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Dynamics of residue decomposition and N_2 fixation of grain legumes upon sugarcane residue retention as an alternative to burning

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Abstract

Burning of sugarcane residues contributes to air pollution and sugarcane producers have been forced to abandon it. The change from burning to residue retention is likely to alter the cycling of nutrients. Additionally, there is often a time gap of 6–8 months between two different sugarcane cycles during which legumes could be planted. Thus, the objective of this study was to assess the effects of burning, mulching or incorporation of sugarcane residues on residue decomposition and N mineralization (sugarcane residue management period) and subsequently upon ploughing (legume period) on N dynamics, N_2 fixation, development and nutrient yields of groundnut and soybean grown between two sugarcane cycles on a sandy soil in Northeast Thailand.

Soil microbial biomass N increased when sugarcane residues were incorporated instead of burned or surface applied at 14 days after initiation of cane residue management. Thereafter, high net N mineralization was accompanied by a reduction in microbial biomass N, indicating that mineralized N was derived from microbial N turnover. However, upon ploughing after 96 days the different previous sugarcane residue management strategies had no significant ($P > 0.05$) effect on net mineral N and microbial biomass N during the subsequent legume period. Although, ^{15}N enrichment in control reference plants and plant N uptake indicated significant N immobilization effects persisting into the legume crop phase, the proportion of N derived from N_2 fixation (%Ndfa) or amount of N_2 fixed were not significantly different between sugarcane residue management treatments. Soybean fixed more N_2 (78%Ndfa, 234 kg N fixed ha^{-1}) than groundnut (67%Ndfa, 170 kg N fixed ha^{-1}) due to its larger N demand and a poorer utilization of soil N (64 kg N ha^{-1} vs. 85 kg N ha^{-1}). Groundnut led to a positive soil N balance while that of soybean was negative due to its high nitrogen harvest index. Legume residues returned 61 and 146 kg N ha^{-1} to the soil for soybean and groundnut, respectively, compared to only 34–39 kg N ha^{-1} by fallow weeds. Sugarcane residue retention improved soil organic carbon and N content. The results suggested that although a change from burning to sugarcane residues retention led to alterations in N cycling and improved soil organic matter it did not significantly affect N_2 fixation due to the uniforming action of ploughing and the extended time gap between sugarcane residue incorporation and legume planting.

Keywords: Sugarcane residues; Burning; Incorporation; Mulching; N immobilization; N_2 fixation; Groundnut; Soybean

1. Introduction

Burning of cane residues either before or after sugarcane harvest is widely practiced in many tropical

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countries. Farmers burn sugarcane to reduce the amount of leafy extraneous material, including stalk tops and dead leaves delivered with the cane to the factories for processing and to control pests. Additionally, sugarcane burning facilitates manual harvesting thus reducing labor and production costs. This practice significantly reduces the amount of trash that needs to be dealt with, but pollutes the surrounding neighborhood with smoke and ash. In addition, residue combustion is a source of particulate and gaseous (CO_2, NO, NO_2 and N_2O) emissions to the atmosphere that may contribute to the ''greenhouse effect'', and the associated global warming. Some studies have reported beneficial effects of crop residue burning on soil nutrient availability (Russell et al., 1974). Giardina et al. (2000) reported that slash-and-burn of a tropical forest resulted in transformations of non-plant-available P and N in the soil into mineral forms readily available to plants. However, residue burning may adversely affect soil fertility due to the fact that it causes losses of some nutrients and organic matter over time. Recently, sugarcane producers have been required to adopt alternative sugarcane residue management practices (e.g. cane residue retention), since burning has raised air pollution concerns (Basanta et al., 2003).

The effect of retaining crop residues in farming systems is generally thought to be advantageous over burning and physical removal from the point of view of nutrient cycling. Significant increases in crop yield after retaining crop residues due to the combined effects of improved soil organic matter, soil structure, increased water use efficiency and reduced numbers of some plant pathogens (Graham and Haynes, 2005; Zeleke et al., 2004; Govaerts et al., 2006) have been observed. Ng Kee Kwong et al. (1987) reported of the beneficial effect of sugarcane trash to supply N to the following sugarcane crop and its capacity to improve organic matter in the soil in the long term. Basanta et al. (2003) found that sugarcane trash retained as a surface blanket allowed N recycling of 105 kg N ha^{-1} $year^{-1}$, while the practice of burning cane trash before harvest left only 31 kg N ha^{-1} $year^{-1}$ for recycling. Green cane harvesting followed by mulching led to a more efficient recycling of the N applied to the system and therefore reduced fertilizer-N needs (Basanta et al., 2003). Moreover, green cane harvesting with retention of a trash blanket increased size and activity of the microbial community and activity of soil enzymes assayed (Graham and Haynes, 2005) which may be useful for biological control and integrated pest management (Govaerts et al., 2006). Thus, in the short term, the high C:N ratio of sugarcane residues will lead to microbial immobilization of nutrients and hence net N mineralization may be delayed with important implications for crops grown subsequently.

Sugarcane is usually grown under rainfed conditions. In northeast of Thailand only one or two ratoon crops may be harvested due to the poor soil fertility of the very sandy soils. Here, sugarcane is generally planted during October to December and harvested in December to April of the following year. Thus, there is a time gap of 6–8 months between the last ratoon crop harvest and the next sugarcane planting. Farmers are now being encouraged not to burn sugarcane residues and to grow green manure legumes instead during this fallow period. However, green manure legumes do not generate an economic return and are not generally accepted by small farmers who have limited resources (Whitmore et al., 2000). Grain legumes such as groundnut and soybean are other alternatives because they can provide cash income as well as improve soil fertility. Retention of legume crop residues has been shown to increase soil organic matter and nutrient content in several cropping systems (Promsakha Na Sakonnakhon et al., 2005; Basanta et al., 2003).

It is generally accepted that legumes make a substantial net N contribution to soil fertility in crop rotations. They can fix substantial amounts of atmospheric N_2, which allows them to be grown in N-impoverished soil without fertilizer N inputs. Groundnut (*Arachis hypogaea* L.) and soybean (*Glycine max* (L) Merr.) fix between 80 and 150 kg N ha^{-1} (Toomsan et al., 1995) in Northeast Thailand. Mineral nitrogen availability in the soil is one major factor regulating N_2 fixation. Vice versa, addition of high C:N ratio residues may enhance N_2 fixation due to their effect on immobilization of mineral N in the soil. According to Shah et al. (2003), mungbean fixed 112 kg N ha^{-1} when wheat residues were incorporated, while only 74 kg N ha^{-1} when wheat residues were removed. However, no research on the effect of burning, mulching and incorporation of sugarcane residues on dynamics of N, N_2 fixation, growth and yield of grain legumes grown during the fallow period have been reported to date. This study hypothesizes that mulching and incorporation of high C:N ratio sugarcane residues instead of burning can play a significant role in improving soil fertility, growth and yield and N_2 fixation of groundnut and soybean during the fallow phase between two sugarcane cycles. These, in turn could contribute to increases in yield and N use efficiency of a following sugarcane crop when groundnut and soybean residues are subsequently recycled. The objective of this study was thus to assess the effects of burning, mulching and