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Influence of Different Plant Materials in Combination with Chicken Manure on Soil Carbon and Nitrogen Contents and Vegetable Yield

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ABSTRACT

The use of plant materials as soil amendments is an uncommon practice amongst major farming communities in Ghana, although it is necessary for soil fertility improvement. An examination of the effects of soil amendments is necessary to encourage the use of under-utilized organic resources in Ghana. Thus, a field experiment was conducted using 8 different tropical plant materials mixed with chicken manure as soil amendments for growth of tomato as a test crop. The plant materials included *Leucaena leucocephala*, *Centrosema pubescens*, *Sesbania sesban*, *Gliricidia sepium*, *Mucuna pruriens*, *Pueraria phaseoloides*, *Azadirachta indica*, and *Theobroma cacao*. There were two other treatments: one with equivalent amounts of chemical fertilizers and the other with no-fertilizer input (control). Plant materials were mixed with chicken manure to obtain a uniform carbon-to-nitrogen (C:N) ratio of 5:1. Except the no-fertilizer control, all treatments received the same amount of nitrogen (N). To clarify the decomposition pattern of the plant materials in soil, an incubation experiment was conducted using only the plant materials before the field experiment. The *Gliricidia* treatment released significantly more mineral N than the other plant materials in the incubation experiment. However, the tomato fruit yield was not enhanced in the *Gliricidia* treatment in the field experiment. The known quality parameters of the tested plant materials, such as total N, total carbon (C), C:N ratio, and total polyphenols, had minimal effects on their mineralization dynamics. *Azadirachta* showed the best synergistic effect with chicken manure through significantly increasing soil microbial biomass and fruit yield of tomato. This result provides insights into the possible adoption of *Azadirachta* in combination with chicken manure as a soil amendment in small-scale agricultural holdings.

Key Words: C:N ratio, microbial biomass, mineralization pattern, organic material, soil amendment, synergy

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INTRODUCTION

Traditional farming systems in sub-Saharan Africa (SSA) depend primarily on mining soil nutrients (Vanlauwe *et al.*, 2010). These practices, coupled with other environmental factors, have gradually reduced the productive potentials of SSA soils despite the increase in land area for crop cultivation. The need for sound agronomic practices is therefore important for addressing the food security challenges that confront the region. The conceptual framework of the Integrated Soil Fertility Management (ISFM) as proposed by Vanlauwe *et al.* (2010) asserts that organic resource management is an important contributor to a successful African green revolution.

The incorporation of organic material into soil is considered a good management practice because it stimulates soil microbial activity and increases soil fertility and quality through subsequent mineralization of plant nutrients (Randhawa *et al.*, 2005). However, traditional organic input methods such as the use of crop residue and animal manure are generally of low effectiveness (Gachengo *et al.*, 1998) and are usually unable to satisfy the nutrient demands of cultivated crops. An

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alternative practical strategy is to co-apply available plant residues with readily available inorganic or organic nitrogen (N). In some instances, this approach can overcome organic substrate limitations while reducing the rate of application of readily available N sources. This practice has been suggested as a promising strategy to enhance agricultural productivity in SSA (Bationo and Mokwunye, 1991). In Ghana, the practice of using organic materials to improve agricultural soil is still in its infancy. However, there are a number of crop residues that are under-utilized in their respective farming communities.

The quality of organic materials is reflected in the carbon (C), nitrogen (N), lignin, polyphenol (Cadisch and Giller, 1997; Vahdat *et al.*, 2011; Abera *et al.*, 2012), water-soluble N, and cellulose contents and the (C:N) ratio (Bending *et al.*, 1998). These quality indicators are useful in predicting the N turnover and mineralization of organic materials. Of all the quality indicators, the C:N ratio, which relates to the initial N concentration of the organic material, serves as the best single criterion for predicting the N release pattern of organic materials (Palm *et al.*, 2001). Generally, plant material with a low C:N ratio (*i.e.*, smaller than 10:1) results in greater N availability at the early stages of decomposition, while polymers such as cellulose with a high C:N ratio (*i.e.*, greater than 30:1) are degraded slowly during the latter stages of decomposition (Hooker and Stark, 2008). To maximize the optimal benefits of these organic amendments, both the short- and long-term effects must be considered. The short-term effects relate directly to the nutrient supply (Palm *et al.,* 2001), while the long-term effects concern soil conservation and restoration (Diacono and Montemurro, 2010). To maximize N delivery, the synchronization of net N mineralization with crop growth is desirable. One approach to achieve this synchrony involves an adjustment of the C:N ratio by mixing residues of different qualities (Handayant *et al.*, 1997; Abera *et al.*, 2012).

In the West SSA region, organic resources suitable for use as soil amendments are in heavy demand as fodder, construction materials, and cooking fuels (Lamers and Feil, 1993). In contrast, chicken manure is abundant in the peri-urban areas of southern Ghana (Boateng *et al.*, 2006). Due to the rising cost of inorganic fertilizers in the country, the use of chicken manure as a soil amendment has increased. This has commonly been observed among small-scale agricultural activities. Unlike chemical fertilizers, chicken manure contains nutrients that are released more slowly and stored for long periods in the soil (Yang *et al.*, 2015). Previous studies on soil productivity improvement in Ghana have focused on the use of animal manure, green manure, and certain crop residues (Cofie *et al.*, 2007). Such studies have dealt less with research on existing, highly diverse plant materials such as leguminous cover crops, crop residues, and agroforestry species and the added benefits generated through their combined application with animal-based sources.

Nutrient release from plant material as affected by decomposition dynamics has a marked influence on crop yield and soil fertility. However, there are contrasting opinions of N addition from plant materials on soil N mineralization. Thus, the objective of this study was to investigate the mineralization dynamics of different organic materials available in Ghana and to determine their effects when combined with chicken manure on vegetable yield and soil fertility. A laboratory incubation experiment using only plant materials and a field experiment using plant materials and chicken manure with tomato as a test crop were conducted in an effort to characterize the plant materials as both potential soil-improving material and fertilizer.

MATERIALS AND METHODS

Study site

This study was conducted at the Sakaecho Experimental Field (35°41′14.8″ N and 139°28′41.4″ E, 65 m above sea level) of Tokyo University of Agriculture and Technology (TUAT), Tokyo, Japan from April to August 2013. The field had previously been used for soybean cultivation and had been left bare for 2 years before the experiment. The climate of the study area is humid subtropical with hot humid summers. A mean temperature during the growing season ranged from 13–36 °C with a mean annual rainfall of 1 500 mm. The soil is defined as an upland Haplic Andosol, rich in humus (Hirata *et al.*, 1999). The texture of the soil (0–10 cm) was 320 g kg^{-1} sand, 560 g kg^{-1} silt, and 120 g kg^{-1} clay.

Preparation and analysis of the plant materials used

Plant materials used in the study were collected from various fields in Ghana from May to August, 2012. *Leucaena leucocephala* and *Azadirachta indica* were selected because of their invasiveness. *Centrosema pubescens* was selected due to its availability in almost all farms within all of the ecological zones of Ghana. *Sesbania sesban* was selected because of its high N content and common use as green manure. *Gliricidia sepium* was selected for its use in agroforestry systems and ease of regeneration. *Mucuna pruriens* is a co-