ABSTRAK

Efisiensi pemupukan nitrogen pada bidang pertanian masih tergolong rendah akibat tingginya kehilangan unsur hara melalui proses penyiraman, volatilisasi, dan limpasan permukaan (*surface runoff*). Tujuan dari penelitian ini adalah untuk meneliti apakah penggunaan pupuk pelepasan lambat berbasis biochar adalah salah satu pendekatan yang dapat digunakan untuk menyelesaikan masalah ini. Penelitian ini akan menyelidiki manfaat pemanfaatan biochar dari tempurung kelapa yang dipelletisasi dengan penambahan bentonit sebagai perekat. Penelitian juga akan mengevaluasi sifat fisik pelet, kapasitas adsorpsi-desorpsi urea, karakter kinetika dan isoterm adsorpsi, dan respons pertumbuhan tanaman jagun. Biochar dari tempurung kelapa dicampurkan dengan perekat bentonit pada variasi 5–30% (b/b) dan dibentuk menjadi pelet. Pelet yang dihasilkan diuji sifat fisiknya meliputi ketahanan rendam, penyerapan air, dan densitas. Uji adsorpsi urea dilakukan menggunakan larutan urea dengan variasi konsentrasi awal 50 hingga 2000 ppm untuk memperoleh kapasitas adsorpsi pada kesetimbangan dan dianalisis menggunakan model isoterm Langmuir dan Freundlich. Uji kinetika adsorpsi dan desorpsi dilakukan untuk mempelajari laju interaksi urea terhadap waktu, dengan pemodelan menggunakan kinetika pseudo-first-order (PFO) dan pseudo-second-order (PSO). Evaluasi kinerja agronomis dilakukan melalui uji tanam jagung selama 45 hari pada media tanah dengan penambahan pelet biochar–bentonit sebesar 2% (b/b). Hasil penelitian menunjukkan bahwa kadar bentonit yang lebih tinggi dapat meningkatkan stabilitas fisik pelet biochar. Dengan komposisi ideal, pelet biochar memiliki kadar bentonit antara 20 dan 25%. Mekanisme adsorpsi lebih jelas dijelaskan oleh model isoterm Langmuir, yang menunjukkan dominasi adsorpsi monolayer. Kapasitas adsorpsi urea meningkat seiring dengan kadar bentonite. Kinetika desorpsi urea lebih sesuai dengan model PFO, yang menunjukkan perbedaan mekanisme dominan antara penjerapan dan pelepasan nutrien. Sebaliknya, kinetika adsorpsi urea mengikuti model PSO. Pada uji tanaman, pelet biochar-bentonit membantu pertumbuhan vegetatif tanaman jagung dan mempertahankan urea residual setelah periode tanam, yang menunjukkan pelepasan nitrogen yang bertahap. Meskipun belum memenuhi semua kriteria kuantitatif pupuk pelepasan lambat yang ditetapkan oleh European Committee for Standardization (CEN), profil pelepasan urea pada media air menunjukkan karakter pelepasan yang lebih lambat dibandingkan urea konvensional.

Kata kunci: biochar, bentonit, pupuk pelepasan lambat, adsorpsi urea, kinetika, isoterm Langmuir, jagung.

ABSTRACT

Nitrogen fertilization efficiency in agricultural fields is still relatively low due to high nutrient losses through leaching, volatilization, and surface runoff. The aim of this study is to investigate whether the use of biochar-based slow-release fertilizers is an approach that can be used to address this issue. This study will explore the benefits of utilizing biochar from coconut shells that are pelletized with the addition of bentonite as a binder. The study will also evaluate the physical properties of the pellets, urea adsorption-desorption capacity, adsorption kinetics and isotherm characteristics, and the growth response of maize plants. Coconut shell biochar is mixed with bentonite binder in variations of 5–30% (w/w) and formed into pellets. The resulting pellets are tested for physical properties including water soaking resistance, water absorption, and density. The urea adsorption test was carried out using urea solutions with initial concentration variations from 50 to 2000 ppm to obtain the adsorption capacity at equilibrium and analyzed using the Langmuir and Freundlich isotherm models. The adsorption and desorption kinetics tests were conducted to study the rate of urea interaction over time, modeled using pseudo-first-order (PFO) and pseudo-second-order (PSO) kinetics. Agronomic performance evaluation was performed through a 45-day corn planting test on soil media with the addition of 2% (w/w) biochar–bentonite pellets. The results showed that higher bentonite content can improve the physical stability of biochar pellets. With the ideal composition, biochar pellets contain between 20 and 25% bentonite. The adsorption mechanism is better explained by the Langmuir isotherm model, indicating dominant monolayer adsorption. The urea adsorption capacity increased with the bentonite content. The desorption kinetics of urea are more consistent with the PFO model, indicating a difference in the dominant mechanisms between nutrient adsorption and release. In contrast, the adsorption kinetics of urea follow the PSO model. In plant tests, biochar-bentonite pellets aided the vegetative growth of maize and retained residual urea after the planting period, indicating gradual nitrogen release. Although it has not yet met all the quantitative criteria for slow-release fertilizers set by the European Committee for Standardization (CEN), the urea release profile in water media shows a slower release behavior compared to conventional urea.

Keywords: biochar, bentonite, slow-release fertilizer, urea adsorption, kinetics, Langmuir isotherm, corn.