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Dynamic of Water Absorption in Controlled Release Fertilizer and its Relationship with the Release of Nutrient

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Abstract

Controlled release fertilizer (CRF) is a prominent green technology that helps to reduce the adverse effect of fertilizer on the environment. A good CRF is expected to synchronize with the nutrient uptake of plants along the crop duration. The water absorption which related to the delay of nutrient release also plays an important role in order to produce a good CRF. This work studied the water absorption in the coating and in the fertilizers using weighing technique. Moreover, the relationships between the absorption processes with the release of nutrient were also pointed out and compared to those in literature. Results showed that water penetration in the coating took place sooner and faster than that in the fertilizers. And, the lag time in nutrient release profile should be linked to the water infiltration in the coating rather than that in fertilizers. Moreover, the absorbency curve followed a first-order kinetic and was similar to cited literature.

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Keywords: Water absorption; controlled release fertilizer; CRF

1. Introduction

Controlled release fertilizer (CRF) is a new green generation of fertilizer that provides nutrient continuously for a whole crop application in a controlled manner. The release of nutrient from CRF is expected to synchronize with the nutrient uptake from plant [1, 2]. The amount of fertilizer lost to the environment, therefore, can be reduced.

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Consequently, it helps to increase the nutrient use efficiency (NUE) and prevents the adverse effect to the environment (e.g., greenhouse gasses [3], groundwater contamination [4]). In general, CRFs can be divided into three groups: reservoir, chemically controlled release, and matrix type [5]. Among these types, reservoir type is the most common one. The fertilizer core is encapsulated within an inert carrier, and these are regarded as coated fertilizers where nutrient release is controlled by the diffusion through the coating.

Nomenclature

S_{cw}	water saturation level in the coating
S_{fw}	water saturation level in the fertilizers
$m_{coat}(t)$	is the weight of coating at time step t after immersed, g,
$m_{absorbed\_water}(t)$	is the weight of water absorbed by the fertilizer at time t after immersed, g

To specify CRF for various types of plants and weather conditions, it is required to manipulate the characteristic of the coating structure, diffusivity, and geometry of fertilizers [6]. Nowadays, numerous researchers [7–13] have attempted to produce novel coating material in order to have a good CRF. Goertz studied the release of nitrogen from sulfur-coated urea, and the release was controlled by sulfur thickness [14]. Wu [15] studied the characteristic of nutrient release from acetate coated granule. Boli Ni [16] investigate novel slow release fertilizer based on attapulgite (APT) clay and guar gum. Li Chen [17] developed urea with a starch-g-poly (L-lactide) coating. Sarwono [18] worked on modified tapioca starch with lignin as the improved hydrophobicity coating. Rashid et al. [19] enhanced the release characteristic of urea–kaolinite fertilizer with chitosan binder. Depending on the material, the release curve of CRFs can be either a linear, power law or sigmoidal pattern. In general, the release mechanism begins with a wetting process where water penetrates in fertilizer through the coating. The dissolution process comes, quickly dissolves the soluble fertilizer core when water reaches the inner wall of the coat, and then increases the internal pressure of the solution. The third process is the release of nutrient from the core to the outer space. Fig. 1 illustrates the entire release process of fertilizer [20].

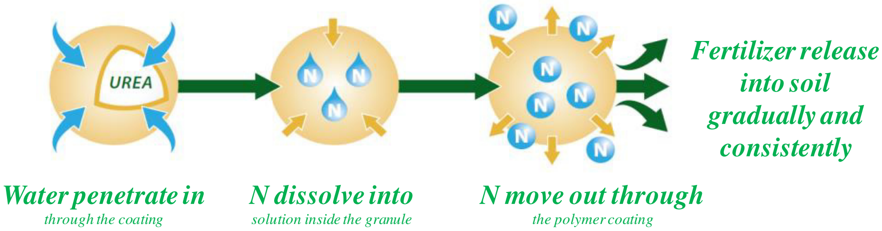

Fig. 1. A demonstration of an entire nutrient release process (obtained from Agrium Advanced Technologies [20]).

Water penetration (or water absorbency) into the coating layer is the first stage of the release process. The absorption process has a vital role in the release process. For example, if water can not penetrate in the coat, the release will not occur. If the water penetrates fast, the release will occur soon. However, this absorption process gets less attention in most of the researches. It is mostly neglected because its duration is very short as compared to the time for total release process and sometimes nearly invisible, especially in the case of power law release. Hence, the researchers mostly concentrate on the nutrient release process. In 2003, Shaviv [22] has related the water absorption time to the lag time (t_0) in his model to estimate the entire release process.

In the nutrient release profile, the lag time is the delay period during which there is no nutrient released. For commercial controlled-release fertilizers, this time usually takes a few days to weeks and occupies around 5% of the total release times. Although the lag time is short, it sometimes plays an important role in the development of the plant, especially when fertilizer is applied together with the seeds. If the lag time is less than the germination time, nutrient releases sooner and accumulates in the vicinity of seeds area. This high concentration can cause damage to the seeds and young roots. For example, nitrogen should not release before the 1st week after planting for a reproductive growth in the case of MR219 rice variety [23]. If the lag time is prolonged, plants can not receive