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Green mulch decomposition and nitrogen release from leaves of two *Inga* spp. in an organic alley-cropping practice in the humid tropics

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Abstract

Inga edulis Mart and *Inga samanensis* Uribe are promising yet little studied legume trees for use in agroforestry on acidic soils. The objective of this study was to analyze the decomposition and N release processes of green mulch from these species. Litterbags filled with leaves from each species were placed on the ground in an organic maize (*Zea mays* L.) alley-cropping experiment at the time of maize sowing and collected every 2 weeks over a 20 week period, and measured for dry matter, N, hemicellulose, cellulose, and lignin content. Three types of models were applied to the data, according to the characteristics of each component, to analyze the decomposition dynamics of whole leaves and leaf components: a negative exponential decay function, an inverted Michaelis–Menten function, and a linear regression. Initial decay of *I. samanensis* mulch was faster than *I. edulis* mulch. However, the recalcitrant fraction was about half of the initial litter mass in both *Inga* spp. Hemicellulose disappeared almost completely from the litter during the 20-week incubation period, while no significant lignin decay occurred. After a slow start, cellulose partially decayed following linear kinetics. The half-life of labile N, estimated as a Michaelis–Menten parameter, was 10 weeks in *I. samanensis* and ca. 24 weeks in *I. edulis* litter. Polyphenol content was significantly higher in *I. edulis*. Litter of *I. edulis* and *I. samanensis* may be classified as 'low-quality' and 'medium-quality' mulch, respectively. Due to the relatively large recalcitrant mulch fraction, both *Inga* spp. may promote C sequestration and long-term N accumulation in soil.

Keywords: Inga edulis; *Inga samanensis*; Decay models; Litterbags; Mulch quality; Polyphenol content

1. Introduction

Depletion of soil organic matter is a serious threat to agricultural production and food security in many tropical regions. Decreases in soil organic matter leads to a decline in agricultural and biomass productivity, poor environmental quality, soil degradation and nutrient depletion, and finally to food insecurity (Lal, 2004). This regressive process concerns both large-scale commercial agriculture that targets short-term benefits in the global market place and small-holder agriculture where the tradition of sustainable agriculture is broken under population pressure, rapidly changing natural and social environment, and degrading soils. Reverting the degradation of tropical soils calls for sustainable agricultural practices including no-till farming, application of compost and mulch, legume cover crops, and agroforestry (Lal, 2004).

Organic agriculture that is defined as 'a holistic production management system, which promotes and enhances ecosystem health, including biological cycles and soil biological activity' (FAO, 2002) is a promising alternative for many tropical cropping systems in Latin America. The annual value of organic market in the USA was \$10 billions in 2002, and it is doubling every 2–3 years. World organic trade grows by 20–30% per year (Geier, 2003). Since organic farmers cannot compensate for a loss in soil fertility by inputs of industrial fertilizers, the building and maintenance of soil fertility is a central objective of organic agriculture (FAO, 2002). Green mulch produced by

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pruning legume trees in agroforestry is a good source of N (Mafongoya and Nair, 1997; Aihou et al., 1999; Tossah et al., 1999) that is compatible with organic agriculture. Green mulch also increases soil organic matter reserves, promotes C sequestration, and recycles other nutrients (Lal, 2004).

A prerequisite for developing management strategies for legume green mulch is a clear understanding of the factors that govern the decomposition process (Vanlauwe et al., 1997). Nitrogen content (Vanlauwe et al., 1997), polyphenol content (Palm and Sanchez, 1990), polyphenol to N ratio (Oglesby and Fownes, 1992), lignin plus polyphenol to N ratio (Handayanto et al., 1994; Vanlauwe et al., 1997), and C to N ratio and lignin to N ratio (Cadisch and Giller, 1997; Vanlauwe et al., 1997) of tree tissue used for green mulch have been associated with its decomposition and N release rates.

Pruning residues used for green mulch can be classified based on N release rate (Mafongoya et al., 1997). 'High-quality' prunings have an N content higher than 2.5%, contain less than 15% lignin, and less than 4% polyphenols (Palm et al., 2001). However, these materials may release N too quickly to be taken up completely by the crop (Mafongoya et al., 1997). If lignin content is higher than 15%, polyphenol higher than 3%, and N less than 2.5%, N can be immobilized (Palm et al., 2001). 'Low-quality' plant materials release N too slowly to meet crop demands, but they may have a longer residual influence in the soil. 'Medium-quality' mulch is expected to release N in synchrony with crop demand (Mafongoya et al., 1997).

