Available online at www.sciencedirect.com
ScienceDirect
Agriculture, Ecosystems and Environment 118 (2007) 191–200
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

Nutrient recycling during the decomposition of apple leaves (*Malus domestica*) and mowed grasses in an orchard

Massimo Tagliavini [a,*], Giustino Tonon [a], Francesca Scandellari [a], Ana Quiñones [b], Simone Palmieri [a], Giulia Menarbin [a], Paola Gioacchini [c], Andrea Masia [a]

[a] *Dipartimento di Colture Arboree, Alma Mater Studiorum, Università di Bologna, Viale Fanin 46, 40127 Bologna, Italy*
[b] *Departamento de Nutrición Mineral, Instituto Valenciano de Investigaciones Agrarias, Carretera Moncada-Náquera, km. 4,5, 46113 Moncada, Valencia, España, Spain*
[c] *Dipartimento di Scienze e Tecnologie Agroambientali, Sezione di Chimica Agraria, Alma Mater Studiorum, Università di Bologna, Viale Fanin 44, 40127 Bologna, Italy*

Received 21 December 2005; received in revised form 11 May 2006; accepted 12 May 2006
Available online 24 July 2006

Abstract

Each year, significant fractions of nutrients absorbed by trees and orchard grasses, return to the soil by abscised leaves and mowed biomass. Using litter bag technique and labelled (^{15}N) litter, we assessed the decay dynamics and the related nutrient releases in a mature, drip irrigated, apple (*Malus domestica*) orchard located in the Eastern Po Valley (Italy) on a silty clay loam soil. Litter bags containing abscised apple leaves were placed in December 2001 on the soil surface and collected over a 2-year period, while the decomposition of perennial ryegrass was studied over a 6-month period from May 2002. The dynamics of mass and C losses from decomposing apple leaves fitted to a single exponential decay model. At 1 year from their placement, about 50% of original mass was lost, while and additional 20% was not recovered in the second year. Initial C losses were not accompanied by degradation of cellulose which started only in the spring of the year after their placement on the soil. Along with the decomposition process, the remaining litter was progressively enriched in lignin-like compounds. Net N and S immobilization occurred during the winter–spring period and net release of these nutrients occurred only in the second year. Ryegrass lost about half their mass and original N content after 6 weeks and most of sward derived N was recovered in the underneath soil volume. Both apple and ryegrass released most their initial K content during the period of decomposition. The knowledge of the dynamics of nutrient release on the orchard floor will be useful for predicting nutrient availability for tree uptake and therefore for managing amounts and dynamics of nutrient supply.

Keywords: Apple; Labelled nitrogen; Litter decay; Nutrient fluxes; Ryegrass

1. Introduction

Sustainable management of mineral nutrition in tree plantations aims at optimizing the use of internal sources of nutrients and reducing the need for external nutrient inputs and losses. Each year, significant fractions of nutrients taken up by the trees from the soil or remobilized from internal storage return to the soil by abscised leaves, pruning wood and rhizodeposition. Similarly, mowed biomass from grasses growing in the orchard alleys contain large amounts of nutrients (Haynes and Goh, 1980). These litters undergo a decomposition process, whose understanding is important at the ecosystem levels (Berg and McClaugherty, 2003). From one side it should be considered that carbon dioxide is released during the decomposition process and that part of the litter components more resistant to decay forms humus, a major carbon storage product. Nutrient cycling is also clearly related to decomposition and the nutrient availability in a given soil is due in large part to their release during the decomposition of soil organic matter (SOM), including plant litter. The accumulation of organic matter in the soil as a

* Corresponding author. Tel.: +39 0512096436; fax: +39 0512096401.
E-mail address: massimo.tagliavini@unibo.it (M. Tagliavini).

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doi:10.1016/j.agee.2006.05.018

consequence of decomposition also indirectly affects soil fertility and nutrient availability to plants.

Biochemical quality of litter and external factors affect the decomposition process. Soil management of apple orchards usually does not include soil tillage (Merwin, 2003), but uses grassed alleys and herbicided tree strips. Consequently, the decay process of most plant material returning to the soil occurs on the soil surface. Important biochemical characteristics governing the decomposition process are C:N ratio, water soluble components, cellulose and lignin concentrations. While extensive research on litter decomposition and nutrient release has been conducted in forest ecosystems (Guo and Sims, 1999; Magill and Aber, 1998; Teklay and Malmer, 2004) and for several residues of agricultural crops (Chaves et al., 2004; Quemada and Cabrera, 1995), the process of decomposition of litter in orchard systems and the dynamics of nutrients release have received little (Tutua et al., 2002) or no attention.

