Biol Fertil Soils (1998) 26:136–140

ORIGINAL PAPER

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Quality of different mulch materials and their decomposition and N release under low moisture regimes

Received: 6 January 1997

Abstract During the dry season in the tropics, agriculture which is solely dependent upon rainfall as its source of water is frequently affected by soil moisture stress, resulting in crop failures. Farmers therefore depend mainly on other sources of limited water supply during this period, such as ground water. Soil moisture conservation measures, especially surface mulching with loppings and, occasionally, leaf litter and crop residues, are practised. Our objective was to study the decomposition and nitrogen (N) release from these plant materials under continuously wet, low moisture regimes, i.e. comparable to those which prevail in the mulches used in the agriculture. A greenhouse experiment was conducted with fresh, chopped leaves of six leguminous trees, wild sunflower and rice, which were spread as a mulch on a layer of soil. They were maintained at eight moisture levels (a total of between zero and 43 l water m^{-2} applied over 8 weeks) by spraying water. Different optimal moisture requirements for the rapid decomposition of these species were observed. These were presumably determined by different physical and chemical properties of the leaves. The amount of water received to the mulches and their soluble polyphenolic and carbon (C) concentrations played an important role in determining the decomposition and the mode of N release under non-limiting conditions of leaf N. Specifically, the C concentration governed N release, while the effect of polyphenolics was important when their concentration was low, as a result of leaching under relatively high moisture regimes. Leaves with a high polyphenolic and C content, which were subjected to high leaching losses of these fractions, underwent a change in their N dynamics from net immobilization to mineralization. This study indicates that leaves with a fast rate of decomposition should be mixed with other species, leaves which decompose more slowly in order to increase the conservation of soil moisture and also improve the synchronization between N release from the mulch and its demand by crops.

Key words Leaves · Low moisture · Decomposition · Nitrogen release

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Introduction

During the dry season in the tropics agriculture which is solely dependent upon rainfall as its source of water is frequently affected by soil moisture stress, resulting in crop failures. In the dry zone of Sri Lanka, which contributes most to crop production, it is not uncommon that 60% of the expected monthly rainfall during the major part of the dry season (May–July) is less than 25 mm (Domros 1974). This rainfall occurs during 2–5 days $month^{-1}$ (Department of Meteorology 1990). Farmers therefore mainly depend on other sources of limited water supply for their crops during this period, such as ground water obtained from "agro-wells", which are deep pits dug down to the ground water table. Frequent watering of crops with the limited water accumulated in these wells is a common practice. Soil moisture conservation measures, especially surface mulching with prunings of different plant species, e.g. *Gliricidia sepium*, *Erythrina lithosperma* etc., of "live-fences" and crop residues – mainly rice straw – are simultaneously applied. Leaf litter collected from the trees of gardens is also used occasionally as a mulch. This method of crop management during the dry season is common in many South Asian countries.

Due to the frequently, limited water supply and high evaporation under the elevated atmospheric temperatures which prevail during the dry season, continuously wet, low moisture regimes are maintained in the mulch, which favour slow decomposition. The rate of decomposition differs according to the availability of moisture. The mulch also suppresses weeds before decomposition and supplies nutrients to the soil during decomposition. No information is available as to how much the mulch decomposes at the low moisture regimes, and to what extent it contributes nitrogen (N) to the soil. A number of studies (e.g. Taylor et al. 1989; Palm and Sanchez 1991; Oglesby and Fownes 1992; Constantinides and Fownes 1994) have been conducted to examine the decomposition and N release from different leaf and litter types in forest and agroforestry systems. However, these studies examined the effect of moisture levels that are optimal for microbial decomposition. Although there is no consensus between these studies regarding which chemical parameter is the best indicator of decomposition, initial N, lignin and polyphenolics, and the ratios between the latter two fractions and N levels have been generally ascribed as the determinants of decompositions and N release.

Our objective was to study the decomposition and N release of leaves from a range of species applied as mulch under continuously wet, low moisture regimes. The results of this study should also be useful for determining how to efficiently use mulch in the agricultural systems described above.