Inga spp. (Mimosaceae) are potential components of low-input sustainable agriculture because they have high biomass productivity and a tolerance to acid soils (Hands, 1998). In addition to providing nutrients, green prunings of *Inga* spp. form a permanent mulch cover that helps to control weeds and breaks the erosive force of heavy rains of the humid tropics. Latin American farmers have traditionally used *Inga edulis* Mart as a shade tree for coffee (*Coffea arabica* L.) and cacao (*Theobroma cacao* L.) plantations. *I. edulis* has recently attracted attention in agroforestry because of its rapid growth in poor acidic soils (Hands, 1998). Many other *Inga* spp. have the characteristics needed for use in agroforestry, like *Inga samanensis* Uribe. It grows naturally near rivers and in the borders of wet forests. This species has potential as a shade tree and for firewood production (Zamora and Pennington, 2001).

The objectives of this experiment were to (1) determine the decomposition rate of *I. edulis* and *I. samanensis* leaves in an organic alley-cropping system under humid tropical conditions, (2) study the fate of various compounds in leaves during the decomposition process, and (3) fit mathematical models for analyzing and predicting leaf decomposition and N release rate of these two species.

2. Materials and methods

2.1. Study site

The study was conducted at the EARTH University Organic Farm in conjunction with a maize (*Zea mays* L.) alley-cropping experiment using *I. edulis* and *I. samanensis* as hedgerow trees. EARTH University is located in the Caribbean coastal plain of Costa Rica (10°10′ N, 83°37′ W, 95 m a.s.l.). The climatic zone is classified as a premontane, wet forest, basal belt transition (Bolaños and Watson, 1993). Annual rainfall averages 3464 mm and is evenly distributed throughout the year. Annual mean temperature is 25.1 °C. The soil is classified as Thaptic Hapludand with the following characteristics: pH 5.12 in water; organic C 3.47%, N 0.59% (Kjeldahl); exchangeable acidity 0.3 cmol (+) kg^{-1}; Ca 4.2, Mg 1.4, and K 0.15 cmol (+) kg^{-1}; P 14.2 mg kg^{-1} (modified Olsen); Cu 28.1, Fe 109, Zn 18, and Mn 5.8 mg kg^{-1}.

The maize alley-cropping experiment was established in 1999. Seedlings of *I. samanensis* and *I. edulis* were planted in separate 25×25 m plots, in east–west oriented rows at 4-m between-row and 0.5-m within-row density totaling 5000 trees ha^{-1}. Experiment was arranged in randomized complete blocks with 4 replicates per species. The trees were pruned approximately every 6 months leaving 5–10% of the foliage. Maize was sown immediately after pruning at the rate of 40,000 plants ha^{-1}. Maize rows were 1 m apart and two seeds were sown every 50 cm within the row. Two maize cycles were cropped on the site before this study.

The green mulch decomposition experiment was conducted from May to September 2002. A 5-month period was selected because it was 1-month longer than the 4-month maize intercropping with *Inga* trees. In May 2002, leaves of *I. samanensis* and *I. edulis* were collected from the alley cropping experiment and sun-dried in a glasshouse for 3 days. Litterbags measuring 25×25 cm with 2-mm mesh were filled with 42 g (dry mass) of *I. edulis* or *I. samanensis* leaves. Litterbags were placed on the ground in the center of the alleys of the plot where the material was collected at the time of maize sowing. Each of the four replicates consisted of 10 litterbags. One litterbag per species and replicate was collected every 2 weeks from week 2–20. Trees were allowed to regrow, but were lightly pruned 6 weeks after maize sowing to reduce shading. Only small branches overhanging the alleys were removed and the material was left in the alleys. This is a normal practice in alley cropping, and the microclimate and soil conditions during the experiment were representative to the studied cropping system.

2.2. Chemical analysis

Leaf material remaining in each litterbag was dried at 60 °C for 72 h to determine dry matter. The leaves were ground to pass through a 686-μm screen. Nitrogen