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Research Paper

Synthesis of tapioca starch/palm oil encapsulated urea-impregnated biochar derived from peppercorn waste as a sustainable controlled-release fertilizer

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ABSTRACT

Nutrient leaching and volatilization cause environmental pollution, thus the pursuit of developing controlled-release fertilizer formulation is necessary. Biochar-based fertilizer exhibits slow-release characteristic, however the nutrient release mechanism needs to be improved. To overcome this limitation, the approach of applying encapsulation technology with biochar-based fertilizer has been implemented in this study. Black peppercorn waste was used to synthesize urea-impregnated biochar (UIB). Central composite design was used to investigate the effects of pyrolysis temperature, residence time and urea:biochar ratio on nitrogen content of UIB. The optimum condition to synthesize UIB was at 400 °C pyrolysis temperature, 120 min residence time and 0.6:1 urea: biochar ratio, which resulted in 16.07% nitrogen content. The tapioca starch/palm oil (PO) biofilm formulated using 8 g of tapioca starch and 0.12 μL of PO was coated on the UIB to produce encapsulated urea-impregnated biochar (EUIB). The UIB and EUIB pellets achieved complete release of nitrogen in water after 90 min and 330 min, respectively. The nutrient release mechanism of UIB and EUIB was best described by the Higuchi model and Korsmeyer-Peppas model, respectively. The improvement of water retention ratio of UIB and EUIB pellets was more significant in sandy-textural soil as compared to clayey-textural soil. The EUIB derived from peppercorn waste has the potential to be utilized as a sustainable controlled-release fertilizer for agriculture.

1. Introduction

Biochar is a high-carbon material synthesized by thermo-chemical method under the absence of oxygen. Biochar is produced using a variety of organic materials as precursors, including manure, agricultural waste and urban waste (Fachini et al., 2021). Biochar is used in numerous applications, including wastewater treatment and agriculture. Biochar is commonly used to adsorb heavy metals for wastewater treatment (Xue et al., 2019). In agriculture, biochar is widely utilized for soil amendment to enhance the soil properties including pH, cation exchange capacity, water retention, nutrient retention, microbial growth and enzymatic activities. (Kapoor et al., 2022). However, the drawback of utilizing pristine biochar for soil amendment is that the quantity of nutrients present in the biochar is not significant. Moreover, high application rate of pristine biochar is required to improve the crop production, which is unprofitable to farmers.

Crop production is often improved through the utilization of chemical fertilizers, however they are costly and not environmentally sustainable. Nitrogen is the primary essential macronutrient for plant growth and usually nourished with synthetic fertilizer (Singh et al., 2021). Urea is one of the chemical fertilizers which has been widely used as a nitrogen fertilizer in agricultural sector since urea has a relatively low production cost as well as having a high nitrogen content (up to 46%) as compared to other nitrogen-based fertilizers (Dimin et al., 2014). However, the main drawback is that urea is a water soluble-based fertilizer which is easily lost through volatilization and leaching, thus resulting in low nitrogen use efficiency and causing environmental pollution. Recently, biochar has been developed as a nutrient carrier to deliver nutrients to plants. The nutrient enriched biochar not only increases the nutrient use efficiency by the plant, but it also reduces the

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