This paper reports two experiments using litter bag technique aimed at assessing the decay dynamics of abscised apple leaves and mowed grass and the related nutrient releases. The uptake of nitrogen deriving from the decomposition of labelled (^{15}N) apple leaves by apple trees under field conditions is reported as well.

2. Materials and methods

The experiments were carried out in an apple (*Malus domestica*, Borkh.) orchard of the cv. Mondial Gala grafted on M9 rootstock, located at the Experimental Farm of the University of Bologna, in Cadriano (44°35′N, 11°27′E, 33 m above sea level). During the study the lowest average air temperature was recorded in January 2002 (1 °C) and the highest in August 2003 (28.4 °C). The climate of the area is temperate with cumulative rainfall accounting for 808 mm in 2002 and 598 mm in 2003, mainly concentrated in spring and autumn. Trees were planted on a silty clay loam soil (FAO classification: Haplic Calcisoil) in the winter 1996/1997 at 3.6 m × 1.0 m spacing. The alleyways consisted of mown turf grass (a commercial mixture of *Lolium perenne*, *Festuca rubra* and *Poa pratensis*), sown at the end of 1997. A 1.8 m width soil strip centred on the tree row was maintained weed-free by 3–4 applications per year of glyphosate (1.2 kg 100 L^{-1}). Irrigation was provided by drippers located in correspondence to the centre of the tree row. During 1997–2001, trees received an annual supply of fertilizers providing a total (kg ha^{-1} $year^{-1}$) of 80 N, 25 P, 100 K and 10 Mg. No fertilizers were supplied to the trees during the decomposition studies.

2.1. Experiment 1—decomposition of abscised apple leaves and nutrient release

2.1.1. Preparation and deposition of litter bags

In fall 2001, fresh leaf litter was collected on nylon screens surrounding three randomly chosen trees. One mm mesh nylon window screenings were cut and sewn into 25 cm × 25 cm bags according to Magill and Aber (1998) and Harmon et al. (1999). From the bulk of leaf litter, three sub-samples were taken to determine initial moisture, cellulose, lignin, total C and mineral nutrient concentration. The equivalent of 26 g of dry litter was placed into each bag; this amount was representative of the leaf litter present in the weed-free tree row space of adjacent trees after leaf abscission was completed. Twenty-seven bags in total were prepared and placed on 7 December 2001 on the soil surface, below three selected trees (nine bags per tree).

Collection of three bags each sampling time (one randomly chosen from below each tree) was performed in 2002 on 8 January (week 4), 7 March (week 13), 8 April (week 17), 13 May (week 22), 26 July (week 33) and 10 December (week 52), and in 2003 on 16 April (week 70), 26 August (week 88) and 3 December (week 102) according to Harmon et al. (1999). Decomposing leaf litter was cleaned and split in two parts: one part was oven dried at 70 °C and ground samples (0.2 mm mesh) prepared for chemical analysis, while the remaining material was used for determination of microbial biomass. Litter water content was determined each time.

2.1.2. Mineral nutrient analysis

Total N and C concentrations were determined by an elemental analyser (EA 1110, Carlo Erba instruments) on a representative amount of ground vegetal material.

Phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) concentrations were determined by an ICP-OES (Vista MPX, Varian). The mineralization of samples was obtained with the Ethos TC microwave labstation (Milestone, Bergamo, Italy), according to US EPA Methods 3052 (Kingston, 1988; Kingston and Jassie, 1988). A representative quantity of each sample was dry-ashed at 500 °C for 2 h, and then treated with few drops of hydrogen peroxide (30 wt.% solution in water) and 3 cm^3 of nitric acid (33 wt.% solution in water), and the excess of nitric acid was evaporated on hot plate (at 80–100 °C). Finally, the mineral residual was dissolved in 10 cm^3 of hydrochloric acid (18 wt.% solution in water) (Isaac, 1990).

2.1.3. Extraction of structural biomass and lignin and cellulose analyses

Cell walls were extracted from the dry milled powder according to the method of Blaschke et al. (2002). Briefly samples of 200 mg dry weight were suspended in 20 mL of washing buffer (100 mM KPi, pH 7.8, 0.5% Triton X-100), stirred overnight at room temperature and centrifuged at 5500 × *g* for 20 min. The pellet was resuspended in washing buffer and the extraction was repeated twice (for 30 min). The resulting pellet was washed four times (30 min each time) in methanol. The final pellet contained mainly cell walls, i.e. structural biomass (SBM). The SBM pellet was dried at 80 °C for 12 h, weighed and utilised for lignin and cellulose analyses.