Development of Controlled Release Fertilizer Using Alginate Hydrogel and Biochar

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Abstract

Environmental challenges arising from chemical fertilizer utilization have resulted in significant primary nutrient losses from soil through leaching processes during heavy rainfall events, particularly affecting water-soluble nutrients, and nitrogen volatilization in the form of ammonia gas. These processes contribute to environmental degradation, including water pollution such as eutrophication, soil deterioration, and hazardous greenhouse gas emissions. In response to these environmental concerns, this research focuses on the development of potassium chloride fertilizer (KCl) in controlled-release fertilizer (CRF) form utilizing hydrogel technology. The formulation incorporates alginate encapsulation combined with biochar derived from various organic materials, including corn cobs, longan husks,and conventional charcoal. Biochar demonstrates superior nutrient absorption and controlled release properties attributed to its highly porous microstructure,which provides excellent nutrient storage capacity and effective control over nutrient release kinetics. The hydrogel pellet formation process employed a systematic dipping methodology involving three consecutive five-minute immersion cycles, utilizing an optimized ionic crosslinking technique designed to create a robust hydrogel structure capable of effectively controlling nutrient release. The experimental investigation encompassed nine distinct formulations, with potassium chloride release characteristics evaluated using precipitation titration techniques to quantify chloride ion concentrations following seven-day water immersion periods. The experimental results demonstrated that the developed formulations significantly enhanced plant nutrient utilization efficiency and increased agricultural productivity while maintaining environmental compatibility, thereby supporting sustainable agricultural development approaches consistent with sufficiency economy principles.

Keywords

Controlled release fertilizer, potassium chloride, hydrogel, biochar, alginate.