Materials and methods

Greenhouse experiment

Three wooden frames (1×1×0.12 m) divided into 64 (8×8) equal-sized chambers by planks were used for the study. They were placed and pressed on a 4 cm layer of red yellow podzolic (Ultisol) soil [pH 5.7, 3.34% organic carbon (C), 0.136% total N and 50–60% water holding capacity, i.e. 0.3 kg water kg^{-1} soil], covered with a 4 mm polypropylene mesh. Organic debris and stones were removed from the soil. Because this was a greenhouse experiment, the influence of soil meso- and macrofauna on decomposition was limited. Fully matured fresh leaves were collected from six leguminous trees (*G. sepium*, *Leucaena leucocephala*, *E. lithosperma*, *Acacia mangium*, *Albizia saman* and *Delonix regia*) and wild sunflower (*Tithonia diversifolia*). Matured, fresh rice (*Oryza sativa*) leaves were also included, although rice straw with a relatively high C/N ratio is normally used under agricultural conditions. The aim of using the fresh leaves belonging to different families with varied leaf properties was to attempt to construct a continuous range of chemical parameters which indicated their quality as mulch. This certainly helps in proper correlation analyses between the quality parameters and leaf N release due to even distribution of the data. The leaves were chopped into 1 cm^2 pieces and mixed thoroughly. Sub-samples were ground and stored for later analyses. Ten grams fresh weight of chopped leaves from each of the eight plant species were spread on the mesh as a mulch in each chamber. This represented 1.7–3.8 g dry matter (ca. 3 t ha^{-1}) for each species. The plant species and eight, low moisture regimes were included in a randomized complete block design where each of the three frames represented one block. The eight moisture regimes were as follows: a total of 0, 6 l m^{-2}, 12 l m^{-2}, 18 l m^{-2}, 25 l m^{-2}, 31 l m^{-2}, 37 l m^{-2} and 43 l m^{-2} applied over 8 weeks on the spread leaves. In order to apply the given quantity of water, the mulches were watered every other day with different numbers of sprays using a spray bottle. This was done with extreme care in order not to mix up the different moisture regimes. In this set-up, the role of soil moisture in the decomposition of the mulches was minimal since the moisture required for this was applied from above, simulating watering in the field. The soil layer was used in order to help the rapid growth of microflora active in decomposition on the leaves, thereby simulating field conditions, while the mesh fascilitated the collection of decomposed leaf residues on the soil. Initially, the chopped leaves were partially in contact with the soil through the mesh; as they decomposed, contact increased.

During the period of study, the relative humidity and temperature in the greenhouse ranged from 78% to 91%, and from 30.3 °C to 21.4 °C, day and night, respectively. The average length of day and night ranged from 12.2 to 12.3 h and from 11.7 to 11.8 h, respectively. After 8 weeks, residual material on the mesh, as well as on the soil, was collected carefully, oven-dried, weighed and ground for later analyses.

Plant analysis

The ground samples taken at the beginning of the experiment were analysed for organic carbon (Walkley and Black 1934), total N (Kjeldahl method), soluble polyphenolics (Anderson and Ingram 1989) and lignin (Van Soest and Wine 1968) concentrations. The ground, residue materials collected at 8 weeks were analyzed for total N, in order to calculate leaf N release. There was an insufficient amount of residues, of *T. diversifolia* and *G. sepium*, in particular for the analysis of other chemical fractions.

Data analysis

Correlation, linear and non-linear regression analyses were carried out using the Statistical Analysis System programme (SAS 1987).

Results and discussion

The most significant relationships between percentage remaining weight of leaves and moisture regimes calculated by simple linear models were obtained for *A. mangium*, *A. saman*, *G. sepium* and *L. leucocephala* (Fig. 1). However, data from *D. regia*, *E. lithosperma*, *O. sativa* and *T. diversifolia* showed better fits in quadratic models (Fig. 2). There is generally an optimal moisture requirement for the maximum metabolic activity of microbes involved in decomposition (Couteaux et al. 1995), which is associated with maximum decomposition and is given by the minima of the quadratic models. The absence of such minima in the other species' data, fitted by the simple linear models, implies that the range of moisture regimes used in the study did not include their optimal moisture requirement for decomposition; this may exceed 43 l m^{-2} over a period of 8 weeks. *T. diversifolia* leaves were almost completely decomposed under a moisture regime of 25 l m^{-2} over 8 weeks (Fig. 2). It is hypothesized that the differences in the optimal moisture requirement for decomposition are due to a range of physical and chemical properties of the leaves. Absorption and retention of moisture are goverened by characteristics of the waxy cuticle, and fibre content, of leaves. Even when the optimal moisture requirement for decomposition is fulfilled, chemical constituents in leaves modify further the action of decomposing microbes. The simple linear models explained between 54% and 83% of the observed variability in the percentage remaining weight of the different species. The corresponding range for the quadratic models was between 80% and 84%.

The N concentration which reflects the protein concentration, ranged from 42.7 g kg^{-1} in *T. diversifolia* to 23.1 g kg^{-1} in *A. mangium* (Table 1). This latter species had the highest polyphenolic concentration. The lignin concentration varied between species, ranging from