Multicomponent hydrogel fertilizer technology for sustainable agriculture

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Currently, agriculture is facing many challenges. The growing world population and climate change force the search for new solutions that maximizing agricultural production. It is necessary to use agro-products and fertilizers that support plant growth effectively while not affecting the environment (Nuzzo et al., 2020). Traditional fertilizers have many disadvantages, all the nutrients are released almost immediately and leach very quickly from the soil to groundwater due to their high mobility. They can also contain heavy metals that could be absorbed by plants or migrate into aquatic environments (Skrzypczak et al., 2021). Precision agriculture can respond to emerging challenges and needs. One possibility is the application of advanced hydrogel matrices that can deliver nutrients to plants in a slowed or controlled manner. By introducing innovative fertilizers, nutrient availability can be extended and plant growth and yield can be enhanced. Such fertilizers are formulated from natural, biodegradable materials (sodium alginate, carboxymethylcellulose, chitosan, starch) that additionally retain water in the soil, improving soil hydration status (Sim et al., 2021).

This paper presents the results of a study on the development of a hydrogel matrix allowing for the slowed release of macronutrients, such as nitrogen, phosphorus and potassium. For this purpose, the hydrogel structure was modified by varying the concentrations of sodium alginate (ALG) and carboxymethylcellulose (CMC). The model hydrogel was considered to have a high swelling capacity while maintaining a spherical shape to provide the largest possible exchange surface area for fertilizer nutrients and water. It has been indicated that the introduction of CMC chains into alginate matrices improves the absorbability of the hydrogel and gives the ability to re-swell. However, these fertilizers release nutrients rapidly in both aqueous and soil environments. The choice of preparation method was also an important aspect. Apart from the classical crosslinking technique in $CaCl_2$ solution, crosslinking in calcium chloride solution with NPK addition was carried out. This allowed for a reduction in the osmotic pressure difference, nutrients were absorbed into the matrix and did not diffuse outside the hydrogel rapidly. The additional route of fertilizer salt incorporation during the crosslinking process made it possible to obtain fertilizers with increased nutrient doses. The exact content of fertilizer nutrients in the prepared matrices was examined by induced plasma emission spectroscopy (ICP-OES). The kinetics of their release was also determined.

In the next stage, the fertilizer was modified by introducing a coating slowing down the release to prepare matrices with the lowest possible permeability and thus avoid rapid diffusion of nutrients, especially potassium and phosphorus. Various natural components (alginate, chitosan, starch, bentonite) in different compositions were used to prepare the slow-release fertilizers. The effects of the prepared fertilizers on plants in germination tests and pot trials were also investigated.

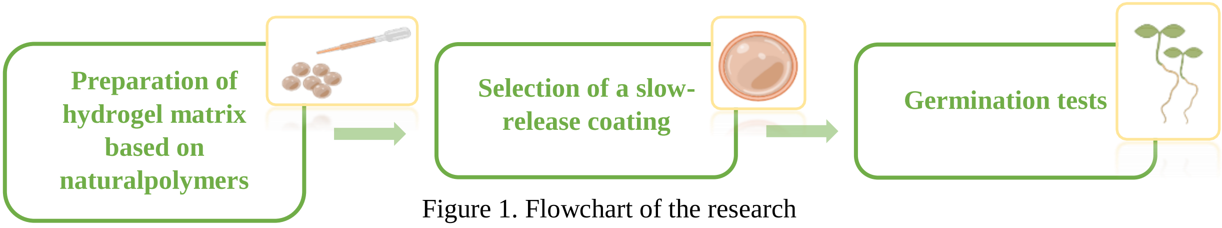

Figure 1. Flowchart of the research

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