decrease in release profile of nutrient, after 30 days, had released only 70% of nutrient. These characteristics, the fertilizer would be a good alternative to systems with high leaching of NO$_3^-$.

2. Phosphorus (P)

Tropical soils are rich in Iron (Fe) and Aluminum (Al) minerals. These minerals have high interaction with P forms absorbed by plants (H$_3$PO$_4$, e HPO$_4^{2-}$), adsorbing them, and fix posteriorly, making P non-labile to plants sometime later [14]. This reaction makes P the most limiting nutrient and at the same time more consumed by agriculture in these regions.

Searching alternatives to minimize problems of P fixation in tropical soils, Benicio et al. [6,15], produced a matrix to encapsulate P, based in LDHs. The materials presented a slow release profile, due to prolonged protection to phosphate ions. The use of LDHs resulted in greater dry mass production in corn plants, and increase agronomic efficiency of P in 6% in sandy soil, and 16% in clayey soil [6]. Beyond increasing moderately, the soil pH, the LDH matrix provides physical protection to phosphate ions, reducing your contact with soil particles. In literature are found many papers showing LDHs potential to use as enhanced efficiency fertilizers [16-18].

3. Boron (B)

Boron is a micronutrient with many biological functions in plants, required in small quantities, your lack limits the crop production. In agriculture, B applied such as borax acid (H$_3$BO$_3$), easily leached species, these characteristics make difficult your management in many agricultural systems. Castro et al. [19] studied the use of LDHs to produce fertilizers able to reduce B leaching and increase crop production. The studies have shown that the boron intercalation in LHD reduced leaching of 44% to 9% on the first day after incubation when compared to H$_3$BO$_3$ use. The researchers reported that a slow-release profile is mainly responsible for the found result.

Final Considerations

Despite great advances in agriculture in recent years, classical problems still persist and need to be resolved to improve crop production. The majority part of production problems is related to the dynamic of nutrients in soils. In this short review, we saw examples, where some problems involving soil fertilization can be minimized with the use of nanocomposites to produce enhanced efficiency fertilizers. The nanocomposites have peculiar properties, originating from their physicochemical characteristics and your great variety, and may, used as a raw material in the production of modern fertilizers. Besides fertilizers, nanocomposites can be used with other purposes in agriculture. There is much to be studied and validated, however, we welcome the use of these materials in agriculture.

References